# Forest Depletions Caused by Insects and Diseases in Canada

## 1982–1987

Forest Insect and Disease Survey
Information Report ST-X-8

Natural Resources Canada / Ressources naturelles Canada
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Canada

# Forest Depletions Caused by Insects and Diseases in Canada 1982 – 1987

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## Abstract

Forest managers and planners who develop pest control policies and research programs require an estimate of the losses attributable to various causes in order to plan for the sustainability of our forests. Forest depletion is the term used to describe the loss of wood from the forest through mortality and loss of growth. Factors causing forest depletion include harvesting, wildfires, damage from storms, forest declines and from insects and diseases. This report describes losses over the period 1982–1987, primarily from insects and diseases.

Total losses over the period were 102 756 000 million $m^3$ from insects and diseases. The major causes of depletion continue to be the spruce budworm, the mountain pine beetle, root rots, decays and mistletoes. The spruce budworm was the primary cause of losses on conifers; the forest tent caterpillar caused the major losses on hardwoods. Some pests caused significant depletions in particular regions; examples include the hemlock looper in Newfoundland, and gypsy moth in Ontario and the eastern larch beetle in the Maritimes.

# Introduction

Forests play a large role in the development and daily life of Canadians. They are subjected to a variety of agents which damage them and which reduce the amount of fibre available for harvest. These agents include fire, blowdown, storms, harvesting, the conversion of forests to other uses, and insect and disease pests. All are significant contributors to the depletion of Canadian forests. Insects and diseases in particular are the subject of this report. Forest managers and planners who develop pest control policies and research programs require an estimate of the losses attributable to various causes in order to plan for the sustainability of our forests. Knowledge of the state of these impacts, both direct losses from mortality and indirect losses of growth, are necessary to ensure the sustainable development of forests – development that meets the needs of the present without compromising the potential of future generations to meet their own needs.

One measure of the sustainability of forests is the relationship between forest growth and losses, an accounting of how the forest is being affected by insects and diseases. It is estimated that the pressures of harvesting combined with the effects of natural factors (fire, insects and diseases) on the forest are resulting in substantial depletions, and it is possible that more wood is being lost than is growing (Table 1).

The estimated value of the volume of wood lost is about $6 billion. Volume and value are measures of the depletion of the resource; measures reflecting loss of amenity and loss of biodiversity are less easily quantifiable but are also important. Losses must be considered not only as the economic value of the wood lost but also in terms of amenity and recreational or conservation/biodiversity values inherent in forests. In order to maintain our current economic activity, the loss of this approximately 140 million m³ from insects, diseases, and fire needs to be reduced.

**Table 1.** Annual forest losses, 1982–1987 (in thousands of cubic metres).

| | |
|---|---|
| Losses | |
| Losses from insects | 51.6 |
| Losses from diseases | 51.2 |
| Losses from fire | 36.0 |
| Harvest | 160.0 |
| Total depletion | 298.8 |
| Annual growth (range) | 244.3-346.0 |

Forestry Canada's Forest Insect and Disease Survey (FIDS) develops estimates for the losses caused by insects and diseases. These losses amount to almost 102.8 million m³ annually over the period 1982-1987 and are spread throughout all provinces (Table 2). The volume of losses comprises about 70% of the annual harvest; that is, for every 10 trees harvested and used, another seven are lost.

**Table 2.** Annual losses from insects and diseases (mortality and growth loss) by Province, 1982–1987 (in thousands of cubic metres).

| Province | Insects | Diseases | Total |
|---|---|---|---|
| Newfoundland | 2 653 | 1 037 | 3 690 |
| Prince Edward Island | 271 | 33 | 304 |
| Nova Scotia | 1 610 | 278 | 1 888 |
| New Brunswick | 5 882 | 864 | 6 746 |
| Quebec | 10 309 | 6 029 | 16 338 |
| Ontario | 11 250 | 20 586 | 31 836 |
| Manitoba | 472 | 560 | 1 032 |
| Saskatchewan | 133 | 436 | 569 |
| Alberta | 1 785 | 378 | 2 163 |
| Northwest Territories | | NA | |
| British Columbia | 16 635 | 20 477 | 37 112 |
| Yukon | 500 | 500 | 1 000 |
| Total | 51 501 | 51 178 | 102 679 |

NA = Not applicable.

Losses are also about evenly divided between those caused by insects and those caused by diseases, although the proportion varies widely among provinces. It is apparent from the data in Tables 1 and 2 that Canadian forests are being subjected to considerable pressures from the combined effects of insects and disease damage, wildfires, and harvesting. The loss components are being addressed through programs of integrated pest management, control of wildfires and forest management programs designed to improve productivity. Reduction of these losses will also enhance other forest values. Not only are Canadian forests nearing full utilization from harvesting, but they are in demand for recreation, for use as parks and, in certain areas, for conservation. Therefore, the most practical way to ensure sustainability is to protect the forest we now have.

The term "depletion" includes not only mortality caused by insects and diseases, but also losses of volume due to unrealized growth. This occurs during insect outbreaks which do not kill trees but reduce their growth rate. Therefore, the accumulation of wood over time is reduced resulting in a real and quantifiable loss of forest productivity. Losses caused by insects and diseases are expressed as volume of wood removed from the inventory of merchantable trees; in the case of growth losses, this is considered a loss from the potential inventory.

In general, it is difficult to develop loss estimates for all pests because the understanding of their relation to the damage they cause is not always complete. Consequently, aggregated or gross loss estimates for forest pests probably

underestimate the actual losses. Depletion is also occurring in pre-commercial stands, but because these stands are composed of small trees, volumes affected are negligible. Some pests, such as the white pine weevil and stem cankers, have a significant effect on tree quality. Such impacts are not always reflected in volume losses. This report describes only those losses for which estimates were made, rather than the total losses which may be occurring.

This report estimates and describes the pest-caused losses occurring from 1982 to 1987, a period designated by FIDS for the assembly of depletion data in Canada. The data include those from losses which may have been caused by more than one factor but do not take into account wood which may have been salvaged from insect-killed stands. Losses from the previous reporting period, 1977-1981, were presented in Sterner and Davidson (1982). Losses presented here are ones caused by the important and some minor pests.

## Methods

There are substantial problems with the development of any system of estimating the impact of forest insects and diseases on the growth and productivity of forests. Gross (1985) provided an informative discussion of the interpretation, calculation and precision of pest loss estimates; for example, it is not possible to use a uniform methodology for all regions. The method used and the interpretation of the data derived therefrom depend on the quality of estimates of the impacts. At the same time, the methods are constantly being refined and improved, as data collection and processing become more efficient.

The basis of development for the estimation of losses is the Geographic Information System (GIS) methodology developed by Power and D'Eon (1988) and D'Eon and Power (1991). This methodology is used for estimating the impacts of the important defoliating insects and for estimating mortality and growth loss. Mortality and growth losses are estimated based on the area defoliated and the severity and duration of defoliation. In Quebec, estimates for spruce budworm losses were developed by Forêts Québec (Bordeleau et al. 1988). Most estimates for losses in British Columbia were obtained according to Alfaro (1989) and Shore and Alfaro (1986).

Estimates of growth losses were also developed using GIS technology (Power and D'Eon 1991). In addition, growth loss factors were derived from studies by Blais (1958), Batzer (1973), Piene (1980), Pedersen (1981), and Archambault (1983). Growth loss factors for trembling aspen, including those caused by the large aspen tortrix (*Choristoneura conflictana*), were based on several studies from North America; factors were then derived to obtain estimates for moderate and severe defoliation (Pendrel 1991). Losses were estimated for two years of recovery after defoliation had stopped, and the loss in each recovery year was estimated to be 75% and 50% of the loss in the previous year. Loss factors for sugar maple were derived similarly based on studies by Bauce and Allen (1991) and Gross (1991).

For gypsy moth (*Lymantria dispar*), annual growth losses of 20, 40 and 50% were estimated for 1, 2 or 3 consecutive years of moderate or severe defoliation on red oak. Two recovery years, calculated as in the GIS procedure, were also considered based on studies of Wargo (1981) and Campbell and Garlo (1982).

Losses caused by the Douglas-fir tussock moth (*Orgyia pseudotsugata* McD.) are based on methods developed by Alfaro et al. (1989); those caused by the false hemlock looper are estimated from Alfaro (1988) and those from the larch casebearer by Alfaro et al. (1991).

Few data exist for growth losses due to Swaine jack pine sawfly (*Neodiprion swainei*) defoliation. Most studies have dealt with tree mortality in relation to complete defoliation of different age classes of foliage. Craighead (1940) reported a 75% reduction of growth after a complete removal of old foliage. O'Neill (1962) reported missing rings after severe defoliation by Swaine jack pine sawfly. A growth reduction of 25% and 50% after moderate and severe defoliation respectively was estimated. No estimates were developed for years during which recovery occurred, nor were the cumulative effects of defoliation considered. This is a conservative estimate of growth losses, but, until more precise data become available, these estimates will be used.

