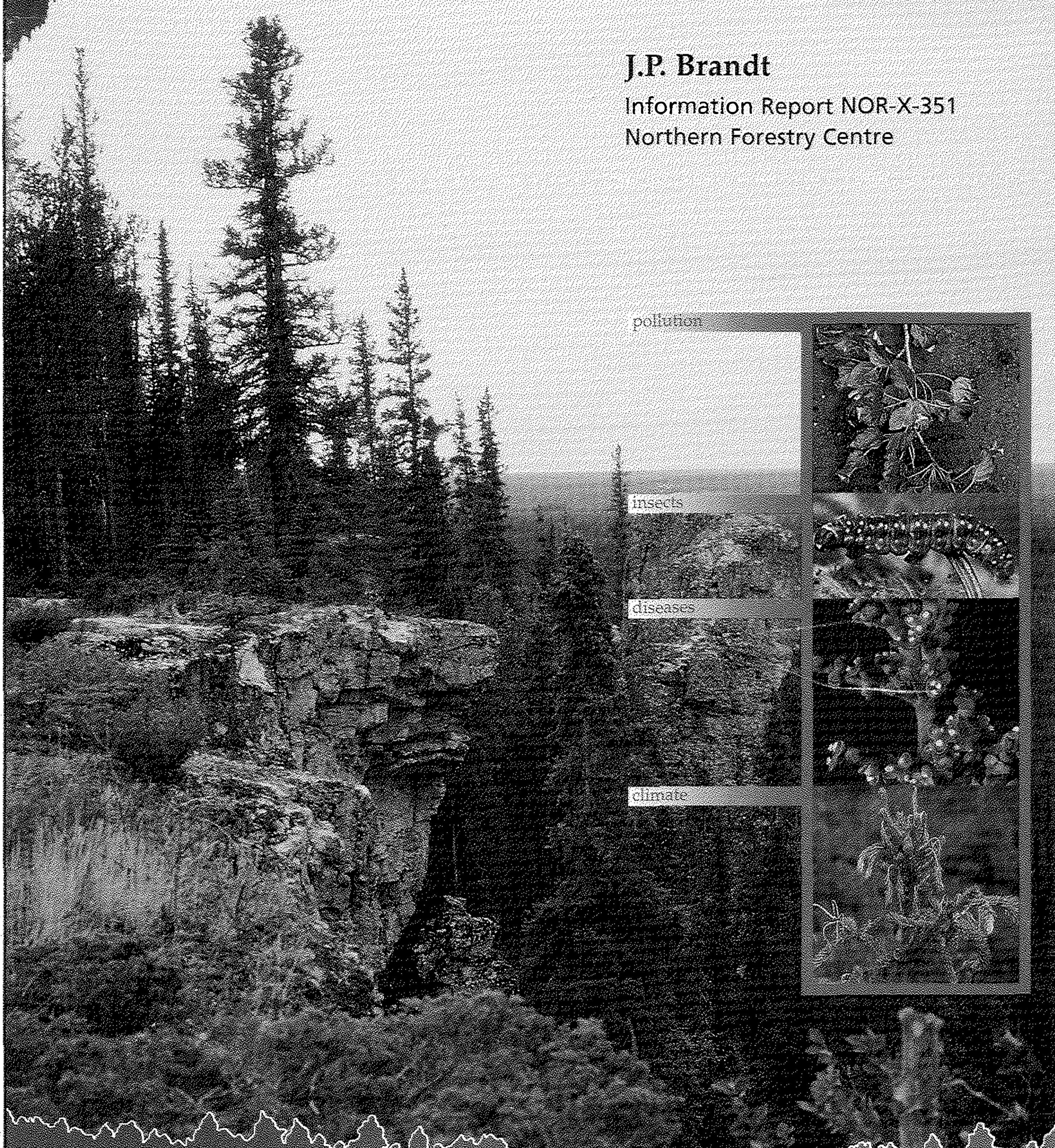
Forest health monitoring

in west-central Canada in 1996

J.P. Brandt

Information Report NOR-X-351
Northern Forestry Centre



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FOREST HEALTH MONITORING IN WEST-CENTRAL CANADA IN 1996

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ABSTRACT

Results of forest health monitoring activities in Alberta, Saskatchewan, Manitoba, and the Northwest Territories are summarized for 1996. These results are based on assessments made on 17 permanent biomonitoring plots and assessments of major forest disturbances. Brief descriptions are given of major forest disturbances in the region, including forest tent caterpillar (*Malacosoma disstria* Hbn.), which defoliated 411 855 ha of trembling aspen forests; lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.), which causes severe disease on 430 202 ha of pine forests; spruce budworm (*Choristoneura fumiferana* [Clem.]), which defoliated 760 131 ha of white spruce–balsam fir forests; and forest fires, which destroyed 492 027 ha. Current climatic data from across the region are compared to 30-year normals for a number of parameters. Details of the assessments completed on the 17 permanent biomonitoring plots in the region are also given. Generally, tree condition of jack pine, lodgepole pine, white spruce, and trembling aspen on the biomonitoring plots was good, with most trees having less than 25% crown damage. Annual mortality rates were within the range of 0.4–3.3%. The state of regeneration on the biomonitoring plots is also discussed. Descriptions of the current status of quarantine pests in Canada of concern to the forestry sector are given.

RÉSUMÉ

Ce rapport rend compte des résultats des activités de surveillance de la santé des forêts en Alberta, en Saskatchewan, au Manitoba et dans les Territoires du Nord-Ouest en 1996. Ces résultats sont fondés sur des évaluations de 17 parcelles permanentes de biosurveillance et des évaluations des principales infestations de ravageurs. On trouvera de brèves descriptions des principales sources de perturbation des forêts dans la région, notamment la livrée des forêts (*Malacosoma disstria* Hbn), responsable de la défoliation de 411 855 ha de forêts de peupliers faux-trembles; le faux-gui du pin (*Arceuthobium americanum* Nutt. ex Engelm.), responsable d'une grave maladie touchant 430 202 ha de forêts de pins; la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana* [Clem.]), responsable de la défoliation de 760 131 ha de forêts d'épinettes blanches et sapins baumiers, et les incendies de forêts qui ont détruit 492 027 ha. Les données climatiques actuelles pour toute la région sont comparées aux normales de 30 ans pour un certain nombre de paramètres. Les auteurs donnent des détails sur les évaluations des 17 parcelles permanentes de biosurveillance dans la région. En général, l'état du pin gris, du pin tordu latifolié, de l'épinette blanche et du peuplier faux-tremble dans ces parcelles était bon, moins de 25 % du houppier de la plupart des arbres étant touché. Le taux mortalité annuel était compris entre 0,4 et 3,3 %. Les auteurs traitent également de l'état de régénération des parcelles de biosurveillance. Ils décrivent aussi l'état actuel des ravageurs justiciables de quarantaine au Canada qui sont une source de préoccupation pour le secteur forestier.

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The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Natural Resources Canada.

INTRODUCTION

Forests consist of many components including trees, shrubs and other plants, lichens, fungi, animals, insects, soils, nutrients, decomposing organic matter, and water, that act together to form diverse and complex ecosystems. Forest health was defined by O'Laughlin et al. (1994) as "the vigour or vitality of interacting biotic and abiotic elements of a system characterized by extensive tree cover that function together to sustain life and are isolated mentally for human purposes."

This report summarizes forest health monitoring activities in west-central Canada (Fig. 1) in 1996 conducted by the Forest Health Unit, based at the Northern Forestry Centre in Edmonton, Alberta, and its various collaborators. The Forest Health Network (FHN) is one of 10 science and technology networks within the Canadian Forest Service (CFS) and is concerned with the abiotic, biotic, and edaphic factors that affect trees. Assessing many of the other components of a forest fall outside both the expertise and the mandate of the FHN and the CFS in general. Assessments made on a national network of permanent biomonitoring plots are conducted annually by FHN staff and data recorded are archived in a national forest health data base maintained at the Maritimes Forestry Centre, the FHN's lead centre in Fredericton, New Brunswick. Collections of insect and disease specimens made during assessments on the network of plots or during other related assessments are maintained at the Northern Forestry Centre in an insect reference collection and a mycological herbarium. Provincial surveys of insect and disease infestations are archived in a geographic information system (GIS). Records of new pests or changes in pest distribution are added as necessary to the national data base. Reference collections and the national forest health data base contain information that supports forest health assessments, plant quarantine activities, and research projects.

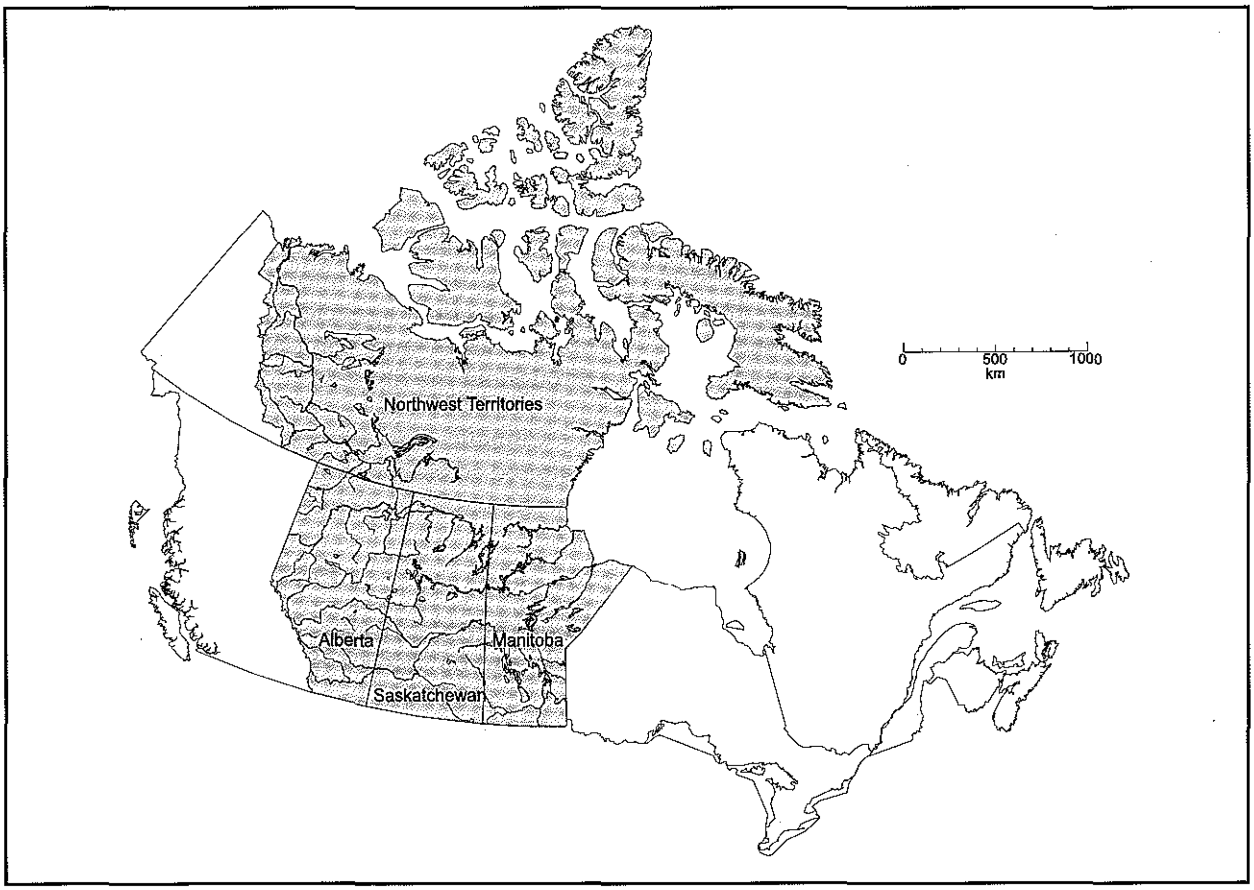

Figure 1. West-central Canada, the study area.

MAJOR FOREST DISTURBANCES

Disturbances play an important role in forest ecosystems. Certain insects and diseases attack healthy trees making them susceptible to colonization by secondary organisms. These actions, however, also free nutrients and allow them to cycle from one generation of plants to the next. Fire destroys forests but, in so doing, prepares the site for recolonization by removing existing vegetation and baring the mineral soil for seeding. Severe weather conditions such as wind can destroy large areas of forests, but these areas are subsequently recycled by insects, fungi, and other decomposers.

Whether ultimately positive or negative, disturbances cause significant damage to forests, at least in the short term. Many forest pests significantly damage their hosts by causing reductions in growth or tree mortality due to defoliation. Pollutants and global warming have been linked to increased frequency and severity of pest outbreaks, as well as in influencing forest fires and other disturbance agents. Such damage has implications on the sustainability of Canadian forests, especially in light of the many demands placed on our forests. When outbreaks occur of the conifer-defoliating budworms such as *Choristoneura fumiferana* (Clem.) and *C. pinus pinus* Free. or the hardwood defoliators such as *Malacosoma disstria* Hbn. and *Choristoneura conflictana* (Wlk.), the area of affected forests can typically cover 1 million ha annually in west-central Canada. Lodgepole pine dwarf mistletoe (*Arceuthobium americanum* Nutt. ex Engelm.) is a parasitic plant that affects the productivity of large areas of lodgepole pine (*Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm.) and jack pine (*Pinus banksiana* Lamb.) forests in the region. Forest fires also cause significant disturbances, generally burning anywhere from tens to hundreds of thousands of hectares of forests annually. Losses due to forest pests and fire in the study area were estimated to be 16.2 and 93.4 million m^3/year, respectively, between 1988 and 1992; harvest levels for the same period were about 17.7 million m^3/year (Brandt 1995a). Obviously, forest disturbances must be considered when examining the long-term health of Canadian forests.

Methods

Information on pest outbreaks is usually collected during aerial surveys, but ground survey information is also used. Pest surveys were completed by the forestry branches of Manitoba Natural Resources and Saskatchewan Environment and Resource Management in Manitoba and Saskatchewan, and by the collaborative efforts of the Land and Forest Service of Alberta Environmental Protection, the Forest Management Division of Northwest Territories Department of Resources, Wildlife and Economic Development, and the CFS in Alberta and in the Northwest Territories. Aerial surveys involve flying in fixed- or rotary-wing aircraft at speeds up to 110 knots and at an elevation of about 300 m aboveground, with an observer trained to recognize damage caused by pests and other damage agents accompanying the pilot. As the aircraft flies over forests the observer sketches the visible damage on maps (i.e., insect defoliation, mistletoe-infested stands, windfall, and red belt), rates the damage, and identifies the causal agent. Mapped information is generally sketched on 1:250 000 scale maps, but other scale maps are used as well. Maps are then digitized using a GIS and archived.

Forest fire information has been compiled by the Canadian Interagency Forest Fire Center in Winnipeg based on information from provincial fire protection agencies. These agencies map burned areas and compile forest fire statistics throughout the fire season.

Climatic data from several weather stations scattered across the study area were obtained from the Climate Service Unit of Environment Canada.

Pests

Forest Tent Caterpillar
Malacosoma disstria Hbn.

Forest tent caterpillar continued to play a major role as a disturbance factor in trembling aspen (*Populus tremuloides* Michx.) forests in west-central Canada in 1996. In this year, 411 855 ha of trembling aspen were defoliated across the region, compared to 364 470 ha in 1995, an increase of 13% (Table 1).

Table 1. **Area of forest tent caterpillar defoliation in west-central Canada, as determined from aerial and ground surveys in 1995 and 1996**

Location	Defoliation class	Area of defoliation (ha)		Change (%)
		1995	1996	
Alberta	Light	0	3 038	–[a]
	Light-to-moderate	0	38 639	–
	Moderate	17 553	8 764	–50
	Moderate-to-severe	51 976	81 359	+57
	Severe	152 488	938	–99
	Total	222 017	132 738	-40
Saskatchewan	Light	0	13 787	–
	Light-to-moderate	4 782	65	–99
	Moderate	56 125	26 057	–54
	Moderate-to-severe	8 604	2 025	–76
	Severe	40 320	10 634	–74
	Total	109 831	52 568	–52
Manitoba	Light	0	0	0
	Light-to-moderate	0	0	0
	Moderate	163	1 719	+955
	Moderate-to-severe	0	0	0
	Severe	0	0	0
	Total	163	1 719	+955
Northwest Territories	Light	3 294	15 084	+358
	Light-to-moderate	6 499	73 397	+1 029
	Moderate	4 836	48 052	+894
	Moderate-to-severe	17 830	85 333	+379
	Severe	0	2 964	–
	Total	32 459	224 830	+593
Total		364 470	411 855	+13

[a] Not applicable.

In Alberta, the area of forest affected by forest tent caterpillar defoliation decreased by 40% to 132 738 ha. The year's cold, late spring appeared to have played a role in reducing populations of this insect. Defoliation was observed at most of the same general areas as those observed in 1995, but the level of defoliation and area of defoliated trees were reduced (Brandt et al. 1996). General areas where forest tent caterpillar activity continued (Figs. 2 and 3) included those near the Peace River townsite from Reno north to Dixonville and west to the Shaftsberry Ferry (54 225 ha); along Highway 35 north of the village of Hawk Hills (31 636 ha); southwest of Grande Prairie (4946 ha); west of the village of Bad Heart (954 ha); south, north, and east of Cooking Lake and parts of Elk Island National Park (37 470 ha); and south of Bonnyville near Moose and Muriel lakes (3507 ha).

In Saskatchewan, forest tent caterpillar infestations declined 52% in area. Here, too, the reduction in area of infestations was related to the cold, late spring. The infestation near Battleford and south to Sonningdale (Fig. 4) decreased in size to 8859 ha, compared to 91 049 ha in 1995. The infestation east of North Battleford along Highway 40 increased substantially in size to the north; there were 5459 ha defoliated in this area compared to 436 ha in 1995. The area of defoliation south of Glaslyn along Highway 4 (38 250 ha) was comparable in size to that observed in 1995.

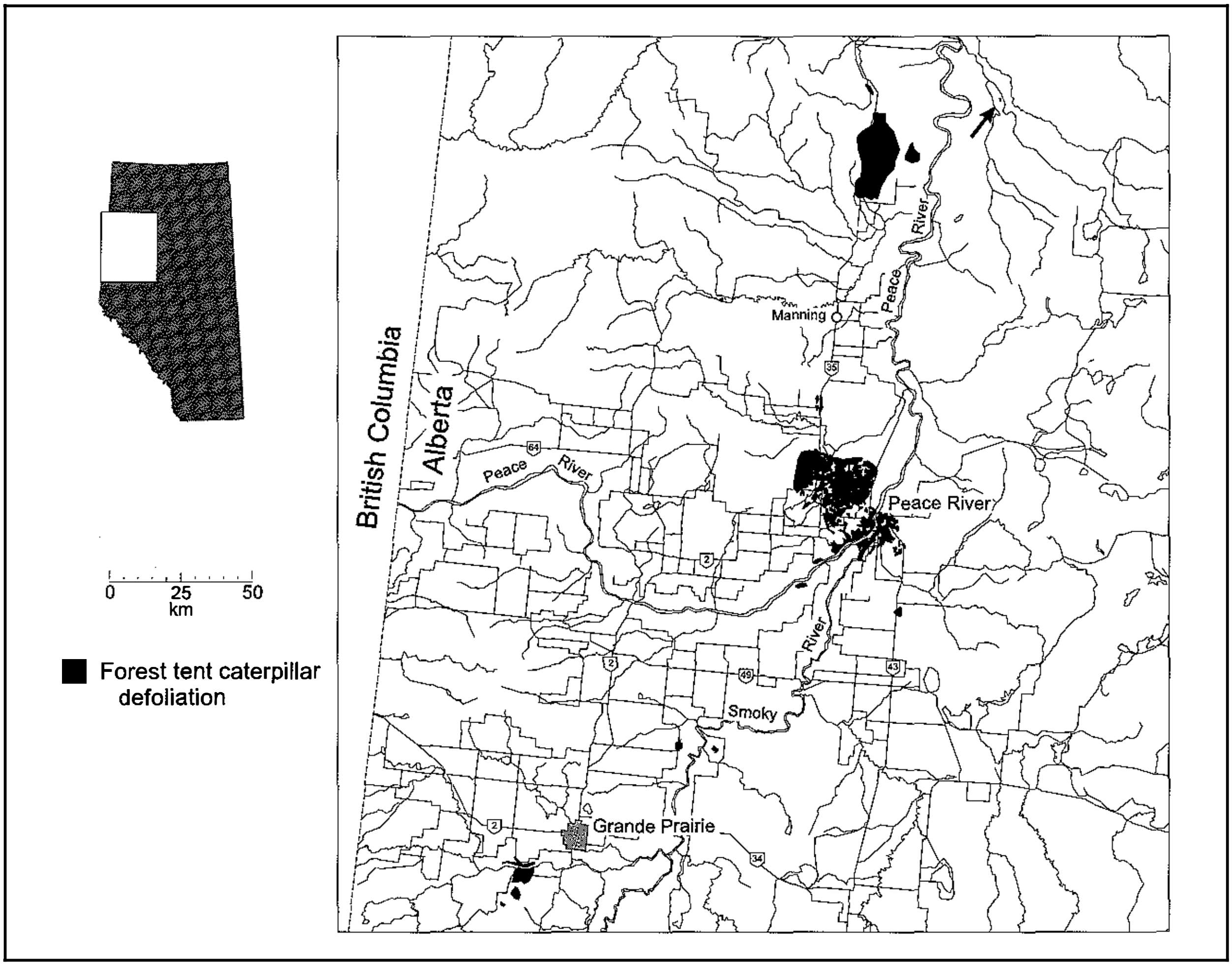

Figure 2. Areas of forest tent caterpillar defoliation in northwestern Alberta in 1996.

