

**PEST-CAUSED DEPLETIONS TO  
THE FOREST RESOURCE OF  
ONTARIO, 1982-1987**

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### ABSTRACT

This report contains a summary of damage to forests in Ontario caused by insects and diseases. For the 6-year period from 1982 to 1987, an average annual growth loss of 2,818,772 m<sup>3</sup> and mortality of 8,411,626 m<sup>3</sup> occurred from insect activity and a 668,571-m<sup>3</sup> growth loss, 5,947,665-m<sup>3</sup> decay loss and 13,969,768 m<sup>3</sup> of mortality were caused by diseases. Total pest-caused losses were 31,836,402 m<sup>3</sup>. Data are also summarized by Ontario Ministry of Natural Resources administrative region (as they existed from 1982 to 1987).

### RÉSUMÉ

Ce rapport contient un résumé des dommages causés aux forêts de l'Ontario par les insectes et les maladies. Pour la période de six ans allant de 1982 à 1987, un déficit de croissance annuel moyen de 2 818 772 m<sup>3</sup> et une mortalité de 8 411 626 m<sup>3</sup> ont été causés par les insectes, alors qu'un déficit de croissance de 668 571 m<sup>3</sup>, une perte due à la pourriture de 5 947 665 m<sup>3</sup> et une mortalité de 13 969 768 m<sup>3</sup> ont été causés par les maladies. Les pertes totales dues aux ravageurs ont été de 31 836 402 m<sup>3</sup>. Les données ont également été résumées par la région administrative du ministère des Ressources naturelles de l'Ontario (données de 1982 à 1987).

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## INTRODUCTION

When a forest manager notices an insect, a disease or an unexplained anomaly in the forest, the first question asked is "What is it?" Once that is answered, the next question is "What is it going to do to the trees and the forest?" Depending on the response to the second question, a third query may be made: "What can I do about it?" Often the answers to the first and third questions are reasonably easy to provide. Identification of the problem is the necessary first step, and assistance from a taxonomist or systematist usually solves that dilemma. When the insect or disease is identified, then control techniques can be prescribed by a pest manager. The second question, dealing with the impact of the pest, is often not so easily answered.

Impact can take many forms, from a general weakening of the tree so that it is more susceptible to other stresses, to loss of height growth or annual increment, to outright mortality. A given pest may not necessarily inflict a specific foreseeable impact. Depending on the severity of the attack, the extent of the outbreak, the duration of the infestation, the virulence of the pathogen and the availability of a suitable host and conditions, for instance, any degree of impact could occur. Thus, the entomologist or pathologist, unable to predict the future, must base a response to the question of probable impact on past infestations or epidemics, past impacts and comparisons with the current situation.

Even so, the answer provided to the forest manager may still not adequately satisfy his or her needs. The word impact can mean different things to different people. Strictly speaking, it includes all effects that a pest can exert on its host throughout the range of the host. This has been called the "biological impact" by some people. This type of impact is biologically valid in that it reports the full range of impacts (from growth loss to mortality) on all susceptible hosts regardless of size, value, location or age. It represents the total impact that the pest will have on its host species.

If a portion of the host species complex is of no real importance or value as a timber resource, then inclusion of the loss of these stems may reduce the usefulness of the impact assessment from the point of view of timber management. Estimating the impact on only those trees which hold a value, the so-called "economic impact", may be more useful to the forest manager. This is, however, much more difficult to calculate, especially when deriving provincewide statistics for a jurisdiction the size of Ontario. The entomologist or pathologist should not make decisions on the commercial operability of the

stands affected, on which stands are valued for recreational purposes or wildlife habitat, or on which areas do not contain a perceived value.

As a result, the biological impact is normally the value calculated and provided to the forest manager. It may not provide the precise answer requested, but it can indicate the relative impact to be expected from a pest. The forest manager can then decide whether some form of intervention is necessary on the basis of the value of the trees being attacked.

To assist in the determination of the significance of these pest impacts, a comparison can be made with the volume of wood harvested for the same period of time. The pests reported in the present study accounted for a mean annual biological loss of 31.8 million m<sup>3</sup>. In comparison, an annual average of 19.1 million m<sup>3</sup> was harvested during the 1982–1987 period of review (Anon. 1987, Anon. 1990).

This publication reviews and reports on the biological impacts associated with the major pests in Ontario's forests from 1982 to 1987. It has been compiled as part of a national Forestry Canada assessment by the six Forest Insect and Disease Survey (FIDS) units, and is similar to an exercise conducted for the 1977–1981 period (Sternier and Davidson 1982). A report specific to Ontario for the latter project can be found in Gross (1985).

As indicated by the list of authors, this exercise and publication is the result of extensive collaboration between Forestry Canada and Ontario Ministry of Natural Resources (OMNR) staff. It has been conducted and presented so as to be of maximum use and applicability to all users of Ontario's forests, while adhering to the scientific requirements of the federal Forest Insect and Disease Survey.

This publication will first describe the methodology used to interpret the forest inventory, on which the pest impact assessments are based, and the individual estimators used for each pest species. The calculated impacts for insects and diseases are then presented. Data on pests for each OMNR administrative region (as they existed from 1982 to 1987) are presented in Appendices 2–7.

## METHODS

### Inventory

Estimates and methods of analysis for the 1982 to 1987 exercise are comparable with those in the previous report by Gross (1985). Generally, the same analytical approach was used. In the present report, however, OMNR's Forest Resources Group was actively engaged

in the exercise, providing computer access to the Ontario Forest Resources Inventory (FRI) and considerable programming assistance.

The FRI inventory changes as data for various management units are updated. Most of the computer analyses were performed in the Fall of 1989. Table 1 shows the gross standing volume present at that time, by species. Data presented in the publication *The Forest Resources of Ontario* (Anon. 1986) provide a good approximation of the forest resource database. The portion of Ontario covered by the FRI is illustrated in Figure 1; impact data are presented by OMNR administrative region and as provincewide estimates.

Table 1. Gross standing volumes of tree species based on the Ontario Forest Resources Inventory as it existed in the fall of 1990.

Tree species	Gross standing volume (m <sup>3</sup> )
<i>Softwoods</i>	
Cedar, white	123,243,069
Fir, balsam	316,897,554
Hemlock	37,550,726
Larch	26,622,596
Pine, jack	691,823,739
red	34,483,373
Scots	2,098,011
white	110,532,207
Spruce, black	1,917,545,402
white	121,065,109
Total softwoods	3,381,861,786
<i>Hardwoods</i>	
Ash, black	28,901,310
white	8,745
Basswood	9,866,099
Beech	21,490,838
Birch, white	497,048,590
yellow	69,674,307
Cherry	3,376,687
Elm	4,704,363
Maple, hard	277,103,140
soft	70,636,468
Oak, red	37,199,053
white	3,456,312
Poplar, aspen	912,034,604
balsam	2,959,431
Other hardwoods	9,854,118
Total hardwoods	1,948,314,065
Total (all species)	5,330,175,851

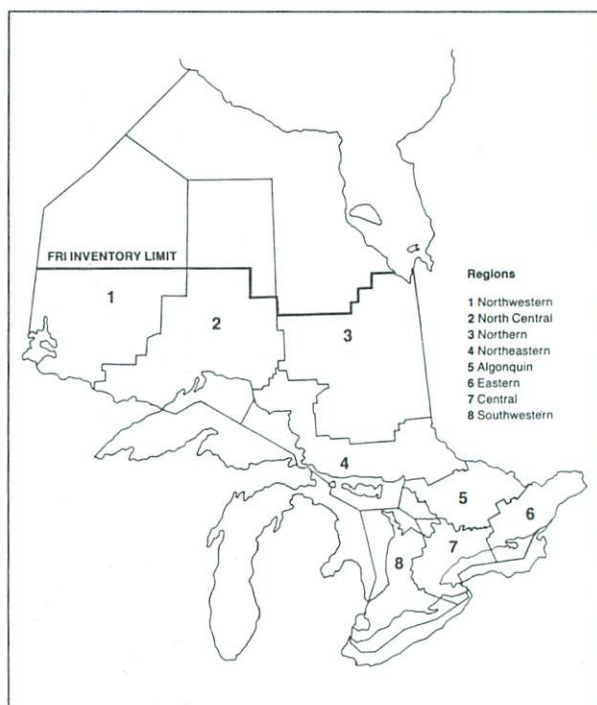


Figure 1. Administrative Regions of the Ontario Ministry of Natural Resources plus the northern limit of Forest Resources Inventory (FRI) coverage. Regional boundaries are those that existed before OMNR's reorganization in 1991.