Estimates for losses from diseases consist of those attributed to heart and butt rots and cankers. Heart and butt rots cause some volume loss without mortality. Total and annual losses were tabulated by species groups and maturity classes from percent volume reductions as estimated by Lavallée (1986, 1987) for balsam fir and black spruce and as calculated by Basham and Morawski (1964) for all other species. Losses from Hypoxylon canker were estimated for total volume of poplars (mostly trembling aspen) and all maturity classes.

## Results and Discussion

Forests are depleted by a wide range of insects and diseases; however, most of the damage is caused by a few widely occurring organisms including several conifer and hardwood defoliators and stem and root rots. Forest declines, storms, frost and drought also cause damage, but the extent of this damage is difficult to quantify and is seldom estimated. Damage attributed to the major causes is discussed in terms of area damaged and the volume of wood killed or lost to growth.

**Spruce Budworm** – *Choristoneura fumiferana* Clem.

Over 61 million ha of spruce and fir trees cover the North American continent and in Canada about 56 million ha of spruce–fir forest is host to the most important of the budworms, the spruce budworm. This is the most damaging insect in our boreal conifer forests, defoliating balsam fir, red spruce, white spruce and black spruce. For many years attempts have been made to limit damage from the insect by spraying chemical insecticides. Longer-term attempts to avoid damage by the insect are to reduce the amount of susceptible forest through stand conversion and other silvicultural practices.

The area of moderate to severe defoliation ranged from 12 to about 24 million ha/yr, averaging over 16 million ha annually from 1982 to 1987 (Table 3). Peak years of defoliation were 1983 and 1985.

In Newfoundland, moderate and severe defoliation occurred on extensive areas in 1982–1984 and then declined to a few thousand hectares, although tree mortality and growth loss continued after 1984. In the Maritimes a widespread spruce budworm outbreak peaked at 2 million ha of moderate and severe defoliation in New Brunswick in 1983 (Magasi 1988). In Nova Scotia, the area of defoliation fluctuated annually. By 1987 no more defoliation was detected, but mortality continued as a result of earlier defoliation. On Prince Edward Island, defoliation existed at reduced levels compared to the 6 years prior to 1982; by 1987 no significant amount could be detected.

In Quebec, the spruce budworm was by far the most destructive insect damaging forests. The outbreak remained important in the central and eastern parts of the province until 1986 when it collapsed; and by 1987, only the Gaspésie and Côte-Nord regions were being defoliated. In Ontario, the area defoliated peaked in 1985 at 12 million ha and remained at about 8-9 million ha during the remaining years. Defoliation was minimal in the western provinces, consequently losses were also small.

The estimated loss of volume attributed to spruce budworm damage was over 27 million $m^3$ annually, about 10% of which was in the form of loss of growth (Table 4). Over 6 years this is more than 163 million $m^3$, equivalent to the annual harvest in all of Canada. In Newfoundland, the largest volume of tree mortality occurred in black spruce, peaking in 1982–1983, and declining to zero by 1986. Growth losses were larger for balsam fir than for black spruce because much larger areas of fir had been damaged. Total volume depletion for the 6 years was estimated at 7 371 000 $m^3$ of spruce and fir. Similarly in the Maritimes, extensive tree mortality already existed by 1982; many trees were in a weakened state and little additional defoliation was needed to kill them. Average annual losses for the 5 years preceding 1982 were lower in New Brunswick at 4.62 million $m^3$ and much greater in Nova Scotia at 3.15 million $m^3$. Damage estimates had not been made previously for Prince Edward Island.

In Quebec, mean annual growth losses were estimated to be 1.5 million $m^3$ and annual mortality 8.5 million $m^3$ for an annual loss of 10.0 million $m^3$. In Ontario, defoliation by the spruce budworm caused an average annual mortality of 7.2 million $m^3$ and a growth loss of 1.6 million $m^3$ over the period. The total loss from the start of the outbreak in 1967 to 1987 was 126.5 million $m^3$. Most of the infestation was in the northern and northeastern regions where it collapsed in1981; elsewhere the outbreak continued to expand until 1987.

**Table 3.** Area of moderate to severe defoliation by the spruce budworm, 1982–1987 (in thousands of hectares).

| Province | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Newfoundland | 42 | 68 | 15 | | 2 | 4 |
| Nova Scotia | 175 | 294 | 59 | 319 | 289 | 0 |
| New Brunswick | 1 202 | 2 028 | 730 | 1 070 | 927 | 430 |
| Prince Edward Island | 13 | 22 | 15 | 54 | 65 | 0 |
| Quebec | 8 787 | 12 266 | 7 139 | 6 291 | 2 080 | 740 |
| Ontario | 8 023 | 9 040 | 8 748 | 12 332 | 8 856 | 7 190 |
| Manitoba | 31 | 41 | 143 | 78 | 34 | 16 |
| Saskatchewan | 2 | 13 | 15 | 15 | 19 | 32 |
| Alberta | 1 | | 2 | | 0 | 6 |
| Northwest Territories | 1 | 12 | 11 | 13[a] | 13 | 3 |
| British Columbia | | | NA | NA | 95[a] | 39[a] |
| Total | 18 277 | 23 785 | 16 877 | 20 174 | 12 380 | 8 460 / 99 953 |

[a] Light to moderate defoliation.
NA = Not applicable

Growth losses and tree mortality continued for several years after defoliation stopped. However, no mortality occurred within the area of collapse after 1985 and growth of the surviving trees recovered at about the same time.

**Table 4.** Average annual mortality and growth loss from the spruce budworm, 1982–1987 (in cubic metres).

| Province[a] | Mortality loss/yr | Growth loss/yr | Total loss/yr |
|---|---|---|---|
| Newfoundland | 228 500 | 70 000 | 298 500 |
| Nova Scotia | 140 000 | 145 000 | 285 000 |
| New Brunswick | 5 152 000 | 602 000 | 5 754 000 |
| Prince Edward Island | 140 000 | 16 000 | 156 000 |
| Quebec | 8 532 100 | 504 011 | 10 036 111 |
| Ontario | 7 166 500 | 566 100 | 8 732 600 |
| Manitoba | 500 | 1 100 | 1 600 |
| Saskatchewan | 600 | 8 800 | 9 400 |
| Alberta | 0 | 0 | 0 |
| Northwest Territories | 800 | 0 | 800 |
| British Columbia | 0 | 22 100 | 22 100 |
| Total | 23 361 000 | 3 935 | 27 296 |

[a] No mortality or growth losses reported from Prairie provinces.

During the reporting period, outbreaks of the spruce budworm in the commercial forests of the Prairie provinces and the Northwest Territories were small and resulted in losses of 70 700 m³. These losses are small in comparison with regions in which extensive outbreaks occurred. In British Columbia, defoliation was first reported in 1984 with a peak of 94 700 ha in 1986 but mortality of mature timber from 1982 to 1986 was small (Shore and Alfaro 1986). Understorey trees were often damaged and showed a reduction in diameter of 3–4% from the previous infestation causing a loss of 25% of mean annual increment for the period 1982–1987.

**Western Spruce Budworm** – *Choristoneura occidentalis* Free.

The western spruce budworm occurs in British Columbia primarily on Douglas-fir. Defoliation results in loss of growth and seeds, top kill, and occasionally mortality. The main effect of defoliation is a reduction in height and diameter growth and consequent volume losses. The average annual growth loss for the period was 300 000 m³ and mortality was 71 900 m³. Comparable figures for the period 1977–1981 are 602 000 m² and 120 000 m³.

**Jack Pine Budworm** – *Choristoneura pinus pinus* Free.

The jack pine budworm is common over the range of jack pine in Ontario, Manitoba and Saskatchewan. Outbreaks last 2–3 years on a 6–8 year cycle in eastern Canada and 10 years in western Canada. Defoliation results in growth loss and top kill. Tree mortality is rare. Outbreaks peaked in Ontario and Manitoba in 1984 and 1985 and declined rapidly thereafter(Table 5). By 1987 nearly all defoliation was in Ontario. Losses are reported for Ontario only.

In Ontario, two infestations started in 1983, one in the northeastern and Algonquin regions north and east of Lake Huron which spread northward into the northern region in 1984. Large areas were defoliated in 1985 and 1986; after this, budworm activity was negligible. The other infestation started in the Atikokan District of the north central region and expanded into the northwestern and north central regions. Significant defoliation was still present at the end of the period. In Ontario, total mortality over the period caused by the jack pine budworm was 7.3 million m³ with an additional loss of 3.5 million m³ in growth (Table 6). Average annual mortality was 1 216 740 m³ and growth loss was 589 836 m³.

