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Spruce Beetle and the Forests of the Southwest Yukon

Rod Garbutt, Brad Hawkes, and Eric Allen

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Contents

Abstract

Beginning in about 1990, populations of spruce beetle, *Dendroctonus rufipennis* Kirby (Coleoptera: Scolytidae), reached epidemic levels and began killing drought-stressed white spruce, *Picea glauca* within Kluane National Park and Reserve in the southwest Yukon.

By 1994, when the infestation was first discovered, the beetle had already killed spruce over an area of 32 000 ha and had moved from the Alsek River drainage within the park into public forest lands and First Nations settlement lands within the Shakwak Trench north of Haines Junction. In 2000, while the infestation continued to expand, a decision was made to establish a network of plots within infested stands to assess and document the changes that were occurring to the treed overstory and understory, as well as to the associated flora. Also, in response to the greatly increased fire hazard posed by the beetle-killed trees, tree crown and surface fuels were analyzed and a relative fire hazard rating system was developed. From 2000 to 2003, 27 plots were established in the Alsek River drainage within Kluane National Park, the Shakwak Trench from Congdon Creek in the north to Klukshu Village in the south and east within the Dezadeash River Valley as far as Canyon. A supplementary root disease assessment was completed within selected plots in 2003.

As of the date of this report, spruce beetles are still killing trees over large areas, with an accumulated area of infestation in excess of 350 000 ha, and trees are still dying within some of the plots. This establishment report summarizes the findings from the first round of assessments and will serve as a baseline against which later assessments will be compared. To realize the full intent of the project, the second round will be completed some years after the collapse of the beetle infestation when the trees have begun shedding their fine fuels. This will allow the stands to begin adjusting to the loss or partial loss of the white spruce overstory, and increased light penetration to the forest floor will have begun to stimulate a response in the treed understory and the surface vegetation.

Résumé

Au début des années 1990, les populations de dendroctone de l'épinette (*Dendroctonus rufipennis* (Kirby), Coleoptera : Scolytidae) ont atteint des niveaux épidémiques et ont commencé à décimer les épinettes blanches (*Picea glauca)* affaiblies par la sécheresse dans le parc national et la réserve Kluane, dans le sud-ouest du Yukon.

En 1994, quand l'infestation a été découverte, le dendroctone avait déjà ravagé 32 000 hectares d'épinettes et s'était déplacé du bassin de drainage de la rivière Alsek, à l'intérieur du parc, jusque sur les terres forestières publiques et les terres des Premières nations visées par un règlement le long du sillon de Shakwak, au nord de Haines Junction. En 2000, tandis que l'infestation continuait de s'étendre, on a décidé d'établir un réseau de parcelles d'étude à l'intérieur des peuplements infestés afin d'évaluer et de documenter les changements survenus à l'étage supérieur et au sous-étage du couvert forestier, de même qu'à la flore adjacente. De plus, en raison du risque d'incendie grandement accru que présentaient les arbres ravagés par le dendroctone, les combustibles de surface et à la couronne des arbres ont été analysés, puis un système d'évaluation des risques immanents d'incendie a été mis au point. Entre 2000 et 2002, 27 parcelles d'étude ont été établies entre le lac Kluane au nord et le village Klukshu au sud, ainsi qu'à l'est, dans la vallée de la rivière Dezadeash, jusqu'à Canyon.

Au moment de la préparation du présent rapport, le dendroctone de l'épinette continuait de détruire des arbres sur de vastes étendues. La zone d'infestation dépassait les 350 000 hectares et des arbres continuaient de mourir à l'intérieur de certaines des parcelles d'étude. Ce rapport d'établissement résume les conclusions de la première ronde d'analyses et servira de point de référence pour les analyses futures. La deuxième ronde d'analyses s'effectuera quelques années après la fin de l'infestation de dendroctone, lorsque les arbres auront commencé à se délester d'une partie de leur combustible léger. Cela permettra aux peuplements de commencer à s'adapter à la perte totale ou partielle de l'étage supérieur d'épinettes blanches. De plus, la plus grande quantité de lumière pénétrant jusqu'au tapis forestier aura commencé à stimuler la croissance du sous-étage forestier et de la végétation de surface.

Introduction

This report includes data gathered from 2000 to 2003 by the Canadian Forest Service (CFS) Forest Health Group based at the Pacific Forestry Centre in Victoria, with support from the Forest Resources Branch of the Department of Indian Affairs and Northern Development (DIAND) and, following devolution, the Yukon government's Department of Renewable Resources, Forest Management Branch. In the first three years, 27 Forest Assessment (FA) plots were established in the Shakwak Trench, from Congdon Creek in the north, to Klukshu in the south, and in the Alsek River drainage within Kluane National Park. In the fourth year a supplementary root disease assessment was made in stands adjacent to selected plots. Plot data reflects the local plant communities before, during or closely following the invasion of the spruce bark beetle, *Dendroctonus rufipennis*, that has dramatically reduced the overstory and significantly altered the environment within white spruce, *Picea glauca*, stands in the southwest Yukon.

Prior to the early 1990s, a large proportion of damage in Yukon forests, reported annually by the CFS Forest Insect and Disease Survey (FIDS), was related directly or indirectly to the long northern winters with their recurring periods of intense cold (FIDS annual reports 1958-1996). Much of this damage was due to frost-induced bud mortality, dieback from desiccating winter winds, or 'red belt' from early spring warm spells that induced the trees to become active while groundwater was still frozen. The survival of insects as well has been strongly influenced if not determined by the vagaries of winter weather, particularly the early onset of cold, and cold reversions in spring.

Climate moderation during the last half of the 20th century has led to milder winters and warmer growing seasons (Whitfield et al. 2002). The change has affected insect populations in two ways; it has allowed some populations to move northward and successfully occupy habitats that were formerly denied them, and it has enhanced the survival of endemic populations resulting in a marked increase in damage to their hosts. Examples of the first effect include the lodgepole terminal weevil, *Pissodes terminalis*, and the western balsam bark beetle, *Dryocoetes confusus*. Neither of these two insects had been recorded in Yukon forests before 1990, but recently, high populations and visible damage have become widespread. By the late 1990s, *D. confusus* had caused extensive mortality of sub alpine fir, *Abies lasiocarpa,* to the limit of the host's northern range. The spruce bark beetle infestation in the southwest Yukon is an example of the second effect.

The spruce beetle is native to all northern spruce forests in North America (Furniss and Carolyn 1977). Hosts include white, Engelmann (*P. engelmannii*), and Sitka (*P. sitchensis*) spruce. Endemic beetle populations survive by attacking severely stressed or recently killed trees (Humphreys and Safranyik 1993). Normal attrition within mature forests provides enough of this type of host material to maintain scattered endemic populations. At these levels spruce beetles will not attack healthy trees because normal tree defenses, chiefly the production of fluid resin at the points of attack, easily overcome small populations by washing attacking adults from the trees. Only when beetle populations are high can green trees be successfully mass attacked. Periodic disturbances such as blowdown events, droughts or floods cause large numbers of trees to be suddenly killed or severely stressed, and propel endemic beetle populations into an epidemic stage. With abundant susceptible host and favourable weather, large brood populations can develop with the capability of mounting the mass attacks required to overcome the defenses of healthy trees. Historically, infestations have arisen quickly, usually within a few years of the triggering event, moved into green standing timber and then collapsed after a few more years. Unlike most other bark beetles that complete their lifecycle in a single year, throughout its range, under normal conditions, the spruce beetle is a two-year cycle insect. This means that a single generation must overwinter twice and suffer the attrition wrought by climate, disease, parasites and predators. For this reason alone, infestations rarely last more than four years.

Of the only two prior recorded infestations in the southwest Yukon, the first occurred in the late 1930s (Berg and Henry 2003). Until recently this infestation was thought to have initiated in spruce that had been felled and left during the construction of the Haines Road in 1942. A recent dendrochronological study undertaken by Alaska spruce beetle researcher Dr. Ed Berg, however, found evidence of understory release resulting from overstory mortality beginning about five years earlier. It is most likely that the earlier mortality was also caused by spruce beetle. And though it is not known how the infestation began, there is little doubt that it was exacerbated by the addition of susceptible host material during highway construction. In the summer of 1943, in a timber condition report submitted to the U.S. Army, Sgt. H. L. Holman noted, "South of the Dezadeash (River) there is an insect infestation which is causing quite serious damage to a merchantable spruce stand and which has spread over several square miles." The second infestation occurred in 1977 following construction of the Aishihik dam and diversion canal. White spruce mortality occurred over about 100 ha. The latter infestation was thought to have been human-caused – a direct result of the then normal practice of leaving felled timber on-site. When first seen in 1994, it was immediately apparent that the current infestation was on an entirely different scale of size and intensity than seen before in the Yukon or even in British Columbia, where many large infestations have been documented.

The first difference was the mode of initiation. There was no evidence of recent blowdown in the infested area and there was no industrial activity to provide recently felled trees or stumps. In fact, the infestation initiator was less of an event than it was the progressive onset of a condition. In the late 1980s, white spruce stands throughout the southwest Yukon came under stress due to significantly increased average temperatures during the growing season (Whitfield et al. 2002). The additional heat coupled with normal or below normal precipitation induced a drought condition by increasing transpiration rates beyond the capacity of the thin soils to replace the lost moisture (Dr. Ed Berg, ecologist working at the Kenai National Wildlife Reserve, pers. comm.). In the normally dry southwest Yukon, with respect to the interaction between trees and opportunistic forest insects, the effect was threefold. First, spruce beetles and others were attracted by chemical signals emitted by the drought-stressed trees. Second, the attacked trees, in an already weakened condition, had limited resources with which to repel attacks. Finally, favorable weather conditions during the June/July beetle larval development period allowed approximately 25% of the population to cycle in a single year instead of the normal two (Garbutt 1994). The situation was further aggravated by a succession of mild winters and high survival of beetle progeny. Under these near ideal conditions the spruce beetle was so successful that, by 1999, it had progressively attacked and killed most of the mature white spruce in the Alsek River corridor within Kluane National Park, in the Shakwak Trench immediately north and south of Haines Junction, and in the Tatshenshini River Valley just south of the British Columbia border (Garbutt 2003).

Due to a historical lack of damage-causing insect activity in the southwest there was no established routine of aerial pest reconnaissance. Therefore, when it was first identified in 1994, the infestation had incubated for up to four years within the remote Alsek and Tatshenshini river drainages and had expanded out through the mouth of the Alsek and into the Shakwak Trench. Beetle movement during this period was aided by the strong southwest winds that frequently traverse the valley corridors. By then the infestation was already 32 000 ha in size (Map 1 in Appendix 1). Over the next four years the infestation continued to build, fueled by an abundance of available susceptible host and by the high incidence of one-year-cycling, peaking in 1998 with attacks scattered over 107 000 ha (Maps 2 – 5 in Appendix 1) (Figure 1). In addition to improving survival and greatly accelerating population growth, the one-year-cycling also resulted in large numbers of currently attacked trees in every year instead of every two years. It was, therefore, no coincidence that when the beetle reverted to an entirely two-year-cycle population in the later 1990s, their numbers began to decline (Maps 6 – 10 in Appendix 1). In 2000 and 2001, with the population already in decline, the Yukon experienced two successive growing seasons with unusually cool wet weather. The additional moisture effectively ended the prolonged drought and the trees showed signs of renewed vigour by repelling many beetle attacks with copious flows of resin. However, instead of hastening the collapse of the infestation, populations were still high enough that many attacks were successful, and the newly rehydrated trees apparently provided such an improved environment for beetle progeny development that, in 2002, white spruce were killed over an area triple that of the previous year

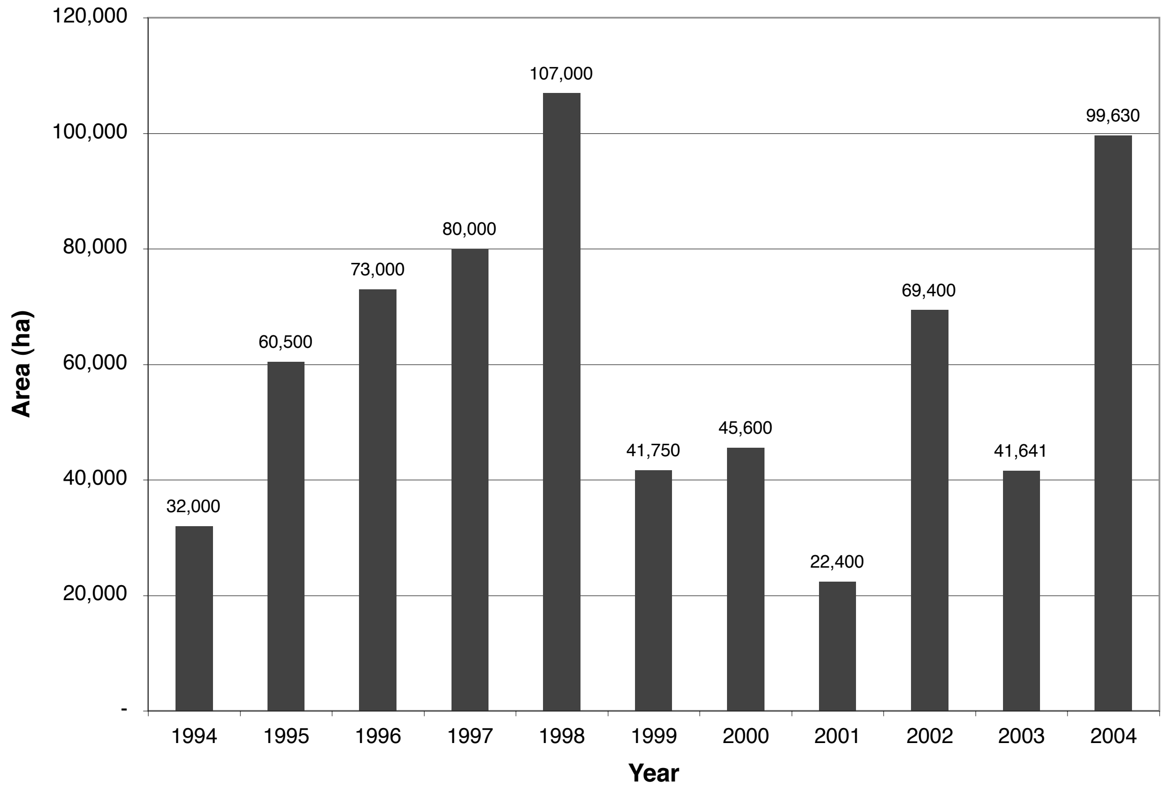

Figure 1. Area of spruce beetle mortality by year

(Maps 9 - 11 in Appendix 1). By 2005 the cumulative area of mortality was over 340 000 ha and counting (cumulative map in Appendix 1). Consequently, forested areas within the two river valleys with uniform stands of formerly mature green timber are now uniformly grey. Much of the spruce in the Shakwak Trench from Kluane Lake south to the British Columbia border has also been killed.

Understanding the forces fueling the spruce beetle infestation requires a familiarity with the patterns of forest structure and the historical forces that created them. The infested area falls within the large Boreal Cordillera Ecozone, which covers most of northern British Columbia and southern Yukon. The zone is subdivided into 12 ecoregions of which two, the Ruby Ranges Ecoregion in the north Shakwak Trench, and the Yukon-Stikine Highlands Ecoregion in the south, are of concern in this study. Within the lowland or montane vegetation zone, Douglas (1974) identified ten communities within four distinct forest types. Of the ten communities, six are dominated by white spruce, two by balsam poplar, *Populus balsamifera*, one by trembling aspen, *P. tremuloides,* and one by scouler willow, *Salix scouleriana*. Above approximately 1000 m, the montane forest gives way to the sub-alpine zone dominated by shrubs such as Salix spp. and dwarf birch, *Betula glandulosa*, accompanied by scattered stunted white spruce.

Singularly important and unique to this part of the Yukon is that white spruce is the only naturally occurring conifer. Low rainfall and a mountainous landscape have excluded black spruce, *Picea mariana*, which thrives in the wetter and flatter areas farther north where bog habitats prevail. Lodgepole pine, *Pinus contorta*, is found in pure and spruce co-dominant stands starting about 100 km to the east, but has not yet become established in the southwest. As elsewhere in the boreal forest, fire is a major influence in the Shakwak Trench. The fire history including lightning- and human-caused fires has helped shape the mosaic of age classes across the forested landscape. Human-caused fires were particularly frequent during the gold rush years around the turn of the 20th century, when fires were set to remove vegetation (Francis 1996). Due to its northwest-southeast orientation, the trench has an abundance of north and south slopes. Francis (1996) found that, on south slopes, from Kloo Lake north to Kluane Lake, small- to medium-sized wildfires were frequent, while north slopes were characterized by infrequent large burns. Though stand composition was similar on both aspects and most were susceptible to beetle attack, north slope stands tended to be significantly older. In a fire management and history study within Kluane National Park, Hawkes (1983) noted that between 1963 and 1981 there were no lightning-caused fires. His research found that, within the park, lightning-caused fires occurred only once every 20 to 50 years and fires tended to be smaller than those farther north in drier regions of the trench. This infrequency of lightning-caused fires is due to the lightning-shadow effect of the St. Elias mountain range to the west. Fire, therefore, is less of a disturbance factor in the Shakwak Trench than in most other areas of the boreal forest.

For valley bottom stands in the upper Alsek River drainage and central Shakwak Trench, a second determining factor in the stand age mosaic has been the recent geological history which has included two large-scale floods (approximately 250 and 150 years ago) caused by the damming of the Alsek River by the Lowell Glacier (Douglas 1974). The resultant massive lakes are referred to as Neoglacial Lake Alsek. A dendrochronological study (Clague and Rampton 1982) concluded that the larger of the two most recent floods occurred in the mid 1700s when water was dammed to a depth of over 150 m at the toe of the glacier and the resultant lake extended into the Dezadeash River Valley far beyond present day Haines Junction. When the floods receded, a massive seedbed was left in its wake, and, according to native oral history, grasses dominated for many years before eventually succeeding to spruce.

The size and intensity of the beetle infestation constitutes a sudden and dramatic force of change to the local ecosystem, though it is too early to speculate on its nature or degree. In the southwestern Yukon, succession in white spruce stands normally takes one of two pathways; spruce to spruce, with the understory succeeding the overstory, or aspen (or aspen/willow) to spruce. The second pathway is taken following a major disturbance such as fire. Since most of the stands in the study contained little or no aspen, with the reduction or loss of the white spruce overstory, understory spruce regeneration and woody shrubs such as willows Salix spp., soapberry, *Sheperdia canadensis*, or dwarf birch, *Betula glandulosa*, will compete for dominance. All of these shrubs were commonly found in the plots.

It is our hypothesis that the infestation could dramatically alter the structure of the ecosystem, particularly as the dead trees could contribute to the size and intensity of wildfires. In the absence of wildfire, the degree of alteration will be determined primarily by the abundance of a healthy surviving white spruce understory. Given that most seed-bearing conifers have been killed by the beetle there will be a very limited seed source. Additionally, until beetle-killed trees start falling (30-40 years), seedbeds will also be limited, for there will have been no soil disturbance. Those areas with sparse understory could be dominated, at least in the near future, by the most aggressive of the local woody shrubs.

Our research involved the characterization of the stands within the park and the Shakwak Trench using a network of permanent Forest Assessment (FA) plots. Within the plots, a range of site and vegetation characteristics were measured, including overstory (species, age, height, diameter, dominance, health, etc.), understory (species, number in three size classes, distribution), herb/shrub identification, ground cover by species and biomass, and volumes of coarse and fine woody debris. Twenty-seven plots were established within a limited range of ecotypes containing beetle attack intensities ranging from unattacked to near complete overstory mortality. Initially, 32 plots were established from Congdon Creek on the west side of Kluane Lake in the north, as far south as the Village of Klukshu. The abundance of selected herbs and shrubs was used to run a Principal Component Analysis that graphically identified the ecological disparity amongst the plots. On the strength of this analysis four of the plots, mainly those at higher elevations, were found to be ecologically disparate, and were dropped from the study. A fifth plot was lost to a highway relocation project and we were left with a total of 27 plots (Figure 2).