A conscientious accounting effort was made to avoid inclusion of depletion by any particular pest within depletions estimated for other pests. For instance, mortality caused by the spruce budworm does not include the mortality caused by root rot. This was not a simple proportional allocation of damage among various pests, as data for the actual amount of mortality that occurred did not exist. As well, some pest damage, such as that caused by root rots, eliminates trees before they are included in the inventory, whereas damage attributed to defoliators became a depletion of the actual inventoried forest encountered by the pest. However, some bias of this nature could exist in the information contained in the background literature that was the basis for various estimates applied to modify the inventory data.

Growth loss estimates were determined as a function of current annual increment, whereas mortality and decay estimates were a function of gross standing volumes. Less specific terms such as growth loss, mortality and decay are used in the text. Pests and tree species in this report are named using common nomenclature rather than Latin binomials. Scientific nomenclature and authorities for these common names are listed in Appendix I.

## Softwood Defoliators

### *Spruce budworm*

Impact analysis was the same as that described in the 1977–1981 impact report by Gross (1985), and the same inventory data were used for this exercise. Several factors influenced the decision to use that inventory rather than the current FRI inventory used for all other pests. First, reported annual impact estimates for spruce budworm during the 1982–1987 period had been based on the previous inventory. Second, large portions of the current FRI sampled a forest that had been depleted by budworm activity. Estimators such as the percentage of mortality attributable to the budworm could not be applied to data that did not reflect the forest actually attacked by the budworm.

Tables 2 and 3 show the growth loss and mortality factors that were applied. Mortality of balsam fir usually begins after about 4 years of moderate-to-severe defoliation. Black spruce and white spruce mortality generally started after 6 or 7 years of defoliation. A more complete discussion of the derivation of these estimators is provided by Gross (1985).

Table 2. Reductions in growth rate associated with spruce budworm defoliation.

Years of moderate-to-severe defoliation	Reduction of growth rate (%)	
	Black spruce or White spruce	Balsam fir
1	22	00
2	31	18
3	40	35
4	50	57
5	60	81
6	70	91
7	78	100

Table 3. Percentage of volume loss based on the number of years that mortality caused by spruce budworm was present in a stand.

No. of years of mortality	Balsam fir	White spruce	Black spruce
1	5.0	0	0
2	20.0	0	0
3	35.7	8.1	4.8
4	52.5	15.5	9.7
5	75.0	26.6	16.2
6	82.5	30.2	18.3
7	90.0	33.9	20.5
8	95.0	36.4	22.2
9	97.0	37.3	22.5

### *Jack pine budworm*

Growth losses were interpreted from data presented by Kulman et al. (1963), Kulman (1971) and Cerezke (1986) and a preliminary analysis of FIDS data for the Ontario infestations. Losses were assigned from the various stand defoliation histories that were identified by analysis of FIDS aerial sketch-mapped data using Geographic Information Systems (GIS). For example, stands in areas that experienced 1 year of severe (>75%) defoliation had growth loss rates of 20, 40 and 20% for the year of defoliation and the 2nd and 3rd year following, respectively. Mortality losses were also assigned by stand defoliation histories. These were based on a number of 100-tree mortality study plots established by FIDS during the infestations. Stands that experienced one severe defoliation experienced 1, 1 and 0.5% mortality, respectively, in the 2nd, 3rd and 4th year after the onset of defoliation. Few trees died during the initial year of defoliation. Loss rates were assigned to each stand for each year of the infestation based on historical GIS data.

## Hardwood Defoliators

For each hardwood defoliator or complex of defoliators, the proportion of growing-stock volume affected (growth loss and mortality estimates) was determined from individual FRI stand volumes found within FIDS areas of mapped moderate-to-severe defoliation. Susceptible stands did not include those with a composition of <20% of a susceptible host (a known preferred tree species) or stands younger than 20 years.

### *Forest tent caterpillar*

All hardwood stands defoliated by the forest tent caterpillar that contained preferred species in the Northeastern, Algonquin, Eastern, Central and Southwestern regions were considered affected. Tree species considered to be preferred hosts in these regions were poplar, white birch, hard maple and species of oak. Most broadleaved species other than soft maple were affected. For the Northwestern, North Central and Northern regions, only white birch and poplar were affected. Growth loss was determined as a function of the current annual volume increment of a stand using growth reduction rates of 75% for poplar and 40% for all other host species (Rose 1958, Gross 1991). Since infestations by the forest tent caterpillar in southern Ontario did not begin to expand until 1985, mortality estimates for sugar maple were not significant during the period covered by this report.

## **Gypsy moth**

Known attributes of gypsy moth infestations influenced the way stand data were processed for this pest. In the United States and Europe, studies have shown that outbreaks of gypsy moth can usually be attributed to infestations that start on low-quality oak sites but that eventually spread to better site classes and other species of trees (Campbell 1979). When gypsy moth infestations reached outbreak levels, secondary hosts in a stand were also considered affected as long as the total stand component of less preferred species did not exceed 40%. Species that were considered unattractive were soft maple, yellow birch, black cherry, white ash and all conifers except white pine. Because the infestation was relatively new, low-site-class ( $\leq 3$ ) stands were selected first for inclusion in the impact estimates for the mapped area of defoliation. When the area affected exceeded the total area of low-site-class ( $\leq 3$ ) stands, additional defoliation was allocated under the site-class-2 or better category, since such stands ordinarily would not be affected until most stands of lower site class were affected.

Growth loss was estimated as a function of the current annual volume increment for a stand and the proportional content of preferred and secondary host species at a growth loss rate of 40% (Kulman 1971). Tree mortality, based on FIDS data from 1982 to 1987, occurred mostly on red oak and white oak on site class 3 or 4 sites, and totaled 7%. This provided an average annual mortality rate of 1.17% that was applied to oak volumes in affected stands.

## **Other hardwood defoliators**

The birch skeletonizer and what are referred to as the aspen complex and the maple complex of defoliators were treated similarly. Annual volume growth was reduced by 40% for host species in defoliated stands. For the aspen complex, stands entered the analysis if their aspen content was greater than 20%.

## **Diseases**

### **Root rots**

Estimators of mortality and growth loss caused by root rots were applied to FRI stand data by age class. Stands younger than 30 years were treated as unaffected. Impact estimators were based on data from Whitney (1976), but were adjusted to reflect average stand conditions in each region. This adjustment reduced damage levels to 30% for the Northwestern and North Central regions, 21% for Northern region and 24% for all other regions. This decision was based on the same personal

impressions that justified this approach for the 1977–1981 impact-assessment exercise (Gross 1985).

Mortality rates for spruce and fir were based on data presented by Whitney (1976; Tables 3, 4 and 6). These data were interpreted to get an accumulated total mortality for each age class, which was the percentage mortality listed for an age class plus one-half of the mortality listed for the previous age class. This adjustment provided for dead trees that rotted and disintegrated or that were no longer of a size that qualified as a dominant or codominant tree. Regression models for mortality estimates were fitted to the data by age for each tree species. The models provided mortality rates that were applied to FRI stand data. This age-class approach was the major factor responsible for a 2,744,566-m<sup>3</sup> (25%) reduction in the average annual loss caused by root rot for the 1982–1987 period (Table 14) compared with the loss reported for the 1977–1981 period (Gross 1985). Rather than assuming that the mortality listed for all age classes (Whitney 1976, Table 1) occurred over a 10-year period, the age-class approach to more specific data provided a more sensitive estimate.

Mortality rates for pines were given a fixed value of 0.1% mortality per year. This rate was assigned based on the knowledge that root rots were active in pine stands and that overall mortality rates were low. The same estimators were used for the previous report (Gross 1985).

Estimates of growth loss were based on the same reduction rates applied in the 1977–1981 report (Gross 1985). Rates were 22% for black spruce, 10% for white spruce and 19% for balsam fir. Application of these rates to the percentage of trees affected for each age class (Whitney 1976; Tables 14, 15 and 16) provided an overall estimate that was 419,427 m<sup>3</sup> lower (38%) than the estimate for the previous (1977–1981) report. No growth loss was estimated for pine species because background estimator information was unavailable.

## **Wood decay**

Losses to decay were estimated by determining a rate of loss by species and age class from data in Morawski et al. (1958) and Basham and Morawski (1964). These authors reported the percentage of total merchantable volume that was culled because of decay. The differences among age classes in percent decayed were interpreted to be the rate at which decay was progressing for a respective age class and species. These cull rates were applied to the FRI inventory volumes in each stand. This differed from the approach taken in the 1977–1981 impact exercise, in which an average all-age-class decay level was applied to annual growth data. The assumption

was that the new volume exposed to decay each year was proportional to the annual growth. The ability to approach actual inventory volumes by age-class-specific decay rates was a far superior approach. Differences between estimates for this and the previous exercise were mostly a result of different estimation procedures rather than a change in the intensity of decay in the forest.

