TECHNICAL REPORT 026

Vegetation Development and Fire Effects at the Walker Creek Site

Comparison of Forest Floor and Mineral Soil Plots

2006

BRITISH COLUMBIA

Ministry of Forests and Range
Forest Science Program

Vegetation Development and Fire Effects at the Walker Creek Site

Comparison of Forest Floor and Mineral Soil Plots

Evelyn Hamilton

British Columbia
Ministry of Forests and Range
Forest Science Program

Library and Archives Canada Cataloguing in Publication Data

Hamilton, Evelyn Hope, 1954-

Vegetation development and fire effects at the Walker Creek site : comparison of forest floor and mineral soil plots

(Research report ; 26)

Includes bibliographical references: p.

ISBN 0-7726-5483-2

1. Prescribed burning - Environmental aspects - British Columbia - Walker Creek Region (Fraser-Fort George). 2. Forest regeneration - British Columbia - Walker Creek Region (Fraser-Fort George). 3. Forest site quality - British Columbia - Walker Creek Region (Fraser-Fort George). I. British Columbia. Forest Science Program. II. Title. III. Series: Research report (British Columbia. Forest Science Program) ; 26.

SD147.B7H35 2006 634.9'55 C2006-960000-7

Citation

Hamilton, E.H. 2006. Vegetation development and fire effects at the Walker Creek site: comparison of forest floor and mineral soil plots. B.C. Min. For. Range, Res. Br., Victoria, B.C. Tech. Rep. 026. <http://www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr026.htm>

Prepared by

Evelyn Hamilton
B.C. Ministry of Forests and Range
Research Branch
PO Box 9519, Stn Prov Govt
Victoria, BC V8W 9C2

Copies of this report may be obtained, depending on supply, from:
Government Publications Services
2nd Floor, 563 Superior Street
Victoria, BC V8V 4R6
TOLL FREE 1-800-663-6105
PHONE (250) 387-6409
FAX (250) 387-1120
http://www.publications.gov.bc.ca

For more information on Forest Science Program publications, visit our web site at:
http://www.for.gov.bc.ca/scripts/hfd/pubs/hfdcatalog/index.asp

ABSTRACT

The objective of this study was to quantify the response of vegetation on a cutblock in the SBSvk subzone under known burning conditions by monitoring fire weather, fire effects, and vegetation development. Vegetation succession on forest floor[1] and mineral soil (skid roads) permanent sample plots was monitored.

Standard fire weather information was collected along with fuel loading and forest floor layer depths (i.e., litter and duff[2] layer depth) before and after burning to characterize the fire effects and burning conditions. Methods outlined in the Canadian Forest Fire Weather Index System (CFFWIS) were used.

The observed fire effects (duff and woody fuel consumption and mineral soil exposure) were compared to those predicted when the Prescribed Fire Predictor was used in conjunction with the CFFWIS predictions of Duff Moisture Code (DMC) and duff moisture level (DML) derived from sampling the duff at the time of burning.

Cover and height of vascular species was monitored in 147 permanent sampling plots for 10 years. Mode of establishment of species was determined where possible.

The equation devised by Lawson, Dalrymple, and Hawkes in 1997 for pine/spruce–feathermoss sites in the Yukon approximated the DMC and DML relationship found on this site. The DML was accurately predicted by the CFFWIS. Actual duff consumption and mineral soil exposure were significantly lower than predicted and woody fuel consumption was greater than predicted. These discrepancies reflect the limitations of the Prescribed Fire Predictor on this site under the conditions in which the burn was done.

There were 32 vascular plant species on the forest floor plots prior to burning. By the tenth year after burning, there were 74 species. There were 13 vascular plant species in the mineral soil plots before burning and 52 by year 10. Many herb and shrub species established on the mineral soil plots in the first year after burning.

Most of the species that were present on the site as a whole before burning survived until year 10. In addition, a number of new species became established. Some of these were invasive species typical of early seral sites; however, many were species typical of forested stands.

Five shrub species established from buried seeds in a number of the plots. All of these species were present as parent plants on the site before burning, including *Ribes* and *Rubus* species, and *Sambucus racemosa*. All shrubs, and almost all herbs, present before burning resprouted after burning. Three new species of hardwood trees established in the plots after burning, as well as two new species of shrubs and 33 new species of herbs.

1 Forest floor refers to the LFH layer of the soil or the organic layer [L=litter, F=fermentation (partially decomposed), and H=humus (well decomposed)].

2 Duff is the term used in fire science to refer to the moderately compacted FH layer.

ACKNOWLEDGEMENTS

Special thanks are extended to H. K. Yearsley, who was involved in the data collection, analysis, and writing. Her assistance was greatly appreciated. Thanks are also extended to S. Low, T. Fleming, and C. Cadrin, who collected field data. S. Low and L. Stordeur helped analyze the data. This study was done in co-operation with the Canadian Forestry Service. B. Hawkes, S. Taylor, R. DeJong, and G. Dalrymple helped determine burn impacts and monitor fire weather conditions. The co-operation of the Prince George Forest District staff, particularly R. Richards and R. Fahlman, and the Prince George Wood Preservers was appreciated. W. Bergerud and V. Sit advised on the analysis of the data. J. Parminter and B. Hawkes reviewed the report.

CONTENTS

APPENDICES

TABLES

FIGURES

1 INTRODUCTION

1.1 Background and Rationale

Development of sustainable forest management practices requires an understanding of the short- and long-term effects of logging and site preparation on all forest vegetation. Clearcutting and slashburning have been widely practised in the province of British Columbia, Canada. Although vegetation monitoring for various purposes (e.g., wildlife habitat, vegetation management) has been carried out in British Columbia, many of these projects have a relatively narrow focus (e.g., selected species, short time span). Little is known about patterns of vegetation development after burning or how management activities, particularly slashburn severity, influence these patterns.

Slashburning has been widely used in British Columbia and some work has been done to to improve the tools used to predict fire effects in cutblocks (i.e., the CFFWIS and PFP) (Blackhall and Auclair 1982; Alexander 1984; Brown et al. 1985; Hawkes and Lawson 1986; Lawson and Taylor 1986; Katuski 1989). There is relatively little ecosystem-specific work that encorporates recent information into revised decision-support tools. A significant amount of the more recent published work on fire effects pertains to mature forests (Hawkes and Lawson 1983; Hawkes and Taylor 1994; Lawson et al. 1997).

This report provides information that can be used to guide the application of the most commonly used tools—the CFFWIS and PFP—in SBS cutblocks.

The strong positive response to FRDA Report 018 (Hamilton and Yearsley 1988), which presented information on vegetation development in the SBS zone, indicates that predictive models of forest vegetation succession are needed. These models, which illustrate expected changes in floristic composition and structure, are essential to the development of management prescriptions to meet integrated resource use objectives such as regenerating forests, providing wildlife habitat, and maintaining biodiversity.

1.2 Objectives

The objectives of this study were:

1) to quantify and describe changes in percent cover, height, species composition, and diversity of vegetation on forest floor and mineral soil substrates, for 10 years after burning in an SBSvk subzone site;
2) to determine the relationship between actual fire effects (i.e., duff and woody fuel consumption and mineral soil exposure) and those predicted by the Prescribed Fire Predictor (Muraro 1975); and
3) to determine the relationship between predicted and actual duff moisture level when various conversion equations (Lawson et al. 1997) are used with the Canadian Forest Fire Weather Index System (van Wagner 1987) to predict duff moisture level.

