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A History of the Eastern Larch Beetle, *Dendroctonus Simplex* (Coleoptera: Scolytidae), in North America

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A HISTORY OF THE EASTERN LARCH BEETLE, *DENDROCTONUS SIMPLEX* (COLEOPTERA: SCOLYTIDAE), IN NORTH AMERICA

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ABSTRACT

The eastern larch beetle, *Dendroctonus simplex,* is reputedly a secondary pest but may attack and kill tamarack and ornamental larches throughout Canada, the northeastern United States, and Alaska. Isolated infestations of this pest have been reported for over 100 years. The first recorded widespread outbreaks of *D. simplex* started in eastern Canada and the northeastern United States as well as in Alaska in the mid-1970s. During the outbreak in the Atlantic provinces, in excess of 1.4 million m^3 of tamarack was killed. No damage estimates are available for Quebec and the United States. Insect defoliators were the most common factors predisposing tamarack to beetle attack.

The eastern larch beetle, *Dendroctonus simplex* LeConte (Coleoptera: Scolytidae), occurs throughout the natural range of tamarack, *Larix laricina,* its principal host, from Newfoundland and the northeastern United States to British Columbia and Alaska (Wood 1982). In addition to tamarack, its also attacks exotic species of *Larix* planted within its range. This bark beetle species is generally characterized as a secondary pest which attacks weakened and recently felled trees (Werner 1986, Langor and Raske 1987a). However, recent history suggests that this insect can develop widespread outbreaks that result in the death of healthy trees.

Aspects of the life history of *D. simplex* in cut logs have been described (Hopkins 1909, Swaine 1911, 1918, Simpson 1929, Prebble 1933, Furniss 1976). Recently, the biology of *D. simplex* in standing trees was studied in Alaska (Werner 1986) and in Newfoundland (Langor 1985, 1987, Langor and Raske 1987a, b, 1988a). Adult *D. simplex* overwinter in the trees in which they developed and emerge in April to May in Newfoundland (May to June in Alaska) to disperse to new trees to reproduce. Only one generation is produced per year. In Alaska, only one brood is produced per year. However, in Newfoundland a small proportion (< 5%) of the beetles that re-emerge following production of a first brood in May and June disperse to new trees to produce a second brood in July. The needles of about 50% of trees attacked in the spring turn yellow prematurely in August and early September, thus making them conspicuous (Raske et al. 1978).

Tree mortality caused by *D. simplex* has been recorded from all Canadian provinces and territories and from the states of Maine, New Hampshire, Vermont, New York, West Virginia, Maryland, Minnesota, Michigan, and Alaska. Before 1970, tree mortality attributable to *D. simplex* was isolated and scattered. However, since the mid-1970s,

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widespread outbreaks have occurred throughout eastern Canada, the northeastern United States and Alaska; the first recorded extensive outbreaks for this species. Predisposing factors that may have triggered the outbreak (e.g., fire, flooding, drought, and insect defoliators) varied within and between regions.

Information on *D. simplex* is scattered in many survey reports that are often difficult to obtain (Langor and Raske 1988b). To aid researchers that have an interest in this forest pest, we present an historical sketch of *D. simplex* damage to tamarack in seven geo-political regions. Descriptions of *D. simplex* infestation levels (e.g. low, moderate, severe, extensive) and the number of trees killed (e.g. few, many) in this paper are those of the authors cited and have no published numerical data associated with them.

METHODS

Information on the eastern larch beetle was gathered in several ways. Initially, a computerized literature search was conducted which helped locate recent journal articles. In Canada, the best source of historical information on forest pests is the Forest Insect and Disease Survey (FIDS) which was initiated in 1936. All national and regional annual FIDS reports were checked for information on *D. simplex*. Also, FIDS personnel were contacted in each region to obtain recent and unpublished information. Because we were unable to access many state Forest Pest Reports from the United States, written requests for information on *D. simplex* were made to state forestry agencies and to USDA Forest Service laboratories in Maine, New Hampshire, Vermont, New York, Michigan, and Alaska. Our contacts in those states provided us with recent and unpublished information and checked previous (at least back to 1970) Forest Pest Reports.

HISTORICAL SUMMARY

1. Newfoundland and Labrador

The species was first recorded from the province by Bright (1971). The first recorded outbreak of *D. simplex* on the island of Newfoundland started in the mid-1970s (Raske et al. 1978). Defoliation by the spruce budworm, *Choristoneura fumiferana* (Clem.) (Lepidoptera: Tortricidae), was thought to have triggered this outbreak in central and western Newfoundland, from where it spread to the eastern and southern coasts. Cumulative effects of severe defoliation of tamarack stands by budworm larvae in the mid-1970s reduced tree vigor and wood production but caused little direct mortality (Otvos and Moody 1978). The abundance of susceptible host material for *D. simplex* allowed populations to build to outbreak levels in 2 to 3 years. This was followed by spread of beetles into healthy, apparently unstressed, tamarack stands, especially in the eastern region of the island.