#### **Hypoxylon canker**

Surveys conducted in the early 1980s by FIDS indicated that about 2% of the aspen in Ontario have been affected by Hypoxylon stem cankers. Mortality studies conducted from 1983 to 1986 by FIDS indicated a 12.2% mortality rate for trees with stem cankers. These estimators were applied to aspen volumes in all stands older than 20 years to calculate the 2,178,910 m<sup>3</sup> annual loss estimate. A much higher estimate (6,184,000 m<sup>3</sup> mortality) for the 1977–1981 period was reported by Gross (1985). This latter estimate was based on a higher annual mortality rate of 33% interpreted from data presented by Anderson and Martin (1981) and applied to the same 2% incidence of cankering.

#### **Diebacks**

Mortality rates for diebacks and declines were based on FIDS data from a variety of projects. Oak and maple study areas that contain plots of 25 to 100 sample trees have been observed annually for several years, and the results indicate an average annual mortality of about 1% for oak and 0.5% for maple. These rates were applied to the volume of these species in stands older than 80 years. FIDS has just begun monitoring stands of white birch, and a 1% mortality rate for stands older than 50 years seemed appropriate as an initial estimate.

### **PEST-CAUSED DEPLETION ESTIMATES FOR ONTARIO**

#### **Pests of Juvenile Trees**

The pest-caused depletions to the forest resources of Ontario were estimated on the basis of effects on standing volume or current annual increment. Mortality, growth loss and cull caused by wood decay are kinds of depletion that affect these inventory statistics. There are, however, a number of important pests that damage trees in young stands when current growth and volume are relatively small. Although the ultimate influence on stand productivity can be devastating, the damage does not represent much of a depletion with respect to current inventory statistics. Examples include white pine weevil, which can have a drastic effect on tree quality; pine

stem rusts, such as white pine blister rust; *Scleroderris* canker; and various pine or spruce sawflies that kill young trees. These pests affect stocking, growth and yield, but predicting their influence would be very difficult. Hence, this report should not be considered an attempt to evaluate the effects of all serious pests. Although a pest-caused loss of 31,836,402 m<sup>3</sup> (Table 4, Fig. 2) is impressive, in many respects it represents only a part of the true situation.

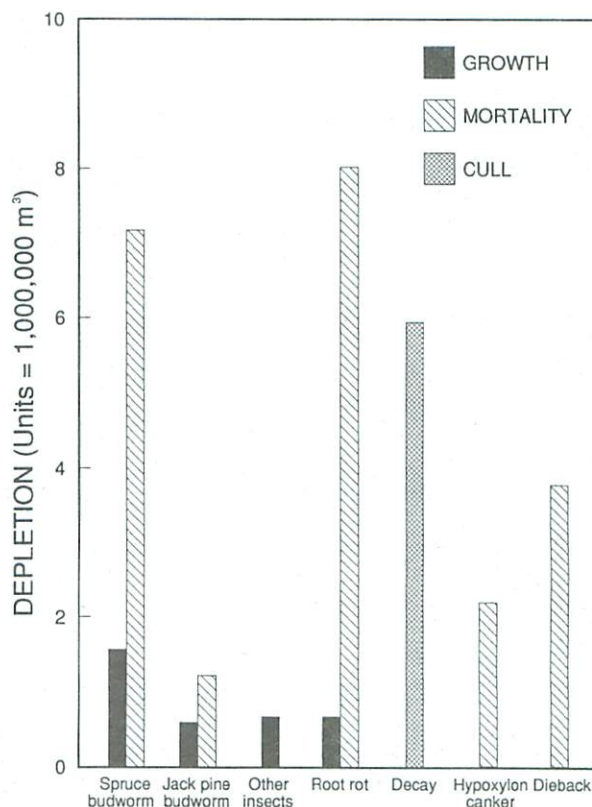


Figure 2. Pest depletion in Ontario forests, which averaged 31,836,402 m<sup>3</sup> annually for the 1982–1987 period.

#### **Spruce Budworm**

Spruce budworm defoliation caused an average annual growth loss of 1,566,100 m<sup>3</sup> and a mortality loss of 7,166,500 m<sup>3</sup> during the 1982–1987 period (Table 5). Annual estimates are presented in Table 6. Growth loss and mortality trends for the infestation from 1967 to 1987 are illustrated in Figure 3. The total growth loss and mortality that accumulated through 1987 was 126,542,600 m<sup>3</sup>.

The spruce budworm infestation that started in 1967 continued through the 1982–1987 period. However, a large part of the infestation in the Northern and North-eastern regions collapsed in 1981. Elsewhere, in the Northwestern and North Central regions and western

parts of the Northern and Northeastern regions, the infestation continued to expand through 1987. Studies have shown that the influence of defoliation on growth continues for several years after defoliation stops. The

analysis also includes growth loss for a large area within which mortality has had a drastic effect on stocking and growth. Based on information collected from FIDS mortality plots, mortality also continued for several years in

Table 4. Average annual pest-caused losses in Ontario forests from 1982 to 1987.

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total (m <sup>3</sup> )
Spruce budworm	Spruce, black	322,000	—	867,800	1,189,800
	white	165,900	—	896,600	1,062,500
	Fir, balsam	1,078,200	—	5,402,100	6,480,300
	Total	1,566,100	—	7,166,500	8,732,600
Jack pine budworm	Pine, jack	589,836	—	1,216,740	1,806,576
Gypsy moth <sup>a</sup>	Oak, red	14,748	—	23,956	38,704
	white	2,616	—	4,430	7,046
	Other hardwoods & pine, white	8,457	—	—	8,457
	Total	25,821	—	28,386	54,207
Forest tent caterpillar	Poplar	128,921	—	—	128,921
	Birch, white	60,901	—	—	60,901
	yellow	5,998	—	—	5,998
	Maple, hard	29,659	—	—	29,659
	Other hardwoods	11,816	—	—	11,816
	Total	237,295	—	—	237,295
Birch skeletonizer	Birch, white	185,726	—	—	185,726
Aspen complex <sup>b</sup>	Poplar	218,640	—	—	218,640
Maple complex <sup>c</sup>	Maple, hard	15,084	—	—	15,084
	soft	270	—	—	270
	Total	15,354	—	—	15,354
Total (all insects)		2,838,772		8,411,626	11,250,398
Root rot	Spruce, black	355,974	—	5,172,802	5,528,776
	white	10,491	—	382,086	392,577
	Fir, balsam	302,106	—	1,670,895	1,973,001
	Pine, jack	0	—	666,546	666,546
	red	0	—	29,831	29,831
	white	0	—	98,272	98,272
	Total	668,571	—	8,020,432	8,689,003
Decay	Softwoods	—	2,785,207	—	2,785,207
	Hardwoods	—	3,162,458	—	3,162,458
	Total	—	5,947,665	—	5,947,665
Hypoxylon canker	Poplar	—	—	2,178,910	2,178,910
Diebacks	Birch, white	—	—	3,128,668	3,128,668
	Maple, hard	—	—	602,301	602,301
	Oak, red	—	—	39,457	39,457
	Total	—	—	3,770,426	3,770,426
Total (disease)		668,571	5,947,665	13,969,768	20,586,004
<b>Total (all pests)</b>		<b>3,507,343</b>	<b>5,947,665</b>	<b>22,381,394</b>	<b>31,836,402</b>

<sup>a</sup> See comments on mortality caused by gypsy moth defoliation in the section on gypsy moth.

<sup>b</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

<sup>c</sup> The maple complex includes the Bruce spanworm, maple trumpet skeletonizer and maple leafcutter.

the areas in which the budworm population collapsed. In the analysis, no mortality was assessed within the area of collapse after 1985 and growth of the surviving trees was considered to have recovered at about the same time.

Table 5. Volume of growth loss and mortality resulting from defoliation by spruce budworm in Ontario from 1982 to 1987.