The data from 2000-2003 form the baseline against which post-disturbance data will be compared when the plots are resurveyed as early as 2010. This assessment, to some extent, complements data from a co-operative study between Parks Canada and the Arctic Institute known as the Kluane Ecological Monitoring Project (KEMP), which monitors wildlife population indicators at various sites within the

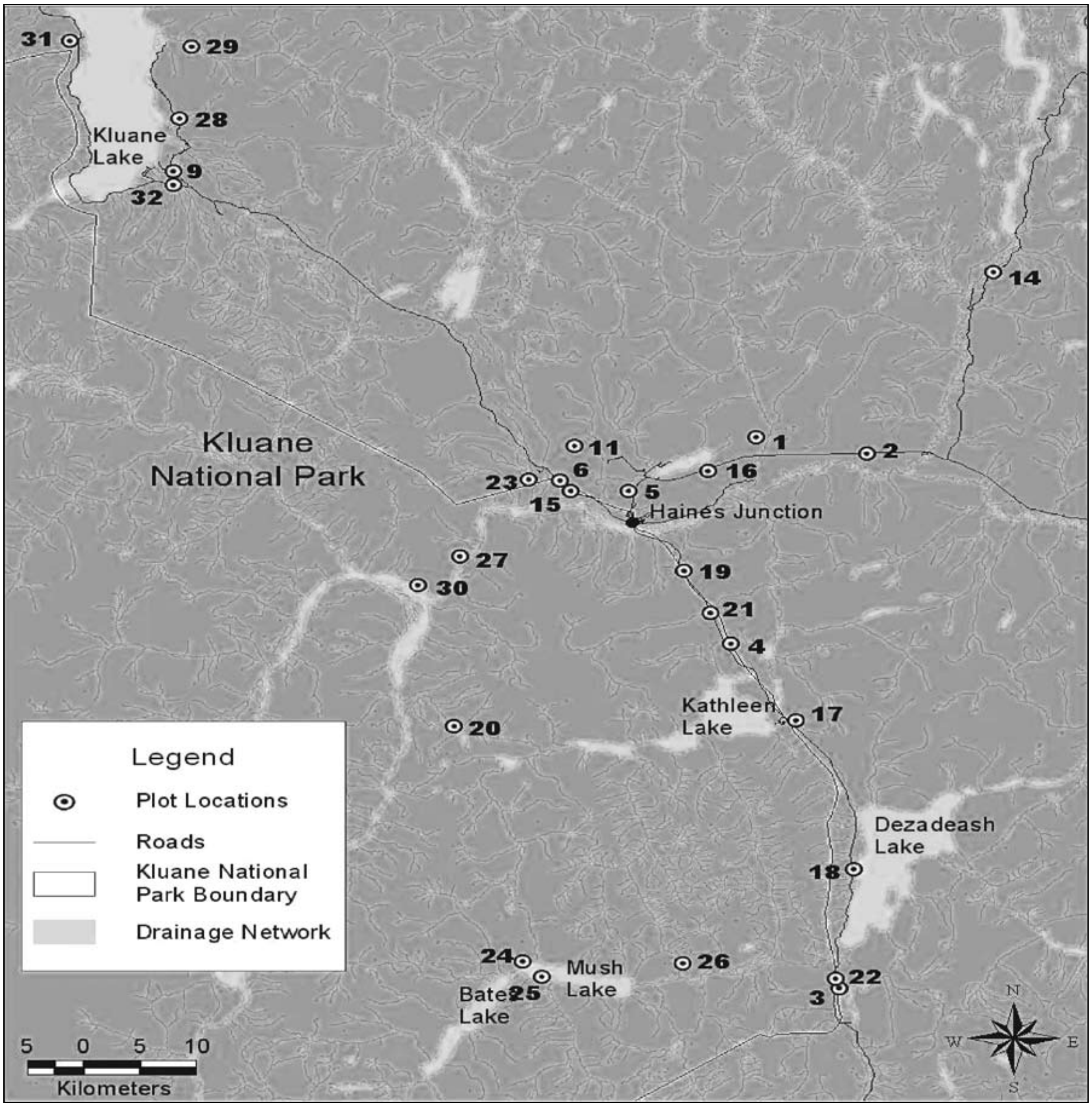

Figure 2. Location of 27 forest health assessment plots

Shakwak Trench. Data from the recent and future FA assessments will help establish timeframes for changes to selected wildlife populations.

Locating non-infested control plots proved very difficult due to the size and intensity of the infestation, so most of the 27 plots contained at least some beetle-caused mortality. The scarcity of non-infested plots may compromise the strict experimental validity of 'before and after' vegetation patterns, but will not diminish the real value of determining patterns of succession following a major disturbance.

Though the FA plots provided baseline data on many aspects of stand structure and vegetation associations, information on the influence of root disease on stand health and composition was missing. The role of root disease in predisposing spruce trees to attack by spruce beetle was first made prominent in a talk given in Whitehorse in 1995 by retired Idaho mycologist and root disease specialist, Dr. Art Partridge. He believed the spruce beetle epidemic to be essentially a root rot problem. In all of the years of Forest Insect and Disease (FIDS) surveys throughout the Yukon and subsequent work in spruce beetle infested stands, tomentosus root disease, *Inonotus tomentosus*, had frequently been found in association with individual windfallen trees, but there had been no evidence of an epidemic of the proportions suggested. In 2001 a study in north-central British Columbia examined the relationship between spruce beetle and tomentosus root disease (Lewis and Lindgren 2002). The results indicated that tomentosus root disease had a role in maintaining endemic (low) populations of spruce beetle, but at epidemic levels no relationship could be found. Nevertheless, the role of root disease in predisposing the white spruce to beetle attack in the southwest Yukon remained unknown. Determining the incidence and severity of *I. tomentosus* root disease in these beetle-affected stands was a first step in understanding beetle/root disease dynamics in the Yukon, and determining the potential impact of root disease on spruce regeneration.

Methodology

Plot Location

Points of Commencement (POCs) were pre-selected at random from all 1 km Universal Transverse Mercator (UTM) nodes within forested areas. Two of the plots (20 and 30) were accessed by helicopter and two (24 and 25) by boat. Budget constraints did not allow for extensive helicopter use and the remaining plots were accessed by road. For road access plots, only those UTM nodes within 1 km of the closest access point were considered. The map in Figure 2 shows plot locations.

A 5 × 5 cm cedar plot stake was placed in a prominent location at roadside entrance points and helicopter drop-off points. Using a Garmin 12 XL GPS (Geographic Positioning System), the UTM grid coordinates were determined at the stake. Using this coordinate and the POC that had been pre-entered onto the GPS, bearing and distance from the stake to the POC was determined. Plot number, stake coordinates, distance and bearing to the POC were recorded on the stake. No further GPS readings were taken along the traverse. A hand-held compass and standard hip chain were used on the traverse. The plot POC was marked with a steel pin.

Each plot contains four, 4 × 25 m sub-plots. Each subplot covers 100 m^2, with a total plot area of 400 m^2. Plots 1-19, established in the summer of 2000, were linear in layout, with 25 m between subplots. On the advice of ecologist Dr. Fangliang He (formerly of the Canadian Forest Service, Pacific Forestry Centre (CFS/PFC)), who reviewed the methodology in the winter of 2001/02, the subsequent 18 plots established in July 2002 were laid out in the form of a cross with subplots at the end of each arm of the cross. This new, more compact design reduced the chance of encountering more than one forest type within the plot. The intersection point of the arms was at the 12.5 m point between plots (Figure 3). In the linear design all sub-plots were established along the same compass bearing used to traverse to the plot. For those laid out in a cross, the first two sub-plots were aligned with the traverse. Reeled 30-m nylon chains were used for layouts and measurements, with the lie of the chain determining the center-lines of the sub-plots.

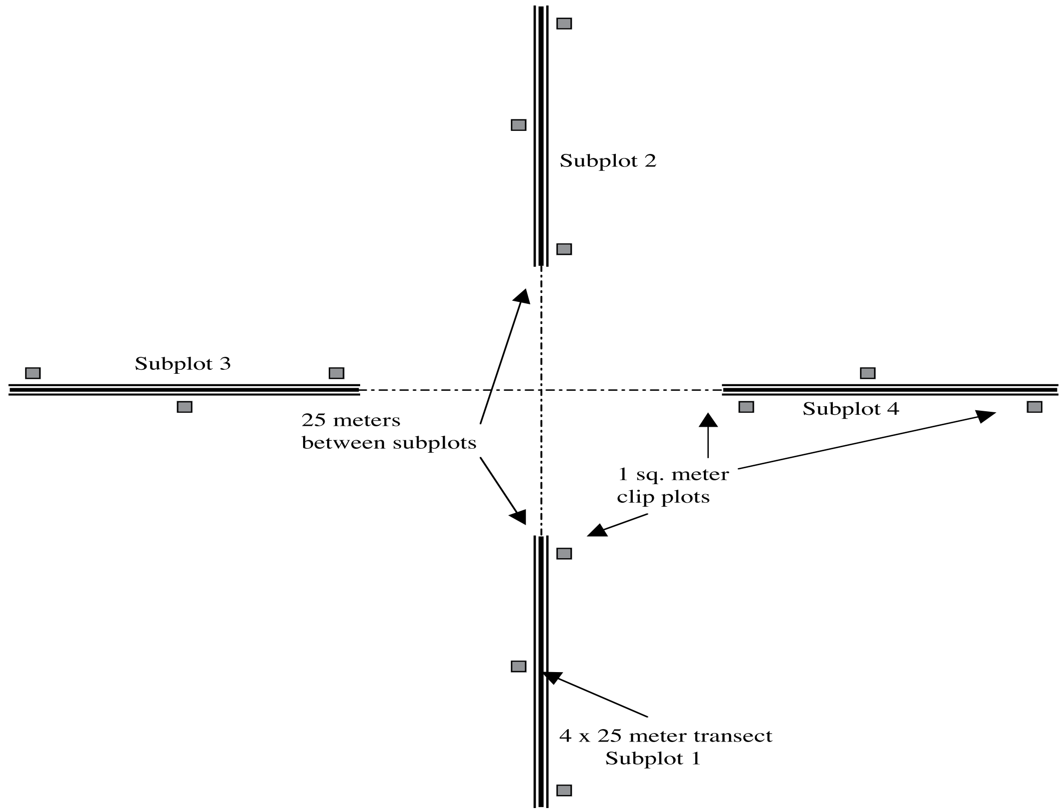

Figure 3. Yukon Forest Health Assessment Plot Layout

Tree data – overstory

All coniferous and deciduous trees over 10 cm in diameter at breast height (dbh) (1.3 m) that fell within 4 × 25 m sub-plots were tallied and diameters recorded. All tallied trees were numbered using tree marking paint. Heights and ages were determined from 12 trees of each major species randomly selected within each plot. Heights were measured with a hypsometer and ages determined by extracting increment cores at breast height. Cores were stored in plastic straws for later examination. Plot averages for these characteristics (white spruce only) are contained in Table 1. All increment core data are contained in Appendix 2.

The attack status with respect to spruce beetle was recorded for each tree as follows:

Healthy – unattacked
Current – attacked and killed in the current year
Red – attacked and killed in the previous year
Grey – attacked and killed two or more years previously
Partial – either currently or previously attacked but not killed
Pitch-out – beetle attacks overcome by tree's defensive resin flow
Dead – by causes other than spruce beetle

A height-diameter curve (Appendix 3) was developed from the tree heights and diameters in all plots. These data were used to calculate individual tree volumes using the whole stem volume equations (next page) developed by the British Columbia Forest Service (British Columbia Forest Service 1976) for white spruce and trembling aspen in forest inventory zones K and L in northern British Columbia.

Whole stem cubic volume equation: (Source: BC Forest Service 1976)

For northern white spruce:

Logarithmic (Log) volume = -4.379777 + 1.78394 × Log D.B.H. + 1.14628 × Log Height

For northern trembling aspen:

Logarithmic (Log) volume = -4.419728 + 1.89476 × Log D.B.H. + 1.05373 × Log Height

Nearest Neighbour Analysis

The species, density and spacial distribution of the overstory and understory trees are key to determining the dynamics within a stand as well as the successional pathway. With the loss or partial loss of overstory trees to the spruce beetle, understory trees assume a more dominant position in the stand, and with increased light, moisture and nutrients, understory trees form the succeeding stand. In some instances, as in Plot 17, where trembling aspen comprised one-third of the overstory, the initial growth release will benefit the aspen, while the white spruce understory will release more slowly.

It became evident during plot establishment that, in some stands, especially those with a deep moss ground cover, conifer regeneration occurred primarily when and where a disturbance such as a wind-fallen tree exposed some mineral soil. In these cases the root pits serve as seedbeds supporting clumps of spruce regeneration. Therefore, despite a high aggregate number of stems per hectare, the trees are often not evenly distributed within the stand. By the time these clumps self-thin and stabilize, only a fraction of the young trees will remain and overall density will be significantly reduced. Current understory tree density, therefore, is not by itself a reliable indicator of future stocking levels. Nearest Neighbour (Clarke and Evans 1954; Byth and Ripley 1980) provides an analysis of the distribution as well as the density of trees in the stands. It measures whether the trees in a particular size class tend towards a clumped, regular (i.e., well spaced), or random distribution. The measurement and analysis was applied separately to three size classes of coniferous and/or deciduous trees. The largest size class represents the overstory. The smaller two size classes represent the first and second stages of overstory recruitment.

The three size classes were:

1. <1.3 m in height (understory)
2. ≥1.3 m in height <10 cm dbh (understory)
3. ≥10 cm dbh (overstory)

Within each 25-m subplot, eight meter-points were randomly selected. The circumference around each point was divided into four quadrants (Figure 4). Using an 8-m carpenter's tape or (if the trees were beyond 8 m) a hypsometer, the distance was measured to the closest tree in each size class in each quadrant. Only living trees were tallied in the two smaller size classes, but in the largest size class, dead as well as living trees were accepted. The 4 m transect width did not apply in this measure, as many of the nearest neighbours were well beyond that distance. A total of 128 (4 quadrants × 8 random points per subplot × 4 subplots) measurements were taken for each of the three size classes for a total of 384 measurements per plot. The data were analyzed using the Point to Event Distance Estimator (Byth and Ripley 1980) (next page) to determine the number of trees per hectare in each size class. The Nearest Neighbour Distance Index (Clarke and Evans 1954) (next page) was then used to determine distribution patterns.

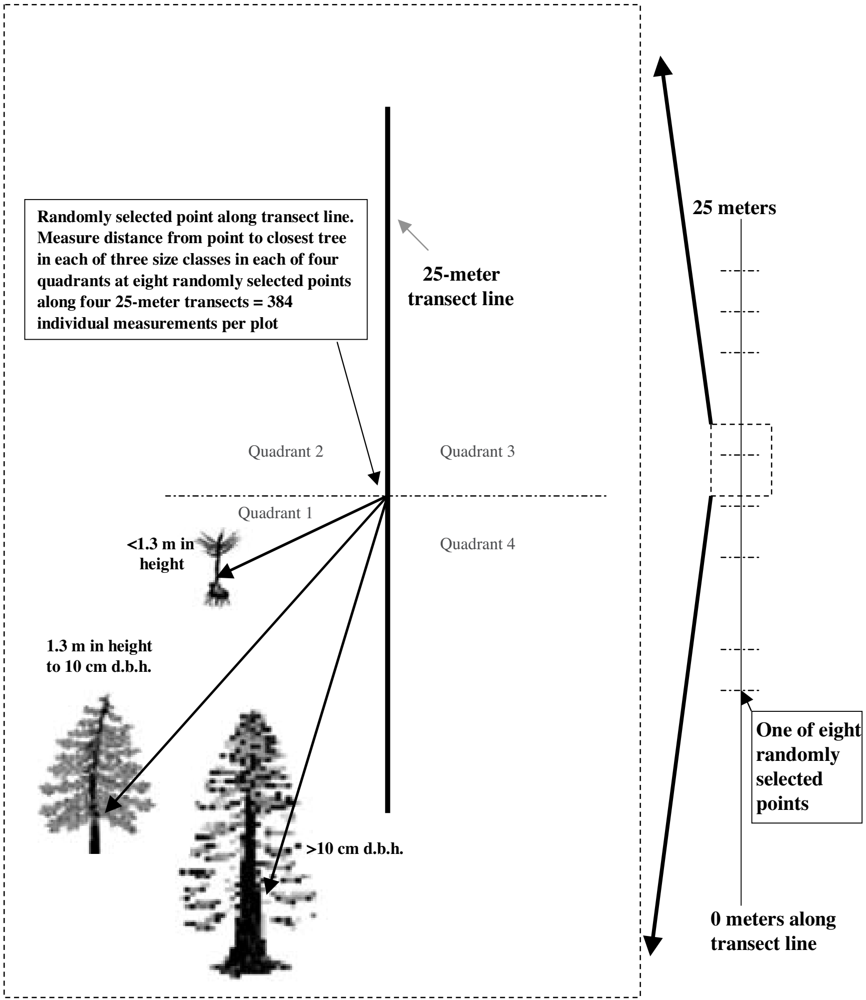

Figure 4. Nearest Neighbour Analysis

Nearest Neighbour Distance Index (Source: Clark and Evans 1954)

R = the nearest neighbour index
r_A = average distance from randomly selected points to their nearest neighbour

$$R = \frac{r_A}{r_E}$$

r_E = expected mean distance between nearest neighbours. Under the Poisson distribution with intensity λ we have:

$$r_E = \frac{1}{2\sqrt{\lambda}}$$

Point-to-Event Distance Estimator (Source: Byth and Ripley 1980)

$$\lambda = \frac{n}{\pi \Sigma r_i^2}$$

λ = Estimate of population density
n = Sample size
r_i = Distance from event *i* to its nearest event

Vegetation – Percent Cover and Biomass Collections

Percent cover

Within-plot ground vegetation assessment methodology followed that was used in a similar study in the Wrangell-St. Elias National Park and Preserve from 1997 to 1999 (Werner and Allen 1999). Vegetation was tallied at every meter point along the 25-m centerline within each of the four sub-plots. If any part of any plant was touched by a thin rod suspended vertically at each meter point, that plant was identified and tallied. Often several species in different strata were tallied at each point. Plant species were identified in the field using the guide "Plants of Northern British Columbia" (MacKinnon et al. 1992). Where identifications, primarily of mosses, lichens and graminoids, could not be made in the field, samples were taken for later expert identification. The results from this analysis were summarized in Table 2.

Shrub biomass

Biomass data was also collected from every vertical shrub (as distinguished from horizontal shrubs like *Empetrum nigrum* and *Arctostaphylos uva-ursi*) along each 4 × 25 m transect line recorded during vegetation point sampling described above. Shrub species included *Shepherdia canadensis, Salix spp, Rosa acicularis, Ledum groenlandicum* and *Betula glandulosa*. Height and crown diameter were measured and recorded. Crown diameter was calculated as the average of two horizontal measurements taken at right angles to one another. For most of the *Shepherdia* and all of the other shrubs, the volume was calculated as if the plants formed a cone, with the average crown diameter as the top, tapering to zero or near zero, depending upon the diameter of the stem at ground level. An exception was made for some of the larger full-crowned *Shepherdia* which were cylindrical rather than conic in shape. For these plants the same average diameter was used for top and bottom for the volume calculation. A shrub volume-to-biomass regression will be developed using data from more than 30 individual shrubs of each species collected from outside the plots. Each extra-plot specimen was measured in the same way and volumes calculated. These volumes will be used as the independent variable of the regression. The extra-plot shrubs were collected (5 shrub species × 30 samples = 150 samples) and later clipped into small pieces, bagged and dried in ovens at 70°C for up to three days to determine dry weights.

Herbaceous biomass

Herbaceous material was sampled from 1-m^2 clip plots offset at 90 degrees, 5 m from the 1-, 12.5- and 24-m points along the transect lines (3 clip plots/subplot = 12 samples per plot). The 1- and 24-m quadrants were offset to the right and the 12.5-m quadrant offset to the left (Figure 4). All herbaceous material including horizontal shrubs, herbs, forbs, and grasses were clipped at the litter surface and bagged as a single sample. Lichens and mosses were collected together in a separate sample. Lichens were clipped at ground level like the herbs while the mosses were torn from the substrate so the sample included the brown lower mass as well as the green upper. Samples were placed in paper bags and clearly labeled as to type i.e., herb or moss, with the plot number, subplot number (1-4), and clip plot number (1-3). For example, a bag marked "herb 15-4-3" indicated a herbaceous collection from plot 15, subplot 4, clip plot 3. If the moss cover was uniform over the whole 1-m^2 clip plot, a sub-sample was collected within a 30-cm^2 quadrant nested within the clip plot. The quadrant frame was placed in the lower corner nearest the transect centerline. Sub-samples were clearly indicated as such on the bag. Each clip plot was photographed. Samples were surface dried in the field, boxed, and sent to the Pacific Forestry Centre in Victoria, British Columbia where they were oven-dried at 70°C and weighed.