Tamarack mortality caused by *D. simplex* was first noticed in 1976 (Raske et al. 1978) and continued to increase over most of the island, especially in the central region, through 1981 (Fig. 1) (Clarke et al. 1979, 1980, 1981, 1982). Tamarack mortality started to decrease in most areas of the island in 1982 (Clarke and Carew 1983) and on the Avalon Peninsula in 1983 (Clarke and Carew 1984). By 1985, *D. simplex* populations were near endemic levels everywhere except in a few small stands south of Gander Lake (Clarke and Carew 1986). Infestations further decreased in 1986 and 1987 (A. G. Raske, unpublished).

Infestations of *D. simplex* were first recorded from Labrador in 1984 in tamarack stands previously defoliated by the larch sawfly, *Pristiphora erichsonii* (Hartig) (Hymenoptera: Tenthredinidae), along the Churchill River Road and from Gull Lake to Cartwright (Fig.

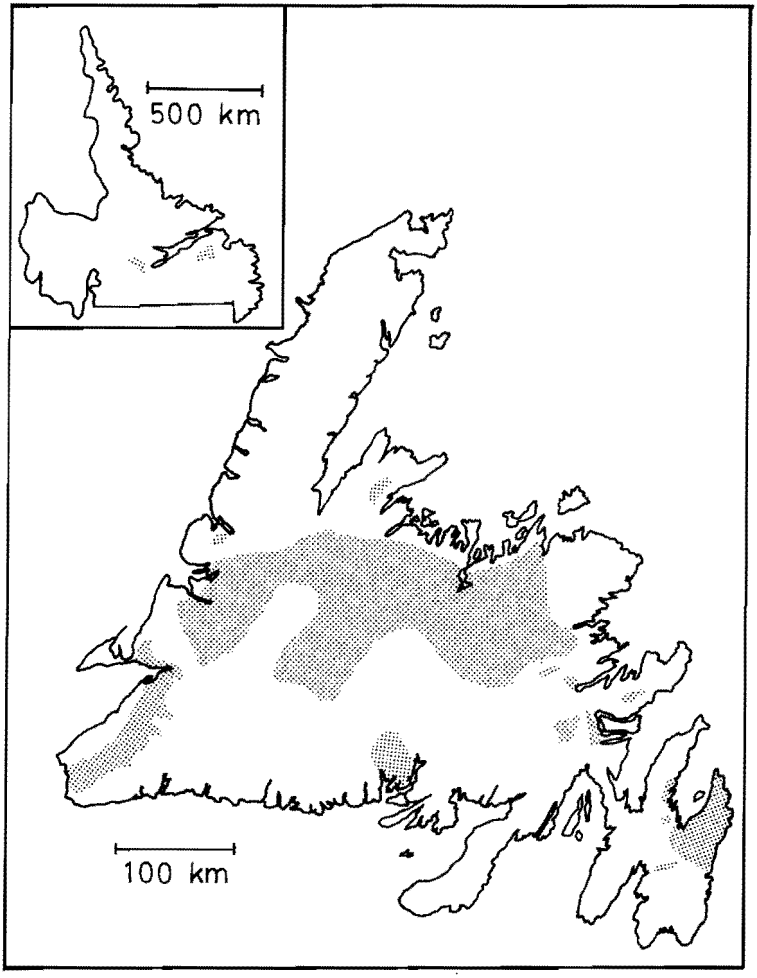

Figure 1. Distribution of *D. simplex* infestations in tamarack in Newfoundland and Labrador (inset) between 1976 and 1986.

1) (Clarke and Carew 1984, 1985). Many more trees have been killed since (A.G. Raske, unpublished).

Because tamarack is a very scattered component of Newfoundland's forests (Page et al. 1974), it was difficult to accurately estimate tree mortality. Tamarack killed by *D. simplex* was surveyed in Newfoundland in the fall of 1978, 1981, and 1985. In 1978, a road survey, covering in excess of 1200 km, tallied dead and dying tamarack, whose needles had turned yellow prematurely, along highways and some secondary roads. More than 1650 dead tamarack were counted but an estimated 50% of those attacked in 1978 were missed because their needles were still green (Raske et al. 1978). The average diameter at breast height (DBH) of attacked trees was 19.8 cm (n = 443, SD = 6.2, range = 8–48