1.3 Study Area

The study site is located in the Prince George Forest District in northern British Columbia, at kilometre 55 on the Walker Creek Forest Road, in the McGregor River Valley (Figure 1). This block is located at 1050 m elevation, in the Very Wet Cool subzone of the Sub-Boreal Spruce zone (SBSvk) (DeLong 2003) (Figure 2). Before logging took place, the site supported a mature Sxw-Devil's club (SBSvk/01) site series forest (DeLong 2003); however, small patches of a wetter site series (SBSvk/07) occur around seepage areas, and drier site series (SBSvk/05) are found on localized elevated sites. Soil texture is silty clay loam with a 10 cm thick LFH layer. Average slope is 23% with a northeast aspect.

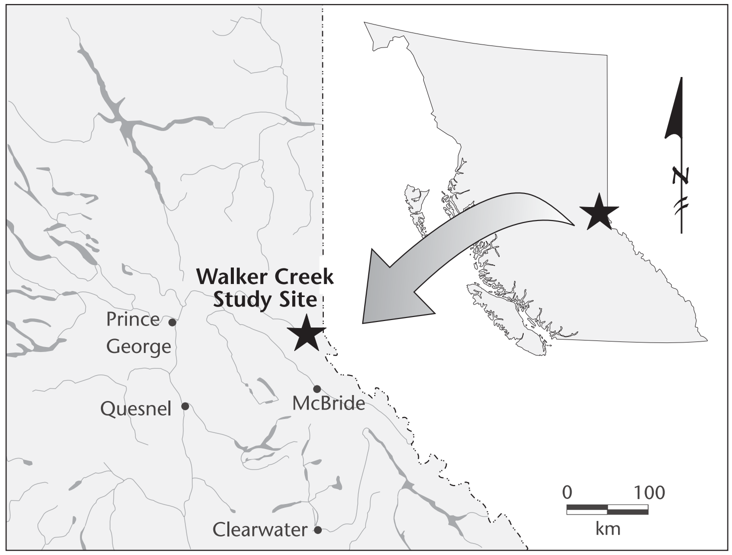

FIGURE 1 *Location of Walker Creek study site.*

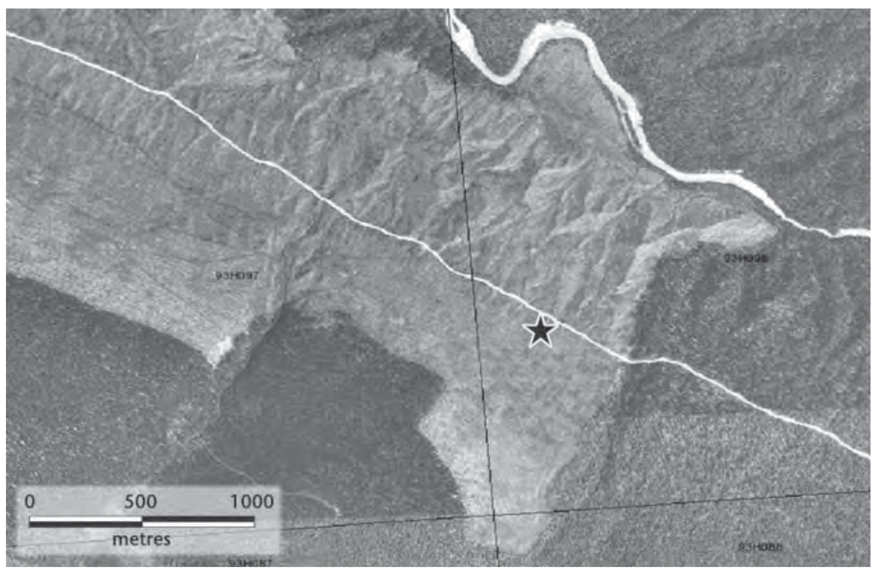

FIGURE 2 *Close-up of study site location.*

Logging took place in the winter of 1985–1986 when snow cover was deep enough to prevent disturbance of the forest floor or destruction of understorey vegetation, except on skid roads. The site was slashburned on August 12, 1986 and planted in May 1987 (Figure 3).

FIGURE 3 *Walker Creek site (Block 5) – (A) 1986, pre-burn, (B) June 1987, 1 year after burning, (C) 1991, 5 years after burning, (D) 1996, 10 years after burning.*

2.1 Data Collection

A fire weather station was established on the study site at the beginning of the summer of 1986 and Canadian Forest Fire Weather Index System Codes and Indices were calculated following standard procedures (van Wagner 1987).

Forest floor moisture level was sampled just before burning, using gravimetric sampling. Four samples of each of the 0- to 2-, 2- to 4-, 4- to 6-, and 6- to 8- cm layer of the forest floor were taken from representative sites on the cutblock immediately prior to burning. Samples were stored in aluminum tins and weighed before and after drying in a forced-air convection oven at 70°C for 24 hours.

Five sample blocks, each 30 × 60 m, were established in the cutblock after the site was logged and skid roads established, but before it was burned. These blocks do not represent different treatment areas, but were a means of distributing plots more widely on the site. After the site was slashburned, block corners were permanently marked with tall wooden stakes.

Vegetation monitoring plots were randomly located at grid points (in a 6 × 6 m grid) laid out in each block. Thirty 1 m diameter circular vegetation monitoring plots were located in each block for a total of 150 plots. Plot centres were marked with metal rebar stakes.

Vegetation monitoring plots were classified as forest floor (n = 128) or mineral soil or skid road (n = 19), depending on the dominant substrate. Three plots were abandoned for various reasons.

Four depth of burn (DOB) pins were established in a grid pattern in each forest floor substrate plot, for a total of 512 pins. Pre-burn litter depth, duff depth, and DOB were measured in each plot.

Fuel loading and consumption were determined for a subset of the forest floor substrate plots selected at random. A modification of standard fuel assessment methods (Trowbridge et al. 1994) described in Hawkes (1986) was used. Sixty small fuel loading and consumption triangles (2.6 m per side) were established over each plot. The size class of all woody fuels encountered along the sides of the triangles was determined for fuels < 7 cm in diameter. The diameter of fuels > 7 cm in diameter was measured. Sampling was done before and after burning.

Pre-burn vegetation data were collected in late July of 1986, after logging, but before the site was slashburned. Post-burn data were collected in July or August of 1987, 1988, 1989, 1991, and 1996 (1, 2, 3, 5, and 10 years after burning). Estimated percent cover of each plant species in each plot was recorded in all sampling years. Mean height was recorded for shrub species and selected tall herb species. In addition, the total percent cover and mean height (all species combined) were recorded. Bryophytes are included in the total percent cover estimates. Only vascular plants are included in the total height values since bryophytes contribute little to the above-ground structure of forest vegetation.

All vascular plant species were recorded, but only the more common species of bryophytes were recorded because data collectors were not sufficiently trained to recognize rarer and less well-known species; therefore, our data probably do not adequately represent the diversity of this life-form group.

