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Vegetation establishment during 5 years following wildfire in northern British Columbia and southern Yukon Territory

E. T. Oswald
B. N. Brown

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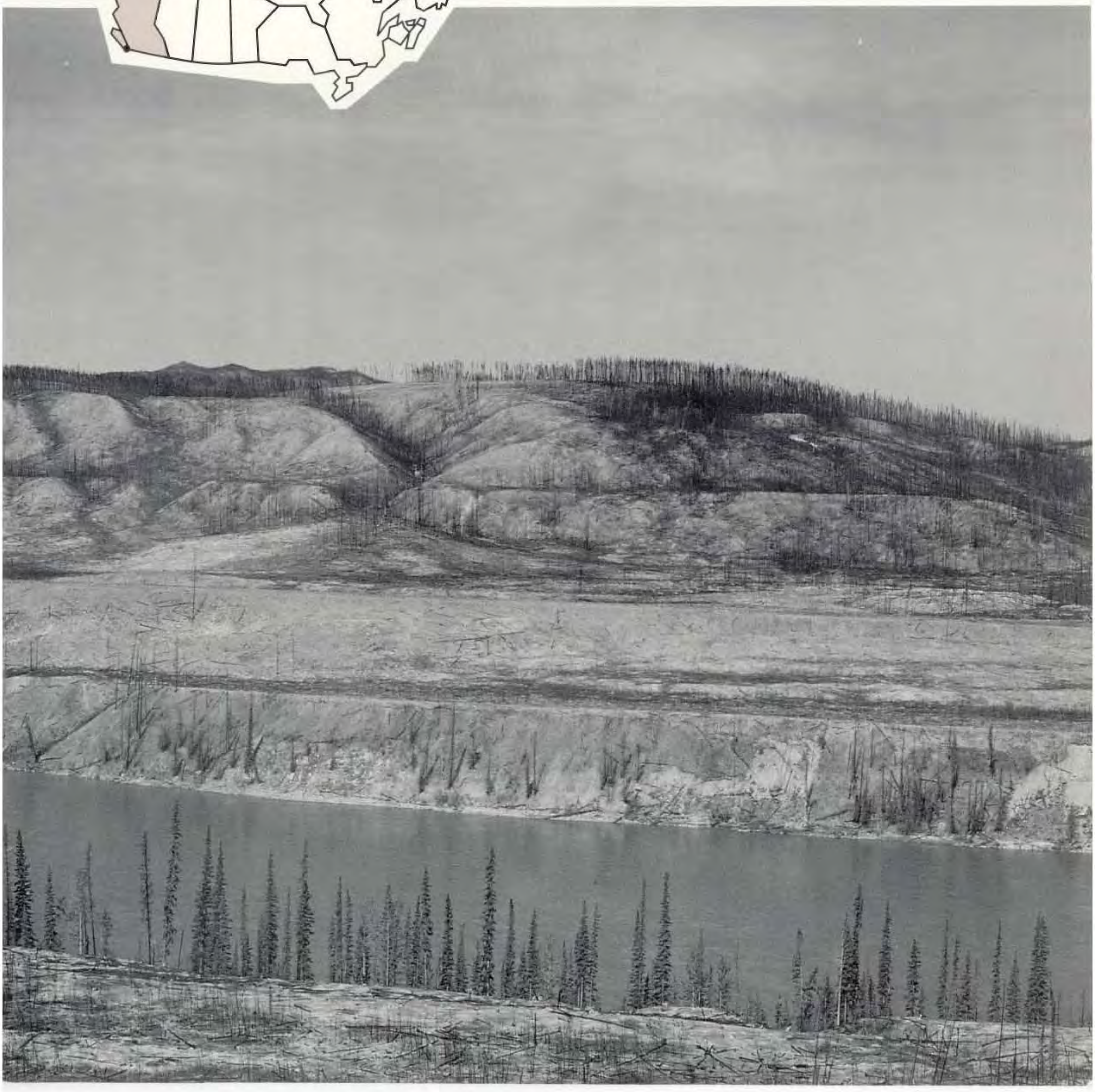
Pacific and Yukon Region



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Abstract

A study on revegetation following wildfires was conducted on four fires near the Yukon Territory - British Columbia border (60° N. Lat.). One wildfire occurred at Aishihik junction off the Alaska Highway in south-central Yukon in 1980; and three fires occurred near Watson Lake, Yukon Territory in 1982 — one in Yukon and two in British Columbia. This report covers the first 5 years of vegetation succession on 47 plots established in the areas burnt by these four fires. Coniferous tree seedlings or aspen juveniles appeared on all plots within 3 years, and varied in density from 700 to 80 100 juveniles/ha in the fifth year. Shrubs, mostly regenerating from root stalks and rhizomes, were frequently the tallest plants. Forbs did not appear to be major competitors as some populations would attain a peak coverage during the second or third year and then diminish, while others remained with low coverage. A moss, *Ceratodon purpureus*, provided the most coverage of all species on most sites. The stable communities on a site can apparently be predicted after about 5 years based on the species of trees, shrubs, and forbs present, but additional monitoring is required to confirm this and document the various seral stages.

Résumé

On a étudié la restauration de la couverture végétale par suite de feux de friches dans quatre sites près de la frontière du Territoire du Yukon et de la Colombie-Britannique (60° de latitude N.). Un des feux s'est produit en 1980 à Aishihik Junction, près de la route de l'Alaska, dans le centre sud du Yukon, et les trois autre sont survenus en 1982 près de Watson Lake (Territoire du Yukon) - un au Yukon et deux en Colombie-Britannique. Dans le présent article, on étudie la succession végétale durant les cinq premières années qui ont suivi les feux, dans 47 parcelles établies dans les régions brûlées. Des semis de conifères et des jeunes trembles sont apparus dans toutes les parcelles en l'espace de trois ans et leur densité variait de 700 à 80 100 jeunes/ha la cinquième année. Les plantes les plus hautes étaient fréquemment des arbrisseaux, qui, pour la plupart, se sont régénérés à partir de drageons racinaires et de rhizomes. Il semble que les herbes non graminéennes n'aient pas constitué des compétiteurs importants, puisque certaines populations ont atteint une couverture maximale durant la deuxième ou la troisième année, pour voir ensuite leur densité diminuer, tandis que d'autres populations ont maintenu une couverture faible. Dans la plupart des sites, l'espèce dominante de la couverture était la mousse *Ceratodon purpureus*. Il semble que l'on puisse prévoir la composition des communautés stables dans un site après environ cinq ans en se fondant sur les espèces d'arbres, d'arbrisseaux et d'herbes non graminéennes présentes, mais une surveillance additionnelle est nécessaire pour confirmer cette prévision et documenter les divers stades de succession.

Acknowledgments

Special thanks are extended to the Forest Resources, Northern Affairs Program, Department of Northern Affairs for their continued support throughout this study, and in particular to Don White and Christine Boyd who collected the fifth year data. This program also provided financial support for a student to formulate a computer analysis procedure. Keith Kepke, Head of Fire Management for Forest Resources, Northern Affairs Program, kindly provided information on the fires in the Yukon Territory. We would also like to thank John Parminter of the British Columbia Ministry of Forests for providing data he collected on plots established in the vicinity of, but prior to, two of the fires examined in this report, and for data on the two fires in northern British Columbia.

Introduction

Wildfires have been a prominent feature in the ecology of the forested terrain in the Yukon and northeastern British Columbia (Rowe 1970) and are the main extensive and drastic disturbance since glaciation and volcanic ash deposition. A forest stand over 250 years of age in the general vicinity of the study areas is rare (Hawkes 1982), indicating that nearly every area burns at least once in this period of time. Indeed, some tracts of land in southern Yukon currently support only shrubs due to the elimination of tree species and their propagules as a result of repeated fires at short intervals. Although the current fire management policy greatly curtails the size of many fires, particularly those in easily accessible areas, wildfires can still be extensive when they occur in remote areas and when burning conditions are optimal. The interval between fires not only affects stand ages, but has a strong influence on the species of trees, shrubs, herbs, and bryophytes that occupy various sites, and on site productivity.

Several attempts have been made to model vegetation succession following wildfires by examining post-fire stands of various ages on different sites (Arno et al. 1985; Parminter 1983; Kelsall et al. 1977; Viereck and Schandelmeier 1980; and Van Wagner 1984). However, as stated by Stickney (1980, 1985) "This approach describes forest succession as it is perceived rather than as it is observed to occur." Several studies on succession of forest vegetation during the early stages after a wildfire (Lyon 1976, 1984; Crane et al. 1983; Grier 1975; Viereck and Dyrness 1979) have indicated that the succession is unpredictable and variable. There are several factors that if quantified could reduce variability and improve the prediction of forest succession following a wildfire: 1) degree of disturbance (fire intensity and organic matter reduction); 2) time of year, particularly in relation to vegetation phenology; 3) macro- and micro-climatic conditions before and after the fire, which vary from year to year; 4) site and habitat conditions which can vary considerably from area to area, even over small distances within a mountainous forest site type; 5) soil conditions, which, although related to site, the texture and amount of incorporated organic matter, and the depth and moisture content of the surface organic layer, influence the propagules that survive a fire; 6) geographic variations within or among vegetation types which, along with time of year and fire intensity, are related to the propagules available for recolonization; 7) successional stage, or stand history, of vegetation just prior to the fire; and 8) activities of the various agents influential in propagule dispersal (wind, water, birds, and animals, including man) and the distance from which the propagules originate.

This report describes the first 5 years of vegetation succession following four wildfires near the Yukon Territory - British Columbia border (60° N. latitude). Three fires occurred in the vicinity of Watson Lake, Yukon Territory — one in Yukon and two in British Columbia — and the other fire occurred near Haines Junction, Yukon Territory. The main objectives of the study are to monitor and describe the forest vegetation development and succession on different sites, to compare the seral stages among the site types, and to develop prediction models for vegetation succession following wildfire.

Study Areas

The Wildfires

The study areas consist of selected portions of four wildfires (Figure 1). The Aishihik fire, which started from a broken power line, burned 747 ha near the Aishihik Junction off the Alaska Highway in south-central Yukon (60° 52'N, 137° 02'W) mostly during a 10-day period in early June, 1980. This area lies in the Ruby Range Ecoregion (Oswald and Senyk 1977), and in the Aishihik River Valley just north of its confluence with the Dezadeash River Valley which is part of the Takhini Intermontane Valley Physiographic Subdivision of Bostock (1965). Most of the plots are located on a high terrace consisting of stratified loose sand, gravel, and silt with an occasional boulder, and are of glaciofluvial or glaciolacustrine origin. One plot is located on alluvial gravelly sand and silt of an older flood plain above current normal flood levels. This study area would most likely be included in the Spruce-Willow-Birch Biogeoclimatic Zone (British Columbia Ministry of Forests, 1988).

The prefire vegetation consisted of open-growing white spruce [*Picea glauca* (Moench) Voss] mostly 10-15 m in height with kinnikinnick [*Arctostaphylos uva-ursi* (L.) Spreng.] and grass on the more sandy soils and mixed willow [Salix spp.] and Labrador tea [*Ledum groenlandicum* Oeder] most often with feathermoss [mostly *Hylocomium splendens* (Hedw.) B.S.G., *Pleurozium schreberi* (Brid.)

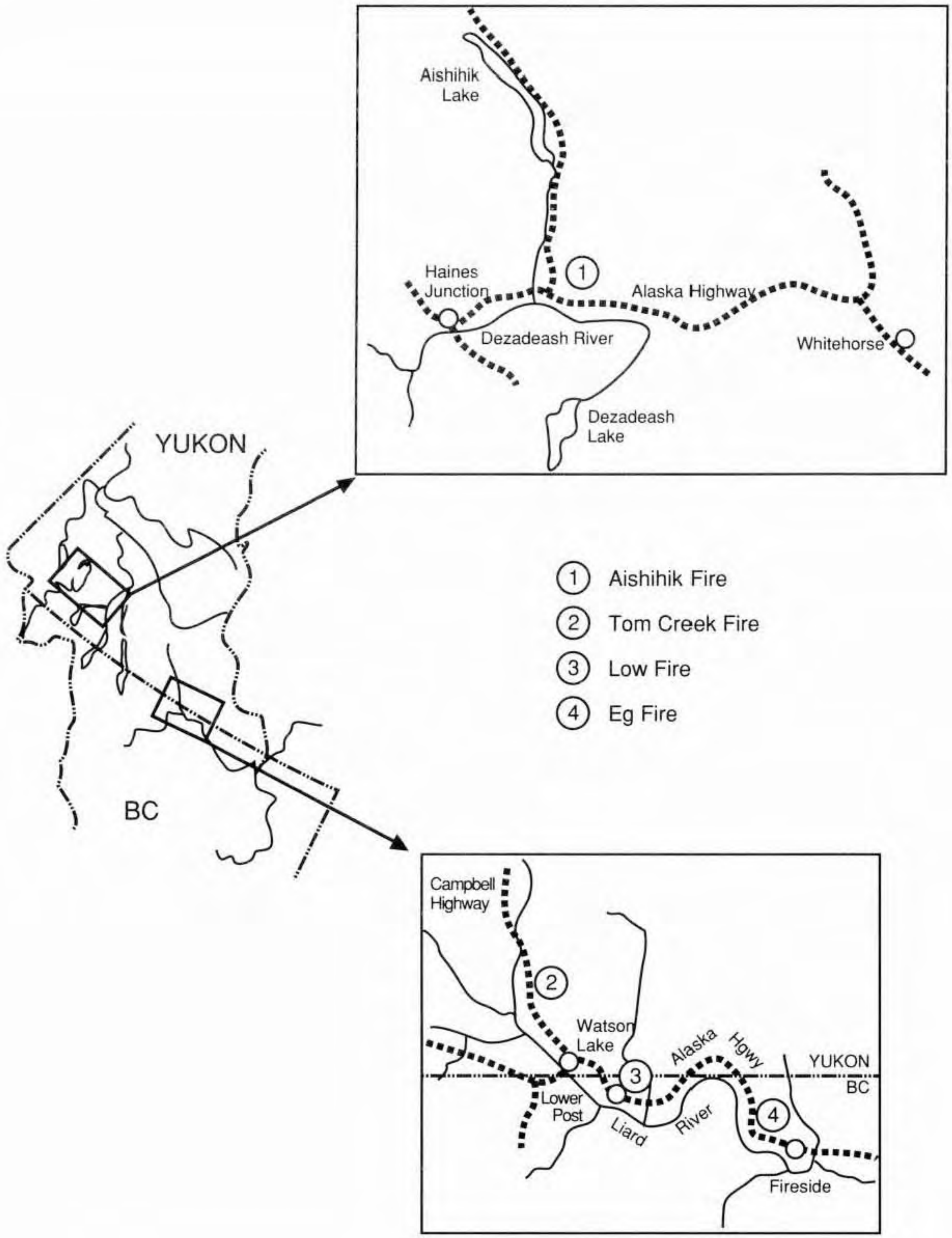

Figure 1. Map showing location of study areas

Mitt, *Ptilium crista-castrensis* (Hedw.) De Not., and *Thuidium abietinum* (Hedw.) B.S.G.] on more silty soils. The alluvial site had white spruce about 20 m tall with an understory of twinflower [*Linnaea borealis* L.] and feathermoss, based on previous unpublished work and adjacent unburned vegetation. Aspen [*Populus tremuloides* Michx.] was generally present along the roads and mixed with white spruce particularly in openings, and a few nearly pure aspen stands of different ages were consumed in the fire.

Three separate wildfires occurred in southeastern Yukon and northern British Columbia in the vicinity of Watson Lake, Yukon Territory in 1982. All three are in the Liard Plain Physiographic Subdivision (Bostock 1965), the Liard River Ecoregion (Oswald and Senyk 1977), and in the Boreal White and Black Spruce Biogeoclimatic Zone (British Columbia Ministry of Forests 1988). One lightning-caused fire occurred near Tom Creek (60° 13'N, 128° 55'W) on mostly morainal soils with some exposed bedrock. This fire, known by number WL 13-82 and referred to in this report as the Tom Fire, burned 8000 ha over a 13-day period in early July. Lodgepole pine [*Pinus contorta* Dougl.] about 120 years old, often mixed with black spruce [*Picea mariana* (Mill.) B.S.P.] of similar age, was the dominant tree species, but stands of nearly pure black spruce occurred on the more moist sites, and stands of nearly pure lodgepole pine occurred on the driest sites. Rose [*Rosa acicularis* Lindl.], lingonberry [*Vaccinium vitis-idaea* L.], and willow [*Salix* spp.] were the most common shrubs on moist to drier sites, whereas bilberry willow [*Salix myrtillifolia* Anderss.], Labrador tea, and red bear-berry [*Arctostaphylos rubra* (Rehd. & Wils.) Fern.] dominated on wetter sites with black spruce.

The other two wildfires occurred just south of the British Columbia-Yukon border. Both of these fires occurred on a variety of soil materials, and consumed a variety of forest stands related in species composition and age to the local fire history. Parminter (1983) located some fire history and ecology plots in the vicinity of these two fires in 1981 and found that previous fires had occurred approximately in 1965, 1959, 1921, 1883, 1871, and 1865 in the general area within and outside the current wildfires. A few of his plots occurred within the areas burnt in the 1982 fires. The Low Fire was in the vicinity of Lower Post, British Columbia near 59° 58'N, 128° 30'W and occurred on glaciolacustrine, glaciofluvial, and aeolian capped morainal material. The fire, which originated from an escaped garbage dump fire on July 29 and which was brought under control on August 3, burned 1200 ha. Though some aspen, white spruce, black spruce, white birch [*Betula papyrifera* Marsh.], and tamarack [*Larix laricina* (Du Roi) K. Koch] were present, lodgepole pine was the most prevalent tree species. Most of this area was easily accessible and selective logging had removed some of the larger trees from some sites; thus, the dominant remaining tree heights were between 15 and 20 m. The understory vegetation before burning consisted mostly of willow, Labrador tea, kinnikinnick, and feathermoss.

The largest fire, actually the coalescence of about three lightning-caused fires originating near Egnell Lakes collectively known as the Eg Fire, occurred mostly to the north of the village of Fireside, British Columbia (59° 40'N, 127° 9'W). Cowell (1983) described the development of this fire, which began on June 19 and was brought under control on August 15, and monitored the smoke plume around the world. Due to its size (182 000 ha), it encompassed a variety of soil types originating largely from coarse to fine textured materials on alluvial, aeolian, glaciofluvial, and morainal deposits. Several wildfires have occurred over the area in the past 150 years, so the preburn vegetation was a complex of stands of different ages ranging from dense lodgepole pine trees up to about 2 m in height and around 15 years of age to mature trees 15 m or more in height and approximately 150 years old (Parminter 1983). The forest cover was likely also influenced by the construction and presence of the Alaska Highway, which was originally built in 1942; this highway crosses the burned area and local wood was used for construction purposes and subsequently as cord wood. Black spruce was prevalent in some older stands, particularly the cooler and more moist areas; white spruce and lodgepole pine usually dominated stands on medium to coarse textured soils. Aspen and balsam poplar [*Populus balsamifera* L.] dominated seepage areas and most medium textured soils, and white birch was widely scattered, but was most prevalent on the cooler sites. Tamarack was present on some slopes and in a few depressions, but was never dominant. Preburn understory vegetation varied from virtually nothing more than some lichens in the dense, young pine stands to kinnikinnick, lingonberry, and grass on drier sites, and alder [*Alnus crispa* (Ait.) Pursh] or willow, or both, on the more moist sites. The more mature stands usually supported a feathermoss understory. Because of the size and the preburn vegetal complexity of the burned area, it is very difficult to confidently estimate the preburn understory where the vegetation was completely consumed.

Climate

The climate in the Aishihik area is influenced by the maritime regime from the Pacific Ocean after passing over the Coast Mountains; however, for general considerations it is a cold temperate climate with short, warm summers and long, cold winters. Precipitation at Haines Junction, 35 km southwest of the burnt area, averages about 280 mm annually, with about 90 mm falling during the June to August period. The annual mean temperature is -3°C, with average temperatures in January of -21°C and in July of 12°C. The average May to September temperature is 9°C. These figures vary insignificantly from comparable figures at Whitehorse, 125 km (by road) east of the burnt area; Whitehorse is about 2°C warmer, and more moist (by 8 mm) during the summer, although the annual precipitation at Whitehorse is less (260 mm).