cm). Generally, trees attacked and killed tended to be the largest in the stand. Trees smaller than 12 cm DBH were rarely attacked but trees as small as 2 cm DBH have been attacked and killed on occasion (Werner 1986, A. G. Raske, unpublished). In October 1981, an aerial survey of 268,500 ha of Newfoundland forests tallied over 11,000 dead tamarack. Extrapolation from these data estimates that in excess of 118,000 trees, representing about 18,500 m^3 of wood, were killed by *D. simplex*, mostly in north-central Newfoundland (Clarke et al. 1982). We believe this to be an underestimate of the total losses because the needles of about only 50% of infested trees turn yellow prematurely and are visible from the air (Raske et al. 1978). An aerial survey of *D. simplex* infested stands near Baie d'Espoir in southern Newfoundland in 1985 estimated 79% mortality of tamarack (1400 dead trees) from 26 photographs taken to sample the infestations. *D. simplex* killed in excess of 180,000 tamarack (about 42,000 m^3 of wood) on 90,000 ha in that region. Most of this damage occurred from 1981–82 and was thus not counted during the 1981 survey. The estimated total volume of tamarack killed by *D. simplex* from 1976 to 1986 is in excess of 100,000 m^3. No damage estimates for Labrador are available.

2. Maritimes

The earliest recorded damage by *D. simplex* in the maritimes was an infestation on tamarack at Lohne's Lake, South Milford, Nova Scotia (Brown 1939). More recently, a population build-up of *D. simplex* began in the mid-1970s following a period of several years of moderate to severe defoliation of tamarack by the larch sawfly (Magasi 1977). *D. simplex* first caused extensive tamarack mortality in Nova Scotia and Prince Edward Island in 1977 (Magasi 1977) and in New Brunswick in 1978 (Magasi 1979) and has since spread over most of the maritimes (Fig. 2). Tamarack mortality increased in the maritimes through 1981 (Magasi 1979, 1980, 1981, 1982) but gradually declined since 1982 (Magasi 1983, 1984, 1985, 1986, 1987). *D. simplex* killed the larger trees in the stands but trees as small as 6 cm DBH were attacked and killed (Magasi 1984). No *D. simplex* infestations were observed in Nova Scotia in 1987 but the number of infestations in New Brunswick and Prince Edward Island increased from the previous year.

From 1977 to 1986, four surveys of varying rigor evaluated tamarack mortality due to *D. simplex* attacks:

(1) In 1977, at ten locations surveyed in Nova Scotia and three in Prince Edward Island, the proportion of tamarack killed or damaged by *D. simplex* was 66% and 25% representing about 68% and 31% of merchantable volume, respectively (Magasi 1977).

(2) In 1978, 33 of 99 plots (all contained at least 20% tamarack) examined in the maritime provinces contained trees infested by *D. simplex* (Magasi 1979). The proportion of tamarack stems killed or damaged by *D. simplex* in the plots in Nova Scotia, Prince Edward Island and New Brunswick was 33%, 25%, and 7% representing 48%, 30%, and 4% of merchantable tamarack volume, respectively. In 11 plots in Nova Scotia and one in Prince Edward Island, 59% of the tamarack were dead (69% of plot volume) and a further 19% were infested in 1978. Almost 500,000 m^3 of tamarack were killed by *D. simplex* in the maritimes by 1978, 80% of which was in eastern and central Nova Scotia.

(3) Beetle infestations increased in 1979 and 1980 (Magasi 1980, 1981), but the forests were not surveyed again until the fall of 1981 (Magasi 1982). By that time, cumulative mortality of tamarack by *D. simplex* since the start of the outbreak in Nova Scotia, Prince Edward Island and New Brunswick was 64%, 13%, and 24%, representing 972,000 m^3, 11,600 m^3, and 314,000 m^3 of dead wood, respectively. Although *D. simplex* populations have decreased gradually since 1981, many trees were killed each year. At a central research plot in New Brunswick a further 2.9%, 3.8%, 2.8%, 6.7%, and 7.6% of tamarack were attacked (and most died) in 1983, 1984, 1985, 1986, and 1987, respectively (Magasi 1984, 1985, 1986, 1987, 1988a).

(4) In 1985, cumulative mortality of merchantable tamarack caused by *D. simplex* in Prince Edward Island and New Brunswick since the start of the outbreak was 23% and 30% representing an addition of 10% and 6% since 1981, respectively (Magasi 1986).