Percent cover is defined as an estimate of the actual area covered by projecting the leaves of the species onto the ground, not the area defined by the outline of the plants. This allows for differences in leaf coverage and overlap to be taken into account. Cover estimates represent the composite cover, not the sum of the individual species covers (i.e., total estimates cannot exceed 100%).

Height is considered to be the average height of a species in the plot, taking into account the proportion of the cover of individual plants with different heights. This is done by taking several measurements where there is obvious variation, and estimating the mean. For example, if 5% of the species cover is 150 cm tall, but 50% cover is only 90 cm tall, then the estimated average is much closer to 90 cm than to 150 cm.

2.2 Data Analysis

Fuel loading, fuel consumption, and depth of burn were calculated using a variation on standard methods (Trowbridge et al. 1994) developed for microplot studies (Hawkes 1986). Mean fuel consumption was calculated by averaging the fuel consumption for each of the 12 microplots in a block and calculating a block average. The overall average was the average of the five block averages. The standard error reported is the standard error of the mean based on five block means.

Forest floor moisture content of the layer corresponding to the DMC was determined by averaging the values for the seven samples taken from the 4- to 6- cm (4) and 6- to 8- cm (3) layers. The DMC estimates the moisture content of the moderately compacted F layers in boreal forests (average depth of 7 cm and oven dry weight of 5 kg/m^2) (van Wagner 1987).

Pre-disturbance vegetation data were compared to the appropriate units in the provincial Biogeoclimatic Ecosystem Classification (BEC) database, and to a draft version of the field guide update for the southeast part of the Northern Interior Forest Region (DeLong 2003) to determine the site series classification.

Mean percent cover and mean height were calculated for each species and for total vegetation on each substrate type (i.e., mineral soil and forest floor) by year. Mean percent cover was calculated as the sum of percent covers for each species, divided by the total number of plots in each substrate type. Mean height was calculated as the sum of height values for each species, divided by the number of plots in which the species occurred. Frequency of occurrence (percent presence) was calculated for each species within forest floor and mineral soil plots as:

$$\frac{(\text{number of plots in which a species occurred}) \times 100}{\text{total number of plots per substrate type}}$$

Graphs of mean percent cover and height were used to determine patterns of change over time. Selected species and total species (i.e., all species combined) in each year were examined.

Plants identified only to family or genus were not counted as separate species if members of that genus were identified to species on the site (e.g., *Poa* sp. and Poaceae were considered to be *Poa palustris* for the purpose of species counts).

3.1 Fire Weather and Fire Effects

3.1.1 Fire weather At the time of burning, the CFFWIS Codes and Indices and weather conditions (van Wagner 1987) for this site were as indicated in Table 1.

TABLE 1 *Canadian Forest Fire Weather Index System Codes and Indices and weather conditions (van Wagner 1987) for the site at the time of burning*

Code, Index, or weather condition	Value
Fine Fuel Moisture Code (FFMC)	88
Duff Moisture Code (DMC)	27
Drought Code (DC)	190
Initial Spread Index (ISI)	7
Build Up Index (BUI)	39
Fire Weather Index (FWI)	15
Days Since Rain (DSR)	3
Wind speed	12 km/hr
Temperature (dry bulb)	20.0 °C
Temperature (wet bulb)	13.0 °C
Relative humidity	47%

Measured duff moisture level (DML) on this site was 305% (SE = 23), which corresponds to an equivalent DMC (eDMC) of 30 (95% confidence limit = 27–33) when the conversion equation in Lawson et al. (1997) for Pine/White spruce–feathermoss sites in the Yukon is used to convert DML to DMC (Table 2). The DMC National Standard/British Columbia Coastal Western Hemlock (CWH) zone conversion equation (van Wagner 1987) predicted a DMC of zero. The equation developed for the Southern Interior of British Columbia (Lawson and Dalrymple 1996) did not fit our data since the moisture level at our site was higher than that recorded for any sites used to develop the Southern Interior equation (Table 2).

When the correlation between DMC and DML developed by Lawson et al. (1997) for Pine/White spruce–feathermoss sites was used, a good relationship between the DML predicted by the DMC (predicted DML) and the DML determined by gravimetric sampling (measured DML) was observed. This suggests that the forest floor characteristics (i.e., moisture holding capacity, bulk density) on the Walker site were similar to those observed on Pine/White spruce–feathermoss sites in the Yukon. The DMC National Standard/CWH conversion equation and Southern Interior of British Columbia conversion equations did not apply well to the Walker site, suggesting that the characteristics of the sites used to determine those equations are significantly different from those on the Walker site (Table 2).

TABLE 2 *Measured and predicted duff moisture level (DML) and observed and equivalent Duff Moisture Code (DMC) at the Walker Creek site using three DML/DMC conversion equations (standard error is in brackets)*

DML/DMC conversion equation	Reference	Measured[a] duff moisture level (%) n=7	Predicted duff[b] moisture level (%)	Observed[c] Duff Moisture Code (DMC)	Equivalent[d] Duff Moisture Code (eDMC)
Pine/White spruce–feathermoss, etc[e]	Lawson et al. 1997	305 (23)	360	27	30
Southern Interior of British Columbia[f]	Lawson and Dalrymple 1996	305 (23)	150	27	Below 0 (out of range of data)
DMC National Standard[g]	van Wagner 1987	305 (23)	160	27	0

a Based on measured duff moisture level (gravimetric sampling) at the Walker Creek site.
b Predicted from various conversion equations using DMC derived from weather station data.
c Calculated on the basis of on-site fire weather station data.
d Calculated from conversion equation based on measured duff moisture level (from gravimetric sampling) at the Walker Creek site.
e MC=exp[(DMC-157.3)/-24.6]+20
f MC=exp[(DMC-223.9)/-41.7]+20
g MC=exp[(DMC-244.7)/-43.4]+20

3.1.2 Fire effects Total pre-burn woody fuel loading was 85.3 tonnes/ha, and woody fuel consumption was 32%. Consumption of woody fuels less than 7 cm in diameter was 78.6% and for fuels greater than 7 cm in diameter it was 18.4% (Table 3).

TABLE 3 *Pre- and post-burn woody fuel loading (total, < 7 cm, and > 7 cm) and consumption*

Variable	Pre-burn loading (tonnes/ha)	Post-burn loading (tonnes/ha)	Consumption (%)
Total woody fuel	85.3[a]	58.0	32.0[b]
< 7 cm diameter fuel	18.8	4.1	78.6
> 7 cm diameter fuel	66.5	54.0	18.4

a Standard Deviation (SD)=28.9, Standard Error (SE)=3.5 (based on plots means), SE of mean=13 (based on block means)
b SD=7.88, SE=1.01, SE of mean=3.5

Pre-burn forest floor depth was 11.46 cm, and pre-burn litter depth was 1.54 cm. Average forest floor (LFH) consumption or depth of burn was 1.96 cm (based on all plots) or approximately 17% (Table 4).