Litter biomass

Undecomposed forest litter was collected from 30-cm^2 quadrants at each clip plot (as per the moss sub-sample above). For the purposes of this study, litter was defined as all dead, undecomposed, non-woody organic material. Fine woody debris was sampled using a different protocol, so is not included here. These samples were normally comprised of bark fragments, dead herbaceous material, needles and cones. All woody material was separated from the sample and discarded, either in the field or in the lab. The litter was bagged and the bags marked as per the herb/moss collections. These samples were boxed with the herbaceous material and sent to the Pacific Forestry Centre for drying and weighing. At the same time the "l/moss" (litter and moss as one measure to the base of the green moss layer) and 'fh' (fermentation and humus layers from the top of the brown moss layer to the bottom of the humus) depths were measured and recorded adjacent to each quadrat (12 per plot). The average depth of both l/moss and fh layers for each plot is contained in the plot summaries (Appendix 4).

Fire Hazard Rating and Spot Fire Potential

For the purposes of this study we have three separate protocols to measure fire hazard and one to measure spot fire potential. The first involves the loads of surface coarse and fine fuels which contribute to the chance of ignition and to the intensity of a surface fire. The second involves the tree crown characteristics including the distance from the ground to the base of the continuous crown, crown bulk density and crown vertical continuity. This protocol recognizes that the tree-borne fuels, especially those remaining in recently killed trees, contribute significantly to the laddering potential and intensity of a crown fire. The third protocol, which also contributes to crown fire intensity and spread, is simply the number of dead trees per hectare.

Surface fuels - coarse and fine woody debris

Coarse and fine woody debris were sampled using methodology described by Trowbridge et al. (1987). The diameter of every piece of downed debris over 7.0 cm at the point that it was intercepted by the transect centerline was measured at the centerpoint of interception. The measurements along with the species (if possible – the species was almost always white spruce) were recorded on the data sheet. Stumps and leaning trees were not tallied.

Line intersect pins were placed along the transect line at intervals of 5 m within each of the four subplots in each plot. The fine woody debris was sampled using five size classes >0 ≤7.0 cm in diameter. Only woody debris such as branches and twigs intersected by the plot centerline were sampled. Sampling proceeded as follows:

Size class 1 (> 0 ≤ 0.5 cm) was tallied within the first 5 m only
Size class 2 (> 0.5 ≤ 1.0 cm) was tallied within the first 10 m.
Size class 3 (> 1.0 ≤ 3.0 cm) was tallied within the first 15 m
Size class 4 (> 3.0 ≤ 5.0 cm) was tallied within the first 20 m
Size class 5 (> 5.0 ≤ 7.0 cm) was tallied within the entire 25 m

A "go/no-go" gauge was used to determine the size class of each individual piece. To be tallied, a piece needed to be wood (as in a tree or woody shrub stem, branch or twig), be above the duff layer and have been crossed by the plot centerline. Hence, tree needles and other leaves or parts of herbaceous plants were not tallied. No living materials were tallied. The diameters of each piece of coarse woody debris and the number of intersections in each of the five classes of fine woody debris were entered into the fuel loading program (available from the Fire Research Group at CFS/PFC), which calculated the total fuel volume in m^3/ha and load in tonnes/ha.

Tree fuels

As the study progressed, some of the unusual features of the stands became increasingly evident. Among these was the relative openness of the stands and the tendency for the lower crowns, in many instances, to sweep close to the ground. Another unique feature of these trees compared to those farther south is the network of fine branchlets that are often so dense that they are impenetrable to light. Because of the slow progress of decay, these branchlets are retained and remain highly flammable for many years after the needles have been shed. The potential for surface fires to be laddered upward increases as the gap between the ground and crown fuels is reduced, particularly if branches have sufficient fine branch density and vertical continuity to facilitate surface fire transfer upward into the remainder of the crown. The crown fuel assessment is an attempt to estimate for all living and dead plot trees with dbh over 10 cm, how crown characteristics might influence crown fire development and spread. From these measures, combined with the density of dead trees and the local abundance of surface woody debris, an overall tree fire hazard rating system was developed. It is important to note that the rating system has not been supported by fire behaviour experimentation and as such may not reflect actual fire hazard. It is an estimate of relative hazard only. A stand with a high rating is not necessarily a high fire hazard stand, but is considered to be at a higher hazard than a stand with a lower score.

Another factor in estimating fire behaviour and spread rate is the determination of spot fire potential ahead of the main fire front. Some factors that influence fire behaviour include aspect, slope, relative humidity, rainfall, temperature and wind speed. Since the plots were all on relatively flat ground, slope and aspect adjustments were not factors, and the weather cannot be used as part of a static assessment. Three or four years after trees die they begin shedding their bark. If a high intensity fire occurs while the bark is shedding, loose shards of flaming bark can be caught in the convection column and propelled in advance of the fire front, initiating new fires. We therefore used the number of loose bark trees as our measure of spot fire potential.

Crown base height

The distance in centimeters from the ground to the lowest point of the lowest living or dead branch forming the base of the continuous crown gives a measure of ground fuel proximity. To be considered, a branch must have borne fine fuels in the form of at least tertiary branchlets. These branch selection criteria were fairly subjective, especially in the more marginal situations with older grey trees, and in the more closed canopy stands where lower branches of even living trees had long since been shaded out. Remaining branches may be short with low branchlet density and there may be significant gaps between branches. Judgement must determine the lowest branch with sufficient fine fuel volume to be readily ignited and laddered upward. This distance is recorded on the field forms and later assigned a value of 1, 2 or 3 depending upon the distance. If the distance is ≤ 0.5 m it scored 3. Distances from > 0.5 ≤ 1 m scored 2 and > 1 m scored 1. Photographic examples are included in Appendix 5.

Crown branch density

Coarse and fine branch density is a relative estimate of the overall crown bulk density (loading per unit volume); factors that contribute to crown fuel consumption and crown fire spread. It was also recorded as 1 (low), 2 (moderate) or 3 (high). Examples of all three classes are included in Appendix 5.

Crown vertical continuity

The crown vertical continuity estimate is a measure of the tendency for fire to be laddered upward once it has become established in the lower crown. These are also relative estimates, recorded as 1 (low), 2 (moderate) or 3 (high), and depended on the recorder being familiar with the range of local crown configurations and having some understanding of fire behaviour. To score 3 a tree crown had many branches supporting fine branchlets that would readily ignite as fire moved upward. There must also have been no crown gaps greater than 1 m from the base of the crown to the top. Any lesser condition with coarser fuels or larger crown gaps was scored 2 or 1 depending upon the degree of departure from a crown which scored 3. Examples are included in Appendix 5.

Crown fuel characteristic rating

The numbers assigned to the three characteristics listed above were added and then averaged for each plot. The totals ranged from 3, the lowest hazard, to 9, the highest. These numbers represent relative hazard only and cannot be considered to reflect actual fire behaviour. In the event that a fire is started by lightning or other ignition source, stands with the higher rating are considered to have a higher probability of crown fire development and spread than stands with a much lower rating, especially if they are combined with a high loading of surface woody debris, a high density of dead trees and a high incidence of loose bark. The relative fire hazard ratings and spot fire potential ratings are summarized in Table 3.

Surface woody debris rating

Since most wildfires start as surface fires, the risk of subsequent crown fire activity will be greatly influenced by the amount of woody debris on the forest floor. The greater the load of surface fuel, the greater the possibility that the flames will be laddered upward. The fine and coarse woody debris assessment provided a measure of surface fuel loads for each plot. For the purposes of this study, the amount of surface fuel was assigned a hazard rating on an ascending scale from 1-3. Less than 20 tonnes/ha has been assigned a hazard rating of 1; ≥20<50 tonnes/ha, a 2; and ≥50 tonnes/ha, a 3.

Dead tree density

Crown fire initiation intensity and potential spread rate is greater in the dry crowns of recently killed trees than in live trees. Fire behaviour will, therefore, be influenced by the density of these dead crowns. Dead tree density has been rated on an ascending scale of 1-3. Stands with <500 dead stems/ha of trees ≥10 cm dbh were rated as 1; ≥500<900 dead stems/ha were rated as 2; and ≥900 dead stems/ha, as 3.

Spot fire potential rating

Sloughing bark on dead trees can influence spread rate by causing spot fires ahead of the main fire front. Loose bark incidence was recorded as 1 if there was loose bark, or 0 if there was no loose bark. The stand rating was determined by the percentage of stems/ha with loose bark. Stands with <15% loose-bark trees were given a score of 1; ≥15 <30% loose-bark trees were scored 2 and ≥30% were scored 3. Because the incidence of loose bark was a spot fire potential rating rather than a fire hazard rating it stood alone, while

Crown fuel characteristics[1]

Crown Base	>1m	>.5m≤1m	≤.5 m	subtotals
height	1	2	3	1-3
Crown bulk	low	medium	high	
density	1	2	3	1-3
Crown vertical	low	medium	high	
continuity	1	2	3	1-3

Stand totals

Dead tree density	>0<500	≥500<900	≥900	
stems/ha >10 cm dbh	1	2	3	1-3
Surface woody	>0<20	≥20<50	≥50	
debris (tonnes/ha)	1	2	3	1-3
			total	**5-15**

Spot fire potential rating

Loose bark trees	>0<15	≥15<30	≥30
(% stems >10 cm dbh)	1	2	3

[1] refer to photographic examples in Appendix 5

Figure 5. Fire Hazard and Spot Fire Potential Ratings

the crown and dead woody fuel ratings were combined into a single number. The fire risk and spread potential criteria are summarized in Figure 5.

Soil temperature

Soil temperatures were measured during the month of July using an 'Omega Engineering' electronic soil temperature probe at 5-, 10- and 20-cm depths below the bottom of the litter (or moss) layer. Temperatures were recorded at each of the three clip plots in each of the four subplots. Soil temperatures averaged from the 12 readings at the three depths from each plot are contained in the individual plot summaries (Appendix 4).

Crown closure

Vertical photos for the purpose of determining crown closure were taken adjacent to each 1-m^2 clip plot quadrant within each plot (with the exception of Plot 20). There were, therefore, 12 photos taken per plot. Photos were taken with a digital camera mounted at breast height (1.3 m) on a tripod and fitted with a hemispheric (fisheye) lens. The digital photos were analyzed using Gap Light Analyzer (GLA) imaging software (Copyright 1999: Simon Fraser University, Burnaby, B.C.; Institute of Ecosystem Studies, Millbrook, New York). The software determined the number of pixels of light transmitted above a predetermined level of brightness, as a percentage of a selected circle, the diameter of which extended from the top to the bottom of the photo frame. Because the lens incorporated a 180º field of view, the numbers generated, rather than being an absolute measure of crown openness, are used to compare the openness of stands relative to one other. Representative photos from each plot with the averages and ranges of crown openings are contained in Appendix 6.

Inonotus tomentosus

A survey for the incidence and severity of infections caused by the root disease *I. tomentosus* was carried out in conjunction with the plot surveys. Root rot plots were established adjacent to 9 of the 27 FA plots. The selected plots represented a cross section of climatic regimes from the driest near Kluane Lake to the wettest near Dezadeash Lake.

A single root rot assessment comprised three fixed diameter subplots. Because the assessment employed the destructive sampling of tree roots, it was necessary to avoid disturbance to the FA plots. The three subplots were accordingly offset 25 m. When done in conjunction with linear plots (Figure 6), the first two 25-m offsets were run at right angles from opposite sides of the mid point between FA subplots 2 and 3, and the third was run off the end of subplot 4. When adjacent to FA plots that were laid out in a cross (Figure 7), the three root rot subplots were offset from the ends of FA subplots 2, 3 and 4. The appropriate radius was selected for each subplot to yield approximately 30 trees (i.e., 90 trees per site). The radius was chosen from six radii that represented even fractions of a hectare. It was selected on the basis of the tree density at the first subplot and was used for all three subplots. Only trees ≥10 cm dbh were sampled. All trees within the subplots were flagged and numbered. Diameters were measured and recorded, as was the tree status with respect to bark beetle attack. The six tree status classes employed in the FA plot tree assessment were also used here, with an extra class called "old grey", to differentiate trees that had been beetle-killed early in or prior to the infestation from those killed more recently. If a tree had been dead long enough that the bark was shedding, it was classed as "old grey". This differentiation was applied only to trees killed by spruce beetle.

Four roots from each plot tree were excavated using a pulaski or small mattock. Ideally, selected roots radiated from all four sides of the tree, thereby maximizing the number of contacts with adjacent trees. Excavated roots were sectioned at a point approximately 1 m distal to the bole. Roots were sectioned using either an axe or chain saw and root sections examined for the presence of either rot or the pink stain characteristic of the incipient stage of the disease. The condition of each root section was recorded as either healthy, stained, rotted (*I. tomentosus*) or rotted (not *I. tomentosus*) (Table 4). If the root

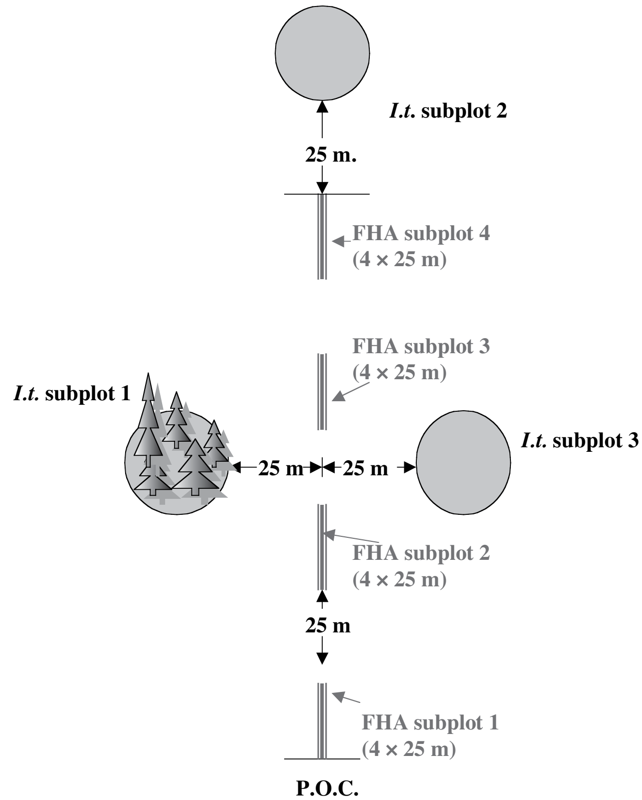

Figure 6. *Inonotus tomentosus* plot locations relative to linear FHA subplots.

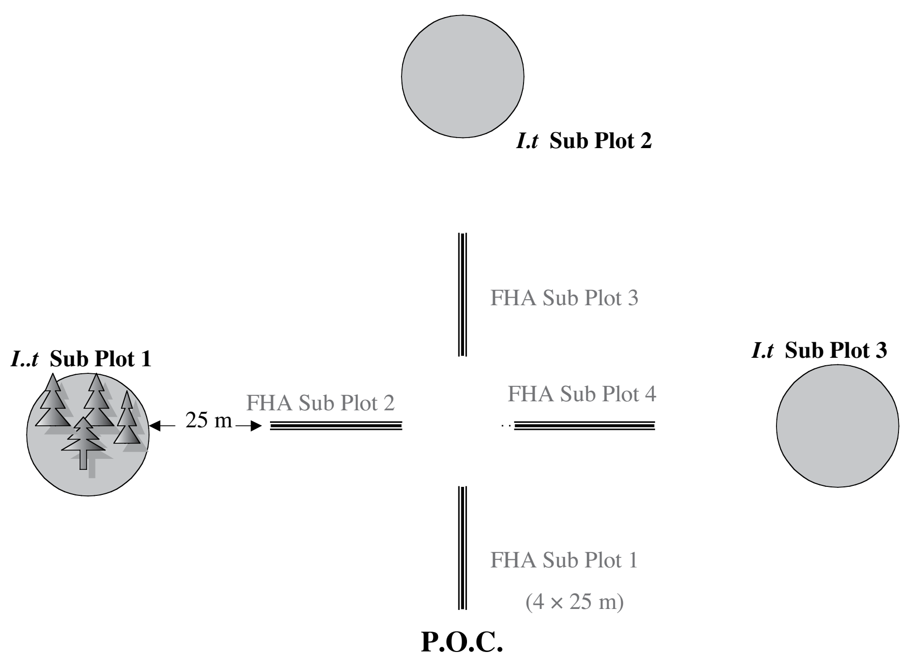

Figure 7. *Inonotus tomentosus* plot locations relative to cross-shaped FHA plots.

section was stained or rotted with the white-pitted rot characteristic o*f I. tomentosu*s, a sample was taken. This involved re-sectioning the root at least 5 cm beyond the first cut, and removing a full section of root as a sample. A felt marker was used to record plot number, tree number and root number both on the root section and on the paper bag in which the sample was stored. To avoid any possibility of cross infection, each bag contained only one root section. So many stained roots were encountered that we eventually imposed a limit of 20 samples per sub-plot. Root samples were later packed into boxes and shipped to CFS/PFC where they were placed in cold storage until such time as they could be cultured. Samples were later removed from cold storage and washed in a bleach solution to reduce surface contamination. Samples were split longitudinally through the heart and, using sterile technique, four slivers of wood were removed from the heart and placed on a petri dish, plated with 2% malt extract agar. The petri dish was then sealed and marked with the plot and sample numbers and set aside at room temperature while the fungi in the wood grew out on the plate. If and when fungi culture from the stained root samples, they will be analyzed using a DNA-specific probe developed at the Canadian Forest Service, Laurentian Forestry Centre in St. Foy, Quebec (Germain et al. 2002). The probe recognizes DNA that is unique to *I. tomentosus*. For the purposes of this report, the presence of the pink stain and/or advanced white-pitted rot were taken to indicate infection by *I. tomentosus*.

Results and Discussion

Data accumulated from 3 years of plot establishment are summarized in Tables 1 to 8. Since this is the first phase of a two-phase project, much of the data gathered constitutes a baseline against which the data from the second assessment, starting sometime after 2010, will be compared. In the intervening years plots will be maintained and the status of the plot trees with respect to spruce beetle attacks, will be periodically updated.

Table 1: Plot location and plot tree data

Plot No.[1]	UTM[2] Zone	Easting	Northing	No. Spruce	No. Deciduous[3]	Avg. dbh[4](cm)	DBH Range	Tree heights (m)[5] Avg.	Range	Tree Ages (yr)[5] Avg.	Range
1	08	372643	6748325	62	1	17.9	10 - 46	19.3	12.8 - 26.9	169	147 - 232
2	08	382429	6748023	35	5	16.3	10 - 36	15.4	11.2 - 23.5	73	51 - 126
3	08	387906	6689450	62	12	17.4	10 - 38	13.4	9.9 - 17.0	146	50 - 229
4	08	373285	6725611	37	11	15.5	10 - 30	11.5	9.1 - 17.1	104	54 - 148
5	08	362332	6741220	72	0	12.3	10 - 33	17.7	14.3 - 23.3	184	135 - 240
6	08	356740	6741531	37	0	22.1	10 - 34	15.9	8.3 - 27.3	99	43 - 158
9	07	624601	6769159	37	0	15.5	10 - 35	10.6	6.5 - 13.5	78	42 - 129
11	08	357080	6745375	67	6	13.4	10 - 27	10.6	8.1 - 11.8	56	44 - 67
14	08	390983	6768965	57	0	15.9	10 -31	14.9	10.7 - 20.6	137	77 - 179
15	08	357411	6740827	43	0	20.7	10 - 57	13.5	8.8 - 18.1	94	56 - 131
16	08	368995	6744148	48	2	17.4	10 - 37	16.7	12.9 - 19.1	121	94 - 161
17	08	382799	6714818	24	13	19.1	10 - 36	12.9	8.7 - 17.2	138	78 - 247
18	08	387072	6702392	24	13	20.8	10 - 43	15.1	7.4 - 19.1	147	95 - 222
19	08	368258	6733013	57	4	14.2	10 - 28	12.5	8.7 - 17.8	172	63 - 316
20	08	350440	6713828	63	0	18.5	10 - 44	12.4	6.9 - 19.1	95	55 - 126
21	08	371072	6728790	51	24	18.2	10 - 35	15.4	6.8 - 20.1	115	85 - 153
22	08	387068	6690251	34	0	18.7	10 - 34	15.5	9.4 - 17.6	186	78 - 247
23	08	353487	6741264	28	0	26.2	12 - 47	16.8	9.4 - 20.8	110	31 - 169
24	08	359547	6688742	62	3	14.5	10 - 44	9.2	8.3 - 11.9	77	43 - 99
25	08	361460	6687212	45	0	16.0	10 - 35	11.4	7.8 - 15.4	125	73 - 157
26	08	373569	6690230	19	9	16.7	10 - 29	12.2	7.4 - 17.7	121	80 - 194
27	08	348564	6732175	30	0	24.4	10 - 37	13.6	8.9 - 15.3	69	53 - 97
28	07	641810	6775114	53	0	20.2	10 - 34	15.2	9.9 - 20.5	135	66 - 163
29	07	641131	6783071	27	0	12.6	10 - 23	9.9	8.1 - 12.9	78	65 - 86
30	08	341353	6737053	31	0	17.8	10 - 38	14.7	8.2 - 17.8	133	120 - 145
31	07	630659	6781454	34	0	24.4	10 - 43	16.9	9.5 - 23.5	230	90 - 356
32	07	642840	6767964	88	0	18.2	10 - 31	15.5	7.7 - 21.4	256	139 - 293
			Average			18.0		14.0		128	
			Standard deviation[6]			±3.53		±2.55		±48.6	

[1] Plots 1-19 assessed in 2000, Plot 20 in 2001 and the remainder in 2002.