Region	Tree species	Average annual loss (m <sup>3</sup> ), 1982–1987	
		Growth	Mortality
Northwestern	Fir, balsam	26,300	78,800
	Spruce, white	4,200	10,300
	Spruce, black	15,500	19,500
		46,000	108,600
North Central	Fir, balsam	114,300	259,200
	Spruce, white	18,500	18,000
	Spruce, black	50,800	38,800
		183,600	316,000
Northern	Fir, balsam	502,300	3,664,900
	Spruce, white	69,000	521,900
	Spruce, black	176,500	668,000
		747,800	4,854,800
Northeastern	Fir, balsam	402,200	1,158,000
	Spruce, white	67,800	275,700
	Spruce, black	75,500	130,800
		545,500	1,564,500
Algonquin	Fir, balsam	32,700	226,000
	Spruce, white	6,300	67,500
	Spruce, black	3,700	10,700
		42,700	304,200
Southwestern, Central and Eastern	Fir, balsam	400	15,200
	Spruce, white	50	3,200
	Spruce, black	50	0
		500	18,400
Ontario total	Fir, balsam	1,078,200	5,402,100
	Spruce, white	165,900	896,600
	Spruce, black	322,000	867,800
		1,566,100	7,166,500

### Jack Pine Budworm

Jack pine budworm defoliation caused an average annual growth loss of 589,836 m<sup>3</sup> and mortality of 1,216,740 m<sup>3</sup> during the 1982–1987 period. Total damage for the 1982–1987 period was 3,539,020 m<sup>3</sup> growth loss and 7,300,441 m<sup>3</sup> mortality. Two infestations started in 1983. One infestation began in the Northeastern and Algonquin regions just north and east of Lake Huron, spreading northward into Northern Region in

1984. Large forested areas were defoliated in 1985 and 1986, after which budworm activity was negligible. Another western infestation started in Atikokan District of North Central Region. It expanded into Northwestern Region and further into North Central Region, and significant defoliation was still present at the end of the 1982–1987 period. Provincewide and regional estimates of growth loss and mortality are presented in Table 7.

Table 6. Volume of growth loss and mortality resulting from defoliation by spruce budworm in Ontario from 1982 to 1987, and cumulative losses for the entire infestation from 1967 to 1987.

Year	Tree species	Growth loss (m <sup>3</sup> )	
		Growth loss (m <sup>3</sup> )	Mortality (m <sup>3</sup> )
1982	Fir, balsam	1,446,600	11,252,000
	Spruce, white	205,100	1,768,000
	Spruce, black	352,100	1,595,000
		2,003,800	14,615,000
1983	Fir, balsam	1,287,600	7,966,000
	Spruce, white	185,100	1,743,000
	Spruce, black	340,100	1,727,000
		1,812,800	11,436,000
1984	Fir, balsam	1,061,000	5,858,000
	Spruce, white	167,100	971,000
	Spruce, black	321,100	1,089,000
		1,549,200	7,918,000
1985	Fir, balsam	989,000	4,034,000
	Spruce, white	164,000	491,000
	Spruce, black	334,000	499,000
		1,487,000	5,024,000
1986	Fir, balsam	943,000	2,287,000
	Spruce, white	157,000	356,000
	Spruce, black	337,000	197,000
		1,437,000	2,840,000
1987	Fir, balsam	742,000	1,015,000
	Spruce, white	117,000	50,000
	Spruce, black	248,000	100,000
		1,107,000	1,165,000
Total 1982–1987			
	Fir, balsam	6,469,200	32,412,000
	Spruce, white	995,300	5,379,000
	Spruce, black	1,932,300	5,207,000
		9,396,800	42,998,000
Total 1967–1987			
	Fir, balsam	13,387,000	82,256,000
	Spruce, white	2,126,300	13,424,000
	Spruce, black	3,911,300	11,438,000
		19,424,600	107,118,000

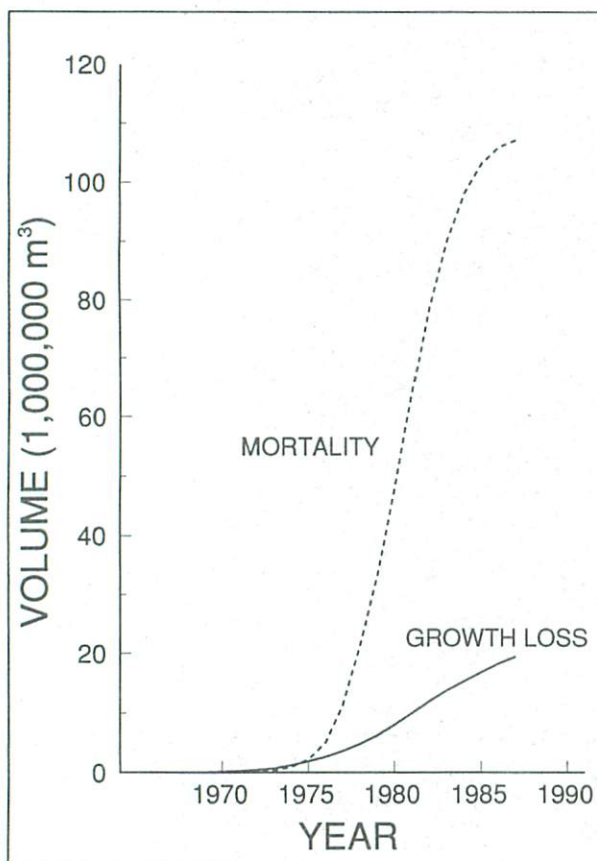


Figure 3. Cumulative volume of mortality and growth loss caused by the current spruce budworm infestation. The combined mortality and growth loss through 1987 was 126,542,600 m<sup>3</sup>.

### Forest Tent Caterpillar

Infestations by the forest tent caterpillar continued to expand throughout the 1982–1987 period. For this period, an average annual growth loss of 237,295 m<sup>3</sup> occurred (Table 8). Mortality of maple and oak caused by forest tent caterpillar defoliation was reported (Gross 1985) for the previous (1977–1981) period. During the current period, susceptible stands in southern Ontario did not seem to experience enough defoliation by the end of 1987 to cause much mortality.

### Gypsy Moth

Defoliation by the gypsy moth caused an average annual growth loss of 25,821 m<sup>3</sup> and mortality of 28,386 m<sup>3</sup> (Tables 9 and 10). Most of this damage occurred in Eastern Region from 1985 through 1987. The total loss for the 1982–1987 period was 325,246 m<sup>3</sup>. These data reflect the impact of an introduced pest early in an infestation, and the associated incipient losses. It should be noted that the annual mortality rate of 1.17% attributed

to the gypsy moth is probably not much different from what would be expected from normal mortality in hardwood stands growing on poor sites.

Table 7. Growth loss and mortality caused by jack pine budworm defoliation in Ontario from 1982 to 1987.

Region Year	Growth loss (m <sup>3</sup> )	Mortality (m <sup>3</sup> )
<i>Northwestern</i>		
1983	0	0
1984	28,969	0
1985	246,250	100,414
1986	584,458	900,567
1987	608,813	1,563,236
Total	1,468,490	2,564,217
<i>North Central</i>		
1983	0	1,350
1984	49,242	4,781
1985	121,573	152,724
1986	99,590	252,209
1987	43,321	228,247
Total	315,076	637,961
<i>Northern</i>		
1983	0	0
1984	37,440	0
1985	256,448	143,676
1986	424,029	929,861
1987	251,075	1,011,305
Total	968,992	2,084,842
<i>Northeastern</i>		
1983	1,640	0
1984	60,255	8,354
1985	233,048	288,908
1986	300,765	810,584
1987	175,733	817,589
Total	771,441	1,925,435
<i>Algonquin</i>		
1983	951	0
1984	2,688	5,233
1985	3,897	9,495
1986	4,692	33,965
1987	2,793	39,293
Total	15,021	87,986
<i>Ontario</i>		
1983	3,941	0
1984	178,594	18,368
1985	861,216	695,217
1986	1,413,534	2,927,186
1987	1,081,735	3,659,670
Total	3,539,020	7,300,441
Total loss		10,839,461

Table 8. Annual growth loss caused by forest tent caterpillar defoliation in Ontario from 1982 to 1987.

