FIDS REPORT

FOREST TENT CATERPILLAR IN BRITISH COLUMBIA 1935-1993

FIDS Report 94-8

Pacific and Yukon Region

Forest Insect and Disease Survey

Forestry Canada Forêts Canada

Canada

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R.L. Ferris

Forest Insect and Disease Survey

Department of Natural Resources Canada
Canadian Forest Service
Pacific Forestry Centre
506 West Burnside Road
Victoria, B.C.
V8Z 1M5

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SUMMARY

Forest tent caterpillar, *Malacosoma disstria* Hubner, (FTC) populations have been recorded in B.C. since 1935. Outbreaks have persisted from 1 to 11 years in the Vancouver and Prince George regions respectively. There are only five short periods that an active infestation has not been recorded somewhere in the Province. Volume loss, branch kill and occasional tree mortality has resulted.

The prediction of defoliation from egg sampling is a good indication of local populations in the following year. They have been used successfully to predict defoliation. Larvae sampling can be used to confirm populations, define infestation areas and sample for parasites and disease. Aerial Surveys are used for estimating the area and severity of the defoliation.

Damage varies from trace defoliation with no significant impact to severe defoliation with volume loss. There is also an aesthetic loss from loss of foliage. Defoliation causes volume loss, some branch dieback and occasional tree mortality. Research done on damage indicates moderate to severe defoliation for two years or longer causes increment loss and branch mortality. None of the research or history records indicate that significant mortality is likely. The volume loss can be significant (40 m3/ha/yr.) and may require management.

Both natural and chemical controls are options for the forest manager. Natural controls including weather, starvation, parasitism and disease are difficult to plan with but offer a biologically safe way of control. Being aware of the natural controls and planning the applied controls so they do not negatively effect each other is one of the important planning considerations. Natural control by a nuclear polyhedrosis virus (NPV) in combination with other natural factors is the most common method of control.

Silvicultural practices have not been use to reduce the impact of forest tent caterpillar.

Applied controls can be with a naturally occurring organism or chemical spray. *Bacillus thuringiensis* (BT) is effective in reducing populations and nuclear polyhedrosis virus is being developed for other insects and may be applied to FTC. Chemical pesticides are effective controls, but may also harm other organisms that could contribute to the FTC management. Some FTC populations that may be controlled are on trees in urban areas, parks, managed or other high value stands.

Controlling FTC occurs mainly through natural means. Applied controls are occasionally used in high value areas, BT and other pesticides have been used successfully to reduced damage.

INTRODUCTION

The purpose of this report is to present information that may be used to manage FTC within British Columbia. As more deciduous species are utilized, the damage caused by forest tent caterpillar becomes more important. Data in the report is compiled and summarized from published and unpublished reports on forest tent caterpillar since its discovery near Pemberton in 1935. The report uses the Forest Insect and Disease Conditions, and History of Population Fluctuations and Infestation of Important Forest Insects, Canadian Forest Service, Pacific Forestry Centre, Victoria, B.C., file reports. The damage appraisal information is based on studies done elsewhere and reported in the literature.

Forest tent caterpillar is an important forest defoliator in British Columbia. Outbreaks have occurred periodically in six biogeoclimatic zones in the Cariboo, Kamloops, Nelson, Prince George, Prince Rupert and Vancouver forest regions.

The Forest Insect and Disease Survey (FIDS) detects and appraises defoliator populations annually using ground and aerial surveys to record damage. The information is available to the public, government agencies and industry.

BIOLOGY

Hosts and Distribution

Trembling aspen (*Populus tremuloides* Michx.) is the preferred host of forest tent caterpillar. All age class stands are damaged. After the larvae have defoliated the preferred host they migrate to other species and continue feeding. Other poplars, willows (Salix spp.) alder (Alnus spp.), birch (Betula spp.), plum and cherry (Prunus spp.), Apple (Malus spp.) and other deciduous trees and shrubs are attacked.

This native pest of North America occurs in every forest region in British Columbia(Figure 1). Infestations in North America date back 200 years. In British Columbia the first recorded infestation was in 1935 at Pemberton Meadows in the Vancouver Forest Region. Damage occurs in the Interior