Watson Lake, which is roughly in the middle of the other three burns, endures a more continental climate than Haines Junction or Whitehorse, with a wider range in maximum and minimum temperatures and more precipitation. The average annual temperature here is -3°C, with averages during January and July of -25°C and 15°C, respectively, and an average during the May to September period of 9°C. The annual precipitation is 434 mm, with 147 mm falling during the June to August period. Based on surrounding topographic features, it is likely the Tom Creek area is somewhat more moist and cooler than at Watson Lake, and the other two areas could be slightly drier.

Methods and Plot Description

Plot locations are subjective in the sense that we selected the general site types and uniform conditions within each site type, and without pre-conceived bias in that a stake was tossed to find the first preselected plot corner which was always the lower left, or proximal left if on level ground. Plots were located so as to sample a variety of the soil, physiographic, geologic, and preburn vegetation types present within each of the burned areas. The number of potential sites available for sampling exceeded the amount of time available for plot analysis, so all types and conditions were not sampled.

The Eg Fire presented the greatest number of possible sample sites, not only due to the combinations of soil-related materials, but also due to the various types of preburn vegetation and apparent fire intensities. Where the trees were small and dense, there was often total consumption of aboveground wood fibre and only ash remained. Where trees were larger, most often the burned boles remained standing until they were blown over by winds. Plots were located in each of these situations over a range of terrain conditions. The Tom Fire probably provided the best moisture gradient as nearly all plots are located along a transect from near the toe to the top of a westerly-facing slope (approximately 10%) with about a 150 m rise over a distance of about 2 km. In all study areas the plots are mostly located close to roads or drivable trails, but are sufficiently removed so as not to be influenced by the roads. A few plots are up to 0.5 km from the road, and the route realignment has moved the road even farther away from some plots.

Grass was seeded in selected areas along the Alaska Highway in northern British Columbia in an effort to control erosion and dust; however, climatic conditions subsequent to aerial seeding apparently prevented a significant amount of grass establishment within or near any of the plots.

A plot consists of a 10 X 10 m square divided into four 5 X 5 m subplots with a 1 X 1 m quadrat in the outer corner (Figure 2). The subplots are used for measuring woody plants, with the intention they can be meshed together when the trees get too large

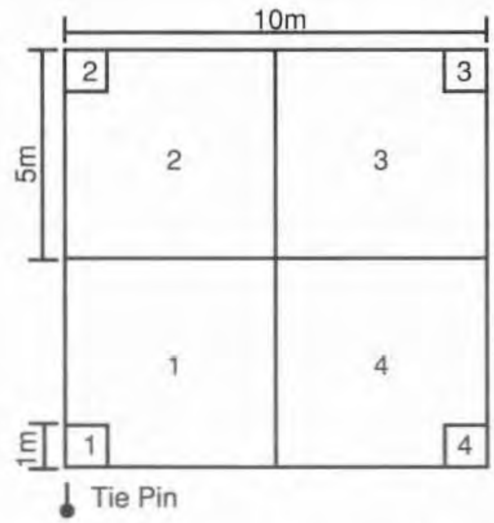

Figure 2. Plot layout showing position of subplots and quadrats

to be measured in the smaller plots. The quadrats are used for the herbaceous and bryoid species. Though the different plot segments are in close proximity to each other, the variation in physical features, burn intensity, and species invasion, particularly among the quadrats, is such that they are measured individually and considered as separate samples.

For each plot, the general physical conditions, such as slope, aspect, position on slope, landform, amount of exposed mineral soil, depth of remaining organic matter, and depth of ash, were recorded. Soil classification follows the system of the Agriculture Canada Expert Committee on Soil Survey (1987), and the site moisture regime was adopted from Walmsley et al. (1980). Most of these data were also valid for the subplots, but any variations were noted. The microhabitats of the quadrats varied such that it was necessary to treat each one separately for physical conditions, fire intensity, depth of ash, and related parameters. The vegetation analyses consisted of estimating the percent cover of each species, counting the number of plants, and determining the average heights of woody species. Most plots were examined 1, 2, 3, and 5 years after burning. It is anticipated that the plots will be examined 10 years after burning and, after that, at 10-year intervals until stand maturity. Those at Aishihik commenced on the third year following the fire. Botanical nomenclature follows Porsild and Cody (1980), Hulten (1968), and Hitchcock et al. (1969) for vascular plants and Lawton (1971) for mosses. Some common names were obtained from Taylor and MacBryde (1977).

Burn intensity was estimated, based mostly on the amount and size of remaining woody material and proportion of duff consumed (DeByle 1981). Where all woody vegetation except standing tree boles with a diameter at breast height (dbh) of more than 10 cm was consumed, the burn intensity was considered severe; if tree and shrub branches were only killed and scorched, the burn intensity was considered low. In a moderate burn, twigs up to about 1 cm in diameter were totally consumed, and those larger than 1 cm were partially burned. Often the depth of ash or remaining organic material, or the relationship between the two, depended more on site conditions and previous fire history than the severity of the current fire. This was based on the greater amounts of organic matter accumulation on moist, more productive sites as opposed to dry, less productive, sites, and the consumption of organic material during previous fires estimated from the amount of charcoal.

General Revegetation

There is a marked difference in the vegetation initiation and succession between the Aishihik area and the Watson Lake area. The difference can be explained by the fact that the Aishihik area is in a different Ecoregion, and has different surficial materials, climate, and prefire vegetation. In addition, different times have elapsed in these areas since fire disturbance. The area examined in the Tom Fire differs from that of the Low and Eg fires in that the preburn vegetation consisted of continuous mature lodgepole pine and black spruce forest, along a gradient of morainal material, moisture, and elevation on the same moderate slope and westerly aspect. Other parts of the Tom Fire, and parts of the Low and Eg fires that were sampled, have similar site conditions, but also contain a larger range of site types.

The general revegetation development in each of the Eg (Figure 3), Low (Figure 4), and Tom (Figure 5) fires follows similar patterns except for the greater abundance of herbs in relation to non-vascular plants in the second and third years in the Tom Fire (Table 1). The revegetation at Aishihik may have been similar, but our records are only for years three and five, and they indicate a different pattern (Figure 6) in that herbs appeared to be more abundant in the third and fifth years than at the other fires. In all fires, however, herb coverage declined and non-vascular coverage increased during the third to fifth years. Revegetation assessment of the burns near Watson Lake began the year following the fire, so any vegetation development during the year of the burn is unknown. The non-vascular vegetation, mostly mosses and liverworts, had the greatest initial growth in the Eg Fire, but leveled off between years two and three, and then regained virtually the same rate of increase over years three to five as they did the first year. Herbs had a more rapid initial increase following the Tom and Low fires, while in the Eg fire herbs steadily increased in percent cover over the first three years and then declined. Shrubs and trees increased in a more continuous and gradual fashion in all three areas. Some forbs, such as fireweed [*Epilobium angustifolium* L.], cranesbill [*Geranium bicknellii* Britt.], and corydalis [*Corydalis sempervirens* (L.) Pers.] were relatively abundant in the second and third years, but either declined or were totally absent in the fifth year (Figure 7). Some shrubs, such as willow [*Salix* spp.], alder, and rose often started the first year from root stalks or underground stems and

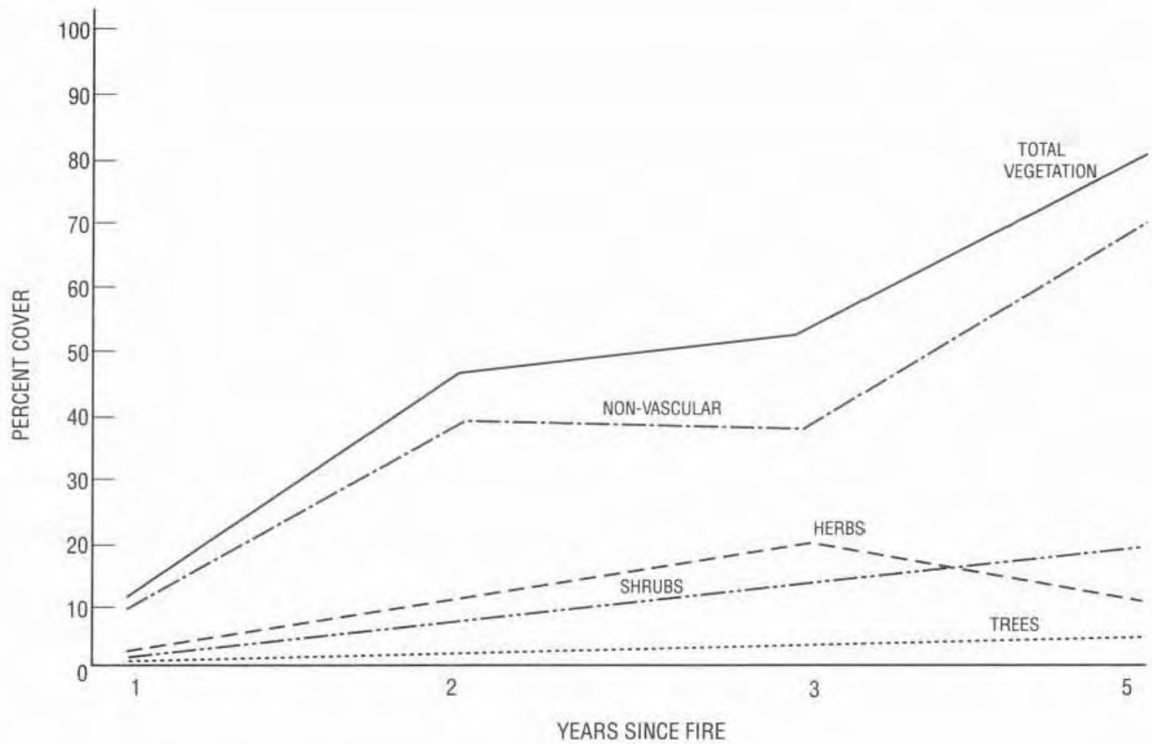

Figure 3. Vegetation development over a five-year period following the Eg Fire

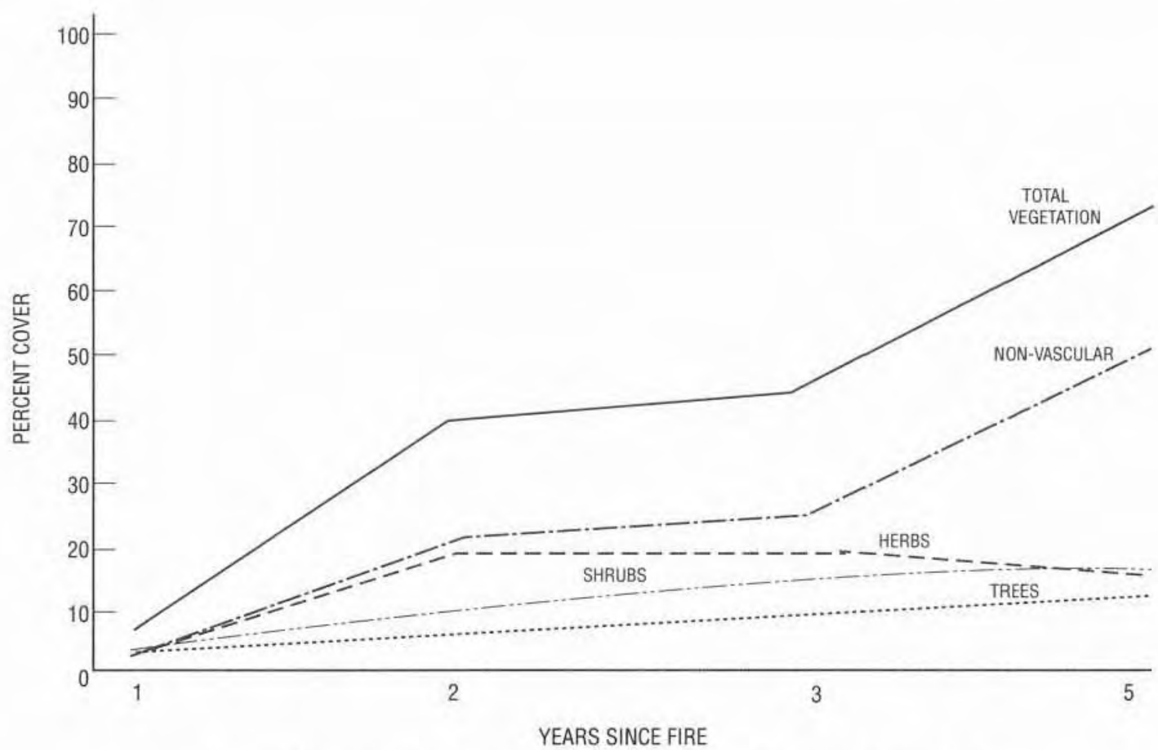

Figure 4. Vegetation development over a five-year period following the Low Fire

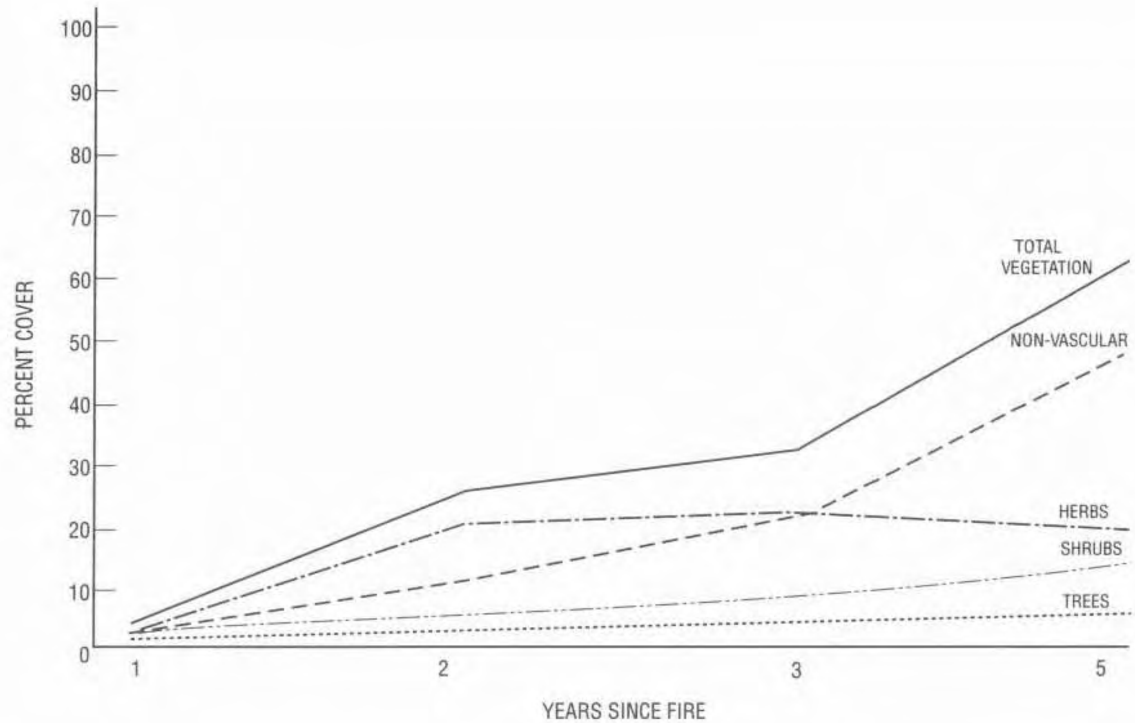

Figure 5. Vegetation development over a five-year period following the Tom Fire

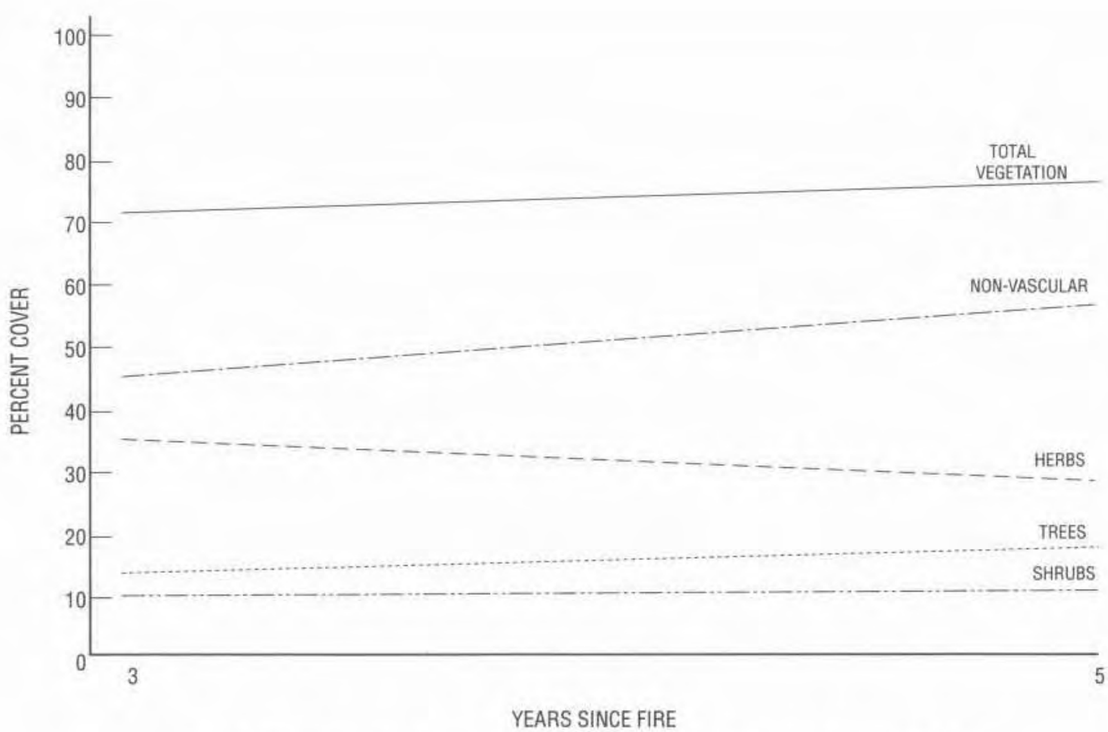

Figure 6. Vegetation development at three and five years following the Aishihik Fire

were augmented by subsequent seedlings, and their coverage tended to continue increasing over the five-year period (Figure 8).

The trees, mostly lodgepole pine, black spruce, and white spruce which began germination and establishment from seed, and aspen which originated from a combination of seeds, root stalks, and suckers the first year, increased their coverage mostly from plant development in subsequent years. In general, lodgepole pine and aspen were the most commonly and abundantly encountered reproducing tree species, but black spruce, white spruce, white birch, and balsam poplar were sometimes present as well and sometimes abundant (Appendix A). Lodgepole pine had the greatest number of seedlings beginning in the first year, but also had a relatively high rate of mortality, mostly due to dessication. The succumbed seedlings were most often replaced by new ones over the first three years or so; very few new seedlings were observed after that, except in a couple of exceptional cases. Aspen had a more gradual introduction, mostly by vegetative propagation to begin with and later by seeds drifting in from outside sources. The spruces were slower to appear, and thus showed major increases in the third and fifth years. Appendix B contains information on tree reproduction for each 10 m X 10 m plot, which is the summation of data from four 5 m X 5 m subplots, for each burned area, and an indication of the principal prefire tree species as determined from boles left standing after the fires.