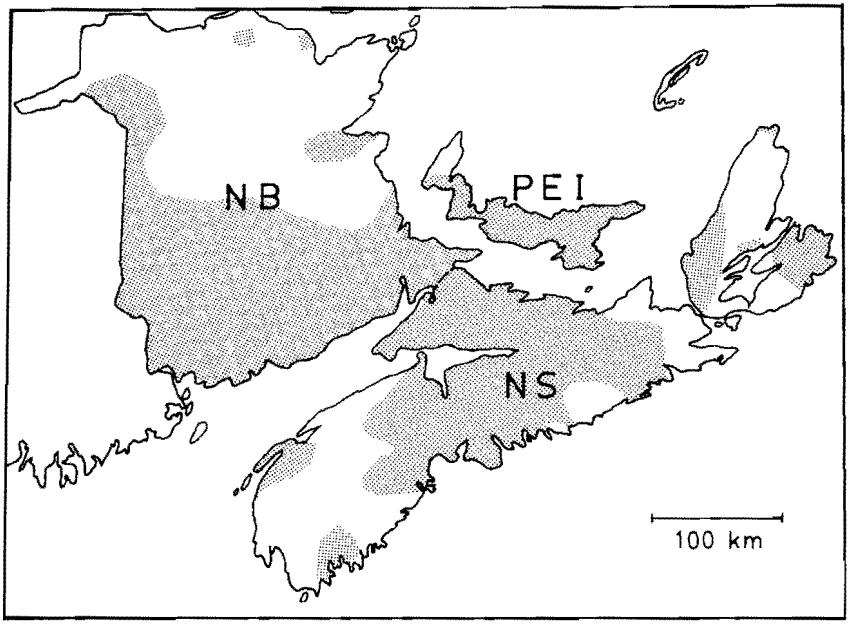

Figure 2. Distribution of *D. simplex* infestations in tamarack in the maritime provinces between 1977 and 1986; condensed from references. NB- New Brunswick, NS- Nova Scotia, PEI- Prince Edward Island.

Total mortality of merchantable tamarack in Nova Scotia in 1985 was 49%. The decrease of 15% since 1981 is probably a result of the disappearance of old dead trees from the stands (Magasi 1986).

3. Quebec

D. simplex was first recorded from Quebec by Provancher (1878) and later by Swaine (1911). Localized infestations were reported from the Quebec city area in 1926 and Lac St-Jean area in 1930 (D. Lachance, pers. comm.).

The outbreak of *D. simplex* in Quebec was not as extensive as that in the Atlantic provinces. However, *D. simplex* infestations of tamarack and ornamental larches were reported from 1980 to 1983, mostly in the south-central region of the province (Fig. 3) (Lachance et al. 1981, 1984, Benoit et al. 1982, 1983). Defoliation of tamarack by the larch sawfly was thought to be a predisposing agent in some regions (Benoit et al. 1982). From 3% to 90% mortality of tamarack was recorded at numerous sites in 1980 (Lachance et al. 1981). More sites became infested in 1981 and 1982, especially along the international border south of Montreal (Benoit et al. 1982, 1983).

Of 41 sites (182 ha) surveyed in 1983, most located in the extreme-south central region, 35 (93 ha) had tamarack mortality ranging from 11% to 95% (Benoit and Blais 1984, Lachance et al. 1984). The volume of tamarack killed and dying was estimated at 3030 m^3, 22.5% of the total. The average DBH of infested trees was 22 cm. Beetle populations have been at endemic levels from 1984 to present.

Table 1.—Summary of *D. simplex* infestations in Ontario from 1965 to 1969.

Forest region/district	Year	Notes
Northwest/		
Kenora	1961	Several trees infested in Mutrie Township (Jackson 1962).
Ft. Frances	1963	Heavy beetle infestation in Dobie Township (Thomson 1964).
North-central/		
Geraldton	1962–63	Moderate infestations in eastern part of district (Jansons 1963, 1964).
Northern/		
Gogama	1962–63	Light infestation in Muskego Township (Trinnell 1962, Trieselmann 1963).
Kapuskasing	1961	Light infestation between Teetzel and Pearce Townships (Grisdale and MacLeod 1962).
	1962	Light infestation in Kohler Township (Foster 1963).
Cochrane	1961	71% of tamarack were killed in a plot near Glockenmeyer Township (Grisdale and MacLeod 1962).
	1962	10% to 80% (mean = 47%) of tamarack were killed in 7 plots throught the district (Foster 1963).
Swastika	1961	54% of tamarack were killed in a plot at Gauthier Township (Grisdale and MacLeod 1962).
	1962	Beetle populations remained high in the district (Foster 1963).
Southwestern/		
Lake Erie	1960–61	Tamarack were killed at several sites in Norfolk County. Some European larch were killed on 3 plantations in the district. There was no evidence of a predisposing agent (Foster 1961, 1962).
Eastern/		
Tweed	1966	*D. simplex* populations were high in Kennebec Township in trees that were weakened by a change in the water table due to highway construction (Livesey 1966).