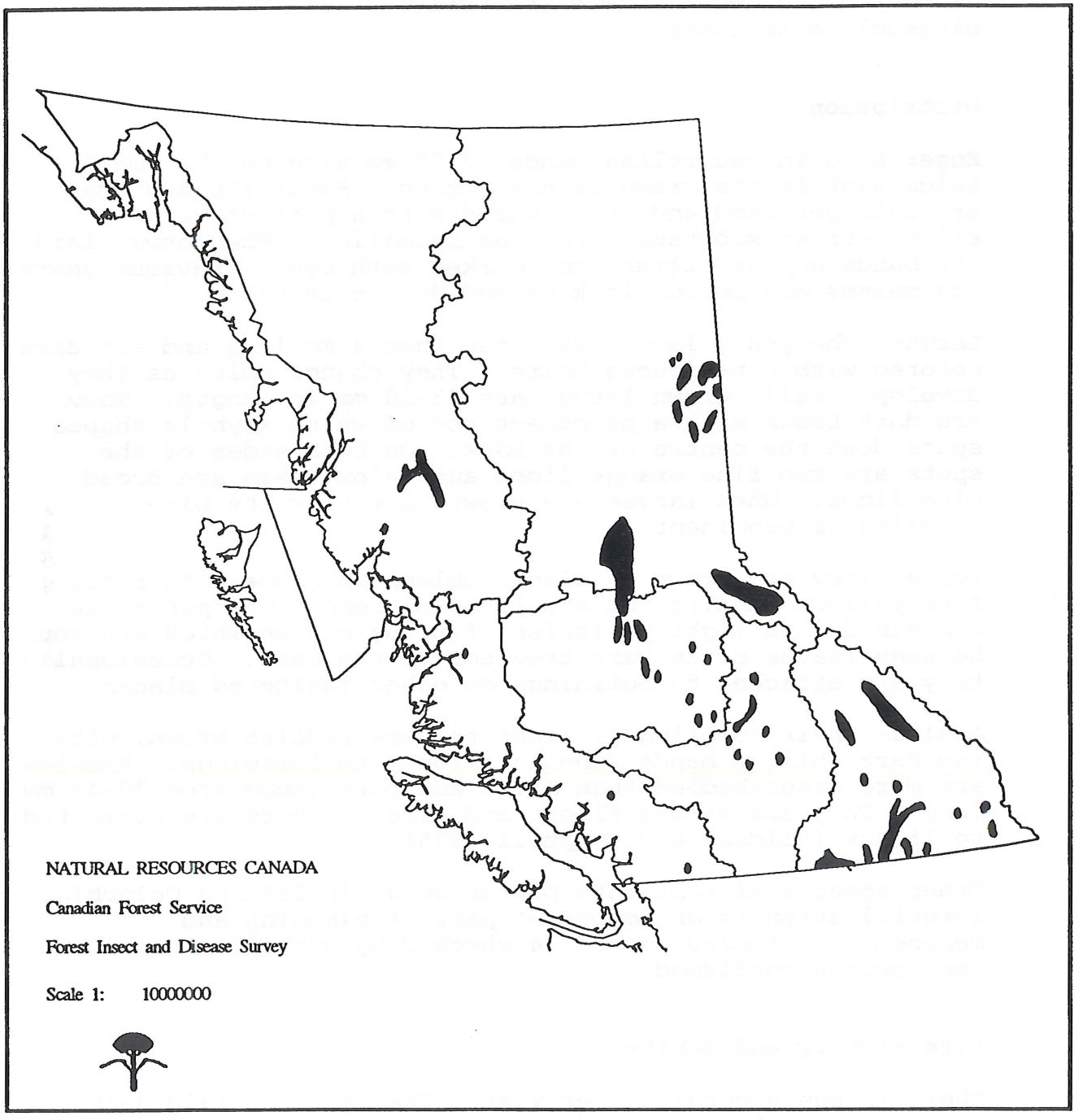


Figure 1: Areas where stands have been defoliated by forest tent caterpillar, British Columbia, 1935-1993

Douglas-fir (IDF), Interior Cedar Hemlock (ICH), Sub-Boreal spruce (SBS), Coastal Western Hemlock (CWH), Boreal White and Black Spruce (BWBS) and Coastal Douglas-fir (CDF) biogeoclimatic zones.

Description

Eggs: Laid in encircling bands 12-25 mm wide on the small twigs high in the crown of host trees. About 150-200 eggs are laid per band and are covered with a protective silvery-brown substance known as spumiline. When newly laid the bands appear silvery but darken with age. Previous years egg masses are porous looking and duller in color.

Larvae: The young larvae are less than 3 mm long and are dark colored with conspicuous hairs. They change color as they develop. Fully grown larvae are 45-55 mm in length. They are dark brown with a prominent row of white keyhole shaped spots down the centre of the back. On both sides of the spots are two fine orange lines and below these are broad blue lines. When larvae are viewed dorsally the blue coloring is prominent.

Pupae: They are brown to black, oblong in shape with short fine yellowish hairs and are 15-20 mm long. The pupae are contained in a light-yellowish, fibrous cocoon which are spun between leaves or in bark crevices of the host. Occasionally they are attached to buildings or other sheltered places.

Adults: Their coloring is light to dark reddish brown, with two dark oblique bands running across the forewings. Females are more stout-bodied than males and both range from 30-45 mm long. They are strong fliers and great numbers are attracted to lights (Hildahl and Campbell 1975).

Other species of tent caterpillar occur in British Columbia. Identification is an important part of planning and management. Samples should be checked by qualified staff and the species confirmed.

Life History and Habits

There is one generation per year. The eggs are laid July through early August and develop into first instar larvae in three weeks. They overwinter in the eggs and emerge early the following spring when the buds open (April to June). The eggs hatch when stimulated by warm, dry weather.

The first instar larvae are small black caterpillars that feed in groups on new foliage. Forest tent caterpillar do not build tents but spin webbing that they travel on. When resting or molting they are often on the sunny side of the tree. In bad weather they move to the sheltered side. There are five instars and the last instar is when most of the feeding occurs. Nearly five times more feeding is done in the last instar compared to all the previous instars combined. They remain larvae for five to eight weeks before pupating. The caterpillars enclose themselves in silken cocoons and emerge after about 10 days as adults. Pupation usually occurs in July but can be as early as June or as late as August. The moths emerge and live for 5-10 days; during that time infestations are spread by moth flights being carried long distances by high winds. Large numbers of moths are attracted to lights in urban centres. The adults mate and the female lays her eggs (Hildahl and Campbell 1975).

HISTORY

There have been FTC infestations in all six forest regions in British Columbia. The shortest one was for one year at Pemberton and the longest is 11 years in the Prince George region (Figure 2). In the last 12 years the greatest defoliation has occurred in the Prince George region were over 190 000 ha were defoliated in 1990 (Figure 3). The history is divided using the natural breaks in the infestations. This results in varying time periods but shows the provincial infestation history as well as regional.

FOREST TENT CATERPILLAR INFESTATIONS BY REGION AND YEARS

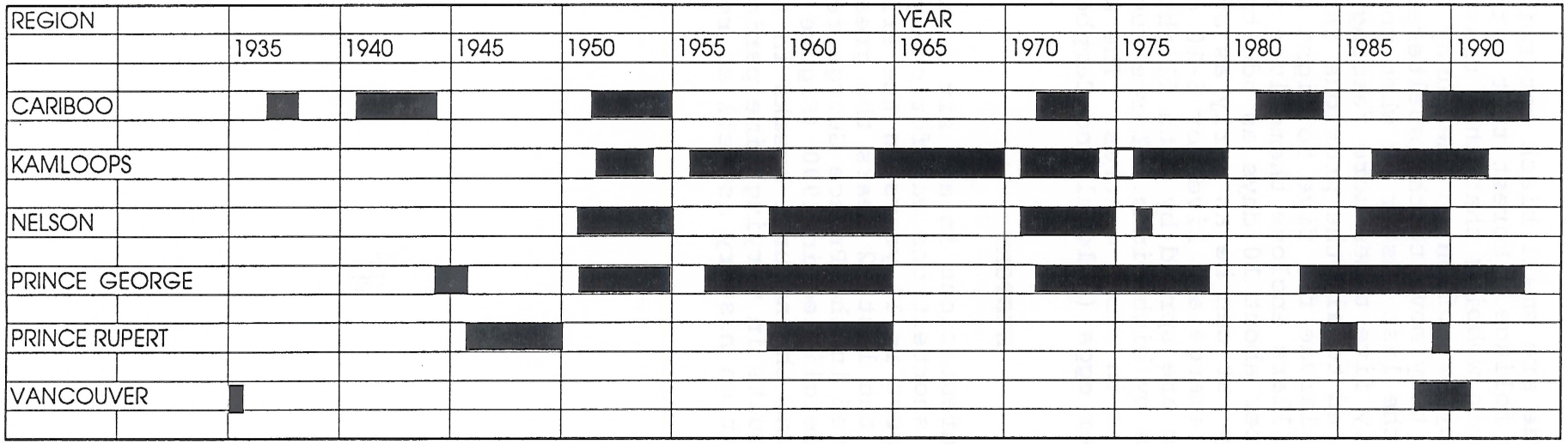


Figure 2: Infestations by region and years, British Columbia, 1935-1993.