TABLE 4 *Pre-burn LFH and litter layer depth, depth of burn and percent consumption of LFH layer*

Pre-burn LFH depth (cm)	Litter depth (cm)	Depth of burn (cm)	Consumption (%)
11.46	1.54	1.96	17.1

Although woody fuel consumption was greater than predicted, in general, the fire effects were less than predicted. Predicted duff (FH) consumption was 40–45%, which was significantly more than the measured duff consumption (17%); predicted mineral soil exposure was 20–30%, which was significantly more than measured (3%); and predicted consumption of woody fuels less than 22 cm in diameter was 25%, which was significantly less than the measured total woody fuel consumption (42%). The 95% confidence limits around the measured moisture content of 305% were 260–350%. The equivalent DMCs (eDMCs) were 26–33. There was as no difference between duff consumption predicted by the PFP on the basis of the DMC and that predicted on the basis of these eDMCs (Table 5).

TABLE 5 *Actual and predicted duff consumption, woody fuel consumption, and mineral soil exposure based on weather station–derived DMC and equivalent DMC (eDMC), which was derived from gravimetric sampling to determine duff moisture level (DML)*

	Duff consumption (%)		Mineral soil exposure (%)		Total woody fuel consumption (%)	
Method	**Predicted**[a]	**Actual**	**Predicted**	**Actual**	**Predicted**[b]	**Actual**[c]
Weather station DMC= 27	40–45[d]	17.1	20–30[e]	3	25	32
Gravimetric sampling[f] MC=305% eDMC=30	40–45[d]	17.1	20–30[e]	3	25	32
Lower 95% confidence limit MC = 260% eDMC = 26	40–45[d]	17.1	20–30[e]	3	25	32
Upper 95% confidence limit MC = 350% eDMC = 33	40–45[d]	17.1	20–30[e]	3	25	32

a Duff consumption predicted by Prescribed Fire Predictor (Muraro 1975).
b Woody fuels consumption predicted by Prescribed Fire Predictor (Muraro 1975) for fuels < 22 cm in diameter.
c Actual consumption of all woody fuels (< 7 cm and > 7 cm).
d Measured forest floor depth pre-burn was 10.2 cm; 40% consumption is based on initial forest floor depth of 5–10 cm; 45% is based on initial forest floor depth of 10–15 cm.
e Measured forest floor depth pre-burn was 10.2 cm; 30% mineral soil exposure is based on an initial forest floor depth of 5–10 cm; 20% mineral soil exposure is based on an initial forest floor depth of 10–15 cm.
f Based on average measured duff moisture level (DML) of 305% (SE = 23); equivalent DMC (eDMC) calculated using Lawson et al. 1997 relationship for Pine/White spruce–feathermoss sites in the Yukon.

The discrepancy between predicted and actual first-order fire effects likely reflects the limitations of the Prescribed Fire Predictor (Muraro 1975) on these sites, since the CFFWIS indices were consistent with that expected based on measured forest floor moisture level.

3.2 Vegetation

3.2.1 General response to prescribed burning

Species diversity Forty vascular plant species and subspecies (two trees, 11 shrubs, 27 herbs) were observed in all the plots before prescribed burning in 1986; by 1996 (year 10), 73 species (six trees, 13 shrubs, 54 herbs) were recorded. Of these, 33 were new species or subspecies (four trees, two shrubs, 27 herbs) (Table 6). Some of these were invasive species typical of early seral sites; however, many were species typical of forested stands.

Mode and timing of establishment All shrubs and almost all herbs that were present before prescribed burning resprouted after burning and most survived until year 10. Five shrub species established from buried seeds in a number of the plots: *Ribes lacustre, Ribes laxiflorum, Rubus parviflorus, Rubus idaeus,* and *Sambucus racemosa*. These species were present as parent plants on the site before prescribed burning. New herb species that are typical of early seral habitat, such as *Anaphalis margaritacea* and *Hieracium albiflorum,* appeared to have established from seed transported to the site. Some of the new species more typical of forested sites likely established by vegetative extension from sources just off the plots. Species continued to establish over the length of the study.

Dynamics A*lnus crispa, Betula papyrifera,* and *Oplopanax horridus* showed a strong trend of increasing cover and frequency of occurrence after burning, with no apparent decline by year 10. Some herbs, including *Gymnocarpium dryopteris* and *Cornus canadensis,* also showed this pattern (Table 6). These species were considered increasers.

New seed-bank germinants of *Ribes* and *Rubus* shrub species and *Sambucus racemosa* proliferated immediately after burning, which resulted in an increase in the cover and frequency of occurrence of these species. Most of the germinants died, however, so there was a decline in cover and abundance over time. *Epilobium angustifolium* and *Equisetum* species also showed an increase in cover and frequency after burning and then a decline as other species became more prevalent. These species were classified as ones that increased and then declined (Table 6).

New species included those not previously observed on the site including a number of invasive weedy species, such as *Arnica* species, *Anaphalis margaritacea,* and *Calamagrostis* species (Table 6). Most of these were thought to have established from wind-blown seed that originated off-site.

The fire-sensitive decreasers, including *Lycopodium annotinum, Moneses uniflora,* and *Listera cordata,* appeared to disappear after burning. None of these species were very common before prescribed burning. *Rubus pedatus* was also sensitive to burning and declined significantly in cover and frequency of occurrence, but, because it was previously quite common, it did not disappear from the site completely (Table 6).

TABLE 6 *Patterns of change in cover and frequency for selected species*

Increasers: Increased in cover and frequency over time

Trees and shrubs
- *Alnus crispa*
- *Betula papyrifera*
- *Oplopanax horridus*

Herbs
- *Cornus canadensis*
- *Dryopteris expansa (assimilis)*
- *Galium triflorum*
- *Gymnocarpium dryopteris*
- *Rubus pedatus*
- *Streptopus roseus*
- *Tiarella trifoliata*
- *Veratrum viride*

Increases then declines: Increased in cover and then decreased in cover; increased in frequency of occurrence

Shrubs
- *Ribes lacustre*
- *Ribes laxiflorum*
- *Rubus idaeus*
- *Rubus parviflorus*
- *Sambucus racemosa*

Herbs
- *Athyrium filix-femina*
- *Epilobium angustifolium*
- *Equisetum arvense*
- *Equisetum sylvaticum*

Decreasers: Decreased in cover after logging and burning

Herbs
- *Disporum hookeri*
- *Listera cordata*
- *Lycopodium annotinum*
- *Moneses uniflora*
- *Rubus pedatus*

New species: Established after logging and burning

Trees and shrubs
- *Betula papyrifera*
- *Populus balsamifera*
- *Ribes glandulosum*
- *Sorbus scopulina*
- *Thuja plicata*

Herbs
- *Actaea rubra*
- *Agrostis scabra*
- *Anaphalis margaritacea*
- *Arnica cordifolia*
- *Arnica latifolia*
- *Botrychium* sp.
- *Calamagrostis canadensis*
- *Calamagrostis stricta* ssp. *inexpansa*
- *Carex* sp.
- *Chrysosplenium tetrandrum*
- *Crepis* sp.