Table 1. Mean percent cover by vegetation stratum and year for each fire

Stratum	Years after fire	Fire			
		Tom	Low	Eg	Aishihik
Trees	1	<1	<1	<1	-
	2	<1	4	<1	-
	3	<1	6	2	11
	5	2	8	4	15
Shrubs	1	<1	1	<1	-
	2	3	8	5	-
	3	5	11	11	8
	5	10	13	17	8
Herbs	1	<1	2	2	-
	2	18	16	11	-
	3	19	16	18	33
	5	16	12	9	26
Non-vascular	1	1	<1	9	-
	2	9	18	38	-
	3	18	21	37	43
	5	44	47	68	54
All	1	2	3	11	-
	2	23	37	45	-
	3	29	41	51	69
	5	59	69	79	74

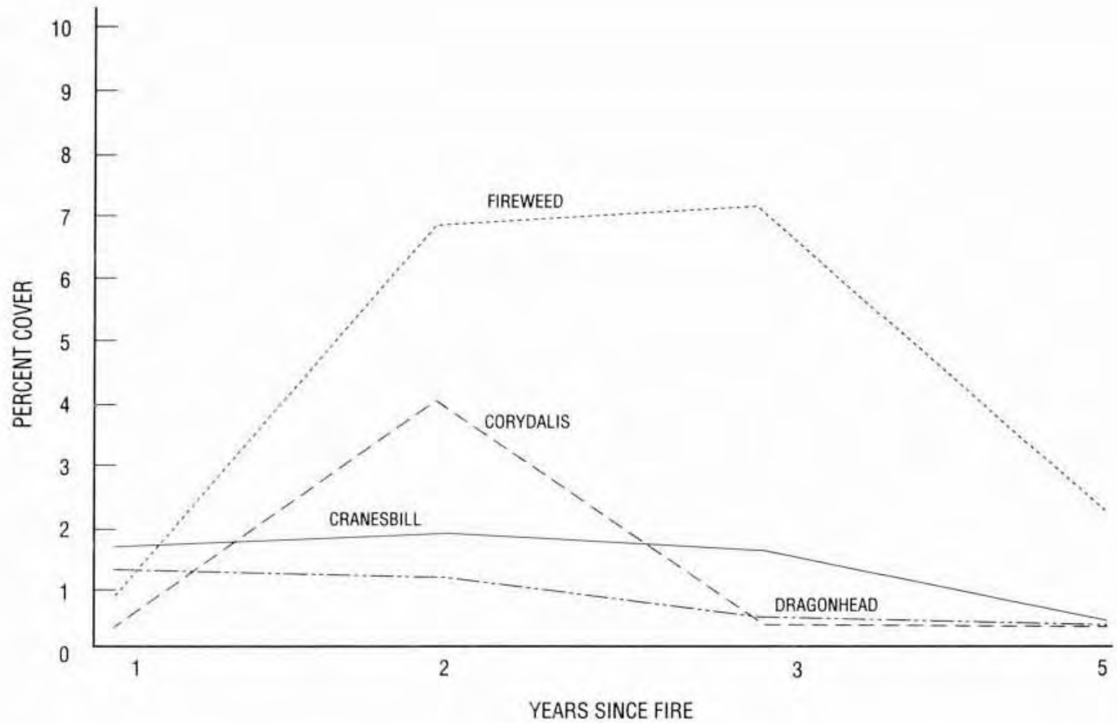

Figure 7. Successional progression of fireweed, corydalis, cranesbill, and dragonhead over a five-year period following the Eg and Low fires

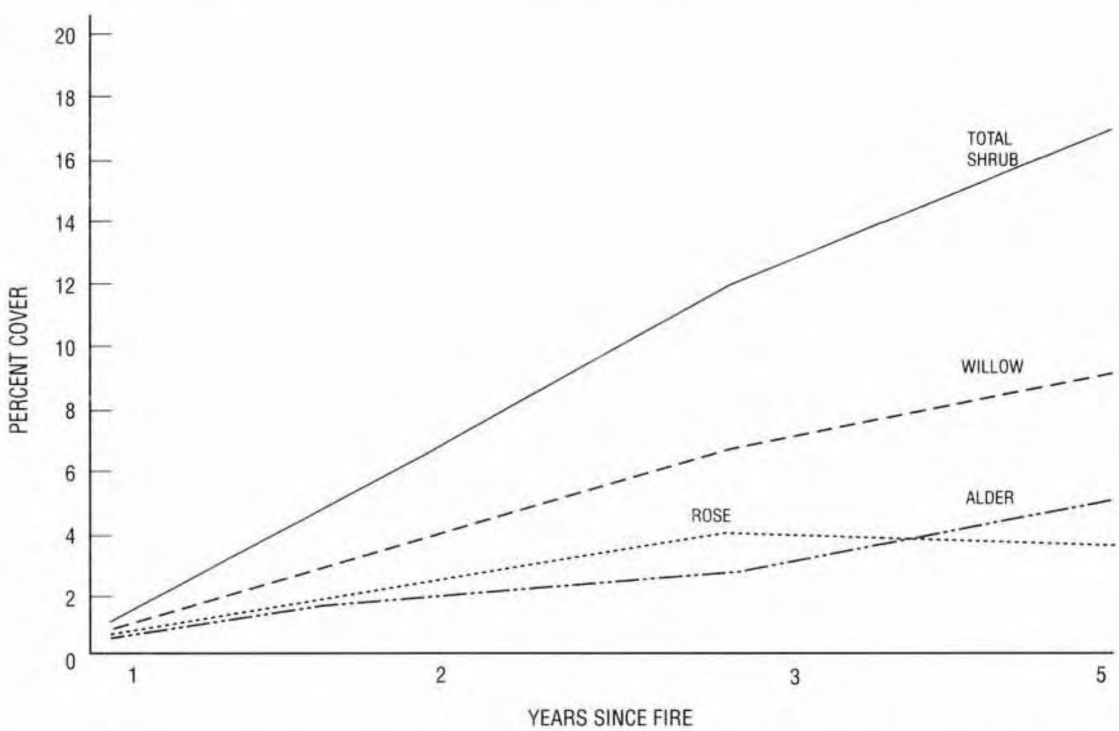

Figure 8. Successional progression of total shrubs, willow, alder, and rose over a five-year period following the Eg and Low fires

Tom Fire

General description

The alignment selected for revegetation assessment in the Tom Fire constituted a good moisture gradient going from near the toe of a slope to the crest. A plot located in a poorly drained, subhydric, lower slope position and one in a moderately well drained, subhygric, mid-slope position supported black spruce stands prior to the fire. The other sites had supported lodgepole pine as the dominant tree species, although black spruce was often present. The productivity (based on tree size and density) and understory vegetation reflected the variation in site moisture. Although the transect was interrupted by rock outcrops, shallow soils, and some slope alterations, sites with more favorable moisture regimes had larger or more dense trees and a richer or more lush understory; also, the more moist sites tended to receive lighter burns than the drier sites. Table 2 contains a summation of tree regeneration data for all sites examined in the Tom Fire, and Table B1 of Appendix B gives tree regeneration data by plot, the total number of juveniles per hectare, and the prefire forest composition. Lodgepole pine seedlings occurred in 90% of the subplots, and had the highest number per hectare after five years, but black spruce, aspen, and white birch were also present. Willow, raspberry, and alder had the highest constancy among the shurbs, fireweed among the forbs, and ceratodon [*Ceratodon purpureus* (Hedw.) Brid.] and polytrichum [*Polytrichum juniperinum* Hedw.] among the non-vascular plants (Table 3). A few sites representing a range of conditions are described in the following sections. The percent cover figures given in the following detailed descriptions are for subplots; thus, they will not necessarily be the same as those given for the entire plots in Table 3.

Representative sites

Lower slope site (plot 35)

This plot was the lowest plot on the slope and it supported a stand in which lodgepole pine was dominant and also contained a component of black spruce (subplot 35-1 is shown in Figure 9). This plot is located on moderately well drained, coarse textured, morainal soil, classed as Gleysol, on a lower slope position with a subhygric ecological moisture regime, and it was severely burned. Lodgepole pine seedlings became established at the rate of 5700/ha the first year; by the fifth year they had increasing to 8200/ha and had reached heights to about 20 cm. No black spruce seedlings were observed in the first two years. However, by the fifth year there were about 12 800 black spruce seedlings per ha; most were no more than 7 cm in height, although a few were up to 14 cm. Aspen was the only other tree species becoming established. It also was not observed during the first two years (indicating seed immigration) but by the fifth year there were about 3900 aspen seedlings per hectare, and some had reached a height of over 20 cm. These tree seedlings are generally masked in Figure 9 by the shrubs and forbs. Although most shrubs appeared to originate from root stalks, only rose, alder, and diamond willow [*Salix glauca* L.] appeared in the first year after the burn. After five years, rose was the most abundant with 39 000 stems/ha and provided the most cover, but alder at 2 m and diamond willow at 3.8 m were the tallest. Fireweed appears to have mostly started from seed as it was rare in the first year but had increased to over 30% cover by the third year; it was reduced to about 5% cover by the fifth year. Ceratodon, although somewhat discontinuous, provided about 35% cover by year five; polytrichum was another prominent bryophyte with patchy distribution, but it provided about 10% cover by the fifth year.

Mid-slope site (plot 39)

Mid-slope plots, exemplified by plot 39, possessed a well drained, coarse textured, mesic, Orthic Dystric Brunisol soil derived from morainal material, and generally they were lightly burned (subplot 39-4 is shown in Figure 10). The prefire tree cover in subplot 39-4 was dominated by lodgepole pine with a minor component of aspen. Lodgepole pine seedlings were abundant in this plot; there were 21 800/ha in the first year, but by the fifth year they had declined to about 16 000/ha and were up to 25 cm in height. Although aspen was sparse (about 100 stems/ha) and did not appear until year three, it attained heights of over 1 m in five years. Spruce and white birch became sparsely distributed after year two, and birch was the tallest tree species at 1.8 m. Alder, which originated from root stalks, attained the greatest height at 2.7 m and provided about 5% cover. Raspberry [*Rubus idaeus* L.] mostly started in year two; it was the most prolific shrub (3500 stems/ha)

Table 2. Tree regeneration characteristics after five years in 44 subplots at the Tom Fire

	Tree species			
	Black spruce	Lodgepole pine	Trembling aspen	White birch
Subplots in which species occurred	37	40	38	29
Juveniles*/subplot (average)	12.3	38.1	14.5	15.1
Juveniles/subplot (range)	1 - 47	1 - 120	1 - 75	1 - 105
Juveniles/ha (average)**	4150	13 750	5010	5110
Juveniles/ha (range)**	100 - 13 200	200 - 40 600	300 - 15 300	300 - 31 000
Average height (cm)	8.1	18.8	36.6	21.9
Height range (cm)	3 - 15	6 - 30	5 - 125	3 - 38

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

** These are based on data from 10 X 10 m plots.

Table 3. Average fifth year percent cover of the more prevalent shrubs, forbs, and non-vascular plants in 10 X 10 m plots at the Tom Fire

	Plot										
Type of vegetation	34	35	36	37	38	39	40	41	42	43	44
Shrubs											
Rose	<1	4	0	0	5	0	0	0	0	0	0
Alder	0	3	10	<1	0	3	9	2	4	<1	1
Lingonberry	<1	0	1	<1	<1	0	<1	<1	<1	<1	<1
Willow	1	2	<1	1	<1	<1	2	1	<1	<1	<1
Raspberry	<1	<1	0	<1	2	10	<1	<1	<1	<1	2
Skunk currant	<1	<1	0	<1			1	0	0	1	28
All*	30**	9	11	3	10	16	12	4	5	2	32
Forbs											
Fireweed	<1	5	<1	5	2	10	2	3	2	4	2
Bunchberry	<1	2	<1	4	22	9	0	0	0	0	3
All*	5	7	<1	10	50	19	2	3	2	4	15
Non-vascular plants											
Ceratodon	35	34	<1	17	5	44	24	3	6	5	55
Bryum	8	<1	<1	3	<1	7	0	0	0	6	0
Polytrichum	<1	11	3	42	2	30	28	14	14	33	12
Liverwort	0	<1	0	1	<1	0	5	<1	3	0	0
All*	45	47	4	63	8	81	57	17	23	44	67

* May include less prevalent species which are not listed separately

** Nearly all *Salix myrtillifolia* Anderss. and *Ledum groenlandicum* Oeder

Figure 9. Five years of vegetation development on subplot 35-1 following the Tom Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

Figure 10. Five years of vegetation development on subplot 39-4 following the Tom Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

by year five and provided about 10% cover. Skunk currant [*Ribes glandulosum* Grauer] was the only other shrub species of importance, providing about 4% cover. Fireweed was the most common herb, but it seemed to peak in year three with about 20% cover and was reduced to about 10% cover by year five. Corydalis had less than 1% cover in year one, peaked at about 24% cover in year two, and did not appear after that. Ceratodon, beginning the first year and attaining about 45% cover in five years, and polytrichum, beginning mostly after the second year and attaining about 30% cover in the fifth year, were the most common bryophytes.

Upper slope site (plot 41)

The upper slope plot was located on well drained, coarse textured, submesic, morainal material with Orthic Dystric Brunisol soil development, and it endured a light to moderately severe burn (subplot 41-2 is shown in Figure 11). The prefire tree layer was dominated by lodgepole pine although a few aspen and white birch were present. Lodgepole pine seedlings were abundant; even in the first year following the fire there were 41 000/ha, dropping to 30 300/ha in the second and third years, and increasing to 31 700/ha in the fifth year. Aspen appeared the third year with 8500 stems/ha and increased to 15 300 stems/ha in the fifth year. White birch became apparent in the third year and attained a density of 2400 stems/ha in year five. Spruce seedlings were not detected until the fifth year when they amounted to 4900/ha. Willow was the most predominant shrub. It first appeared in the second year most likely from seed; by the fifth year there were over 4900 willow stems/ha which provided about 1% cover. Lingonberry, though not observed until the second year, mostly started from buried stems and root stalks, and amounted to about 12 300 stems/ha with about 1% cover in the fifth year. Fireweed was slow to get started; very little was observed until the third year and it provided about 5% cover by the fifth year. Ceratodon was observed the second year, but did not expand beyond 1% cover by the fifth year; polytrichum was more abundant with nearly 10% cover by the fifth year.

Wet lower slope site (Plot 34)

In the early seral vegetation of a lower slope site where black spruce was dominant prior to the fire (subplot 34-2 is shown in Figure 12), black spruce seedlings, though not present the first year, were the most common tree species; there were 800 black spruce stems/ha the second year, 1700 stems/ha the third year, and 4100 stems/ha the fifth year after the burn. During this period, 900 lodgepole pine seedlings/ha were observed in year three, but these had died back to 200/ha by the fifth year. Aspen appears to have entered by seed since there was no detectable aspen in the prefire stand and it did not appear in the plot until the third year when there were 1700 stems/ha. This increased to 5300 stems/ha in year five. In the fifth year, black spruce seedlings often attained 5 cm in height and aspen 9 cm, but the total tree cover was less than 1%. Though tamarack was present in the preburn tree cover, no seedlings were detected in the five-year assessment period. Nearly all species of shrubs sprouted from root stalks. Bilberry willow was the most proliferous shrub with an estimated 18 000 stems/ha in the first year increasing to 25 800/ha by the fifth year. It attained a height of about 25 cm by year five and had a coverage of about 25%. Labrador tea was the second most prolific shrub; it appeared mostly after the first year, and attained heights of up to 35 cm and a coverage of about 15% in five years. Other shrubs included diamond willow and shrub birch [*Betula glandulosa* Michx.] which attained the greatest heights (100 cm) in five years, as well as rose, shrubby cinquefoil [*Potentilla fruticosa* L.], and red bearberry. Red fescue [*Festuca rubra* L.] was the only herb providing more than 1% cover, although it had a spotty distribution. Ceratodon was the dominant bryophyte, but it had limited coverage until the fifth year.

Low Fire

General description

In the Low Fire, two sites of approximately the same age of trees prior to the fire are described. Parminter (1983) located a plot in the immediate vicinity of these plots in 1981, and recorded a dense growth of lodgepole pine with some aspen that had resulted from a fire in 1959. One of these had a dominance of young aspen with a secondary component of lodgepole pine, and the other was virtually all lodgepole pine with a few scattered aspen. Both are on coarse textured, rapidly drained, Orthic Dystric Brunisol soils developed from eolian material. They have endured a severe burn, resulting in less than 1 cm of ash and less than 1 cm of remaining organic material. Mineral soil was exposed on over 90% of the site after burning. These data are also indicative of previous fires that may have removed organic material and a xeric moisture regime which inhibits organic matter accumulation. Table 4 contains a summation of tree regeneration data for all sites examined in the Low Fire, and Table B2 of Appendix B gives data by plot and includes the total seedlings/ha of all tree species and an indication of the prefire forest composition. Aspen juveniles occurred in all plots, but lodgepole pine was sometimes more abundant in the fifth year. Ceratodon provided the most ground cover (Table 5). A few sites representing a range of conditions are described in the following sections. The percent cover figures given in the following detailed descriptions are for subplots; thus, they will not necessarily be the same as those given for the entire plots in Table 5.

Representative sites

Aspen site (plot 13)

In the aspen plot (subplot 13-3 is shown in Figure 13), aspen regeneration was initiated the first year largely from sprouts at a rate of about 4400 stems/ha. This increased to 23 000 stems/ha with heights of 2.0 to 2.5 m by the fifth year; the greatest increase occured in the second year. No other tree species were observed on this plot during the first five-year period. A few alder and long-beaked willow [*Salix bebbiana* Sarg.] resprouted from root stalks and attained heights of 2 m and 2.9 m, respectively, in five years. However, rose was the most prevalent shrub; it originated from root stalks and rhizomes during the first year, and by the fifth year there were over 2500 stems/ha and it provided 10% cover. Forbs and bryophytes were sparse and had a patchy distribution. Dogbane [*Apocynum androsaemifolium* L.], fireweed, and dwarf scouring-rush [*Equisetum scirpoides* Michx.] were among the more common forbs; these seemed to peak in three years, and in the fifth year they were present in lesser amounts. Cranesbill was present the second year, but not thereafter. Ceratodon was sparse in the third year, but increased to provide over 10% cover by the fifth year.

Lodgepole pine site (plot 15)

In the site dominated by lodgepole pine (subplot 15-3 is shown in Figure 14), aspen was the most prevalent tree species with over 2300 stems/ha in the first year. This increased to 9200 stems/ha providing about 7% cover by the fifth year. Lodgepole pine, although it had a few scattered seedlings the first year, only had 3800 stems/ha by the fifth year. Spruce seedlings were rare. In a plot very close to this one, Parminter (1983) estimated there were 54 400 lodgepole pine and 666 aspen stems/ha 22 years after the 1959 burn. Kinnikinnick and lingonberry were the primary shrub species, but even they provided only 1% cover by the fifth year. Twinflower, included with the herb class, provided 2% to 3% cover. Ceratodon provided the most ground cover; it became evident mostly in the second year and covered at least 70% of the ground by the fifth year.

Eg Fire

General description

The Eg Fire covered the largest area among the four fires examined in this report, and thus consumed the greatest diversity of forests and site types. The occurence of previous fires was obvious from the age, size, and species diversity of forest stands prior to the current fire; previous fires were also evident from the remaining post-fire poles, slash, etc. The fire severity also reflected the combination of forest status and site condition at the time of the burn; even though a fire of this size creates its own environment, the more moist sites supporting more mature forest stands did not have the same severity (based on amount and size of woody material left and the depth of organic matter and ash) as dryer sites supporting small trees. Table 6 contains a summation of tree regeneration data for all subplots in the Eg Fire, and Table B3 of Appendix B contains regeneration data for each plot, the total number of juveniles per plot and an indication of the preburn forest composition. Aspen, which occurred in 96% of the plots, was the most constant species, and it often had the greatest number of stems per hectare, but lodgepole pine and black spruce were also common. Willow, fireweed, and ceratodon occurred in all plots, but alder and rose were sometimes prevalent (Table 7). A few sites representing a range of conditions are described in the following sections. The percent cover figures given in the following detailed descriptions are for subplots, thus will not necessarily be the same as given for the plots in Table 7.