[2] Universal Transverse Mercator grid system.

[3] Trembling aspen (with the exception of plot 18 which contained, in addition to aspen, seven balsam poplar, *Populus balsamifera* and five willows, *Salix glauca*.

[4] Diameter at breast height (1.3 m) of spruce and deciduous spp. ≥ 10 cm dbh.

[5] All increment cores taken at breast height. See Appendix 2 for all increment core data. Tree heights and ages are for white spruce only.

[6] 95% confidence limit.

Table 2. Percent cover of surface vegetation by species, within each plot

Species	Common Name	Plot number: 1	2	3	4	5	6	9	11	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Arctostaphylos rubra	alpine bearberry			4	1	7			1	1						1				1						3		
Arctostaphylos uva-ursi	bearberry		3	12	40				2			2	8		5	2										7		29
Empetrum nigrum	crowberry			10	11	2							28		64			50		9	18	45						
Betula glandulosa	scrub birch			7									3		8			12			30			17				
Ledum groenlandicum	Labrador tea												2					13										
Rosa acicularis	prickly rose	1	9		2	2	2					4	3	14		1	3		7	2	3	1						
Salix spp	willow			3	3		1		2			2	10	2	9	24		18	6	6	11	2	2			1		
Sheperdia canadensis	soapberry		1	4	2			7	1			1	1	38			21		3	2							1	
Vaccinium spp												3	29	6	2							6						
Vaccinium vitis-idaea	lingonberry												6					18		4	11	5						
Arnica cordifolia	Arnica			10	5								10			2												
Cornus canadensis	bunchberry			26	5								13	8				9		31	19	27						
Geocaulon lividum	commandra	5		2	14												5	19		11		5				2	23	
Linnaea borealis	twinflower	11	11	19	21				14	4		26	23	20	11	2	9	10	25	11	1	17	46	28				
Lupinus arcticus	arctic lupine	4			8		5	1	8		1		17	2	3	9	2	1	2	2		8					18	
Mertensia paniculata	bluebell	2	1			2								6		36	8	1	4	3		4	8	1		4		
Hylocomium splendens	step moss	81	6	35	5	66	23	1		68		60	3	31	73			11									70	
Pleurozium schreberi	feather moss							14	5							22	9	49		13	18	52		68	46			38
Cladonia borealis	red pixie cup			1	1																							
Cladonia gonecha															4													
Cladonia pyxidata	pixie cup lichen				1																							
Peltigera spp						1		2	3		1														1		2	
Peltigera aphthosa	freckled lichen	7	14	3	1	7	10	2	8	15	7	1	3	1	10		3	2		1				4	1	2		

Table 3. Relative fire hazard rating and spot fire potential

	Crown characteristic ratings[1]										
Plot No.	Crown base height	Fine branch density	Vertical continuity	Sub-total	Woody fuel loading[2]	No. dead spruce/ ha[3]	Dead tree rating	Total	Fire hazard rating[4]	loose bark (%)[5]	Spot fire potential[6]
1	1.48	1.67	1.80	4.95	1	900	3	9.0	2	14	1
2	2.94	2.17	2.34	7.46	1	275	1	9.5	3	0	1
3	1.83	1.67	1.88	5.38	2	1000	3	10.4	4	42	3
4	2.19	2.11	2.42	6.72	1	350	1	8.7	2	8	1
5	1.22	1.15	1.11	3.49	1	675	2	7.5	1	39	3
6	2.17	2.30	2.39	6.87	1	550	2	9.9	3	17	2
9	2.94	2.65	2.74	8.32	1	275	1	11.3	5	0	1
11	2.98	2.49	2.54	8.02	1	475	1	11.0	5	1	1
14	2.15	1.82	2.06	6.03	1	475	1	8.0	2	28	2
15	2.49	2.79	2.70	7.98	1	350	1	10.0	3	21	2
16	1.36	1.45	1.53	4.34	2	300	1	7.3	1	18	2
17	1.88	1.79	1.88	5.54	1	425	1	7.5	1	22	2
18	1.16	2.50	2.44	6.10	3	175	1	9.1	3	3	1
19	1.24	1.36	1.83	4.43	1	525	2	7.4	1	27	2
20	2.43	2.20	2.21	6.84	2	1025	3	12.8	5	33	3
21	2.10	1.50	2.12	5.71	1	900	3	9.7	3	12	1
22	2.45	2.00	2.33	6.79	1	475	1	8.8	2	47	3
23	2.70	1.85	2.19	6.74	3	1000	3	12.8	6	43	3
24	2.95	1.98	2.38	7.32	1	350	1	9.3	3	6	1
25	2.53	1.63	2.30	6.47	2	550	2	11.5	4	22	2
26	2.67	1.94	2.39	7.00	2	175	1	10.0	4	0	1
27	2.53	2.13	2.60	7.27	1	475	1	9.3	3	30	2
28	2.38	1.98	2.44	6.79	1	1050	3	10.8	4	63	3
29	2.70	2.07	2.52	7.30	1	575	2	10.3	4	4	1
30	2.16	2.00	2.68	6.84	1	525	2	9.8	3	52	3
31	1.44	2.00	2.28	5.72	2	250	1	9.7	3	26	3
32	1.89	2.04	2.72	6.64	2	1775	3	11.6	5	74	3

1 Averaged for all plot trees on an ascending scale from 1 (low) to 3 (high). Crown base height based upon distance from ground to crown base. Density and vertical continuity were assessed subjectively.

2 from Table 8: < 20 tonnes/ha = 1; ≥ 20 < 50 = 2; ≥ 50 = 3

3 1 = < 500; 2 = ≥ 500 < 900; 3 = ≥ 900.

4 < 8 = 1; ≥ 8 < 9 = 2; ≥ 9 < 10 = 3; ≥ 10 < 11 = 4; ≥ 11 < 12 = 5; ≥ 12 = 6

5 Percentage of white spruce in the stand with loose bark

6 > 0 < 15% = 1; ≥ 15 < 30% = 2; ≥ 31% = 3

Table 4. Incidence of root disease *Inonotus tomentosus (I.t.)* in white spruce roots

Plot No.	Location[1]	No. trees assessed	Root Condition (%)[2]			
			Healthy[2]	Stained[2]	Advanced (*I.t*)[2]	Rotted (not *I.t.*)[2]
31	Congdon Creek	84	76.7	21.1	0	2
9	Silver Creek	75	84	14.7	0	1
16	Macintosh south	125	45.7	41.4	5.7	5
1	Marshall Creek	128	41.3	42.8	0.08	19
15	Pine Lake	71	66.4	24.8	0.08	9
19	7.5 km -S- of H.J.	81	28.4	59.2	0	10
21	Quill Cr (-S-)	92	62	32.6	0	6
26	Mush Road	69	15.9	78.3	0	4
22	Dezadeash Lake	96	9.4	68.8	1	19
	average	91	39.2	40.3	0.8	8.1

[1] listed in order from north to south, roughly corresponding to the precipitation gradient from driest to wettest.

[2] where possible four roots were assessed per tree.

1 = Healthy (all four roots)
2 = One or more roots with stain characteristic of *I. tomentosus*
3 = One or more roots with advanced rot characteristic of *I. tomentosus*
4 = One or more roots rotten (not *I. tomentosus*)

Table 5. Density and distribution of white spruce and deciduous species by canopy strata using Nearest Neighbour Analysis

	Stand Density (stems/ha)			Distribution[1]		
Plot No.	>0≤1.3 m in height	>1.3 m in height <10 cm dbh[2]	≥10 cm dbh	>0≤1.3 m in height	>1.3 m in height <10 cm dbh	≥10cm dbh
1	717	641	1252	0.82	1.32	1.14
2	434	724	891	1.02	0.72	1.01
3	533	650	1519	0.74	0.70	0.79
4	2006	1280	1284	0.87	0.68	0.66
5	2198	608	1389	0.78	1.24	1.12
6	558	435	895	1.21	0.87	1.03
9	877	1248	424	0.38	0.64	0.96
11	250	1215	1492	0.55	0.65	0.90
14	490	775	1001	0.79	0.70	1.03
15	534	714	923	0.90	1.17	1.20
16	1263	767	1036	0.80	0.75	0.88
17	1111	753	845	0.95	0.82	1.06
18	177	183	711	0.75	1.78	1.09
19	2415	2900	1013	0.95	0.97	0.85
20	250	324	513	1.03	1.06	0.83
21	546	188	1194	0.85	1.08	1.21
22	197	179	693	1.23	0.94	1.18
23	92	42	615	0.86	1.44	1.29
24	1025	1414	901	0.49	0.57	0.92
25	1069	1394	674	1.06	0.96	1.03
26	1343	2454	863	0.57	0.88	1.15
27	334	180	664	0.99	0.83	1.09
28	889	796	1017	1.10	0.99	0.65
29	88	2724	407	1.07	0.68	0.74
30	826	148	523	0.79	0.99	0.88
31	1081	310	795	1.44	1.16	0.77
32	881	142	1759	0.65	0.86	1.12
Average	822	859	937	0.88	0.94	0.99

[1] Values approachng 1.0 indicate a random tree distribution
Values >1.0 indicate an increasingly regular distribution
Values <1.0 indicate an increasingly clumped distribution.

[2] diameter at breast height (1.3 m)

Table 6. Stand density and volume of white spruce and deciduous spp.

Plot No.	Stand density (stems/ha)			Volume (m^3/ha)[1]		
	Spruce	Deciduous	Total	Spruce	Deciduous[2]	Total
1	1550	25	1575	368.0	0.0	368.0
2	1000	0	1000	149.8	0.0	149.8
3	1550	300	1850	240.2	40.4	280.7
4	925	275	1200	101.3	18.7	119.6
5	1800	0	1800	361.3	0.0	361.3
6	925	0	925	283.9	0.0	283.9
9	925	0	925	119.1	0.0	119.1
11	1675	150	1825	104.5	4.7	109.2
14	1475	0	1475	204.1	0.0	204.1
15	1075	0	1075	288.4	0.0	288.4
16	1200	50	1250	223.5	23.8	247.3
17	600	325	925	87.6	83.7	171.3
18	600	325	925	293.0	52.8	345.8
19	1425	100	1525	122.3	12.9	135.2
20	1575	0	1575	262.8	0.0	262.8
21	1275	600	1875	235.7	70.8	306.5
22	850	0	850	174.1	0.0	174.1
23	700	0	700	269.8	0.0	269.8
24	1550	75	1625	169.6	43.5	213.1
25	1125	0	1125	117.8	0.0	117.8
26	475	225	700	284.3	64.2	348.5
27	750	0	750	192.0	0.0	192.0
28	1325	0	1325	246.9	0.0	246.9
29	675	0	675	37.6	0.0	37.6
30	775	0	775	136.4	0.0	136.4
31	850	0	850	309.4	0.0	309.4
32	2200	0	2200	442.3	0.0	442.3

[1] All tallied trees (white spruce and deciduous trees) ≥ 10 cm in diameter at breast height were included (both living and dead).

[2] 90%+ trembling aspen; <10% balsam poplar

Table 7. Volume (m^3/ha) of white spruce in each spruce beetle attack category

Plot no.	Year assessed	Total	Spruce beetle attack category						
			Healthy[1]	Current[2]	Red[3]	Grey[4]	Partial[5]	Pitch-out[6]	Dead[7]
1	2000	368.0	186.4	50.6	0.0	55.9	47.0	0.0	28.1
2	2000	139.0	135.7	0.0	0.0	3.4	0.0	0.0	0.0
3	2000	240.0	115.0	0.0	0.0	125.0	0.0	0.0	0.0
4	2000	101.3	63.7	9.5	0.0	28.0	0.0	0.0	0.0
5	2000	361.3	91.9	50.2	0.0	176.9	42.4	0.0	0.0
6	2000	283.9	29.5	72.8	37.4	131.8	12.4	0.0	0.0
9	2000	119.1	57.6	23.9	23.0	12.0	2.6	0.0	0.0
11	2000	104.5	51.9	20.6	7.7	10.0	14.3	0.0	0.0
14	2000	204.1	146.4	0.0	6.7	48.4	0.0	0.0	2.6
15	2000	288.4	27.9	33.5	0.0	169.8	46.7	0.0	10.7
16	2000	223.5	135.4	0.0	0.0	84.6	3.5	0.0	0.0
17	2000	87.6	30.4	14.5	0.0	41.2	1.5	0.0	0.0
18	2000	293.0	182.1	16.7	0.0	88.3	5.9	0.0	0.0
19	2000	122.3	61.2	4.0	0.0	54.9	2.3	0.0	0.0
20	2000	262.8	48.5	0.0	0.0	199.7	0.0	0.0	14.6
21	2002	356.8	124.2	71.4	29.9	79.5	42.8	0.0	9.0
22	2002	174.1	48.1	0.0	0.0	109.0	17.0	0.0	0.0
23	2002	269.7	19.4	3.8	0.0	174.8	0.0	64.6	7.3
24	2002	169.6	64.2	18.7	19.2	44.9	14.2	8.5	0.0
25	2002	117.8	14.1	10.6	1.3	57.1	16.0	18.8	0.0
26	2002	284.3	41.7	40.2	1.3	121.5	41.3	38.4	0.0
27	2002	192.0	15.1	17.7	0.0	125.8	0.0	33.5	0.0
28	2002	246.9	14.1	0.0	9.8	202.7	0.0	14.8	5.5
29	2002	50.2	13.2	13.1	0.9	0.0	7.8	14.1	0.9
30	2002	136.4	20.4	4.6	1.6	109.7	0.0	0.0	0.0
31	2002	327.3	212.5	26.2	0.0	19.5	0.0	0.0	69.1
32	2002	442.4	49.6	10.0	6.1	317.5	4.5	14.6	40.1

[1] includes deciduous volume

[2] killed by beetles in the current year

[3] killed by beetles in the previous year

[4] killed by beetles two or more years ago

[5] attacked by beetles but not killed

[6] beetle attack repelled by tree defenses

[7] killed by agent other than spruce beetle

Table 8. Fuel loads (tonnes/ha) of woody debris by size class[1]

Plot No.	Fine >0 ≤.5 cm	>.5 ≤1.0 cm	>1 ≤3.0 cm	>3 ≤5.0 cm	>5 ≤7.0 cm	total ≤ 7 cm	Coarse total >7cm	Total fuel load
1	0.31	0.67	0.79	0.47	1.21	3.45	9.78	13.23
2	0.42	0.59	2.58	1.66	1.61	6.86	11.21	18.07
3	0.31	0.64	1.76	0.71	0.81	4.23	22.47	26.70
4	0.15	0.32	0.92	0.96	2.23	4.58	0.47	5.05
5	0.9	1.71	2.24	0.81	0.2	5.86	18.98	24.84
6	0.55	0.67	0.88	0.7	0.2	3	3.9	6.90
9	0.33	0.66	2.12	2.87	3.65	9.63	23.42	33.05
11	0.24	0.85	2.73	0.82	0.6	4.74	18.63	23.37
14	0.72	0.92	1.66	0.59	0.8	4.69	10.28	14.97
15	0.59	0.37	0.89	1.06	0.6	3.51	13.13	16.64
16	0.33	0.48	1.08	1.2	2.84	5.93	17.48	23.41
17	0.13	0.29	0.82	0.6	1.01	2.85	2.41	5.26
18	0.49	0.99	2.47	1.31	2.43	7.69	41.04	48.73
19	0.26	0.23	0.6	0.48	1.42	2.99	2.08	5.07
20	5.69	0.66	3.03	0.93	1	11.31	28.99	40.30
21	0.25	0.68	2.1	2.5	1.97	7.5	1.84	9.34
22	0.19	0.44	0.63	0.83	0.4	2.49	16.57	19.06
23	0.62	1.33	2.75	5.38	4.05	14.13	56.82	70.95
24	0.41	0.21	1.62	0.72	1.22	4.18	6.13	10.31
25	0.24	0.41	1.29	0.48	1.62	4.04	26.25	30.29
26	0.21	0.25	0.47	1.91	1.81	4.65	22.28	26.93
27	0.12	0.36	1.73	1.2	0.41	3.82	0	3.82
28	0.42	0.54	1.09	1.29	0.4	3.74	9.67	13.41
29	0.48	0.54	1.71	0.25	1.21	4.19	14.26	18.45
30	0.76	0.77	2.36	0.23	0.2	4.32	6.07	10.39
31	0.26	0.79	1.81	0.83	0.2	3.89	40.03	43.92
32	0.32	1.07	1.94	0.59	2.02	5.94	15.99	21.93

[1] size classes based on Trowbridge et al. (1987)

Stand Succession

Within most of the study area, current beetle activity has diminished or abated (Garbutt 2003, 2004). In these stands some stability has been re-established and it is possible, using the data from the first stage of the assessment, to make some predictions regarding future forest structure in the wake of the spruce beetle outbreak. At the time this report was written the infestation continued unabated in the southern Shakwak Valley and southern portions of Kluane National Park. Stands with ongoing beetle activity are still undergoing adjustments to overstory density so the degree of structural change has not yet been established. It is clear, however, that whatever the paths of succession following the infestation, even in the absence of another major disturbance such as fire, the process will take many years.

Trees in the Yukon grow slowly and there is a tendency, particularly in the more open stands, toward the development of dense crowns with branches supporting networks of finer branchlets. It is also common for these crowns to extend to within a meter of the ground. Approximately a year after being killed by spruce beetles the trees undergo a 'primary thinning' when they lose their needles. There is, no doubt, an initial increase in light penetration following needle drop, but it is only following 'secondary thinning', the slow progressive shedding of the branchlets, that more light will penetrate to the understory. From the evidence provided by trees that died prior to the spruce beetle outbreak and have shed their branches, the process is driven not by decay, but by wind breakage which results in a significant increase in fine woody debris beneath the remaining crown. To realize the purpose of this study, which is to measure vegetative response in the wake of the spruce beetle infestation, we may have to wait 10 years or more before we see a response in the understory trees and measurable changes in ground vegetation patterns.

Aside from residual overstory density, the most important factor determining future stand structure is the health, density and distribution of the treed understory. A large range in understory (<10 cm dbh) tree density (134 stems/ha in plot 23 to 5315 stems/ha in plot 19), a tendency toward a clumped distribution (Nearest Neighbour Analysis distribution value <1 in 2/3 of the plots), and the slow growth rates will all influence the time required for these trees to become part of the overstory. Tree seedling germination most frequently follows a disturbance that bares mineral soil, and, where there is an opportunity for one seedling to be successful, there are often many more. Over time, competition thins the clumps of young trees and determines the spacing, tending toward a more random distribution in the sapling stage. The current living and dead overstory had a smaller range of densities (424 to 1519 stems/ha) and, on average, a near random distribution (0.975), though this was not necessarily reflected in individual stands which ranged from strongly clumped (0.594) in Plot 19 to a much more regular distribution (1.293) in Plot 23.

Modeling of stand dynamics would be needed to predict future stand structures. This would be an ambitious undertaking involving detailed stem analysis and destructive sampling that is beyond the scope of this project and report. Also, we have been witnessing for more than 20 years the accelerated effects of climate moderation, in particular the increased temperatures during the growing season that were largely responsible for the spruce beetle outbreak (Whitfield et al. 2002; Dr. Ed Berg, pers. comm.). There are no reliable current data to predict how these changes will affect the composition and growth rates of future stands. Instead, we will need to wait for the second assessment at some undetermined future date.