Region	Growth loss (m <sup>3</sup> )					Total
	Poplar	Birch white	Birch yellow	Hard maple	Other hardwoods	
<i>Northwestern</i>						
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	5,096	575	0	0	0	5,671
Total	5,096	575	0	0	0	5,671
<i>North Central</i>						
1982	18,268	5,722	0	0	0	23,990
1983	13,753	4,308	0	0	0	18,061
1984	13,578	4,253	0	0	0	17,831
1985	3,752	995	0	0	0	4,747
1986	270	85	0	0	0	355
1987	1,186	15,707	0	0	0	16,893
Total	50,807	31,070	0	0	0	81,877
<i>Northern</i>						
1982	54,540	8,563	0	0	0	63,103
1983	3,324	742	0	0	0	4,066
1984	26,660	5,952	0	0	0	32,612
1985	67,290	15,426	0	0	0	82,716
1986	36,944	9,272	0	0	0	46,216
1987	86,561	59,330	0	0	0	145,891
Total	275,319	99,285	0	0	0	374,604
<i>Northeastern</i>						
1982	2,537	928	18	186	98	3,767
1983	0	0	0	0	0	0
1984	12,619	6,099	250	657	158	19,783
1985	23,457	11,349	465	1,171	276	36,718
1986	67,823	31,446	3,120	10,693	3,537	116,619
1987	261,468	165,646	16,961	63,353	22,330	529,758
Total	367,904	215,468	20,814	76,060	26,399	706,645
<i>Algonquin</i>						
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	102	27	21	142	64	356
1986	15,269	4,057	3,138	21,221	9,429	53,114
1987	53,400	14,061	11,904	78,208	32,502	190,075
Total	68,771	18,145	15,063	99,571	41,995	243,545
<i>Eastern</i>						
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	330	59	5	226	272	892
Total	330	59	5	226	272	892
<i>Central</i>						
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	5,300	807	105	2,096	2,227	10,535
Total	5,300	807	105	2,096	2,227	10,535

(cont'd)

Table 8. Annual growth loss caused by forest tent caterpillar defoliation in Ontario from 1982 to 1987 (concl.).

Region	Growth loss (m <sup>3</sup> )					Total
	Poplar	Birch		Hard maple	Other hardwoods	
		white	yellow			
<i>Southwestern</i>						
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
Total	0	0	0	0	0	0
<i>Ontario</i>						
1982	75,345	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 9. Annual growth loss caused by gypsy moth in Ontario from 1982 to 1987.

Region	Growth loss (m <sup>3</sup> )				Region	Growth loss (m <sup>3</sup> )			
	Oak		Other	Total		Oak		Other	Total
Year	red	white	hardwoods			Year	red	white	
<i>Algonquin</i>					<i>Southwestern</i>				
1982	0	0	0	0	1982	0	0	0	0
1983	0	0	0	0	1983	0	0	0	0
1984	0	0	0	0	1984	0	0	0	0
1985	37	0	35	72	1985	0	0	0	0
1986	14	0	18	32	1986	0	0	0	0
1987	5	0	35	40	1987	7	9	23	39
Total	56	0	88	144	Total	7	9	23	39
<i>Eastern</i>					<i>Ontario</i>				
1982	306	47	180	533	1982	306	47	180	533
1983	2,542	228	1,359	4,129	1983	2,542	228	1,359	4,129
1984	5,771	1,035	3,331	10,137	1984	5,771	1,035	3,331	10,137
1985	21,172	3,279	11,665	36,116	1985	21,211	3,280	11,700	36,191
1986	14,092	3,064	8,563	25,719	1986	14,142	3,073	8,611	25,826
1987	44,433	8,004	25,435	77,872	1987	44,521	8,032	25,559	78,112
Total	88,316	15,657	50,533	154,506	Total	88,493	15,695	50,740	154,928
<i>Central</i>									
1982	0	0	0	0					
1983	0	0	0	0					
1984	0	0	0	0					
1985	2	1	0	3					
1986	36	9	30	75					
1987	76	19	66	161					
Total	114	29	96	239					

Table 10. Annual mortality<sup>a</sup> caused by gypsy moth in Ontario from 1982 to 1987.

Region	Growth loss (m <sup>3</sup> )			
	Oak		Other	Total
	red	white	hardwoods	
<i>Algonquin</i>				
1982	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	113	0	0	113
1986	57	0	0	57
1987	13	0	0	13
Total	183	0	0	183
<i>Eastern</i>				
1982	502	90	0	592
1983	3,976	434	0	4,410
1984	9,407	1,803	0	11,210
1985	34,062	5,368	0	39,430
1986	23,206	5,245	0	28,451
1987	72,179	13,574	0	85,753
Total	143,332	26,514	0	169,846
<i>Central</i>				
1982	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	4	1	0	5
1986	60	17	0	77
1987	130	36	0	166
Total	194	54	0	248
<i>Southwestern</i>				
1982	0	0	0	0
1983	0	0	0	0
1984	0	0	0	0
1985	0	0	0	0
1986	0	0	0	0
1987	26	15	0	41
Total	26	15	0	41
<i>Ontario</i>				
1982	502	90	0	592
1983	3,976	434	0	4,410
1984	9,407	1,803	0	11,210
1985	34,179	5,369	0	39,548
1986	23,323	5,262	0	28,585
1987	72,348	13,625	0	85,973
Total	143,735	26,583	0	170,318

<sup>a</sup> See comments (p. 8) on mortality caused by gypsy moth.

Table 11. Annual growth loss of white birch caused by the birch skeletonizer in Ontario between 1982 and 1984.

Region	Growth loss (m <sup>3</sup> )
Year	
<i>Northwestern</i>	
1982	83,893
1983	56,451
1984	0
Total	140,344
<i>North Central</i>	
1982	96,134
1983	262
1984	83
Total	96,479
<i>Northern</i>	
1982	383,639
1983	225,368
1984	6,193
Total	615,200
<i>Northeastern</i>	
1982	65,535
1983	129,191
1984	32,813
Total	227,539
<i>Algonquin</i>	
1982	3
1983	18,896
1984	145
Total	19,044
<i>Eastern</i>	
1982	0
1983	0
1984	0
Total	0
<i>Central</i>	
1982	3,481
1983	3,481
1984	0
Total	6,962
<i>Southwestern</i>	
1982	492
1983	8,294
1984	0
Total	8,786
<i>Ontario</i>	
1982	633,177
1983	441,943
1984	39,234
Total	1,114,354

## Birch Skeletonizer

Defoliation by the birch skeletonizer was widespread in Ontario in 1982 and 1983, and some of the infestation remained in 1984. Total growth loss for the 3-year period was 1,114,354 m<sup>3</sup>, and the average annual loss for the 1982–1987 report period was 185,726 m<sup>3</sup>.

## Aspen Complex

A variety of defoliators (especially the Bruce spanworm, aspen leafblotch miner and large aspen tortrix) affected aspen during the 1982–1987 period (Table 12). Losses caused by forest tent caterpillar defoliation are reported separately. Growth loss assessments for infestations of these insects indicated an average annual loss of 218,640 m<sup>3</sup>. The total loss for the 1982–1987 period was 1,311,839 m<sup>3</sup>.

## Maple Complex

Hard maple and soft maple stands experienced infestations by several insect species. This complex includes the maple leafcutter, maple trumpet skeletonizer and Bruce spanworm. Average annual growth loss was

15,354 m<sup>3</sup> for the combined impact of these infestations (Table 13). The total loss for the 1982–1987 period was 92,124 m<sup>3</sup>.

## Root Rots

Root rots of coniferous species caused an average annual mortality of 8,020,432 m<sup>3</sup> and a growth loss of 668,571 m<sup>3</sup> (Table 14). Broadleaved species are also being affected, but estimates of the impact on these species simply do not exist. Root rots are a contributing factor in the dieback and decline of several broadleaved species such as maple and oak. Hence, some of the influence of root rot is reported later in this report as part of the section on dieback.

Both the mortality and growth loss estimates for the 1982–1987 period are considerably lower than estimates for the previous period (Gross 1985). However, the actual status of root rot in the forest has not necessarily changed. Rather, the ability to construct impact estimates and approach the inventory by age class in the present report provided a much better control of the estimation process (see the Methods section).

Table 12. Annual growth losses caused by the aspen complex of defoliating insects from 1982 to 1987. Infestations by the Bruce spanworm, aspen leafblotch miner and the large aspen tortrix are included.

Region	Growth loss	Region	Growth loss	Region	Growth loss
Year	(m <sup>3</sup> )	Year	(m <sup>3</sup> )	Year	(m <sup>3</sup> )
<i>Northwestern</i>		<i>Eastern</i>		<i>Central</i>	
1982	784,547	1982	0	1982	27
1983	1,316	1983	0	1983	69
1984	0	1984	0	1984	0
1985	0	1985	5	1985	0
1986	0	1986	5	1986	4
1987	0	1987	0	1987	0
Total	785,863	Total	10	Total	100
<i>North Central</i>		<i>Northern</i>		<i>Southwestern</i>	
1982	0	1982	0	1982	0
1983	0	1983	0	1983	0
1984	0	1984	0	1984	0
1985	6,782	1985	0	1985	0
1986	75,786	1986	96,601	1986	0
1987	231,069	1987	0	1987	0
Total	313,637	Total	96,601	Total	0
<i>Algonquin</i>		<i>Northeastern</i>		<i>Ontario</i>	
1982	0	1982	0	1982	784,574
1983	0	1983	890	1983	2,275
1984	0	1984	1,324	1984	1,324
1985	0	1985	3,504	1985	10,291
1986	24,511	1986	43,396	1986	240,303
1987	26,904	1987	15,099	1987	273,072
Total	51,415	Total	64,213	Total	1,311,839

Table 13. Annual growth loss caused by the maple complex of defoliating insects (the maple leafcutter, maple trumpet skeletonizer and Bruce spanworm).