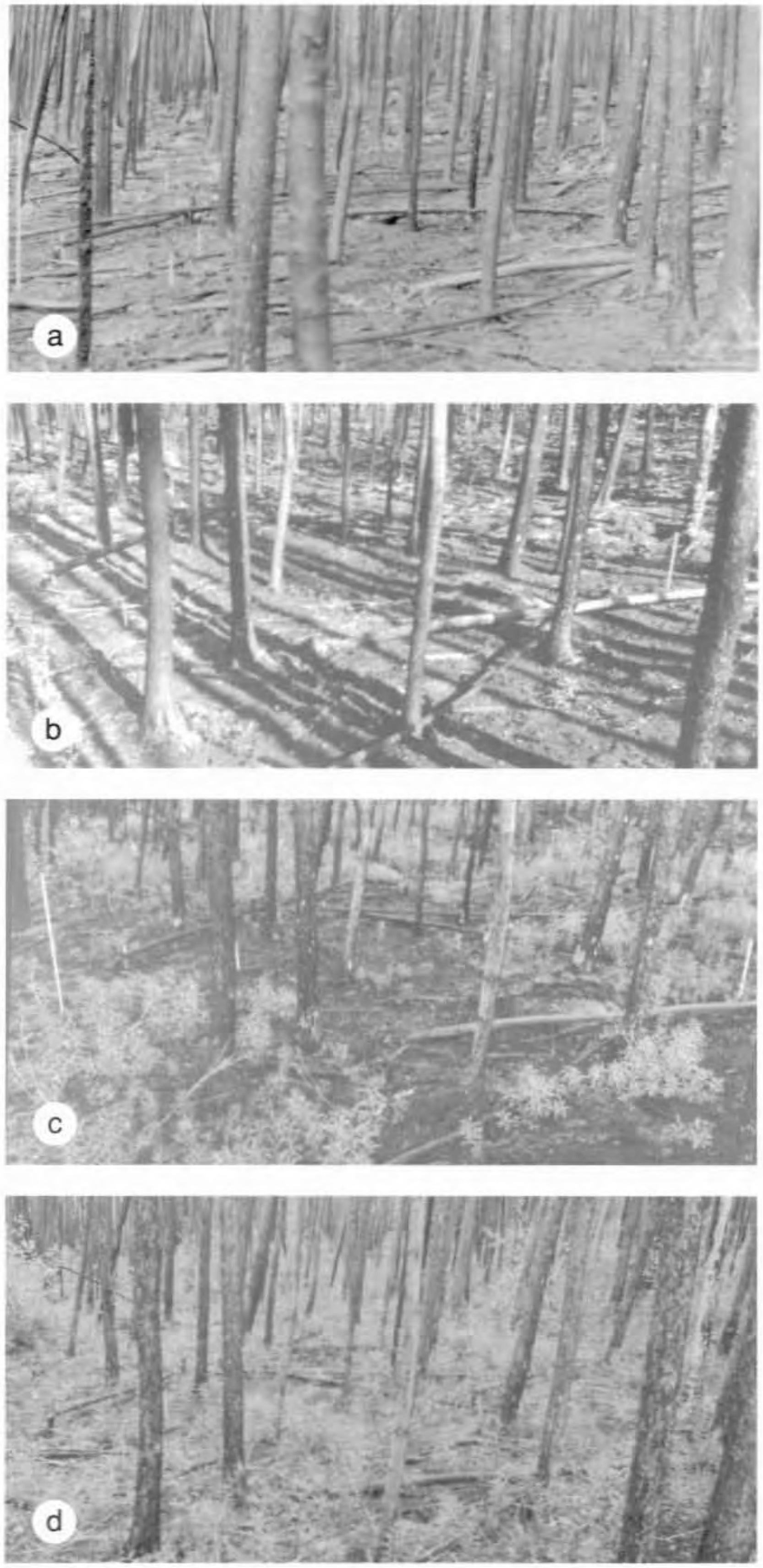

Figure 11. Five years of vegetation development on subplot 41-2 following the Tom Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

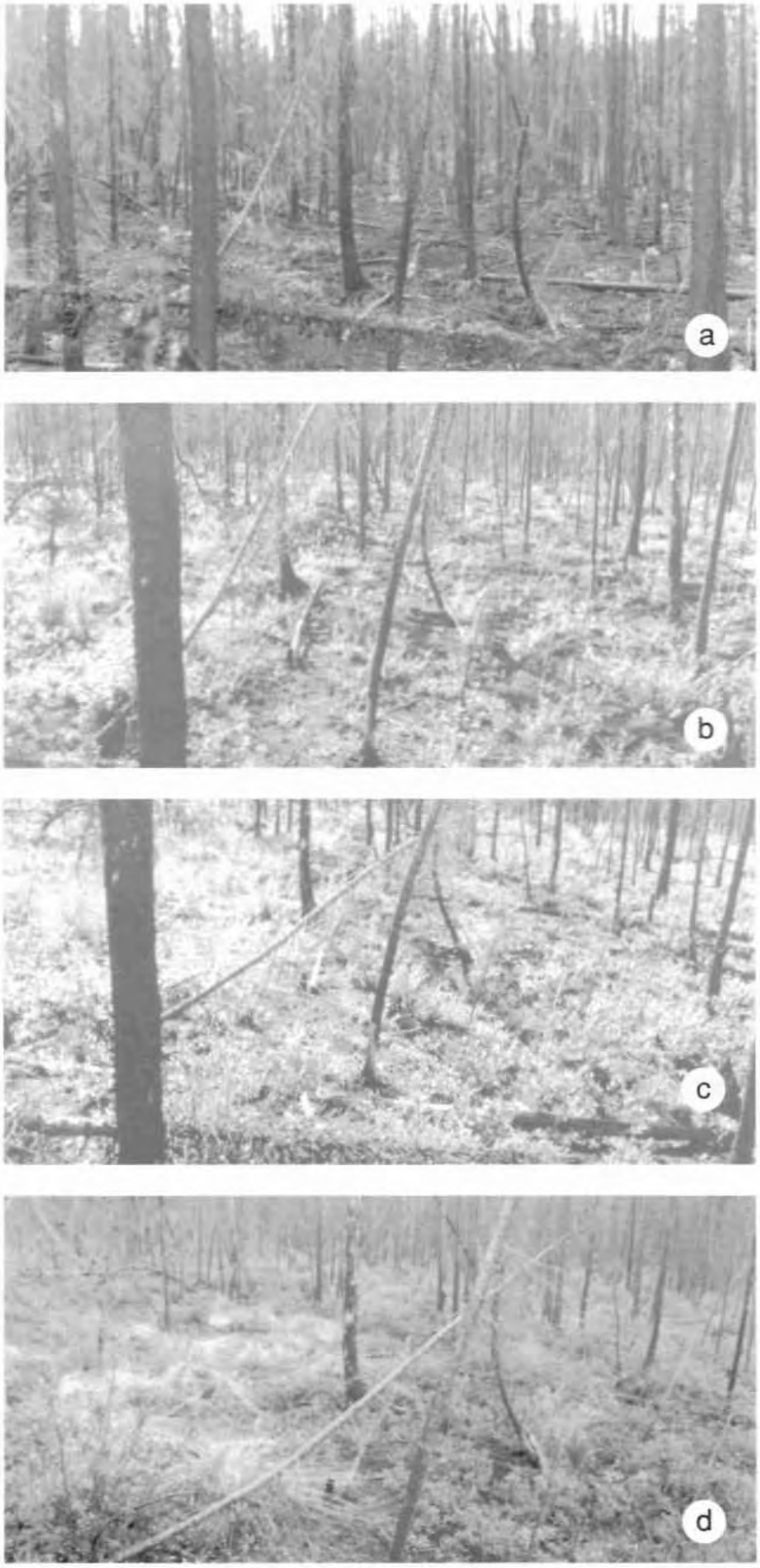

Figure 12. Five years of vegetation development on subplot 34-2 following the Tom Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

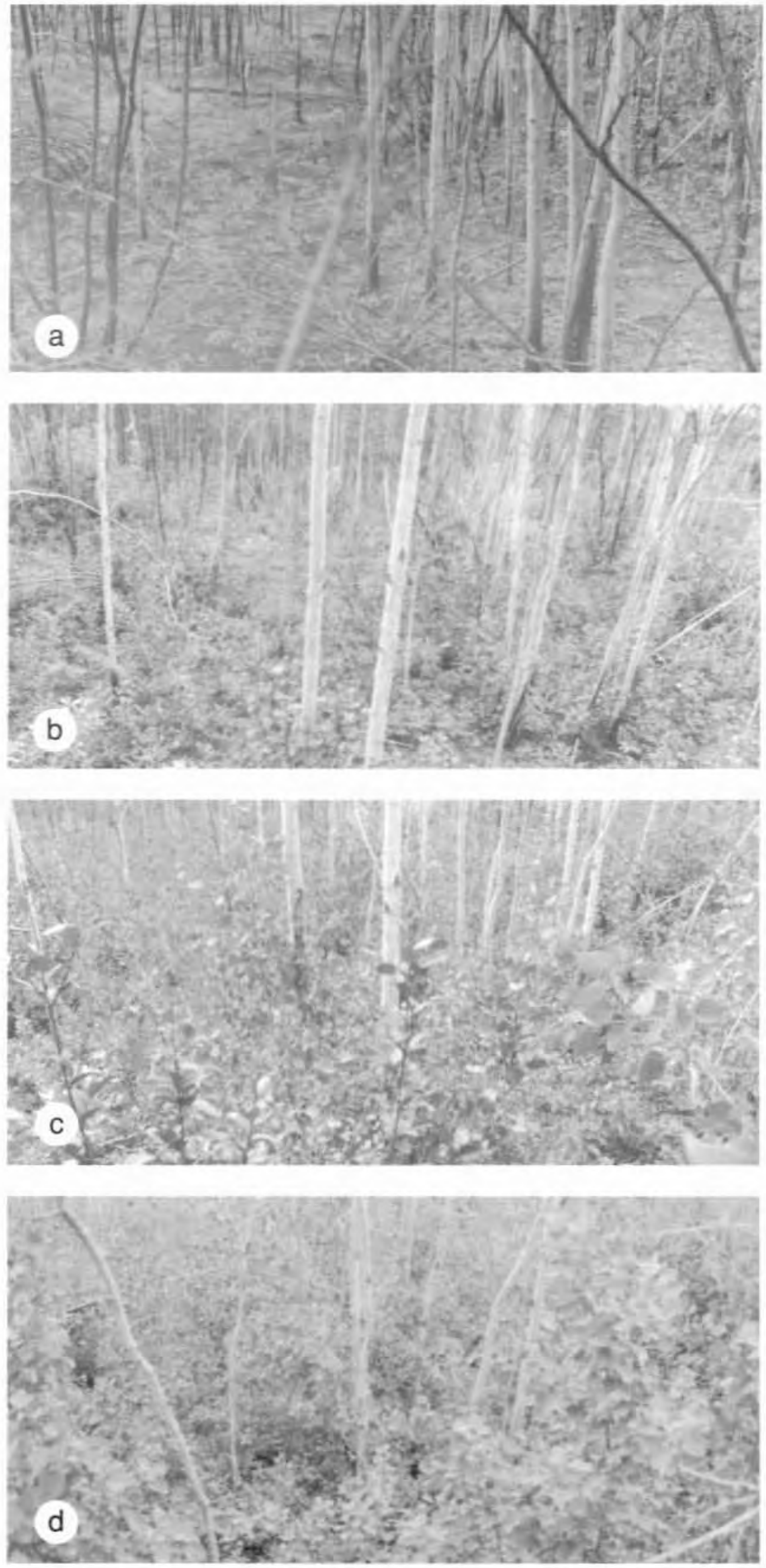

Figure 13. Five years of vegetation development on subplot 13-3 following the Low Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

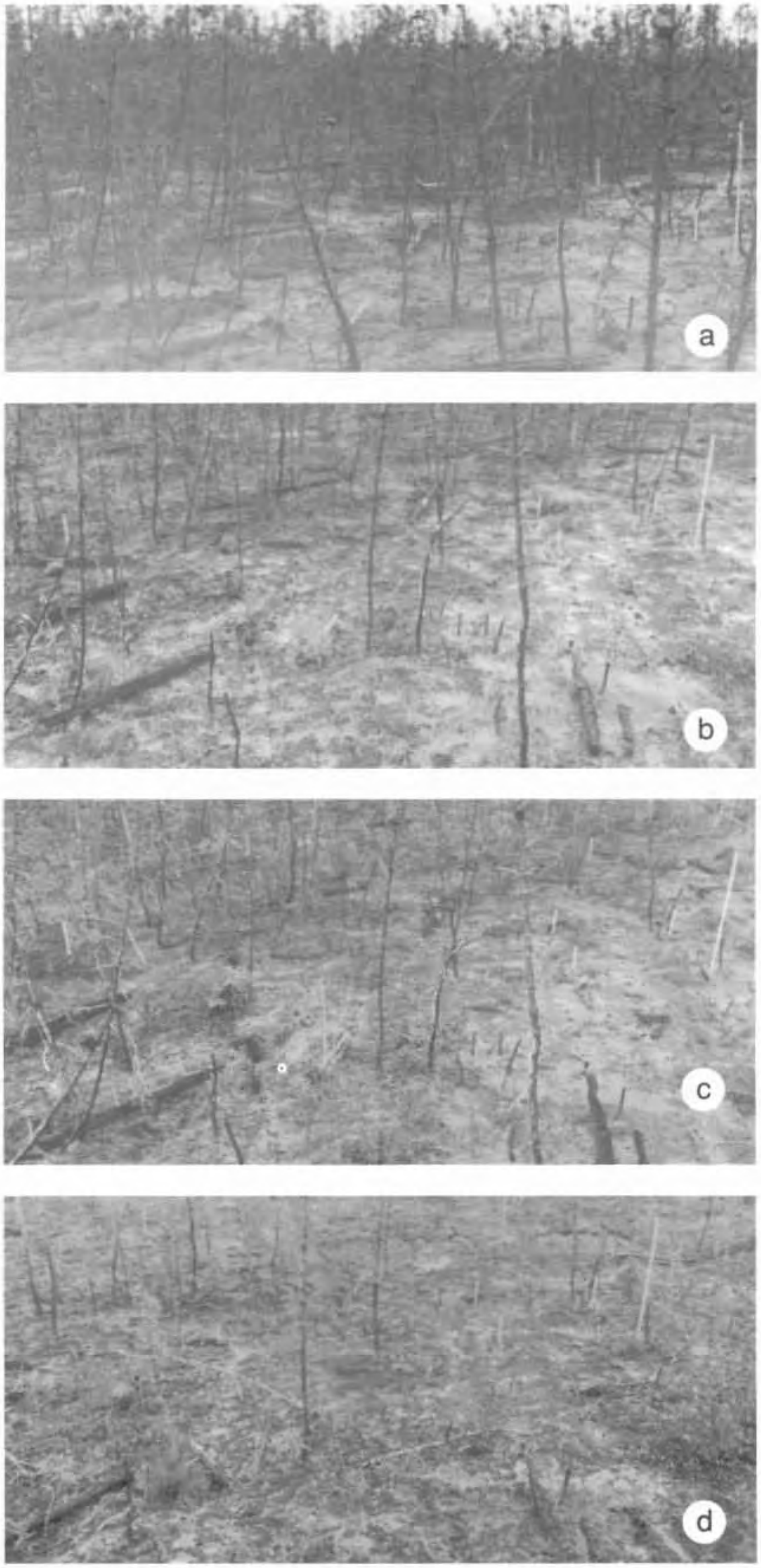

Figure 14. Five years of vegetation development on subplot 15-3 following the Low Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

Table 4. Tree regeneration characteristics after five years in 24 subplots at the Low Fire

	Tree species			
	Black spruce	Lodgepole pine	Trembling aspen	White birch
Subplots in which species occurred	15	20	24	1
Juveniles*/subplot (average)	25.7	37.4	28.9	1.0
Juveniles/subplot (range)	1 - 150	7 - 50	10 - 250	—
Juveniles/ha (average)**	7720	14 960	11 560	100
Juveniles/ha (range)**	100 - 31 500	1500 - 50 200	7100 - 32 000	—
Average height (cm)	4.8	22.7	88.8	3
Height range (cm)	2 - 13	7 - 50	10 - 250	—

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

** These are based on data from 10 X 10 m plots

Table 5. Average fifth year percent cover of the more prevalent shrubs, forbs, and non-vascular plants in 10 X 10 m plots at the Low Fire

	Plot					
Type of vegetation	10	11	12	13	14	15
Shrubs						
Rose	<1	4	0	8	6	0
Kinnikinnick	0	<1	1	<1	0	3
Lingonberry	<1	<1	<1	<1	0	<1
Willow	12	10	2	0	2	<1
Buffalo-berry	<1	5	0	0	<1	0
Long-beaked willow	0	<1	0	8	3	0
All*	17	20	4	24	10	3
Forbs						
Fireweed	2	2	0	2	4	<1
Dwarf scouring rush	<1	<1	0	2	<1	<1
Bunchberry	<1	4	0	0	1	0
Twinflower	0	10	2	0	1	4
All*	3	16	3	4	14	5
Non-vascular plants						
Ceratodon	36	26	19	14	62	56
Polytrichum	9	14	<1	<1	<1	<1
All*	47	43	19	15	63	69

* May include less prevalent species which are not listed separately

Table 6. Tree regeneration characteristics after five years for 84 subplots at the Eg Fire

	Tree species					
	White spruce	Black spruce	Lodgepole pine	Trembling aspen	White birch	Balsam poplar
Subplots on which species occurred	4	43	57	81	13	10
Juveniles*/subplot (average)	35.8	9.8	9.2	19.9	1.1	6.6
Juveniles/subplot (range)	22 - 50	1 - 35	1 - 60	1 - 84	1 - 2	1 - 21
Juveniles/ha (average)**	14 300	2800	2747	7662	171	1525
Juveniles/ha (range)**	—	200 - 10 100	100 - 13 900	600 - 17 900	100 - 300	100 - 5400
Average height (cm)	4.3	7.2	28.8	59.8	32.5	156.9
Height range (cm)	3 - 5	2 - 22	4 - 79	5 - 310	4 - 250	50 -275

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.
** These are based on data from 10 X 10 m plots.

Table 7. Average fifth year percent cover of the more prevalent shrubs, forbs, and non-vascular plants in 10 X 10 m plots at the Eg Fire

Type of vegetation	Plot 16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	45	47	48
Shrubs																					
Rose	1	<1	1	<1	7	2	9	1	0	17	1	<1	0	2	3	13	0	26	0	<1	<1
High bush cranberry	0	0	<1	0	0	0	<1	0	0	0	0	<1	0	0	2	<1	0	2	0	0	0
Alder	0	0	0	0	<1	0	<1	<1	7	34	0	0	0	0	24	5	0	17	0	0	0
Willow	3	22	2	3	7	<1	1	7	11	20	12	48	11	4	8	2	16	5	7	6	9
Long-beaked willow	0	0	4	3	0	<1	0	4	2	0	0	2	0	0	0	0	1	0	0	0	0
All*	4	22	8	6	15	5	16	14	20	75	14	50	11	6	38	20	17	50	8	7	10
Forbs																					
Fireweed	<1	4	<1	<1	<1	<1	4	<1	<1	<1	6	2	2	<1	7	2	<1	2	<1	<1	3
Dwarf scouring rush	<1	<1	<1	1	2	<1	<1	22	0	<1	11	0	<1	<1	0	<1	<1	<1	<1	1	<1
Dandelion	<1	<1	<1	<1	<1	<1	0	<1	0	<1	<1	1	<1	<1	<1	<1	<1	<1	0	0	<1
Bunchberry	6	0	2	10	<1	4	0	<1	1	0	0	0	0	3	7	<1	0	3	9	0	<1
Twinflower	0	0	6	0	2	2	<1	0	<1	6	0	0	0	6	0	0	0	<1	0	1	0
All*	9	5	9	13	5	14	6	25	1	7	16	4	2	12	16	4	<1	8	11	3	4
Non-vascular plants																					
Ceratodon	49	30	27	6	60	67	79	33	48	3	74	1	48	39	61	50	82	35	73	63	32
Bryum	0	7	0	1	<1	23	3	<1	33	10	8	10	0	0	<1	0	0	10	0	0	0
Polytrichum	2	10	20	3	<1	<1	1	0	<1	15	0	<1	4	<1	11	<1	8	31	2	5	29
All*	51	59	47	10	60	90	83	53	81	28	86	71	52	40	72	62	94	76	75	68	61

* May include less prevalent species which are not listed separately

Representative sites

Moist black spruce site (plot 26)

One site (exemplified by plot 26) supported a mature black spruce stand and was located in a moisture-receiving situation on morainal material and possessed medium textured, moderately well drained, Orthic Gleysol soil (subplot 26-4 is shown in Figure 15). The site was moderately burned. There were 5 to 10 cm of organic matter remaining, nearly 5 cm of ash, and virtually no exposed mineral soil, although much of the smaller woody stems were not consumed (Figure 15). Black spruce regeneration was initiated the first year but even after five years it amounted to only 2200 stems/ha and had only attained heights of up to 7 cm. Aspen, which did not become obvious until the third year, most likely originated from seed blown in. By the fifth year it had over 2000 stems/ha and some had attained heights of over 30 cm. Only two lodgepole pine seedlings were observed in the plot, and they had heights of 9 and 16 cm after five years. The most prominent woody plant on this site was willow with over 12 100 stems/ha which had attained heights of up to 1.7 m and provided about 10% cover by the fifth year. It is considered to have originated partially from seed and partially from root stalks since no root stalks or rhizomes could be found associated with some plants. Raspberry, rose, and Labrador tea were also present. Fireweed was by far the most prominent forb; it became noticeable in the second year, peaked with about 30% cover in the third year, and was reduced to less than 10% cover in the fifth year. Dwarf scouring-rush became well established by the fifth year. Ceratodon was the most abundant bryophyte, providing about 75% ground cover in years three and five, though marchantia [*Marchantia polymorpha* L.] had a surge in the second year when it provided over 10% cover.