Fire Hazard

The spruce beetle epidemic has contributed significantly to the fire hazard by increasing surface and crown dead woody fuel loads. The dry climate and the resultant low moisture content of the surface woody fuels, combined with low crown base heights, has created an increase in probability of ignition and potential for crown fires. There was a wide range of surface fine and coarse woody fuel loading (4-71 tonnes per hectare), reflecting the variability in stand ages and resultant levels of self-thinning as well as blowdown, breakage and dead crown breakdown. The highest surface fuel loading was in Plot 23 near the mouth of the Alsek River, one of the earliest infested by the spruce beetle and an area that experiences strong, gusty outflow winds from the Alsek River valley. The second highest, at 48.7 tonnes/ha, was Plot 18 which was near the center of the previous spruce beetle outbreak in the late 1930s and early

1940s. Other plots with high levels included Plot 31 which was among the oldest (average tree age 230 years) with a high incidence of heart rot, and Plot 20 which was also among the earliest beetle infested, having a relatively high dead white spruce tree density and also subject to the Alsek River winds.

The crown fuel assessment portion of the fire hazard rating indicated that most trees had crown base heights less than 1 m above the ground, moderate to high fine branch density, and a high degree of crown vertical continuity from base to top. Also, there were many white spruce with loose bark creating a high spot fire potential. The density of dead white spruce crowns varied widely among the plots due in part to variation in spruce beetle attack intensities, but also because the infestation was ongoing while assessments were being made. In southern areas such as Mush Lake and south of Dezadeash Lake, the majority of infested trees were killed after plot establishment so the number of dead trees is now far greater. The distribution of fine fuels will change slowly in the coming years as the fine branchlets break off and fall to the forest floor. While thinning within the crowns will decrease the crown fire initiation and spread rates, it will increase the fine woody fuel load beneath the trees. Eventually the crowns will thin to the point that the decrease in crown vertical continuity and risk of crowning will be greater than the increased hazard represented by the accumulation of surface fuels, and the risk of fast-spreading crown fire will decrease accordingly. The maximum surface fuel loading, however, will occur as the standing dead trees fall. After almost 70 years, nearly all trees killed by the late 1930s and early 1940s outbreak are now on the ground, but the clear etching of spruce beetle galleries on the boles testify to the slow progress of decay (in spite of this being the wetter end of the study area). It could be 30 years before the trees begin falling, although the process may begin sooner in stands in and adjacent to the mouth of Alsek that are subject to the strong southwest winds. The period of fall-down will be documented by future measurements in the FA plots. If most or all of the mature spruce trees die in the current outbreak and fall, plot stem volumes indicate future surface coarse woody fuel loadings could increase by as much as 200 tonnes/ha.

The slow progress of decay also ensures that the elevated fire hazard, represented by the suspended fine fuels and the additional needle tinder on the forest floor, will remain for many years. If, during this period, a lightning strike ignites the surface fuels in an area of moderate to high spruce beetle mortality, and the surface fire is intense enough to ignite the tree crowns, a wildfire of exceptional intensity is almost certain to follow. In that event an entirely new successional study would need to be undertaken.

Root Disease

The root disease survey was undertaken in response to concerns that *I. tomentosus* was contributing to the severity of the spruce beetle epidemic by predisposing the white spruce to attack. The survey found that less than 1% of the trees exhibited signs of an advanced stage of the disease while 40.3% had root staining characteristic of the incipient stage of the disease (Table 4). None of the still living trees (i.e., unattacked by spruce beetle) exhibited any crown symptoms that would suggest that their growth was affected. There was no evident difference in the incidence of either advanced disease or root staining between un-attacked trees and ones killed by beetles. Eliminating all trees <15 cm dbh which could bias against attack by beetles (beetles prefer the larger trees) and could bias for infection (due to stress caused by suppression), a total of 254 trees in the plots had been killed by spruce beetles and 173 were healthy. Of the spruce beetle-killed trees, 49.6% had at least one stained root while the remaining 50.4% were free of symptoms. Of the healthy trees, 51.4% were stained and 48.6% were symptom free. The disease survey results strongly suggest that *I. tomentosus* has had little or no role in predisposing the white spruce to attack by the spruce beetle. There was, however, a difference in the frequency of root staining between the dry northern part of the survey area and the much wetter south. The two plots near Kluane Lake (Congdon Creek and Silver City) averaged a 20% incidence compared to an average of 74% at plots near Mush and Dezadeash lakes.

The Future

The warming climate and resulting spruce beetle epidemic have served to severely disturb forested stands in the southwest Yukon, and the ongoing influence of these two conditions means that the historical pattern of spruce-to-spruce succession is no longer guaranteed. One of the most striking and important characteristics of the relatively open white spruce forests in the north is the tendency for the trees to support dense networks of fine branchlets. Even after the trees have died and shed their needles the dense crowns are retained and light penetration to the forest floor remains limited. Only when the branchlets are finally shed will the successional changes brought by the death of the overstory become increasingly evident and measurable. It is the shedding of these branchlets, therefore, that will determine the timing of the second round of assessments. We had hoped to begin the second round as early as 2010, beginning in plots that were affected early in the infestation. However, an examination of trees in Plot 23 that have been dead for 10 years showed little change in crown bulk densities. Most of the other plots were infested more recently and it is now anticipated that the second round may be delayed to as late as 2015. We hope the value of the information obtained from the second round will inspire a third in about 2025 to further track the restructuring of the stands and monitor the effects of increased woody debris as the crowns are shed and the trees begin to fall out of the canopy to become surface woody debris. Meanwhile selected plots will be monitored periodically to update overstory condition.

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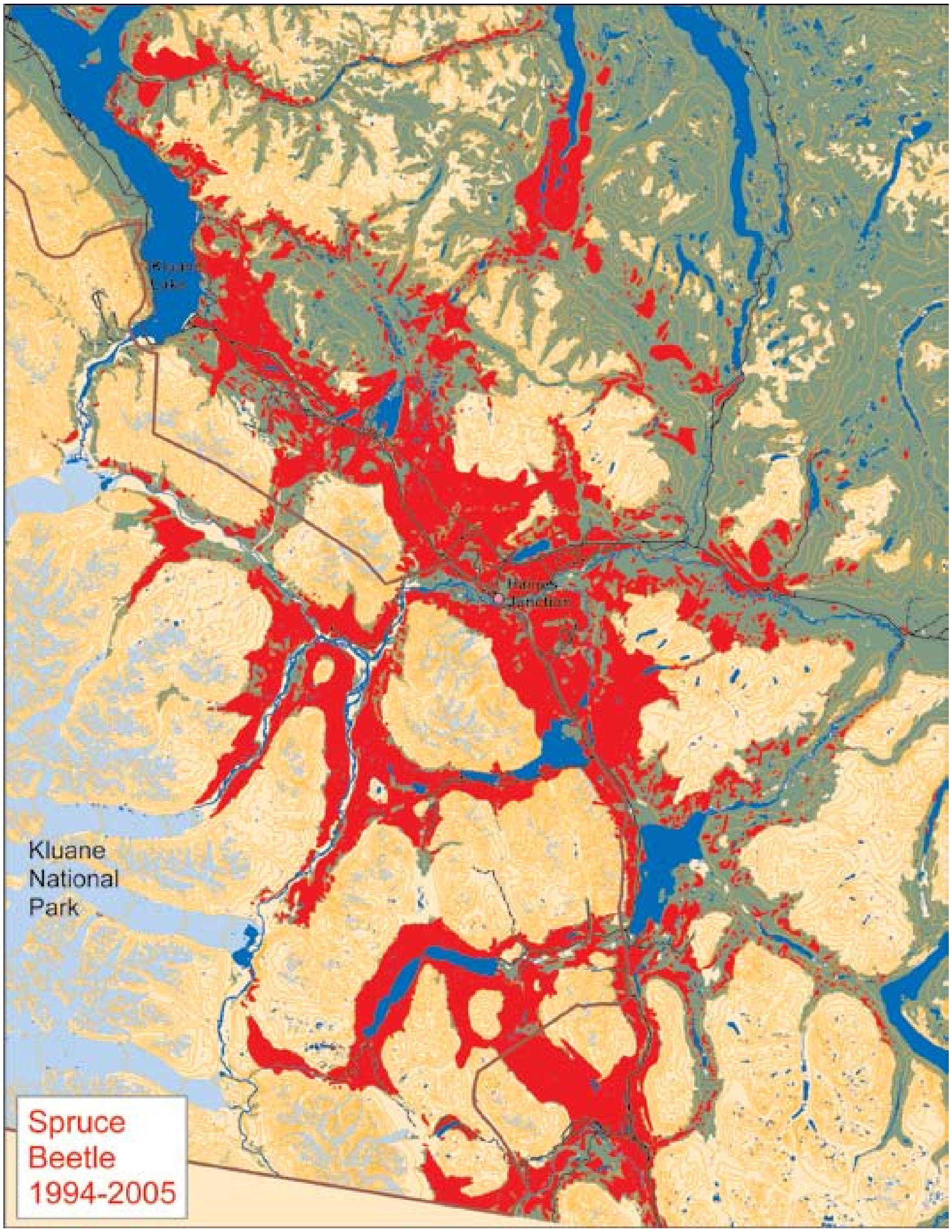
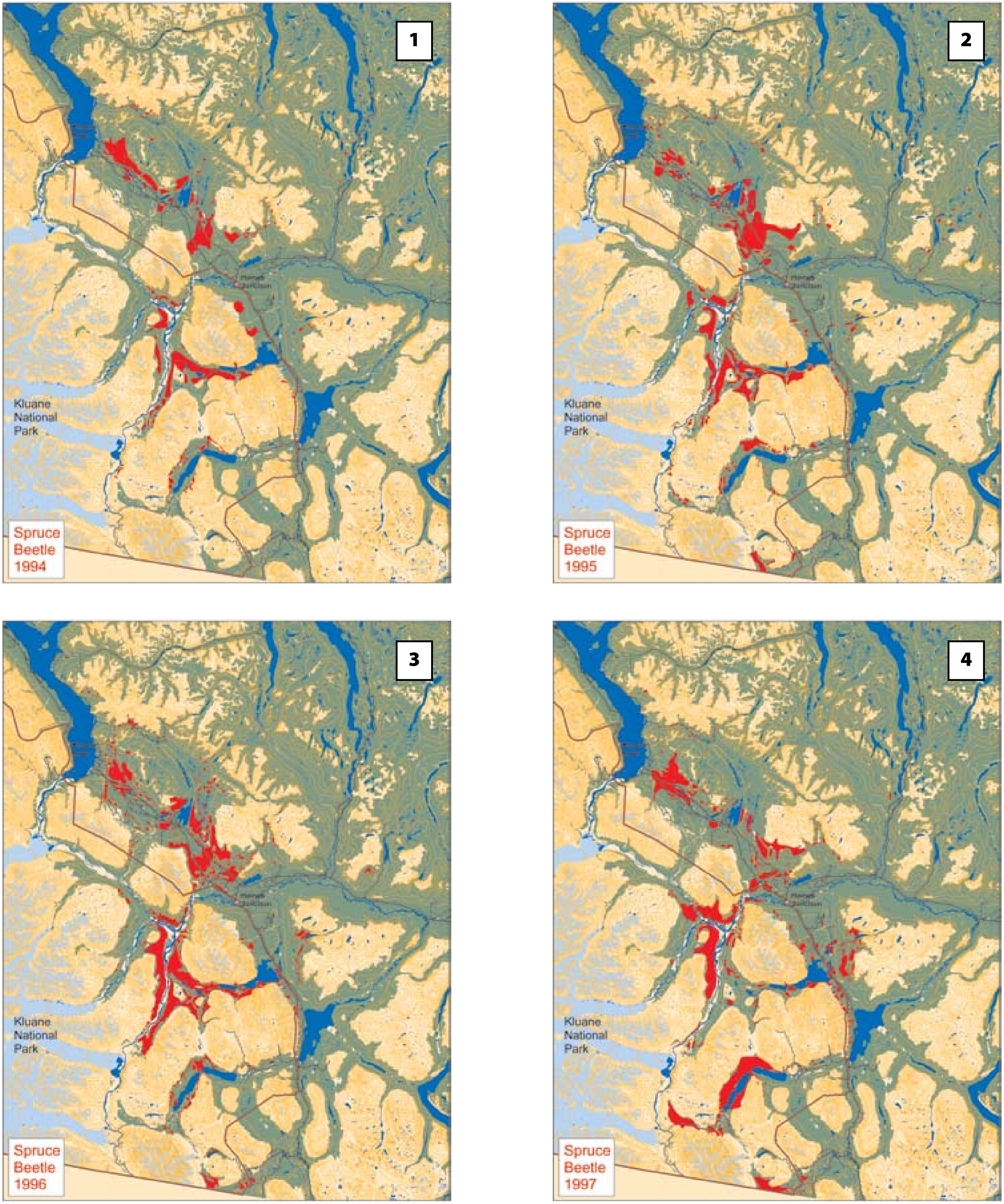
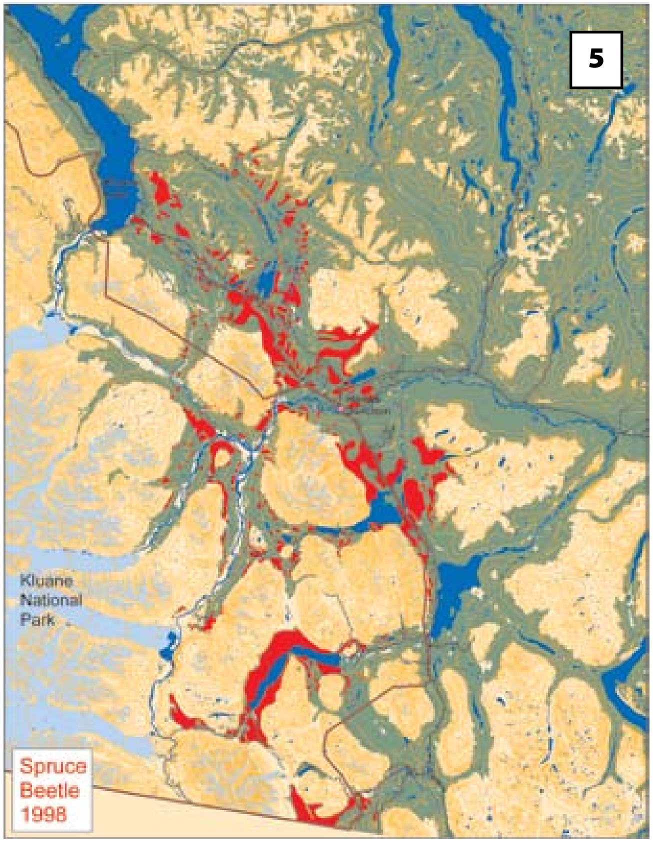
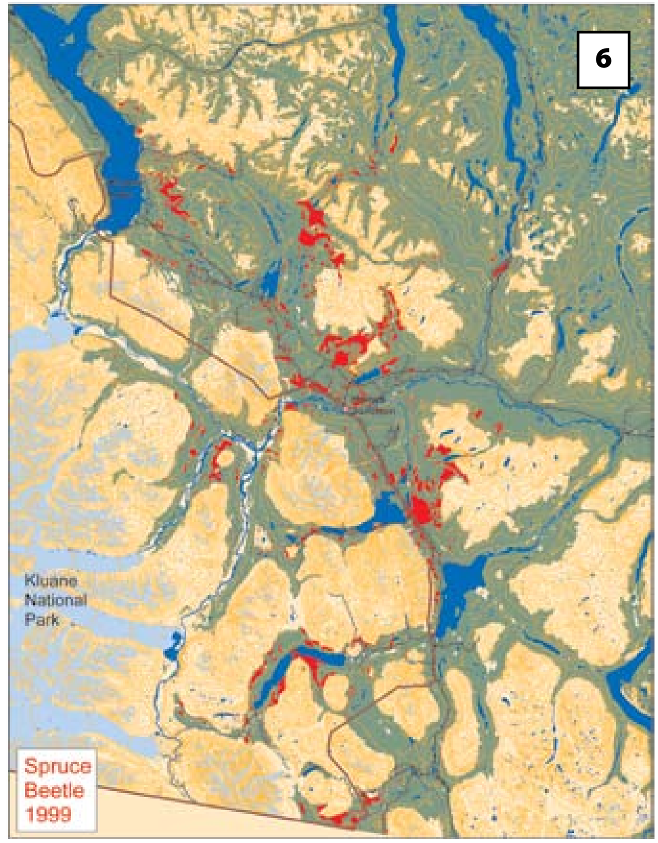
Appendix 1. Spruce beetle damage over time

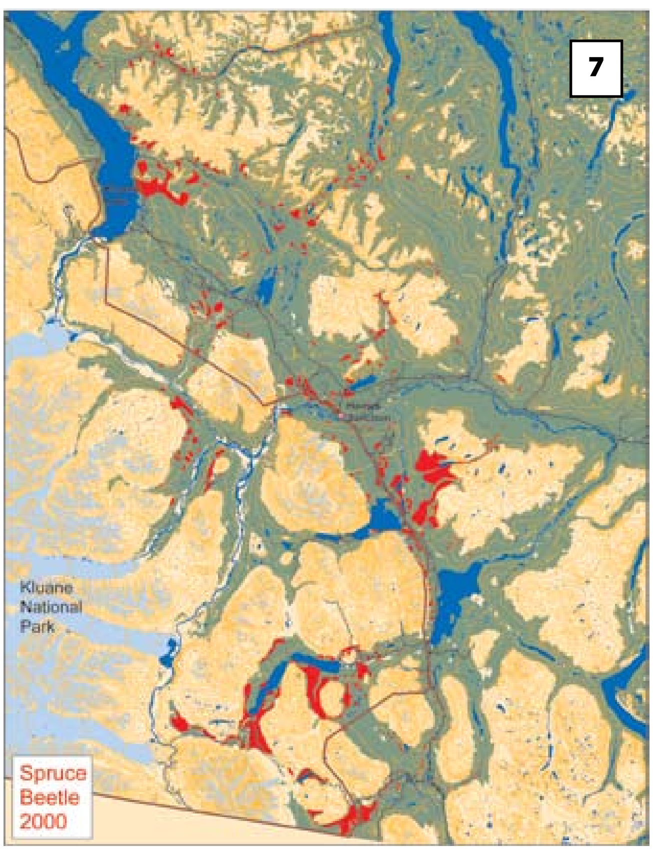


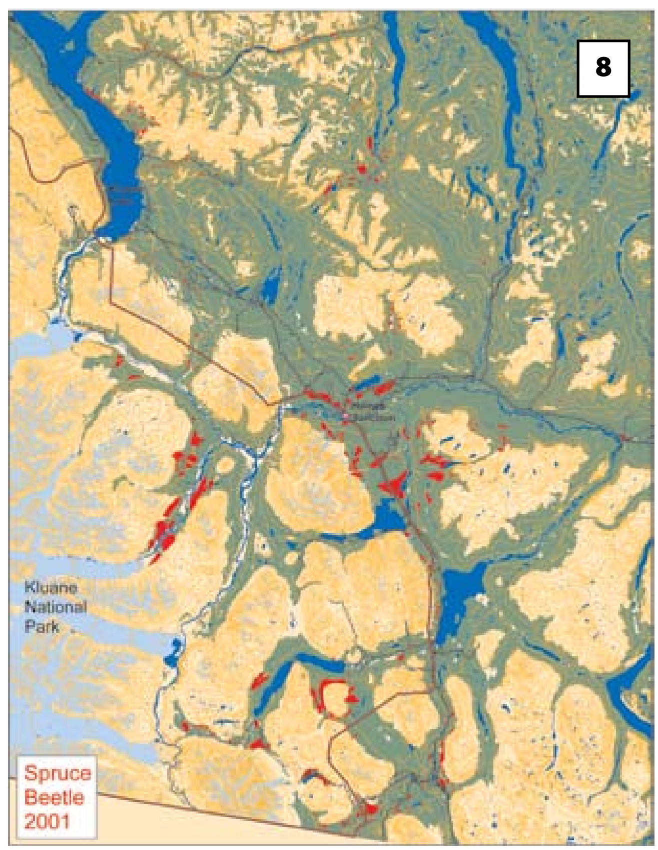
Composite map of spruce beetle damage from 1994-2005. Damage is indicated by red. Within these areas an average of over 50% of the white spruce overstory has been killed. The following 11 maps indicate the damage for particular years.