The area of forest tent caterpillar defoliation in Manitoba increased from 163 ha in 1995 to 1719 ha in 1996. A small infestation continued in the Duck Mountain Provincial Forest (Fig. 5), where 23 ha of trembling aspen were defoliated. Most of the increase in activity in the province occurred near Manigotagan and Hollow Water. Defoliation of trees in this area covered 1696 ha, all of which was rated as moderate.

The greatest amount of activity by forest tent caterpillar occurred in the Northwest Territories. This was the second consecutive year of defoliation in the first outbreak of the insect in the territory. The area of the outbreak dramatically increased in 1996: 224 830 ha compared to 32 459 ha in 1995. Defoliation north, south, and east of Fort Liard expanded farther north to include areas near the South Nahanni River (18 896 ha), and the Liard River near its confluence with the Blackstone River (3226 ha); and west to include areas near Fisherman Lake and the Kotaneelee River (29 526 ha) (Fig. 6).

Lodgepole Pine Dwarf Mistletoe *Arceuthobium americanum* Nutt. ex Engelm.

The parasitic lodgepole pine dwarf mistletoe significantly affects the productivity of jack and lodgepole pine stands in the prairie provinces (Brandt 1995a). Several areas of severe lodgepole pine dwarf mistletoe infestations were mapped in 1996. These areas are in addition to those mapped in 1994 and 1995 (Brandt 1995b, Brandt et al. 1996). In Alberta, 12 930 ha of infested lodgepole pine stands were mapped along the upper reaches of the North Saskatchewan River inside and just outside of Banff National Park, and in the Bow River valley in Banff National Park. In Saskatchewan, newly mapped infestations occurred in scattered jack pine forests in Saskatchewan near Brightsand Lake (467 ha) and north of Prince Albert National Park to west of Cree Lake (37 559 ha). A detailed summary of mapped areas of severe mistletoe infections in the study area is provided in Table 2.

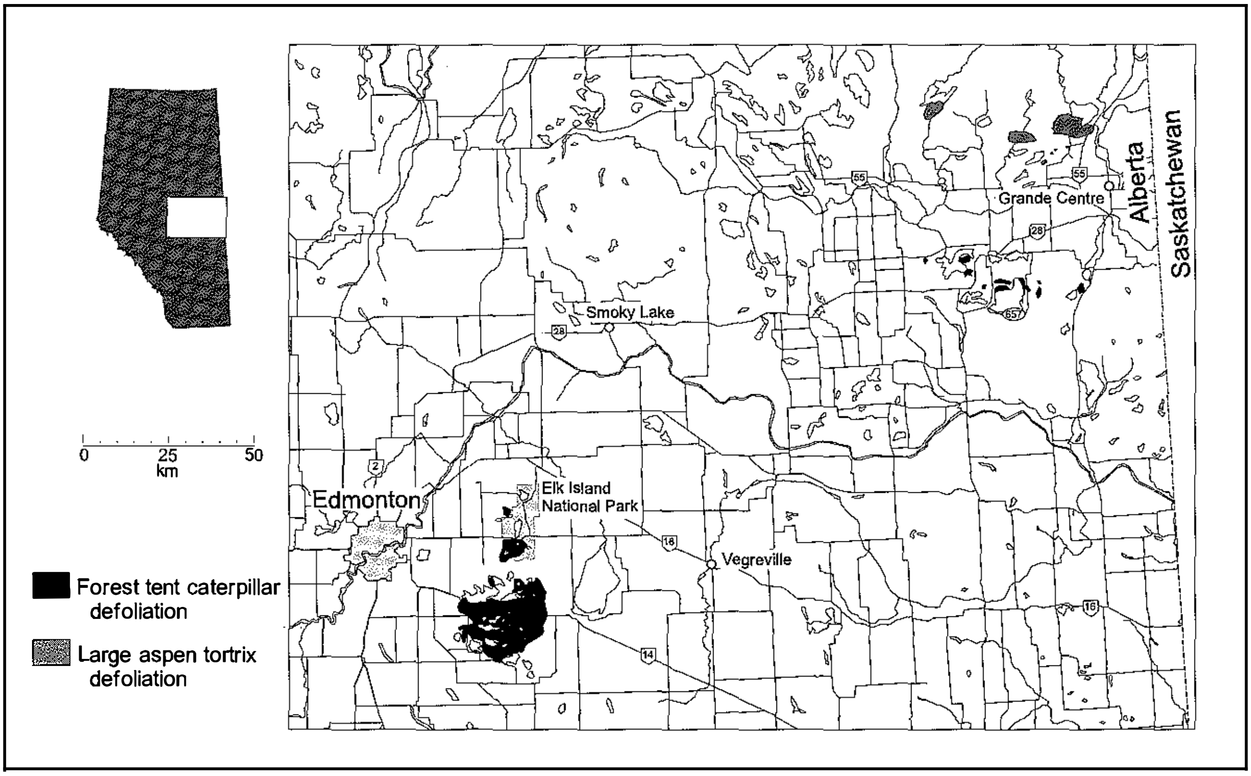

Figure 3. Areas of forest tent caterpillar and large aspen tortrix defoliation in east-central Alberta in 1996.

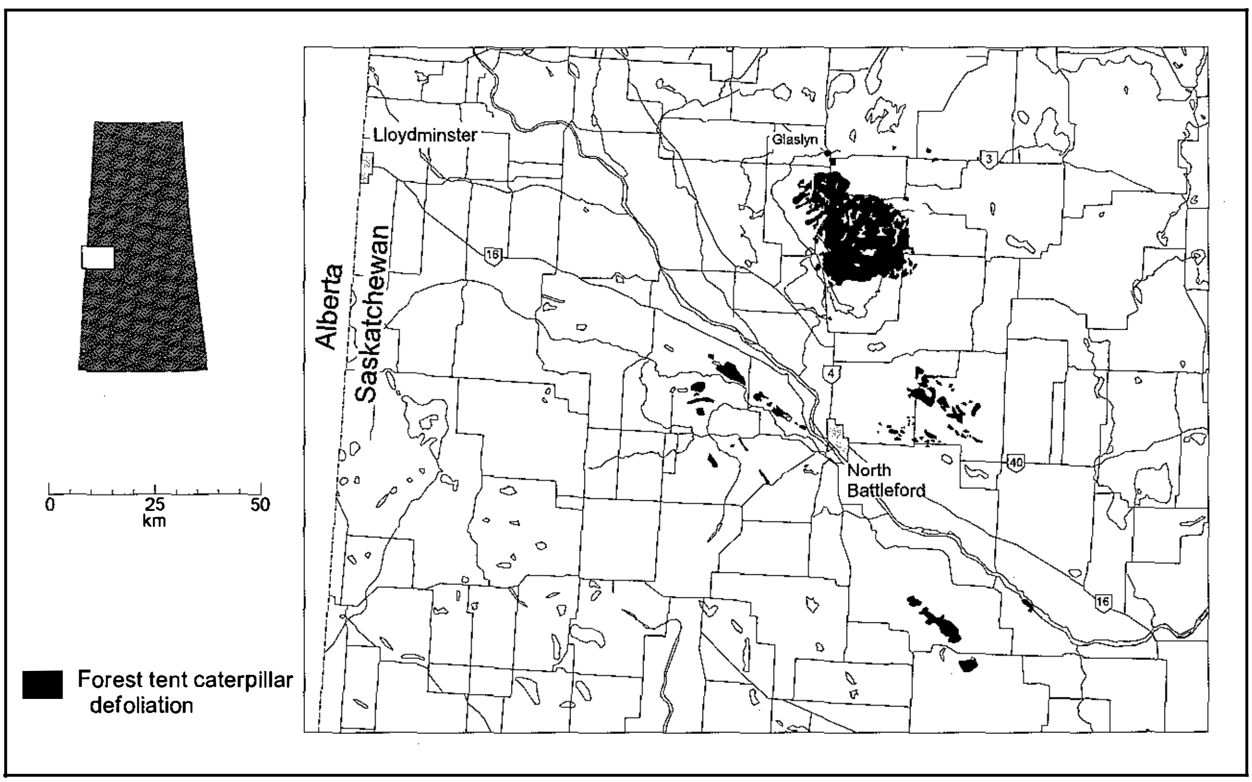

Figure 4. Areas of forest tent caterpillar defoliation in west-central Saskatchewan in 1996.

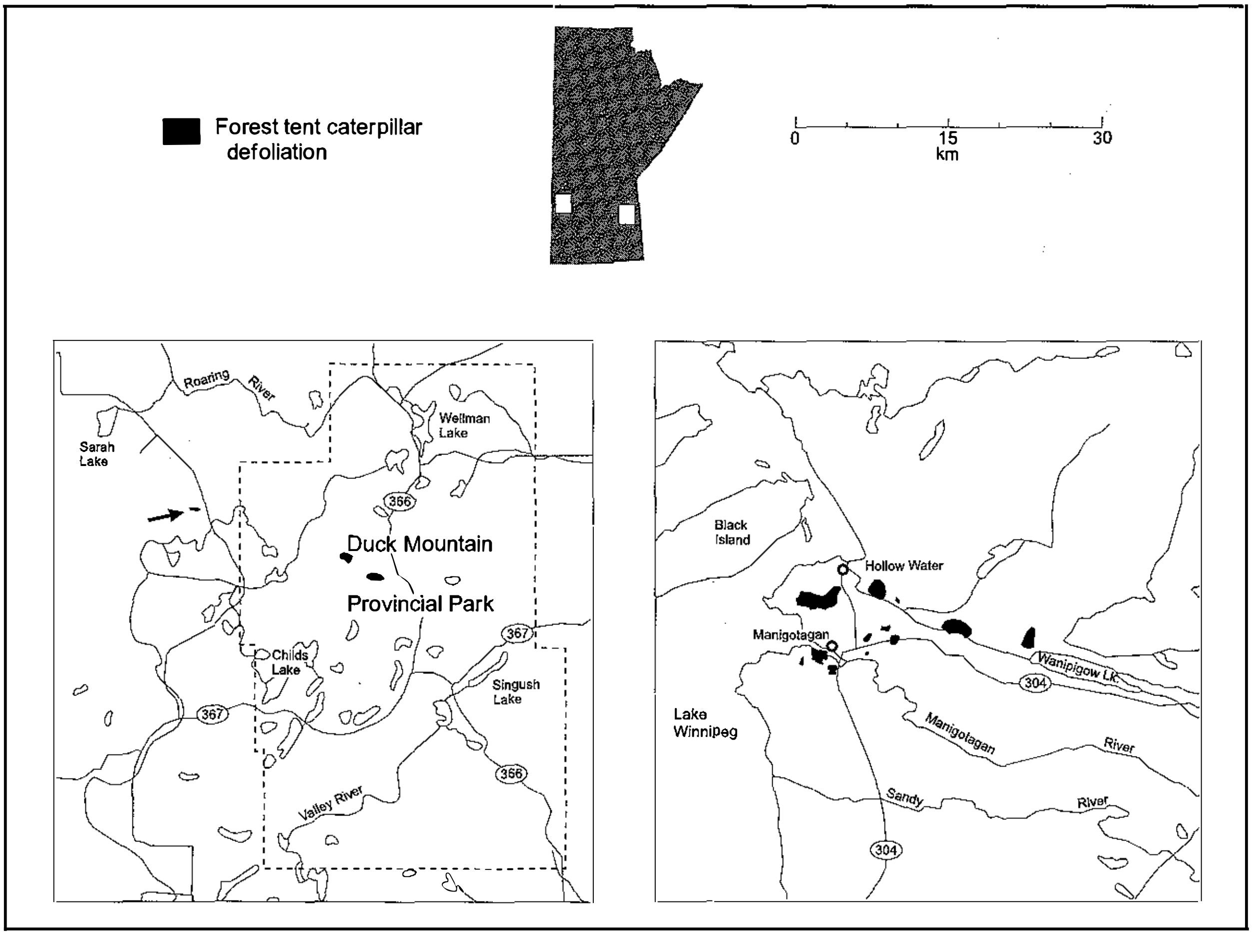

Figure 5. Areas of forest tent caterpillar defoliation in Manitoba in 1996.

Table 2. Area of severe infection by lodgepole pine dwarf mistletoe mapped during aerial and ground surveys in 1994–96 in west-central Canada

	Mapped areas of severe infection (ha)			
Location	1994	1995	1996	Total
Alberta				
Jack pine	112 125	63 888	0	176 013
Lodgepole pine	54 329	199	12 930	67 458
Saskatchewan				
Jack pine	123 982	12 723	38 026	174 731
Lodgepole pine	--[a]	0	0	--
Manitoba				
Jack pine	12 000	0	0	12 000
Northwest Territories				
Jack pine	0	0	0	0
Total	302 436	76 810	50 956	430 202

[a] Only small areas (<200 ha) exist in Cypress Hills Provincial Park.

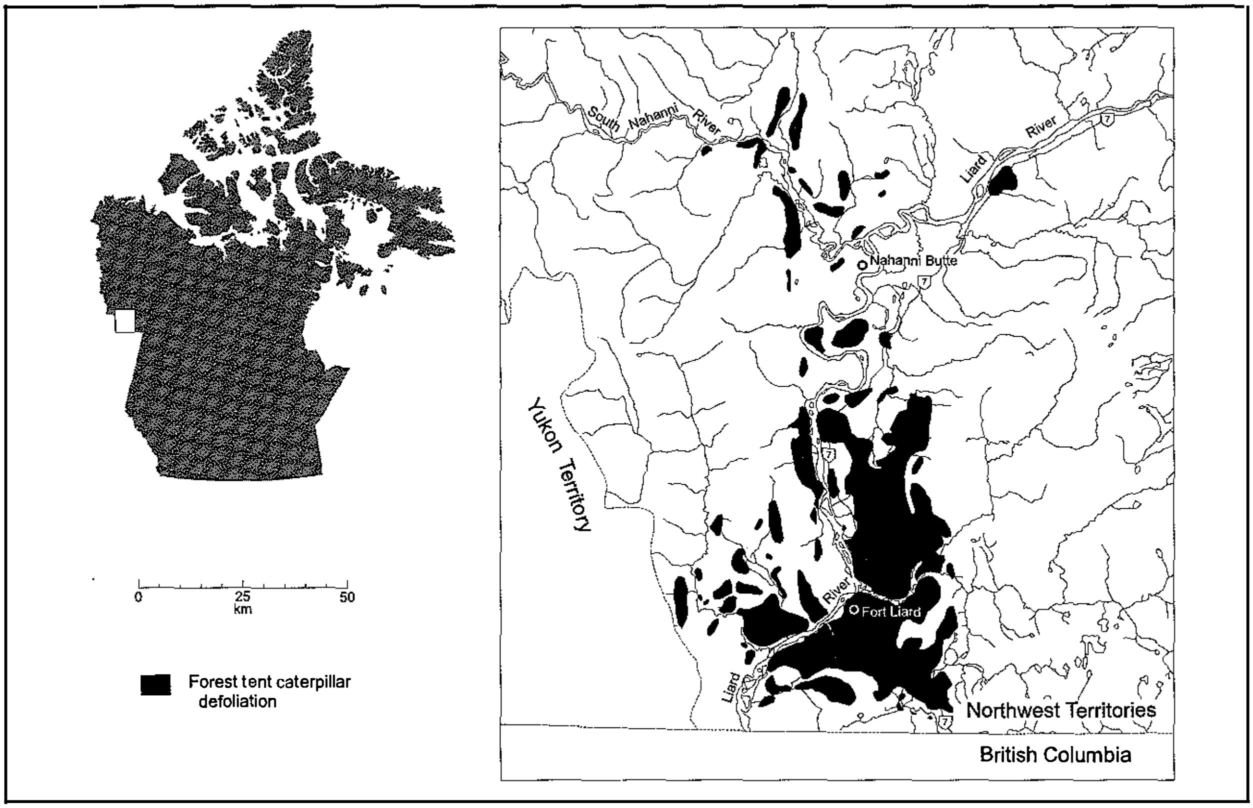

Figure 6. Areas of forest tent caterpillar defoliation in the southwestern Northwest Territories in 1996.

Spruce Budworm
Choristoneura fumiferana (Clem.)

One of the principal damage agents of white spruce (*Picea glauca* [Moench] Voss) and balsam fir (*Abies balsamea* [L.] Mill.) forests in west-central Canada's boreal region is the spruce budworm. Defoliation caused by this insect continued to affect forests in all four jurisdictions in the region in 1996. A total of 760 131 ha were defoliated, an increase of 92% over that observed in 1995 (Table 3). Many of the general areas where defoliation occurred over the past several years continued to harbor spruce budworm infestations, though there were some notable exceptions.

The area of spruce budworm defoliation in Alberta covered 222 952 ha in 1996, this was an increase of 9% over levels of defoliation noted in 1995. Of the total area of white spruce affected by defoliation in Alberta, 44% (98 531 ha) was rated as severe and 56% (124 421 ha) was rated as moderate. Outbreaks in northwestern Alberta (Fig. 7) declined in area, mainly due to aerial applications of *Bacillus thuringiensis* var. *kurstaki* (*Btk*) by the Alberta Land and Forest Service over previous years. A dramatic decline occurred in the former main infestation along the Chinchaga River (including areas on the Zama ridge and several areas northwest of Paddle Prairie), where there was a reduction in the area of forests affected by defoliation from 95 685 ha in 1995 to 16 369 ha in 1996. Another area of infestation decline occurred along the Zama River and to the northeast, where there was no defoliation in 1996 compared to 12 340 ha in 1995. The remaining infestations in northwestern Alberta changed little from 1995. The total area of spruce-budworm-defoliated spruce trees in northwestern Alberta covered 92 316 ha, of which, 9272 ha were moderately defoliated and 83 044 ha were severely defoliated. In northeastern Alberta, the infestation along the Athabasca River and adjacent areas remained similar to that observed in 1995. These infestations covered 16 387 ha (Fig. 8). Spruce budworm defoliation in the Alberta portion of Wood Buffalo National Park and vicinity increased to levels observed in 1994 after a decline in 1995. These infestations (Fig. 9) occurred mainly along the Peace (59 288 ha) and Slave (9379 ha) rivers and the interior of the park near the Alberta–Northwest Territories border (45 582 ha). The total area of defoliation in northeastern Alberta by defoliation class was 115 149 ha of moderate, and 15 487 ha of severe.

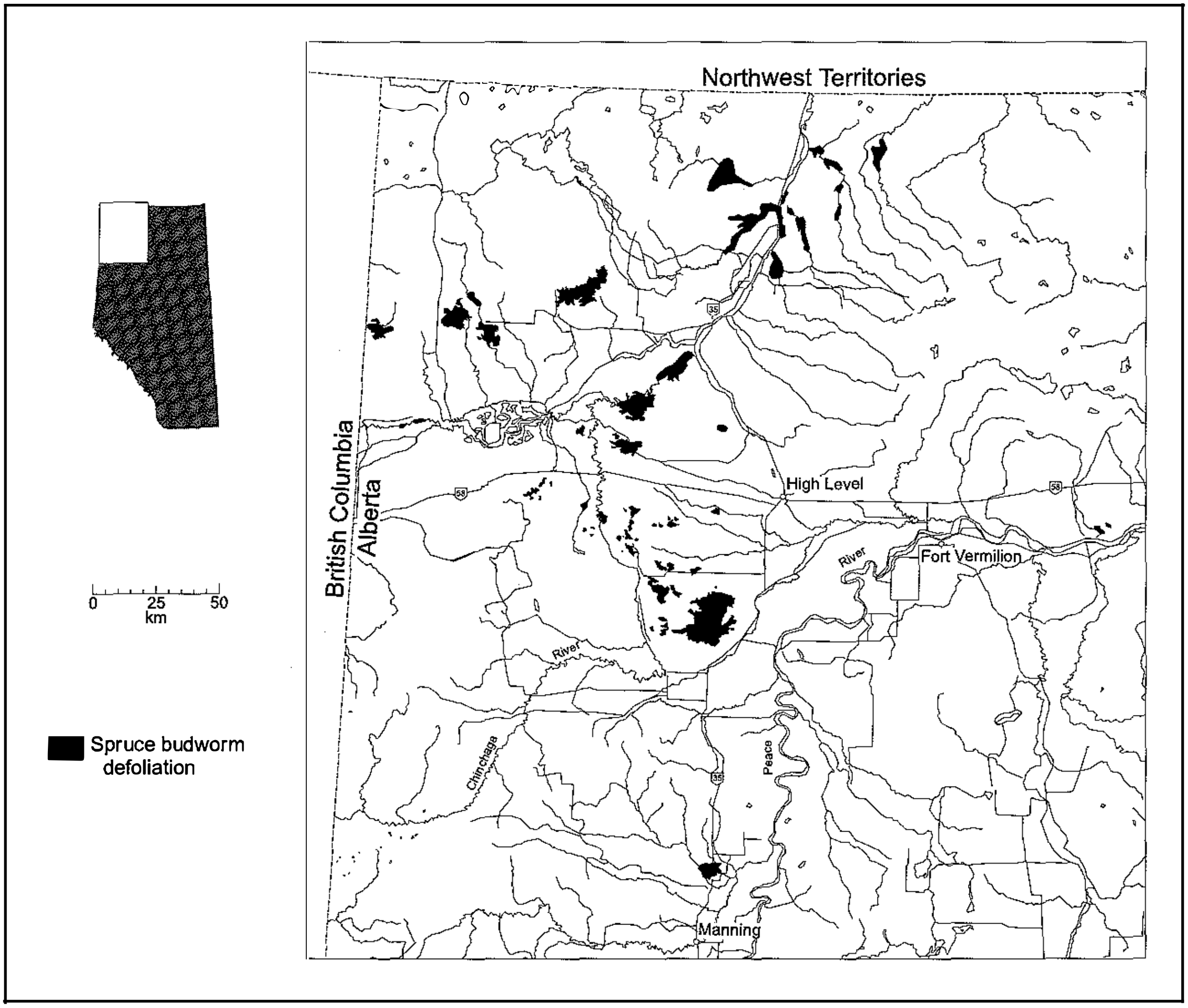

Figure 7. Areas of spruce budworm defoliation in northwestern Alberta in 1996.