Region	Growth loss (m <sup>3</sup> )		
	Maple		Total
Year	hard	soft	
<i>Algonquin</i>			
1982	49	0	49
1983	125	20	145
1984	5,513	1,124	6,637
1985	0	9	9
1986	35,341	4	35,345
1987	49,057	0	49,057
Total	90,085	1,157	91,242
<i>Eastern</i>			
1982	0	0	0
1983	0	25	25
1984	17	154	171
1985	34	142	176
1986	8	2	10
1987	3	11	14
Total	62	334	396
<i>Central</i>			
1982	0	3	3
1983	0	4	4
1984	0	7	7
1985	4	13	17
1986	4	0	4
1987	0	0	0
Total	8	27	35
<i>Southwestern</i>			
1982	0	0	0
1983	339	99	438
1984	0	0	0
1985	0	0	0
1986	7	6	13
1987	0	0	0
Total	346	105	451
<i>Ontario</i>			
1982	49	3	52
1983	464	148	612
1984	5,530	1,285	6,815
1985	38	164	202
1986	35,360	12	35,372
1987	49,060	11	49,071
Total	90,501	1,623	92,124

Losses as a result of mortality are not losses to standing volumes that are detected by a periodic inventory, such as the FRI, that only reports standing volumes for live trees. However, they represent a real loss of standing volume in terms of determining depletion of supply. Our expectation is that 8,020,433 m<sup>3</sup> of trees will die annually as a result of root rot. If one attempts to compare actual and expected (from inventory data) yields, then this mortality becomes important.

The growth loss of 668,571 m<sup>3</sup> caused by root rots represents a direct reduction in the expected annual volume increment, which represents only surviving trees. This estimate is conservative as it contains no provision for growth lost by trees already killed by root rot and which do not appear on the inventory. Mortality is commonly aggregated in patches within affected stands, and the influence on growth is largely a function of reduced stocking. Data were not available to provide the basis for an analysis of this kind of growth loss. However, considering the magnitude of mortality, an additional loss of several hundred thousand m<sup>3</sup> seems appropriate.

### Wood Decay

An average annual volume loss of 5,947,665 m<sup>3</sup> was caused by wood decay during the 1982–1987 period (Table 15). The cull associated with decayed wood has a considerable negative influence on the net yield of the forest. The FRI inventory data report gross standing volumes, which foresters generally interpret as estimates of expected net volumes in a manner similar to that used in this report. Growth, yield and allowable cut data must be considered in terms of net volumes as well as gross standing volumes. Then, decay data indicate the rate at which sound timber is deteriorating, and decay volumes represent a depletion rate with respect to the gross standing volume available for harvest.

The total average annual decay loss (5,947,665 m<sup>3</sup>) for the 1982–1987 period was considerably lower (–34%) than the losses (9,045,000 m<sup>3</sup>) reported for the 1977–1981 period (Gross 1985). As was the case with root rots, computer access to the FRI inventory provided an increase in estimator sensitivity by allowing the use of decay rates by age class. Much of the difference in total decay loss between the 1977–1981 report and the present report was contained in estimates for aspen (–2,272,935 m<sup>3</sup>) and sugar maple (–611,000 m<sup>3</sup>). Both species had high decay rates in the relatively older age classes (Morawski et al. 1958).

Table 14. Average annual growth loss and mortality caused by root rot diseases in Ontario from 1982 to 1987.

Region		Growth loss (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Region		Growth loss (m <sup>3</sup> )	Mortality (m <sup>3</sup> )
<i>Northwestern</i>				<i>Eastern</i>			
Fir,	balsam	81,810	393,946	Fir,	balsam	3,894	15,892
Pine,	jack	0	330,419	Pine,	jack	0	33
	red	0	4,099		red	0	1,002
	white	0	5,471		white	0	10,072
Spruce,	black	148,671	2,028,881	Spruce,	black	36	301
	white	2,364	55,621		white	272	4,755
Total		232,845	2,818,437	Total		4,202	32,055
<i>North Central</i>				<i>Central</i>			
Fir,	balsam	93,670	521,605	Fir,	balsam	1,057	4,330
Pine,	jack	0	133,994	Pine,	jack	0	219
	red	0	2,888		red	0	2,679
	white	0	4,581		white	0	2,543
Spruce,	black	112,662	1,573,995	Spruce,	black	7	66
	white	2,636	84,667		white	115	1,851
Total		208,968	2,321,730	Total		1,179	11,688
<i>Northern</i>				<i>Southwestern</i>			
Fir,	balsam	60,242	348,919	Fir,	balsam	1,170	4,522
Pine,	jack	0	120,718	Pine,	jack	0	171
	red	0	342		red	0	799
	white	0	3,305		white	0	1,124
Spruce,	black	78,377	1,320,755	Spruce,	black	5	33
	white	1,979	86,842		white	100	1,752
Total		140,598	1,880,881	Total		1,275	8,401
<i>Northeastern</i>				<i>Ontario</i>			
Fir,	balsam	42,599	279,117	Fir,	balsam	302,106	1,670,895
Pine,	jack	0	79,020	Pine,	jack	0	666,546
	red	0	10,677		red	0	29,831
	white	0	36,269		white	0	98,272
Spruce,	black	15,055	235,781	Spruce,	black	355,974	5,172,802
	white	2,195	115,873		white	10,491	382,086
Total		59,849	756,737	Total		668,571	8,020,432
<i>Algonquin</i>							
Fir,	balsam	17,664	102,564				
Pine,	jack	0	1,972				
	red	0	7,345				
	white	0	34,907				
Spruce,	black	1,161	12,990				
	white	830	30,725				
Total		19,655	190,503				

### Hypoxylon Canker

Hypoxylon canker of aspen caused mortality that averaged 2,178,910 m<sup>3</sup> annually. There is a growth-loss impact associated with this mortality, and sometimes the canker kills only part of the live crown, resulting in a low-quality, disfigured tree. These aspects of damage are not included in this report Gross (1985) reported

a much higher annual mortality (6,184,000 m<sup>3</sup>) for the 1977–1981 period. The difference between the two periods was mostly due to the application of a lower rate of mortality, which was identified from FIDS studies conducted in Ontario, in the present report. These studies also indicated that most stands younger than 20 years had a negligible amount of damage due to Hypoxylon canker.

Table 15. Average annual timber volume losses caused by cull associated with wood decay from 1982 to 1987.

Tree species	Decay loss (m <sup>3</sup> ) <sup>a</sup> , by Region								Total decay loss (m <sup>3</sup> ) <sup>a</sup> , Ontario
	North-western	North Central	Northern	North-eastern	Algonquin	Eastern	Central	South-western	
<i>Softwoods</i>									
Cedar, white	20,601	32,341	71,446	72,791	21,253	22,425	18,614	12,716	272,187
Fir, balsam	119,694	176,689	182,404	129,293	82,279	12,993	3,398	3,632	710,382
Hemlock	6	6	12	5,821	19,808	1,045	861	237	27,796
Larch	828	660	4,109	514	366	155	87	70	6,789
Pine, jack	413,883	154,219	133,937	98,058	2,162	12	85	152	802,508
red	223	82	23	800	296	9	2	6	1,441
Scots	3	2	8	10	15	11	52	27	128
white	10,182	7,619	5,130	71,805	73,063	14,202	3,487	1,358	186,846
Spruce, black	243,621	192,676	249,274	35,080	1,787	37	9	3	722,487
white	5,503	10,434	15,572	17,710	4,576	479	178	191	54,643
Total softwoods	814,544	574,728	661,915	431,882	205,605	51,368	26,773	18,392	2,785,207
<i>Hardwoods</i>									
Ash, black	16,398	5,585	686	12,457	37,566	20,098	16,789	18,029	127,608
white	19	0	0	0	0	0	0	0	19
Basswood	1	0	0	333	1,237	712	282	186	2,751
Beech	2	3	1	2,622	22,577	1,810	2,881	2,277	32,173
Birch, white	50,752	108,613	94,810	147,056	22,352	2,732	2,175	1,362	429,852
yellow	0	47	2,797	99,812	55,160	344	573	439	159,172
Butternut	1	0	0	0	0	0	0	0	1
Cherry	0	0	0	49	784	22	94	137	1,086
Elm	44	15	2	384	1,582	154	35	15	2,231
Ironwood	0	0	0	0	0	0	0	0	0
Maple, hard	2	6	958	92,112	186,189	11,337	8,054	9,039	307,697
soft	686	584	1,223	14,160	19,218	6,459	3,394	3,299	49,023
Oak, red	1	1	0	1,584	6,517	2,114	962	231	11,410
white	9	1	0	3	70	301	194	217	795
Poplar, aspen	412,535	532,240	616,754	289,803	121,473	28,960	21,905	8,496	2,032,166
balsam	3,692	0	0	0	0	0	0	0	3,692
Other hardwoods	1	0	0	1,241	546	561	192	241	2,782
Total hardwoods	484,143	647,095	717,231	661,616	475,271	75,604	57,530	43,968	3,162,458
Total (all species)	1,298,687	1,221,823	1,379,146	1,093,498	680,876	126,972	84,303	62,360	5,947,665

<sup>a</sup> gross total volume

Table 16. Average annual mortality losses to aspen caused by Hypoxylon canker in Ontario from 1982 to 1987.