Epilobium ciliatum
Festuca occidentalis
Galium boreale
Heuchera sp.
Hieracium albiflorum
Leptarrhena pyrolifolia
Luzula parviflora
Lycopodium clavatum
Lycopodium complanatum
Mitella sp.
Osmorhiza chilensis
Petasites palmatus
Phleum alpinum
Phleum pratensis
Platanthera sp.
Poa palustris
Ranunculus sp.
Rubus pubescens
Senecio triangularis
Urtica dioica
Vahlodea atropurpurea
Valeriana sitchensis

3.2.2 Forest floor versus mineral soil plots

Species diversity In the forest floor plots, 40 vascular plant species or subspecies were recorded before prescribed burning (two trees, 11 shrubs, 27 herbs) and 69 were evident by year 10 (five trees, 13 shrubs, 51 herbs). In the mineral soil plots, there were 13 vascular species or subspecies (one tree, two shrubs, 10 herbs) before prescribed burning and 49 species or subspecies (four trees, 12 shrubs, 33 herbs) by year 10. Many of the herb and shrub species that established in the mineral plots did so in the first year after burning.

Shrubs The species composition of the shrub layer in the mineral soil and forest floor plots was very similar by year 10. Ten of the 11 shrub taxa found in the forest floor plots before burning, and both shrub taxa (*Oplopanax horridus* and *Rubus parviflorus*) recorded in the mineral soil plots before burning, survived until year 10. In the forest floor plots, *Vaccinium membranaceum* reappeared in year 2, *Salix* sp. reappeared in year 10, and *Sorbus scopulina* appeared for the first time in year 10. All of the shrubs that established from buried seeds (two *Rubus* species, two *Ribes* species, and *Sambucus racemosa*) were found in a higher percentage of the forest floor plots than in the mineral soil plots by year 10. Most shrubs that established from seeds blown onto the site after burning (e.g., *Salix, Alnus,* and *Populus*) were more common in mineral soil plots than in forest floor plots. By year 10, *Salix* sp. had seeded in to 21% of the mineral soil plots and 2.3% of the forest floor plots. *Alnus crispa* was present in 47% of the mineral soil plots and only 7.8% of the forest floor plots in year 10. *Oplopanax horridus* was more common in the forest floor plots (42% presence) than in the mineral soil plots (10% presence) by year 10.

Herbs The species composition of the herb layer in the mineral soil and forest floor plots was fairly similar by year 10. Around 80% of the pre-burn herbs were also present in all post-burn years (20 of 28 in the forest floor plots and 10 of 10 in the mineral soil plots). Two species, *Disporum hookeri* and *Moneses uniflora,* had not reappeared in any plots by year 10.

Weedy herb species were more common on the mineral soil plots by year 10 (e.g., *Anaphalis margaritacea, Taraxacum officinale,* and *Poa* sp.). Species more common on the forest floor plots included *Streptopus lanceolatus,* and *Tiarella* and *Viola* species, which are more typical of forests than of disturbed habitats.

Carex was the only species that occurred exclusively in the mineral soil plots. Even 10 years after the site was logged, several taxa found in the forest floor plots (e.g., *Disporum hookeri, Moneses uniflora, Rubus pubescens,* and *Actaea rubra*) had not been found in the mineral soil plots. The greater number of species occurring in the forest floor plots may be explained, in part, by the relatively few number of mineral soil plots (19) compared to forest floor plots (128); therefore, there was more area for species to establish in the forest floor plots.

Bryophytes Bryophytes were not recorded in the mineral soil plots until 1988. They were also severely reduced in the forest floor plots, but had started to establish by year 2. The increase in the number of bryophyte species observed over time is likely due, in part, to the more rigorous sampling done in year 10 when an expert was contracted to verify species identification.

Cover Before burning, abundance of vegetation was very low on the mineral soil plots compared to the forest floor plots (Appendix 1). Mean percent cover in the forest floor plots increased to 91% by 1996. Mineral soil plots had an average of about 87% cover by 1996; however, although the rate of increase slowed for forest floor plots after 1988, this slowdown did not occur for mineral soil plots until after 1989. Since 1991, total cover has continued to increase at the same very slow rate on both substrates. Shrubs are responsible for the continued increase in cover on the mineral soil plots, and herbs are in decline. This increase in cover on the mineral soil plots is largely due to an increase in both the presence and abundance of alder (Appendix 2), with minor increases in planted conifers and non-vascular plants. Herb cover levelled off and shrub cover declined on the forest floor plots. The increase in total cover is probably due to an increase in non-vascular plants.

In the forest floor plots, total vegetation cover exceeded pre-burn levels in the year after burning. This may have been because the pre-burn data were recorded after logging, so the values could be considerably lower, due to the presence of slash. Also, because the site is relatively rich and moist and the burn severity was low, vegetation may have been able to recover very quickly. Since most of the vegetation in the mineral soil plots was destroyed by skid road construction, it is not possible to know what the vegetation cover was in these plots prior to logging; however, it was presumably similar to that of the forest floor plots.

On the forest floor plots, post-burn shrub abundance patterns are driven largely by *Rubus parviflorus,* the most abundant shrub species in every year after burning.

Height Patterns of total vegetation height growth were different in the mineral soil versus forest floor plots, although vegetation height was very similar by 1996 (Appendix 3). The main difference was that, while height showed an initial decrease in the forest floor plots in year 1, it then increased to exceed pre-burn levels by 1996. Height on the mineral soil plots continued to increase over time.

Total vegetation height in the forest floor plots exceeded pre-burn levels by year 2 and continued to increase. As with cover, the fact that heights are greater than pre-burn values may reflect that these data were collected after logging. Alternatively, the much greater herb heights after burning (due to an increase in fireweed) may be keeping the total height values elevated beyond those for the forest understorey.

As noted already, the mineral soil plots had so little vegetation to start with that both abundance and height could only increase. By year 2, both percent cover and height on these plots had achieved the same levels as the pre-burn vegetation on the forest floor plots.

By year 10, the tallest species on forest floor and mineral soil plots were the trees, including the planted spruce trees (84 cm tall on the forest floor plots and 119 cm tall on the mineral soil plots), *Alnus crispa* (approximately 140 cm tall), and *Betula papyrifera* (200 cm tall). The tallest shrubs were *Salix* spp., *Rubus parviflorus, Vaccinium membranaceum,* and *Lonicera involucrata,* all of which were over 50 cm tall by year 10. The tallest herbs were *Epilobium angustifolium, Calamagrostis* spp., *Cinna latifolia, Poa* spp., *Phleum* spp., *Streptopus amplexifolius, Smilacina racemosa, Urtica dioica,* and *Veratrum viride*. Most of these species were over 50 cm tall by year 10, with little difference in height on the mineral soil versus the forest floor plots.

4 CONCLUSIONS

Lawson et al.'s (1997) equation for Pine/White spruce–feathermoss sites in the Yukon approximated the DMC–duff moisture level relationship found on this site better than did the British Columbia equations (Lawson and Darymple 1996). Even though DMC was fairly accurately predicted by the CFFWIS on this site, actual duff consumption and mineral soil exposure were much lower than predicted and fuel consumption was greater than predicted. These discrepancies reflect the limitations of the Prescribed Fire Predictor (Muraro 1975). Further work is needed to develop tools that predict fire effects on clearcut sites.

The fire effects were not severe and the fire did not appear to have a significant enduring effect on native vascular species composition, with most of the original species re-establishing fairly quickly. The removal of the forest floor layer by skid road construction appeared to have had a short-lived effect on the vascular species composition, and most species re-established by year 10. The vegetation on the skid roads was of comparable stature to that on the forest floor substrates by year 10. This rapid regrowth is likely due in part to the fact that this site was quite moist and rich and logged in the winter when the snow cover was deep. Therefore, soil compaction, which can significantly limit vegetation growth, was less problematic.