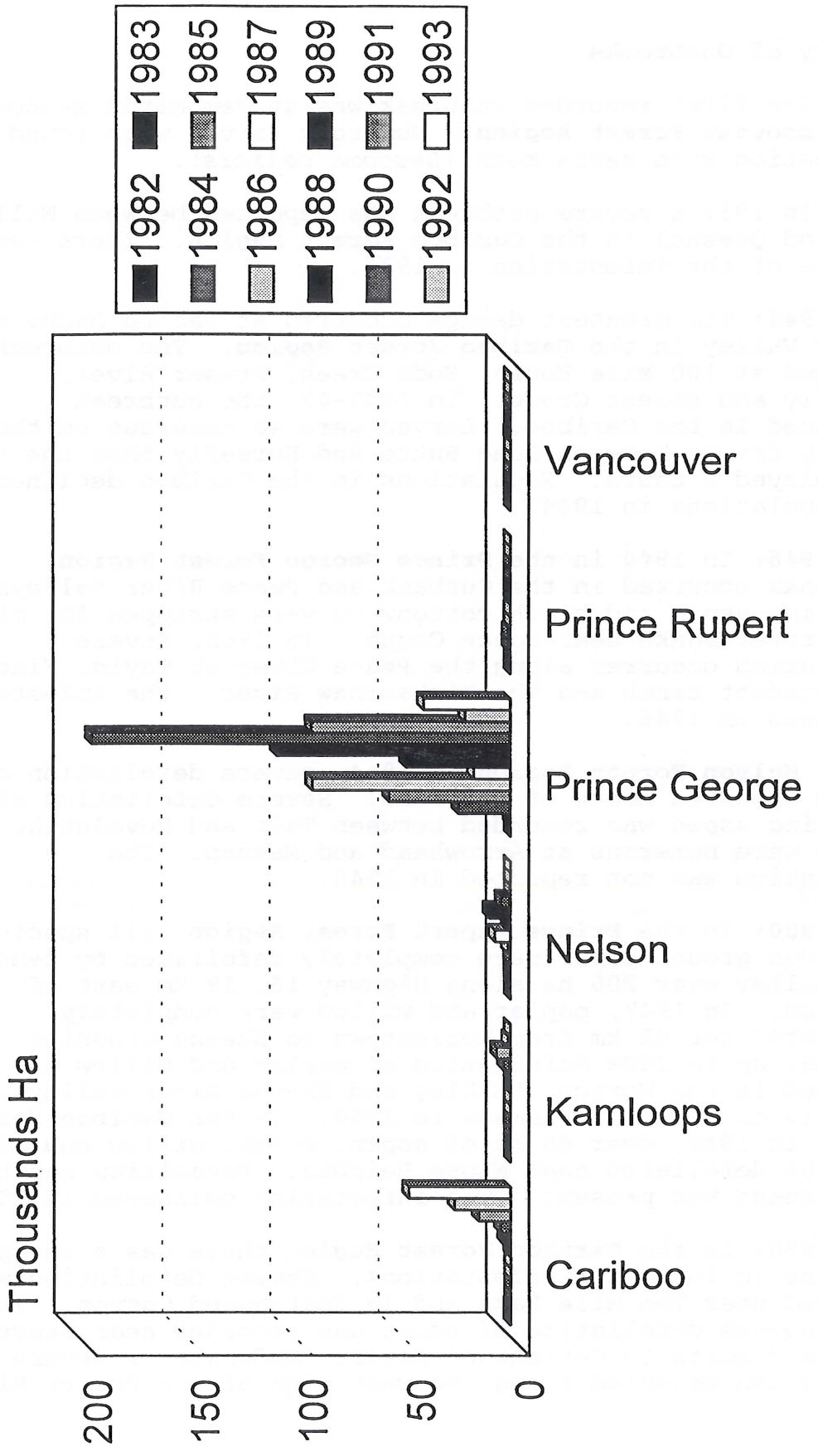


Figure 3: Area of forest tent caterpillar defoliation (ha) by region in British Columbia, 1982-1993.

History of Outbreaks

1935: The first recorded outbreak was at Pemberton Meadows in the **Vancouver Forest Region**. Numerous larvae were found in combination with satin moth (*Leucoma salicis*).

1937: In 1937 a severe outbreak was reported between Williams Lake and Quesnel in the **Cariboo Forest Region**. There were no reports of the infestation in 1938.

1941-1944: The greatest damage occurred at Lac La Hache and Beaver Valley in the **Cariboo Forest Region**. The outbreaks occurred at 100 Mile House, Soda Creek, Fraser River, Horsefly and Forest Grove. In 1942-43, the outbreak continued in the Cariboo. Larvae were so numerous on the railway tracks between Lone Butte and Horsefly that the train was delayed 2 hours. Populations in the Cariboo declined to low populations in 1944.

1944-1946: In 1944 in the **Prince George Forest Region**, outbreaks occurred in the Cutbank and Peace River Valleys. Trembling aspen and black cottonwood were stripped for miles along river banks near Pouce Coupe. In 1945, severe defoliation occurred along the Peace River at Taylor Flats, the adjacent bench and the Kiskatinaw River. The infestation collapsed in 1946.

In the **Nelson Forest Region** in 1944, severe defoliation of willow occurred north of Rossland. Severe defoliation of trembling aspen was recorded between Taft and Revelstoke and larvae were numerous at Arrowhead and Nakusp. The infestation was not reported in 1945.

1946-1950: In the **Prince Rupert Forest Region**, all species of deciduous ground cover were completely defoliated by tent caterpillar over 200 ha along Highway 16, 19 km east of Hazelton. In 1947, poplar and willow were completely defoliated for 42 km from Moricetown to Skeena Crossing. In 1948-49, up to 100% defoliation of poplar and willow was recorded in the Morice, Bulkley and Skeena River valleys. There is no record of damage in 1950. In the Cariboo Forest Region in 1949, over 40 ha of aspen, birch, willow and alder were 90% defoliated near Moose Heights. Parasitism was high and disease was present. The infestation collapsed in 1950.

1951-1955: In the **Cariboo Forest Region** there was a sharp increase in localized infestations. Severe defoliation was recorded near Ten Mile Lake and in Cottonwood Canyon. In 1952, severe defoliation of aspen was recorded near Beaver creek and north to Cottonwood River. Moderate to severe defoliation occurred along the west side of the Fraser River

for 14 km north of Quesnel and 19 km west of Bouchie Lake. The Quesnel infestation expanded in 1953 north for 128 km along the Fraser River. Large populations resulted in larval starvation near Quesnel. The nuclear polyhedrosis virus (NPV) was noted in some larvae. In 1954, infestations were recorded near Soda Creek, Williams Lake, Horsefly, east of Lac La Hache and over 5000 ha along Horsefly Lake. Severe defoliation also occurred along the Fraser River from Macalister to Prince George. The infestations collapsed in 1955.

In the **Kamloops Forest Region** in 1952, defoliation was recorded from Birch Island to Vavenby. In 1953, severe defoliation occurred on Canoe Mountain near Blue River, and Vavenby to Birch Island. The infestation collapsed in 1954.