Table 3. Area of spruce budworm defoliation in west-central Canada, as determined from aerial and ground surveys in 1995 and 1996. Estimates include all areas with visible defoliation (i.e., ≥35% defoliation).

Location	Area of defoliation (ha)		Change
	1995	1996	(%)
Alberta	203 741	222 952	+9
Saskatchewan	98 910	113 972	+15
Manitoba	55 592	70 239	+26
Northwest Territories	36 822	352 968	+859
Total	395 065	760 131	+92

In Saskatchewan, the total area of defoliated white spruce–balsam fir forests was 113 972 ha, an increase of 15% over that in 1995. Infestations on the eastern side of the province near Hudson Bay north to Amisk Lake (Fig. 10) covered 57 356 ha, of which 4328 ha were moderately defoliated and 53 028 ha were moderately to severely defoliated. In the La Ronge area, 32 999 ha of defoliation occurred. The infestations north of Big River near Doré, Delaronde, Green, and Smoothstone lakes persisted in 1996; these outbreaks covered an area of 12 451 ha, compared to 13 394 ha in 1995. Infestations in Prince Albert National Park and between the park boundary and Montreal Lake were 8138 ha in size. A new infestation was detected north of Candle Lake; the area of this infestation was 1628 ha. The only other areas where spruce budworm defoliation was observed were in several areas southwest of Prince Albert in and adjacent to the Nisbet Provincial Forest (1400 ha). The total area of moderate defoliation in Saskatchewan was 10 521 ha, while the areas of moderate-to-severe and severe defoliation covered 100 099 and 3352 ha, respectively.

Spruce budworm infestations in Manitoba occurred in the southeastern part of the province (Fig. 11) and in the Duck Mountain area (Fig. 12). Defoliated trees covered 70 239 ha, of which 51 160 ha were moderately defoliated and 19 079 ha were severely defoliated. Spruce budworm defoliation has been chronic in southeastern Manitoba for several years. Outbreaks continued in most of the areas where defoliation occurred in 1995. The area of defoliation in southeastern Manitoba covered 49 849 ha, with defoliation rated as moderate on 30 898 ha and severe on 18 951 ha. Defoliated area on Duck Mountain increased dramatically in 1996; there were 20 262 ha of moderate defoliation and 128 ha of severe defoliation, compared to 1816 ha of total defoliation in 1995.

Populations of spruce budworm continued to fluctuate widely in the Northwest Territories.

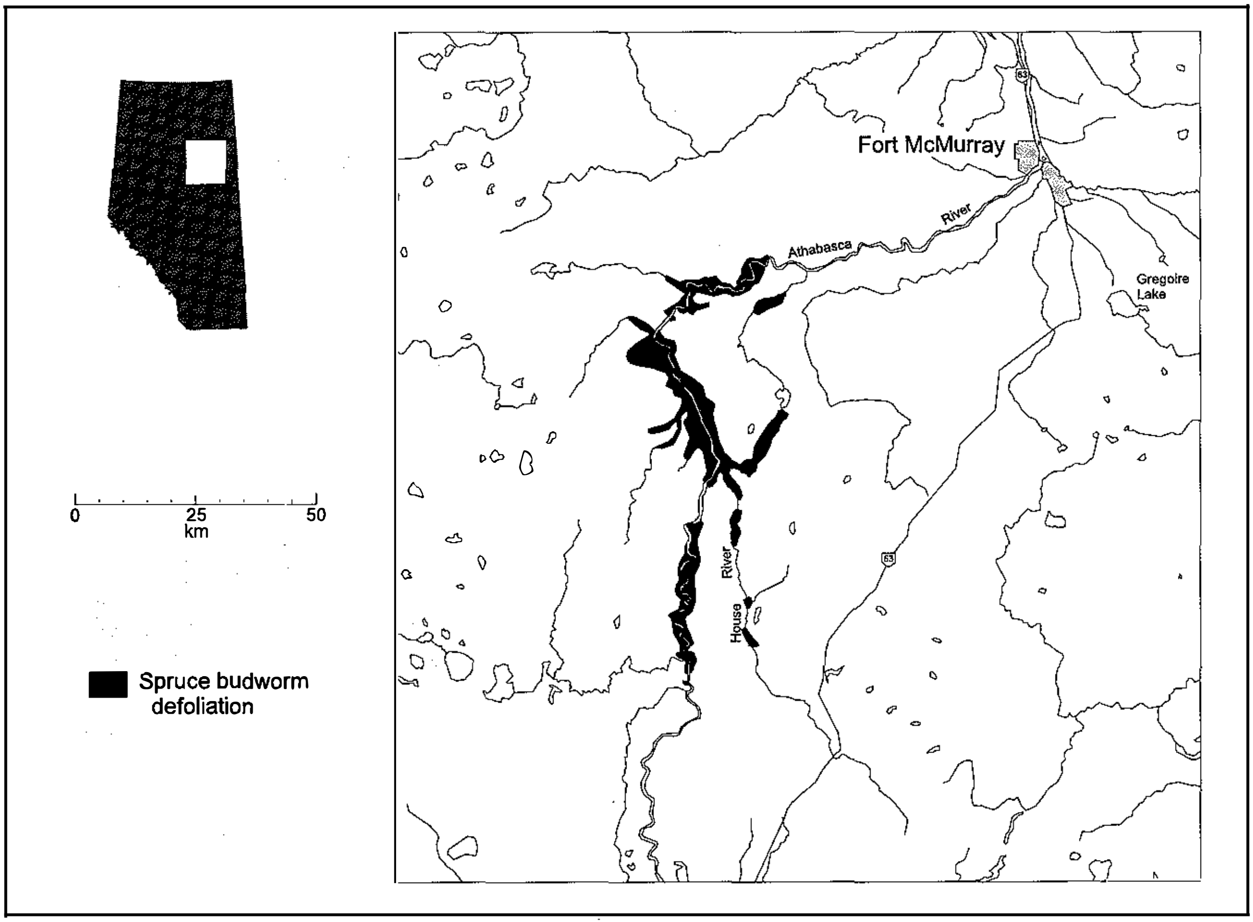

Figure 8. Areas of spruce budworm defoliation near the Athabasca River in northeastern Alberta in 1996.

After dropping dramatically in 1995 from levels observed in 1994, area of defoliation in 1996 increased to a level comparable to that observed in 1994. A total of 352 968 ha were defoliated in 1996, an increase of 859% from 1995. In the Slave River area (Fig. 9), there was 41 750 ha of moderate defoliation and 144 827 ha of severe defoliation along the Slave and Taltson rivers. In the Northwest Territories portion of Wood Buffalo National Park, defoliation occurred on 43 692 ha (7958 ha of moderate; 35 734 ha of severe). Along the Mackenzie River and its tributaries between Great Slave Lake and Fort Norman (Fig. 13), 122 699 ha were defoliated; 95% of the defoliation in this area was rated as moderate while the remainder was rated severe.

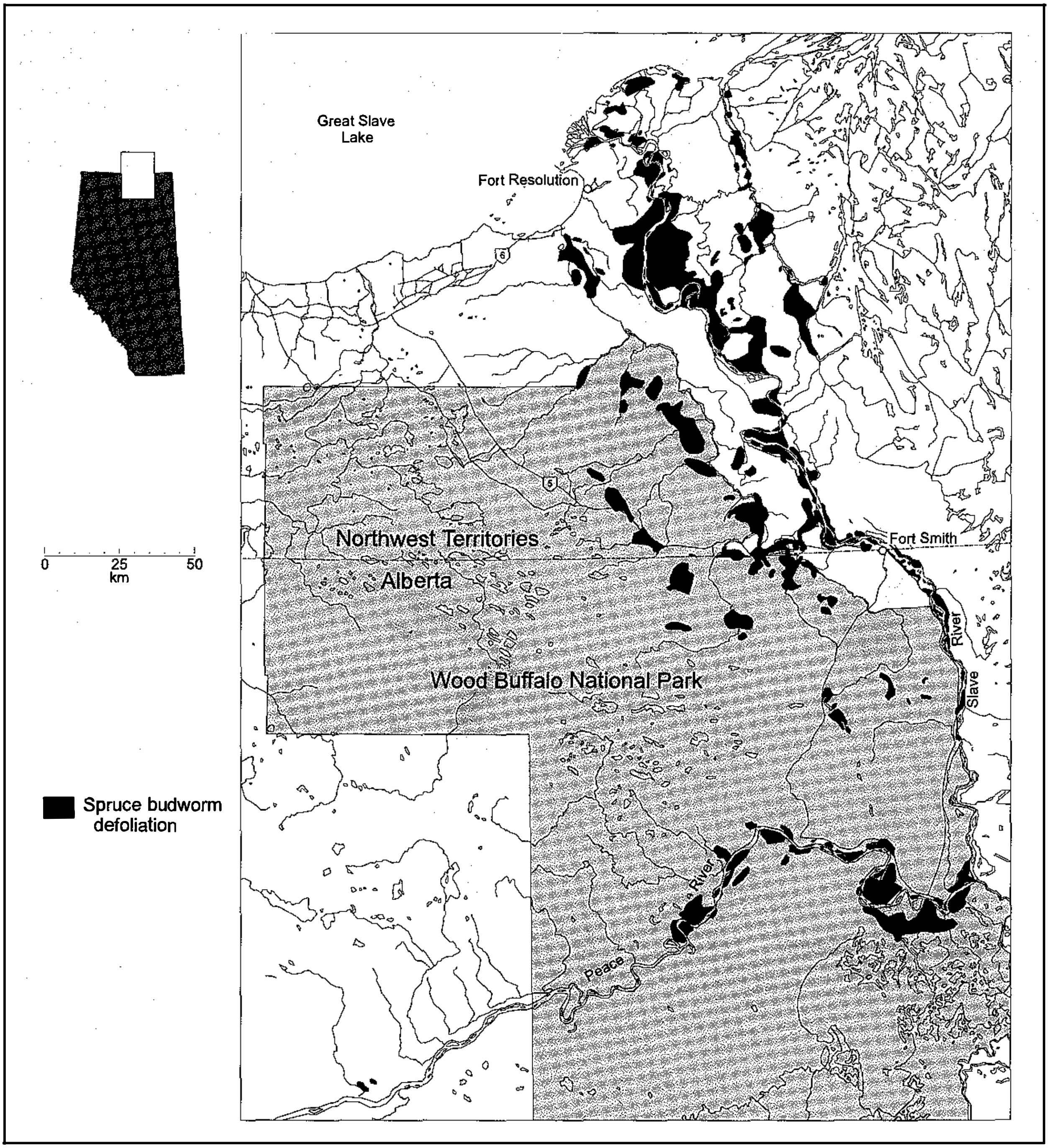

Figure 9. Areas of spruce budworm defoliation along the Peace and Slave rivers in northern Alberta and the southern Northwest Territories in 1996.

Other Noteworthy Damage Agents

Aspen twoleaf tier (*Enargia decolor* [Wlk.]) was observed causing trembling aspen defoliation over 4761 ha in the Green, Doré, and Delaronde lakes area of Saskatchewan this year. Of the total defoliation, 4334 ha were rated light and 427 ha were rated moderate.

The infestation of Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.), which was active in Jasper National Park beginning in 1991, declined in activity. Few dead or fading trees were observed during a survey conducted in October by CFS and park staff.

Monitoring activities by Manitoba Natural Resources in Manitoba and the CFS in Alberta, Saskatchewan, and Manitoba detected no change in the population status of jack pine budworm (*Choristoneura pinus pinus* Free.) (Keith Knowles, Manitoba Natural Resources, Winnipeg, Manitoba, January 1997, personal communication; Jan Volney, Canadian Forest Service, Edmonton, Alberta, January 1997, personal communication.). This defoliator of jack pine trees has not caused significant defoliation in the prairie provinces since the last major outbreak, which collapsed in 1987.

Large aspen tortrix (*Choristoneura conflictana* [Wlk.]) remained active in the region but the area defoliated was low. There were 10 034 ha of light and light-to-moderate defoliation in Alberta, most of which occurred west of Cold Lake (Fig. 3). The remaining area (331 ha of light defoliation) occurred in Wood Buffalo National Park. In Saskatchewan there were 32 229 ha of trembling aspen forests affected by large aspen tortrix defoliation northeast of La Ronge and west of Flin Flon (Fig. 14). Slightly less than 89% of this defoliation

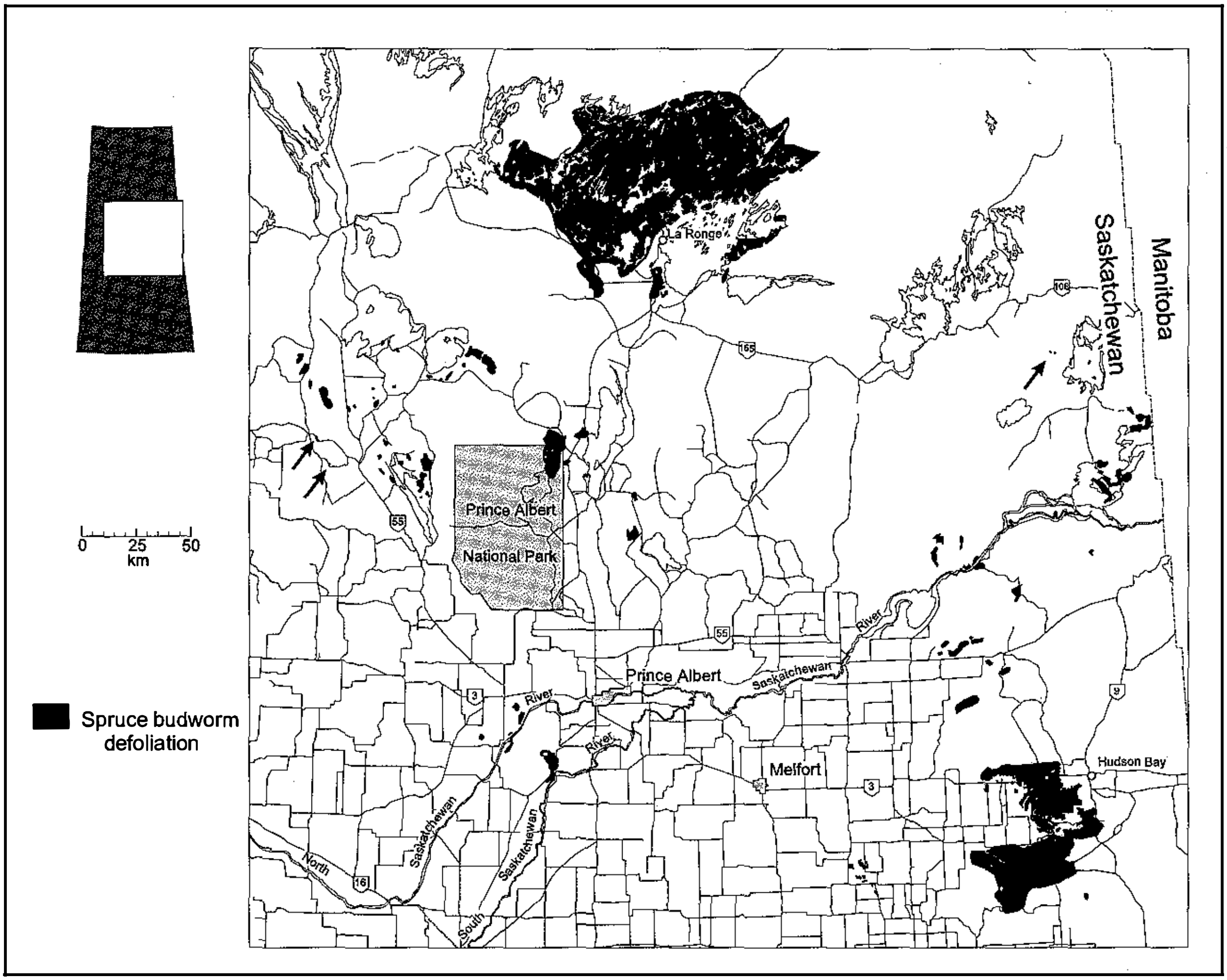

Figure 10. Areas of spruce budworm defoliation in central Saskatchewan in 1996.

was rated as light, 11% was rated as moderate, and less than 1% was rated as severe.

Aerial surveys of mountain pine beetle (*Dendroctonus ponderosae* Hopk.) were conducted in areas in Alberta where dispersing beetles might invade from British Columbia or the United States, and included the foothills region southwest of Calgary to the Canada–U.S. border, Willmore Wilderness Provincial Park, and Jasper, Banff, and Waterton Lakes national parks. No recently killed trees were observed during the 1996 surveys. Based on the surveys, no established populations of the insect resided in the province in 1996.

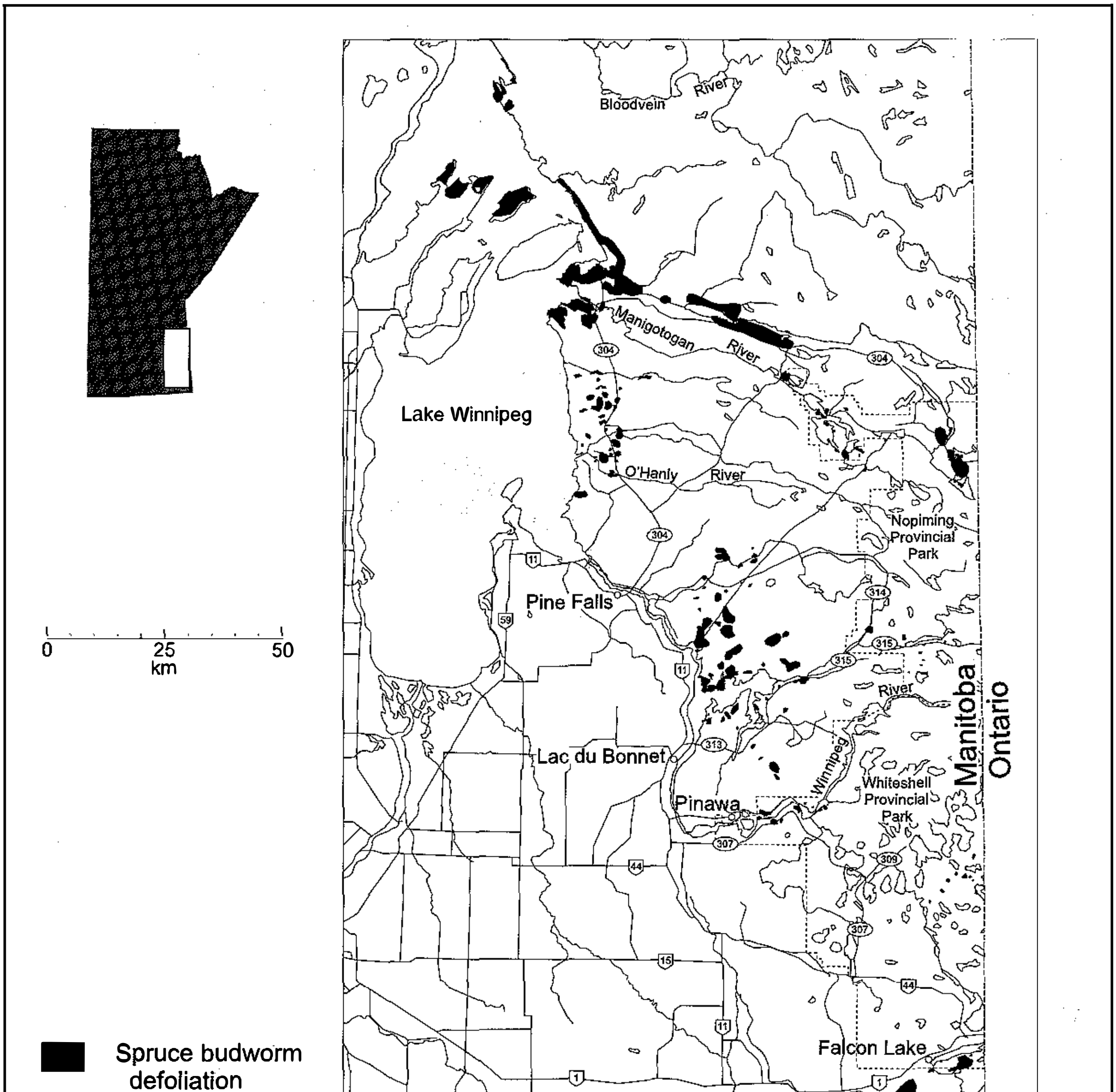

Figure 11. Areas of spruce budworm defoliation in southeastern Manitoba in 1996.