In the Prairie provinces, Manitoba experienced the greatest area defoliated, reaching a maximum in 1985 with over 2 million ha defoliated. In Saskatchewan, the peak level of defoliation occurred in 1986 with defoliation of 176 000 ha. In Alberta, the first outbreak of jack pine budworm was recorded when 70 ha were defoliated in 1985. By 1987 these outbreaks occupied 2 670 ha in all three provinces and had largely disappeared. Over the course of the defoliation,

**Table 5.** Area of moderate to severe defoliation by the jack pine budworm, 1982–1987 (in hectares).

| Province | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Ontario | 981 | 67 142 | 150 158 | 3 660 069 | 1 743 725 | 504 749 |
| Manitoba | 0[a] | 154 500 | 761 000 | 2 048 000 | 132 000 | 100 |
| Saskatchewan | | | 27 000 | 131 000 | 176 000 | 2 500 |
| Alberta | | | | 70 | 70 | 70 |
| Total | 981 | 221 642 | 1 918 158 | 5 839 139 | 2 051 795 | 507 419 |

[a] Defoliation present but area not reported

**Table 6.** Annual mortality and growth loss caused by the jack pine budworm in Ontario, 1982–1987 (in cubic metres).

| Year | Mortality | Growth loss | Total |
|---|---|---|---|
| 1983 | 0 | 3 941 | 3 941 |
| 1984 | 18 368 | 178 594 | 196 962 |
| 1985 | 695 217 | 861 216 | 1 556 433 |
| 1986 | 2 927 186 | 413 534 | 4 340 720 |
| 1987 | 3 659 670 | 081 735 | 4 741 405 |
| Average | 216 740 | 589 837 | 806 577 |

depletion consisting of mortality and growth losses in Manitoba were 2 730 600 m³ and in Saskatchewan losses were 306 900 m³.

**Forest Tent Caterpillar** – *Malacosoma disstria* Hbn.

Forest tent caterpillar damages a wide variety of hardwoods – aspen, oaks, maples, birches, and elms. It causes substantial losses in growth, but little mortality. The appearance of ornamentals and shade trees is also greatly affected by the caterpillar.

In the Maritimes, the first year of the report period coincided with the most intense and widespread forest tent caterpillar defoliation for several years, but by 1987 this infestation had declined to a few defoliated patches of variable intensity (Table 7). In Quebec, more than 350 000 ha were affected in 1982 after the outbreak in the southern part of the province in 1981. But the area damaged declined rapidly in subsequent years. From 1985 to 1987, a new outbreak occurred in Abitibi-Temiscamingue, a previously undamaged region. In Ontario, infestations continued to expand during 1982–1987. In British Columbia, pockets of defoliation began in 1983, peaked at 93 400 ha in 1986 and declined slightly for 2 years.

Mortality occurred only sporadically in immature stands where trees were under additional stress from overstocking or other causes; the depletion here is from loss of growth (Table 8). Losses were considerable, given the large areas and high volume of aspen affected. In the Maritimes, the average annual volume lost was 49 200 m³ in New Brunswick; 27 000 m³ in Nova Scotia; and 19 000 m³ in Prince Edward Island, representing 10%, 3% and 5% respectively of the potential aspen growth. No significant losses had been reported during the 1977–1981 period. In Quebec, mean annual growth losses were 68 102 m³ of aspen, 50 656 m³ of maple and 103 728 m³ of other hardwood species, to a total of 222 490 m³.

In Ontario, the average annual growth loss was 237 295 m³ and occurred primarily on poplar and white birch (Table 9). Susceptible stands in southern Ontario were not defoliated enough to cause appreciable mortality, although there may be an association with the mortality reported as dieback and decline in Table 18. In the Prairie provinces the outbreak declined from a maximum of over 5 million ha in 1982 to just over 500 000 ha by 1987. Losses due to the insect ranged from 15 700 m³ in Manitoba to 1.7 million m³ in Alberta (Table 8). Losses were small in British Columbia, 37 600 m³ during the period (Table 8).

**Table 7.** Area of moderate to severe defoliation by the forest tent caterpillar, 1982–1987 (in thousands of hectares).

| Province | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Prince Edward Island | 19 | 67 | 37 | 0 | 0 | 0 |
| Nova Scotia | 5 | 35 | 46 | * | * | 0 |
| New Brunswick | 1 389 | 119 | 94 | 0 | 0 | 0 |
| Quebec | 353 | 0 | * | 182 | 479 | 561 |
| Ontario | 104 | 31 | 127 | 209 | 433 | 650 |
| Manitoba | 198[a] | 198[a] | 77 | 20 | 17 | 4 |
| Saskatchewan | 693[a] | 70[a] | 0 | 31 | 177[b] | 250[c] |
| Alberta | 4 290[a] | 319[a] | 0 | 155 | 316[b] | 322[b] |
| British Columbia | | 2 | 31 | 59 | 93 | 24 |
| Total | 7 051 | 2 841 | 412 | 656 | 1 515 | 3 81[illegible] |

[a] 33% of the total land area mapped.
[b] 10% of the total land area mapped.
[c] 20% of the total land area mapped.
* less than 1 000 ha.

**Table 8.** Average annual growth loss caused by the forest tent caterpillar, 1982–1987 (in cubic metres).

| Province | Growth loss |
|---|---|
| Newfoundland | |
| Prince Edward Island | 19 000 |
| Nova Scotia | 27 000 |
| New Brunswick | 49 200 |
| Quebec | 222 490 |
| Ontario | 237 295 |
| Manitoba | 15 700 |
| Saskatchewan | 72 400 |
| Alberta | 713 300 |
| British Columbia | 37 600 |
| Total | 2 393 985 |

**Eastern Hemlock Looper** – *Lambdina fiscellaria fiscellaria* (Gn.)

The eastern hemlock looper occurs throughout Canada but has its greatest impact in Newfoundland. The looper feeds mainly on balsam fir foliage, and outbreaks last 3–6 years, with 10–15 years between outbreaks. Growth loss results from defoliation and trees can be killed in 1–2 years. The recent outbreak in Newfoundland expanded rapidly and caused considerable mortality within 3 years (Table 10). Losses from this pest far exceeded those from spruce budworm during the period.

**Gypsy Moth** – *Lymantria dispar* (L.)

The gypsy moth is an important pest on hardwoods in Ontario and Quebec and occurs sporadically in the Maritimes. It is periodically introduced into British Columbia but is not yet established. Control actions are taken because of the severe effects on both forests and ornamental trees.

In Ontario, defoliation by gypsy moth varied widely for the 1982–1987 period (Table 11). In Quebec, local infestations were observed in southern Quebec in 1982 where 8 738 ha of moderate to severe defoliation occurred, mostly on red oak. No defoliation occurred until 1985 when small areas were defoliated. Small local infestations also occurred occasionally in the Maritimes.

**Table 10.** Annual mortality and growth loss caused by hemlock looper defoliation in Newfoundland, 1982–1987 (in cubic metres).

| Year | Mortality | Growth loss | Total |
|---|---|---|---|
| 1982 | | | 0 |
| 1983 | | 700 | 700 |
| 1984 | | 67 000 | 67 000 |
| 1985 | | 82 000 | 82 000 |
| 1986 | 3 207 000 | 283 000 | 3 490 000 |
| 1987 | 4 592 000 | 278 000 | 4 870 000 |
| Total | 7 799 000 | 710 700 | 8 509 700 |

Gypsy moth defoliation caused an average annual growth loss of 25 821 $m^3$ and mortality loss of 28 386 $m^3$ in Ontario for a total average annual loss of 54 207 $m^3$ (Tables 11 and 12). Most of this impact occurred in the eastern region in 1985, 1986 and 1987. In Quebec, a mean annual growth loss of 2 770 $m^3$ occurred over the period. These data reflect the impact of an introduced pest at an early stage in the infestation. It should be noted that the annual mortality rate of 1.17%, attributed to gypsy moth is probably similar to that from natural thinning in hardwood stands growing on similar sites.

**Swaine Jack Pine Sawfly** – *Neodiprion swanei* Midd.

Infestations of jack pine by this insect have been considerable in 1982 and 1983 in the regions of Saguenay–Lac St-Jean and St-Maurice valley in Quebec. Large areas were treated with chemical insecticides in 1983, and infestations have lessened for the rest of the period. Mean

**Table 9.** Annual growth loss caused by forest tent caterpillar in Ontario, 1982–1987 (in cubic metres).

| Year | Poplar | White birch | Yellow birch | Sugar maple | Other hardwoods | Total |
|---|---|---|---|---|---|---|
| 1982 | 74 345 | 15 213 | 18 | 186 | 98 | 90 860 |
| 1983 | 17 077 | 5 050 | 0 | 0 | 0 | 22 127 |
| 1984 | 52 857 | 16 304 | 250 | 657 | 158 | 70 226 |
| 1985 | 94 601 | 27 797 | 486 | 1 313 | 340 | 124 537 |
| 1986 | 120 306 | 44 860 | 6 258 | 31 914 | 12 966 | 216 304 |
| 1987 | 413 341 | 256 185 | 28 975 | 143 883 | 57 331 | 899 715 |
| Total | 773 527 | 365 409 | 35 987 | 177 953 | 70 893 | 1 423 769 |

**Table 11.** Area of moderate to severe defoliation by gypsy moth in Ontario and Quebec, 1982–1987 (in hectares).

| Year of infestation | Area of defoliation Quebec | Ontario |
|---|---|---|
| 1982 | 8 73 | 84 800 |
| 1983 | — | 40 954 |
| 1984 | — | 80 624 |
| 1985 | 198 | 246 342 |
| 1986 | 4 700 | 167 776 |
| 1987 | 1 180 | 12 678 |
| Total | 14 8165 | 53 174 |

annual depletion, mortality and growth loss amounted to 6 238 m³.