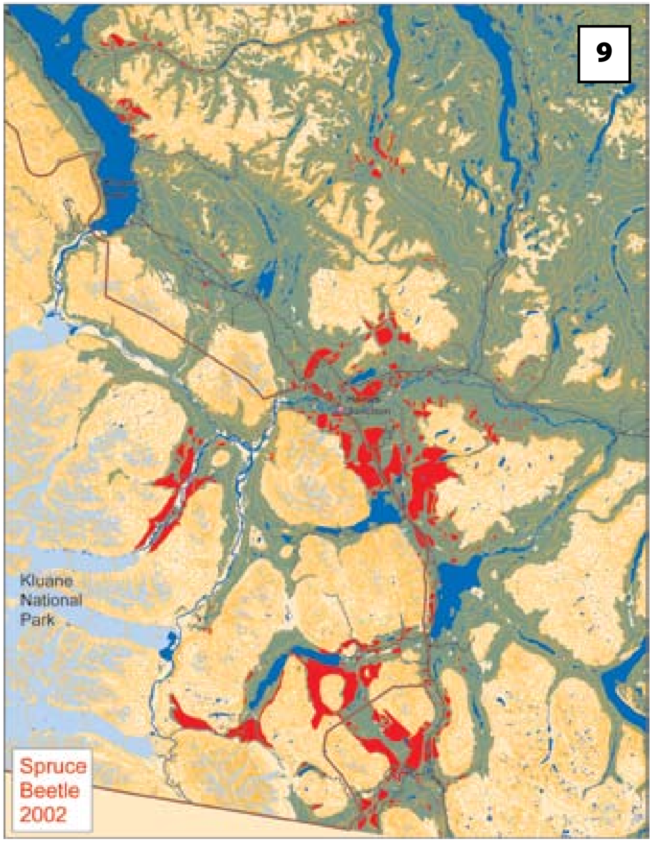

1
Kluane
National
Park
Spruce
Beetle
1994
2
Kluane
National
Park
Spruce
Beetle
1995
3
Kluane
National
Park
Spruce
Beetle
1996
4
Kluane
National
Park
Spruce
Beetle
1997

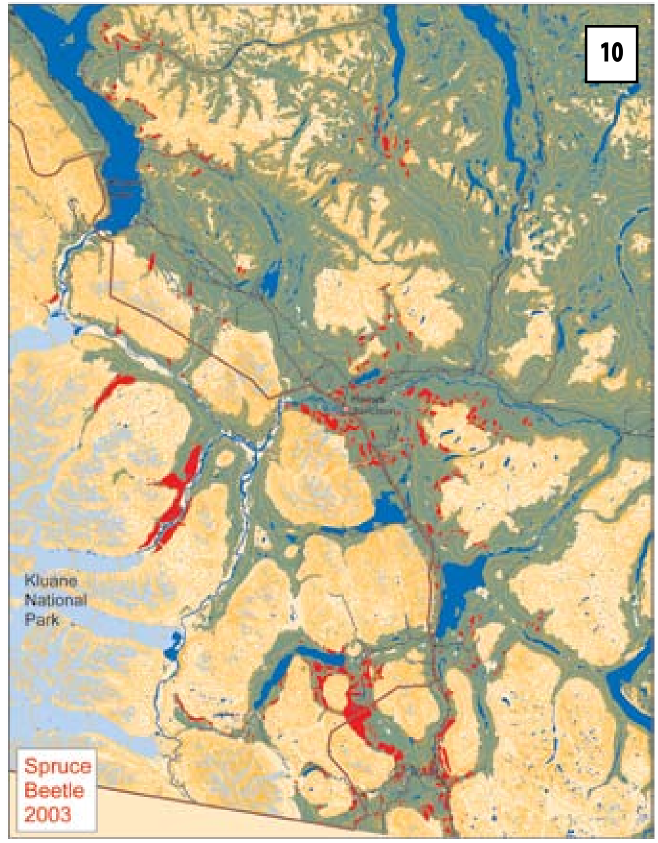

5
Kluane
National
Park
Spruce
Beetle
1998

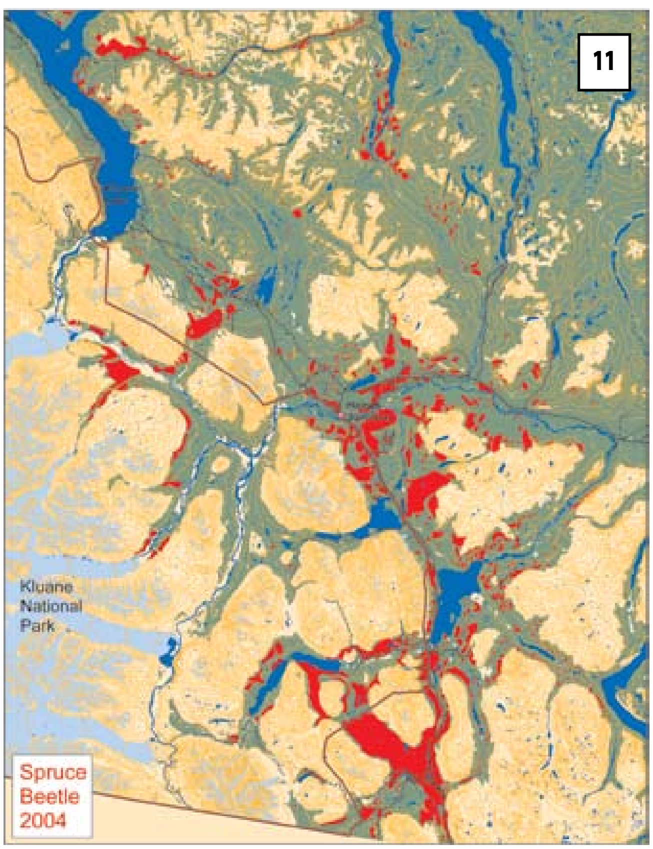

6
Kluane
National
Park
Spruce
Beetle
1999


7
Kluane
National
Park
Spruce
Beetle
2000


8
Kluane
National
Park
Spruce
Beetle
2001


9
Kluane
National
Park
Spruce
Beetle
2002


10
Kluane
National
Park
Spruce
Beetle
2003


11
Kluane
National
Park
Spruce
Beetle
2004

Appendix 2. Yukon Increment Core Data - Age in years at breast height

(Plots 1-19 cored in 2000; plots 20-32 cored in 2002)

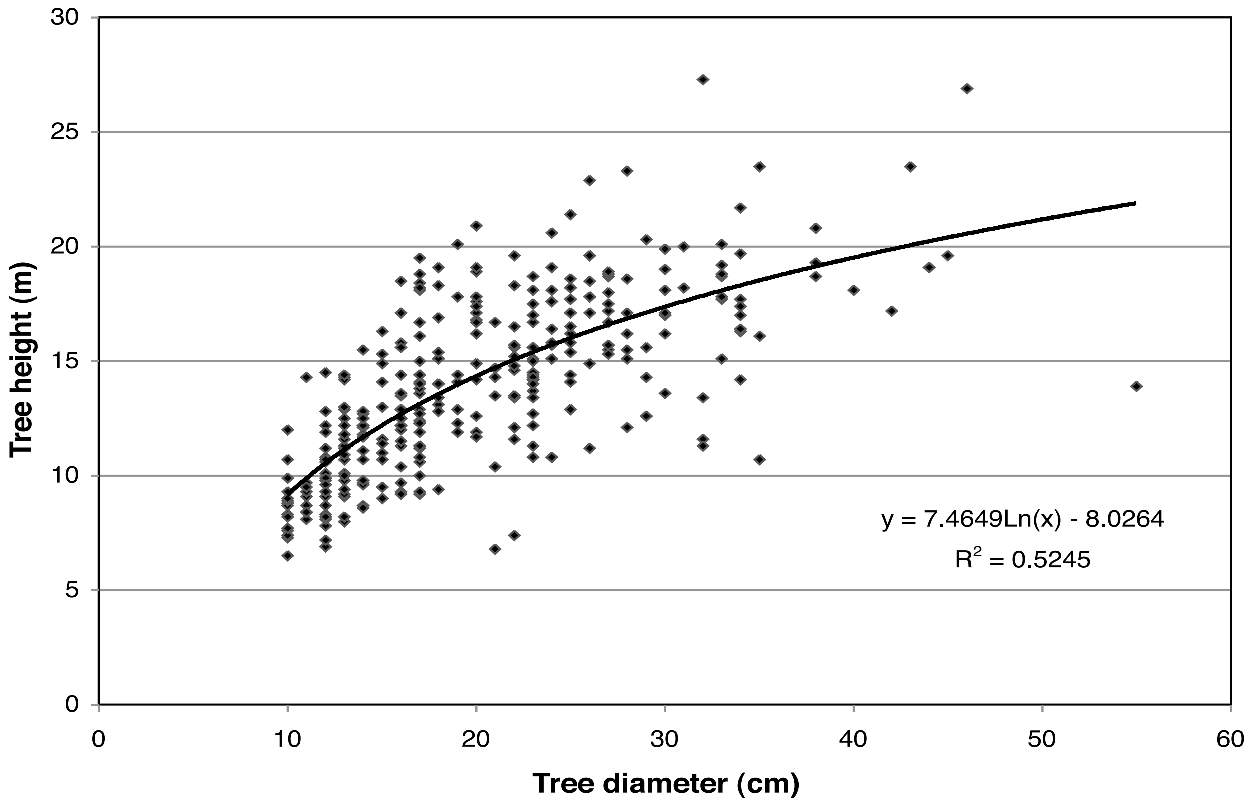
Plot Number	species*	Core Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	Avg. age	Standard Deviation
1	wS	147	232	182	180	160	158	165	167	158	158	150	167			169	±23
2	wS	126	51	74	111	60	71	64	60	68	61	65	68			73	±22
3	wS	226	229	143	170	167	105	50	78	49	194	193	144			146	±63
4	wS	128	148	122	87	71	54	88	133	67	109	128	108			104	±30
5	wS	142	218	196	170	172	159	185	135	230	156	206	240			184	±68
6	wS	58	89	79	87	89	65	95	129	158	43	156	135			99	±38
9	wS	129	70	129	58	58	42	60								78	±36
11	wS	44	60	67	60	55	55	65	50	56	51	61	47			56	±7
14	wS	167	163	128	179	77	79	196	90	90	153	152	175			137	±43
15	wS	94	79	122	61	86	100	103	92	109	89	131	56			94	±22
16	wS	117	120	103	161	150	140	113	108	126	112	94	110			121	±20
17	wS	131	172	112	152	138	147	140	124	142	133	92	157	149		138	±20
18	wS	198	222	100	95	154	184	123	136	140	129	120	166			147	±39
19	wS	120	200	316	218	80	63	226	155	326	152	98	107			172	±87
20	wS	77	105	62	61	55	110	107	126	120	123					95	±28
21	wS(tA,bCo)	121	153	85	105	123	93	123	119	89	122	122	122			115	±19
22	wS	78	247	212	218	187	208	203	166	192	170	221	124			186	±46
23	wS	145	129	148	31	85	78	110	120	94	137	169	79			110	±39
24	wS	65	81	80	79	75	68	88	43	69	79	73	76	99	97	77	±14
25	wS	155	105	171	126	124	118	64	157	73	143	110	153			125	±33
26	wS(tA)	108	88	120	80	103	143	99	82	131	141	194	166			121	±35
27	wS	83	66	56	78	58	63	82	53	53	82	97	58			69	±15
28	wS	161	163	147	90	174	153	139	152	66	69	163	143			135	±38
29	wS	68	81	72	85	83	86	76	81	65	71	75	86	79		78	±7
30	wS	136	120	127	127	143	137	125	145	132	140	127	131	141		133	±8
31	wS	233	232	270	303	114	105	342	356	90	352	219	139			230	±99
32	wS	256	274	274	276	247	177	139	292	293	288	283	273			256	±48

* wS = white spruce

tA = trembling aspen

bCo = black cottonwood

Appendix 3. White spruce height – diameter curve based on forest health assessment plots established in 2000-2002.



Appendix 4. Plot summaries

Plot 1

Name: Marshall Creek
Location: Approximately 15 km east of Haines Junction
Stand: mature white spruce

UTM

zone	easting	northing
8	372643	6748325

avg. age	169 years @ dbh[1]
range -	147 - 232 years
avg dbh -	17.9 cm
range -	10 - 48 cm
avg height -	19.3 m
range -	12.8 - 26.9 m

Volume (m^3/ha)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
368	349.5	177	101.1	44.6	22.4

Stand density:

class 1[2] -	1575 stems/ha
class 2[3] -	641 stems/ha
class 3[4] -	717 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(5)
shrub:	prickly rose (1)
dwarf shrub:	twinflower (11),
herb:	commandra (5), arctic lupine (4), bluebell (2)
grass:	Poa sp. (2)
moss:	step moss (81)
lichen:	Peltigera (7), Cladina sp. (2)

Average soil temperatures (⁰ C)

5 cm[5]:	7.3
10 cm:	4.8
20 cm:	3.0

[5] below live moss layer where applicable

Litter/moss depth: 4.5 cm
f/h depth[6]: 5.4 cm

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	9.8
fine woody debris[8]:	3.5

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	1.5
branch density[10]:	1.7
vertical continuity[11]:	1.8
total	5.0

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 900

Fire hazard rating[12]: 2 (low)
Spot fire potential[13]: 1 (low)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 2

Name: Canyon
Location: beside entrance to HJ Garbage Dump Road
Stand: semi-mature white spruce

average age - 73
age range - 52 - 126
average dbh - 16.3 cm
dbh range - 10 - 36 cm
average height - 15.4 m
height range - 11.2 - 23.5 m

UTM		
zone	easting	northing
8	382429	6748023

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
153.3	139	135.7	3.4	0	0

Stand density:

class 1[2] - 1000 stems/ha
class 2[3] - 724 stems/ha
class 3[4] - 434 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren (36)
shrub: prickly rose (9), kinnikinnik (3), soapberry (1)
dwarf shrub: twinflower (11)
herb: bluebell (1)
grass:
moss: step moss (6)
lichen: Peltigera sp. (14), Cladonia sp. (4)

Average soil temperatures (^{0} C)

5 cm[5]: 11.1
10 cm: 8.4
20 cm: 6.2

[5] below live moss layer where applicable

Litter/moss depth (cm): 1.3
f/h depth[6] (cm): 2.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]: 11.2
fine woody debris[8]: 6.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]: 2.9
branch density[10]: 2.2
vertical continuity[11]: 2.3
total 7.5

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3 = high

Dead tree density (stems/ha): 275

Fire hazard rating[12]: **4 (moderate)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 3

Name: Klukshu
Location: 760 m -S- of Haines Rd, just past Klukshu R.
Stand: mature white spruce + scatt. trembling aspen

UTM		
zone	easting	northing
8	387906	6689450

- average age - 146
- age range - 50-229
- average dbh - 17.4 cm
- dbh range - 10 - 38 cm
- average height - 13.37 m
- height range - 9.9 - 17 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
280.7	240.2	115	125.2	0	0

Stand density:
- class 1[2] - 1850 stems/ha
- class 2[3] - 650 stems/ha
- class 3[4] - 533 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
- **barren** (15)
- shrub: dwarf birch (7), soapberry (4
- dwarf shrub: twinflower (19), kinnikinnik (12), crowberry (10), red bearberry (4),
- herb: bunchberry (26), Arnica (10), Commandra (2)
- grass: unid. (13)
- moss: step moss (35)
- lichen: Peltigera sp (3), Cladonia sp (1)

Average soil temperatures (^{0} C)
- 5 cm[5]: 7.0
- 10 cm: 5.6
- 20 cm: 5.1

[5] below live moss layer where applicable

Litter/moss depth: 2.8
f/h depth[6]: 4.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
- coarse woody debris[7]: 22.5
- fine woody debris[8]: 4.2

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
- crown base height[9]: 1.8
- branch density[10]: 1.7
- vertical continuity[11]: 1.9
- total 5.4

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3 = high

Dead tree density (stems/ha): 1000

Fire hazard rating[12]: **4 (moderate)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 4

Name: Kathleen North
Location: North of Kathleen Lake
Stand: semi-mature white spruce + scatt. aspen

average age -	104
age range -	54 - 148
average dbh -	15.54 cm
dbh range -	10-30 cm
average height -	11.45 m
height range -	9.1 - 17.1 m

UTM		
zone	easting	northing
8	373285	6725611

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
119.6	100.9	63.3	37.5	0	0

Stand density:

class 1[2] -	1200 stems/ha
class 2[3] -	1280 stems/ha
class 3[4] -	2006 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(22)
shrub:	Salix sp. (3), prickly rose (2), soapberry (2)
dwarf shrub:	kinnikinnik (40), twinflower (21), crowberry (11),
grass:	unid. (16)
moss:	step moss (5)
lichen:	Cladonia sp. (2), Peltigera sp. (1)

Average soil temperatures (^{0} C)

5 cm[5]:	6.3
10 cm:	5.7
20 cm:	5.2

[5] below live moss layer where applicable

Litter/moss depth: 2.0
f/h depth[6]: 3.5

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	0.5
fine woody debris[8]:	4.6

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.2
branch density[10]:	2.1
vertical continuity[11]:	2.4
total	6.7

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3 = high

Dead tree density (stems/ha): 350

Fire hazard rating[12]: **2 (low)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 5

Name: Canyon
Location: Haines Junction Airport Road
Stand: mature white spruce

average age -	184
age range -	135 - 240
average dbh -	12.28 cm
dbh range -	10 - 33 cm
average height -	17.65 m
height range -	14.3 - 23.3 m

UTM		
zone	easting	northing
8	362332	6741220

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
361.3	361.3	91.9	227	42.4	0

Stand density:

class 1[2] -	1800 stems/ha
class 2[3] -	608 stems/ha
class 3[4] -	2198 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(21)
shrub:	prickly rose (2)
dwarf shrub:	red bearberry (7), crowberry (2)
herb:	bluebell (2)
grass:	
moss:	step moss (66)
lichen:	Peltigera sp. (8)

Average soil temperatures (^{0} C)

5 cm[5]:	3.2
10 cm:	1.4
20 cm:	0.3

[5] below live moss layer where applicable

Litter/moss depth: 8.6
f/h depth[6]: 9.9

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	19.0
fine woody debris[8]:	5.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	1.2
branch density[10]:	1.2
vertical continuity[11]:	1.1
total	3.5

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3 = high

Dead tree density (stems/ha): 675

Fire hazard rating[12]: **1 (low)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 6

Name: Bear Cr.
Location: approx. 7 km -NE- of Haines Junction
Stand: semi-mature white spruce

average age -	99
age range -	43 - 158
average dbh -	22 cm
dbh range -	10 - 34 cm
average height -	15.9 m
height range -	8.3 - 27.3 m

UTM		
zone	easting	northing
8	356740	6769159

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
283.9	283.9	29.5	242	12.4	0

Stand density:

class 1[2] -	925 stems/ha
class 2[3] -	435 stems/ha
class 3[4] -	558 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(23)
shrub:	prickly rose (2), Salix sp. (1)
dwarf shrub:	
herb:	arctic lupine (5)
grass:	inid. (1)
moss:	step moss (23)
lichen:	Peltigera (10)

Average soil temperatures (^{0} C)

5 cm[5]:	8.1
10 cm:	5.4
20 cm:	4.2

[5] below live moss layer where applicable

Litter/moss depth: 3.3
f/h depth[6]: 3.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	3.9
fine woody debris[8]:	3

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.2
branch density[10]:	2.3
vertical continuity[11]:	2.4
total	6.9

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3 = high

Dead tree density (stems/ha): 550

Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 9

Name: Silver City
Location: off Siver City access road
Stand: semi-mature white spruce

average age -	78
age range -	42 - 129
average dbh -	15.4 cm
dbh range -	10 - 35 cm
average height -	10.6 m
height range -	6.5 - 13.5 m

UTM		
zone	easting	northing
7	642601	6769159

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
119.1	119.1	57.6	58.9	2.6	0

Stand density:

class 1[2] -	775 stems/ha
class 2[3] -	1248 stems/ha
class 3[4] -	549 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(45)
shrub:	soapberry (7)
herb:	arctic lupine (1)
grass:	unud (4)
moss:	red-stemmed fether moss (14), step moss (1)
lichen:	peltigera sp. (4), Cladonia sp. (3)

Average soil temperatures (^{0} C)