Beetles were detected at several locations by means of pheromone-baited trap trees as part of monitoring activities conducted by the Alberta Land and Forest Service. It is suspected that these beetles migrated eastward from existing outbreaks in the neighboring province of British Columbia.

The localized outbreak of satin moth (*Leucoma salicis* [L.]) remained active in the Edmonton area. This nonnative pest was found at 57 new sites, mostly in the north half of the city. In addition to hybrid poplars (*Populus* spp.), which appear to be the preferred host in the Edmonton area, four small groups of native balsam poplar (*Populus balsamifera* L.) were infested. One of these groups of trees was in a rural setting near the northern city limits. In the near future this moth could move to natural stands of balsam poplar or trembling aspen to the north of the city. No spraying to limit the spread of the insect was conducted in 1996, but the City did continue its work with parasitoids of satin moth.

No new activity by spruce beetle (*Dendroctonus rufipennis* [Kby.]) was observed during aerial surveys in 1996. These observations were supported by results from the beetle-trapping program conducted in northwestern Alberta by the Alberta Land and Forest Service.

Forest Fires

Both the number of forest fires and the area burned were lower in the region compared to averages of the previous 10 years (Table 4). Areas burned in Alberta, Saskatchewan, Manitoba, and the Northwest Territories were 88%, 96%, and 39% lower, respectively, than the average of the previous 10 years. The number of forest-fire starts was down by 25–60% in the three prairie provinces, while in the Northwest Territories, number of starts was up slightly. Some of the reduction in fire activity was related to the above-normal snow accumulations in the winter of 1995–96 and the wet, late spring. The fire season began about 2 weeks later than normal throughout the region.

Climate

Climatic data from several weather stations scattered across the study area were summarized and are presented in Table 5.

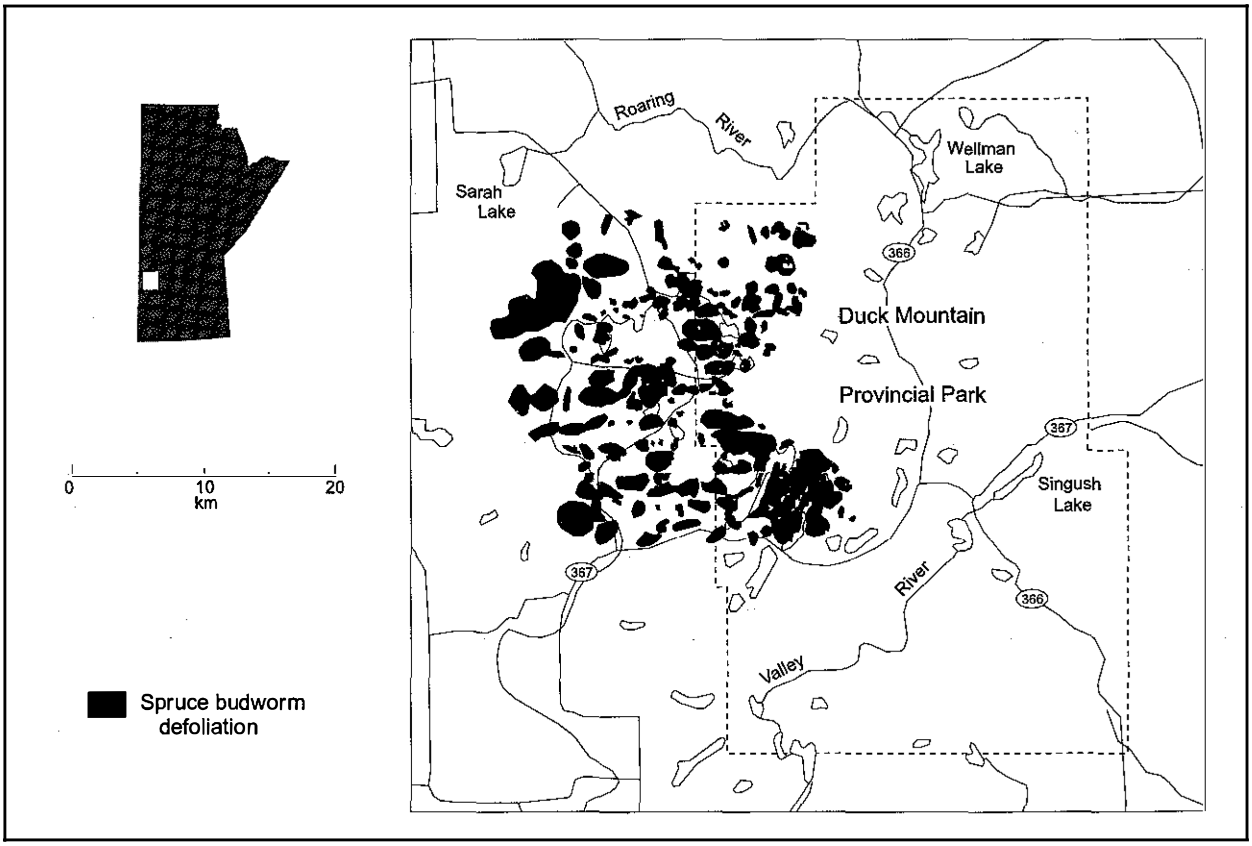

Figure 12. Areas of spruce budworm defoliation in western Manitoba in 1996.

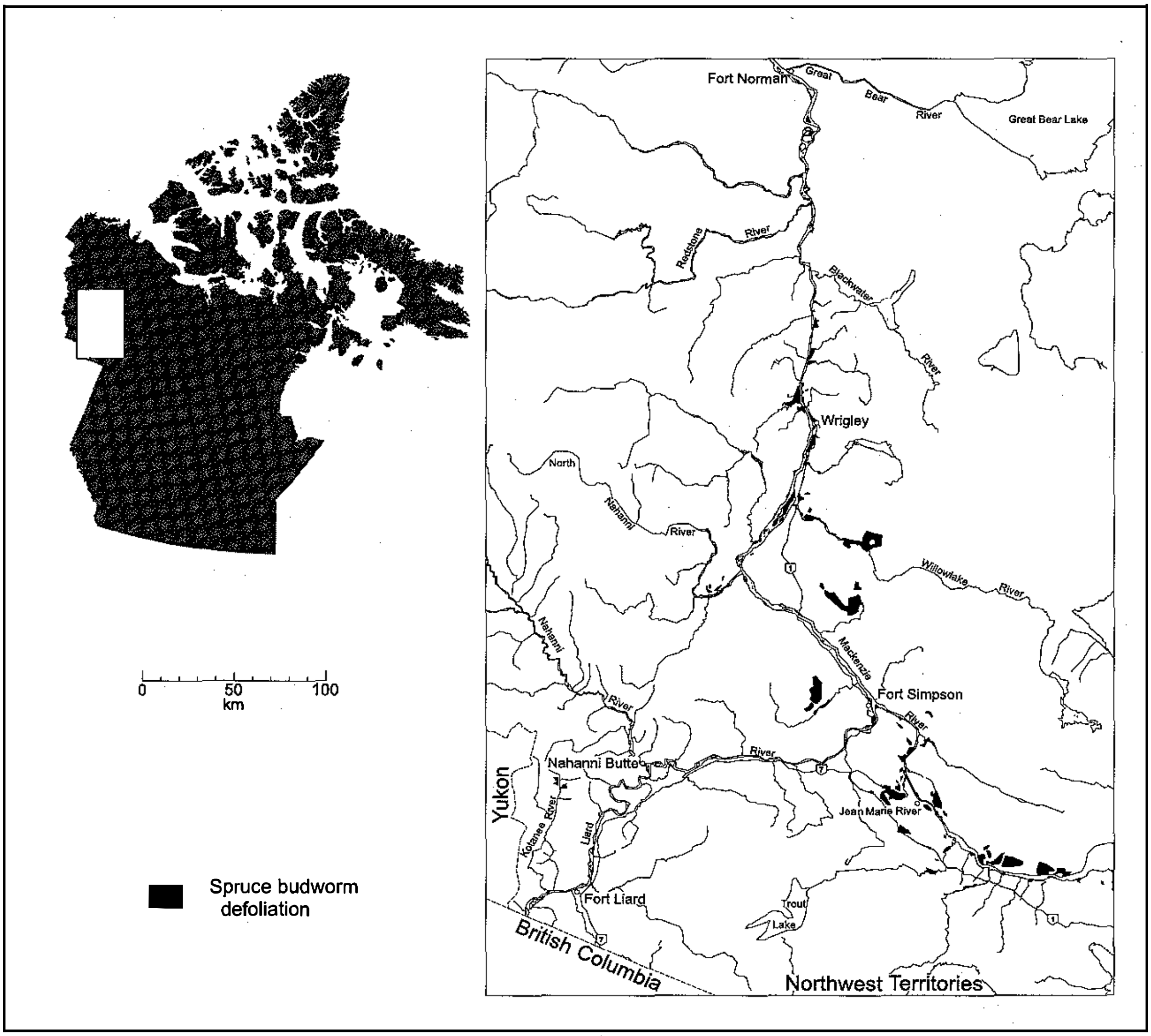

Figure 13. Areas of spruce budworm defoliation along the Mackenzie River and its tributaries in the Northwest Territories in 1996.

Table 4. Forest-fire starts and area burned in 1996 and in the previous 10-year period in west-central Canada. (Source: Canadian Interagency Forest Fire Centre, Winnipeg, Manitoba.)

		Jurisdiction				
		Alberta	Saskatchewan	Manitoba	Northwest Territories	Total
Wildfire starts	10-yr average	941	777	563	348	2 629
	1996	373	428	424	350	1 575
Area burned	10-yr average	16 652	315 140	611 385	588 064	1 531 241
	1996	1 991	14 163	114 401	361 472	492 027

Table 5. **Thirty-year climate normals and 1996 measurements for selected locations across west-central Canada**

Location	Month	Mean temperature (°C) Normal[a]	Mean temperature (°C) Actual[b]	Total precipitation (mm) Normal	Total precipitation (mm) Actual
Alberta					
Entrance	November 1995	–4.4	–6.1	22.9	37.6
	December 1995	–8.0	–14.1	21.6	6.8
	January 1996	–11.7	–18.8	32.9	38.1
	February 1996	–8.0	–3.9	22.2	5.2
	March 1996	–3.0	–5.8	22.9	17.4
	April 1996	3.3	5.2	23.1	14.4
	May 1996	8.3	5.5	60.1	115.0
	June 1996	12.3	n/a	72.4	n/a
	July 1996	14.2	14.9	91.6	41.0
	August 1996	13.5	14.5	63.4	42.6
	September 1996	8.6	8.1	48.9	45.0
	October 1996	4.3	2.0	22.4	2.6
Fort McMurray	November 1995	–9.0	–12.0	26.4	24.1
	December 1995	–17.3	–16.1	23.0	21.2
	January 1996	–19.8	–25.7	20.4	30.8
	February 1996	–14.9	–13.7	16.0	22.2
	March 1996	–7.9	–12.4	17.3	17.6
	April 1996	2.8	2.0	22.6	18.9
	May 1996	10.1	7.4	40.7	36.0
	June 1996	14.6	14.8	63.9	99.9
	July 1996	16.6	16.7	79.1	107.5
	August 1996	15.2	16.0	71.8	103.8
	September 1996	9.1	8.8	51.4	99.3
	October 1996	3.3	1.1	32.2	28.2
Grande Prairie	November 1995	–6.9	–10.3	28.6	74.4
	December 1995	–13.6	–17.3	26.9	37.9
	January 1996	–15.4	–24.5	32.7	26.5
	February 1996	–11.7	–10.3	20.5	15.8
	March 1996	–5.9	–8.8	18.6	23.3
	April 1996	3.3	4.5	19.8	24.4
	May 1996	10.1	6.9	35.3	52.9
	June 1996	14.1	12.9	74.2	34.3
	July 1996	16.0	15.0	67.9	79.1
	August 1996	14.9	15.0	61.8	51.3
	September 1996	9.8	8.2	42.2	67.6
	October 1996	4.4	1.9	21.7	22.8
High Level	November 1995	–12.8	–15.8	29.2	39.0
	December 1995	–20.2	–21.4	22.2	16.5
	January 1996	–21.4	29.8	22.9	19.4
	February 1996	–18.0	–18.0	17.0	16.2
	March 1996	–10.4	–15.0	19.2	35.7
	April 1996	1.9	0.3	17.1	19.0
	May 1996	14.2	6.5	41.5	14.0
	June 1996	16.2	13.9	65.0	41.8
	July 1996	16.2	16.2	61.0	38.0
	August 1996	14.0	14.5	n/a	43.3
	September 1996	8.2	8.6	34.1	17.5
	October 1996	n/a	–1.7	n/a	26.2

Table 5. Continued

Location	Month	Mean temperature (°C) Normal[a]	Mean temperature (°C) Actual[b]	Total precipitation (mm) Normal	Total precipitation (mm) Actual
Medicine Hat	November 1995	–2.1	–3.6	14.8	29.0
	December 1995	–8.6	–12.7	16.2	19.8
	January 1996	–10.7	–17.7	17.3	26.0
	February 1996	–6.8	–6.4	10.3	8.4
	March 1996	–1.2	–4.6	16.0	9.8
	April 1996	6.3	7.4	26.0	17.5
	May 1996	12.4	9.6	42.3	52.1
	June 1996	17.1	17.0	56.4	74.8
	July 1996	19.8	19.6	40.9	21.3
	August 1996	19.2	20.3	30.6	11.8
	September 1996	13.0	11.8	36.3	64.1
	October 1996	7.3	5.9	15.5	10.3
Peace River	November 1995	–8.5	–11.5	23.0	43.4
	December 1995	–15.2	–18.1	19.9	28.0
	January 1996	–17.5	–26.5	22.6	22.2
	February 1996	–13.3	–12.3	19.3	19.4
	March 1996	–7.2	–10.0	15.1	11.4
	April 1996	3.0	3.6	15.8	34.7
	May 1996	9.9	7.2	31.5	54.5
	June 1996	14.1	12.6	63.4	121.0
	July 1996	15.9	15.0	61.7	81.6
	August 1996	14.6	14.9	50.9	75.4
	September 1996	9.2	8.3	40.4	34.4
	October 1996	3.4	0.7	24.1	30.6
Red Deer	November 1995	–5.3	–8.0	14.8	35.2
	December 1995	–11.9	–15.0	18.8	16.1
	January 1996	–13.5	–20.5	20.7	28.0
	February 1996	–10.0	–10.6	14.7	1.8
	March 1996	–4.7	–7.9	16.5	26.2
	April 1996	3.7	4.1	22.9	10.0
	May 1996	9.9	6.9	49.2	42.4
	June 1996	14.0	13.0	85.5	81.1
	July 1996	15.8	15.9	87.9	100.9
	August 1996	15.0	15.7	64.8	37.4
	September 1996	9.9	8.6	54.2	64.0
	October 1996	4.6	3.3	20.2	23.2
Saskatchewan					
La Ronge	November 1995	–8.9	–12.3	29.1	29.7
	December 1995	–18.0	–17.3	21.8	13.0
	January 1996	–20.9	–25.7	18.9	17.1
	February 1996	–16.9	–15.4	15.1	17.4
	March 1996	–9.5	–13.6	18.5	11.0
	April 1996	1.1	–0.9	27.1	76.0
	May 1996	8.7	6.3	40.1	33.1
	June 1996	14.2	15.5	79.4	60.5
	July 1996	16.9	17.6	84.3	102.9
	August 1996	15.4	16.7	60.3	77.1
	September 1996	9.4	9.1	59.3	92.9
	October 1996	2.6	1.3	35.4	36.6

Table 5. **Continued**

Location	Month	Mean temperature (°C)		Total precipitation (mm)	
		Normal[a]	Actual[b]	Normal	Actual
Prince Albert	November 1995	–7.5	–11.3	16.5	27.4
	December 1995	–16.9	–17.1	19.1	27.7
	January 1996	–19.8	–25.0	15.4	4.6
	February 1996	–15.9	–14.0	13.6	5.0
	March 1996	–8.8	–11.6	18.2	7.6
	April 1996	2.6	1.4	22.2	59.6
	May 1996	10.4	7.9	41.6	56.1
	June 1996	15.2	16.2	66.9	42.6
	July 1996	17.6	17.6	72.1	69.3
	August 1996	16.1	17.9	58.6	36.0
	September 1996	9.9	10.0	39.8	79.2
	October 1996	3.7	2.6	21.6	31.4
Manitoba					
Flin Flon	November 1995	–8.4	–12.9	27.0	23.0
	December 1995	–18.8	–17.8	23.8	24.0
	January 1996	–21.7	–26.1	19.3	10.6
	February 1996	–17.4	–16.2	14.6	17.6
	March 1996	–10.1	–14.8	20.8	30.6
	April 1996	0.7	–1.6	28.7	15.8
	May 1996	8.9	6.1	41.0	62.6
	June 1996	14.7	16.2	70.2	88.6
	July 1996	17.8	19.0	67.1	66.8
	August 1996	16.4	18.5	74.3	35.8
	September 1996	9.4	10.4	60.2	68.4
	October 1996	2.6	1.3	37.1	59.0
Grand Rapids	November 1995	–6.9	–11.3	26.8	20.0
	December 1995	–16.6	–16.5	19.4	22.8
	January 1996	–19.8	–22.9	16.4	11.1
	February 1996	–16.7	–14.9	12.8	18.1
	March 1996	–9.1	–13.0	24.8	13.2
	April 1996	0.5	–1.9	24.6	35.5
	May 1996	8.3	5.7	38.9	52.0
	June 1996	14.9	15.7	75.2	36.5
	July 1996	18.8	19.1	75.1	34.1
	August 1996	17.5	19.4	67.2	33.7
	September 1996	11.2	12.3	60.7	34.5
	October 1996	4.0	5.2	41.5	22.1
Lynn Lake	November 1995	–12.5	–16.6	31.3	24.8
	December 1995	–22.5	–20.1	22.8	32.6
	January 1996	–25.2	–28.6	20.4	6.4
	February 1996	–21.2	–19.3	16.0	22.0
	March 1996	–13.7	–17.9	16.2	38.4
	April 1996	–2.3	–5.1	23.0	7.6
	May 1996	6.2	4.7	44.0	27.2
	June 1996	12.5	14.5	65.2	79.6
	July 1996	15.8	17.4	77.4	57.0
	August 1996	14.0	15.6	73.2	55.8
	September 1996	6.9	8.4	59.4	69.6
	October 1996	–0.3	–1.1	43.5	56.4
The Pas	November 1995	–7.7	–12.7	26.6	30.6
	December 1995	–18.0	–17.1	19.8	19.0

Table 5. Continued

Location	Month	Mean temperature (°C)		Total precipitation (mm)	
		Normal[a]	Actual[b]	Normal	Actual
	January 1996	–21.4	–24.9	16.6	12.6
	February 1996	–17.5	–16.1	15.1	12.8
	March 1996	–10.0	–14.2	21.0	21.6
	April 1996	0.5	–1.7	26.2	27.0
	May 1996	8.7	5.7	33.6	75.8
	June 1996	14.8	15.7	63.1	73.6
	July 1996	17.7	18.6	69.1	44.7
	August 1996	16.4	18.1	65.0	24.2
	September 1996	9.9	10.8	58.3	49.7
	October 1996	3.5	2.8	37.5	68.5
Thompson	November 1995	–11.8	–17.4	33.8	24.1
	December 1995	–22.1	–21.2	28.1	43.7
	January 1996	–25.0	–28.8	20.3	8.2
	February 1996	–21.0	–18.9	13.9	27.6
	March 1996	–13.3	–17.6	21.3	32.2
	April 1996	–2.4	–5.1	28.0	18.0
	May 1996	6.3	3.9	45.8	52.6
	June 1996	12.3	13.8	71.5	93.4
	July 1996	15.7	16.8	84.3	43.7
	August 1996	13.8	15.3	77.7	43.3
	September 1996	7.2	8.5	63.4	58.6
	October 1996	0.0	–1.1	47.5	56.3
Winnipeg	November 1995	–4.7	–10.6	21.2	44.6
	December 1995	–14.6	–16.4	18.6	19.1
	January 1996	–18.3	–22.8	19.3	22.6
	February 1996	–15.1	–15.1	14.8	36.8
	March 1996	–7.0	–13.0	23.1	34.2
	April 1996	3.8	–1.6	35.9	53.6
	May 1996	11.6	9.3	59.8	84.2
	June 1996	16.9	18.6	83.8	83.8
	July 1996	19.8	18.9	72.0	97.3
	August 1996	18.3	19.2	75.3	85.5
	September 1996	12.4	13.0	51.3	49.8
	October 1996	5.7	5.3	29.5	27.4
Northwest Territories					
Fort Simpson	November 1995	–16.8	–18.6	25.7	10.8
	December 1995	–23.8	–25.5	18.9	19.7
	January 1996	–26.7	–29.3	19.6	21.3
	February 1996	–22.0	–19.3	17.8	17.5
	March 1996	–14.2	–13.5	17.6	15.3
	April 1996	–1.3	–1.3	16.4	19.4
	May 1996	8.5	7.6	29.8	19.5
	June 1996	14.7	15.9	44.3	27.4
	July 1996	16.9	18.0	53.3	92.4
	August 1996	14.3	13.6	50.7	114.4
	September 1996	7.5	7.9	30.2	36.0
	October 1996	–2.0	–5.8	36.1	22.3
Fort Smith	November 1995	–12.6	–14.8	25.2	36.8
	December 1995	–21.7	–19.3	19.2	21.6
	January 1996	–25.4	–28.1	19.9	7.4
	February 1996	–21.2	–18.3	14.3	12.6

Table 5. Concluded

Location	Month	Mean temperature (°C)		Total precipitation (mm)	
		Normal[a]	Actual[b]	Normal	Actual
	March 1996	−14.0	−17.5	13.9	22.6
	April 1996	−1.4	−1.6	13.5	6.2
	May 1996	8.1	6.5	29.2	10.9
	June 1996	14.0	15.0	45.3	57.9
	July 1996	16.3	17.8	56.8	57.2
	August 1996	14.3	15.2	49.1	50.4
	September 1996	7.6	9.8	38.5	123.2
	October 1996	0.4	−1.1	28.1	53.0
Hay River	November 1995	−12.4	−15.3	32.6	18.0
	December 1995	−20.9	−21.2	20.8	13.6
	January 1996	−24.5	−26.6	22.2	2.8
	February 1996	−21.2	−18.4	17.6	5.5
	March 1996	−15.8	−17.1	16.1	13.8
	April 1996	−3.5	−3.4	15.3	8.9
	May 1996	5.9	4.1	21.7	19.0
	June 1996	12.3	12.6	35.0	6.1
	July 1996	15.8	16.5	45.3	70.4
	August 1996	14.4	14.9	43.8	51.4
	September 1996	8.2	9.6	37.7	35.0
	October 1996	0.9	−2.9	34.2	40.4

[a] Sources: Canadian Climate Program. 1993a. Canadian climate normals, 1961–90, Prairie provinces. Environ. Can., Atmos. Environ. Serv., Ottawa, Ontario.
Canadian Climate Program. 1993b. Canadian climate normals, 1961–90, Yukon and Northwest Territories. Environ. Can., Atmos. Environ. Serv., Ottawa, Ontario.