**Birch Skeletonizer** – *Bucculatrix canadensisella* Cham.

Defoliation by birch skeletonizer was widespread in Ontario in 1982–1983 and continued into 1984. The growth loss for the period was 1 114 354 m³, with an average loss during 1982–1987 of 185 726 m³.

**Aspen Defoliator Complex**

In Quebec and Ontario, a variety of defoliators infested aspen during the period including the Bruce spanworm (*Operophtera bruceata* Hlst.), the large aspen tortrix (*Choristoneura conflictana* Wlk.) and the aspen leafblotch miner.

The Bruce spanworm is a defoliator of hardwoods and is most destructive in Ontario and Quebec. In Quebec, the spanworm defoliated large areas of trembling aspen stands in the Lower St. Lawrence region between 1982 and 1984. Sugarbushes were also defoliated in the southeastern and southwestern parts of the province in 1984 and 1986 respectively. This resulted in average annual growth losses of 8 694 m³ of aspen, 12 814 m³ of maple, and 11 784 m³ of other hardwoods. In Ontario, extensive areas were defoliated by the spanworm as the outbreak expanded rapidly over the period. The area of moderate to severe defoliation increased from 4 285 ha in 1984 to 1 053 717 ha in 1987. Growth losses in Ontario, caused by both the Bruce spanworm and the large aspen tortrix, caused an average annual growth loss of 218 640 m³, or a total loss of 1 311 839 m³.

In Quebec, heavy defoliations by the large aspen tortrix were observed in 1986 and 1987 in the Saguenay–Lac St-Jean and Côte-Nord regions. More than 300 000 ha of aspen forests were severely defoliated in 1987 with 94 528 ha being moderately to severely defoliated. The mean annual growth loss was estimated at 10 526 m³ of aspen.

**Maple Defoliator Complex**

In Ontario, maple stands were infested by the maple leafcutter, the maple trumpet skeletonizer and the Bruce spanworm during 1982–1987. Average annual growth loss was 15 354 m³ for their combined impact, the total for the period was 92 124 m³.

**Defoliators in British Columbia**

The Douglas-fir tussock moth and the western blackheaded budworm are important pests in British Columbia. Mortality follows quickly after defoliation. In the case of the budworm, one year of defoliation on old-growth western hemlock, true firs, and spruce is enough to kill trees. Damage by these and other defoliators amounted to substantial mortality over the period (Table 13).

**Mountain Pine Beetle** – *Dendroctonus ponderosae* Hopk.

The mountain pine beetle is the most destructive insect in western Canada and occurs throughout British Columbia, the mountainous parts of Alberta and in the area of Cypress Hills of Saskatchewan. Its primary hosts are lodgepole pine and the western white pines.

In British Columbia, outbreaks have been recorded at various locations sporadically since 1910. The current series of outbreaks started during the late 1960s and early 1970s. The area of newly red trees (attacked the previous year and

**Table 12.** Annual growth loss and mortality caused by gypsy moth in Ontario, 1982–1987 (in cubic metres).

| Year | Red oak Growth loss | Red oak Mortality | White oak Growth loss | White oak Mortality | Other hardwoods[a] Growth loss | Total |
|---|---|---|---|---|---|---|
| 1982 | 306 | 502 | 47 | 90 | 180 | 1 125 |
| 1983 | 2 542 | 3 976 | 228 | 434 | 1 359 | 8 539 |
| 1984 | 5 771 | 9 407 | 1 035 | 1 803 | 3 331 | 21 347 |
| 1985 | 21 211 | 34 179 | 3 280 | 5 369 | 11 700 | 75 739 |
| 1986 | 14 142 | 23 323 | 3 073 | 5 262 | 8 611 | 54 411 |
| 1987 | 44 521 | 72 348 | 8 032 | 13 625 | 25 559 | 164 085 |
| Total | 88 493 | 143 735 | 15 695 | 26 583 | 50 740 | 325 246 |

[a] No mortality.

**Table 13.** Annual losses from miscellaneous defoliators in British Columbia, 1982–1986 (in thousands of cubic metres).

| Insect | Mortality | Growth loss | Total |
|---|---|---|---|
| Douglas-fir tussock moth | 927.2 | 23.3 | 950.5 |
| Black-headed budwormt | 149. | 58.9 | 208.0 |
| Two-year-cycle budworm | 0 | 8. | 8. |
| False hemlock looper | | | |
| Larch sawfly | | 3.4 | 3.4 |
| Total | 076.3 | 94.8 | 171. |

often called 'faders') increased annually to 1984 when it peaked at 462 150 ha. This declined to 67 000 by 1987. Cumulatively, over 204 million mature pine have been killed, and harvesting plans throughout British Columbia have been severely affected. The average annual volume of timber killed over the period is estimated at 9.8 million m³ (Table 14).

In Alberta, an infestation in the southern end of the Bow/Crow Forest affected 15 000 ha during the late 1970s (Anon. 1985). A subsequent control program was successful in limiting the spread of the insect, and salvage logging occurred on about 10 000 ha of the beetle-infested area.

In Alberta the average annual volume loss over the period was 64 183 m³; in Saskatchewan the comparable figure was only 177 m³.

**Table 14.** Volume loss caused by the mountain pine beetle in western Canada, 1982–1987 (in cubic metres).

| Year | British Columbia | Alberta | Saskat-chewan | Total |
|---|---|---|---|---|
| 1982 | 15 680 000 | 190 080 | 253 | 15 780 333 |
| 1983 | 17 765 000 | 77 880 | 733 | 17 843 613 |
| 1984 | 12 195 000 | 74 151 | 299 | 12 269 450 |
| 19856 | 515 000 | 42 900 | 28 | 6 557 928 |
| 19863 | 539 000 | 89 | | 3 539 090 |
| 19872 | 962 000 | 0 | 0 | 2 962 000 |
| Total | 58 656 000 | 385 100 | 1 061 | 58 952 414 |
| Average | 9 776 000 | 64 183 | 177 | 9 825 402 |

**Spruce Beetle** – *Dendroctonus rufipennis* (Kby.)

The spruce beetle occurs throughout Canada, and is most damaging in British Columbia, Alberta, and the Maritime Provinces. White, Engelmann, and Sitka spruces are hosts of this beetle, and mortality results from feeding in the cambium tissue. In the Maritimes, spruce beetle damage occurred primarily in Nova Scotia and Prince Edward Island. Damage intensity peaked by 1980–1981 and by 1984 little new mortality was occurring. The beetles attack mostly white spruce and to a lesser extent red spruce. In Nova Scotia, annual losses of white spruce were 217 000 m³, in Prince Edward Island, losses were 79 000 m³. No significant amounts were lost in New Brunswick. These losses are less than half of the 500 000 m³ reported in Nova Scotia and the 150 000 m³ reported in Prince Edward Island for the 1977–1981 period.

In Alberta, the spruce beetle was active at outbreak levels in the northwest during the first three years of the period, elsewhere it was present at endemic levels only. Forest harvesting activities were increased in infected areas to salvage as much wood as possible. It was estimated that a minimum of 47 500 m³ of white spruce was killed by spruce beetle activity during the one outbreak (Moody and Cerezke 1985). In British Columbia, the area of mature white and Engelmann spruce killed peaked at about 100 000 ha in 1982 and gradually declined to near endemic levels in 1986. Over the period, the annual mortality of white spruce caused by the spruce beetle was 1 910 000 m³.

**Eastern larch beetle** – *Dendroctonus simplex* LeC.

The eastern larch beetle attacks larch and is significant mainly in the Atlantic provinces. It has caused extensive tree mortality, but was in the declining phase of its outbreak between 1982 and 1987 in Newfoundland (Langor and Raske 1989). In the Maritimes, beetle infestations also declined during 1982–1987 (Magasi 1988). In Nova Scotia and Prince Edward Island, where outbreaks began 2–3 years before those in New Brunswick, many long-dead trees fell down and therefore were no longer counted in surveys. After 1982, additional stands became infested but the intensity lessened, so that the degree of impact is difficult to estimate.

The average annual volume lost was 65 000 m³ in New Brunswick, 81 000 m³ in Nova Scotia and 18 000 m³ in Prince Edward Island. These losses are about the same in New Brunswick as for the 1977–1981 period, but much reduced in Nova Scotia (Sterner and Davidson 1982). The average annual volume loss in Newfoundland was 6 000 m³. No previous estimate was published for Prince Edward Island; however, the current loss is estimated to be about 50% of the 1977–1981 values.