In the **Nelson Forest Region** in 1951, there was severe defoliation of aspen and birch. The damage was in the East Kootenay at Nicholson, 800 ha; Parson, 800 ha; Brisco, 400 ha; and Sinclair Creek, 6 ha. Severe infestations continued in 1952 from Golden to Brisco, along Moberley Bench, in Mt. Revelstoke National Park and along the Columbia River from Revelstoke to Sidmouth. In 1953, severe defoliation of aspen was recorded between Brisco and Donald. Large populations defoliated over 4000 ha of aspen in the Revelstoke area, south to Arrowhead and north along the Big Bend Highway. Outbreaks at Summit Lake and Three Forks defoliated 1800 ha. and defoliation occurred for 15 km along the Granby Valley. The infestation continued in 1954. There was 485 ha defoliated at Summit Lake. The infestation in the Arrowhead area declined to moderate intensity but extended over 400 ha along Pingston Ridge. Moderate to severe defoliation occurred at New Denver, Retallack, Revelstoke and along the west part of the Big Bend Highway. NPV caused the Granby River infestation to collapse. The rest of the populations collapsed in 1955 due to larval disease and egg mortality.

In the **Prince George Forest Region** in 1951, localized infestations were recorded near Prince George and McBride. Large egg populations were found near Rearguard, Woodpecker, Tabor Lake, Yardly Lake and Hixon. The infestations increased in 1952. Damage occurred along the Fraser River near McBride, Dunster, Shore, Rearguard, and Swiftwater; also near Tabor Lake, Reid Lake and one km south of the Salmon River on the Hart Highway. In 1953, severe defoliation occurred in the Prince George, Hixon and Strathnaver areas. Small population increases occurred as far north as Salmon River. Isolated infestations were recorded near the Parsnip River bridge, Cluculz Lake and from Legrand to Mount Robson. Light defoliation occurred in the Prophet, Minaker and Muskwa River valleys. NPV killed larvae at Beaverley. Severe

defoliation occurred in 1954, from Prince George to Ahbau, northward to the Salmon River, McBride to Mt. Robson and spot infestations near Cluculz Lake. In 1955 the infestation collapsed, possibly due to egg mortality caused by a late frost.

1956-1965: An infestation at Barton Creek near Adams Lake in the **Kamloops Forest Region**, and expanded to 300 ha. There was up to 100% defoliation during the infestation which resulted in mortality of 5 to 10 trees per ha at the centre. Larval parasitism was high in 1959. In 1960 the Barton Creek infestation collapsed.

In the **Nelson Forest Region** in 1959, a small infestation was recorded north of Nicholson near Golden. Colonies were observed at Marblehead, north of Lardeau. Near Golden in 1960, the aspen trees were 50% defoliated. Up to 350 egg masses per tree were found between Nicholson and Donald. In 1961, an epidemic between Donald and Invermere caused severe defoliation. The damage occurred in aspen belts over an area 100 km long and 16 km wide. Near Warfield 40 ha were severely defoliated. Severe defoliation occurred in 1962 from Brisco to Donald, Trail to Robson and Harrod to Gray Creek. In the Slocan Valley, 16 ha of aspen were severely defoliated. Light defoliation was recorded from Invermere to Brisco and along the Kicking Horse Valley. Defoliation also occurred at Waneta, Christina Lake, Browns and Mother Lode creeks. At Summit Lake 16 ha were 100% defoliated. The outbreak collapsed in 1963 between Donald and Nicholson. Severe defoliation was recorded from Edgewater to Spillimacheen and near Invermere. There was 15 square kilometers of defoliation at Summit Lake and moderate defoliation in the south Slocan area. In 1964 the epidemic decreased. Severe defoliation occurred from Crescent Valley to Slocan, Retallack to New Denver, Slocan Lake to Box Lake and in the Salmon River Valleys along Stagleap and Big Sheep creeks. The infestations in the Columbia Valley declined in 1964 and collapsed in 1965.

In the **Prince George Forest Region** in 1957, moderate to severe defoliation (60%) was recorded from Croydon Station to Dunster. The infestation increased in 1958 from McBride to Tete Jaune Cache where there was 40-60% defoliation. In 1959, there was 60-100% defoliation over 45 km of aspen near McBride. The infestation continued in 1960 near McBride on both sides of the Fraser River. Light defoliation was recorded in the Canoe River Valley. In 1961, the infestation increased in size and intensity from McBride to Valemount, McLennan River Valley and near the Peace River bridge. The infestation increased in 1962 to 1025 sq. km from Upper Fraser to Goat River to Mt. Robson. South of the Peace River

Bridge near Taylor, severe defoliation was recorded over 80 sq. km. The population decreased in 1963. The infestation from McBride to Valemount caused mostly moderate to severe defoliation. Along the Peace River the infestation decreased to light defoliation. The populations continued to decline in 1964 with 13 sq. km of moderate defoliation recorded near McBride. In 1965 the infestation collapsed.

In the **Prince Rupert Forest Region** in 1959, severe defoliation of poplar and willow occurred near Kitwanga, Telkwa and Kispiox rivers and on the east side of the Bulkley River. In 1960, severe defoliation occurred between Hazelton and Kitwanga in the Skeena River Valley. Forest tent caterpillar populations increased in 1961 causing severe defoliation over an increased area on both sides of the Skeena River from Cedarvale to Smithers. Egg counts done in the fall indicated a continuing infestation. Severe defoliation of poplar and willow occurred in 1962. Damage was visible from Cedarvale in the Skeena River Valley to Utsum Creek in the Bulkley River Valley and from the Kitwanga River Valley to Kitwanga Lake. In 1963, light to moderate defoliation occurred from Cedarvale to Hazelton. The outbreak in the Bulkley River Valley spread eastward causing severe defoliation around Smithers and Telkwa and on both sides of the valley to Houston. Severe aspen defoliation occurred in 1964 along the Bulkley River Valley from Telkwa to east of Houston. Patches of defoliation occurred from Telkwa to Smithers and along the Skeena River from Cedarvale to Hazelton. In 1965 the infestations in the Bulkley Valley subsided.

1964-1970: In the **Kamloops Forest Region**, infestations occurred in trembling aspen. Damage occurred along Wells Gray Park Road covering 130 ha in 1964 and expanding to 6500 ha by 1969. In 1970 the infestation collapsed.

1971-1979: In the **Cariboo Forest Region** severe defoliation was recorded in 1972. Trembling aspen was damaged over 3749 ha along the Fraser River near Quesnel. Severe defoliation was also recorded around Higdon Creek and Dragon Lake over 2068 ha. Moderate defoliation occurred over 1034 ha south of the Cottonwood River and over 646 ha between Bouchie Lake and Moose Heights. Defoliation increased in 1973 to 70 700 ha from Australian to Greening along Highway 97, for 32 km along the Wells-Barkerville Road, 24 km along the Blackwater Road and 9 km along the Nazko Road. In 1974 the infestation collapsed.