[b] Source: Environ. Can., Atmos. Environ. Branch, Climate Serv. Unit, Prairie and Northern Region, Edmonton, Alberta.

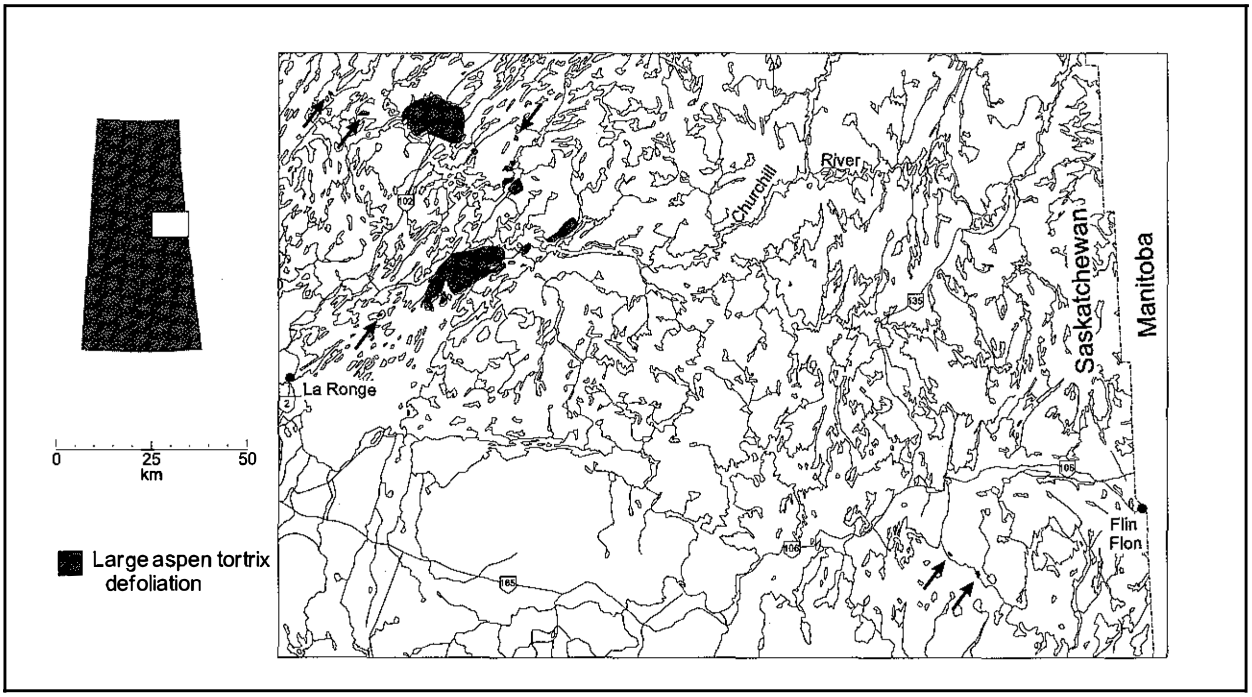

Figure 14. Areas of large aspen tortrix defoliation in east-central Saskatchewan in 1996.

Generally, precipitation between November 1995 and March 1996 was higher than the 30-year normals in most locations in Alberta and Manitoba. The increase was as much as 62% higher at some locations. In Saskatchewan and at two of the three locations in the Northwest Territories, precipitation for the same period was lower by 14–25%. Precipitation in April and May were above normal at most locations in Alberta, Saskatchewan, and Manitoba, but lower in the Northwest Territories. The summer months, from June through August, were drier than normal in the three prairie provinces. The drop in precipitation ranged from 8 to 52%. In the Northwest Territories during the same period, precipitation was as much as 58% higher than the 30-year normals. Spring was late in 1996 as evidenced by the lower temperatures observed across the study area during March, April, and May. Temperatures in June, July, and August were higher than the 30-year normals except for northwestern Alberta where temperatures in High Level, Peace River, and Grande Prairie were lower than normal.

FOREST HEALTH CONDITIONS ON BIOMONITORING PLOTS

There are 17 biomonitoring plots maintained and monitored by the CFS in west-central Canada. These plots, which were primarily established in 1985, are part of a permanent, nation-wide network of 151 plots on which changes in tree condition and growth, minor vegetation, insect and disease incidence, and soil condition are assessed. The main purpose of the plot network is to monitor and assess forest health in stands comprised of the major tree species in Canada in order to detect changes related to natural or anthropogenic factors. Locations of biomonitoring plots are shown in Figure 15; other descriptive information is summarized in Table 6.

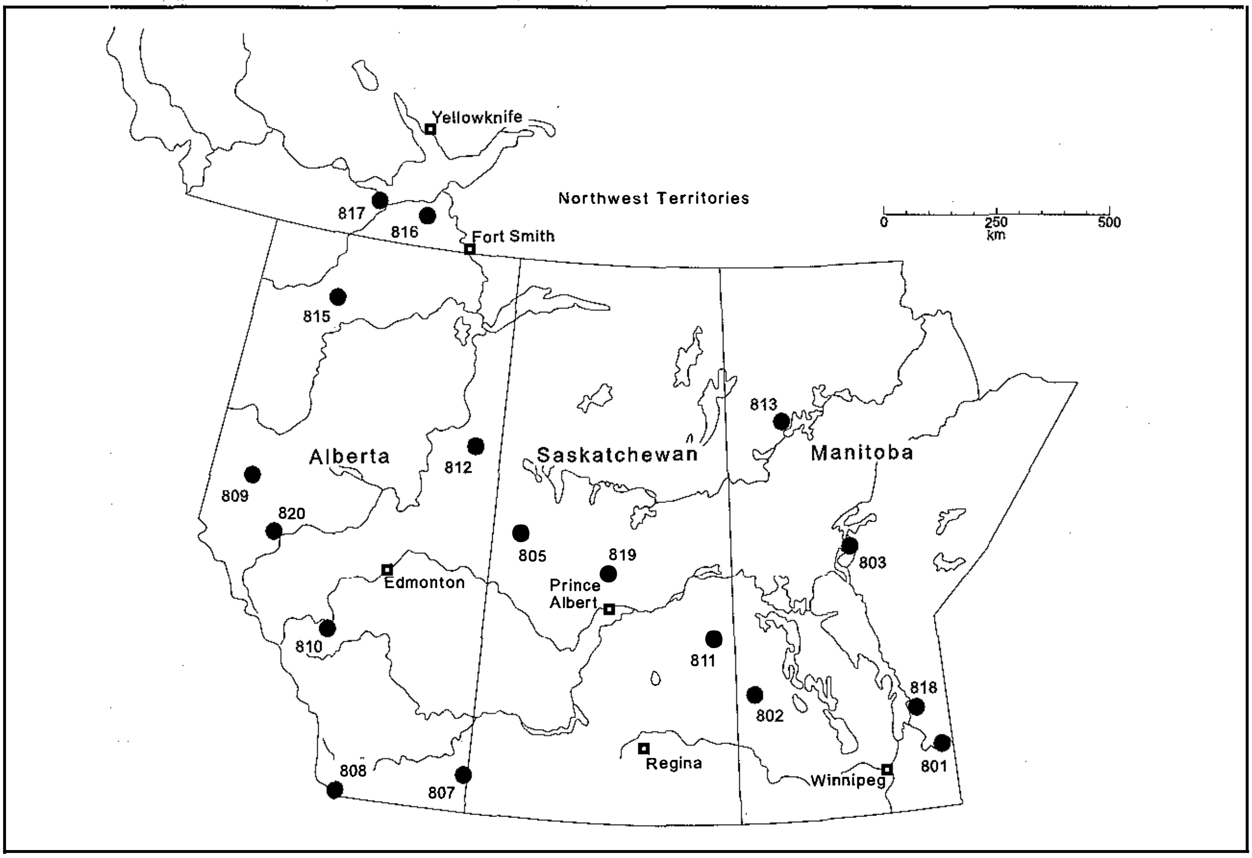

Figure 15. Locations of Forest Health Network permanent sample plots used for biomonitoring of forest conditions in west-central Canada. Numbers indicate plot designations.

Table 6. A description of biomonitoring plots in west-central Canada

Plot	General location	Establishment year	Ecozone	Ecoregion	Species present	Number living trees
801	Whiteshell Provincial Park	1985	Boreal Shield	Lake of the Woods	Jack pine	55
					Scots pine	1
802	Duck Mountain Provincial Park	1985	Boreal Plains	Mid-Boreal Uplands	Trembling aspen	29
					Black spruce	15
					White spruce	10
803	Jenpeg	1985	Boreal Shield	Hayes River Upland	Jack pine	53
805	Meadow Lake Provincial Park	1985	Boreal Plains	Boreal Transition	Jack pine	42
807	Cypress Hills Provincial Park	1985	Prairies	Cypress Upland	Lodgepole pine	81
808	Waterton Lakes National Park	1985	Montane Cordillera	Northern Continental Divide	Lodgepole pine	80
809	Grande Prairie	1985	Boreal Plains	Western Alberta Upland	White spruce	30
					Balsam fir	22
					Black spruce	11
					White birch	3
810	Rocky Mountain House	1985	Boreal Plains	Western Alberta Upland	Lodgepole pine	51
					Balsam fir	1
811	Hudson Bay	1986	Boreal Plains	Boreal Transition	White spruce	57
					Trembling aspen	1
					Balsam poplar	1
812	Gregoire Lake Provincial Park	1986	Boreal Plains	Mid-Boreal Uplands	White spruce	37
					Balsam fir	2
813	Leaf Rapids	1990	Boreal Shield	Churchill River Upland	Jack pine	47
815	Watt Mountain	1991	Taiga Plains	Hay River Lowland	White spruce	33
					Trembling aspen	11
					Balsam poplar	2
					Birch spp.	1
816	East Hay River	1991	Taiga Plains	Hay River Lowland	Trembling aspen	36
					White spruce	9
					Balsam poplar	8
817	Kakisa Lake	1991	Taiga Plains	Hay River Lowland	White spruce	40
					Trembling aspen	8
818	Manitoba Model Forest	1993	Boreal Shield	Lac Seul Upland	Trembling aspen	10
					Balsam fir	6
819	Prince Albert National Park	1993	Boreal Plains	Mid-Boreal Uplands	Trembling aspen	31
					White spruce	18
					Black spruce	1
820	Foothills Model Forest	1993	Boreal Plains	Western Alberta Upland	Trembling aspen	29
					White spruce	21
					Black spruce	4
					Lodgepole pine	3

Methods

Plot characteristics such as location, elevation, slope, aspect, and tree mapping were measured and recorded in the establishment year. A detailed soil description was also completed at this time according to the Canadian system of soil classification. Vertical and radial tree growth, crown structure and density, and conifer shoot growth were measured and recorded in the establishment year and every subsequent fifth year. These measurements were made on all trees with a diameter at breast height (1.3 m) greater than 10 cm. In addition, foliage and soil samples were collected for detailed chemical analyses in the laboratory. Every second year, regeneration and ground vegetation were assessed. Tree mortality and condition were assessed in the establishment year and every subsequent year. Several assessments were made of abiotic foliar symptoms and insect and disease conditions during every growing season. The permanent biomonitoring plots are 10×40 m in size and are located in representative stands. Each plot contains four 2×2 m subplots for regeneration and minor vegetation assessments.

There were two sets of tree condition classes: one for conifers (except larch species) (Table 7) and one for hardwoods (Table 8). Both sets of classes took into consideration the level of twig and branch dieback in the outer crown and defoliation. Defoliation was defined as foliage missing, whatever the reason, from the normal foliage complement of the tree. Also considered was the size of the foliage and whether it was affected by disease. Beginning in 1993, the hardwood classes of D'Eon et al. (1994) were modified slightly from those of Magasi (1988). Magasi's codes were used in the analysis of the hardwood tree condition data. The causes of death of trees that had died since the last assessment were determined by closely examining dead trees, but identification of cause was not always possible because only nondestructive sampling is allowed on plots.

Table 7. The conifer crown classification system used to rate crown condition (D'Eon et al. 1994)

Class code	Description
01	No defoliation.
02	Only current foliage defoliated. Defoliation less than 25%.
03	Current and/or some older foliage defoliated. Defoliation less than 25%.
04	25–50% defoliation.
05	51–75% defoliation.
06	76–90% defoliation.
07	More than 90% defoliation.
08	Tree died since last assessment.
09	Classified as dead in the last annual assessment.

Table 8. The hardwood crown classification system used to rate crown condition (Magasi 1988)

Class code	Description
1	Normal, healthy tree.
2	Foliage thin, off-color, particularly in the upper crown, but no bare twigs or branches.
3	Dead twigs present but no dead branches. Dead twigs occur at the ends of the branches, usually in the top of the crown, and from about 0.5–1.0 m from the edge of the crown. In this and subsequent categories, the foliage is usually, but not necessarily, weak.
4	No dead branches present on up to 25% of the crown.
5	Dead branches present on up to 50% of the crown.
6	More than 50% of the crown is dead, but some living branches still present on the tree.
7	More than 50% of the crown is dead. No living branches present except small adventitious branches, usually at the base of the crown or on the stem.
8	Trees died since last assessment.
9	Classified as dead in the last annual assessment.

In addition to rating of crown condition, any damage to the tree was noted. In each case, the affected part and the agent were identified and the level of damage was classified. Abiotic symptoms categorized included foliar symptoms such as chlorotic, stunted, mottled, or spotted foliage, and mechanical damage from factors such as wind and hail. Biotic symptoms included foliar insects and diseases, woody tissue insects and diseases, and animal damage. Only nondestructive sampling is allowed on each plot, thus many organisms that require such sampling (i.e., root- and trunk-rooting fungi) were probably missed during assessments.

Regeneration by tree species was assessed on the four subplots by tallying all seedlings into 20-cm height classes and tallying all saplings. A seedling was a young tree 16–200 cm in height. Saplings were young trees greater than 2 m in height but less than 10 cm dbh.

Methods applied to the biomonitoring plots are subjective in many cases, especially the rating of tree condition. Beginning in 1995, a quality assurance and quality control (QA/QC) program was initiated. The purpose of the program has been to standardize observations made by field technicians from across the country to minimize observer bias and to increase confidence in the data. Field technicians undergo QA/QC standardization annually.

Detailed descriptions of the original and modified methods are given by Magasi (1988) and D'Eon et al. (1994).

Results and Discussion

All 17 biomonitoring plots were visited at least twice: once in May or June and once in August or September. Overall, tree health was good, with the majority of trees having less than 25% crown damage. Annual mortality rates were within the range of 0.4–3.3%. No unusual damage was observed on trees at any of the sites. A number of pests were observed at various plots. Some of these pests occurred at population levels where damage was evident.

This section provides summaries of tree condition, tree mortality, abiotic foliar symptoms and insect and disease conditions, and regeneration for each of the major tree species represented on the network of biomonitoring plots. Balsam fir, balsam poplar, black spruce (*P. mariana* [Mill.] BSP), Scots pine (*Pinus sylvestris* L.), and white birch (*Betula papyrifera* Marsh.) were present, but these tree species comprised only a minor component of the trees within the network of plots and are not discussed.

Jack Pine
Pinus banksiana Lamb.

Jack pine trees were generally healthy. Crown condition remained relatively constant over the previous 6 years, with 92–100% of the trees in classes with less than 25% crown damage (Table 9). Between 1986 and 1990, tree condition became increasingly worse in that about one-third of the trees suffered 25–50% crown damage by 1990. Trees with 76% or more crown damage between 1991 and 1993 (six trees) died in 1994; there was no obvious cause and their decline leading to death was rapid. In 1996, only 7% and 1% of the trees had crown damage levels of 25–50% and 51–75%, respectively. Many of these trees were in poor condition because of western gall rust (*Endocronartium harknessii* [J.P. Moore] Y. Hiratsuka), broken tops, or competition from adjacent trees.

Table 9. Percentage of living jack pine trees by tree condition class and measurement year since plot establishment[a]

Tree condition class	Living trees (%)											
	1985 (n = 44)	1986 (n = 125)	1987 (n = 124)	1988 (n = 124)	1989 (n = 124)	1990 (n = 144)	1991 (n = 185)	1992 (n = 185)	1993 (n = 183)	1994 (n = 182)	1995 (n = 198)	1996 (n = 197)
1	98	65	65	65	65	69	99	97	78	95	92	29
2	0	0	0	0	0	1	1	1	5	2	2	3
3	0	0	0	0	0	0	0	0	16	4	6	60
4	2	35	35	34	35	30	0	0	1	0	1	7
5	0	0	0	1	0	0	0	0	0	0	1	1
6	0	0	0	0	0	0	0	1	0	0	0	0
7	0	0	0	0	0	0	1	2	1	0	0	0

[a] Some totals exceed 100% due to rounding.

Jack pine mortality remained low from the time of plot establishment, with annual mortality in all years at 1.1% or less. In many years, no mortality occurred. Annual mortality of jack pine on the plots was comparable to jack pine mortality rates observed by others (Jan Volney, Canadian Forest Service, Edmonton, Alberta, January 1997, personal communication.) (Buchman 1983). Mortality was generally highest on Plot 805, a plot where tree condition was poorer than what was generally observed on the other jack pine plots. The cause of the poor tree condition was probably related to drought; drought symptoms were common throughout the area during the same period.

The percentage of living jack pine trees visibly affected by various damage agents changed little from plot establishment in 1985, except for the incidence of a woody-tissue disease (Table 10). The incidence of western gall rust rose between 1985 and 1993, after which time the percentage of trees affected by this disease leveled, with about one-third of the trees infected. Other notable damage agents included a shoot-boring insect belonging to the genus *Rhyacionia*, which was present from 1994 to 1996, and twig dieback in 1993 caused by squirrels removing cones from twigs. Red needles were observed on 28% of the jack pine trees in 1996. While the causal agent was not identified, it was suspected that winter injury was the most probable cause because this type of injury was widespread throughout the region on many conifers. Of all damage agents noted on jack pine trees, western gall rust was the only agent that affected tree condition in a significant way.

Due to the silvics of the species (i.e., fire regenerated), there was little regeneration in the mature jack pine stands represented in the plot network in the region. Only two jack pine seedlings were found on the subplots in 1994 and in 1996. Trembling aspen seedlings were slightly more plentiful, with six seedlings tallied in 1994 and one in 1996.

Based on the assessments made to date on jack pine trees represented on the biomonitoring plots, tree condition was generally healthy, mortality rates were not unusual, and pest incidence was normal relative to pests observed generally in jack pine forests.

Table 10. Percentage of living jack pine trees affected by various damage agents for each year since plot establishment

Year	Number of living trees	Abiotic agent	Foliar insect	Foliar disease	Woody-tissue insect	Woody-tissue disease	Other damage agents
1985	44	0	0	0	0	9	0
1986	125	0	0	0	0	4	0
1987	124	0	0	0	0	7	0
1988	124	0	0	0	0	8	0
1989	124	0	0	0	0	12	0
1990	144	0	0	0	0	13	0
1991	185	0	0	0	0	20	0
1992	185	0	0	0	0	25	0
1993	183	0	0	2	0	28	16
1994	182	0	0	4	7	33	6
1995	198	0	0	0	25	34	4
1996	197	28	5	1	1	34	9

Lodgepole Pine
Pinus contorta Dougl. ex Loud. var. *latifolia* Engelm.