Vascular plant species on this site can be classified as ones that increased, increased and then declined, decreased, or were new. The major increasers were deciduous and coniferous trees, tall shrubs, and some native herbs. A number of the original shrubs and new invasive herb species increased and then declined as the tree layer became more dominant. Decreasers were predominantly shallowly rooted delicate herbs that would have been killed by fire. Most of the new species were herbs that established from seed transported onto the site. The exposure of mineral soil, primarily as a result of skid road construction, provided habitat for species not previously observed on the plots, although they may have been present nearby.

Species diversity increased over time. Many new species established the first year after the site was burned. Most of the original species resprouted after the fire. New species established from seed. Although some of the vascular species (e.g., *Moneses*) were sensitive to fire, no species completely disappeared from the site.

The species composition of the shrub layer at year 10 was quite similar to pre-burn composition. Several new herb species appeared by year 10. Species composition of the forest floor and mineral soil plots was fairly similar by year 10, as was the total vegetation cover and height.

Alexander, M.E. 1984. Prescribed fire behaviour and impact in an Eastern spruce-fir slash complex. Can. Dept. Environ., Can. For. Serv. Res. Notes 4(1):3–7.

Blackhall, J.W. and A.N.D. Auclair. 1982. Best solution models of prescribed fire impacts and fire behaviour in subalpine *Picea glauca – Abies lasiocarpa* forests of British Columbia. *In* Research in prescribed burning : a synthesis text. A.N.D. Auclair (editor). Unpublished report on file with Pacfic Forestry Centre, Victoria, B.C.

Brown, J.K., M.A. Marsden, K.C. Ryan, and E.D. Reinhardt. 1985. Predicting duff and woody fuel consumed by prescribed fire in the northern Rocky Mountains. USDA For. Serv. Res. Pap. INT-337.

DeLong, C.A. 2003. A field guide to site identification and interpretation for the southeast portion of the Prince George Forest Region, B.C. Min. For., Res. Br., Victoria, B.C. Land Manage. Handb. 51. <http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh51.htm>

Haeussler, S., D. Coates, and J. Mather. 1990. Autecological characteristics of common plants in British Columbia: a literature review. Can. For. Serv. and B.C. Min. For., Victoria, B.C. FRDA Rep. 158.

Hamilton, E.H. and H.K. Yearsley. 1988. Vegetation development after clearcutting and site preparation in the SBS Zone. Can. For. Serv. and B.C. Min. For., Victoria B.C. FRDA Rep. 018.

Hawkes, B.C. 1986. Micro-plot approach to prescribed fire effects research. *In* Prescribed burning in the midwest: state of the art. Stevens Point, Wi., pp. 45–53.

Hawkes, B.C. and B.D. Lawson. 1983. Documentation of prescribed fire behavior and effects on forest fuels. *In* Prescribed fire-forest soils symposium proceedings. R.L. Trowbridge and A. Macadam (editors). March 2–3, 1982, Smithers, B.C. B.C. Min. For. and Lands, Victoria, B.C. Land Manage. Rep. 16, pp. 93–114.

________. 1986. Prescribed fire decision-aids in B.C.: current status and future development. *In* Proceedings: Northwest Fire Council, Annual Meeting. November 18–19, 1986, Olympia, Wash. Agric. Can., Min. of State for Forestry and Mines. Pacific Forestry Centre, Victoria, B.C., pp. 1–16.

Hawkes, B.C. and S.W. Taylor. 1994. Testing large woody fuel consumption models for prescribed fires in British Columbia. *In* Proceedings 12th conference on fire and forest meteorology, October 26–28, 1993, Jekyll Island, Ga. Society of American Foresters, Bethesda, Md., pp. 461–471.

Katuski, J. 1989. Relationship between Fire Weather Index Systems codes and indices and fuel consumption during slashburns in the Sub-Boreal Spruce Zone of Central British Columbia. BSF thesis. Faculty of Forestry, Univ. of British Columbia, Vancouver, B.C.

Lawson, B.D. and G.N. Dalrymple. 1996. Ground–truthing the drought code: Field verification of overwinter recharge of forest floor moisture. Natural Resources Canada, Can. For. Serv., Pacific Forestry Centre, Victoria, B.C. FRDA Rep. 268.

Lawson, B.D., G.N. Dalrymple, and B.C. Hawkes. 1997. Predicting forest floor moisture contents from duff moisture code values. Can. For. Serv., Pacific Forestry Centre, Victoria, B.C. Tech. Transfer Note No. 6.

Lawson, B.D. and S.W. Taylor. 1986. Preliminary evaluation of prescribed fire impact relationships and predictors for spruce-balsam slash. *In* Fire Management Papers submitted to the Fire Management Symposium. Central Interior Fire Protection Committee, Prince George, B.C. pp. 48-68.

Muraro, J. 1975. Prescribed Fire Predictor. Environ. Can., Can. For. Serv., Victoria, B.C.

Trowbridge, R., B. Hawkes, A. Macadam, and J. Parminter. 1994. Field handbook for prescribed fire assessments in British Columbia: logging slash fuels. Can. For. Serv. and B.C. Min. For., Victoria, B.C. FRDA Handb. 001. Revised.

van Wagner, C. 1987. Development and structure of the Canadian Forest Fire Weather Index System. Can. For. Serv., Ottawa, Ont. For. Tech. Rep. No. 35.

APPENDIX 1

Mean percent cover of vegetation before and 1, 2, 3, 5, and 10 years after burning by species, layer, year, and substrate type (species known to have established from buried seeds are indicated in bold)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Trees												
Abies lasiocarpa						0.005	0.156					0.002
Alnus crispa ssp. *sinuata*	0.005			0.053	1.763	15.526	2.402			0.555	1.324	2.156
Betula papyrifera											0.004	0.078
Picea glauca × *engelmannii*			0.105			5.158			0.023	0.041	0.281	3.731
Populus balsamifera						0.079						
Thuja plicata												0.004
Shrubs												
Lonicera involucrata							0.016	0.039	0.094		0.313	0.313
Menziesia ferruginea						0.005	0.762	0.008	0.078	0.117	0.250	0.263
Oplopanax horridus	0.132	0.105	0.158	0.316	0.263	0.895	11.817	2.387	3.453	3.085	3.125	2.556
Ribes glandulosum						0.026						0.023
Ribes lacustre		**0.026**	0.421	0.321	0.289	0.558	0.656	**0.509**	0.723	0.650	1.117	1.224
Ribes laxiflorum		**0.274**	1.821	1.168	0.895	0.721	0.262	**2.245**	5.068	5.069	3.204	0.838
Rubus idaeus		**0.026**	0.742	3.263	4.316	4.032	0.293	**1.052**	2.000	2.912	4.111	2.417
Rubus parviflorus	0.026	**1.605**	3.926	6.526	10.474	9.211	6.617	**15.005**	17.250	16.509	20.277	12.520
Salix sp.				0.158	0.426	0.008					0.028	
Sambucus racemosa		**2.900**	7.011	3.211	1.589	1.695	0.086	**15.072**	10.705	3.679	1.500	0.484
Sorbus scopulina												0.008
Vaccinium membranaceum			0.158	0.105	0.263	0.789	0.039		0.008	0.039	0.117	0.047
Vaccinium ovalifolium		0.026				0.053	1.379	0.227	0.570	0.634	1.391	1.873
Vaccinium sp.						0.026						0.001
Herbs												
Actaea rubra									0.001		0.016	0.047
Agrostis scabra					0.026	0.058						
Agrostis sp.										0.001	0.004	0.002
Anaphalis margaritacea					0.158	1.279				0.016	0.009	0.029
Arnica cordifolia						0.026						
Arnica latifolia												0.001
Aruncus dioicus						0.053	0.352	0.547	0.781	0.829	0.645	0.578
Asteraceae					0.026	0.037				0.002		0.009
Athyrium filix-femina	0.026	0.553	0.947	1.158	2.111	3.379	5.527	6.274	7.398	6.891	9.688	9.248
Botrychium sp.									0.004	0.005		0.004