In the **Kamloops Forest Region** in 1971, scattered pockets of severe defoliation were recorded near Winfield, Raft and Mad rivers. In 1972 1600 ha of moderate to severe defoliation of

trembling aspen occurred at Mad River. The infestation remained static at Mad River in 1973 and collapsed in 1974. In 1976, moderate defoliation on trembling aspen was observed northeast of Halamore Lake on 120-200 ha. About 2000 ha of trembling aspen was defoliated in 1977 south of Heffley Lake, north of Gosnell, west of Little Fort and Barriere. In 1978 populations were low. Severe defoliation of trembling aspen occurred in 1979 on 565 ha in Wells Gray Park and 250 ha adjacent to the south park border. In 1980 the infestation collapsed.

In the **Nelson Forest Region** in 1971, moderate to severe defoliation was recorded east of Revelstoke and in the Warfield-Rossland area. Severe defoliation was mapped in 1972 along the Columbia River from Revelstoke to Wigwam, from Donald to Parsons and in the Trail-Warfield areas. In 1973 tent caterpillar caused severe defoliation of deciduous trees in the Trail-Warfield area. Moderate to heavy defoliation occurred east of Golden along the Kicking Horse River as far east as Yoho National Park. Defoliation was visible along the west side of the Columbia River from Windermere Lake, south of Invermere. About 490 ha of trembling aspen was defoliated in 1974 along the west side of the Columbia River near Golden, Parson and Spillimacheen. No defoliation was noted in 1975. In 1976 over 1000 ha of trembling aspen and other deciduous species were defoliated on the Moberley Bench north of Golden. East of Ft. Steele 405 ha of black cottonwood were defoliated. Infestations on the Moberley Bench were heavily infected with virus and many pupae were parasitized. In 1977 the infestations collapsed.

In the **Prince George Forest Region** in 1972, light to moderate defoliation occurred from Prince George to Strathnaver and McBride to Mt. Robson. The outbreak increased in 1973 with up to 100% defoliation common from Prince George to Ahbau. Intermittent defoliation occurred west to Chilako River and north to the Salmon Valley. Severe defoliation was recorded in the McBride - Mt. Robson area. The population declined in 1974, causing intermittent defoliation of aspen stands around Prince George and McBride. This may have been caused by a pupal virus and weather in May. Defoliation increased in 1975 to 80-100% over 4000 ha near McBride, McKale Creek to Horsey Creek, near Miworth and near Mackenzie. No sign of disease was found in the larvae. Infestations increased again in 1976 to about 6600 ha in the McBride area from McKale Creek to Tete Jaune Cache. Late larval and pupal collections contained nuclear polyhedrosis virus. The infestation increased in 1977 to 30 400 ha in the McBride area. This area includes McKale Creek to Kiwa Creek, Tete Jaune Cache to Valemount and near Mt. Robson. No disease was

found in larval collections. Defoliation subsided in 1978 to 2100 ha from McBride to Horsey Creek and near Tete Jaune Cache. In 1979, the population collapsed.

1982-1993: In the **Cariboo Forest Region** in 1982 moderate to severe defoliation was recorded over 490 ha at Bonaparte and Bridge Lakes and east of Horsefly at Black Creek. Trembling aspen was severely defoliated in 1983 over 400 ha east of Horsefly and over 10 ha near Forest Grove. The trees defoliated in 1982 sustained no permanent damage. Low populations were recorded from 1984 to 1987. In 1988, aspen was moderately to severely defoliated over 460 ha. The damage occurred from Canim Lake to Green Lake, including Jim Creek, near Deka and Bridge lakes, south to the Bonaparte River and Green Lake. The area of infestation increased in 1989 to about 3200 ha. Aspen was moderately to severely defoliated near 108 mile, south of Canim Lake, near Deka, Horse, Bridge, Eagan and Green lakes. The most severe damage was mapped over 350 ha east of Deka Lake and over 330 ha along Jim Creek south of Canim Lake. In 1990, the area of aspen defoliation expanded 50% to 4760 ha extending from Bridge Lake to near Horsefly. Aspen stands south of Canim Lake were lightly to moderately defoliated over 1380 ha. Near Horsefly new infestations covered 1250 ha. Patches of poplar over 480 ha were defoliated east of Hendrix Lake. Willow and other shrubs were severely defoliated over 20 ha north of Barkerville in the Williams Creek Valley. The infestation expanded to 15 000 ha of aspen in 1991. Light to severe defoliation occurred from Bridge Lake to Quesnel in 155 separate patches. New infestations were along the Quesnel River from Quesnel to Beaver Creek. The largest increase was in the Horsefly area. Egg mass sampling indicated continuing defoliation. Parasitism by dipterous insects averaged 34% at four locations. Disease was found in 6% of the larvae. In 1992 the infestation expanded to 2600 ha. of light to severe defoliation from Bridge Lake to Quesnel River in 170 separate patches. The most severe and largest infestation occurred around Horsefly. Egg mass sampling indicated continuing defoliation. Parasitism averaged 67% (range 28-92%) by *Diptera* spp insects and disease averaged 15% (range 0-30%) of mainly viral disease. Defoliation in 1993 increased 50% to 4700 ha in 238 patches from Quesnel to Horsefly.

In the **Kamloops Forest Region** in 1987, scattered, total defoliation of poplar, willow, birch and alder occurred along Chase Creek from Falkland to Charcoal Creek. A similar 5 ha mixed stand was 80-100% defoliated south of Monte Lake. In 1988 there was no recorded activity. Defoliation of trembling aspen in 1989 occurred over 1000 ha. About 170 ha was attributed to forest tent caterpillar and the remainder

to *Malacosoma* spp. In 1990, defoliation of trembling aspen, black cottonwood, birch and willow increased to 3200 ha. The damage occurred along the North Thompson Valley from Barriere to Avola, including Wells Gray Park. Up to 100% defoliation occurred along the Clearwater River in Wells Gray Park and along the Mad and Raft rivers. The largest infestation of light to moderate defoliation covered 1000 ha near Blackpool. Aspen stands near Salmon Arm and Tappen were defoliated by mid-summer. Defoliation continued in 1991 on 6500 ha along the North Thompson Valley between Barriere and Avola and Wells Gray Park. The largest infestations were 1400 ha of moderate defoliation at Hemp Creek, 1000 ha of light to moderate at Blackpool and 750 ha at Clearwater and Mad Rivers. Defoliation declined in 1992 to 1120 ha of trembling aspen, black cottonwood, birch and willow in 15 patches. Damage was mainly on islands and along the North Thompson River between Little Fort and Birch Island. There was also light defoliation in two areas of 100 ha each along the Raft River and at Moul Creek north of Clearwater. Larval parasitism by *Diptera* spp. was found in more than a third of the population sampled north of Little Fort. NPV affected more than 50% of the larvae in several stands near Blackpool and Clearwater indicating a declining population. The population collapsed in 1992.