Region	Mortality (m <sup>3</sup> )
Northwestern	451,741
North Central	560,012
Northern	656,047
Northeastern	307,605
Algonquin	129,219
Eastern	10,626
Central	27,169
Southwestern	36,491
Ontario total	2,178,910

## Diebacks

Diebacks and declines caused annual mortality of 3,770,426 m<sup>3</sup> (Table 17). These problems generally result from several aggravating influences, often including insect defoliation and root rots. Diebacks and declines appear as stands of trees with poor vigor, branch dieback and mortality. As such, the mortality loss is in addition to the usual amount of mortality occurring in the forest due to factors such as age and crowding. Declining trees often experience reduced growth, but reference data to estimate the magnitude of a growth impact were not available during the preparation of this report.

Table 17. Average annual mortality associated with declines and diebacks in Ontario from 1982 to 1987.

Region	Tree species	Mortality (m <sup>3</sup> )
Northwestern	Birch, white	340,113
	Maple, hard	9
		340,122
North Central	Birch, white	824,087
Northern	Birch, white	693,645
	Maple, hard	3,393
		697,038
Northeastern	Birch, white	1,046,071
	Maple, hard	312,155
	Oak, red	9,709
		1,367,935
Algonquin	Birch, white	183,006
	Maple, hard	279,945
	Oak, red	27,528
		490,479
Eastern	Birch, white	17,175
	Maple, hard	2,185
	Oak, red	599
		19,959
Central	Birch, white	14,599
	Maple, hard	3,252
	Oak, red	1,331
		19,182
Southwestern	Birch, white	9,972
	Maple, hard	1,362
	Oak, red	290
		11,624
Ontario total	Birch, white	3,128,668
	Maple, hard	602,301
	Oak, red	39,457
		3,770,426

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## APPENDIX 1: Scientific nomenclature

### PESTS

<i>Common Name</i>	<i>Scientific Name<sup>a</sup></i>
Aspen leafblotch miner	<i>Phyllonorycter ontario</i> (Free.)
Birch skeletonizer	<i>Bucculatrix canadensisella</i> Cham.
Bruce spanworm	<i>Operophtera bruceata</i> (Hlst.)
Forest tent caterpillar	<i>Malacosoma disstria</i> Hbn.
Gypsy moth	<i>Lymantria dispar</i> (L.)
Hypoxylon canker	<i>Hypoxylon mammatum</i> (Wahlenb.) J. Miller
Jack pine budworm	<i>Choristoneura pinus pinus</i> Free.
Large aspen tortrix	<i>Choristoneura conflictana</i> (Wlk.)
Maple leafcutter	<i>Paraclemensia acerifoliella</i> (Fitch)
Maple trumpet skeletonizer	<i>Epinotia aceriella</i> (Clem.)
Scleroderris canker	<i>Gremmeniella abietina</i> (Lagerb.) Morelet
Spruce budworm	<i>Choristoneura fumiferana</i> (Clem.)
White pine blister rust	<i>Cronartium ribicola</i> J.C. Fischer
White pine weevil	<i>Pissodes strobi</i> (Peck)

### TREES AND HERBACEOUS PLANTS

<i>Common Name</i>	<i>Scientific Name<sup>a</sup></i>
Ash, black	<i>Fraxinus nigra</i> Marsh.
white	<i>Fraxinus americana</i> L.
Aspen, largetooth	<i>Populus grandidentata</i> Michx.
trembling	<i>Populus tremuloides</i> Michx.
Basswood	<i>Tilia americana</i> L.
Beech	<i>Fagus</i> sp.
Birch, white	<i>Betula papyrifera</i> Marsh.
yellow	<i>Betula alleghaniensis</i> Britton
Cedar, white	<i>Thuja occidentalis</i> L.
Cherry, black	<i>Prunus serotina</i> Ehrh.
Elm	<i>Ulmus</i> sp.
Fir, balsam	<i>Abies balsamea</i> (L.) Mill.
Hemlock	<i>Tsuga</i> sp.
Larch	<i>Larix</i> sp.
Maple, hard	<i>Acer saccharum</i> Marsh.
soft	<i>Acer rubrum</i> L.
Oak, red	<i>Quercus rubra</i> L.
white	<i>Quercus alba</i> L.
Pine, jack	<i>Pinus banksiana</i> Lamb.
red	<i>Pinus resinosa</i> Ait.
Scots	<i>Pinus sylvestris</i> L.
white	<i>Pinus strobus</i> L.
Poplar, aspen	see Aspen <sup>b</sup>
balsam	<i>Populus balsamifera</i> L.
Spruce, black	<i>Picea mariana</i> (Mill.) B.S.P.
white	<i>Picea glauca</i> (Moench) Voss
Sweetfern	<i>Comptonia peregrina</i> L.

<sup>a</sup> Latin binomial

<sup>b</sup> the FRI lists aspen as poplar

**APPENDIX 2.** Average annual pest-caused losses in the forests of Northwestern Region, 1982–1987.

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	15,500	–	19,500	35,000
	white	4,200	–	10,300	14,500
	Fir, balsam	26,300	–	78,800	105,100
	Total	46,000	–	108,600	154,600
Jack pine budworm	Pine, jack	244,748	–	427,370	672,118
Forest tent caterpillar	Poplar	849	–	–	849
	Birch, white	96	–	–	96
	Total	945	–	–	945
Birch skeletonizer	Birch, white	23,391	–	–	23,391
Aspen complex <sup>a</sup>	Poplar	130,977	–	–	130,977
Total insect damage		446,061	–	535,970	982,031
Root rot	Spruce, black	148,671	–	2,028,881	2,177,552
	white	2,364	–	55,621	57,985
	Fir, balsam	81,810	–	393,946	475,756
	Pine jack	–	–	330,419	330,419
	red	–	–	4,099	4,099
	white	–	–	5,471	5,471
	Total	232,845	–	2,818,437	3,051,282
Decay	Softwoods	–	814,544	–	814,544
	Hardwoods	–	484,143	–	484,143
	Total	–	1,298,687	–	1,298,687
Hypoxylon canker	Poplar	–	–	451,741	451,741
Diebacks	Birch, white	–	–	340,113	340,113
	Maple, hard	–	–	9	9
	Total	–	–	340,122	340,122
Total disease damage		232,845	1,298,687	3,610,300	5,141,832
Total pest damage		678,906	1,298,687	4,146,270	6,123,863

<sup>a</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

**APPENDIX 3.** Average annual pest-caused losses in the forests of North Central Region, 1982–1987.

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	50,800	–	38,800	89,600
	white	18,500	–	18,000	36,500
	Fir, balsam	114,300	–	259,200	373,500
	Total	183,600	–	316,000	499,600
Jack pine budworm	Pine, jack	52,513		106,327	158,840
Forest tent caterpillar	Poplar	8,468	–	–	8,468
	Birch, white	5,178	–	–	5,178
	Total	13,646	–	–	13,646
Birch skeletonizer	Birch, white	16,080	–	–	16,080
Aspen complex <sup>a</sup>	Poplar	52,273	–	–	52,273
Total insect damage		318,112	–	422,327	740,439
Root rot	Spruce, black	112,662	–	1,573,995	1,686,657
	white	2,636	–	84,667	87,303
	Fir, balsam	93,670	–	521,605	615,275
	Pine, jack	–	–	133,994	133,994
	red	–	–	2,888	2,888
	white	–	–	4,581	4,581
	Total	208,968	–	2,321,730	2,530,698
Decay	Softwoods	–	574,728	–	574,728
	Hardwoods	–	647,095	–	647,095
	Total	–	1,221,823	–	1,221,823
Hypoxylon canker	Poplar	–	–	560,012	560,012
Diebacks	Birch, white	–	–	824,087	824,087
Total disease damage		208,968	1,221,823	3,705,829	5,136,620
Total pest damage		527,080	1,221,823	4,128,156	5,877,059