Lodgepole pine - white spruce site (plot 33)

A site supporting a mature stand dominated by lodgepole pine with a secondary component of white spruce was located on medium textured, moderately well drained, subhygric, Orthic Regosol soil developed from fluvial material. This stand was light to moderately burned as indicated by the amount of small to medium-sized woody branches remaining (subplot 33-1 is shown in Figure 16). The site had less than 1 cm of ash, less than 5 cm of organic matter, and 35% exposed mineral soil due mostly to lack of organic matter accumulation prior to the fire. White spruce regeneration began in the first year following the fire when there were 1200 stems/ha; by the fifth year this had increased to over 14 300 stems/ha, although the seedling heights were seldom over 5 cm. The relatively high number of spruce seedlings is likely due to the amount of seed surviving the low-severity fire. Lodgepole pine seedlings were not observed the first year, but by the fifth year there were about 13 900 lodgepole pine seedlings/ha which had attained heights of up to 35 cm. There were about 5800 aspen stems/ha and about 5400 balsam poplar stems/ha with heights over 2 m by the fifth year. White birch, originating from root stalks, had only a single stem in the plot, but it attained over 2.5 m in height in five years. This site also had a prominent complement of shrubs; rose was the most prevalent (29 000 stems/ha, 25% cover, and heights to 60 cm in year five) followed by alder (1800 stems/ha, 15% cover, and heights to over 2.5 m in year five). Willow, red blackberry [*Rubus pubescens* Raf.], and high bush cranberry [*Viburnum edule* (Michx.) Raf.] were also well represented. Nearly all the shrubs were initiated from root stalks. This site had a variety of forb species, with bunchberry [*Cornus canadensis* L.], which can reproduce from root stalks, being the most common. All forbs had low cover values. Cranesbill had a surge in the second year, but faded thereafter. Ceratodon was the most prevalent bryophyte, providing about 50% cover, but was beginning to be shaded out in the fifth year. Polytrichum increased from about 3% cover in year three to 30% cover in year five.

Immature black spruce site (plot 18)

A mid-seral (immature) stand dominated by black spruce (subplot 18-1 is shown in Figure 17) with lodgepole pine was located on medium textured, rapidly drained, submesic, glaciofluvial material on which an Eluviated Dystric Brunisol soil developed. This site had little accumulated organic matter, and thus had less than 5 cm of ash, less than 5 cm of remaining organic matter, and about 60% exposed mineral soil following a moderate to severe fire. Most of the small woody material was consumed in the fire (Figure 17). No tree seedlings were observed the first year after the fire, but black spruce, lodgepole pine, and aspen were present in the second year, and had 4700, 2300, and 8300 stems/ha, respectively, by the fifth year. Aspen was the tallest; some aspen shoots had reached a height of 2 m, and it provided about 5% cover. Long-beaked willow was the tallest woody plant; after five years, shoots of long-beaked willow were almost 3 m in height, and it provided about 5% cover. Though other shrub species were present, their numbers and coverage were small. Several species of forbs were present between years two and five, but only bunchberry and twinflower provided more than 1% cover during this period. Ceratodon was the primary bryophyte in the first year, and it provided about 25% cover by the fifth year. Polytrichum occurred mostly in extensive patches, but averaged about 20% cover over the site.

Mid-seral lodgepole pine site (plot 30)

A mid-seral (immature) lodgepole pine stand located on morainal material that had a medium textured, well drained, mesic, Orthic Dystric Brunisol soil was severely burned (subplot 30-2 is shown in Figure 18). The ash depth was less than 1 cm, the remaining organic matter was less than 5 cm, and the exposed mineral surface was nearly 90%, which indicates that little organic matter had accumulated since a previous fire. Lodgepole pine regeneration became evident in the second year and amounted to over 4900 stems/ha by the fifth year and some attained heights of over 50 cm. Spruce (mostly black spruce) seedlings were sparse. None was observed in the first year; by the fifth year there were about 900 stems/ha and some were over 10 cm in height. Aspen produced about 1900 stems/ha by the fifth year, and these were assumed to have mostly originated from seed as they were not observed in the first two years. After five years, few aspen had reached a height of 10 cm. One clump of aspen likely to have started from a root stalk was observed in the second year, and had attained a height of over 50 cm by the fifth year. Rose, willow, and red blackberry were prominent shrubs, with 4500, 5900, and 3000 stems/ha and 3%, 6%, and 1% cover, respectively. Alder, with 6500 stems/ha and 25% cover, was the tallest species; alder had reached a height of over 2 m by the fifth year. Most of the shrubs appeared to originate from root stalks. Several species of forbs were encountered over the five-year period, but most provided their greatest coverage in the second or third year. Fireweed was the most prominent with about 10% cover in the third year and about 7% in the fifth year. Cranesbill was common the first year with about 9% cover, was not observed the second year, but reappeared in the third year with about 2% cover, and was virtually gone by the fifth year. Ceratodon was the most prominent bryophyte; it became established in the first year and attained about 80% cover in the fifth year. Marchantia was rather prevalent the first year with nearly 5% cover, but provided only about 1% cover in the fifth year, while polytrichum was scarce in the first year and provided about 10% cover by the fifth year.

Early seral lodgepole pine site (plot 32)

An immature lodgepole pine stand on coarse textured, rapidly drained, submesic, glaciofluvial material in which an Orthic Dystric Brunisol soil developed was severely burned (subplot 32-4 is shown in Figure 19). The ash and remaining organic matter were each less than 1 cm thick, and there was over 90% exposed mineral soil indicating both a dry moisture regime and previous fires that had eliminated the organic material. Lodgepole pine seedlings were initiated the first year when there were about 800 seedlings/ha. In the second year there were 1800 stems/ha, but by the fifth year there were only about 500 stems/ha. Heights of some survivors were over 15 cm. Aspen, with 6200 stems/ha in the fifth year, was the most prolific tree species; with heights mostly less than 20 cm, it is considered to have orginated from seeds. Spruce (mostly black spruce but some white spruce may be included), balsam poplar, and white birch were sparsely present in the third and fifth years. Willow originated mostly from root stalks the first year, and attained a coverage of about 15% and heights up to 2 m in five years. Long-beaked willow, also originating from a root stalk, was the tallest plant in five years at 2.8 m, although a few balsam poplar originating from root stalks were not far behind. Forbs were poorly represented, and only fireweed provided more than 1% cover after five years. The most ground cover was provided by ceratodon which produced about 80% cover.

Juvenile lodgepole pine - black spruce site (Plot 20)

A young stand dominated by lodgepole pine with a black spruce component was moderately burned (subplot 20-3 is shown in Figure 20). This site was on a medium textured, rapidly drained, submesic, Eutric Dystric Brunisol soil developed on glaciofluvial material. One of Parminter's (1983) plots was located very close to this plot and he recorded 26 600 black spruce, 1700 lodgepole pine,

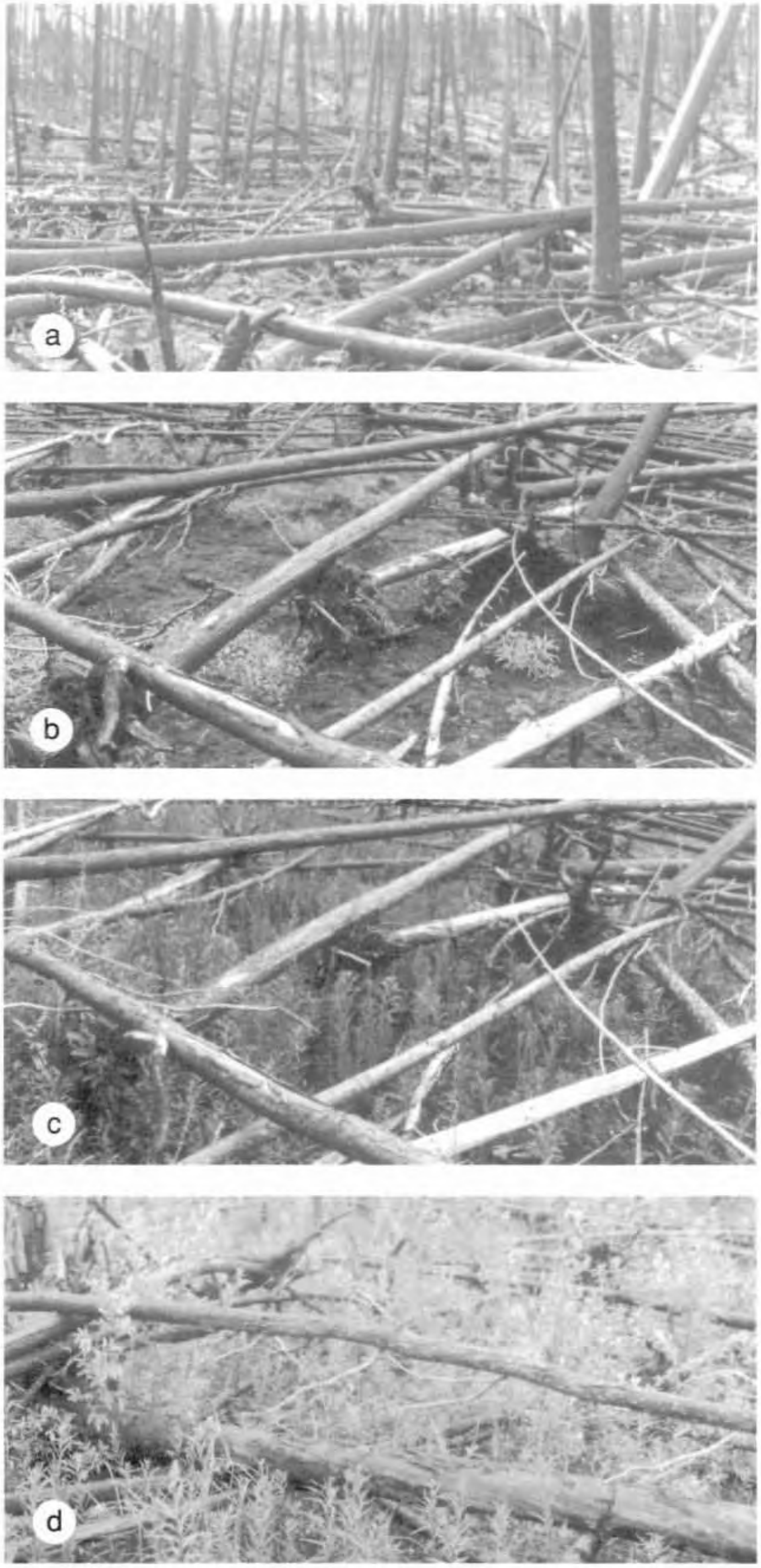

Figure 15. Five years of vegetation development on subplot 26-4 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

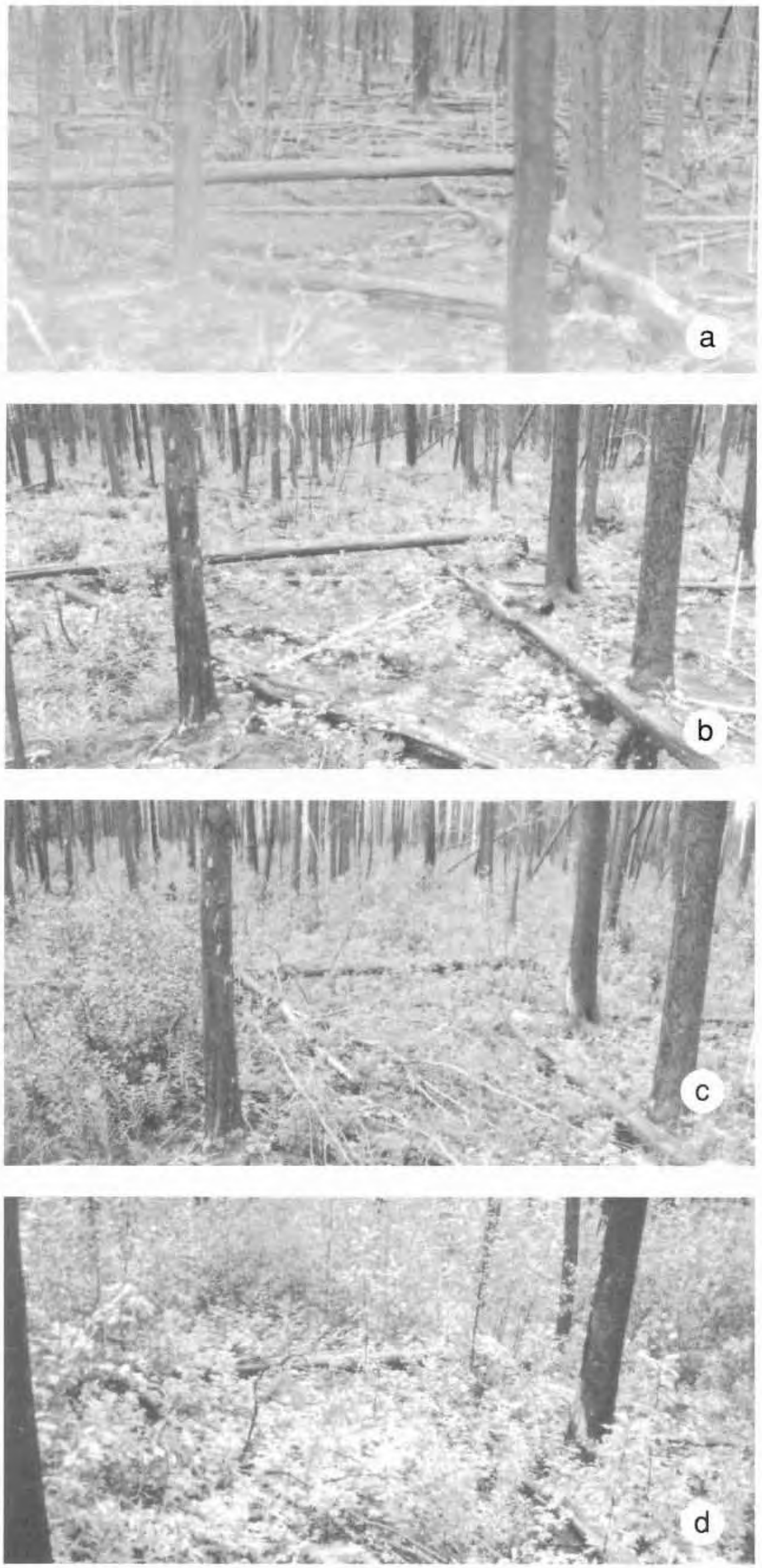

Figure 16. Five years of vegetation development on subplot 33-1 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

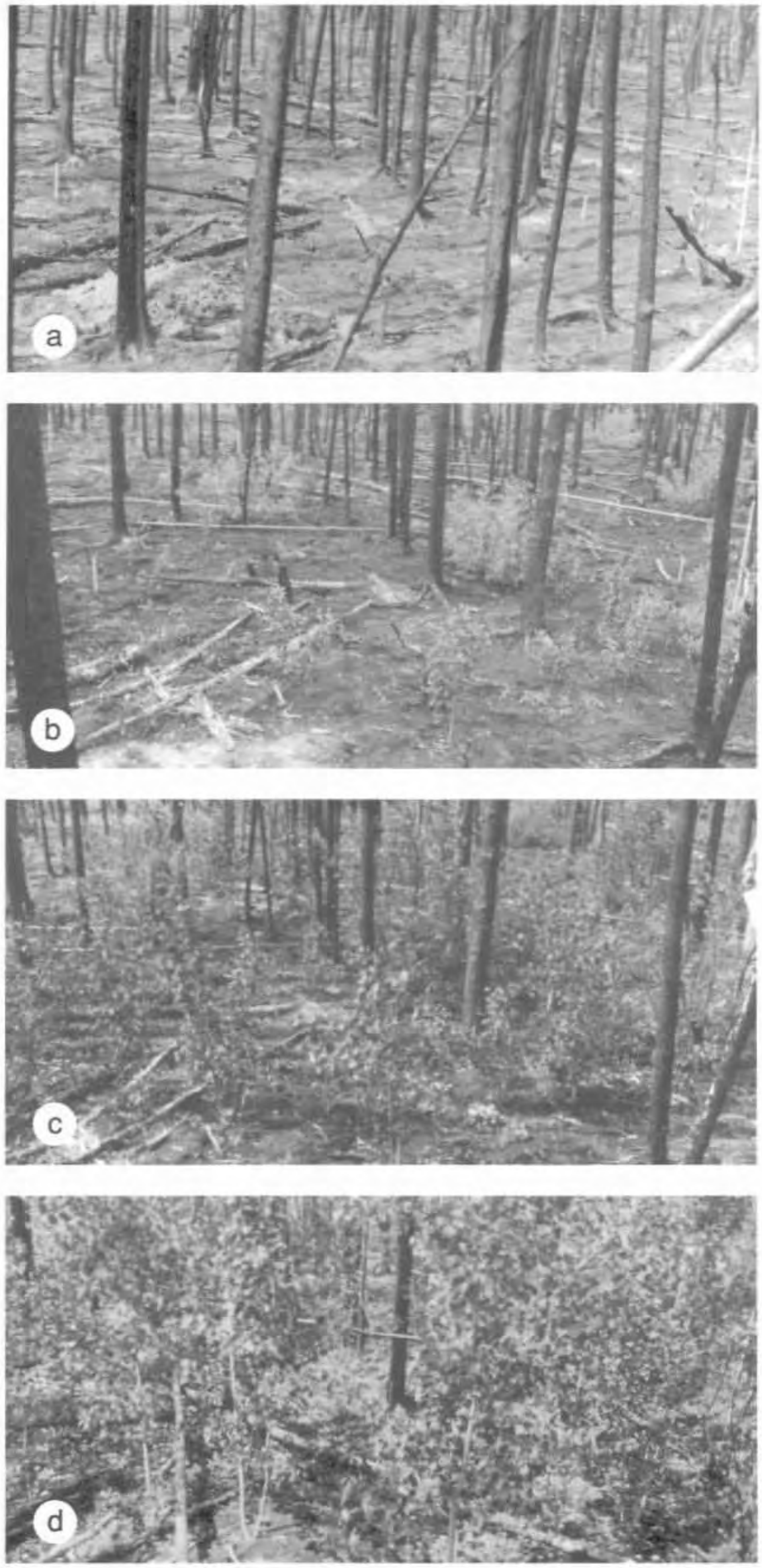

Figure 17. Five years of vegetation development on subplot 18-1 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

Figure 18. Five years of vegetation development on subplot 30-2 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