In the **Nelson Forest Region** scattered moderate defoliation was recorded in 1984, between Warfield and Violin Lake west of Trail and on 2 ha at West Trail. Populations increased in 1985 when 100 ha were severely defoliated in the Warfield-Violin Lake area. The infestation at West Trail increased to 25 ha of moderate defoliation. In 1986, the area increased as 1 200 ha of deciduous trees were moderately to severely defoliated. Defoliation continued in the Trail-Warfield area and expanded to Rossland, Montrose, Casino and China Creek near Castlegar. Near Crawford Creek on the east side of Kootney Lake 100 ha were defoliated. Minor infestations were noted at Castlegar, Crescent Valley, Eholt and Goat River, west of Kitchener. The area of moderate to severe defoliation increased in 1987 to 7 700 ha in 119 infestations. Severe defoliation continued in the Warfield-Trail area and expanded southwest beyond Rossland to King George VI Park, east into Montrose, with spot infestations to Fruitvale. Defoliation occurred from Trail to Castlegar and throughout the Crescent Valley. Spot infestations occurred along Highway 3 to Nelson, along Highway 6 north as far as Passmore and south to Salmo. Defoliation continued over 100 ha at Crawford Creek on the east side of Kootenay Lake. Minor infestations occurred at Eholt, Fort Steele, McRae Creek east of Christina Lake, Gray Creek, Goat River and Galloway. Moderate and severe defoliation was mapped in 1988 over 1500 ha mainly near Fort

Steele. Scattered patches of light to moderate defoliation were also noted along the Rocky Mountain Trench from Wardner to near Golden and Blackberry River. Moderate defoliation occurred near Kitchener, Creston and along the Moyie River north of Yahk. Light defoliation also occurred in the Hosmer area. In 1989, populations increased in the region with 9900 ha of defoliation. From Golden to Blaeberry 8100 ha of severe defoliation was mapped. Defoliation intensity increased near Wasa Lake but decreased from the Fort Steele area south. Small patches of defoliation continued in the Yahk and Creston areas. Populations decreased in 1990 with light to severe defoliation over 4315 ha. Severe defoliation occurred south of Golden from Parson to Spillimacheen and light defoliation continued north to the Blaeberry River area. Light defoliation continued in the Creston and Hosmer areas but collapsed in the Fort Steele area. In 1991, the populations collapsed.

In the **Prince George Forest Region** in 1983 populations increased with 485 ha defoliated north of Prince George in the Salmon Valley. Populations increased in 1984 causing light to severe defoliation over 5420 ha in the Salmon Valley. Population exploded in the Peace River area with 18 680 ha of light to severe defoliation between Dawson Creek and Fort St. John. Egg mass surveys indicated continued defoliation. In 1985 the infestation in the Salmon Valley collapsed due to NPV. Infestations in the Peace River area increased to 56 390 ha of light to severe defoliation. Damage was recorded from south of Pouce Coupe to the Ft. St. John area. Egg mass surveys indicate continued defoliation. The infestation continued in 1986 in the Peace River area. Light to severe defoliation occurred over 91 700 ha from south of Tupper to Charlie Lake and the Alberta border to Pine River. Populations increased in the Salmon Valley near Prince George where light defoliation was recorded over 580 ha. High larval populations but no defoliation were noted in the Tabor mountain area. In 1986 egg mass surveys predicted continuing defoliation in the Peace River area. A cytoplasmic virus (CPV) was isolated in larval collection form Tabor Mountain area. Populations declined in 1987 in the Peace River area and increased near Prince George. About 8655 ha were defoliated in the Peace River area and 8370 ha near Prince George in the Chief Lake and Tabor Mountain areas. Egg Mass surveys predicted continued defoliation. Population continued to decline in 1988 in the Peace River area but increased near Prince George. There were 5035 ha of light to moderate defoliation south of the Peace River in Pouce Coupe and Farmington areas. In the Prince George area 43 280 ha of moderate to severe defoliation were recorded. The defoliation near Prince George was recorded from Salmon Valley to Chief Lake areas, Cranbrook Hill west of Prince

George and north to the Giscome Rapids on the Fraser River. Egg mass surveys predicted high populations near Prince George and the Peace River area. Extremely high numbers of egg masses were found during the surveys. There were 339 egg masses found on one 12 cm dbh trembling aspen near Chief Lake. A major increase in population was recorded in 1989 near Prince George where 103 225 ha were defoliated. The damage occurred from Summit Lake to Pineview and Eaglet Lake to Isle Pierre areas. In the Peace River area populations continued to decrease. About 4805 ha were defoliated in the Pouce Coupe and Farmington areas. Also 260 ha were defoliated near McBride at Castle Creek. This is the first recorded defoliation here since 1978. Egg mass surveys predicted high population near Prince George and decreasing populations in the Peace River area.

Populations exploded in 1990. Over 153 210 ha were defoliated in the Prince George area. About 35 620 ha were defoliated in the Peace River area and 4465 ha near McBride. Defoliation near Prince George stretched from north of Summit Lake to Stoney lake and from Chilako River to Eaglet Lake. Defoliation was also noted in the Sinkut River area near Vanderhoof and in the Bear Lake area. Defoliation in the Peace River area expanded and was recorded from south of Tupper to Ft. St. John, including Taylor. Along the banks of the Peace River and from the Groundbirch area to the Alberta border defoliation was recorded. In the McBride area defoliation was recorded on the north side of the valley from East Twin Creek to Small Creek and near Castle Creek. Egg counts declined but still predicted severe defoliation in the Prince George area. Low population were predicted near McBride and in the Peace River area. NPV was recorded in five larval collections near Prince George and in populations near McBride.

Populations declined in 1991 to 28 000 ha near Prince George. Damage increased near McBride to 6500 ha and decreased in the Peace River area to 4800 ha. Egg mass surveys indicated declining populations near Prince George and in the Peace River area but showed increasing populations near McBride. NPV was found in mass collections. Populations continued to decline in 1992. Near Prince George 2450 ha were defoliated, in the Peace River area populations collapsed. In the McBride area populations increased to 9700 ha. Egg mass surveys indicated decreasing populations near Prince George except for Trapping Lake and increasing populations near McBride. Near Prince George defoliation increased in 1993 to 2200 ha and to 2700 ha at McLeod Lake. In the McBride area 16 000 ha of defoliation was recorded. Several hundred hectares was defoliated near Taylor.

In the **Prince Rupert Forest Region** in 1984 moderate to severe defoliation occurred over 1000 ha from Kitwanga to Moricetown. Deciduous hosts were moderately to severely defoliated in 1989 in Kitimat. No defoliation was recorded in 1991 or 1992.