Between 1985 and 1987, 58–67% of the lodgepole pine trees had less than 25% crown damage. The remaining trees had levels of crown damage between 25–50% (Table 11). In 1988, tree condition improved, with all trees having less than 25% crown damage. In subsequent years, however, tree condition gradually worsened on a small percentage of trees. Many of the trees with 76% or more crown damage in 1992 and 1993 died, reflecting the decrease in the percentage of trees in the high damage classes in the following years. By 1996, 83% of the trees had less than 25% crown damage, compared to 100% of the trees with this level of damage in 1988 and 1989. Twelve percent of the trees had levels of damage of 25–50%; 3% of the trees had levels of 51–75%; and 1% of the trees had levels of more than 90%. The gradual decline in the condition of trees could be related to the increasing incidence of western gall rust and atropellis canker (*Atropellis piniphila* [Weir] Lohman & Cash) on many of the trees.

Annual mortality rates for lodgepole pine remained between 0.5–2.0% in the years following plot establishment. The highest annual mortality was observed in 1987, when four trees died. Cause of death was not readily apparent, but Armillaria rot root (*Armillaria* spp.) is common on dead trees near one of the plots where mortality occurred (Ken Mallett, Canadian Forest Service, Edmonton, Alberta, January 1997, personal communication.). Hamilton and Edwards (1976) reported a rate of 0.6% based on data collected from growth and yield plots in northern Idaho. Of the small percentage of trees that died, 82% were codominant trees at the time of the last remeasurement, and the remainder were suppressed. This suggested that disease played a major role in the demise of these trees.

By far the most important category of damage agents visibly affecting lodgepole pine trees was woody-tissue diseases (Table 12). Principal among this group were the two fungal diseases western gall rust and atropellis canker. Between 1985 and 1991, the incidence of these diseases increased from 28% to 76%. From 1991, the incidences of these diseases leveled at about 80%. Both agents were primarily responsible for tree decline and mortality on the lodgepole pine plots. Other important diseases that affected lodgepole pine trees were the needle cast fungi *Lophodermella concolor* (Dearn.) Darker and *Elytroderma deformans* (Weir) Darker. The greatest incidences of the needle diseases occurred in 1991 and 1994, when 71% and 36%, respectively, of the living trees were infected. These levels of infection corresponded with levels observed elsewhere in the region (Cerezke and Gates 1992; Brandt 1995b).

Lodgepole pine is also a fire-regenerating species and, therefore, very little pine regeneration was observed in the mature pine stands where the plots were located. The principal regenerating tree species in the lodgepole pine stands was alpine fir (*Abies lasiocarpa* [Hook.] Nutt.). All fir regeneration occurred on plots 808 and 810. Other regenerating species found were white spruce and Douglas-fir. Twenty-three seedlings were found on subplots in 1994, compared to 17 in 1996.

Table 11. Percentage of living lodgepole pine trees by tree condition class and measurement year since plot establishment[a]

Tree condition class	Living trees (%)											
	1985 (n = 205)	1986 (n = 203)	1987 (n = 199)	1988 (n = 197)	1989 (n = 196)	1990 (n = 196)	1991 (n = 196)	1992 (n = 194)	1993 (n = 194)	1994 (n = 192)	1995 (n = 215)	1996 (n = 215)
1	0	0	0	46	69	62	51	89	93	32	40	31
2	0	0	0	0	0	13	13	1	0	35	24	0
3	67	67	58	54	31	17	28	4	2	26	23	52
4	33	31	41	0	0	1	4	2	4	5	8	12
5	0	0	0	0	0	7	5	1	0	1	3	3
6	0	1	1	0	0	1	0	2	1	0	0	0
7	0	0	0	0	0	0	0	3	0	1	0	1

[a] Some totals exceed 100% due to rounding.

Overall, lodgepole pine tree condition was generally healthy and mortality rates were low. As with lodgepole pine stands throughout the region, both western gall rust and atropellis canker were common.

White Spruce
Picea glauca (Moench) Voss

From 1985 to 1992, crown condition of white spruce trees was generally good, with all trees having less than 25% crown damage (Table 13). From that time, however, crown condition steadily declined. In 1996, the worse year for crown condition to date, 75% of the trees had damage levels of less than 25%, 16% had damage levels of 25–50%, 5% had damage levels of 51–75%, and the remainder had damage levels of 76–90%. The deterioration in tree health was due to the impact of spruce budworm defoliation on plot 811 and spruce budworm and eastern blackheaded budworm (*Acleris variana* [Fern.]) on plots 815 and 817.

Table 12. Percentage of living lodgepole pine trees affected by various damage agents for each year since plot establishment

Year	Number of living trees	Abiotic agent	Foliar insect	Foliar disease	Woody-tissue insect	Woody-tissue disease	Other damage agents
1985	205	0	0	0	0	28	0
1986	203	0	0	0	0	28	0
1987	199	0	0	0	0	27	0
1988	197	0	0	0	0	33	0
1989	196	0	0	0	0	39	0
1990	196	0	0	0	0	68	0
1991	196	0	0	71	0	76	0
1992	194	0	0	0	0	81	0
1993	194	1	0	2	0	81	7
1994	192	0	0	36	0	80	4
1995	215	0	0	2	0	78	5
1996	215	0	0	2	0	82	6

Table 13. Percentage of living white spruce trees by tree condition class and measurement year since plot establishment[a]

Tree condition class	Living trees (%)											
	1985 (n = 28)	1986 (n = 37)	1987 (n = 94)	1988 (n = 131)	1989 (n = 131)	1990 (n = 132)	1991 (n = 132)	1992 (n = 132)	1993 (n = 251)	1994 (n = 250)	1995 (n = 251)	1996 (n = 255)
1	0	24	55	66	100	97	99	30	54	44	40	31
2	0	0	15	13	0	0	0	28	14	24	20	5
3	100	76	30	21	0	3	1	42	27	26	17	40
4	0	0	0	0	0	0	0	0	3	5	2	16
5	0	0	0	0	0	0	0	0	2	1	20	5
6	0	0	0	0	0	0	0	0	0	0	1	2
7	0	0	0	0	0	0	0	0	0	0	0	0

[a] Some totals exceed 100% due to rounding.

White spruce mortality rates of 0.4% and 0.8% were the lowest of any of the tree species represented on the network of plots. These values are similar to those reported by Buchman and Lentz (1984) for white spruce and Harcombe (1986) for sitka spruce (*Picea sitchensis* [Bong.] Carr.). The cause of mortality was competition from other trees because only suppressed trees died.

Spruce budworm has had, and probably will continue to have, an impact on the condition of white spruce trees represented in the plot network. This serious conifer defoliator was the most common and damaging agent on white spruce trees. The greatest incidence began in 1991 and corresponded with the deterioration of crown condition. Other common but less-serious foliar insects on the white spruce trees included the adelgids *Adelges lariciatus* (Patch) and *A. strobilobius* (Kltb.), and spruce gall midge (*Mayetiola piceae* [Felt]). Another prevalent group of agents was the foliar diseases, the most common being the needle rust *Chrysomyxa ledicola* Lagh. The incidence of foliar diseases was never greater than 34%, except in 1985 (Table 14). Yellow witches' broom of spruce (*C. arctostaphyli* Diet.) was the agent responsible for the low incidence of woody-tissue disease on white spruce trees. This disease had little impact on crown condition.

Regeneration on white spruce plots was diverse. This reflected the mixed age and species composition in plots where spruce was found. Regenerating species found in 1994 and 1996 included balsam fir, alpine fir, white spruce, trembling aspen, balsam poplar, and white birch. In the 1994 assessment, balsam fir (eight seedlings) and balsam poplar (six seedlings) were the most numerous regenerating species. The numbers of regenerating alpine fir, white spruce, and trembling aspen were about half that of the other two species. In the 1996 assessment, balsam poplar (37 seedlings) was by far the most abundant regenerating species. The next most-abundant species was balsam fir (six seedlings), followed by white spruce (four seedlings), trembling aspen (one seedling), and white birch (one seedling).

Overall, white spruce tree condition was generally good except for those trees affected by spruce budworm. Annual mortality rates of trees on the plots were low. Regeneration was abundant and diverse.

Trembling Aspen
Populus tremuloides Michx.

Since 1986, more than 85% of the trembling aspen trees had less than 25% crown damage (Table 15). The majority of the remaining trees had

Table 14. Percentage of living white spruce trees affected by various damage agents for each year since plot establishment

Year	Number of living trees	Abiotic agent	Foliar insect	Foliar disease	Woody-tissue insect	Woody-tissue disease	Other damage agents
1985	28	0	0	100	0	0	0
1986	37	0	14	8	0	0	0
1987	94	0	6	0	0	0	0
1988	131	0	13	21	0	0	0
1989	131	0	1	0	0	0	0
1990	132	0	11	27	0	0	0
1991	132	0	43	32	0	0	0
1992	132	0	45	28	0	3	0
1993	251	1	42	2	0	2	2
1994	250	0	48	9	4	2	5
1995	251	0	42	9	4	1	5
1996	255	0	28	34	0	2	10

25–50% crown damage. Overall, tree condition was good. Beginning in 1993, there was a modest deterioration in condition, with 3–5% of the trees having more than 51% crown damage. All of these trees occurred on plots 818 and 819, two of the newest plots. There was an increased incidence of mechanical damage due to whipping and frost damage on trees on these plots. At the time of this study, it was premature to identify a trend based on data from these two new plots.

Trembling aspen mortality rates were the highest of any of the tree species on the network of plots. Rates ranged from a high of 3.3% in 1991 to a low of 0.6% in 1994. No mortality was observed in 6 out of the 11 years of assessments. Buchman et al. (1983) reported higher mortality rates of 1.9–5.1% for trembling aspen in Michigan, Minnesota, and Wisconsin. Equal proportions of trees died in the suppressed, intermediate, and codominant crown classes.

Table 15. Percentage of living trembling aspen trees by tree condition class and measurement year since plot establishment[a]

Tree condition class	Living trees (%)										
	1986 (n = 29)	1987 (n = 32)	1988 (n = 32)	1989 (n = 32)	1990 (n = 31)	1991 (n = 30)	1992 (n = 30)	1993 (n = 160)	1994 (n = 159)	1995 (n = 155)	1996 (n = 155)
1	93	88	3	100	6	97	97	44	74	66	61
2	0	0	81	0	94	0	0	26	5	4	0
3	0	3	3	0	0	0	0	15	13	17	24
4	7	9	9	0	0	3	3	11	6	9	12
5	0	0	0	0	0	0	0	3	2	3	2
6	0	0	3	0	0	0	0	2	1	1	2
7	0	0	0	0	0	0	0	0	0	0	0

[a] Some totals exceed 100% due to rounding.

Table 16. Percentage of living trembling aspen trees affected by various damage agents for each year since plot establishment

Year	Number of living trees	Abiotic agent	Foliar insect	Foliar disease	Woody-tissue insect	Woody-tissue disease	Other damage agents
1986	29	0	0	0	0	3	0
1987	32	0	63	0	0	9	0
1988	32	0	91	0	0	16	0
1989	32	0	91	0	0	16	0
1990	31	0	94	0	0	13	0
1991	30	0	47	0	0	10	0
1992	30	0	0	0	0	27	0
1993	160	0	58	0	1	11	13
1994	159	5	42	1	0	16	15
1995	155	2	8	0	0	21	14
1996	155	0	19	0	0	22	15

The level of foliar insects peaked in the late 1980s at about 90% and declined after that (Table 16). During this period, large aspen tortrix was the principal agent involved. Other minor insects included various leaf rollers, skeletonizers, and free-feeding defoliators. Levels of false tinder conk (*Phellinus tremulae* [Bond.] Bond. & Boriss.) and poplar Peniophora (*Peniophora polygonia* [Pers.:Fr.] Boud.), the only two woody-tissue diseases of any importance noted on the trembling aspen plots, remained relatively constant at about 15–25% since plot establishment. Other damage agents included wind, which caused whipping damage to several trees, and animals. The level of this group of agents increased in recent years and corresponded to increased damage levels in the tree crowns.

Trembling aspen plots experienced the most diverse and abundant regeneration. Species represented in the regeneration included balsam fir, white spruce, black spruce, lodgepole pine, trembling aspen, balsam poplar, and white birch. A total of 44 seedlings were found on the subplots in 1994 and 31 in 1996. The majority of the seedlings were balsam fir, black spruce, and trembling aspen. In 1994, levels of regeneration on trembling aspen plots were 48%, 48%, and 82% higher than levels of regeneration found on white spruce, lodgepole pine, and jack pine plots, respectively. In 1996, levels of regeneration were 58% lower than levels of regeneration found on white spruce plots, and 45% and 94% higher than levels of regeneration found on lodgepole pine and jack pine plots, respectively.

Generally, trembling aspen health is good on the biomonitoring plots. Tree condition is good, with little impact from pests or other damage agents, mortality rates are low, and regeneration is both abundant and diverse.

Further information on national results from the network of biomonitoring plots is provided by D'Eon and Power (1989), Hall and Addison (1991), Hall (1991, 1993, 1995, 1996a), and Hall and Pendrel (1992).

STATUS OF QUARANTINE PESTS

Introduced insects and diseases dramatically affect North American forest ecosystems (Niemelä and Mattson 1996). There are numerous examples. Since its introduction into North America in 1930, Dutch elm disease has changed the abundance and distribution of American elm (*Ulmus americana* L.) over almost the entire natural range of this tree species in North America. Chestnut blight (*Cryphonectria parasitica* [Murrill] Barr) has all but eliminated American chestnut in eastern North American hardwood forests. An example of an insect that has dramatically affected oak forests in eastern North America and continues to threaten forests elsewhere on the continent is gypsy moth. It is crucial that the spread of introduced species be stopped, or at least slowed, through quarantine programs in order to maintain the integrity and productivity of forest ecosystems.

The primary purpose of the Canada *Plant Protection Act* is "to protect plant life and the agricultural and forestry sectors of the Canadian economy by preventing the importation, exportation and spread of pests and by controlling or eradicating pests in Canada." The CFS has a memorandum of understanding with Agriculture and Agri-Food Canada, which administers and enforces the act, to provide expertise and assistance with quarantine issues related to forestry or forest pests. Under the *Plant Protection Regulations* of the *Plant Protection Act*, many plants, plant products, and other items that might carry pests are either prohibited from, or restricted in, movement within Canada. Prohibition or restriction of movement exists to prevent the importation or movement of all nonnative pests. The rest of this section discusses the pests that are currently of principal concern in the forestry sector.

Balsam Woolly Adelgid
Adelges piceae (Ratz.)

Balsam woolly adelgid is currently distributed in western and eastern Canada (Fig. 16). The adelgid is a small aphid-like insect that damages its host by inserting its mouth parts into living bark cells. This act releases substances into the host that cause growth abnormalities, including brittle wood and swollen twigs. Where the insect was introduced on the east and west coasts of North

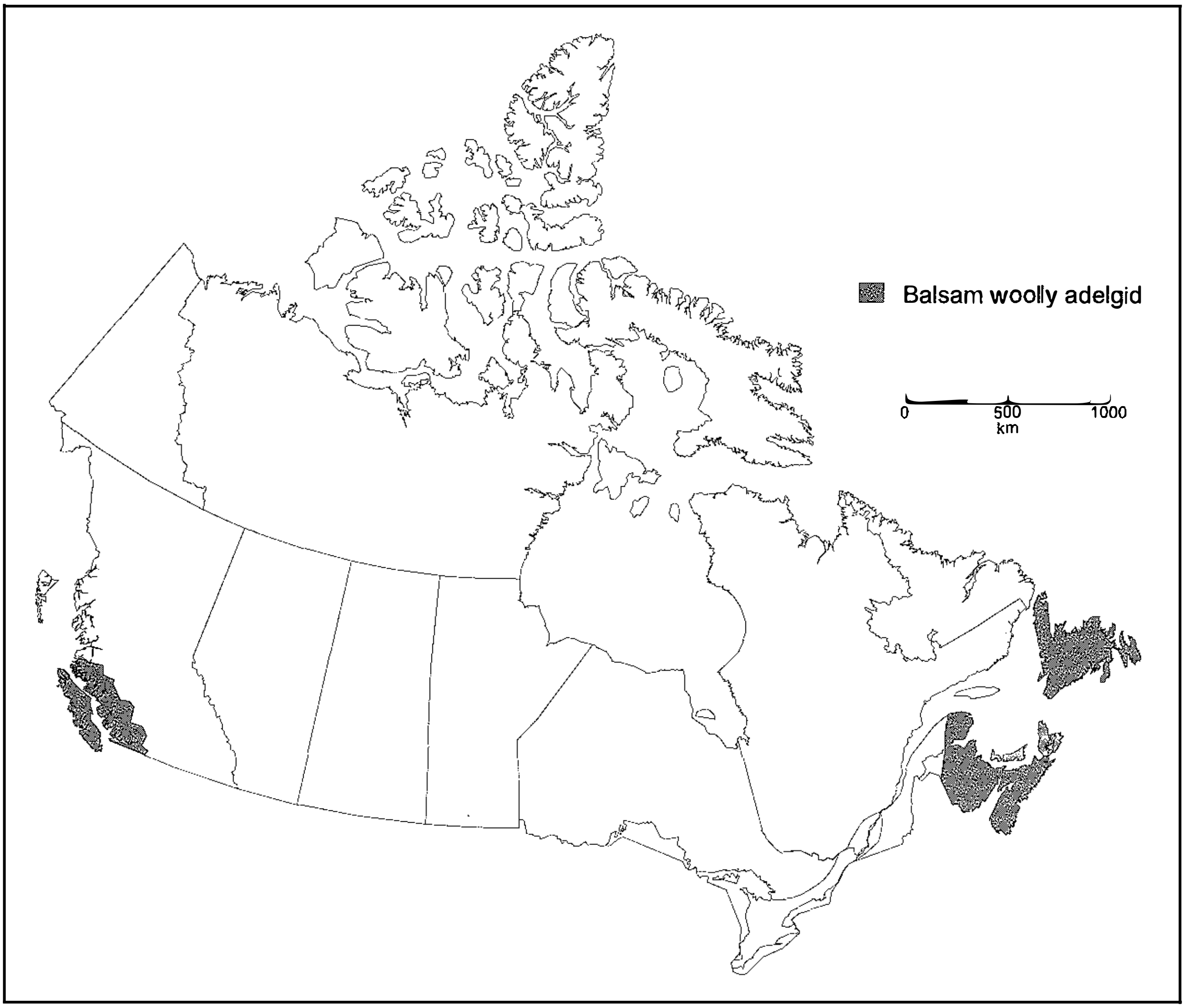

Figure 16. The distribution of balsam woolly adelgid in Canada in 1996. (Source: Forest Health Network, Canadian Forest Service, Fredericton, New Brunswick, and Canadian Forest Service, Victoria, British Columbia.)

America it caused substantial mortality to many species of the genus *Abies* (Johnson et al. 1963, Amman and Speers 1965; Harris 1978). Balsam woolly adelgid's current distribution appears to be regulated by cold winter temperatures (Greenbank 1970).

This serious pest was introduced into North America from its native Europe in about 1900, with the earliest specimen collected from Maine in 1908 (Kotinsky 1916). The insect was established in Nova Scotia by 1910, and had spread to the neighboring provinces of New Brunswick and Prince Edward Island by 1930 (Balch 1952). In 1949, the adelgid was found in southwestern Newfoundland, but it is suspected that the insect had been present at that locality since at least 1940 (Balch 1952). Fir on the Gaspé Peninsula and the Magdalen Islands of Quebec were found to be infested in 1964 (Blais 1965; Martineau 1965). The insect is also found on fir in the states of New York, Maine, Vermont, New Hampshire, Massachusetts, Virginia, North Carolina, and Tennessee in the eastern U.S. (Mitchell et al. 1970). In western North America, the adelgid was first found in California in 1928 (Annand 1928). The state of Oregon was infested by 1930 (Keen 1952), followed by Washington in 1954 (Johnson and Wright 1957), British Columbia in 1958 (Silver 1959), and Idaho in 1983 (Livingston and Dewey 1983).

Dutch Elm Disease
Ophiostoma ulmi (Buis.) Nannf.

Dutch elm disease is caused by the fungus *Ophiostoma ulmi*, which is vectored to its principal host, American elm, by two bark beetles, the smaller European elm bark beetle (*Scolytus multistriatus* [Marsh.]) and the native elm bark beetle (*Hylurgopinus rufipes* [Eichh.]). The disease was introduced into Europe from its native Asia and was subsequently introduced into North America from Europe. The disease was first recorded in North America in 1930 in Ohio (May 1931). By 1944, the disease had been detected in Quebec (Pomerleau 1947), followed by Ontario in 1948 (Reed 1950), New Brunswick in 1957 (Davidson and Newell 1957), Manitoba in 1975 (Petty et al. 1976), and Saskatchewan in 1981 (Hiratsuka et al. 1982). Currently, the disease is distributed over most of the native range of American elm in Canada.

In 1996, surveys to detect the incidence of Dutch elm disease in Alberta were continued by Alberta Agriculture, through the Dutch Elm Disease Initiative, and most of the larger municipalities in the province. Elm bark beetle monitoring was conducted at 97 locations in Alberta, mainly in smaller communities, parks, and at points of entry into the province. At each of the monitoring sites, traps baited with a pheromone were set up to attract the smaller European elm bark beetle, and cut American elm trap logs were used to attract the native elm bark beetle. The smaller European elm bark beetle was intercepted in traps in Calgary for the third consecutive year, in Edmonton for the second consecutive year, and in St. Albert and Vauxhall for the first time. The Dutch elm disease pathogen was not cultured from any of the captured bark beetle specimens. In addition to the trapped beetles, firewood containing galleries of the smaller European elm bark beetle was intercepted at the ports of Coutts, Carway, and Chief Mountain between July and September.