**Douglas-fir Beetle** – *Dendroctonus pseudtosuga* Hopk.

The Douglas-fir beetle generally attacks trees already stressed through other insects such as the Douglas-fir tussock moth (*Orgyia pseudotsugata* McD.). Annual mortality from by Douglas-fir beetle in British Columbia was 84 900 m³ between 1982 and 1987.

**Dwarf Mistletoes** – *Arceuthobium* sp.

By distorting branches and reducing growth by 30–60%, dwarf mistletoe damages lodgepole and jack pine, western hemlock, western larch, Douglas-fir, and spruce mainly in western Canada and spruce in eastern Canada (Kondo and Taylor 1986). The infection of the dwarf mistletoes generally remains constant over time, although environmental factors such as drought can significantly increase tree mortality. The rate of spread of dwarf mistletoe infection is reduced by harvesting affected trees. This reduces the area of infection and stabilizes the annual loss. Annual growth losses were nearly all in British Columbia and occurred mainly on lodgepole pine and western hemlock (Table 15). Lesser amounts of damage and loss in the Prairie provinces occurred on jack and lodgepole pines.

**Table 15.** Annual growth losses caused by the dwarf mistletoe in British Columbia, 1982–1987 (in thousands of cubic metres).

| Host | Growth loss |
|---|---|
| Douglas-fir | 78.7 |
| Western hemlock | 616.7 |
| Lodgepole pine | 038.6 |
| Western larch | 84.9 |
| Total | 818.9 |

**Hypoxylon Canker** – *Hypoxylon mammatum* (Wahl.) J.H. Miller

Hypoxylon canker is an important disease of trembling aspen, occurring from the Maritimes to Alberta. In the Maritimes, Hypoxylon canker is a chronic disease which was estimated to affect 16% of all trembling aspen (Magasi 1988), killing 0.5% per year (Table 16). Both growth loss and mortality occur; however, insufficient information is available to calculate growth loss. Hypoxylon canker has been collected rarely on trembling aspen west of the Rockies and so causes little damage there compared with other areas in Canada.

In Quebec, depletion caused by Hypoxylon canker was estimated for the total volume of poplars (mostly trembling aspen) and all maturity classes. The disease occurs on 1.7% of all trees (Archambault 1982) and an equivalent percentage of the total volume is considered infected. According to Anderson and Martin (1981), infected volume is divided equally between stems and tops; one-sixth and one-twelfth of infected stems and tops were lost annually. Average annual mortality for the period 1982–1987 in Quebec was estimated at 636 000 m³ annually.

In Ontario, surveys during the early 1980s indicated that about 2% of aspen were affected by Hypoxylon canker and had a 12.2% mortality rate for trees with stem cankers. These estimates were applied to aspen volumes in all stands over 20 years of age to estimate the annual loss of close to 2.2 million m³. A much higher estimate for the 1977–1981 period of 6 184 000 m³ mortality was reported by Gross (1985) based on a higher annual mortality rate of 33% (Anderson and Martin 1981).

**Table 16.** Average annual mortality caused by Hypoxylon canker, 1982–1987 (in cubic metres).

| Province | Mortality |
|---|---|
| Prince Edward Island | |
| Nova Scotia | |
| New Brunswick | |
| Quebec | |
| Ontario | |
| Total | 6 076 900 |

**Stem Decays and Root Rots**

There are a number of organisms which cause extensive damage to forest trees. They include the brown cubical rot *Coniophora puteana* Pers.; *Fomes pinicola* (Sw. ex Fr) Cke. and *F. pini* (Brot.: Fr.) Karst.; brown cubical butt rot *Polyporus sericeomollis* Romm.; red butt rot *P. tomentosus* Fr.; and white stringy rot *Poria subacida* (Pk.) Sacc.; all of which contribute to decay (Kondo and Taylor 1986). Organisms particularly significant in British Columbia include *Echinodontium tinctorium*, *Phellinus weirii*, *Leptographium wageneri*, and *Inonotus tomentosus*. Decays become established after the trees have been stressed or wounded by other agents. In addition to the above organisms, Lavallée (1986, 1987) has listed *Stereum sanguinolentum* and *Corticium galactinum* as major decay fungi for balsam fir and black spruce. Basham and Morawski (1964) describe additional species of rots and their hosts. A number of diseases that cause stem decay are also responsible for root rot. *Armillaria* spp. damages weakened trees and is a major cause of mortality in stands and plantations of all ages. Root diseases occur throughout Canada, their effects vary among forest types.

The national totals indicate extensive losses of wood volume as a result of infection by these organisms (Table 17). The highest loss occurs in British Columbia, the next highest in Ontario. Losses in the Prairies and Quebec range from 2.3 to 3.4 million m³ annually. Additional losses were reported from some regions as root and butt rots.

*Newfoundland–Labrador Region*

Depletion caused by butt rot and heart rot fungi are a large proportion of losses described as cull. Cull also includes losses caused by forked or broken stems, but only losses to fungi have been estimated. Volume losses from these organisms vary little from year to year; the average annual loss has been 6 226 000 m³ of balsam fir and spruce. The

amounts are declining gradually as older trees are being harvested.

*Maritimes Region*

Major losses occur from stem and root decays although mortality is seldom evident. Growth loss estimates are difficult to make, since the slow deterioration occurs on the inside of a stem as the roots lose their vigor. Depletion estimates were developed from cull surveys. Average annual losses were 548 000 m³ for New Brunswick, 227 000 m³ for Nova Scotia and 24 000 m³ in Prince Edward Island. About 60% of the losses were on softwoods, primarily balsam fir.

*Quebec Region*

Depletion by stem decay is considered to be endemic causing volume loss, but not necessarily mortality. Annual losses were determined for species groups and maturity classes from percent volume reductions as estimated by Lavallée (1986, 1987) for balsam fir and black spruce and as calculated by Basham and Morawski (1964) for other species. Over the reporting period, 2.6 million m³ of wood were lost due to stem decay in Quebec (Table 17).

*Ontario Region*

Root rots of coniferous species caused an average annual mortality loss of 8 020 432 m³ and growth loss of 668 571 m³. The species with greatest loss was black spruce followed by balsam fir. Over 60% of the mortality was in black spruce, about 20% in balsam fir. Broad-leaved species were also affected, but no estimates were developed for them. Root rots are contributing factors in forest and tree declines, particularly for maple and oak. Consequently some of the root rot damage is reported as part of those losses.

**Table 17.** Annual losses from stem and root decays, all provinces, 1982–1987 (in cubic metres).

| Province | Volume losses |
|---|---|
| Newfoundland | 24 000 |
| Prince Edward Island | 24 000 |
| Nova Scotia | 227 000 |
| New Brunswick | 548 000 |
| Quebec | 2 608 000[a] |
| Ontario | 5 947 665 |
| Manitoba | 3 358 200 |
| Saskatchewan | 2 614 200 |
| Alberta | 2 266 800 |
| British Columbia | 18 657 000 |
| Yukon | 500 |
| Total | 37 288 965 |

[a] Stem decay only.

The growth loss of 668 571 m³ caused by root rots is a direct reduction in the expected annual volume increment for surviving trees. The estimate is conservative since it contains no provision for growth loss by trees killed by root rot. Mortality is commonly aggregated in patches within affected stands, and the growth influence is largely a function of reduced stocking. Data were not available to provide a basis for analysis of this kind of growth loss. However, considering the magnitude of mortality, an additional loss of several hundred thousand cubic metres is appropriate.

The total average annual decay loss of 5 947 665 m³ for the period was reduced by 34% compared with losses of9 045 000 m³ reported for 1977–1981 (Gross 1985). Much of the difference in total decay loss for the 1977–1981 report compared with this report was contained in estimates for aspen (2 272 935 m³) and sugar maple (611 000 m³). Both species had high decay rates in the older age classes (Morawski et al. 1958).

*Northwest Region*

Extensive losses from decay occurred in the region from 1982 to 1987, averaging about 8.2 million m³ annually. Loss estimates are derived from provincial inventory estimates and should be viewed as conservative since they are measured at the point of processing. About three-fourths of decay occur on hardwood species.

*Pacific and Yukon Region*

The total annual depletion from decay was 13 180 000 m³; for root and butt rots it was 5 477 780 m³. About three quarters of the root and butt rots loss resulted in mortality and most of this was caused by Armillaria. Old growth decay and increasing losses in second growth stands combine to make this group the single greatest cause of growth loss and mortality.

**White Pine Blister Rust** – *Cronartium ribicola* J.C. Fisch.

This organism caused significant damage in pines in the Maritimes region. White pine blister rust is an example of a chronic condition which has about the same impact on trees annually. Depletion calculations were developed from changes in inventory data and estimates of loss rates. The average annual mortality was 75 000 m³ for New Brunswick and 9 000 m³ for Nova Scotia, based on the loss rates in 1977–1981.