5 cm[5]:	9.4
10 cm:	6.8
20 cm:	5.0

[5] below live moss layer where applicable

Litter/moss depth: 1.4
f/h depth[6]: 2.5

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	23.4
fine woody debris[8]:	9.6

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.9
branch density[10]:	2.7
vertical continuity[11]:	2.7
total	8.3

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 275

Fire hazard rating[12]: **5 (high)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 11

Name: Upper Mackintosh
Location: Up on the bench behind the old Mackintosh Lodge
Stand: young growth white spruce with scattered aspen

UTM		
zone	easting	northing
8	357080	6745375

average age - 56
age range - 44 - 67
average dbh - 13.4 cm
dbh range - 10 - 27 cm
average height - 10.6 m
height range - 8.1 - 11.8 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
109.3	104.5	51.9	38.3	14.3	0

Stand density:
class 1[2] - 1825 stems/ha
class 2[3] - 1215 stems/ha
class 3[4] - 250 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (44)
shrub: Salix sp. (2), soapberry (1)
dwarf shrub: twinflower (14), kinnikinnik (2), red bearberry (1)
herb: arctic lupine
grass: unid (2)
moss: red-stemmed feather moss (5)
lichen: Peltigera sp. (4), Cladonia sp. (3)

Average soil temperatures (^{0} C)
5 cm[5]: 7.7
10 cm: 5.2
20 cm: 4.1

[5] below live moss layer where applicable

Litter/moss depth: 1.0
f/h depth[6]: 2.3

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 18.6
fine woody debris[8]: 4.7

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 3.0
branch density[10]: 2.5
vertical continuity[11]: 2.5
total 8.0

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 475

Fire hazard rating[12]: **5 (high)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 14

Name: Aishihik
Location: approx. 6 km -S- of Otter Falls
Stand: mature white spruce

UTM		
zone	easting	northing
8	39083	6768965

average age -	137
age range -	77 - 179
average dbh -	15.9 cm
dbh range -	10 - 31 cm
average height -	14.9 m
height range -	10.7 - 20.8 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
204.1	204.1	146.4	55.1	0	2.7

Stand density:

class 1[2] -	1425 stems/ha
class 2[3] -	775 stems/ha
class 3[4] -	490 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(17)
shrub:	
dwarf shrub:	twinflower (4), red bearberry (1)
herb:	
grass:	unid (2)
moss:	step moss (68)
lichen:	Peltigera (15)

Average soil temperatures (^{0} C)

5 cm[5]:	5.0
10 cm:	2.9
20 cm:	1.7

[5] below live moss layer where applicable

Litter/moss depth: 6.5
f/h depth[6]: 5.2

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	10.3
fine woody debris[8]:	4.7

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.2
branch density[10]:	1.8
vertical continuity[11]:	2.1
total	6.0

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 475

Fire hazard rating[12]: **2 (low)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 15

Name: Mackintosh South
Location: approx. 7 km NW of Haines Junction
Stand: semi-mature white spruce

average age -	94
age range -	56 - 131
average dbh -	20.7 cm
dbh range -	10 - 57 cm
average height -	13.5 m
height range -	8.8 - 18.1 m

UTM		
zone	easting	northing
8	357346	6740457

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
288.4	288.4	27.9	203.3	46.7	10.6

[1] Diameter breast height (1.3 m)

Stand density:

class 1[2] -	1075 stems/ha
class 2[3] -	714 stems/ha
class 3[4] -	534 stems/ha

[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(55)
shrub:	
dwarf shrub:	
herb:	Arctic lupine
grass:	unid (2)
moss:	
lichen:	Peltigera (8), Cladonia (1)

Average soil temperatures (^{0} C)

5 cm[5]:	5.8
10 cm:	4.6
20 cm:	4.1

[5] below live moss layer where applicable

Litter/moss depth: 1.7
f/h depth[6]: 3.6

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	13.1
fine woody debris[8]:	3.5

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.5
branch density[10]:	2.8
vertical continuity[11]:	2.7
total	8.0

[9] measured from ground to base of continuous crown
[10] subjective estimate — 1 = low
[11] subjective estimate — 2 = moderate
3=high

Dead tree density (stems/ha): 350

Fire hazard rating[12]: **4 (moderate)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 16

Name: Pine Lake
Location: approx. 12 km -E- of Haines Junction
Stand: mature white spruce + scattered aspen

UTM		
zone	easting	northing
8	368995	6744148

average age - 121
age range - 94 - 161
average dbh - 20.7 cm
dbh range - 10 - 37 cm
average height - 16.7 m
height range - 12.9 - 19.1 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
247.3	223.5	135.4	84.6	2.9	0

Stand density:
class 1[2] - 1250 stems/ha
class 2[3] - 767 stems/ha
class 3[4] - 1263 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (21)
shrub: prickly rose (4), Salix sp (2), soapberry (1)
dwarf shrub: twinflower (26), Vaccinium sp. (3), kinnikinnik (2),
herb:
grass: unid (4)
moss: step moss (60)
lichen: Peltigera (1)

Average soil temperatures (⁰ C)
5 cm[5]: 6.9
10 cm: 4.9
20 cm: 3.6

[5] below live moss layer where applicable

Litter/moss depth: 4.5
f/h depth[6]: 5.7

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 17.5
fine woody debris[8]: 5.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 1.4
branch density[10]: 1.5
vertical continuity[11]: 1.5
total 4.3

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate
1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 300

Fire hazard rating[12]: **1 (low)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 17

Name: Kathleen South
Location: 10 km south, Kathleen Lake
Stand: approx. 50% mature white spruce. 50% aspen

UTM		
zone	easting	northing
8	382799	67184818

- average age - 138
- age range - 78 - 247
- average dbh - 19.1 cm
- dbh range - 10 - 36 cm
- average height - 12.9 m
- height range - 8.7 - 17.2 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
171.3	87.6	30.4	55.7	1.5	0

Stand density:
- class 1[2] - 925 stems/ha
- class 2[3] - 753 stems/ha
- class 3[4] - 911 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
- **barren** (14)
- shrub: Salix sp. (10), dwarf birch (3), prickly rose (3), Labrador tea (2), soapberry (1)
- dwarf shrub: Vaccinium sp (29), crowberry (28), twinflower (23), kinnikinnik (8), lingonberry (6)
- herb: arctic lupine (17), bunchberry (13), arnica (10)
- grass: unid. (23)
- moss: step moss (3)
- lichen: Peltigera (3)

Average soil temperatures (^{0} C)
- 5 cm[5]: 7.9
- 10 cm: 6.7
- 20 cm: 5.7

[5] below live moss layer where applicable

Litter/moss depth: 3.0
f/h depth[6]: 4.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
- coarse woody debris[7]: 2.4
- fine woody debris[8]: 2.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
- crown base height[9]: 1.9
- branch density[10]: 1.8
- vertical continuity[11]: 1.9
- total 5.5

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 425

Fire hazard rating[12]: **1 (low)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 18

Name: Dezadeash North
Location: North end of the lake
Stand: mature white spruce + mixed deciduous spp.

UTM		
zone	easting	northing
8	387072	6702392

average age - 147
age range - 95 - 222
average dbh - 20.8 cm
dbh range - 10 - 43 cm
average height - 15.1 m
height range - 7.4 - 19.1 m

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
156.2	119.2	69.7	43.7	6	0

Stand density:
class 1[2] - 925 stems/ha
class 2[3] - 183 stems/ha
class 3[4] - 177 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (20)
shrub: soapberry (38), prickly rose (14), Salix sp. (2)
dwarf shrubs: twinflower (20), Vaccinium sp. (8)
herb: bunchberry (8), arctic lupine (2)
grass:
moss: step moss (31)
lichen: Peltigera (1)

Average soil temperatures (^{0} C)
5 cm[5]: 6.7
10 cm: 5.5
20 cm: 4.5

[5] below live moss layer where applicable

Litter/moss depth: 5.0
f/h depth[6]: 5.2

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 41.0
fine woody debris[8]: 7.7

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 1.3
branch density[10]: 2.5
vertical continuity[11]: 0.8
total 4.6

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 175

Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 19

Name: 7.5 km Haines Road
Location: 7.5 km -S- of Haines Junction
Stand: mature white spruce + scattered aspen

average age -	172
age range -	63 - 316
average dbh -	14.2 cm
dbh range -	10 - 28 cm
average height -	12.5 m
height range -	8.7 - 17.8 m

UTM		
zone	easting	northing
8	368258	6733013

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
135.2	122.3	61.2	58.9	2.3	0

Stand density:

class 1[2] -	1525 stems/ha
class 2[3] -	2900 stems/ha
class 3[4] -	2415 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(4)
shrub:	Salix sp (9), dwarf birch (8)
dwarf shrub:	crowberry (64), twinflower (11), kinnikinnik (5), Vaccinium sp. (2)
herb:	arctic lupine (3)
grass:	unid. (12)
moss:	step moss (73)
lichen:	Peltigera sp. (10), Cladonia (4)

Average soil temperatures (⁰ C)

5 cm[5]:	5.8
10 cm:	3.8
20 cm:	2.6

[5] below live moss layer where applicable

Litter/moss depth: 6.2
f/h depth[6]: 6.6

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	2.1
fine woody debris[8]:	3.0

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	1.2
branch density[10]:	1.4
vertical continuity[11]:	1.8
total	4.4

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 525

Fire hazard rating[12]: **1 (low)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 20

Name: Trout Lake
Location: Kluane National Park -W- of Kathleen Lakes
Stand: semi-mature white spruce

- average age - 94
- age range - 55 - 126
- average dbh - 18.4 cm
- dbh range - 10 - 44 cm
- average height - 12.4 m
- height range - 6.9 - 19.1 m

UTM		
zone	easting	northing
8	350440	6713828

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
262.8	262.8	48.5	199.7	0	14.6

Stand density:

- class 1[2] - 1575 stems/ha
- class 2[3] - 324 stems/ha
- class 3[4] - 250 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

- **barren** (19)
- shrub: Salix sp (24), prickly rose (1)
- dwarf shrub: lingonberry (2), twinflower (2), kinnikinnik (2), alpine bearberry (1)
- herb: bluebell (36), arctic lupine (9)
- grass: unid (28)
- moss: red-stemmed feather moss (22)
- lichen:

Average soil temperatures (° C)

- 5 cm[5]: no data
- 10 cm:
- 20 cm:

[5] below live moss layer where applicable

Litter/moss depth: 4.8
f/h depth[6]: 6.2

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

- coarse woody debris[7]: 29.0
- fine woody debris[8]: 11.3

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

- crown base height[9]: 2.4
- branch density[10]: 2.2
- vertical continuity[11]: 2.2
- total 6.8

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 1025

Fire hazard rating[12]: **5 (high)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 21

Name: Quill Creek South
Location: approx 13 km -S- of Haines Junction
Stand: white spruce

average age -	115
age range -	85 - 153
average dbh -	18.2 cm
dbh range -	10 - 35 cm
average height -	15.4 m
height range -	6.8 - 20.1 m

UTM		
zone	easting	northing
8	371072	6728790

Volume (cubic meters)

total	spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
356.8	280.1	47.5	180.8	42.8	9

Stand density:

class 1[2] -	1875 stems/ha
class 2[3] -	188 stems/ha
class 3[4] -	546 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(31)
shrub:	soapberry (21), prickly rose (3)
dwarf shrub:	twinflower (9)
herb:	bluebell (8), Commandra (5), arctic lupine (2),
grass:	unid (1)
moss:	red stemmed feather moss (9)
lichen:	Peltigera (3)

Average soil temperatures (^{0} C)

5 cm[5]:	6.65
10 cm:	4.87
20 cm:	3.85

[5] below live moss layer where applicable

Litter/moss depth: 2.75
f/h depth[6]: 4.38

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	1.8
fine woody debris[8]:	7.5

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.1
branch density[10]:	1.5
vertical continuity[11]:	2.12
total	5.71

[9] measured from ground to base of continuous crown
[10] subjective estimate — 1 = low
[11] subjective estimate — 2 = moderate
3=high

Dead tree density (stems/ha): 900

Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 22

Name: Dezadeash South
Location: approx. 2 km -S- of Dezadeash Lake
Stand: mature white spruce

average age -	186
age range -	78 - 247
average dbh -	18.7 cm
dbh range -	10 - 34 cm
average height -	15.5 m
height range -	9.4 - 17.6 m

UTM		
zone	easting	northing
8	387068	6690251

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
216.1	216.1	59.9	135	21.1	0

Stand density:

class 1[2] -	850 stems/ha
class 2[3] -	179 stems/ha
class 3[4] -	197 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(6)
shrub:	Salix sp. (18), dwarf birch (12)
dwarf shrub:	crowberry (50), lingonberry (18), Labrador tea (13)
herb:	Commandra (19), bunchberry (9)
grass:	
moss:	red-stemmed feather moss (49), step moss (11)
lichen:	Peltigera (2)

Average soil temperatures (^{0} C)

5 cm[5]:	6.6
10 cm:	4.8
20 cm:	3.7

[5] below live moss layer where applicable

Litter/moss depth: 5.1
f/h depth[6]: 5.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	16.6
fine woody debris[8]:	2.5

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.5
branch density[10]:	2.0
vertical continuity[11]:	2.3
total	6.8

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 475

Fire hazard rating[12]: 2 (low)
Spot fire potential[13]: 3 (high)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 23

Name: Macintosh West
Location: Behind Macintosh subdivision
Stand: semi-mature white spruce

UTM		
zone	easting	northing
8	353487	6741264

- average age - 110
- age range - 31 - 169
- average dbh - 26.2 cm
- dbh range - 12 - 47 cm
- average height - 16.8 m
- height range - 9.4 - 20.8 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	pitch-out	dead other causes
331.6	331.6	24.4	218.9	79.3	9

Stand density:

- class 1[2] - 700 stems/ha
- class 2[3] - 42 stems/ha
- class 3[4] - 92 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

- **barren** (23)
- shrub: prickly rose (7), Salix sp (6), soapberry (3)
- dwarf shrub: twinflower (25)
- herb: bluebell (4), arctic lupine (2)
- grass:
- moss:
- lichen:

Average soil temperatures (° C)

- 5 cm[5]: 11.7
- 10 cm: 7.3
- 20 cm: 3.9

[5] below live moss layer where applicable

Litter/moss depth: 3.2
f/h depth[6]: 5.8

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

- coarse woody debris[7]: 56.8
- fine woody debris[8]: 14.1

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

- crown base height[9]: 2.7
- branch density[10]: 1.9
- vertical continuity[11]: 2.2
- total 6.7

[9] measured from ground to base of continuous crown
[10] subjective estimate — 1 = low
[11] subjective estimate — 2 = moderate
3=high

Dead tree density (stems/ha): 1000

Fire hazard rating[12]: **6 (high)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 24

Name: Mush Lake #1
Location: Kluane National Park, northwest end of lake
Stand: middle-aged white spruce

UTM		
zone	easting	northing
8	359547	6688742

average age - 77
age range - 43 - 99
average dbh - 14.4 cm
dbh range - 10 - 44 cm
average height - 9.1 m
height range - 8.3 - 11.9 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	pitch-out
202.1	159.5	36.6	96.4	16.6	10

[1] Diameter breast height (1.3 m)

Stand density:
class 1[2] - 1625 stems/ha
class 2[3] - 1414 stems/ha
class 3[4] - 1025 stems/ha

[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (22)
shrub: Salix sp. (6), prickly rose (2), soapberry (2)
dwarf shrub: twinflower (11), crowberry (9), lingonberry (4), alpine bearberry (1)
herb: buchberry (31), Commandra (11), bluebell (3), arctic lupine (2)
grass: unid (4)
moss: red-stemmed feather moss (13)
lichen: Peltigera (1)

Average soil temperatures (⁰ C)
5 cm[5]: 12.2
10 cm: 8.1
20 cm: 6.1

[5] below live moss layer where applicable

Litter/moss depth: 2.1
f/h depth[6]: 4.4

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 6.1
fine woody debris[8]: 4.2

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 3.0
branch density[10]: 2.0
vertical continuity[11]: 2.4
total 7.3

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 350

Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **1 (low)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 25

Name: Mush Lake #2
Location: Kluane National Park, southwest end of lake
Stand: semi-mature white spruce

UTM		
zone	easting	northing
8	361460	6687212

average age - 125
age range - 73 - 157
average dbh - 16.0 cm
dbh range - 10 - 35 cm
average height - 11.4 m
height range - 7.8 - 15.4 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	pitch-out
165.5	165.5	16.6	99.3	22.5	27.2

Stand density:
class 1[2] - 1125 stems/ha
class 2[3] - 1394 stems/ha
class 3[4] - 1069 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (7)
shrub: dwarf birch (30), Salix (11), prickly rose (2)
dwarf shrubs: crowberry (18), lingonberry (11), twinflower (1)
herb: bunchberry (19)
grass: unid (2)
moss: red-stemmed feather moss (18)
lichen:

Average soil temperatures (^{0} C)
5 cm[5]: 5.2
10 cm: 2.6
20 cm: 1.5

[5] below live moss layer where applicable

Litter/moss depth: 2.7
f/h depth[6]: 5.7

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 26.3
fine woody debris[8]: 4.0

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 2.5
branch density[10]: 1.6
vertical continuity[11]: 2.3
total 6.5

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 550
Fire hazard rating[12]: **4 (moderate)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 26

Name: Mush Lake Road
Location: Kluane National Park, Mush Lake Road
Stand: mature white spruce

	UTM	
zone	easting	northing
8	373569	6690230

average age - 121
age range - 80 - 194
average dbh - 16.7 cm
dbh range - 10 - 29 cm
average height - 12.2 m
height range - 7.4 - 17.7 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	pitch-out
168.9	125.3	79.8	33.1	11.5	0.9

Stand density:
class 1[2] - 700 stems/ha
class 2[3] - 2454 stems/ha
class 3[4] - 1343 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (12)
shrub: Salix sp. (2), prickly rose (1)
dwarf shrub: crowberry (45), twinflower (17), Vaccinium spp. (11)
herb: bunchberry (27), arctic lupine (8), Commandra (5), bluebell (4)
grass:
moss: red-stemmed feather moss (52)
lichen:

Average soil temperatures (^{0} C)
5 cm[5]: 8.8
10 cm: 5.4
20 cm: 3.6

[5] below live moss layer where applicable

Litter/moss depth: 3.2
f/h depth[6]: 4.9

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 22.3
fine woody debris[8]: 4.6

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 2.7
branch density[10]: 1.9
vertical continuity[11]: 2.4
total 7.0

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 175
Fire hazard rating[12]: 4 (moderate)
Spot fire potential[13]: 1 (low)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 27

Name: Mouth of Alsek River
Location: Serpentine Creek
Stand: middle-aged white spruce

average age -	69
age range -	53 - 97
average dbh -	24.4 cm
dbh range -	10 - 37 cm
average height -	13.6 m
height range -	8.9 - 15.3 m

UTM		
zone	easting	northing
8	348564	6732175

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	pitch-out
256.5	256.5	18	196	0	42.6

Stand density:

class 1[2] -	750 stems/ha
class 2[3] -	180 stems/ha
class 3[4] -	334 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(27)
shrub:	Salix sp (2)
dwarf shrub:	twinflower (46)
herb:	bluebell (1)
grass:	
moss:	red-stemmed feather moss (69)
lichen:	Peltigera (4)

Average soil temperatures (^{o} C)

5 cm[5]:	10.4
10 cm:	7.3
20 cm:	5.3

[5] below live moss layer where applicable

Litter/moss depth: 2.3
f/h depth[6]: 4.5

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	0
fine woody debris[8]:	3.8

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.5
branch density[10]:	2.1
vertical continuity[11]:	2.6
total	7.3

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 475
Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **2 (moderate)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 28

Name: Cultus Creek #1
Location: adjacent to
Stand: mature white spruce

average age - 135
age range - 66 - 163
average dbh - 20.2 cm
dbh range - 10 - 34 cm
average height - 15.24 m
height range - 9.9 - 20.5 m

UTM		
zone	easting	northing
7	641810	6775114

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	pitch-out	dead other causes
273.8	273.8	14.2	238	16.1	5.5

Stand density:

class 1[2] - 1325 stems/ha
class 2[3] - 796 stems/ha
class 3[4] - 889 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren (6)
shrub: dwarf birch (17)
dwarf shrub: twinflower (28)
herb: bluebell (1)
grass: unid.(5)
moss: red-stemmed feather moss (68)
lichen: Peltigera (4)

Average soil temperatures (^{0} C)