<sup>a</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

**APPENDIX 4. Average annual pest-caused losses in the forests of Northern Region, 1982–1987.**

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	176,500	—	668,000	844,500
	white	69,000	—	521,900	590,900
	Fir, balsam	502,300	—	3,664,900	4,167,200
	Total	747,800	—	4,854,800	5,602,600
Jack pine budworm	Pine, jack	161,499	—	347,474	508,973
Forest tent caterpillar	Poplar	45,886	—	—	45,886
	Birch, white	16,548	—	—	16,548
	Total	62,434	—	—	62,434
Birch skeletonizer	Birch, white	102,533	—	—	102,533
Aspen complex <sup>a</sup>	Poplar	16,100	—	—	16,100
Total insect damage		1,090,366	—	5,202,274	6,292,640
Root rot	Spruce, black	78,377	—	1,320,755	1,399,132
	white	1,979	—	86,842	88,821
	Fir, balsam	60,242	—	348,919	409,161
	Pine, jack	—	—	120,718	120,718
	red	—	—	342	342
	white	—	—	3,305	3,305
	Total	140,598	—	1,880,881	2,021,479
Decay	Softwoods	—	661,915	—	661,915
	Hardwoods	—	717,231	—	717,231
	Total	—	1,379,146	—	1,379,146
Hypoxylon canker	Poplar	—	—	656,047	656,047
Diebacks	Birch, white	—	—	693,645	693,645
	Maple, hard	—	—	3,393	3,393
	Total	—	—	697,038	697,038
Total disease damage		140,598	1,379,146	3,233,966	4,753,710
Total pest damage		1,230,964	1,379,146	8,436,240	11,046,350

<sup>a</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

**APPENDIX 5.** Average annual pest-caused losses in the forests of Northeastern Region, 1982–1987.

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	75,500	–	130,800	206,300
	white	67,800	–	275,700	343,500
	Fir, balsam	402,200	–	1,158,000	1,560,200
	Total	545,500	–	1,564,500	2,110,000
Jack pine budworm	Pine, jack	128,574	–	320,906	449,480
Forest tent caterpillar	Poplar	61,317	–	–	61,317
	Birch, white	35,911	–	–	35,911
	yellow	3,469	–	–	3,469
	Maple, hard	12,677	–	–	12,677
	Other hardwoods	4,400	–	–	4,400
	Total	117,774	–	–	117,774
Birch skeletonizer	Birch, white	37,923	–	–	37,923
Aspen complex <sup>a</sup>	Poplar	10,702	–	–	10,702
Total insect damage		840,473	–	1,885,406	2,725,879
Root rot	Spruce, black	15,055	–	235,781	250,836
	white	2,195	–	115,873	118,068
	Fir, balsam	42,599	–	279,117	321,716
	Pine, jack	–	–	79,020	79,020
	red	–	–	10,677	10,677
	white	–	–	32,269	36,269
	Total	59,849	–	756,737	816,586
Decay	Softwoods	–	431,882	–	431,881
	Hardwoods	–	661,616	–	661,616
	Total	–	1,093,498	–	1,093,498
Hypoxylon canker	Poplar	–	–	307,605	307,605
Diebacks	Birch, white	–	–	1,046,071	1,046,071
	Maple, hard	–	–	312,155	312,155
	Oak, red	–	–	9,709	9,709
	Total	–	–	1,367,935	1,367,935
Total disease damage		59,849	1,093,498	2,432,277	3,585,624
Total pest damage		900,322	1,093,498	4,317,683	6,311,503

<sup>a</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

**APPENDIX 6. Average annual pest-caused losses in the forests of Algonquin Region, 1982–1987.**

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	3,700	–	10,700	14,400
	white	6,300	–	67,500	73,800
	Fir, balsam	32,700	–	226,000	258,700
	Total	42,700	–	304,200	346,900
Jack pine budworm	Pine, jack	2,504	–	14,664	17,168
Gypsy moth <sup>a</sup>	Oak, red	9	–	30	39
	white	0	–	0	0
	Other hardwoods & pine, white	15	–	0	15
	Total	24	–	30	54
Forest tent caterpillar	Poplar	11,462	–	–	11,462
	Birch, white	3,024	–	–	3,024
	yellow	2,510	–	–	2,510
	Maple, hard	16,595	–	–	16,595
	Other hardwoods	6,999	–	–	6,999
	Total	40,590	–	–	40,590
Birch skeletonizer	Birch, white	3,174	–	–	3,174
Aspen complex <sup>b</sup>	Poplar	8,569	–	–	8,569
Maple complex <sup>c</sup>	Maple, hard	15,014	–	–	15,014
	red	193	–	–	193
	Total	15,207	–	–	15,207
Total insect damage		112,768	–	318,894	431,662
Root rot	Spruce, black	1,161	–	12,990	14,151
	white	830	–	30,725	31,555
	Fir, balsam	17,664	–	102,564	120,228
	Pine, jack	–	–	1,972	1,972
	red	–	–	7,345	7,345
	white	–	–	34,907	34,907
	Total	19,655	–	190,503	210,158
Decay	Softwoods	–	205,605	–	205,605
	Hardwoods	–	475,271	–	475,271
	Total	–	680,876	–	680,876
Hypoxylon canker	Poplar	–	–	129,219	129,219
Diebacks	Birch, white	–	–	183,006	183,006
	Maple, hard	–	–	279,945	279,945
	Oak, red	–	–	27,528	27,528
	Total	–	–	490,479	490,479
Total disease damage		19,655	680,876	810,201	1,510,732
<b>Total pest damage</b>		<b>132,423</b>	<b>680,876</b>	<b>1,129,095</b>	<b>1,942,394</b>

<sup>a</sup> See comments in the text on mortality caused by gypsy moth defoliation.

<sup>b</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

<sup>c</sup> The maple complex includes the Bruce spanworm, maple trumpet skeletonizer and maple leafcutter.

**APPENDIX 7.** Average annual pest-caused losses in the forests of the Eastern, Central and Southwestern regions, 1982–1987.)

Pest	Tree species	Growth (m <sup>3</sup> )	Cull (m <sup>3</sup> )	Mortality (m <sup>3</sup> )	Total loss (m <sup>3</sup> )
Spruce budworm	Spruce, black	50	–	0	50
	white	50	–	3,200	3,250
	Fir, balsam	400	–	15,200	15,600
	Total	500	–	18,400	18,900
Gypsy moth <sup>a</sup>	Oak, red	14,740	–	23,926	38,666
	white	2,616	–	4,430	7,046
	Other hardwoods & pine, white	8,442	–	0	8,442
	Total	25,798	–	28,356	54,154
Forest tent caterpillar	Poplar	938	–	–	938
	Birch, white	144	–	–	144
	yellow	19	–	–	19
	Maple, hard	387	–	–	387
	Other hardwoods	417	–	–	417
	Total	1,905	–	–	1,905
Birch skeletonizer	Birch, white	2,625	–	–	2,625
Aspen complex <sup>b</sup>	Poplar	17	–	–	17
Maple complex <sup>c</sup>	Maple, hard	69	–	–	69
	soft	78	–	–	78
	Total	147	–	–	147
Total insect damage		30,992	–	46,756	77,748
Root rot	Spruce, black	48	–	400	448
	white	487	–	8,358	8,845
	Fir, balsam	6,121	–	24,744	30,865
	Pine, jack	–	–	423	423
	red	–	–	4,480	4,480
	white	–	–	13,739	13,739
	Total	6,656	–	52,144	58,800
Decay	Softwoods	–	96,533	–	96,533
	Hardwoods	–	177,102	–	177,102
	Total	–	273,635	–	273,635
Hypoxylon canker	Poplar	–	–	74,286	74,286
Diebacks	Birch, white	–	–	41,746	41,746
	Maple, hard	–	–	6,799	6,799
	Oak, red	–	–	2,220	2,220
	Total	–	–	50,765	50,765
Total disease damage		6,656	273,635	177,195	457,486
Total pest damage		37,648	273,635	223,951	535,234

<sup>a</sup> See comments in the text on mortality caused by gypsy moth defoliation.

<sup>b</sup> The aspen complex includes the Bruce spanworm, large aspen tortrix and aspen leafblotch miner.

<sup>c</sup> The maple complex includes the Bruce spanworm, maple trumpet skeletonizer and maple leafcutter.