**Maple Decline/Hardwood Declines**

Losses have been calculated in Quebec for the long-standing decline in sugar maple. Depletion was estimated from the area of various categories of decline according to Bordeleau et al. (1989). The total area of each decline class was apportioned by the area of the stand types (yellow birch–maple stands versus basswood–maple stands) in which decline occurred. Annual losses from maple decline were about 1 million m³ in Quebec and about 600 000 m³ in Ontario (Table 18). Substantial losses also occurred in white

birch and red oak in Ontario. Dieback and declines caused a total annual mortality of 3 770 426 m³ to various hardwoods. These losses result from several factors, including insect defoliation, root rots and drought.

**Abiotic Losses**

Other abiotic losses have also occurred in forests in Quebec. Between 1982 and 1987, localized ice storms and windfall occurred on 90 787 ha for a net area of 21 804 ha of destroyed forest. In the boreal forest region, 124 ha were depleted, the remainder being destroyed in the mixed or deciduous forest region. Total depletion at 102 000 m³ was estimated from stocking data and then averaged over the period (Table 18).

**Table 18.** Annual mortality from maple declines and diebacks and abiotic causes in Quebec and Ontario, 1982–1987 (in cubic metres).

| Disease | Mortality | Volume loss | Total |
|---|---|---|---|
| Maple – Quebec | 1 087 000 | 596 000 | 2 683 000 |
| White birch – Ontario | 3 128 668 | | |
| Maple – Ontario | 602 301 | | |
| Red oak – Ontario | 39 457 | | |
| **Total (Ontario)** | **3 770 426** | | |
| Abiotic[a] – Quebec | 102 000 | | 102 000 |

[a] From ice storms and windthrow.

**Nursery Losses**

Nursery losses were reported from Quebec caused by both insects and diseases. Average annual losses were 785 000 seedlings lost due to insects and 5 600 000 to diseases.

## Summary

The estimated losses from insects and diseases causing mortality and reductions of growth were considerable during 1982–1987 (Table 2). Total losses over the period averaged 102 756 000 million m³, about two-thirds of which was direct mortality. Reduction of growth was about one-fifth of the total; the remainder was attributed to losses from decay organisms. The major pests affecting the boreal conifer forests continue to be the spruce budworm complex, the mountain pine beetle, root rots, decays and mistletoes. Despite fluctuations and a general decline in the infestation of the spruce budworm, it still caused the highest proportion of the insect-caused losses. On hardwoods, the forest tent caterpillar caused extensive losses in growth although effects on mortality were small. Some pests caused significant depletions in particular regions; examples include the hemlock looper in Newfoundland, the eastern larch beetle in the Maritimes, and the gypsy moth in Ontario.

When the annual losses from insects and diseases are combined with the losses from wildfire and harvest, which for the purposes of this report can be considered a depletion, it is evident that very large volumes of wood are being removed from forests annually (Table 1). Indeed, if these losses are compared to the estimated annual growth in Canadian forests, it is apparent that there is a net deficit in the overall supply of wood. Some may be offset by harvest of damaged wood and utilization of wood already dead, but the amounts are certain to cause concern among those in charge of the management and protection of Canada's forests.

## References


Alfaro, R.I.; Taylor, S.P.; Wegwitz, E.; Brown, R.G. 1987. Douglas-fir tussock moth damage in British Columbia. For. Chron. 6(5): 351-355.

Alfaro, R.I.; Bloomberg, W.J.;Smith, R.B.; Thomson, A.J. 1985. Epidemiology of dwarf mistletoe in western hemlock stands in south coastal B.C. Can. J. For. Res. 15: 909-913.

Alfaro, R.I. 1988. Effects of defoliation by the western false hemlock looper on Douglas-fir tree ring chronologies. Tree-Ring Bull. (48): 3-11.

Alfaro, R.I.; Qiwei, L.; Vallentgoed, J. 1991. Diameter growth losses in western larch caused by larch casebearer defoliation. West. J. Appl. For. 6(4): 105-108.

Alfaro, R.I. 1989. Development of preliminary spruce budworm loss factors for the Kamloops Region. Unpublished. Forestry Canada. File Report.

Alfaro, R.I.; Maclauchlan, L. E. 1991. A method to calculate the losses caused by western spruce budworm in uneven-aged Douglas-fir forests of British Columbia. Unpublished Report.

Anderson, G.W.; Martin, M.P. 1981. Factors related to incidence of Hypoxylon cankers in aspen and survival of cankered trees. For. Sci. 27(3): 461-476.

Anon., 1985. Alberta Phase 3 Forest Inventory, An Overview. Alberta Forestry, Lands and Wildlife, Edmonton. ENR Report No. I/86.

Anon. 1987. Insectes et maladies des arbres — Québec — 1986. Suppl. Forêt Conservation 53(10). 32 p.

Anon. 1988. Canada's Forest Inventory 1986. Forestry Canada, Hull, Quebec. 59 p.

Archambault, L. 1982. Impact du chancre hypoxylonien sur le tremble de deux unités de gestion du Québec. For. Chron. 58: 139-142.

Archambault, L. 1983. Impact of insect defoliation caused by the spruce budworm on volume growth in three fir stands. Canadian Forestry Service, Ottawa. Res. Notes 3: 17-19.

Barter, G.W.; Cameron, D.G. 1955. Some effects of defoliation by the forest tent caterpillar. Canada Dept. of Agriculture, For. Biol. Div., Bi-mon. Prov. Rep. Vol. 11(6).

Basham, J.T.; Morawski, Z.J.R. 1964. Culls studies, the defects and associated Basidiomycete fungi in the heartwood of living trees in the forests of Ontario. Canada Dept. of Forestry Publication, No. 1072, 69 p.

Batzer. 1973. *In* MacLean, D.A. 1985. Effects of spruce budworm outbreaks on forest growth and yield. CANUSA Spruce Budworms Res. Symp. Proc. 1985. part II: 148-175.

Batzer, H.O. 1973. Net effect of spruce budworm defoliation on mortality and growth of balsam fir. J. For. 71: 34-37.

Batzer, H.O.; Hodson, A.C.; Schneider, A.E. 1954. Preliminary results of an inquiry into effects of defoliation of aspen trees by the forest tent caterpillar. Minnesota For. Notes No. 31.

Bauce, E.; Allen, D.C. 1991. Etiology of a sugar maple decline. Can. J. For. Res. 21: 686-693.

Beale, J. 1985. Hemlock dwarf mistletoe in the Vancouver Forest Region. B.C. Min. For. Pest Management Progr. 4: 23-24.

Benoit, P.; Laflamme, G.; Bonneau, G.; Picher, R. 1983. Insectes et maladies des arbres —1982. 23 p.

Bickerstaff, A.; Wallace, W.L.; Evert, F. 1981. Growth of forests in Canada. Part 2: A quantitative description of the land base and the mean annual increment. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ont. Inf. Rep. PI-X-1.

Blais, J.R. 1958a. Effects of defoliation by spruce budworm (*Choristoneura fumiferana* Clem.) on radial growth at breast height of balsam fir (*Abies balsamea* (L.) Mill.) and white spruce (*Picea glauca* (Moench) Voss.). For. Chron. 34: 39-47.

Blais, J.R. 1958b. The vulnerability of balsam fir to spruce budworm attack in northwestern Ontario, with special reference to the physiological age of the tree. For. Chron. 34: 405-422.

Bloomberg, W.J. 1986. Comparison of dwarf mistletoe effects on hemlock in Alaska, B.C., and the Pacific Northwest. 34th Annual Forest Disease Work Conference.

Bloomberg, W.J.; Reynolds, G. 1985. Growth loss and mortality in laminated root rot infection centers in second-growth Douglas-fir on Vancouver Island. For. Sci. 31(2): 497-508.

Bloomberg, W.J.; Morrison, D.J. 1989. Relationship of growth reduction in Douglas-fir to infection by Armillaria root disease in southeastern British Columbia. Phytopathology 79(4): 482-487.

Bloomberg, W.J. 1983. A ground survey method for estimating loss caused by *Phellinus weirii* root rot. iii. Simulation of disease spread and impact. Canadian Forestry Service, Pacific Forestry Centre. BX-X-7. 24 p.

Bolsinger, C.L. 1978. The extent of dwarf mistletoe in six principal softwoods in California, Oregon and Washington as determined from forest survey records. Proc. Symp. on dwarf mistletoe control through forest management, Berkeley, CA. pp. 49-50.

Bonneau, G.; Picher, R.; Lachance, D. 1985. Insectes et maladies des arbres — Québec — 1985. Suppl. Forêt Conservation 52(10). 32 p.

Bonneau, G.; Picher, R.; Lachance, D. 1986. Insectes et maladies des arbres du Québec — 1985. Canadian Forestry Service and Ministère de l'Énergie et des Ressources. 32 p.

Bordeleau, C.; Guérin, D.; Innes, L.; Lachance, D.; Picher, R. 1988. Québec 1987. Insectes et maladies des arbres — Suppl. Forêt Conservation 54(10). 32 p.

Bordeleau, C.; Guérin D.; Innes L.; Lachance D.; Picher R. 1989. Insectes et maladies des arbres — Québec — 1988. Suppl. Forêt Conservation 56(1). 32 p.