In the **Vancouver Forest Region** in 1988, defoliation occurred from Stuie to Bella Coola and near Chilliwack. A virus was prevalent in both populations and a decreased population was expected. The defoliation decreased in 1989. Damage occurred form Stuie to Bella Coola and near Chilliwack. Populations declined again in 1990. Scattered single tree defoliation occurred near Bella Coola along the Nusatsum River. Populations collapsed in 1991.

SAMPLING AND SURVEY METHODS

Egg Sampling

Egg mass sampling is used to determine potential populations the following year. Samples are taken in the fall to predict population levels for the spring. Three representative trembling aspen trees are sampled at each location. The average number of new egg masses per tree is found and related to the average tree diameter at breast height (Table 1). Usually the trees are felled during sampling but counts can also be done with binoculars after the leaves have dropped in the fall and winter. For population predictions only current year egg masses are used. Current egg masses are unhatched and previous year are obviously empty. A sequential sampling system has been studied but practical field use has been unsuccessful.

Table 1: Number of Egg Masses by tree diameter that will cause complete defoliation.

Diameter at breast height (cm)	Number of egg masses
2.5	2
5.0	5
7.5	7
10.0	11
12.5	14
15.0	19

Forest Tent Caterpillar in the Prairie Provinces (Hildahl and Campbell 1975)

An estimation of population increase or decrease can be made by comparing new to one year old egg masses. Identifying last year and older egg mass is more difficult as both are empty and have some degree of weathering. With experience the difference between one year old and older can be determined. The amount of weathering and damage to the egg mass is used along with local knowledge of the infestation. The counts can be expressed as a ratio of new to old egg masses. The higher number indicates the population trend. For example a ratio of 2:1 or greater indicates an increasing population , 1:1 a static population and 1:2 or less a decreasing population. This is useful for predicting changes in defoliation from year to year.

Larval Sampling

Larval sampling is done in the spring to confirm population predictions. The egg mass should be checked for hatch and larva for health and vigor. Representative collections of 100 larvae each are made at several locations in the outbreak and reared to determine parasitism and disease.

Aerial Detection Surveys

Defoliation is recorded by aerial sketch mapping and photography. The infestations are flown in late June when feeding has stopped and before the trees refoliate. Fixed wing aircraft are usually used. The survey is flown at about 300m above ground level and infestations are sketch mapped onto 1:100 000 or 1:250 000 scale topographic maps. The defoliation is classified as:

Light Defoliation:	Discolored foliage visible from the air, some branch tip and upper crown defoliation
Moderate Defoliation:	Pronounced discoloration, noticeably thin foliage top third of many trees severely defoliated, some completely stripped.
Severe Defoliation:	Bare branch tips and completely defoliated tops, most trees more that 50 % defoliated.

Defoliation is the most recognizable feature of damage. Weather conditions, time of day (shadows) and stand age can cause variation in the impression of severity. Surveys should be done in good weather near mid day. The defoliated area can be calculated by entering the data on a geographic information system or dot griding.

DAMAGE

Forest tent caterpillar infestations in British Columbia have been widespread and severe (Figure 2). Since 1935 populations have persisted for 1 to 11 years and then declined. Mortality has been limited to branch dieback and occasional tree mortality. Damage appraisal work has not been done, however no significant tree mortality has been recorded in B.C. (Wood 1992).

Research done in the Prairie Provinces, found that light defoliation causes little change in tree growth. Moderate to severe defoliation for two years or longer may cause a severe increment loss and branch and twig mortality. Tree mortality usually does not occur. Trees refoliate immediately after feeding stops and the trees continue essential photosynthesis (Ives and Wong 1988). In 170 mortality plots studied in Saskatchewan and Manitoba, it was found that tree mortality in attacked stands was not significantly higher than unattacked stands (Hildahl and Reeks 1960). Incremental growth reduction occurred after one year of severe defoliation but not after one or two years of light to moderate defoliation. Recovery of growth the following year was practically complete. Trees with two years of defoliation needed one to two years to recover. The estimated volume loss was 4.5 m3/ha/yr. in Saskatchewan and Manitoba. This is similar to the loss found in Minnesota by Duncan and Hodson (1958).

Studies in Minnesota found mortality was indirectly related to caterpillar feeding and increased with defoliation intensity (Churchill et el 1964). The cause of mortality was attributed to other insects, disease, suppression or other factors that combined with the caterpillar to kill the trees. Trees resumed normal increment growth the second year after severe defoliation.

Radial growth is reduced with increasing intensity and frequency of defoliation (Duncan and Hodson 1958). Studies in Minnesota indicate that serious defoliation does not cause aspen mortality or increase loss from *Saperda* sp. or *Hypoxylon* sp.. Increment loss varies with defoliation intensity and history. Little increment is lost with one year of light defoliation, while nearly 90% is lost with two or three years of severe defoliation.

Batzer and Morris (1978) state that diameter growth may be reduced up to 90% depending on the level of intensity and frequency of defoliation. Defoliation kills few trees except suppressed.

CONTROLS

Natural

A variety of naturally occurring factors affect forest tent caterpillar populations. Starvation, parasites, unfavorable weather conditions and disease all play a role in declining populations and are important natural controls of the the caterpillar.

Unfavorable weather maybe able to bring an outbreak to an end within the first three years (Brown 1966). High mortality of larvae in the egg occurs with temperatures below -41C (Batzer and Morris 1978). Freezing before, during and after hatching kill many. Temperatures above 38C in the shade during moth emergence and egg laying have caused death of adults and low viability of eggs. Outbreaks have been affected by cold weather occurring immediately before or after egg hatch. Cold spells after the hatch may cause mortality by making the larvae too sluggish to feed. In Ontario and eastern Manitoba an outbreak was reduced by 95% in 1953 (Hildahl and Campbell 1975). Three days of wet freezing weather occurred after larval hatch.

Mass starvation due to exhausted food supplies before the caterpillars are fully grown in an important factor in initiating population decline (Hildahl and Campbell 1975). Freezing temperatures destroy the foliage and reduce the food supply of the larvae causing starvation. The insects often completely defoliate the trees and the food supply is depleted before the larvae are fully grown (Brown 1966).

In British Columbia 21 species of parasites attacking Forest tent caterpillar have been recorded by FIDS based on Insectary rearing studies (Table 2). One of the most important is *Arachnidomyia aldrichi* Parkers (Sarcophagidae). This grey fly deposits its young as larvae on the pupae of forest tent caterpillar. The fly larvae then feed on the pupae killing them.

Table 2: Parasites of Forest Tent Caterpillar in British Columbia, based on FIDS records.