4. Ontario

Damage by *D. simplex* was first recorded from Ontario in 1883 when Harrington (1884) reported an infestation in a grove of tamarack near Ottawa. Populations of *D. simplex* increased gradually in many regions of Ontario throughout the 1950s (Foster 1964) and, in 1960, widespread tamarack mortality was reported in parts of northeastern Ontario, mainly between Englehart and James Bay (Grisdale and MacLeod 1962). Some beetle-killed tamarack was reported for most Ontario forest regions between 1960 and 1965 (Table 1). *D. simplex* infestations in most areas were preceded by several years of serious defoliation by the larch sawfly (Grisdale and MacLeod 1962).

The *D. simplex* outbreak in the Atlantic provices and surrounding regions in the 1970s did not extend to Ontario. However, overmature tamarack were killed by *D. simplex* in Galway Township (Southeastern Forest Region) in 1973 (Weir and Biggs 1974) and in South Gower Township (Eastern Forest Region) in 1980 (Howse et al. 1981). *D. simplex* populations are currently at endemic levels throughout Ontario.

5. Prairie Provinces, British Columbia, and Territories

Outbreaks of *D. simplex* have not been recorded from the four westernmost provinces and the territories but scattered, localized infestations have been reported since 1946.

Table 2.—Summary of *D. simplex* infestations in Alberta from 1965 to 1969.

Forest district	Year	Notes
Peace River	1965	*D. simplex* infested weakened tamarack in the Harmon Valley, Dixonville and Grimshaw areas (Layton 1966).
	1966	Light beetle infestations in Meander River area (Susut 1967).
	1967	Low beetle populations in Chisholm Tower, Grassland and Dixonville areas (Tripp and Robins 1968).
	1968	Moderate infestation 13 km south and 15 km west of Wapiti (Caltrell 1969).
	1969	Light infestations near Bald Mountain Tower (Caltrell 1970).
Lac La Biche	1966	*D. simplex* infestations in Sandy River area (Layton 1967).
Grand Prairie-Slave Lake	1966	Moderate infestation 72 km northwest of Slave Lake (Petty 1967).
West-central	1968	Moderate infestations in Blue Ridge area (Emond 1969).
Northeast	1968	*D. simplex* common in fire-weakened tamarack throughout the district (Layton 1969).
	1969	Low beetle populations 16 km northwest of Plamodon (Layton 1970).
MacKenzie	1969	From Ft. Providence south to Tathlina Lake and east to Taltson River about 5% of standing tamarack were attacked. Also, there was some tamarack mortality in Wood Buffalo National Park (Gautreau 1970).

Manitoba and Saskatchewan. In Manitoba, *D. simplex* killed tamarack in the Whiteshell Forest Reserve in 1957–58 (Prentice and Hildahl 1959). The beetle was recorded from Saskatchewan (Prince Albert district) in 1956 and small infestations were reported from several localities in northwestern Saskatchewan in 1958 (Prentice and Hildahl 1959). In 1958, *D. simplex* killed a few (5) trees of tamarack in a plot at Buffalo Narrows, Saskatchewan. From 1962 to 1965, small localized infestations were reported from six localities in the southern quarter of Manitoba and from at least 12 localities in Saskatchewan, from Prince Albert and northwestward to the Alberta border (Drouin and Turnock 1967). From 1964 to 1967, 90% (45 trees) of tamarack were killed by *D. simplex* in a plot near Rennie, Manitoba (Drouin and Turnock 1967).

Alberta. Damage by *D. simplex* was first reported from Alberta in 1914 when tamarack were killed at Mitsue and Smith (Hewitt 1915). In 1946, some Siberian larch, *Larix sibirica* Ledeb., were killed at Oliver nursery near Edmonton (McGuffin and Barker 1947). In 1959, *D. simplex* killed a few trees of 15 to 18 cm DBH near Lac La Biche (Brown et al. 1960). An increase in *D. simplex* infestations was noted in 1963 (Brown and Stevenson 1964). Between 1965 and 1969 numerous localized infestations were reported from six forest districts (Table 2). Fire damage and defoliation by larch sawfly were considered predisposing agents for most beetle activity.

British Columbia. Tree mortality by *D. simplex* was first recorded from British Columbia in 1960 when two flood-damaged tamarack were attacked south of Fort Nelson (Silver and Ross 1961, Woods 1963). In 1962, two felled and one standing tree were attacked by *D. simplex* near Chetwynd Township (Silver and Ross 1963).

Territories. *D. simplex* was first reported from the Yukon in 1962 when a small infestation was located at mile 682 of the Alaska Highway (Silver and Ross 1963). Additionally, low populations of *D. simplex* were reported at Frances Lake in 1968 (Susut 1969).