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Calamagrostis canadensis						0.005						
Calamagrostis stricta ssp. *inexpansa*												0.001
Calamagrostis sp.												0.043
Carex sp.					0.026							
Chrysosplenium tetrandrum									0.035			0.001
Cinna latifolia					1.263	0.468	0.016	0.047	0.070	0.049	0.129	0.027
Circaea alpina	0.011		0.789	0.158	0.158	0.105	0.148	0.278	0.693	0.509	0.470	0.057
Clintonia uniflora							0.008	0.004	0.008	0.016	0.547	0.156
Cornus canadensis	0.005	0.474	0.789	2.368	8.211	5.368	0.722	0.173	1.148	1.642	5.441	9.082
Crepis sp.						0.005						
Disporum hookeri							0.001					
Dryopteris expansa	0.053	0.079	0.421	0.421	0.684	1.000	3.895	0.980	1.649	1.776	2.231	4.229
Epilobium angustifolium		5.932	17.105	19.105	27.842	26.579	0.106	6.566	10.684	12.285	26.484	20.805
Epilobium ciliatum		0.453	2.895	0.758	0.795	0.063		0.942	1.844	0.513	0.209	0.004
Epilobium sp.			3.526	1.137			0.048		6.139	0.562	0.013	
Equisetum arvense	0.026	8.105	16.737	25.684	24.632	5.447	0.184	4.680	13.383	9.250	11.230	2.743
Equisetum sylvaticum		1.263	5.316	8.158	5.105	1.426	0.289	2.738	3.875	4.455	4.184	1.001
Festuca occidentalis												0.001
Galium boreale											0.001	
Galium kamtschaticum							0.012					0.009
Galium triflorum		0.053	0.053	0.268	1.374	0.447	0.053	0.172	0.699	0.401	0.967	0.259
Galium sp.											0.004	
Gymnocarpium dryopteris	0.237	0.226	0.584	1.589	5.132	11.800	10.329	3.191	6.332	6.743	16.442	28.871
Unidentified herb						0.005						
Heuchera sp.												0.008
Hieracium albiflorum						0.184						0.030
Hieracium sp.					0.032	0.058					0.001	0.015
Leptarrhena pyrolifolia						0.011						
Listera cordata							0.016			0.001		0.002
Luzula parviflora												0.001
Lycopodium annotinum						0.053	0.020				0.008	0.565
Lycopodium clavatum												0.098
Lycopodium complanatum												0.009
Lycopodium sp.						0.053						
Mitella sp.												0.016
Moneses uniflora							0.001					

	Mineral soil plots (n = 19)						**Forest floor plots (n = 128)**					
	Pre-burn	**Post-burn**					**Pre-burn**	**Post-burn**				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Osmorhiza chilensis												0.001
Petasites palmatus												0.039
Phleum alpinum												0.001
Phleum pratensis												0.001
Phleum sp.												0.001
Platanthera sp.						0.005			0.001	0.001	0.008	0.001
Poa palustris											0.009	0.086
Poa sp.						0.042						
Poaceae						0.005	0.008	0.001	0.004	0.001	0.045	0.009
Ranunculus sp.												0.001
Rubus pedatus	0.026	0.026	0.105	0.211	1.368	1.632	0.835	0.047	0.039	0.070	0.055	0.108
Rubus pubescens								0.023	0.016	0.001		0.004
Senecio triangularis												0.001
Smilacina racemos							0.008	0.047	0.109	0.102	0.094	0.047
Stellaria sp.							0.002	0.121	0.938	0.016		
Streptopus amplexifolius	0.053		0.158	0.105	0.263	0.158	0.070	0.039	0.234	0.205	0.304	0.349
Streptopus roseus	0.032	0.026	0.158	0.005	0.184	0.895	0.763	0.408	2.463	2.351	1.996	3.718
Taraxacum officinale					0.005	0.016		0.001				
Tiarella trifoliata	0.037	0.184	0.632	0.505	0.237	0.458	1.780	2.020	2.045	2.847	3.180	3.305
Tiarella unifoliata				0.158	0.263	0.326	0.509	0.922	0.775	0.909	1.162	0.903
Urtica dioica			0.053	0.111	0.032	0.111		0.025	0.059	0.085	0.157	0.027
Vahlodea atropurpurea												0.008
Valeriana sitchensis												0.001
Veratrum viride							1.941	1.227	2.008	1.914	1.793	3.055
Viola sp.					0.026	0.053	0.180	0.250	0.320	0.340	0.315	0.398
Bryophytes and Lichens												
Aulacomnium palustre				1.053		0.005				0.195		0.059
Barbilophozia lycopodioides					0.053	0.263	0.078		0.004			
Brachythecium oedipodium												0.001
Brachythecium rivulare											0.001	
Brachythecium salebrosum						1.858						0.396
Brachythecium sp.						0.505			0.176			9.805
Bryum caespiticium												0.005
Bryum pseudotriquetrum												0.001
Bryum weigelii						0.005						0.158
Bryum sp.			2.263	10.526	6.342	2.689			1.121	5.807	11.000	0.798
Ceratodon purpureus						0.016						0.020

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Cladonia carneola						0.005						
Cladonia sp.												0.001
Cratoneuron commutatum												0.001
Dicranum sp.			0.263						1.250			
Leptobryum pyriforme						0.005						0.005
Unidentified lichen												0.001
Unidentified liverwort										0.020		
Lophozia obtusa						0.016						0.002
Marchantia polifolia			1.605	2.432	4.368	2.689			1.830	2.792	4.122	1.158
Mnium glabrescens									0.156	0.016	0.016	
Mnium sp.				0.011	0.005	0.011	1.369			0.002	0.005	0.002
Unidentified moss			6.158	0.263	6.421		0.078	0.234	2.825	1.040	2.004	
Peltigera canina						0.011						0.003
Peltigera sp.												0.002
Philonotis fontana						0.005						0.001
Philonotis sp.						0.005						0.001
Plagiomnium ciliare												0.002
Plagiomnium drummondii												0.039
Plagiomnium ellipticum						0.011						0.169
Plagiomnium medium						0.005						0.003
Plagiomnium sp.						0.021						0.134
Pleurozium schreberi						0.005	0.563			0.078	0.234	0.004
Pogonatum urnigerum						2.658						
Pohlia nutans												0.001
Polytrichum commune												0.313
Polytrichum juniperinum						17.668						12.555
Polytrichum sp.			1.111	5.747	13.268		0.004		0.645	1.138	7.117	1.153
Pottiaceae												0.016
Ptilium crista-castrensis			0.158	0.005			0.281			0.008		0.002
Racomitrium sp.							0.039					
Rhizomnium gracile												0.001
Rhizomnium nudum												0.002
Rhizomnium punctatum												0.003
Rhizomnium sp.						0.005						0.004