Campbell, R.W.; Garlo, A.S. 1982. Gypsy moth in New Jersey pine–oak. J. For. 80: 89-90.

Cerezke, H.F. 1986. Impact studies of the jack pine budworm, *Choristoneura pinus pinus* in the Nisbet Provincial Forest Saskatchewan. *In* Jack pine information exchange. pp. 25-38. Manitoba Dept. Natural Resources, Winnipeg. 96 p.

Churchill, G.B.; John, H.H.; Duncan, D.P.; Hodson, A.C. 1964. Long-term effects of defoliation of aspen by the forest tent caterpillar. Ecology. 45: 630-633.

Craighead, F.C. 1940. Some effects of artificial defoliation on pine and larch. J. For. 38: 885-888.

Duncan, D.P.; Hodson, A.C. 1958. Influence of the forest tent caterpillar upon the forests of Minnesota. For. Sci. 4: 71-93.

Fortin, J. 1983. La croissance forestière au Québec. Service de l'inventaire Forestier, Ministère de l'Énergie et des Ressources. 82 p.

Gagnon, G.; Roy, G.; Gravel, C.; Gagné, J. 1986. État des recherches sur le dépérissement au Ministère de l'Énergie et des Ressources. Journée d'information sur l'acériculture. C.P.V.Q./M.A.P.A.Q. pp. 47-85.

Gray, S.L.; Nietmann, K. 1989. Canada's forest inventory 1986 - technical supplement. Forestry Canada, Petawawa National Forestry Institute, Chalk River, Ont. Inf. Rep. PI-X-86.

Gross, H.L. 1985. The impact of insects and diseases on the forests of Ontario. Canadian Forestry Service, Great Lakes Forest Research Centre, Sault Ste. Marie, Ontario. Inf. Rep. O-X-366.

Gross, H.L. 1991. Dieback and growth loss of sugar maple associated with defoliation by the forest tent caterpillar. For. Chron. 67: 33-42.

Gross, H.L.; Roden, D.B.; Churcher, J.J.; Howse, G.M.; Gertidge, D. 1992. Pest-caused depletions to the forest resource of Ontario, 1982-1987. Forestry Canada/Ontario Ministry of Natural Resources, Joint Rep. 17., 16 p.

Hidahl, V.; Reeks W.A. 1960. Outbreaks of the forest tent caterpillar, *Malacosoma disstria* Hb., and their effects on stands of trembling aspen in Manitoba and Saskatchewan. Can. Entomol. 92: 199-209.

Hiratsuka, Y.; Loman, A.A. 1984. Decay of aspen and balsam poplar in Alberta. Canadian Forestry Service. Northern Forest Research Centre, Edmonton, Alberta. Inf. Rep. NOR-X-262.

Hodson, A.C. 1941. An ecological study of the forest tent caterpillar, *Malacosoma disstria* Hbn., in Northern Minnesota. Univ. Minn. Agric. Tech. Bull. 148: 1-55.

Honer, T.G.; Bickerstaff, A. 1985. Canada's forest area and wood volume balance 1977-81. Canadian Forestry Service, Pacific Forestry Centre, Victoria, British Columbia.

Ives, W.G. 1971. The forest tent caterpillar in Alberta. Canadian Forestry Service, Northern Forestry Centre. Inf. Rep. NOR-4.

Ives, W.G.; Wong, H.R. 1988. Tree and shrubs insects of the Prairie provinces. Canadian Forestry Service, Northern Forestry Centre, Edmonton, Alberta, Inf. Rep. NOR-X-292.

Knight, F.B.; Keikkenen, H.J. 1980. Principles of forest entomology. McGraw-Hill, New York, N.Y.

Kondo, E.S.; Moody, B.H. 1987. Forest insect and disease conditions in Canada 1986. Canadian Forestry Service, Hull, Quebec.

Kondo, E.S.; Taylor, R.G. 1984. Forest insect and disease conditions in Canada 1983. Canadian Forestry Service, Hull, Quebec.

Kondo, E.S.; Taylor, R.G. 1986. Forest insect and disease conditions in Canada 1985. Canadian Forestry Service, Hull, Quebec.

Kulman, H.M. 1971. Effects of insect defoliation on growth and mortality of trees. Ann. Rev. Entomol. 16: 289-324.

Kulman, H.M.; Hodson, A.C.; Duncan, D.P. 1963. Distribution and effects of jack pine budworm defoliation. For. Sci. 9: 146-157.

Lachance, D.; Benoît, P.; Laflamme, G.; Bonneau, G.; Picher, R. 1983. Insectes et maladies des arbres — Québec — 1983. Suppl. Forêt Conservation 50(10). 24 p.

Lachance,D.; Benoît, P.; Laflamme, G.; Bonneau, G.; Picher R. 1984. Insectes et maladies des arbres — Québec — 1984. Suppl. Forêt Conservation 51(10). 32 p.

Lachance, D.; Benoit, P.; Laflamme, G.; Bonneau. G.; Picher, R. 1985. Insectes et maladies des arbres du Québec — 1984. Canadian Forestry Service and Ministère de l'Énergie et des Ressources. 32 p.

Langor, D.W.; Raske, A.G. 1989. A history of the eastern larch beetle, *Dendroctonus simplex* (Coleoptera: Scolytidae), in North America. Great Lakes Entomol. 22: 139-154.

Lavallée, A. 1986. Les caries du sapin baumier dans le centre et le nord-est du Québec. Centre de Foresterie des Laurentides, Service canadien des forêts. Rapport d'information LAU-X-70. 23 p.

Lavallée, A. 1987. Les caries de l'épinette noire dans la forêt boréale au Québec. Centre de Foresterie des Laurentides, Service canadien des forêts. Rapport d'information LAU-X-76. 16 p.

Loma, A.A.; Paul, G.D. 1963. Decay of lodgepole pine in two foothills sections of the boreal forest of Alberta. For. Chron. 39: 422-435.

Loomis, R.C.; Tucker, S.; Hofacker, T.H. (eds.). 1985. Insect and disease conditions in the United States, 1979-83. USDA, USFS General Technical Report WO-46. 93 p.

Magasi, L.P. 1988. Forest pest conditions in the Maritimes 1987. Forestry Canada, Maritimes Region, Inf. Rep. M-X-166.

Moody, B.H.; Cerezke, H.F. 1985. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba and the Northwest Territories in 1984 and predictions for 1985. Northern Forest Research Centre, Edmonton, Alberta. Inf. Rep. NOR-X-269.

Moody, B.H.; Cerezke, H.F. 1986. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba and the Northwest Territories in 1985 and predictions for 1986. Northern Forest Research Centre, Edmonton, Alberta. Inform. Rep. NOR-X-276.

Morawski, Z.J.R.; Basham, J.T.; Turner, K.B. 1958. A survey of the pathological condition in the forests of Ontario. Ontario Dept. ofLands and Forests, Toronto, Ont. Rep. No. 25, Cull Studies. 96 p.

Morrison, D.J. 1981. Armillaria Root Disease. A guide to disease diagnosis, development and management in B.C. Canadian Forestry Service, Pacific Forest Research Centre. BX-X-203.

O'Neill, L.C. 1962. The suppression of growth rings in jack pine in relation to defoliation by the Swaine jack pine sawfly. Can. J. Bot. 41: 227-235.

Pearce, P.A.; Hoyt, J.S. 1969. Decay survey report: An investigation into the major softwood species on the crown lands of New Brunswick. Dept. Natural Resources, New Brunswick.

Pedersen, N.L. 1981. The effects of spruce budworm defoliation on growth characteristics of balsam fir. School of Forestry, Lakehead Univ. Thunder Bay, Ont. 30 p.

Pendrel, B.A. 1991. Insect and disease-caused losses of wood volume in forests of the Maritimes Provinces, 1982–1987. Forestry Canada, Maritimes Region, Inf. Rep. M-X-180E 14 p.

Piene, H. 1980. Effects of insect defoliation on growth and foliar nutrients of young balsam fir. For. Sci. 26: 665-673.

Power, J.M. 1986. FIDSINFOBASE — The Forest Insect and Disease Survey information system. Canadian Forestry Service, Petawawa National Forestry Institute, Chalk River, Ont. Inf. Rep. PI-X-65.

Power, J.M.; D'Eon, S.P. 1991. Quantifying forest depletion using Geographic Information Systems and database technologies. Petawawa National Forestry Institute, Inf. Rep. PI-X-105, 17 p.

Power, J. M.; Taylor, R. 1985. The methodology and interpretation of forest insect caused and disease caused depletion estimates. Forestry Canada. Unpublished Report.

Rose, A.H. 1958. The effect of defoliation on foliage production and radial growth of quaking aspen. For. Sci. 4: 335-342.

Rowe, J.S. 1977. Forest regions of Canada. Canadian Forestry Service, Dept. of Fisheries and Environment, Ottawa, Ontario.