Host and Parasite	Order
EGG	
Telenomus dalmani (Ratzeburg)	Hymenoptera
Tetrastichus silvaticus Gahan	Hymenoptera

Host and Parasite	Order
LARVA	
Iseropus stercorator orgyiae (Ashmead)	Hymenoptera
Aleiodes malcosomatos (Matson)	Hymenoptera
Lespesia frenchii (Williston)	Diptera
PUPA	
Agria housei Shewell	Diptera
Arachnidomyia aldrichi (Parker)	Diptera
Coccygomimus pedalis (Cresson)	Hymenoptera
Itoplectis viduata (Gravenhorst)	Hymenoptera
Therion atalantae fulvescens (Cresson)	Hymenoptera
Chetogena edwardsii (Williston)	Diptera
LARVA AND PUPA	
Compsilura concinnata (Meigen)	Diptera
Agrypon anale (Say)	Hymenoptera
Archytas lateralis (Macquart)	Diptera
Carcelia malacosomae Sellers	Diptera
Euexorista futilis (Osten Sacken)	Diptera
Exorista mella (Walker)	Diptera
Exorista larvarum (Linnaeus)	Diptera
Leschenaultia americana B. & B.	Diptera
Patelloa pachypyga (Aldrich and Weber)	Diptera
Tachinomyia similis (Williston)	Diptera

Nuclear polyhedrosis virus, Microsporidia, *Entomophthora* sp. and *Beauveria* sp. have all been recorded causing disease in forest tent caterpillar in B.C. (Table 3) (Morris 1983). Native biological control agents can have a devastating effect on insect populations and their use could form a part of a management program. The nuclear polyhedrosis virus causes one of the important diseases associated with the caterpillar and is one the primary causes of FTC population collapse. The virus population increases as the infestation ages and will result in the caterpillar population collapsing in older infestations.

Table 3: Microorganisms isolated from Forest Tent Caterpillar in British Columbia.

PATHOGEN	ORGANISM
Nuclear polyhedrosis	Virus
Beauveria sp.	Fungi
Entomophthora sp.	Fungi
Microsporidia	Protozoa

Bacillus thuringiensis (BT) is a naturally occurring organism that is commercially prepared as a microbial insecticide. It is effective in reducing caterpillar populations and information on its use is available from pesticide dispensers.

Chemical

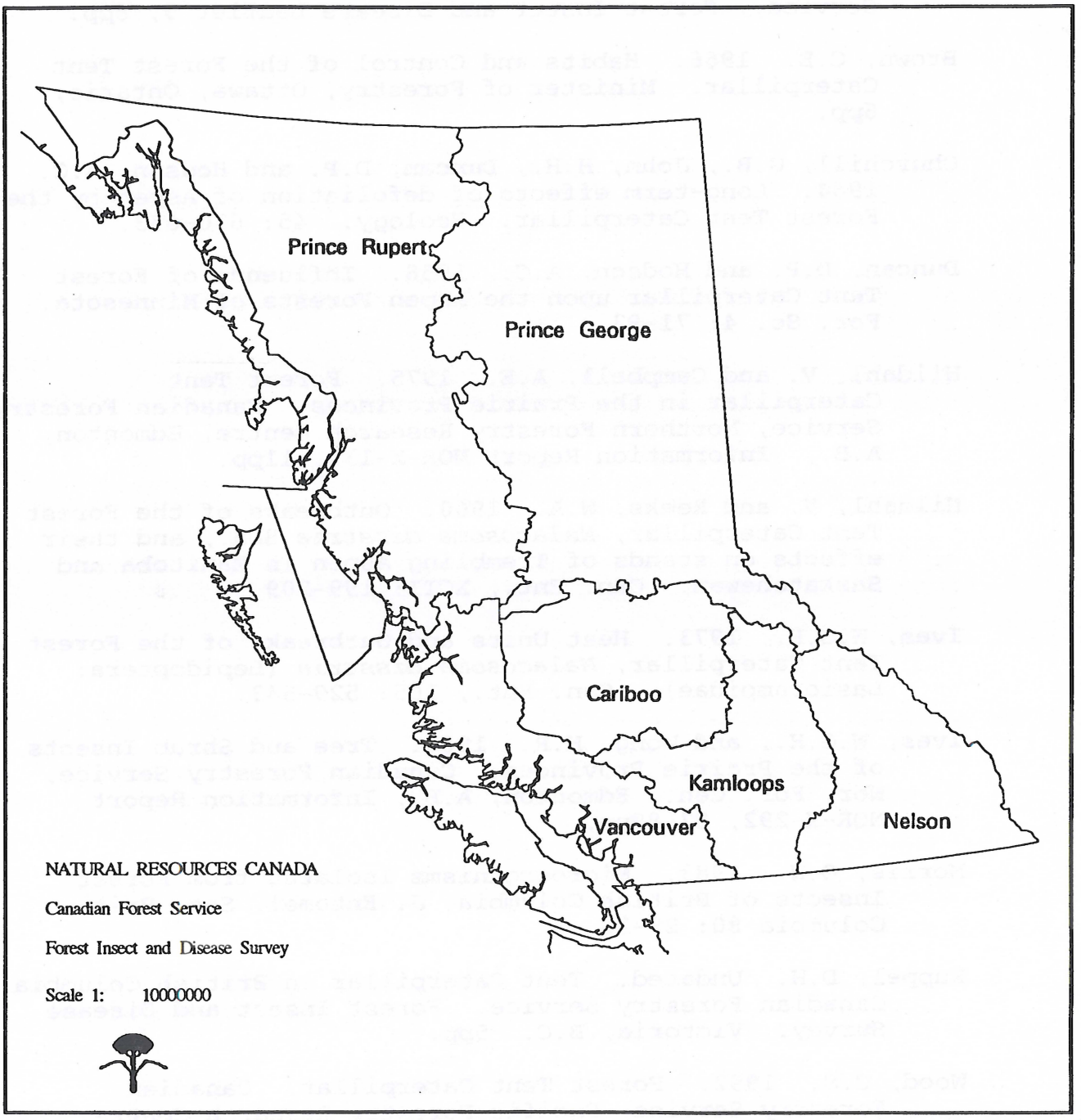
Chemical insecticides can be used to reduce caterpillar populations. The application of the insecticide at the right time will prevent severe foliage loss. Application should be done in late May or early June while the larvae are still small. Application may be by ground or aerial spray. This maybe done with ornamental trees, parks or other stands (Hildahl and Campbell 1975). Hand held sprayers are used for treating med-sized ornamentals up to 4.5m in height. Powered high pressure sprayer and mist blowers are good for treating trees that are readily accessible from the ground. Large areas are usually less expensive to treat from the air, small areas of high value trees and shrubs can be treated from the ground. Information on registered pesticides is available from pesticide dispensers.

Mechanical

Mechanical control can be used in small areas. Egg masses may be removed from branches and larvae colonies cut and burned.

APPENDIX 1

Forest Regions



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