5 cm[5]: 11.5
10 cm: 6.5
20 cm: 3.8

[5] below live moss layer where applicable

Litter/moss depth: 5.7
f/h depth[6]: 6.3

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]: 9.7
fine woody debris[8]: 3.7

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]: 2.4
branch density[10]: 2.0
vertical continuity[11]: 2.4
total 6.8

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 1050
Fire hazard rating[12]: 4 (moderate)
Spot fire potential[13]: 3 (high)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 29

Name: Cultus Creek #2
Location: on bench above Cultus Creek
Stand: mature white spruce

UTM		
zone	easting	northing
7	641131	6783071

average age -	78
age range -	65 - 86
average dbh -	12.6 cm
dbh range -	10 - 23 cm
average height -	9.9 m
height range -	8.1 - 12.9 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	pitch-out by spruce beetle	dead other causes
50.2	50.2	13.2	14	7.8	14.1	0.9

Stand density:

- class 1[2] - 675 stems/ha
- class 2[3] - 2724 stems/ha
- class 3[4] - 88 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren (43)
shrub:
dwarf shrub:
herb:
grass:
moss: red-stemmed feather moss (46)
lichen: Peltigera (2)

Average soil temperatures (^{0} C)

5 cm[5]: 12
10 cm: 8
20 cm: 6

[5] below live moss layer where applicable

Litter/moss depth: 3
f/h depth[6]: 3

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]: 14.3
fine woody debris[8]: 4.2

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]: 2.7
branch density[10]: 2.1
vertical continuity[11]: 2.5
total 7.3

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 575
Fire hazard rating[12]: 4 (moderate)
Spot fire potential[13]: 1 (low)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 30

Name: Kaskawulsh River
Location: Kluane National Park, north side lower Kaskawulsh
Stand: mature white spruce

UTM		
zone	easting	northing
8	341353	6737053

average age -	133
age range -	120 - 145
average dbh -	17.8 cm
dbh range -	10 - 38 cm
average height -	14.7 m
height range -	8.2 - 17.8 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
157	157	23.3	133.7	0	0

Stand density:

class 1[2] -	850 stems/ha
class 2[3] -	148 stems/ha
class 3[4] -	826 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)

barren	(17)
shrub:	Salix sp. ((1)
dwarf shrub:	kinnikinnik (7), alpine bearberry (3)
herb	bluebell (4), Commandra (2)
grass:	inid (11)
moss:	
lichen:	Peltigera sp (2)

Average soil temperatures (° C)

5 cm[5]:	10.3
10 cm:	7.0
20 cm:	3.8

[5] below live moss layer where applicable

Litter/moss depth: 1.8
f/h depth[6]: 3.2

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)

coarse woody debris[7]:	6.1
fine woody debris[8]:	4.3

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)

crown base height[9]:	2.2
branch density[10]:	2.0
vertical continuity[11]:	2.7
total	6.8

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 525
Fire hazard rating[12]: **3 (moderate)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 31

Name: Congdon Creek
Location: Kluane National Park, just southwest of Congdon Cr. Campground
Stand: mature white spruce

UTM		
zone	easting	northing
7	630659	6781454

average age - 230
age range - 90 - 356
average dbh - 24.3 cm
dbh range - 10 - 43 cm
average height - 16.9 m
height range - 9.5 - 23.5 m

Volume (cubic meters)

total	total spruce	healthy	killed by spruce beetle	partial attack by spruce beetle	dead other causes
327.3	327.3	212.5	45.7	0	69.1

Stand density:
class 1[2] - 795 stems/ha
class 2[3] - 310 stems/ha
class 3[4] - 1081 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (14)
shrub: Salix sp (1)
dwarf shrub: kinnikinnik (7), alpine bearberry (3)
herb: bluebell (4), Commandra (2)
grass:
moss:
lichen: Peltigera (2)

Average soil temperatures (^{0} C)
5 cm[5]: 11.8
10 cm: 9.4
20 cm: 7.1

[5] below live moss layer where applicable

Litter/moss depth: 3.3
f/h depth[6]: 2.9

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 40.0
fine woody debris[8]: 3.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 1.4
branch density[10]: 2.0
vertical continuity[11]: 2.3
total 5.7

[9] measured from ground to base of continuous crown
[10] subjective estimate
[11] subjective estimate

1 = low
2 = moderate
3=high

Dead tree density (stems/ha): 250
Fire hazard rating[12]: 3 (moderate)
Spot fire potential[13]: 3 (high)

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Plot 32

Name: Arctic Institute
Location: East side Alcan Hwy just before A.I. turnoff
Stand: mature white spruce

UTM		
zone	easting	northing
7	642840	6767964

average age - 256
age range - 139 - 293
average dbh - 18.2 cm
dbh range - 10 - 31 cm
average height - 15.5 m
height range - 7.7 - 21.4 m

Volume (cubic meters)

total	total spruce	healthy	beetle killed	strip attacked by spruce beetle	pitch-out	dead other causes
442.4	442.4	49.6	333.6	4.5	14.9	40.1

Stand density:
class 1[2] - 2200 stems/ha
class 2[3] - 142 stems/ha
class 3[4] - 881 stems/ha

[1] Diameter breast height (1.3 m)
[2] stems ≥10 cm dbh (from plot transects)
[3] stems ≥1.3 m in height and <10 cm dbh (from N. N. Analysis)
[4] stems <1.3 m in height (from N. N. Analysis)

Commonly encountered ground vegetation (percent cover)
barren (30)
shrub:
dwarf shrub: kinnikinnik (29)
herb:
grass: unid (11)
moss: red-stemmed feather moss (38)
lichen:

Average soil temperatures (^{0} C)
5 cm[5]: 9.3
10 cm: 7.3
20 cm: 5.8

[5] below live moss layer where applicable

Litter/moss depth: 2.0
f/h depth[6]: 3.0

[6] organic fermentation/humus layers

Surface fuels (tonnes/ha)
coarse woody debris[7]: 16.0
fine woody debris[8]: 5.9

[7] >7 cm diameter
[8] ≤7cm diameter

Crown fuel characteristic ratings (all plot stems ≥10 cm dbh)
crown base height[9]: 1.9
branch density[10]: 2.0
vertical continuity[11]: 2.7
total 6.6

[9] measured from ground to base of continuous crown
[10] subjective estimate — 1 = low
[11] subjective estimate — 2 = moderate
3=high

Dead tree density (stems/ha): 1775
Fire hazard rating[12]: **5 (high)**
Spot fire potential[13]: **3 (high)**

[12] on an increasing relative scale from 1-6
[13] on an increasing relative scale of 1-3

Appendix 5. Examples of living and dead white spruce tree crowns assigned a range of fire hazard ratings according to crown characteristics

Hazard Rating: 3 (low)

Crown base height > 1 m	= 1
Branch density low	= 1
Vertical continuity low	= 1

Hazard Rating 4 (low)

Crown base height > 1 m	= 1
Branch density low	= 1
Vertical continuity moderate	= 2

Hazard Rating: 5 (moderate)

Crown base height > 1 m	= 1
Branch density moderate	= 2
Vertical continuity moderate	= 2

Hazard Rating: 6 (moderate)

Crown base height > 1 m	= 1
Branch density moderate	= 2
Vertical continuity high	= 3

Hazard Rating: 6 (moderate)

Crown base height between > 1 m	= 1
Branch density moderate	= 2
Vertical continuity high	= 3

Hazard Rating: 7 (high)

Crown base height between 0.5 and 1 m	= 2
Branch density moderate	= 2
Vertical continuity high	= 3

Hazard Rating: 9 (high)

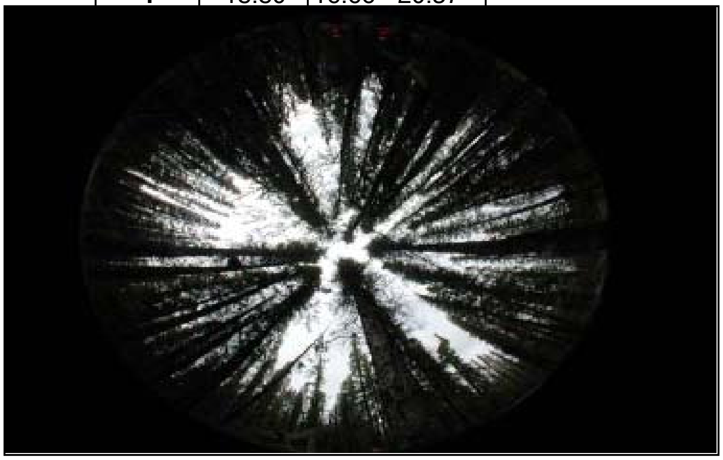
Crown base height < 0.5 m	= 3
Branch density high	= 3
Vertical continuity high	= 3

Hazard Rating: 9 (high)

Crown base height < 0.5 m	= 3
Branch density high	= 3
Vertical continuity high	= 3

Appendix 6. Representative vertical canopy photographs from within each plot using a hemispheric lens

	% Canopy openings	
Plot #	**Avg.**	**Range**
1	18.80	16.66 - 20.37

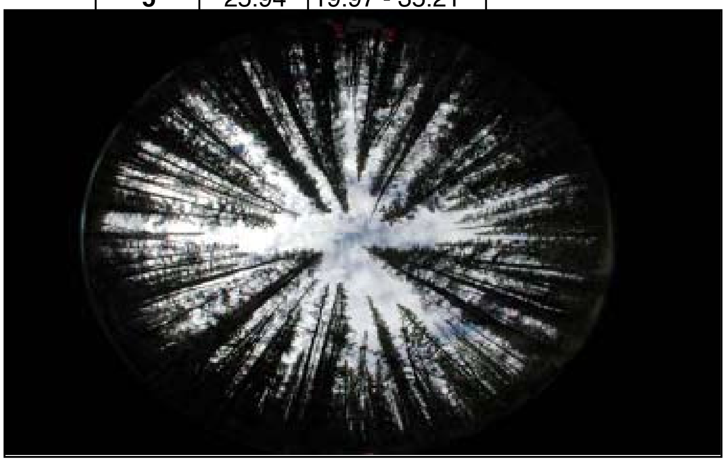


	% Canopy openings	
Plot #	**Avg.**	**Range**
2	20.94	18.51 - 23.33

	% Canopy openings	
Plot #	**Avg.**	**Range**
3	20.41	17.13 - 24.66

	% Canopy openings	
Plot #	**Avg.**	**Range**
4	21.03	15.92 - 26.93

	% Canopy openings	
Plot #	**Avg.**	**Range**
5	25.94	19.97 - 35.21



	% Canopy openings	
Plot #	**Avg.**	**Range**
6	19.56	16.53 - 24.87

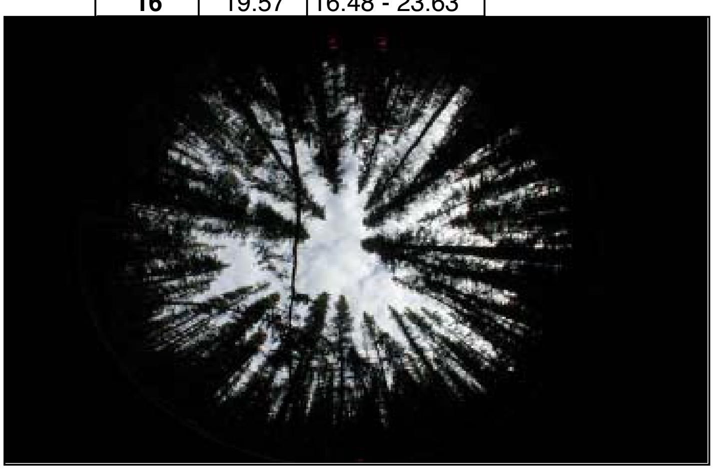
	% Canopy openings	
Plot #	**Avg.**	**Range**
9	26.63	17.92 - 44.98

	% Canopy openings	
Plot #	**Avg.**	**Range**
11	19.92	17.79 - 21.93

	% Canopy openings	
Plot #	**Avg.**	**Range**
14	20.09	16.45 - 24.27

	% Canopy openings	
Plot #	**Avg.**	**Range**
15	23.45	18.3 - 31.16

	% Canopy openings	
Plot #	**Avg.**	**Range**
16	19.57	16.48 - 23.63



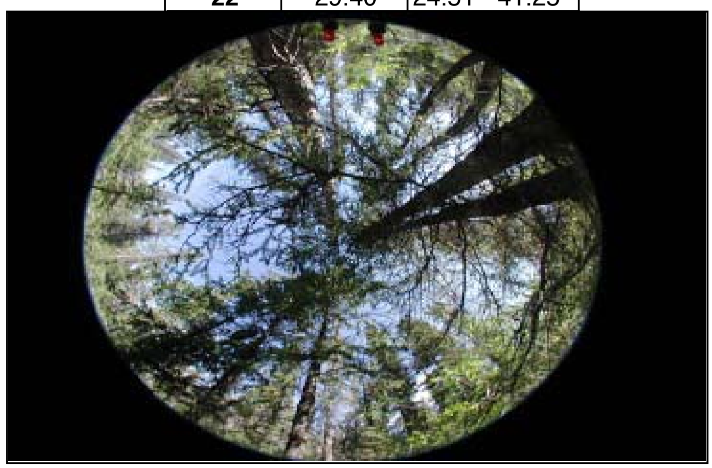
	% Canopy openings	
Plot #	**Avg.**	**Range**
17	24.70	16.82 - 27.15

	% Canopy openings	
Plot #	**Avg.**	**Range**
18	22.00	15.4 - 28.63

	% Canopy openings	
Plot #	**Avg.**	**Range**
19	22.59	18.06 - 25.8

	% Canopy openings	
Plot #	**Avg.**	**Range**
21	22.54	19.82 - 26.37

	% Canopy openings	
Plot #	**Avg.**	**Range**
22	29.40	24.51 - 41.25



	% Canopy openings	
Plot #	**Avg.**	**Range**
23	26.98	17.46 - 37.96

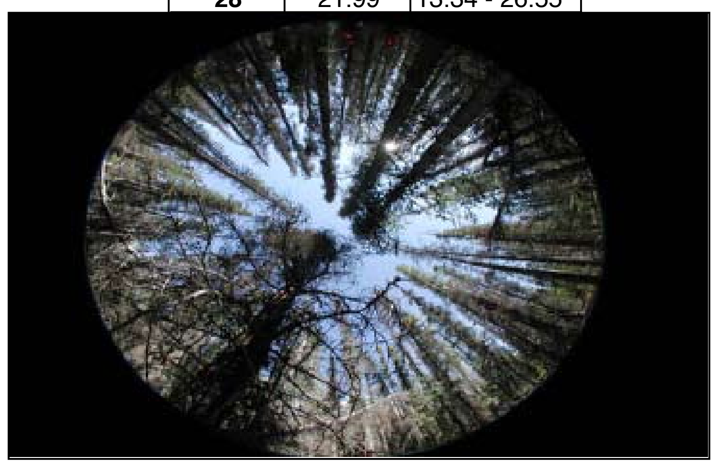
	% Canopy openings	
Plot #	**Avg.**	**Range**
24	23.66	15.98 - 58.84

	% Canopy openings	
Plot #	Avg.	Range
25	27.98	17.85 - 37.48

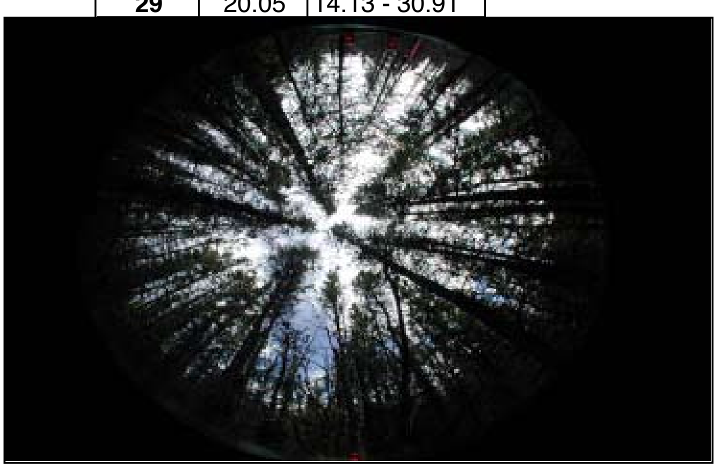
	% Canopy openings	
Plot #	Avg.	Range
26	22.24	18.79 - 25.91

	% Canopy openings	
Plot #	Avg.	Range
27	22.92	18.63 - 30.61

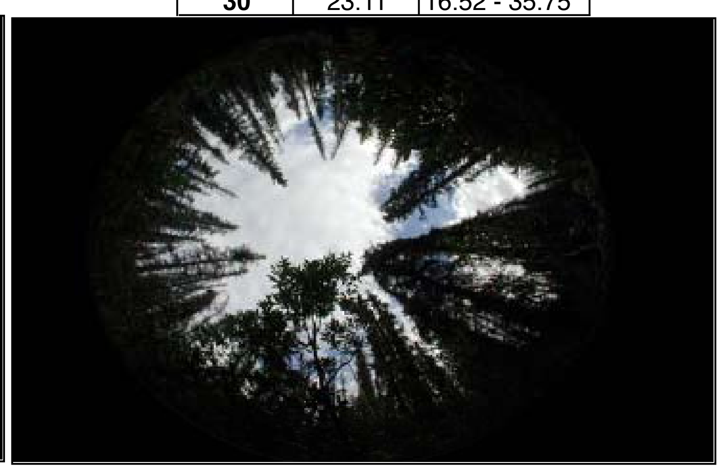
	% Canopy openings	
Plot #	Avg.	Range
28	21.99	13.34 - 26.55



	% Canopy openings	
Plot #	Avg.	Range
29	20.05	14.13 - 30.91



	% Canopy openings	
Plot #	Avg.	Range
30	23.11	16.52 - 35.75



	% Canopy openings	
Plot #	**Avg.**	**Range**
31	24.65	18.62 - 37.82

	% Canopy openings	
Plot #	**Avg.**	**Range**
32	28.09	23.85 - 34.86

Canadian Forest Service Contacts

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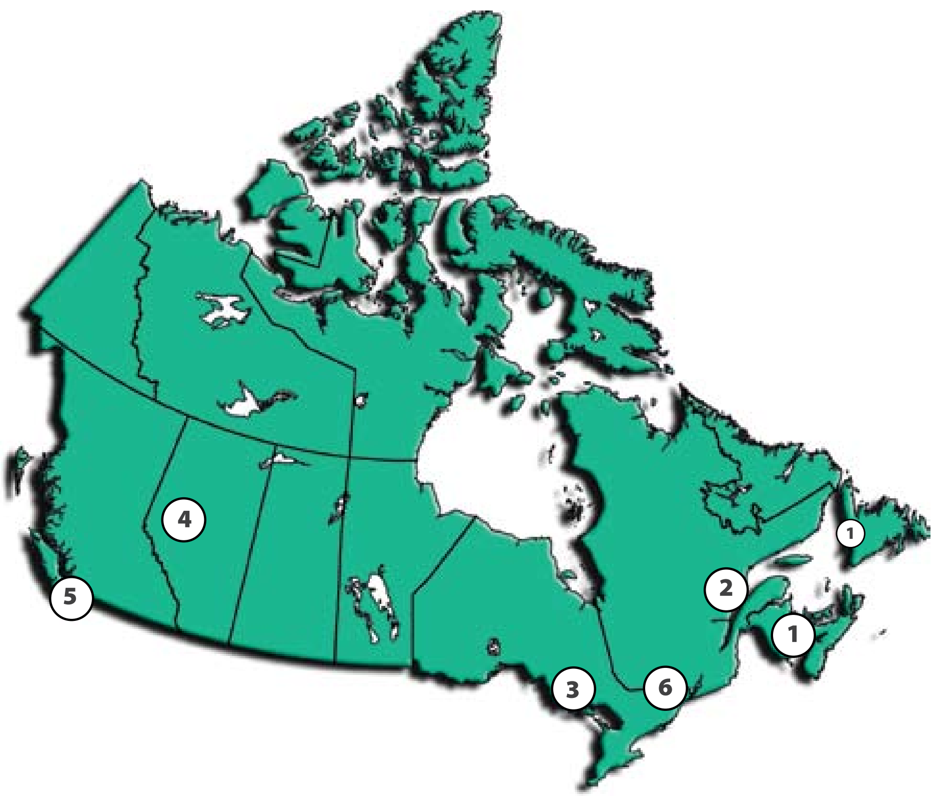

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