Runyon, K.L. 1991. Canada's timber supply: Current status and outlook. Forestry Canada, Maritimes Region, Inf. Rep. E-X-45. 132 p.

Service des plans d'aménagement, M.E.R.Q. 1986. Possibilité et disponibilité en matière ligneuse des forêts publiques du Québec. pp. 1-40.

Sterner, T.E.; Davidson, A.G. 1982. Forest insect and disease conditions in Canada 1981. Canadian Forestry Service, Environment Canada, Hull Quebec. 46 p.

Taylor, S.P. 1986. Forest insects and disease impacts in Tree Supply Areas. Pest Manage. Rep. No. 6, B.C. Forest Service, Victoria, B.C.

Taylor, S.P. 1989. Forest insects and disease impacts in Tree Farm Licences. Pest Manage. Rep. No. 11, B.C. Forest Service, Victoria, B.C.

Thomson, A.J.; Smith, R.B.; Alfaro, R.I. 1984. Growth patterns in immature and mature western hemlock stands infected with dwarf mistletoe. Can. J. For. Res. 14: 665-668.

Unger, L.; Stewart, A. 1988. Vancouver Regional Report 1987. Forestry Canada, Pacific Forest Research Centre, Victoria, B.C. Unpublished Report

Volney, W.J.A. 1988. Analysis of historic jack pine budworm outbreaks in the Prairie provinces of Canada. Can. J. For. Res. 18: 1152-1158.

Van Der Kamp, B.S.; Merler, H. 1984. Root disease of spruce in central British Columbia. Univ. of British Columbia, Vancouver, B.C.

Wargo, P.M. 1981. Defoliation and tree growth. Pages 225-240 *in* C.C. Doane and M.L. McManus (eds.) The gypsy moth: Research toward intergrated pest management. US Dept. Agric., Tech. Bull. 1584.

Whitney, R.D. 1976. Root rot of spruce and balsam fir in N.W. Ontario. I — Damage and implications for forest management. Ontario Region, Great Lakes Forest Research Centre. Inf. Rep. O-X-241.

Wood, C. 1986. Distribution maps of common tree diseases in B.C. Pacific Forestry Centre Inf. Rep. BX-X-281.

Wood, P.M. 1983. A survey to determine root disease losses in coastal B.C. Forests. Presented at the 74th Western Forestry Conference, Dec. 1983. Portland, Oregon.

# Forest Depletions Caused by Insects and Diseases in Canada, 1982–1987

Forest Insect and Disease Survey, Information Report ST–X–8

## Corrections

The following tables in this publication have been corrected.

**Table 4.** Average annual mortality and growth loss from the spruce budworm, 1982–1987 (in cubic metres).

| Province[a] | Mortality loss/yr | Growth loss/yr | Total loss/yr |
|---|---|---|---|
| Newfoundland | 158 500 | 70 000 | 1 298 500 |
| Nova Scotia | 140 000 | 145 000 | 1 285 000 |
| New Brunswick | 5 152 000 | 602 000 | 5 754 000 |
| Prince Edward Island | 140 000 | 16 000 | 156 000 |
| Quebec | 8 532 100 | 1 504 011 | 10 036 111 |
| Ontario | 7 166 500 | 1 566 100 | 8 732 600 |
| Manitoba | 500 | 1 100 | 1 600 |
| Saskatchewan | 600 | 8 800 | 9 400 |
| Alberta | 0 | 0 | 0 |
| Northwest Territories | 800 | 0 | 800 |
| British Columbia | 0 | 22 100 | 22 100 |
| Total | 23 291 000 | 3 935 111 | 27 296 111 |

[1] No mortality or growth losses reported from Prairie provinces.

**Table 6.** Annual mortality and growth loss caused by the jack pine budworm in Ontario, 1982–1987 (in cubic metres).

| Year | Mortality | Growth loss | Total |
|---|---|---|---|
| 1983 | 0 | 3 941 | 3 941 |
| 1984 | 18 368 | 178 594 | 196 962 |
| 1985 | 695 217 | 861 216 | 1 556 433 |
| 1986 | 2 927 186 | 1 413 534 | 4 340 720 |
| 1987 | 3 659 670 | 1 081 735 | 4 741 405 |
| Average | 460 088 | 707 804 | 2 167 892 |

**Table 5.** Area of moderate to severe defoliation by the jack pine budworm, 1982–1987 (in hectares).

| Province | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Ontario | 981 | 67 142 | 1 150 158 | 3 660 069 | 1 743 725 | 504 749 |
| Manitoba | 0[a] | 154 500 | 761 000 | 2 048 000 | 132 000 | 100 |
| Saskatchewan | | | 27 000 | 131 000 | 176 000 | 2 500 |
| Alberta | | | — | 70 | 70 | 70 |
| Total | 981 | 221 642 | 1 938 158 | 5 839 139 | 2 051 795 | 507 419 |

[a] Defoliation present but area not reported.

**Table 7.** Area of moderate to severe defoliation by the forest tent caterpillar, 1982–1987 (in thousands of hectares).

| Province | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Prince Edward Island | 19 | 67 | 37 | 0 | 0 | 0 |
| Nova Scotia | 5 | 35 | 46 | * | * | 0 |
| New Brunswick | 1 389 | 119 | 94 | 0 | 0 | 0 |
| Quebec | 353 | 0 | * | 182 | 479 | 561 |
| Ontario | 104 | 31 | 127 | 209 | 433 | 1 650 |
| Manitoba | 198[a] | 198[a] | 77 | 20 | 17 | 4 |
| Saskatchewan | 693[a] | 70[a] | 0 | 31 | 177[b] | 250[c] |
| Alberta | 4 290[a] | 319[a] | 0 | 155 | 316[b] | 1 322[b] |
| British Columbia | — | 2 | 31 | 59 | 93 | 24 |
| Total | 7 051 | 2 841 | 412 | 656 | 515 | 3 811 |

[a] 33% of the total land area mapped.
[b] 10% of the total land area mapped.
[c] 20% of the total land area mapped.
* less than 1 000 ha.

**Table 9.** Annual growth loss caused by forest tent caterpillar in Ontario, 1982–1987 (in cubic metres).

| Year | Poplar | White birch | Yellow birch | Sugar maple | Other hardwoods | Total |
|---|---|---|---|---|---|---|
| 1982 | 74 345 | 15 213 | 18 | 186 | 98 | 89 860 |
| 1983 | 17 077 | 5 050 | 0 | 0 | 0 | 22 127 |
| 1984 | 52 857 | 16 304 | 250 | 657 | 158 | 70 226 |
| 1985 | 94 601 | 27 797 | 486 | 1 313 | 340 | 124 537 |
| 1986 | 120 306 | 44 860 | 6 258 | 31 914 | 12 966 | 216 304 |
| 1987 | 413 341 | 256 185 | 28 975 | 143 883 | 57 331 | 899 715 |
| Total | 772 527 | 365 409 | 35 987 | 177 953 | 70 893 | 1 422 769 |

**Table 11.** Area of moderate to severe defoliation by gypsy moth in Ontario and Quebec, 1982–1987 (in hectares).

| Year of infestation | Area of defoliation Quebec | Ontario |
|---|---|---|
| 1982 | 8 738 | 4 800 |
| 1983 | — | 40 954 |
| 1984 | | 80 624 |
| 1985 | 198 | 246 342 |
| 1986 | 4 700 | 167 776 |
| 1987 | 1 180 | 12 678 |
| Total | 14 816 | 553 174 |

**Table 14.** Volume loss caused by the mountain pine beetle in western Canada, 1982–1987 (in cubic metres).

| Year | British Columbia | Alberta | Saskatchewan | Total |
|---|---|---|---|---|
| 1982 | 15 680 000 | 190 080 | 253 | 15 870 333 |
| 1983 | 17 765 000 | 77 880 | 733 | 17 843 613 |
| 1984 | 12 195 000 | 74 151 | 299 | 12 269 450 |
| 1985 | 6 515 000 | 42 900 | 28 | 6 557 928 |
| 1986 | 3 539 000 | 89 | | 3 539 090 |
| 1987 | 2 962 000 | 0 | 0 | 2 962 000 |
| Total | 58 656 000 | 385 100 | 1 314 | 59 042 414 |
| Average | 9 776 000 | 64 183 | 219 | 9 840 402 |

**Table 16.** Average annual mortality caused by Hypoxylon canker, 1982–1987 (in cubic metres).

| Province | Mortality |
|---|---|
| Prince Edward Island | |
| Nova Scotia | |
| New Brunswick | |
| Quebec | |
| Ontario | |
| Total | 3 106 900 |

**Table 17.** Annual losses from stem and root decays, all provinces, 1982–1987 (in cubic metres).

| Province | Volume losses |
|---|---|
| Newfoundland | |
| Prince Edward Island | |
| Nova Scotia | |
| New Brunswick | |
| Quebec | |
| Ontario | |
| Manitoba | |
| Saskatchewan | |
| Alberta | |
| British Columbia | |
| Yukon | |
| Total | |

[a] Stem decay only.