The distribution of Dutch elm disease (Fig. 17) in Saskatchewan remains similar to the distribution observed in 1995 (Brandt et al. 1996). The most active disease areas included the Carrot, Saskatchewan (Cumberland delta area), Red Deer, Souris, and Qu'Appelle river valleys, the Wascana, Brokenshell, Indianhead, and Pipestone creek valleys, and the Sipanok Channel valley. The disease continues to spread through riparian forests wherever American elm grows naturally. Ground surveys conducted by the Province also found the disease in 120 elm trees in several small communities, all located close to existing areas where the disease is known to occur. New occurrences of the disease were found along the Cottonwood and Boggy creeks, in Buffalo Pound Provincial Park, and in the Qu'Appelle River valley near Lumsden.

The Forestry Branch of Saskatchewan Environment and Resource Management contracted out tree removal work for the southeastern portion of the province. About 1200 elm trees were anticipated to be cut and burned during the winter of 1996–97. Another 1700 elm trees were slated for removal on Indian reserves near Crooked and Round lakes in the Qu'Appelle River valley.

As in Saskatchewan, the range of Dutch elm disease in Manitoba changed little from what was observed in 1995. Riparian forests with a high incidence of Dutch elm disease included those adjacent to the Red, Assiniboine, Boyne, and Souris rivers. Urban centers with a high incidence of the disease included Brandon, Dauphin, Morden, Portage la Prairie, Selkirk, Steinbach, Winkler, and Winnipeg.

Manitoba Natural Resources sanitation crews removed 5425 elm trees considered to be diseased or hazardous (i.e., dead or dying trees suitable as elm bark beetle brood material) between April 1995 and March 1996. An additional 9032 and 104 trees were removed in Winnipeg and Brandon, respectively, over the same period. Under the Dutch elm disease surveillance program, provincial surveys marked 7300 trees in the province while, in Winnipeg, City surveys marked 7842 trees for removal. There were 5383 diseased trees out of the total number of marked trees; most of these (4497 elm trees) occurred in Winnipeg.

European Larch Canker
Lachnellula wilkommii (Hartig) Dennis

European larch canker is caused by a fungus whose native range includes Europe and Asia (Yde-Anderson 1979b). Over most of the fungus' natural range, the organism causes inconsequential damage to its hosts, which include the genera *Larix* and *Pseudolarix*. Where moisture is abundant and winter temperatures are moderate, however, the disease is more frequent and its symptomatology typically more severe (Yde-Anderson 1979a). As the common name of the organism implies, the fungus causes cankers on its host. These cankers

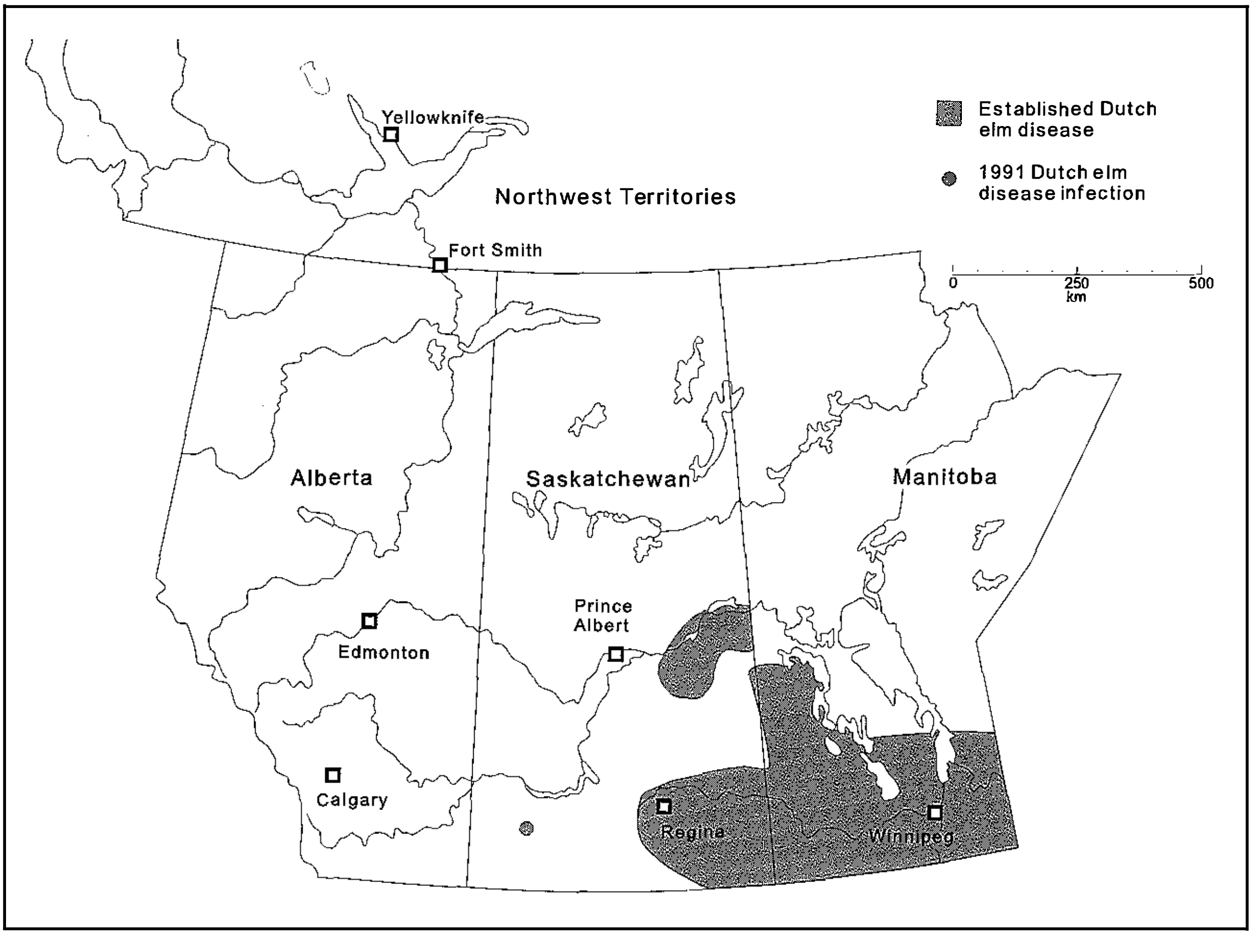

Figure 17. The distribution of Dutch elm disease in the prairie provinces in 1996.

appear as swellings on branches or as depressions on stems. Resin is often exuded at the cankers. The fruiting structures (apothecia) of the fungus are white-yellow and are found in and around the canker. Fruiting usually takes place from September to January in Europe (Yde-Anderson 1979a).

The first time European larch canker was detected in North America was on European (*Larix decidua* Mill.), Japanese (*L. kaempferi* [Lamb.] Carrière), and eastern (*L. laricina* [Du Roi] K. Koch) larches in 1927 in Massachusetts (Spaulding and Siggers 1927). Sanitation efforts up until 1938 were only successful at limiting the distribution of the fungus, not eradicating it (Fowler and Aldrich 1953). The disease was found for the first time on eastern larch in New Brunswick and Nova Scotia in 1980 (Magasi and Pond 1982), in Maine in 1981(Miller-Weeks and Stark 1983), and on Prince Edward Island in 1992 (Simpson and Harrison 1993). The age of the cankers indicated that the fungus had been present in New Brunswick since at least 1958, and in Prince Edward Island since 1988 (Ostaff 1985; Simpson and Harrison 1993). An attempt was made to eradicate the disease on Prince Edward Island, but subsequent surveys again detected the disease in 1995 and 1996. Surveys in Quebec failed to find the disease (Sterner and Davidson 1982). The current distribution of European larch canker in Canada is displayed in Figure 18.

Gypsy Moth
Lymantria dispar (L.)

Gypsy moth is a pest of deciduous and coniferous trees in many regions of the world. There are two strains of insect, the European and the Asian, both of which have been recovered in North America at different times. Females of the European strain are incapable of flight, while those of the Asian strain are capable of flying. Larvae and adults of the European strain are smaller in size compared to the same stages of the Asian strain. Only the European strain is

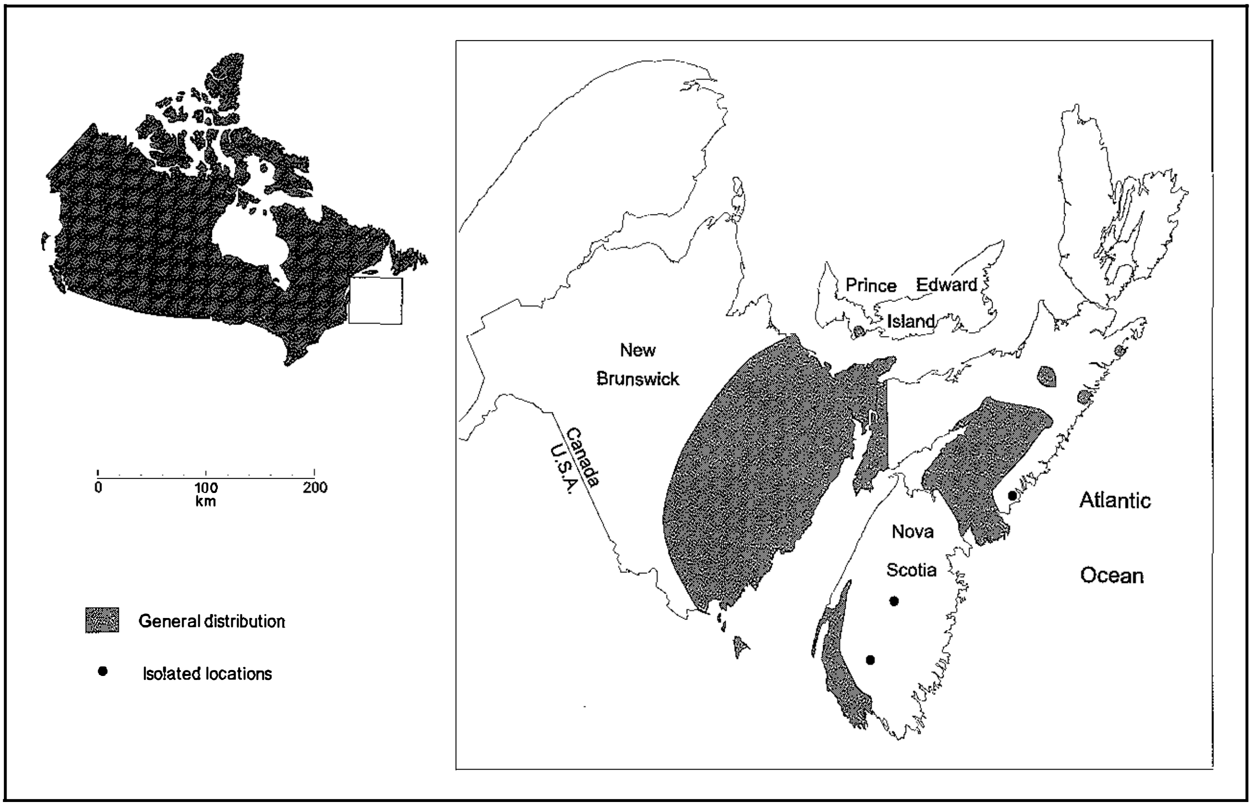

Figure 18. The distribution of European larch canker in Canada in 1996. (Source: Forest Health Network, Canadian Forest Service, Fredericton, New Brunswick.)

established in Canada. The European strain was accidentally introduced into Massachusetts in 1869. In Canada, this strain was first found in Quebec in 1924 (McLaine 1925) and then in New Brunswick in 1936 (McLaine 1938). Both of these infestations were eradicated. Because of their proximity to existing infestations in the northeastern U.S., the provinces of Quebec, Ontario, New Brunswick, and Nova Scotia were subject to periodic incursions of the European strain of gypsy moth throughout the period 1950–69. The insect became established (i.e., egg masses of the insect were found) in Quebec about 1956 (Martineau 1961), followed by Ontario in 1969 (Sippell et al. 1970), and New Brunswick and Nova Scotia in 1981(Sterner and Davidson 1982). The established European strain found in eastern North America is referred to as the "North American biotype" in some publications. Both the Asian and European strains were introduced on several occasions in British Columbia, but control efforts were successful at preventing their establishment. The present distribution of the European strain in Canada is shown in Figure 19.

Agriculture and Agri-Food Canada, in cooperation with other federal, provincial, and municipal agencies, continued its gypsy moth pheromone trapping program in the prairie provinces in 1996. The intent of the program was to detect the spread of the insect into the prairie provinces where the moth is not established. In Alberta, 483 traps were placed throughout the province, concentrated in high-travel areas. One male gypsy moth was caught in Calgary near Canadian Forces Base Currie in one trap out of 75 distributed throughout the city.

In Saskatchewan, Agriculture and Agri-Food Canada and cooperating agencies placed 139 traps around the province, mostly in the southern third of the province but also in a few more northerly locations such as Narrow Hills, Greenwater Lake, and Meadow Lake provincial parks, Candle Lake Provincial Recreation Site, and Prince Albert National Park. There was one positive trapping: four male gypsy moths were captured in a trap on the east side of Regina. This is the second consecutive year in which moths were trapped in this area.

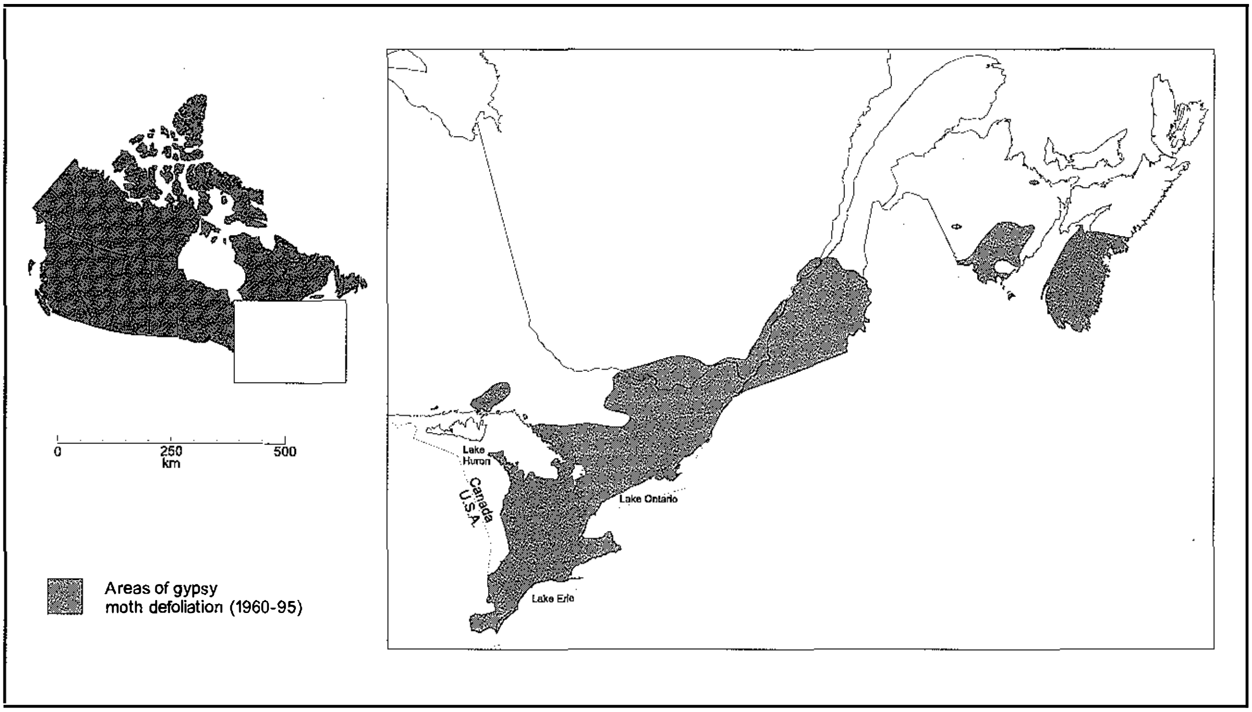

Figure 19. The distribution of gypsy moth in Canada based on areas defoliated between 1960 and 1995.

In Manitoba, 248 traps were deployed. Traps were concentrated south of the Trans-Canada Highway 1, but a few were placed in more northerly locations. Two moths were trapped in two traps in Winnipeg. One trap was near Canadian Forces Base Osbourne, and the other was near the rail yards in the downtown core of the city.

Pine Shoot Beetle
Tomicus piniperda (L.)

Pine shoot beetle is a pest of pines in its native Europe and Asia (Långström 1980). The beetle detrimentally affects its host in two ways: most importantly, by boring into the shoots of healthy trees, and, to a lesser extent, by breeding in the bark of cut or fallen trees or trees of low vigor. Shoot damage often reduces growth of affected trees by 20-45% (Långström 1980). The beetle's principal host in Europe and Asia is Scots pine (*Pinus sylvestris* L.) (Schroeder 1987). Studies in the U.S. indicate that the beetle will feed on jack, red (*P. resinosa* Ait.), and white (*P. strobus* L.) pines (Sadof et al. 1994).

Pine shoot beetle was detected for the first time in North America near Cleveland, Ohio, in the summer of 1992, but probably arrived in the region sometime earlier (Haack and Kucera 1993). Subsequent surveys indicated the beetle was distributed throughout large parts of the states of Illinois, Indiana, Michigan, Ohio, New York, and Pennsylvania (Haack and Lawrence 1995), and in southern Ontario (Fig. 20). Surveys in other parts of Canada have failed to detect the presence of the beetle (Hall 1996b).

Scleroderris Canker
Gremmeniella abietina (Lagerb.) Morelet

Scleroderris canker is caused by the fungus *Gremmeniella abietina*. There are two strains of the disease: a North American race and a European race. There is debate in the scientific community whether both strains are introduced pests. The North American race is distributed over much of eastern North America, and a few occurrences of the disease were found in Jasper National Park in Alberta (Dorworth 1975) and at four separate locations in British Columbia (Tripp et al. 1976, 1978) (Fig. 21). Surveys in other parts of the prairie provinces failed to isolate the disease from pine trees. The North American race has been present in Ontario since at least the 1950s (Martin 1964, Dorworth 1971). Based on this information, some pathologists have concluded that the North

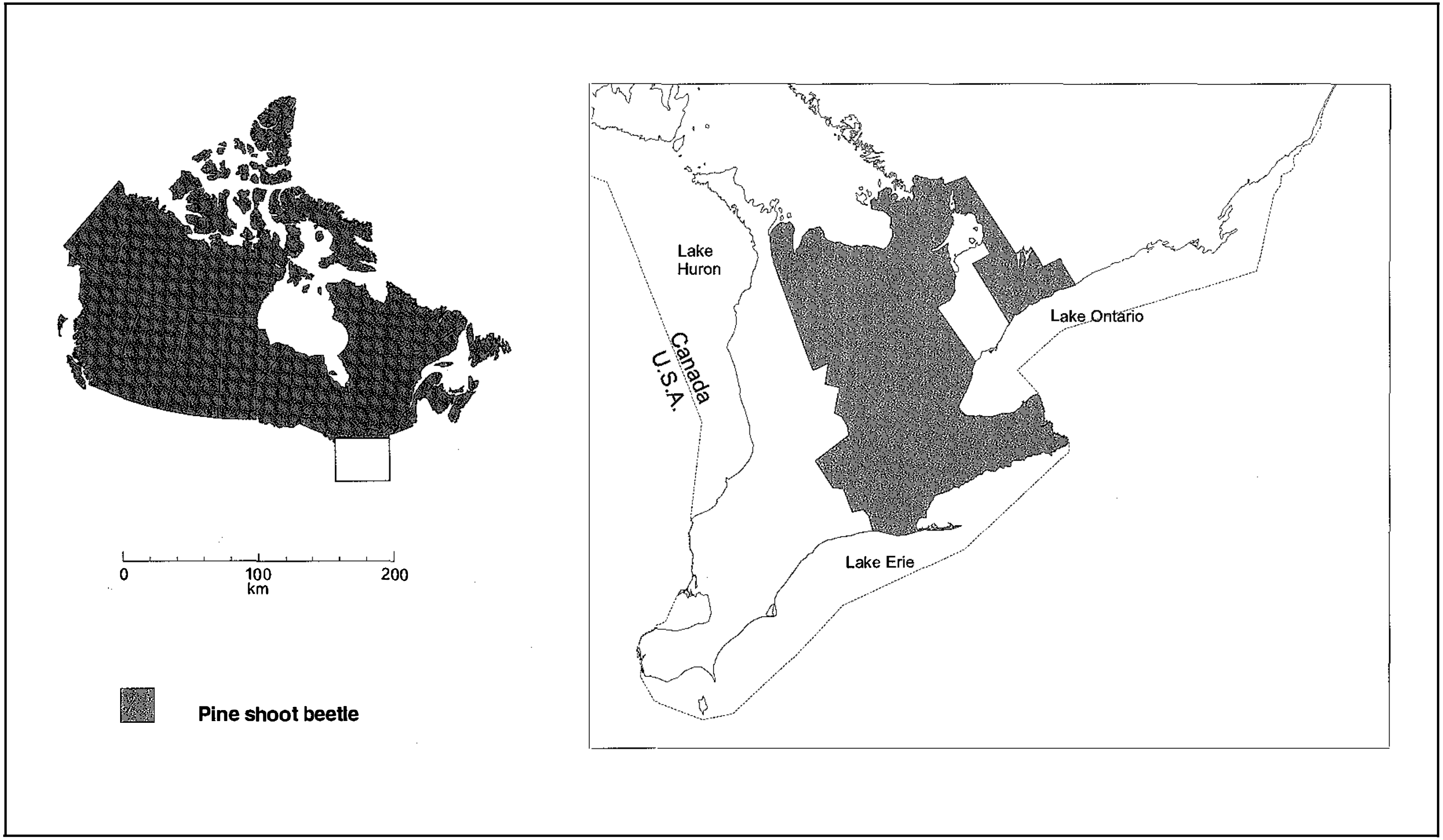

Figure 20. The distribution of pine shoot beetle in Canada in 1996 based on regulated counties. (Source: Agriculture and Agri-Food Canada, Animal and Plant Health Directorate, Napean, Ontario.)