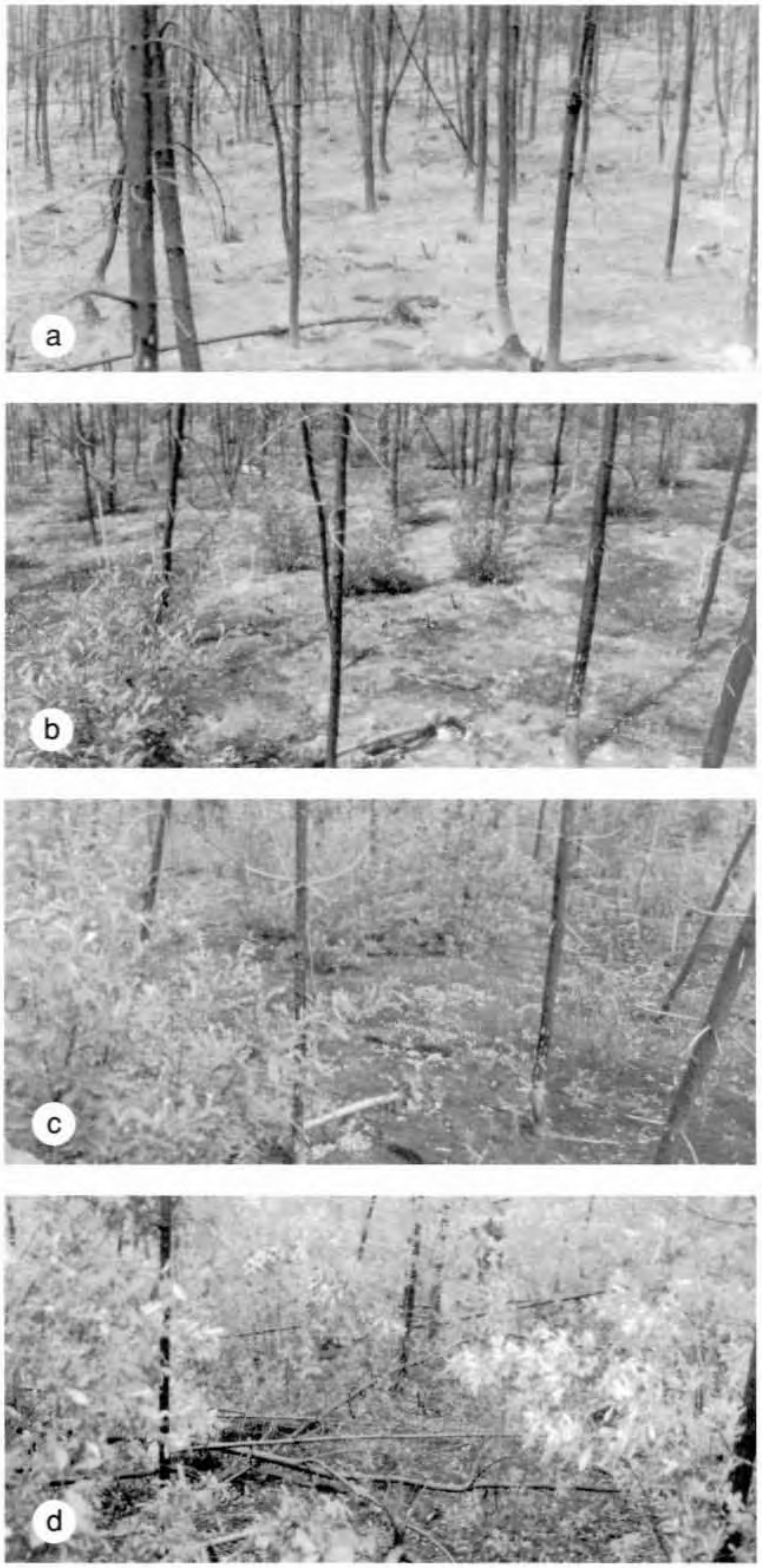

Figure 19. Five years of vegetation development on subplot 32-4 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

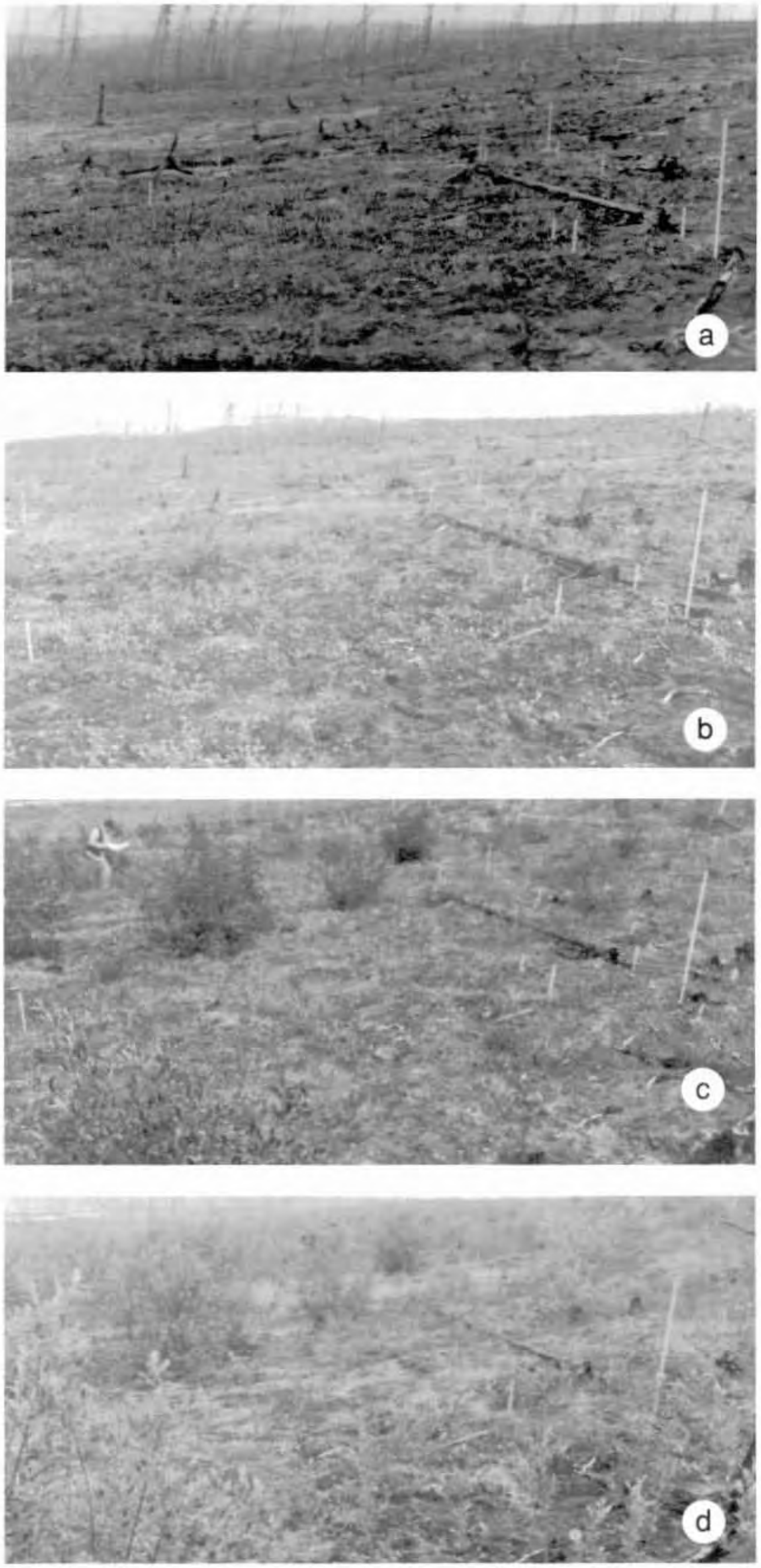

Figure 20. Five years of vegetation development on subplot 20-3 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

and 300 tamarack stems/ha originating from a fire in 1965. The ash and remaining organic material were each less than 5 cm deep and there was about 10% exposed mineral soil. The remaining litter material and the generally dry site conditions indicate that this site did not develop enough woody material since the previous burn to support a more severe fire. Since no conifer seedlings were observed in the five-year study period, the lodgepole pine and spruce on this site before the fire were not of seed-bearing age, or else the seed was all consumed in the fire. Young conifer trees usually have a relatively large crown in relation to the bole, and due to the combustibility of the needles a severe fire usually develops which consumes the entire tree. The absence of seedlings in these stands perhaps supports the contention that conifer seed brought in from distant sources is not a primary factor in conifer regeneration near the center of large burns. Aspen, with 4800 stems/ha in the third year and about 9500/ha in the fifth year, appears to have started from seed as it was rare in the second year and had only attained heights up to about 20 cm in the fifth year. Diamond willow, originating from root stalks, had over 2100 stems/ha with heights of up to 2 m by the fifth year. Alder was sparse, but had heights of up to 1.5 m. Rose was the most abundant shrub with nearly 11 700 stems/ha and a coverage of about 7% in the fifth year. Dryland sedge [*Carex xerantica* L.H. Bailey], with about 20% cover, and dwarf scouring rush, with about 10% cover, were the most common forbs in the second and third years, but these declined considerably in the fifth year. Ceratodon followed an opposite trend and attained about 70% cover in the fifth year.

Juvenile lodgepole pine site (plot 28)

A young lodgepole pine stand about 16 years old that endured a high severity burn was located on medium textured, rapidly drained, submesic, morainal material in which an Orthic Dystric Brunisol developed (subplot 28-3 is shown in Figure 21). Following the last fire, there was less than 1 cm of both ash and remaining organic matter, and the exposed mineral surface was greater than 90%. There was virtually no small or medium-sized woody material remaining (Figure 21). These factors indicate a history of a series of fires at short intervals. Some cone-bearing trees can be seen in the background of Figure 21, and it can be assumed that similar trees may have been present in the foreground prior to the fire. The only vegetation observed in the first year was a bit of moss and a rare fireweed germinant. Lodgepole pine and aspen became established the second year with about 100 and 1500 stems/ha, respectively, and these species had increased to 1000 and 15 500 stems/ha by the fifth year. The pine seedlings, though few in number, had good growth; the average height in the fifth year was over 40 cm, and some had reached a height of 70 cm. No spruce seedlings were observed until the third year, and by the fifth year there were over 5800 black spruce stems/ha averaging about 4 cm in height, although a few had attained heights of about 10 cm. White birch seedlings were observed in the fifth year, although there were less than 300 stems/ha. Willow, mostly originating from root stalks, was the most conspicuous shrub with about 8700 stems/ha, a coverage of about 10%, and heights of over 1.5 m by the fifth year. Fireweed, cranesbill, arnica [*Arnica cordifolia* Hook.], dandelion [*Taraxacum officinale* Weber], dwarf scouring rush, and a daisy were present; however, none provided more than 1% cover by the fifth year. Ceratodon provided the main ground cover with about 50% cover. Polytrichum was common, providing about 5% cover in the fifth year.

Juvenile lodgepole pine site (plot 29)

Another example of a severely burned very young lodgepole pine stand occurred on coarse textured, well drained, mesic, morainal material with an Orthic Dystric Brunisol soil development (subplot 29-1 is shown in Figure 22). It is located in an extensive area that had burned about 17 years previously; the stand of dead trees noticeable in Figure 22 is a small remnant that survived the earlier fire. Lodgepole pine seedlings were observed in the second year; by year five there were about 2400 stems/ha, and they were mostly over 50 cm tall. Aspen, however, had over 4100 stems/ha and they were also mostly over 50 cm tall. A few balsam poplar stems were present and were the tallest trees at just over 1 m. Spruce seedlings were rare. Rose and willow were the most common shrubs, with about 3100 and 6900 stems/ha and about 4% and 7% cover, respectively. Several forbs were present, but bunchberry provided the most cover with about 4%, even though it occurred in patches. Ceratodon provided about 50% ground cover.

Aishihik Fire

General description

Vegetation assessments in the Aishihik burn did not commence until the third year after the fire; thus, the details of vegetation development during earlier stages are unknown. Trembling aspen was the most pronounced species by year three. It occurred in 100% of the plots, 83% of the subplots, and provided the most cover in 33% of the plots; by year five it was present in 89% of the subplots. White spruce seedlings occurred in 44% of the plots (17% of the subplots) by year three, but increased to 77% of the plots (70% of the subplots) by year five. The seedlings were fairly abundant (15 600 stems/ha) in one plot where they averaged about 5 cm in height, but usually there were about 3000 stems/ha with a height of about 2 cm by year five. Table 8 contains regeneration data based on a summation of all subplots in the area, and Table B4 of Appendix B contains regeneration data by plot and gives the total number of juveniles per hectare and the prefire tree species. This area differed from those burned areas to the east in that aspen, white birch, balsam poplar, and white spruce were the only tree species available for recolonization; the nearest lodgepole pine, black spruce, and subalpine fir [*Abies lasiocarpa* (Hook.) Nutt.] were several kilometres away. Rose, which occurred in over 90% of the plots, was the most prominent shrub (Table 9), and it had an ecological affinity to aspen sites. It was most abundant (about 26% cover) in the same plot where aspen had the highest cover; this trend was followed in another plot where aspen had a cover of 36% and rose had 18% cover, and in most other plots where aspen and rose both had less than 5% cover. Willow was thinly scattered. It occurred in 78% of the plots, but had less than 3% cover except in one plot in which it had 18% cover. Fireweed was the most common herb and was present in 100% of the plots and 92% of the subplots. Fireweed appears to have reached a peak in vegetation cover (about 40%) around year three and by year five was beginning to decline (20 to 30% cover). Ceratodon occurred in 100% of the plots (97% of the subplots) and had high coverage (55-95%) in six plots. In most cases plots with high coverage of fireweed also had high coverages of ceratodon (Table 9); rose was most abundant where these two species had low coverages. The percent cover figures given in the following detailed descriptions are for subplots; thus, they will not necessarily be the same as those given for the entire plots in Table 9.

Representative sites

Aspen sites (plots 4 and 7)

Two plots were located in burned aspen stands: one was formerly a young aspen stand about 30 years of age (subplot 4-4 is shown in Figure 23), and the other is an older stand nearly 100 years old (subplot 7-3 is shown in Figure 24). Both sites were on glaciolacustrine materials and were moderaly burned, but the younger stand had fine textured, moderately well drained, mesic, Grey Luvisolic soil, and the older stand was on medium textured, well drained, submesic, Orthic Eutric Brunisol soil.

The younger stand (plot 4) had vigorous suckering of aspen with over 80 000 stems/ha which provided more than 70% cover by year three; the coverage had increased to about 80% by year five. On this plot, the aspen attained heights of nearly 1 m after three years and 1.5 m after five years, although aspen had generally not grown this high on the other plots in the area. White spruce seedlings were rare. Rose was also abundant on this plot with about 50 000 stems/ha originating from root stalks. Forbs and bryophytes were very sparse on this site.

In the mature aspen stand, aspen regeneration was prominent; there were about 20 000 stems/ha which had reached heights of up to 1.5 m and provided about 40% ground cover. Rose was the most common shrub, with over 8400 stems/ha which originated from root stalks and provided about 15% cover. Buffalo-berry [*Shepherdia canadensis* (L.) Nutt.] and willow were also present. This site had a fairly good herb layer composed primarily of fireweed (25% cover), bluebells [*Mertensia paniculata* (Ait.) G. Don] (10% cover), and twinflower (7% cover) in year three. By the fifth year, the fireweed and bluebells had declined while twinflower had increased. Ceratodon was the only bryophyte of consequence and it provided about 10% ground cover.

White spruce site (plot 3)

This site was on a medium textured, moderately well drained, subhygric, Cumulic Regosol on fluvial material and was severely burned (subplot 3-4 is shown in Figure 25). This was a white spruce site with a very small aspen component before the burn, but it did have aspen regeneration. Over 3700 aspen stems/ha, which had reached heights up to 1.5 m, provided about 1% cover by the fifth year. There

Figure 21. Five years of vegetation development on subplot 28-3 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

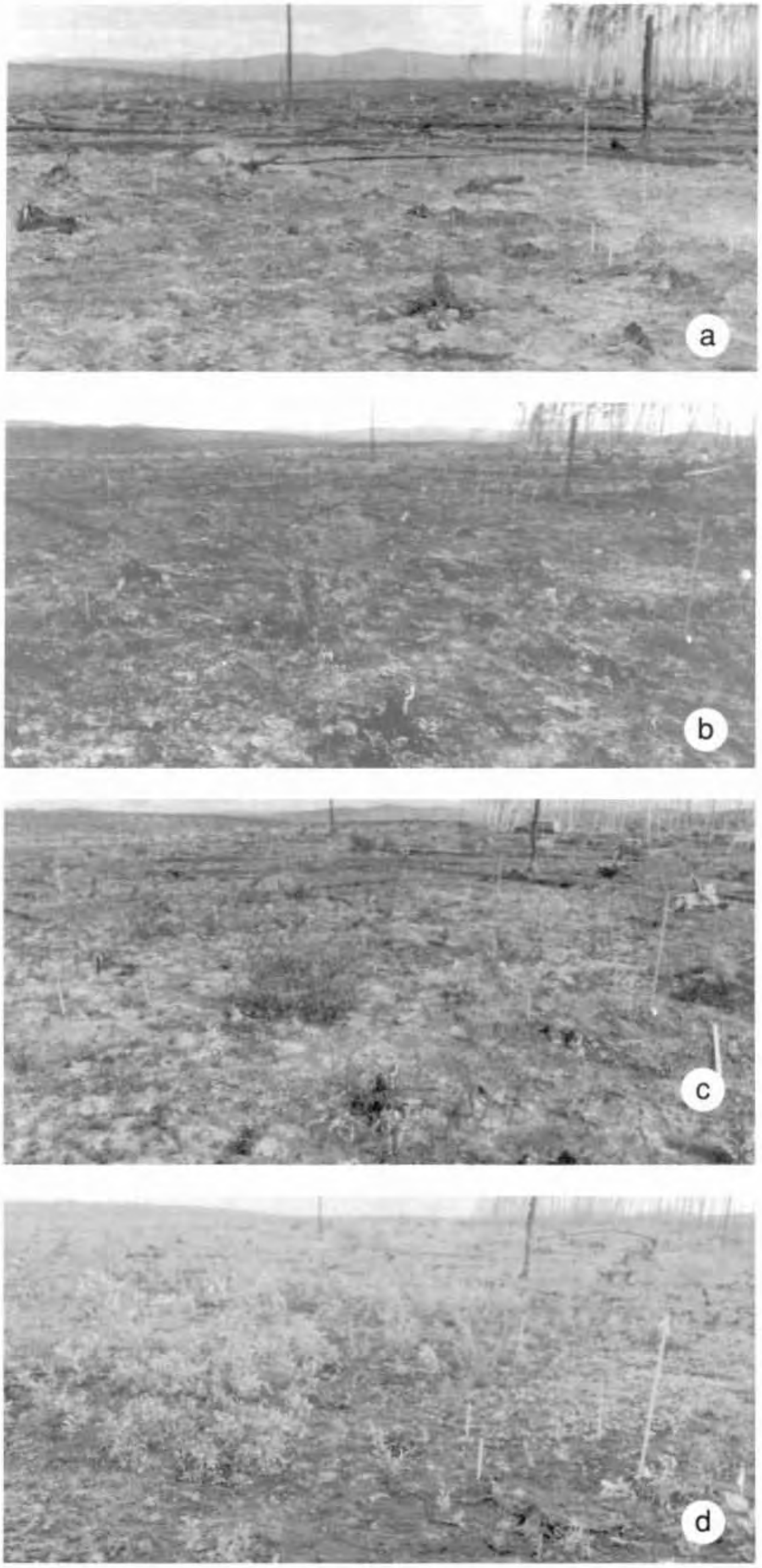

Figure 22. Five years of vegetation development on subplot 29-1 following the Eg Fire.
(a) 1983, one year after burning;
(b) 1984, two years after burning;
(c) 1985, three years after burning;
(d) 1987, five years after burning.