The species was first reported from the Northwest Territories in 1965 when tamarack were attacked (locality unknown) following larch sawfly defoliation (Baranyay and

Stevenson 1966). Up to 10% mortality of tamarack was caused by the beetle in some stands south of Great Slave Lake in 1969 (Tripp et al. 1970).

6. Alaska

During an aerial reconnaissance in 1973, yellow *D. simplex*-infested tamarack were noted about 90 km southwest of Fairbanks (Fig. 4) (Holsten et al. 1985). Affected trees were widely scattered over 47,000 ha. The infested area increased to 142,000 ha in 1975 and 1976 (Baker et al. 1975, Hostetler et al. 1976, Rush et al. 1977). In 1975 and 1976 a species of budmoth, *Zeiraphera* sp. (Lepidoptera: Tortricidae) severely defoliated 240,000 ha of tamarack in the Tanana River drainage and was undoubtedly the predisposing agent for further *D. simplex* infestations (Werner 1986). By 1977, the area of beetle infestation increased to 215,000 ha and extended into the Tanana River valley (U.S. Dept. Agric. 1979a). However, by 1978 the infested area had decreased to 1/15 that of 1977 (U.S. Dept. Agric. 1979b) and continued to decrease and shift northeastward during the next two years (U.S. Dept. Agric. 1980, 1981). Less than 50 ha were infested by *D. simplex* each year from 1981 to 1983 (U.S. Dept. Agric. 1983, 1984) and no infestations were reported from 1983 to 1987. From 1974 to 1980, tamarack mortality occurred over an area of 3.3 million ha in central Alaska (Fig. 4) (Werner 1986), but estimates of total volume of tree mortality for the entire outbreak are not available.

Werner (1986) summarized the impact of *D. simplex* on tamarack that had been severely defoliated by *Zeiraphera* sp. at two sites in the Tanana River valley from 1977 to 1979. Trees ranging from less than 2 cm to greater than 14 cm DBH were attacked but larger trees were more frequently attacked. Overall stand reduction in stems per ha was 50%. The greatest reduction, at 86%, was among trees greater than 8 cm DBH. Trees attacked by *D. simplex* exhibited a more reduced radial growth (caused by *Zeiraphera* defoliation) during the previous three years than did trees that were not attacked.

7. Northeastern United States

Tree mortality by *D. simplex* has occurred in the states of Maine, New Hampshire, Vermont, New York, West Virginia, Maryland, Minnesota, and Michigan (Hopkins 1909, Wood 1982). In Maine, New Hampshire, Vermont, and New York, tamarack has been reputedly declining since the early-1970s (Teillon et al. 1979, Maine Dept. Conserv. 1987, M. J. Birmingham, pers. comm.). The reputed decline is questionable since no published growth increment data are available to verify it. Growth ring measurements from recently beetle-killed and healthy tamarack in New York in 1980 indicated that growth since the mid-1960s had been better than average (G. N. Lanier, unpublished). *Dendroctonus simplex* infestations in these states were subsequently reported as a consequence of tamarack decline rather than a cause, owing to the insect's reputation as a secondary pest. However, *D. simplex* cannot be discounted as a primary cause of tamarack mortality in the northeastern United States pending evidence of widespread tamarack decline in the region preceding the outbreak.

Maine. The species was first reported from Maine by Hopkins (1909). The recent increase in tamarack mortality due to *D. simplex* was first noticed in 1974 in the Augusta area in a stand with poor drainage which had been defoliated by larch casebearer, *Coleophora laricella* Hbn. (Lepidoptera: Coleophoridae) (D. Bradbury, pers. comm.). Since that time, *D. simplex* infestations were reported from many localities in Maine, particularly in the southern half (Fig. 3) (Maine Dept. Conservation 1984, 1987, Dearborn and Stark 1986). No damage estimates were available.

New Hampshire. In the last 15 years only two *D. simplex* infestations have been reported in the state. From 1973 to 1975 in the White Mountain National Forest, large tamarack (25–55 cm DBH), believed to be weakened by unknown causes, were attacked and killed by *D. simplex* (P. Snowden, pers. comm.). In 1983, dead and dying tamarack