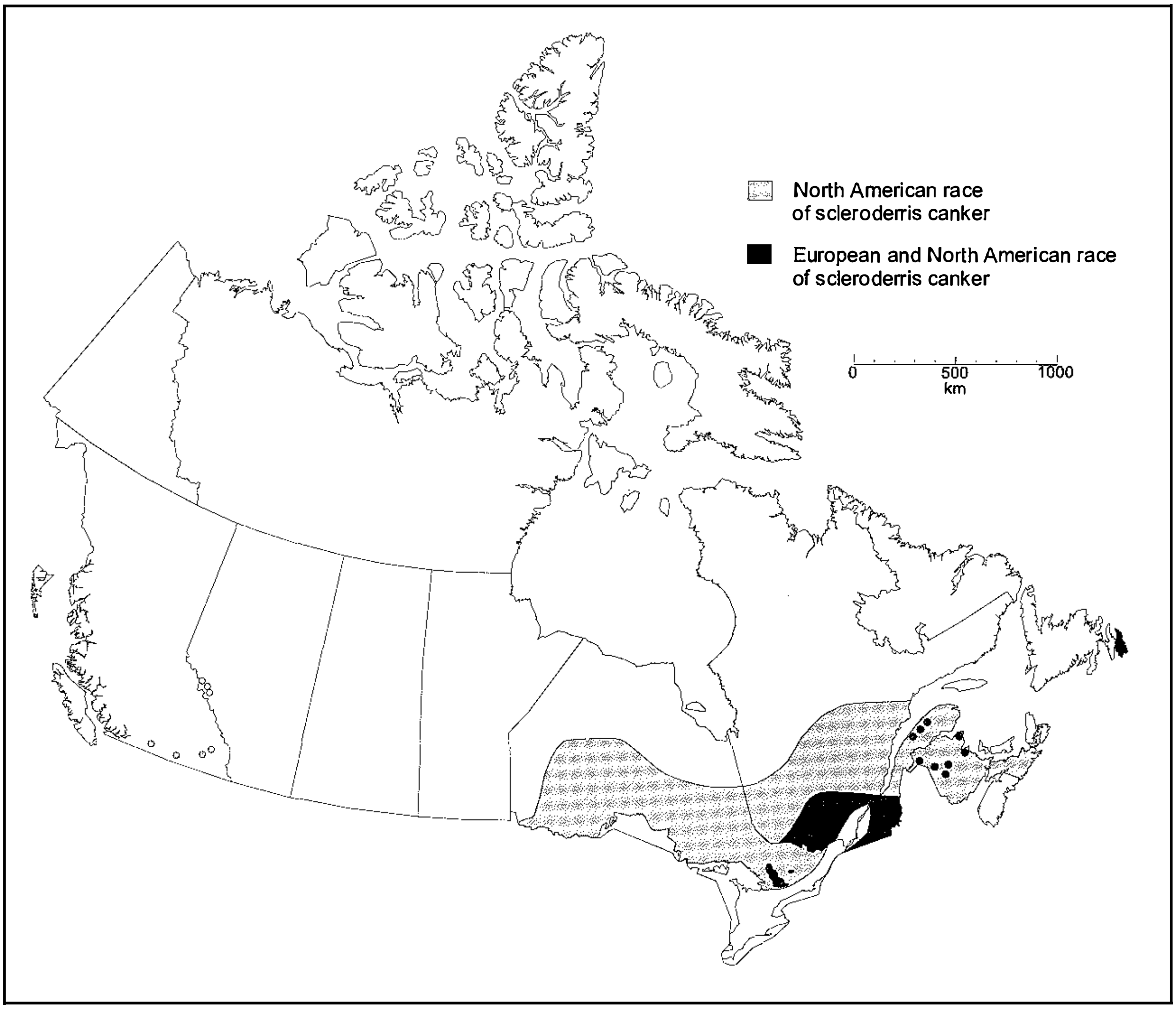

Figure 21. The distribution of scleroderris canker in Canada in 1996 (Hopkin and McKenney 1995).

American race could be indigenous (Hopkin and McKenney 1995). Hosts of the North American race include red and jack pines.

The European strain was first isolated in New York in 1975 from extensively damaged red pine plantations (Skilling 1977). In 1978, this strain was isolated from red pine plantations in Quebec and New Brunswick, followed by Newfoundland in 1980 and Ontario in 1985 (Magasi 1979; Sterner and Davidson 1981; Lachance and Benoit 1982; Sajan and Smith 1986). Artificial inoculation studies have shown that the European race is capable of infecting most conifers native to North America (Skilling et al. 1986). Generally, the European race is considered more virulent than the North American race because of its ability to infect larger trees. Both strains, however, have demonstrated the ability to cause plantation failures.

Spruce Bark Beetle
Ips typographus (L.)

The spruce bark beetle is considered the most destructive bark beetle in the coniferous forests of Europe and Asia (Christiansen and Bakke 1988). The principal host of this insect in its native range is Norway spruce (*Picea abies* [L.]). The pest typically breeds in slash and felled or windblown trees. When sufficient brood material is available, populations build quickly and outbreaks occur. During outbreaks, even healthy trees are attacked and killed. The beetle's ability to kill its host is assisted primarily by the blue stain fungus, *Ophiostoma polonicum* Siemaszko, which it introduces to the host (Christiansen 1985).

Spruce bark beetle has been intercepted or trapped many times in North America, though it is not considered established on this continent. The most-recent detection of the insect was in the summer of 1996 in Montreal, Quebec. Other recent interceptions occurred in Pennsylvania (1993), New Jersey (1994), and Indiana (1995).

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LITERATURE CITED

Amman, G.D.; Speers, C.F. 1965. Balsam woolly aphid in the southern Appalachians. J. For. 63:18–20.

Annand, P.N. 1928. A contribution toward a monograph of the Adelginae (Phylloxeridae) of North America. Stanford Univ. Press, Stanford Univ., California, Stanford Univ. Publ., Univ. Ser., Biol. Sci. 6(1).

Balch, R.E. 1952. Studies of the balsam woolly aphid, *Adelges piceae* (Ratz.) and its effects on balsam fir, *Abies balsamea* (L.) Mill. Dep. Agric., Ottawa, Ontario. Publ. 867.

Blais, J.R. 1965. Discovery of the balsam woolly aphid, *Adelges piceae* (Ratz.), on the Magdalen Islands. Bi-mon. Prog. Rep. 21(1):1–2.

Brandt, J.P. 1995a. Forest insect- and disease-caused impacts to timber resources of west-central Canada: 1988-1992. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-341.

Brandt, J.P. 1995b. Forest insect and disease conditions in west-central Canada in 1994 and predictions for 1995. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-340.

Brandt, J.P.; Knowles, K.R.; Larson, R.E.; Ono, H.; Walter, B.L. 1996. Forest insect and disease conditions in west-central Canada in 1995 and predictions for 1996. Nat. Resour. Can., Can. For. Serv., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-347.

Buchman, R.G. 1983. Survival predictions for major Lake States tree species. U.S. Dep. Agric., For. Serv., North Central For. Exp. Stn., St. Paul, Minnesota. Res. Pap. NC-233.

Buchman, R.G.; Lentz, E.L. 1984. More Lake States tree survival predictions. U.S. Dep. Agric., For. Serv., North Central For. Exp. Stn., St. Paul, Minnesota. Res. Note NC-312.

Buchman, R.G.; Pederson, S.P.; Walters, N.R. 1983. A tree survival model with application to species of the Great Lakes region. Can. J. For. Res. 13:601–608.

Cerezke, H.F.; Gates, H.S. 1992. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba, and the Northwest Territories in 1991. For. Can., Northwest Reg., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-325.

Canadian Climate Program. 1993a. Canadian climate normals, 1961–1990. Prairie provinces. Environ. Can., Atmos. Environ. Serv., Ottawa, Ontario.

Canadian Climate Program. 1993b. Canadian climate normals, 1961–1990. Yukon and Northwest Territories. Environ. Can., Atmos. Environ. Serv., Ottawa, Ontario.

Christiansen, E. 1985. *Ips/Ceratocystis*-infection of Norway spruce: what is a deadly dosage? Z. Angew. Entomol. 99:6–11.

Christiansen, E.; Bakke, A. 1988. The spruce bark beetle of Eurasia. Pages 479–503 *in* A.A. Berryman, ed. Dynamics of forest insect populations: patterns, causes, implications. Plenum Press, New York.

Davidson, A.G.; Newell, W.R. 1957. Atlantic provinces forest disease survey. Pages 24–25 *in* Annual report of the Forest Insect and Disease Survey, 1957. Can. Dep. Agric., For. Biol. Div., Sci. Serv., Ottawa, Ontario.

D'Eon, S.P.; Magasi, L.P.; Lachance, D.; DesRochers, P. 1994. ARNEWS: Canada's national forest health monitoring plot network. Manual on plot establishment and monitoring (revised). Nat. Resour. Can., Can. For. Serv., Petawawa Natl. For. Inst., Chalk River, Ontario. Inf. Rep. PI-X-117.

D'Eon, S.P.; Power, J.M. 1989. The Acid Rain National Early Warning System (ARNEWS) plot network. For. Can., Petawawa Natl. For. Inst., Chalk River, Ontario. Inf. Rep. PI-X-91.

Dorworth, C.E. 1971. Diseases of conifers incited by *Scleroderris lagerbergii* Gremmen: a review and analysis. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario. Publ. 1289.

Dorworth, C.E. 1975. *Gremmeniella abietina* collected in Alberta, Canada. Plant Dis. Rep. 59:272–273.

Fowler, M.E.; Aldrich, K.F. 1953. Resurvey for European larch canker in the United States. Plant Dis. Rep. 37:160–161.

Greenbank, D.O. 1970. Climate and the ecology of the balsam woolly aphid. Can. Entomol. 102:546–578.

Haack, R.A.; Kucera, D. 1993. New introduction - common pine shoot beetle, *Tomicus piniperda* (L.) U.S. Dep. Agric., For. Serv., Northeast. Area, Radnor, Pennsylvania. Pest Alert NA-TP-05-93.

Haack, R.A.; Lawrence, R.K. 1995. Attack densities of *Tomicus piniperda* and *Ips pini* (Coleoptera: Scolytidae) on Scotch pine logs in Michigan in relation to felling date. J. Entomol. Sci. 30:18–28.

Hall, J.P., compiler. 1991. ARNEWS annual report 1990. For. Can., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. ST-X-1.

Hall, J.P., compiler. 1993. ARNEWS annual report 1992. Nat. Resour. Can., Can. For. Serv., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. ST-X-7.

Hall, J.P., compiler. 1995. ARNEWS annual report 1993. Nat. Resour. Can., Can. For. Serv., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. ST-X-9.

Hall, J.P., compiler. 1996a. ARNEWS annual report 1994. Nat. Resour. Can., Can. For. Serv., Sci. Branch, Ottawa, Ontario. Inf. Rep. ST-X-11.

Hall, J.P., compiler. 1996b. Forest insect and disease conditions in Canada, 1994. Nat. Resour. Can., Can. For. Serv., For. Insect Dis. Surv., Ottawa, Ontario.

Hall, J.P.; Addison, P.A. 1991. Response to air pollution: ARNEWS assesses the health of Canada's forests. For. Can., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. DPC-X-34.

Hall, J.P.; Pendrel, B.A., compilers. 1992. ARNEWS annual report 1991. For. Can., Sci. Sustainable Dev. Dir., Ottawa, Ontario. Inf. Rep. ST-X-5.

Hamilton, D.A., Jr.; Edwards, B.M. 1976. Modeling the probability of individual tree mortality. U.S. Dep. Agric., For. Serv., Intermt. For. Range Exp. Stn., Ogden, Utah. Res. Pap. INT-185.

Harcombe, P.A. 1986. Stand development in a 130-year-old spruce–hemlock forest based on age structure and 50 years of mortality data. For. Ecol. Manage. 14:41–58.

Harris, J.W.E. 1978. Balsam woolly aphid. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Victoria, British Columbia. Pest Leafl. 1.

Hiratsuka, Y.; Cerezke, H.F.; Moody, B.H.; Petty, J.; Still, G.N. 1982. Forest insect and disease conditions in Alberta, Saskatchewan, Manitoba, and the Northwest Territories in 1981 and predictions for 1982. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-239.

Hopkin, A.A.; McKenney, D.W. 1995. The distribution and significance of Scleroderris disease in Ontario. Nat. Resour. Can., Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario. North. Ont. Devel. Agree./North. For. Prog. Tech. Rep. TR-7.

Johnson, N.E.; Mitchell, R.G.; Wright, K.H. 1963. Mortality and damage to Pacific silver fir by the balsam woolly aphid in southwestern Washington. J. For. 61:854–860.

Johnson, N.E.; Wright, K.H. 1957. The balsam woolly aphid problem in Oregon and Washington. U.S. Dep. Agric., For. Serv., Pac. Northwest For. Range Exp. Stn., Portland, Oregon. Res. Pap. 18.

Keen, F.P. 1952. Insect enemies of western forests. U.S. Dep. Agric., Washington, D.C. Misc. Publ. 273.

Kotinsky, J. 1916. The European fir trunk bark louse, *Chermes (Dreyfusia) piceae* Ratz. apparently long established in the United States. Proc. Entomol. Soc. Washington 18:14–16.

Lachance, D.; Benoit, P. 1982. Quebec region. Pages 29-37 *in* Annual reports of the Forest Insect and Disease Survey, 1978 and 1979. Dep. Environ., Can. For. Serv., Ottawa, Ontario.

Långström, B. 1980. The distribution of pine shoot beetle attacks within the crown of Scots pine. (Märgborreangreppens fördelning i tallkronan). Swed. Univ. Agric. Sci., Coll. For., Uppsala, Sweden. Stud. For. Suec. 154.

Livingston, R.L.; Dewey, J. 1983. Balsam wooly aphid, report of an Idaho infestation. Idaho Dep. Lands, Coeur d'Alene, Idaho. IDL Rep. 83-7.

Magasi, L.P. 1979. Forest pest conditions in the Maritimes in 1978 with an outlook for 1979. Environ. Can., Can. For. Serv., Marit. For. Res. Cent., Fredericton, New Brunswick. Inf. Rep. M-X-98.

Magasi, L.P. 1988. Acid Rain National Early Warning System: manual on plot establishment and monitoring. Can. For. Serv., For. Sci. Dir., Ottawa, Ontario. Inf. Rep. DPC-X-25.

Magasi, L.P; Pond, S.E. 1982. European larch canker: a new disease in Canada and a new North American host record. Plant Dis. 66:339.

Martin, J.L. 1964. The red pine mortality problem in the Kirkwood Forest Management Unit, Sault Ste. Marie District, Ontario. Dep. For., For. Entomol. Pathol. Branch., For. Insect Lab., Sault Ste. Marie, Ontario. Inf. Rep.

Martineau, R. 1961. Province of Quebec: forest insect survey. Pages 35–40 *in* Annual report of the forest insect and disease survey, 1960. Dep. For., For. Entomol. Pathol. Branch, Ottawa, Ontario.

Martineau, R. 1965. Forest insect conditions: Quebec forest insect and disease survey. Pages 43–47 *in* Annual report of the forest insect and disease survey, 1964. Dep. For., For. Entomol. Pathol. Branch, Ottawa, Ontario.

May, C. 1931. The Dutch elm disease. U.S. Dep. Agric., Washington, D.C. Circ. 170.

McLaine, L.S. 1925. The outbreak of the gipsy moth in Quebec. Annu. Rep. Entomol. Soc. Ont. 55:60–62.

McLaine, L.S. 1938. Some notes on the gypsy moth eradication campaign in New Brunswick, and the Japanese beetle preventive work. Annu. Rep. Entomol. Soc. Ont. 69:43-45.

Miller-Weeks, M.; Stark, D. 1983. European larch canker in Maine. Plant Dis. 67:448.

Mitchell, R.G.; Amman, G.D.; Waters, W.E. 1970. Balsam woolly aphid. U.S. Dep. Agric., For. Serv., Washington, D.C. For. Pest Leafl. 118.

Niemelä, P.; Mattson, W.J. 1996. Invasion of North American forests by European phytophagous insects. BioScience 46:741–753.

O'Laughlin, J.; Livingston, R.L.; Thier, R.; Thornton, J.; Toweill, D.E.; Morelan, L. 1994. Defining and measuring forest health. J. Sustainable For. 2:65–85.

Ostaff, D.P. 1985. Age distribution of European larch canker in New Brunswick. Plant Dis. 69:796–798.

Petty, J.; Caltrell, R.M.; Campbell, A.E.; Emond, F.J.; Hildahl, V.; Patterson, V.B.; Still, G.N.; Susut, J.P.; Tidsbury, R.C. 1976. Annual district reports: Forest insect and disease survey, prairies region, 1975. Environ. Can., Environ. Manage. Serv., North. For. Res. Cent. Edmonton, Alberta. Inf. Rep. NOR-X-154.

Pomerleau, R. 1947. Organization of the campaign against Dutch elm disease in Quebec. For. Insect Invest. Bi-mon. Prog. Rep. 3(6):1–2.

Reed, L.L. 1950. Status of Dutch elm disease in Canada - 1950. For. Insect Invest. Bi-mon. Prog. Rep. 6(6):1.

Sadof, C.S.; Waltz, R.D.; Kellam, C.D. 1994. Differential shoot feeding by adult *Tomicus piniperda* (Coleoptera: Scolytidae) in mixed stands of native and introduced pines in Indiana. Great Lakes Entomol. 27:223–228.

Sajan, R.J.; Smith, B.E. 1986. Results of forest insect and disease surveys in the Algonquin region of Ontario, 1985. Can. For. Serv., Great Lakes For. Cent., Sault Ste. Marie, Ontario. Misc. Rep. 40.

Schroeder, L.M. 1987. Attraction of the bark beetle *Tomicus piniperda* to Scots pine trees in relation to tree vigor and attack density. Entomol. Exp. Appl. 44:53–58.

Silver, G.T. 1959. The balsam woolly aphid, *Adelges piceae* (Ratz.) in British Columbia. Bi-mon. Prog. Rep. 15(1):3.

Simpson, R.A.; Harrison, K.J. 1993. First report of European larch canker on Prince Edward Island, Canada. Disease Notes. Plant Dis. 77:1264.

Sippell, W.L.; Rose, A.H.; Gross, H.L. 1970. Ontario region. Pages 52–71 *in* Annual report of the Forest insect and disease survey, 1969. Dep. Fish. For., Can. For. Serv., Ottawa, Ontario.

Skilling, D.D. 1977. The development of a more virulent strain of *Scleroderris lagerbergii* in New York state. Eur. J. For. Pathol. 7:297–302.

Skilling, D.D.; Schneider, B.; Fasking, D. 1986. Biology and control of scleroderris canker in North America. U.S. Dep. Agric., For. Serv., North Cent. Exp. Stn., St. Paul, Minnesota. Res. Pap. NC-275.

Spaulding, P.; Siggers, P.V. 1927. The European larch canker in America. Science 66:480–481.

Sterner, T.E.; Davidson, A.G., compilers. 1981. Forest insect and disease conditions in Canada, 1980. Can. For. Serv., For. Insect Dis. Surv., Ottawa, Ontario.

Sterner, T.E.; Davidson, A.G., compilers. 1982. Forest insect and disease conditions in Canada, 1981. Can. For. Serv., For. Insect Dis. Surv., Ottawa, Ontario.

Tripp, H.A.; Ross, D.A.; Van Sickle, G.A. 1976. Pacific region. Pages 75–87 *in* Annual report of the forest insect and disease survey, 1975. Dep. Fish. Environ., Can. For. Serv., Ottawa, Ontario.

Tripp, H.A.; Ross, D.A.; Van Sickle, G.A. 1978. Pacific region. Pages 77–90 *in* Annual report of the forest insect and disease survey, 1976. Dep. Environ., Can. For. Serv., Ottawa, Ontario.

Yde-Anderson, A. 1979a. Disease symptoms, taxonomy and morphology of *Lachnellula willkommii*: a literature review. Eur. J. For. Pathol. 9:220-228.

Yde-Anderson, A. 1979b. Host spectrum, host morphology and geographic distribution of larch canker, *Lachnellula willkommii*: a literature review. Eur. J. For. Pathol. 9:211–219.