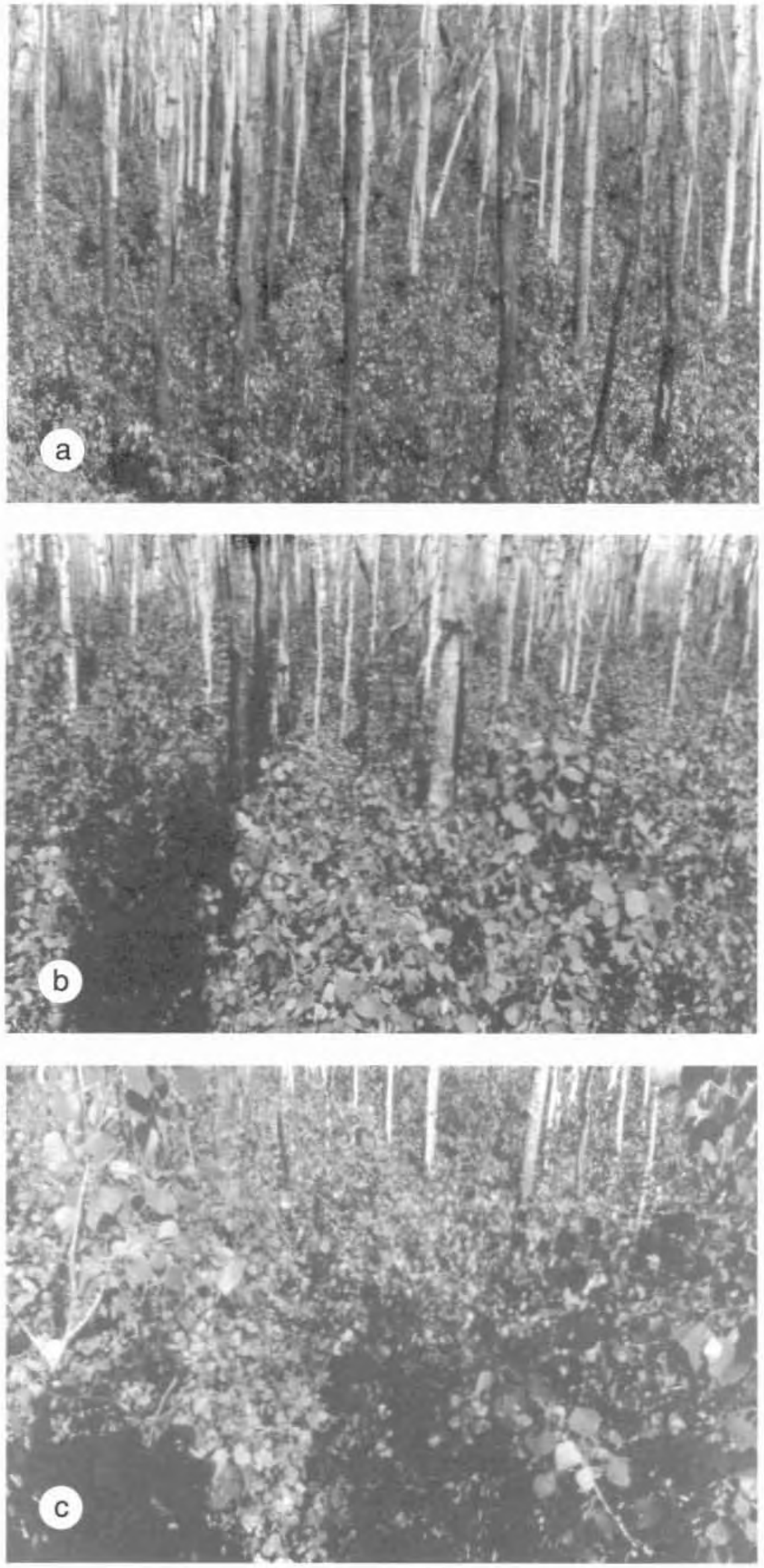

Figure 23. Five years of vegetation development on subplot 4-4 following the Aishihik Fire.
(a) 1983, three years after burning;
(b) 1984, four years after burning;
(c) 1985, five years after burning.

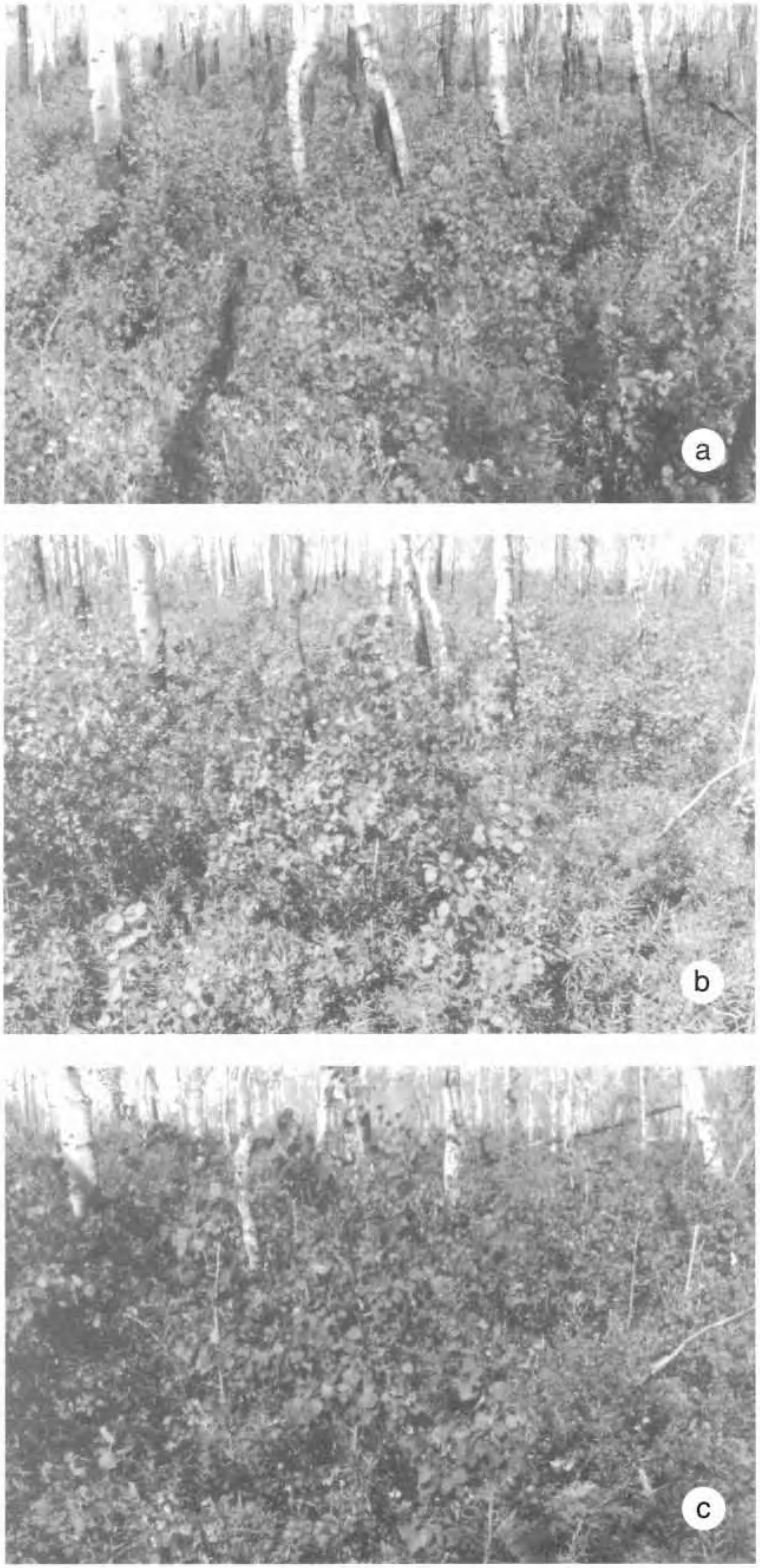

Figure 24. Five years of vegetation development on subplot 7-3 following the Aishihik Fire.
(a) 1983, three years after burning;
(b) 1984, four years after burning;
(c) 1985, five years after burning.

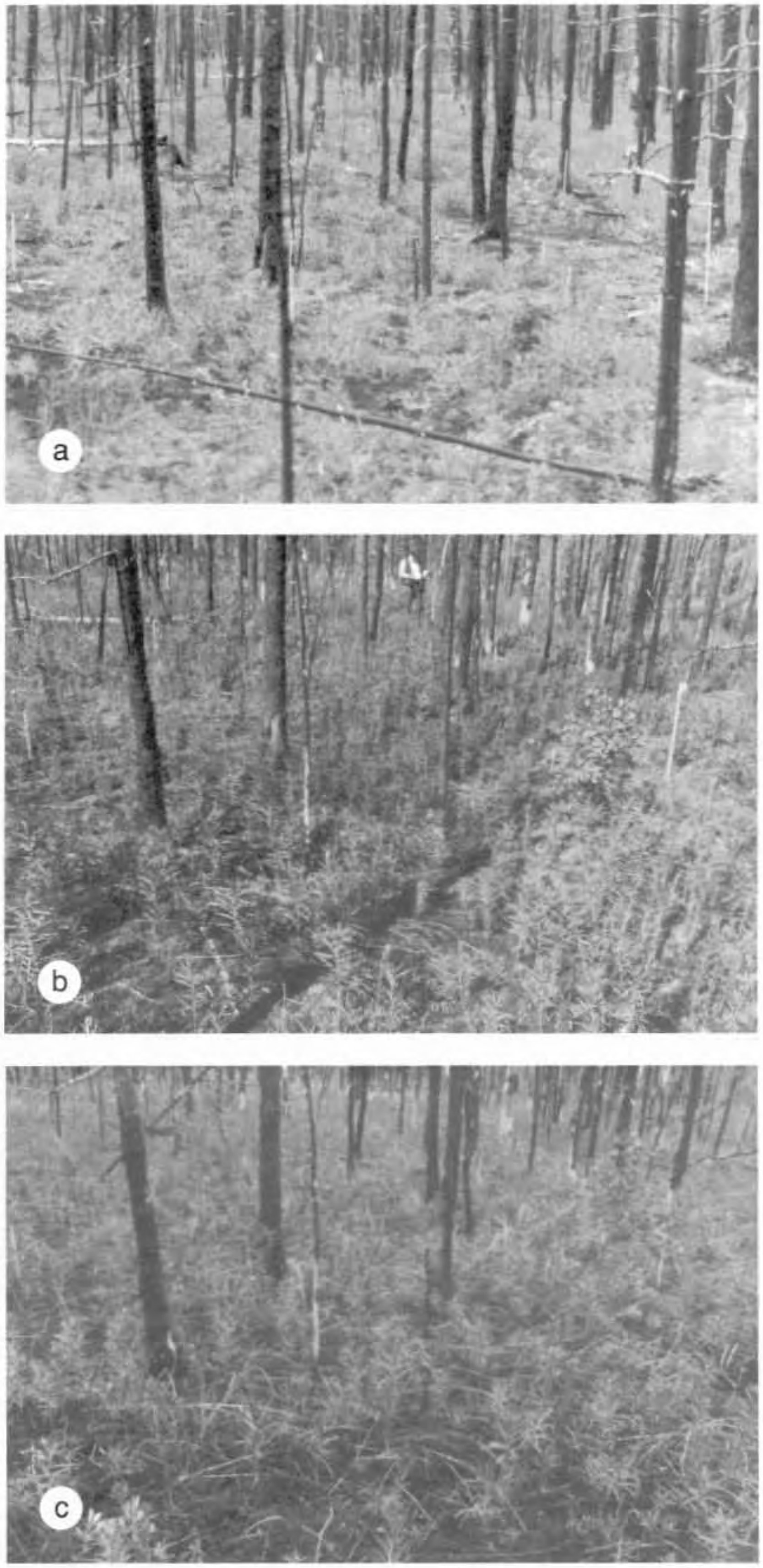

Figure 25. Five years of vegetation development on subplot 3-4 following the Aishihik Fire.
(a) 1983, three years after burning;
(b) 1984, four years after burning;
(c) 1985, five years after burning.

Table 8. Tree regeneration characteristics after five years for 36 subplots at the Aishihik Fire

	Species		
	White spruce	Trembling aspen	White birch
Subplots on which species occurred	25	32	1
Juveniles*/subplot (average)	12.1	41.8	1.0
Juvenile/subplot (range)	1 - 43	1 - 200	—
Juveniles/ha (average)**	4315	14 840	100
Juveniles/ha (range)**	100 - 15 600	100 - 80 000	—
Average height (cm)	2.5	93.8	2.0
Height range (cm)	1 - 10	11 - 175	—

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

**These are based on data from 10 X 10 m plots.

Table 9. Average fifth-year percent cover of the more prevalent shrubs, forbs, and non-vascular plants in 10 X 10 m plots at the Aishihik Fire

Type of vegetation	Plot 1	2	3	4	5	6	7	8	9
Shrubs									
Rose	1	4	0	26	<1	2	18	<1	2
Willow	2	<1	2	0	1	<1	18	0	<1
Kinnikinnick	<1	<1	<1	0	<1	<1	0	0	<1
Buffalo-berry	<1	1	0	0	0	0	<1	<1	<1
All*	3	5	2	26	1	3	36	<1	3
Forbs									
Fireweed	5	1	33	1	11	28	14	33	25
Reed grass	4	7	<1	0	0	1	0	0	0
Bluebells	0	0	0	0	0	0	6	5	0
Twinflower	0	3	0	0	0	0	11	0	0
All*	10	11	33	2	12	36	31	38	30
Non-vascular plants									
Ceratodon	49	31	64	<1	78	58	10	70	79
Pohlia	4	3	15	0	5	5	<1	0	1
All*	53	34	79	<1	83	63	10	70	81

* May include less prevalent species which are not listed separately

were 15 600 white spruce stems/ha in year five — a significant increase from the 1800 stems/ha in year three. Willow, with over 10 900 stems/ha, was the predominant shrub. Fireweed was the dominant herb and provided over 30% cover. Similarly, certatodon was the most abundant bryophyte with over 60% cover, although pohlia (*Pohlia* sp.) was sometimes common.

Discussion

Several factors appear to influence the amount and species composition of tree regeneration, including the age (or maturity) and species composition of the forest canopy before the fire. Lodgepole pine, which has serotinous cones, and black spruce, which has semi-serotinous cones, will have seed available for reforestation following fire provided they are sufficiently mature that adequate viable seed will be produced. Aspen, white birch, and balsam poplar are capable of root stalk or sucker vegetative reproduction, or both, before they reach seed bearing age; this reproductive strategy along with rhizomes is common among the shrubs and some forbs as well. Also, most hardwoods have seeds capable of being disseminated over much greater distances than those of conifers. Most conifer seeds germinate and become better established on mineral soil than in organic material. Frequently the sites where the remaining organic material is over 10 cm in depth are wet and cold; this is not conducive to conifer regeneration, except for black spruce and tamarack which thrive in these conditions. Adequate available moisture following seed germination is critical to conifer regeneration because conifer rootlets develop slower than those in hardwoods; this is especially important where the hardwoods (and shrubs) are already connected to an established root system.

Most plots located in the vicinity of Watson Lake where lodgepole pine and black spruce are common components of forest stands had these species in the reproductive layer within the first three years. This was not the case, however, in some plots in an area previously burnt in 1965; thus, the trees would be less than 17 years old at the time of the current fire, and some were located on wet sites. In the area burned by the Eg Fire and in part of the Low Fire, conifer regeneration the first year was very low, with nearly equal proportions of lodgepole pine and black spruce. In the second and third years, regeneration of both species increased considerably. On the Tom Fire plots and in some of the Low Fire plots where the former stand consisted of mature lodgepole pine, lodgepole pine seedlings were abundant the first year when there were 40 000 lodgepole pine stems/ha, which is in line with the findings of Lyon (1976) in Montana. Most black spruce regeneration did not start until the second or third years, although it was observed in some areas in the first year.

It is not clear why the lodgepole pine and black spruce regeneration was so low on the Eg Fire plots, especially in situations where the prefire stands consisted of mature members of one or both of these species. Even after five years, the highest density of lodgepole pine was 13 900 stems/ha, and a few plots had about 10 000 black spruce stems/ha. The Eg Fire was massive and left virtually no live trees, so the seed for colonization would have to be mostly from on-site sources. It is conceivable that some seed was retained in cones remaining on standing snags and did not fall until the second year. However, some of the plots in areas recently burnt, and thus supporting only young trees at the time of the current fire, had no standing snags, yet had a similar amount of regeneration as some of those plots possessing mature fire-killed snags. Either the seed must have travelled quite a distance to get to these sites, or there was latent seed available, which does not seem likely in light of the amount of unburned organic material remaining. However, some sites that were burnt in 1965 had, at the time of the current fire, a stand dominated by aspen (though some lodgepole pine was also present) and these plots had no conifer regeneration five years after the 1982 fire. Since lodgepole pine and black spruce were not available for colonization at the Aishihik Fire, the only conifer for regeneraton was white spruce, which varied from 2700 to 15 600 stems/ha except where aspen dominated the preburn stand, in which case white spruce regeneration was virtually nil.

Aspen regeneration was present on every plot, although one plot in the Aishihik Fire had only 100 aspen juveniles/ha, one in the Tom Creek Fire had only 300 juveniles/ha, and one in the Eg Fire had only 500 juveniles/ha. Except for one plot in the Low Fire which had 1700 aspen stems/ha in the first year, aspen was rarely found until the second year at which time it generaly was common (sometimes abundant) and grew quite rapidly. The plots in the area burnt in 1965 had between 1900 and 15 500 aspen juveniles/ha, most of which are assumed to have started from rootstalks even though they did not become common until the third year. The other plots generally had a lag period of at least one year, and even in the second year there were usually fewer than 1000 aspen juveniles/ha; however, there are exceptions, such as one where there were 12 600 aspen juveniles/ha in the second year. Based on the number of aspen juveniles in the third year in some of the Aishihik Fire plots that had a prefire aspen stand, they must have also been abundant in the second year at least.

In nearly all sites studied, regeneration does not seem to be lacking. There are some plots which may have a lower stocking than is desireable from a forest management perspective, such as one in the Tom Fire with only 1200 seedlings/ha. On the other hand, some plots had higher stocking than would normally be desired; several had over 40 000 juveniles/ha after five years. There are few guidelines as to what might constitute adequate stocking at year five in the northern boreal forests, but generally speaking, 900 to 1200 trees/ha at rotation is considered acceptable, at least for lodgepole pine and white spruce. It is also known that young stands frequently undergo a natural thinning process which often begins around ten years after a major disturbance. On several sites in the vicinity, lodgepole pine and aspen formed very dense stands that have persisted beyond ten years of age. Observation of tree rings revealed that lodgepole pine, in particular, often formed stands that became very slow-growing at about 25 years of age and remained in that state for several decades. Aspen appears to be better at self thinning, and it is rare to find a stagnated aspen stand over 25 years old. Black spruce stand development is largely unknown. Most mature upland black spruce stands in the area are well spaced with the exception of those in wet and cold sites which usually have depths of organic material greater than 20 cm and fairly dense, slow-growing trees. One plot in the Low Fire had 31 500 black spruce seedlings/ha, but also had 1500 lodgepole pine and 19 000 aspen juveniles/ha on the fifth year; this was a subhygric site with medium textured, moderately well drained soil on glaciolacustrine material that had about 50% exposed mineral soil. A mesic site with medium textured, moderately well drained soil in the Tom Fire had 13 200 black spruce, 25 200 lodgepole pine, and 5800 aspen juveniles/ha after five years. These sites will provide a means for evaluating the successional relationships of these species over time with continued measurements.

The successional sequences for the most part appear to be rather straightforward, and after five years of development the stable vegetation or community type can be predicted in many cases. During the initial period (usually three to five years) the tree species, which reflect the preburn stand, are established. The exceptions occur where the preburn stand did not have trees capable of producing adequate seed and where vegetatively propagating species were prevalent. Aspen grows much faster than conifers during the early to mid seral stages. It not only out-competes the conifer seedlings for light, nutrients, and moisture, but has the potential for further restricting conifer development by smothering the seedlings with litter, particularly the large deciduous leaves, which become compressed on seedlings during snowfalls. Lodgepole pine grows faster than the spruces during the initial seral stages and, if not restricted by competition from one source or another, will dominate the first conifer stand. Both black and white spruce are shade-tolerant, and even though they grow much better without competition, they will eventually out-compete other conifers and the hardwoods. Both lodgepole pine and aspen owe their abundance and wide distribution to the occurrence and frequency of fires. Balsam poplar and white birch were frequently present in small quantities, but are not major components of these boreal forest stands; balsam poplar is prevalant mostly on recent alluvium and white birch on colder sites such as those which occur on north aspects, but neither one competes well with the other boreal species. Tamarack was present in some prefire stands, but was not observed in any post-fire succession plots. The reason for the absence of tamarack in the plots could be its scarcity; few tamarack seedlings were observed in surrounding areas. Tamarack normally requires an open environment on upland sites in this area, is shade-intolerant, produces few viable seeds, and does not compete well. In the later seral stages, conifers usually out-compete the hardwoods, even though aspen and birch may persist as a minor component. In situations where the conifers were virtually eliminated from a site, aspen can dominate a stand until the stand becomes senescent. Climax stands are unknown in the area as the frequency of fire has prevented the attainment of the climax stage. However, black and white spruce, due to their shade-tolerance, should be prominent species in climax stands.