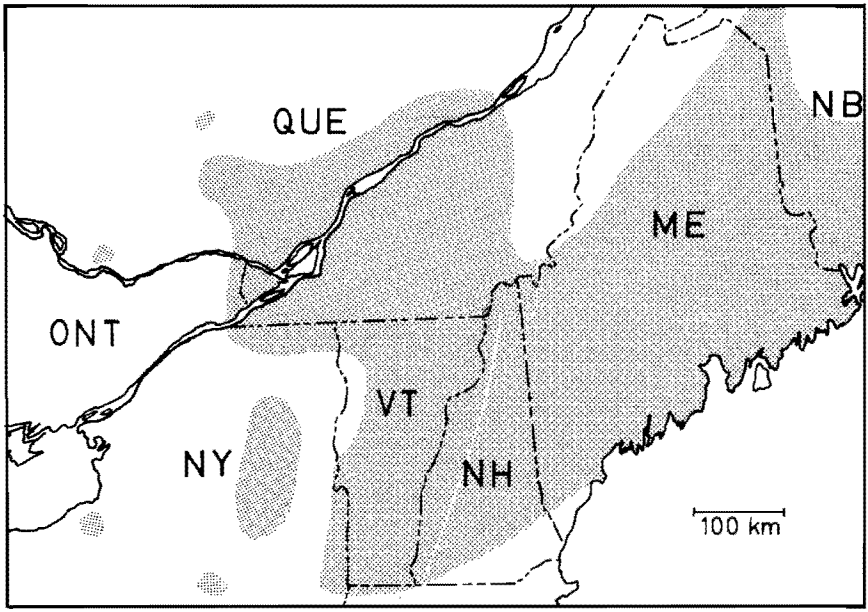

Figure 3. Distribution of *D. simplex* infestations in tamarack in Quebec and the northeastern United States from 1974 and 1986; condensed from references. ME- Maine, NB- New Brunswick, NH- New Hampshire, NY- New York, ONT- Ontario, QUE- Quebec, VT- Vermont.

(> 15 cm DBH) were reported from Orange and Canaan Townships in west-central New Hampshire (P. Snowden, pers. comm.). Although infested by *D. simplex*, it was assumed that the trees were killed or weakened by another factor(s).

Vermont. Since 1976, *D. simplex* was associated with reputed tamarack decline over much of the state (Fig. 3). The decline was first noted in 1976 when 232 ha were affected in Clarendon County in northern Vermont (R. S. Kelley, pers. comm.). Drought conditions during the previous year were thought to be responsible for initiating the decline which increased to cover 3600 ha by 1982 (Teillon et al. 1979, 1980, 1981, 1982). The pinewood nematode, *Bursaphelenchus xylophilus* (Steiner and Buhrer), was found infesting tamarack in many regions of the state (Bergdahl 1982) and was assumed to be largely responsible for killing tamarack in some areas and making them available for colonization by *D. simplex*. The beetle-infested area increased to 2000 ha in 1983 (Teillon et al. 1983) and 43 ha in 1986, mainly in the northeastern corner of the state (Teillon et al. 1986).

New York. *D. simplex* infestations were reported in New York from 1915 to 1917 (Blackman and Stage 1918). Dead tamarack infested by *D. simplex* were first noted at Beaver Lake, Lewis County in 1973 (G. N. Lanier, pers. comm.). Almost all of the mature tamarack (several thousand trees) over an approximately 75 ha area were killed by 1980. Mortality was also extensive at other western Adirondack locations and on the Tug Hill Plateau (Lanier 1981). In 1981-82, European larch, *Larix decidua* Mill. were killed at Wanakena Township (G. N. Lanier, pers. comm.). Up until 1986 *D. simplex* was associated with reputed tamarack decline throughout New York but especially in the northern part of the state (Fig. 3) (M. J. Birmingham, pers. comm.).

Minnesota. Dodge (1938) first reported *D. simplex* from Minnesota. Many tamarack

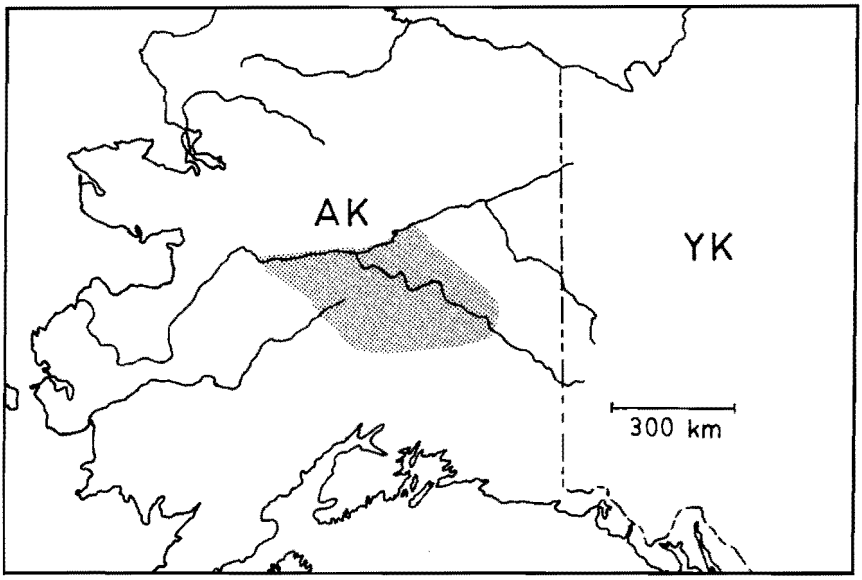

Figure 4. Distribution of *D. simplex* infestations in tamarack in Alaska from 1973 to 1982 [redrafted from (Werner 1986) with permission]. AK- Alaska, YK- Yukon Territory.

were killed in Ramsey and Hennepin counties. Weber (1942) also reported a serious infestation of tamarack by *D. simplex* in the Pine Island State Forest and other isolated infestations throughout the state. In 1984, a *D. simplex* infestation was observed in the northwestern part of the state (Region 1) (Minnesota Dept. Nat. Resources 1985). No damage estimates were given. The infestation was linked to spread of beetles from cut tamarack piled nearby. A policy was initiated to prevent storage of cut tamarack during the summer months. Also in 1984, several small infestations of *D. simplex* were observed in the east-central part of the state (Region 3) (Minnesota Dept. Nat. Resources 1985). Heavy woodpecker predation was observed. Removal of infested trees was recommended to prevent spread.

Michigan. Schwarz (1888) first reported tamarack mortality by *D. simplex* in Michigan. Trees were killed near Grand Ledge in 1881–82 and near Marquette in 1888. Drought was thought to be a predisposing agent. *D. simplex* was found in small numbers in the upper peninsula of Michigan in 1906 (U.S. Dept. Agric. 1907). In 1985, *D. simplex* attacked recently thinned 0.7–0.9 ha plots of tamarack in the Russ and Kellogg Experimental Forests in southern Michigan and by 1986 had killed about 80–90% of the 1350 trees in the plots (Haack and Mattson 1987, R. A. Haack, unpublished). In both plots, beetle populations built up in slash from recent thinning operations and moved to standing trees. At the Kellogg plot, many trees suffered severe ice storm damage in January 1985 which may have predisposed them to *D. simplex* attacks. However, there was no ice storm damage to the Russ plot. Japanese larch, *Larix leptolepis,* were also attacked and killed.

Other states. Hopkins (1899, 1909) observed a small number of *D. simplex*-infested tamarack in Maryland and in Preston County, West Virginia in 1897.

CONCLUSIONS

The cause of the outbreaks of *D. simplex* over much of northeastern North America and Alaska in the 1970s and 1980s is unknown but may reflect the increased maturity of tamarack in those regions. Mature tamarack likely experience decreased vigor and, hence, increased susceptibility to bark beetle attack as compared to younger trees. Increased stress caused by predisposing agents such as fire, local flooding, drought, and especially insect defoliation is believed to promote localized build-up of *D. simplex* populations followed by subsequent spread, even to healthy tamarack stands. Similar predisposing agents are known to foster outbreaks of other bark beetle species (Wilkinson et al. 1978, Hicks 1980, Wright et al. 1984, Mattson and Haack 1987).

The total amount of tamarack killed by this scolytid in the late 1970s and early 1980s is difficult to assess because damage estimates are lacking in several regions. The most recent estimates of cumulative volume of tamarack killed are: Nova Scotia- 972,000 m^3; Newfoundland- 100,000 m^3; New Brunswick- 314,000 m^3; Prince Edward Island- 11,600 m^3; Quebec, Alaska and New England states- no estimate but many thousands of trees in each region. Tamarack mortality far in excess of 1.4 million m^3 in northeastern North America allows us to consider the *D. simplex* outbreak in this region severe, although not as large or as economically important as outbreaks of other *Dendroctonus* species in conifers in western and southern North America. Nonetheless, the tree-killing potential of *D. simplex* has been often understated in the literature. The demonstration of this insect's destructive power in recent outbreaks certainly justifies characterization of this species as a primary pest of mature *Larix*.

D. simplex remains an important threat to native and ornamental larches in parts of North America and the insect may need to be controlled in the future. The use of semiochemicals offers the best route for effective monitoring and control. The pheromone system of *D. simplex* is currently under investigation (G. N. Lanier, pers. comm.). In areas where tamarack is economically important, a hazard rating system, based on stand age and stress by any of the predisposing agents mentioned above, should be developed to help identify susceptible stands. In light of the overwhelming importance of insect defoliators in stressing tamarack and promoting *D. simplex* outbreaks, the population dynamics of local important defoliators of tamarack should be taken into consideration when developing management strategies for the eastern larch beetle. Tamarack is often considered when planning stand conversion to species with high fiber yield and relatively few serious pest problems. The potential susceptibility of tamarack stands to *D. simplex* damage should be considered in species selection.

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