The major shrubs, such as rose, alder, willow, lingonberry, and Labrador tea, regenerate from root stalks or rhizomes, and are usually favored by fires. Frequently the shrubs are a more reliable indicator of site conditions and of the stable community than are the trees. The abundance of the shrub species is apparent by the fifth year, and further increases in the cover provided by shrubs are achieved by plant development. Most species of shrubs do not produce viable seed for at least three years; thus any plants originating from seed during the early seral stages must do so from seed brought in from outside sources and buried seed. Long-beaked willow and alder are usually the tallest plants during the first five years wherever they occur; they even over-top the hardwood tree species. However, they both appear to regenerate only from root stalks, at least initially, and usually were not overly abundant in mature preburn stands; thus, they may not be major competitors. Alder may even be beneficial to the trees because of its nitrogen-fixing abilities. The main shrub competition appears to come from the species that can vegetatively regenerate from means other than just root stalks, such as rose, bilberry willow, diamond willow, raspberry, and skunk currant, which have rhizomes or suckers. These species can be quite prolific on some sites and can retard tree seedling development. However, as the trees develop, the shrubs are held in check, or even reduced in coverage as the stand approaches a late seral or stable state. Some mature black spruce/alder/feathermoss stands in the area appear relatively stable, and may indeed be indicative of a climax condition, but some change is still taking place as the organic mantle increases in thickness and tends to lower the soil temperature at rooting depth.

Some species of forbs have a rather dramatic flush during the second or third year following a fire and then either decline markedly or disappear entirely. Cranesbill, corydalis, dryland sedge, and dragonhead are sometimes present in disturbed areas and in young seral stands, but are rarely seen in mature stands. About two years following a fire they frequently, alone or in combination, will form the greatest amount of ground cover, but by the fifth year they may be totally absent. In some plots, the flush occurred in year two and they were not observed in year three. The reason for their disappearance is not clear. Except for the sedge, they are annuals or biennials, and were observed to be in flower. These species usually occurred on the drier sites, and competition from other species was not adequate to curtail their growth, with the possible exception of ceratodon. Ceratodon is usually found only in disturbed areas, such as road ways, but is always present following fires. It initially forms a scum over the ground surface, and by the second or third year becomes a recognizable plant with the production of capsules, and may cover 90% or more of the ground surface. It appears to persist for at least five years before being shaded out. Its effect on other seral plant species is not known.

Other species of forbs may exhibit a somewhat different successional pattern. Fireweed, dwarf scouring-rush, and bunchberry often reach a peak in ground cover during the second or third years, and then decline somewhat, but they will persist even into mature stands. These species are all rhizomatous, and the rhizomes are largely responsible for the establishment of the species following fires. A network of rhizomes of each species can develop and persist with only a few aboveground plants to sustain it even in dense mature stands. In mature stands, fireweed is usually reduced to a thin population of non-flowering individuals, while scouring-rush and bunchberry can thrive.

Conclusions

By observation of the species present following a fire, and with knowledge of their characteristic successional performance, in most cases the successional and stable communities can be predicted. Emphasis must be placed on the characteristic species, which for the most part are species known to be shade-tolerant. Shade-intolerant species may persist, and even constitute characteristic species, on drier sites because the forest canopy remains open. For example, alder, bilberry willow, buffalo-berry, long-beaked willow, and lingonberry can persist in closed forest stands while diamond willow, kinnikinnick, raspberry, and skunk currant require direct sunlight. Similarly, the feathermosses must have shade to develop, while ceratodon and polytrichum need sunlight. Once the stable community is recognized, it can be correlated to a community type such as those of Oswald and Brown (1986) or of Stanek and Orloci (1987); this facilitates the determination of site quality, and can be a valuable guide to the future management of the stand.

Juvenile trees, particularly of lodgepole pine and aspen, appear within two years following a wildfire on most sites, and can either form pure stands of one species or mixedwood stands. The aspen are derived almost exclusively from root stalks and suckers, and thus are supported by well developed root systems. Lodgepole pine, on the other hand, comes entirely from seed and is subject to establishment perils, such as drought, before an adequate root system is developed to withstand such adversities. Assessments of population densities cannot be reliably made until the seedlings are well established — three years as a very minimum. White spruce, black spruce, and subalpine fir are more difficult to detect during the initial establishment periods due to slower growth during the early seedling stages; thus, population assessments may not be feasible for up to ten years following the fire. In some cases the spruce may not appear until the early seral species have reached maturity.

Although this study includes assessment data for only the first five years of stand development following a wildfire, in addition to the above comments, the following statements can be made:

—Tree regeneration is nearly always plentiful within five years following a wildfire in the Boreal White and Black Spruce Biogeoclimatic Zone.

—The initial tree species most often reflect the species in the prefire stand, but the composition may change; early seral species (aspen and lodgepole pine) dominate over late seral species (white and black spruce and subalpine fir).

—Aspen was present in all plots and abundant in many; most of this came from root stalks and suckers, but some may have come from seed in the second and third years following the fires.

—Lodgepole pine seedlings were the most common conifer juveniles, except in the Aishihik area where this species does not occur; white spruce was most common there.

—White and black spruce often are not present until the second or third year following a fire, and in some cases appear to take over five years to appear.

—The abundances of aspen and lodgepole pine are increased by fire, especially where they are present prior to the fire, and aspen has the advantage of vegetative propagation over lodgepole pine on sites where fires repeat at short intervals.

—Comparison of early post-burn sites with juvenile and mature stands indicates that aspen and lodgepole pine often are initially over-populated following a fire, and that aspen will self-thin better than lodgepole pine; the pine often forms dense stands with stunted growth within about 25 years.

—Most shrubs colonizing after a fire do so from root stalks already present. Aspen and lodgepole pine can compete favorably with the shrubs provided they get established during the initial shrub development stages. Spruce seedlings are restricted by the over-topping shrubs, but eventually penetrate through the shrub canopy.

—Further assessments must be made at intervals of five or ten years to fully characterize the successional stages leading to a mature stand.

Literature Cited

Agriculture Canada Expert Committee on Soil Survey. 1987. The Canadian system of soil classification. 2nd ed. Agric. Can. Publ. 1646. 164 p.

Arno, S.F.; Simmerman, D.G.; Keane, R.E. 1982. Forest succession on four habitat types in western Montana. U.S.D.A. For. Serv. Gen. Tech. Rep. INT-177, Intermountain Forest and Range Experiment Station, Ogden, Utah. 74 p.

British Columbia Ministry of Forests. 1988. Biogeoclimatic Zones of British Columbia 1988. Research Branch, Victoria. Map.

Bostock, H.S. 1965. Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel. Dept. Mines & Resources, Mines and Geology Branch, Geolog. Survey Memoir 247. 106 p.

Cowell, D. 1983. The roar of the fire. ForesTalk. 7(2):14-20.

Crane, M.F.; Habeck, J.R.; Fischer, W.C. 1983. Early postfire revegetation in a western Montana Douglas-fir forest. U.S.D.A. For. Serv. Res. Pap. INT-319. Intermountain Forest and Range Experiment Station, Ogden, Utah. 29 p.

DeByle, N.V. 1981. Clearcutting and fire in the larch/Douglas-fir forests of western Montana - A multifaceted research summary. U.S.D.A. For. Serv., Gen. Tech. Rep. INT-99. Intermountain Forest and Range Experiment Station, Ogden, Utah. 73 p.

Grier, C.C. 1975. Wildfire effects on nutrient distribution and leaching in a coniferous ecosystem. Can. J. For. Res. 5:599-607.

Hawkes, B.C. 1982. Fire history and ecology of forest ecosystems in Kluane National Park: Fire management implications. Pages 266-280 in R.W. Wein, R.R. Riewe, and I.R. Methven, eds. Proc. Resources and Dynamics of the Boreal Zone Conf. Thunder Bay, Ontario. August 1982. Assoc. Canadian Universities for Northern Studies.

Hitchcock, C.L.; Cronquist, A.; Ownbey, M.; Thomson, J.W. 1969. Vascular plants of the Pacific Northwest. University of Washington Press, Seattle and London. 5 Vol.

Hulten, Eric. 1968. Flora of Alaska and neighboring territories. Stanford University Press, Stanford, Calif. 1008 p.

Kelsall, J.P.; Telfer, E.S.; Wright, T.D. 1977. The effects of fire on the ecology of the boreal forest, with particular reference to the Canadian north: a review and selected bibliography. Fish. and Environ. Can., Can. Wildl. Serv., Occ. Pap. No. 32. 58 p.

Lawton, E. 1971. Moss Flora of the Pacific Northwest. The Hattori Botanical Laboratory, Nichinan, Miyazaki, Japan. 362 p + 195 Plates.

Lyon, L.J. 1976. Vegetal development on the Sleeping Child burn in western Montana, 1961 to 1973. U.S.D.A. For. Ser., Res. Pap. INT-184. Intermountain Forest and Range Experiment Station, Ogden, Utah. 24 p.

Lyon, L.J. 1984. The Sleeping Child burn—21 years of postfire change. U.S.D.A. For. Serv. Res. Pap. INT-330. Intermountain Forest and Range Experiment Station, Ogden, Utah. 17 p.

Oswald, E.T.; Brown, B.N. 1986. Forest communities in Lake Laberge Ecoregion, Yukon Territory. Can. For. Ser., Pac. For. Cent., Inf. Rep. BC-X-282. 97 p.

Oswald, E.T.; Senyk, J.P. 1977. Ecoregions of Yukon Territory. Environ. Can., Can. For. Serv., Pac. For. Res. Cent., Inf. Rep. BC-X-164. 115 p.

Parminter, J. 1983. Fire-ecological relationships for the biogeoclimatic zones of the Cassiar Timber Supply Area. B.C. Ministry of Forests. Northern Fire Ecology Project. 173 p.

Porsild, A.E.; Cody, W.J. 1980. Vascular Plants of Continental Northwest Territories, Canada. National Museums of Canada. 667 p.

Rowe, J.S. 1970. Spruce and fire in Northwest Canada and Alaska. Ann. Proc. Tall Timbers Fire Ecol. Conf. 10: 245-254.

Stanek, W.; Orloci, L. 1987. Some silvicultural ecosystems in the Yukon. Can. For. Ser., Pac. For. Cent., Inf. Rep. BC-X-293. 56 p.

Stickney, P.F. 1980. Data base for post-fire succession, first 6 to 9 years, in Montana larch-fir forests. U.S.D.A., For. Ser., Gen. Tech. Rept. INT-62. 133 p.

Stickney, P.F. 1985. Data base for early postfire succession on the Sundance Burn, northern Idaho. U.S.D.A., For. Ser., Gen. Tech. Rept. INT-189. 121 p.

Stickney, P.F. 1986. First decade plant succession following the Sundance forest fire, Northern Idaho. U.S.D.A., For. Ser., Gen. Tech. Rept. INT-197. 26 p.

Taylor, R.L.; MacBryde, B. 1977. Vascular plants of British Columbia; A descriptive resource inventory. Univ. of B.C. Press. Tech. Bull. No. 4. 754 p.

Van Wagner, C.E. 1984. Forest Fire Research in the Canadian Forestry Service. Agric. Can., Can. For. Serv., Inf. Rep. PI-X-48. 39 p.

Viereck, L.A.; Dyrness, C.T. 1979. Ecological effects of the Wickersham Dome fire near Fairbanks, Alaska. U.S.D.A., For. Serv., Gen. Tech. Rep. PNW-90. 71 p.

Viereck, L.A.; Schandelmeier, L.A. 1980. Effects of fire in Alaska and adjacent Canada — a literature review. U.S. Dept. Inter., Bureau of Land Management, BLM-Alaska Tech. Rep. 6. 124 p.

Walmsley, M.; Utzig, G.; Vold, T.; Moon, D.; Van Barneveld, J. (eds.) 1980. Describing ecosystems in the field. B.C. Ministy of Forests, Resource Analysis Branch, RAB Tech. Pap. 2. 226 p.

Appendix A. Number of subplots with seedlings, seedlings per subplot, percent cover, and modal height by year for each species by burn. Total number of subplots: Aishihik Fire - 36; Eg Fire - 84; Low Fire - 24; Tom Fire - 44.

	Number of subplots with seedlings				Mean seedlings per subplot				Mean percent cover				Mean modal height (cm)			
	Years after fire															
Burn Species	1	2	3	5	1	2	3	5	1	2	3	5	1	2	3	
Aishihik*																
White spruce	na	na	9	25	na	na	2.8	12.1	na	na	0.1	0.1	na	na	1.7	2.5
Aspen	na	na	30	32	na	na	43.0	41.8	na	na	16.5	19.7	na	na	49.9	93.8
White birch	na	na	0	1	na	na	0	1.0	na	na	0	0.1	na	na	0	2.0
Eg																
White spruce	4	4	4	4	3.0	7.8	25.0	35.8	0.1	0.3	0.3	0.3	2.0	1.3	1.5	4.3
Black spruce	4	15	37	43	1.3	2.0	4.8	9.8	0.1	0.1	0.1	0.1	1.2	1.7	2.3	7.2
Lodgepole pine	11	45	50	57	1.8	5.3	8.5	9.2	0.1	0.1	0.1	1.2	1.3	3.3	9.6	28.8
Aspen	1	65	81	81	4.0	9.9	13.4	19.9	0.1	1.2	1.9	3.7	14.0	18.1	24.5	59.8
Balsam poplar	1	4	10	10	1.0	4.5	4.9	6.6	0.1	1.6	1.1	2.2	8.0	28.3	54.5	156.9
White birch	1	2	5	13	2.0	1.0	1.0	1.1	0.1	1.1	0.5	0.3	30.0	49.5	34.6	32.5
Tom																
Black spruce	1	7	20	37	1.0	2.1	3.2	12.3	0.1	0.1	0.1	0.1	1.0	1.3	2.1	8.1
Lodgepole pine	40	40	43	40	43.8	32.7	30.5	38.1	0.1	0.2	0.2	1.8	2.0	1.6	4.4	18.8
Aspen	0	2	37	38	0	5.0	7.7	14.5	0	0.1	0.1	0.6	0	5.5	5.8	36.6
White birch	1	6	18	29	1.0	1.0	3.6	15.1	0.1	0.4	0.1	0.5	27.0	13.0	5.9	21.9
Low																
Black spruce	3	4	16	15	1.3	12.5	7.8	25.7	0.1	0.1	0.1	0.2	2.0	1.5	1.9	4.8
Lodgepole pine	13	18	20	20	32.2	25.4	27.4	37.2	0.1	0.2	0.4	2.2	1.7	3.4	8.5	22.7
Aspen	10	21	24	24	6.5	18.4	19.9	28.9	0.6	4.5	6.7	8.3	16.4	37.4	55.7	88.8
White birch	0	0	0	1	0	0	0	1.0	0	0	0	0.1	0	0	0	3.0

* No data are available for years 1 and 2 at the Aishihik fire.

Appendix B. Moisture regime, tree species, prefire canopy species, and percent exposed mineral soil for each plot, the total number of seedlings per hectare.

Table B1. Number of juveniles* of each tree species in each 10 m X 10 m plot, total number of juveniles/ha, and primary tree species at each plot prior to the Tom Fire

Plot	Moisture regime	Tree regeneration after 5 years				Total Juveniles per ha	Prefire primary species	Percent Exposed mineral soil
		Black spruce	Lodgepole pine	Trembling aspen	White birch			
		juveniles/plot						
34	Subhydric	41	2	53	—	9600	Black spruce/Lodgepole pine	5
35	Subhygric	128	82	39	8	25 700	Lodgepole pine/Black spruce	40
36	Mesic	15	78	30	4	12 700	Lodgepole pine/Black spruce	0
37	Mesic	132	252	58	310	75 200	Lodgepole pine/Black spruce	50
38	Subhygric	7	23	21	—	5100	Black spruce	5
39	Mesic	15	160	5	3	18 300	Lodgepole pine/Trembling aspen	40
40	Submesic	36	406	131	24	59 700	Lodgepole pine	30
41	Submesic	49	317	153	24	54 300	Lodgepole pine	2
42	Mesic	9	36	12	4	6100	Lodgepole pine/Black spruce	5
43	Mesic	23	148	46	32	24 900	Lodgepole pine	5
44	Mesic	1	8	3	—	1200	Lodgepole pine/White birch	2

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

Table B2. Number of juveniles* of each tree species in each 10 m x 10 m plot, total number of juveniles/ha, and primary tree species at each plot prior to the Low Fire.

Plot	Moisture regime	Tree regeneration after 5 years				Total Juveniles per ha	Prefire primary species	Percent Exposed mineral soil
		Black spruce	Lodgepole pine	Trembling aspen	White birch			
		juveniles/plot						
10	Subhygric	315	15	194	1	52 500	Black spruce	50
11	Submesic	49	502	71	—	62 200	Lodgepole pine	30
12	Xeric	1	16	25	—	4200	Lodgepole pine	95
13	Xeric	—	—	230	—	23 000	Trembling aspen/Lodgepole pine	90
14	Mesic	19	177	82	—	27 800	Lodgepole pine/Trembling aspen	90
15	Xeric	2	38	92	—	13 200	Lodgepole pine	100

* Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

Table B3. Number of juveniles* of each tree species in each 10 m x 10 m plot, total number of juveniles/ha, and primary tree species at each plot prior to the Eg Fire.

Plot	Moisture regime	Tree regeneration after 5 years (juveniles/plot): White spruce	Black spruce	Lodgepole pine	Trembling aspen	White birch	Balsam poplar	Total Juveniles per ha	Prefire primary species	Percent Exposed mineral soil
16	Mesic	—	28	2	27	—	—	5700	Black spruce	65
17	Mesic	—	101	33	155	1	2	29 200	White spruce/Lodgepole pine	55
18	Submesic	—	47	23	83	—	—	15 300	Black spruce/Lodgepole pine	60
19	Mesic	—	23	7	179	—	—	20 000	Black spruce/Lodgepole pine	10
20	Submesic	—	—	—	95	—	—	9500	Lodgepole pine/Black spruce	10
21	Mesic	—	11	94	92	—	—	19 700	Lodgepole pine	85
22	Subxeric	—	—	7	35	—	—	4200	Lodgepole pine	100
23	Mesic	—	—	—	85	—	—	8500	Lodgepole pine/Trembling aspen	50
24	Subxeric	—	—	2	91	—	—	9300	Lodgepole pine	95
25	Mesic	—	2	21	59	—	—	8200	Lodgepole pine	35
26	Subhygric	—	22	2	20	—	—	4400	Black spruce	0
27	Subhydric	—	2	1	160	1	—	16 400	Trembling aspen/Black spruce	90
28	Submesic	—	58	10	155	3	1	22 700	Lodgepole pine	95
29	Mesic	—	4	24	41	—	4	7300	Lodgepole pine	95
30	Mesic	—	9	49	19	—	—	7700	Lodgepole pine	90
31	Mesic	—	3	14	6	—	—	2300	Lodgepole pine	95
32	Submesic	—	9	5	62	3	—	7900	Lodgepole pine	100
33	Subhygric	143	—	139	58	1	54	39 500	Lodgepole pine/White spruce	35
45	Mesic	—	2	3	86	2	—	9300	Lodgepole pine/Black spruce	95
47	Submesic	—	—	3	46	—	—	4900	Lodgepole pine/Black spruce	95
48	Subhygric	—	99	83	55	1	—	23 700	Black spruce/Lodgepole pine	55

*Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.

Table B4. Number of juveniles of each tree species in each 10 m x 10 m plot, total number of juveniles/ha, and primary tree species at each plot prior to the Aishihik Fire.

Plot	Moisture regime	Tree regeneration after 5 years			Total Juveniles per ha	Prefire primary species	Percent Exposed mineral soil
		White spruce	Trembling aspen	White birch			
		juveniles/plot					
1	Subxeric	30	44	—	7400	White spruce	95
2	Subxeric	44	141	—	18 500	White spruce/Trembling aspen	95
3	Subhygric	156	37	1	19 400	White spruce	100
4	Mesic	1	800	—	80 100	Trembling aspen	0
5	Mesic	17	75	—	9200	White spruce/Trembling aspen	95
6	Subxeric	27	1	—	2800	White spruce	95
7	Submesic	—	200	—	20 000	Trembling aspen	20
8	Mesic	—	7	—	700	White spruce/Trembling aspen	75
9	Mesic	27	31	—	5800	Trembling aspen	85

*Juvenile refers to young trees which are usually seedlings in the case of conifers, but can be seedlings or vegetative propagations of hardwood species.