Appendix 1 (Concluded)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	**Post-burn**					**Pre-burn**	**Post-burn**				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Rhytidiadelphus squarrosus						0.005	0.102					0.003
Rhytidiadelphus sp.												0.001
Roellia roellii						0.005						
HERBS			42	56	68	56.842			45.177	47.04	66.430	66.820
MOSSES AND LICHENS					39.842						34.902	
ROCK												0.586
SHRUBS			9.8	15.807	20	31.474			39.519	32.36	32.859	23.118
TOTAL	0.863	20.058	49.789	70.91	79.06	86.579	45.477	56.766	76.52	78.69	84.141	90.594
WATER												0.078
WOOD						0.263						3.246

APPENDIX 2

Mean percent presence of vegetation before and 1, 2, 3, 5, and 10 years after burning by species, layer, year, and substrate type (species that established from buried seeds are indicated in bold)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	1986	1987	1988	1989	1991	1996	1986	1987	1988	1989	1991	1996
Trees												
Abies lasiocarpa						5.26	0.78					1.56
Alnus crispa ssp. *sinuata*	5.26			5.26	21.05	47.37	10.16			3.13	3.13	7.81
Betula papyrifera											0.78	0.78
Picea glauca × *engelmannii*			5.26			31.58			1.56	3.91	7.03	30.47
Populus balsamifera						10.53						
Thuja plicata												0.78
Shrubs												
Lonicera involucrata							0.78	0.78	1.56		0.78	1.56
Menziesia ferruginea						5.26	6.25	0.78	0.78	0.78	1.56	6.25
Oplopanax horridus	10.53	5.26	5.26	10.53	5.26	10.53	80.47	37.50	34.38	39.84	37.50	42.19
Ribes glandulosum						5.26						1.56
Ribes lacustre		**5.26**	10.53	26.32	26.32	15.79	15.63	**34.38**	32.81	35.94	49.22	54.69
Ribes laxiflorum		**52.63**	36.84	36.84	47.37	36.84	5.47	**68.75**	65.63	70.31	74.22	55.47
Rubus idaeus		**5.26**	26.32	36 84	57.89	57.89	5.47	**41.41**	38.28	50.78	60.94	57.81
Rubus parviflorus	5.26	**42.11**	42.11	52.63	63.16	57.89	42.97	**78.13**	75.78	82.03	84.38	88.28
Salix sp.					10.53	21.05	0.78					2.34
Sambucus racemosa		**47.37**	63.16	47.37	47.37	36.84	1.56	**89.84**	87.50	71.88	60.16	39.06
Sorbus scopulina												0.78
Vaccinium membranaceum			5.26	5.26	10.53	5.26	0.78		0.78	2.34	3.91	1.56
Vaccinium ovalifolium		5.26				10.53	15.63	5.47	4.69	7.81	8.59	15.63
Vaccinium sp.						5.26						0.78
Herbs												
Actaea rubra									0.78		1.56	2.34
Agrostis scabra					5.26	10.53						
Agrostis sp.										0.78	0.78	1.56
Anaphalis margaritacea					5.26	47.37				0.78	1.56	3.91
Arnica cordifolia						5.26						
Arnica latifolia												0.78
Aruncus dioicus						5.26	1.56	1.56	1.56	3.13	3.13	6.25
Asteraceae					5.26	15.79				1.56		2.34
Athyrium filix-femina	5.26	10.53	10.53	15.79	21.05	42.11	36.72	29.69	28.91	33.59	35.16	49.22
Botrychium sp.									0.78	1.56		3.91
Calamagrostis canadensis						5.26						

Appendix 2 (Continued)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	**Post-burn**					**Pre-burn**	**Post-burn**				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Calamagrostis stricta ssp. *inexpansa*												0.78
Calamagrostis sp.												1.56
Carex sp.					5.26							
Chrysosplenium tetrandrum									2.34			0.78
Cinna latifolia					10.53	52.63	0.78	1.56	2.34	3.91	8.59	23.44
Circaea alpina	10.53		5.26	5.26	5.26	5.26	8.59	7.03	8.59	6.25	7.03	5.47
Clintonia uniflora							0.78	0.78	0.78	0.78	0.78	0.78
Cornus canadensis	5.26	15.79	10.53	10.53	15.79	21.05	23.44	14.84	15.63	20.31	22.66	37.50
Crepis sp.						5.26						
Disporum hookeri							0.78					
Dryopteris expansa	5.26	15.79	10.53	15.79	36.84	21.05	55.47	20.31	31.25	29.69	29.69	39.84
Epilobium angustifolium		63.16	57.89	89.47	100.0	100.0	3.91	85.16	87.50	96.09	99.22	100.00
Epilobium ciliatum		52.63	89.47	47.37	31.58	15.79		64.84	56.25	39.06	9.38	3.91
Epilobium sp.			21.05	52.63			3.13		55.47	42.19	3.91	
Equisetum arvense	5.26	47.37	57.89	52.63	63.16	68.42	16.41	51.56	57.81	57.03	60.16	61.72
Equisetum sylvaticum		15.79	21.05	15.79	15.79	15.79	7.81	16.41	18.75	19.53	18.75	21.09
Festuca occidentalis												0.78
Galium boreale											0.78	
Galium kamtschaticum							1.56					3.13
Galium triflorum		5.26	5.26	10.53	21.05	36.84	10.16	17.97	22.66	27.34	32.03	45.31
Galium sp.											0.78	
Gymnocarpium dryopteris	36.84	52.63	36.84	42.11	47.37	78.95	94.53	66.41	81.25	88.28	91.41	96.09
Unidentified herb						5.26						
Heuchera sp.												0.78
Hieracium albiflorum						10.53						6.25
Hieracium sp.					10.53	10.53					0.78	8.59
Leptarrhena pyrolifolia						10.53						
Listera cordata							3.91			0.78		1.56
Luzula parviflora												0.78
Lycopodium annotinum						10.53	1.56				0.78	13.28
Lycopodium clavatum												3.91
Lycopodium complanatum												1.56
Lycopodium sp.						5.26						
Mitella sp.												0.78
Moneses uniflora							0.78					
Osmorhiza chilensis												0.78

Appendix 2 (Continued)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Petasites palmatus												0.78
Phleum alpinum												0.78
Phleum pratensis												0.78
Phleum sp.												0.78
Platanthera sp.						5.26			0.78	0.78	0.78	0.78
Poa palustris											2.34	2.34
Poa sp.						21.05						
Poaceae						5.26	0.78	0.78	0.78	0.78	3.13	5.47
Ranunculus sp.												0.78
Rubus pedatus	5.26	5.26	5.26	5.26	10.53	10.53	42.19	2.34	3.13	3.91	4.69	13.28
Rubus pubescens								2.34	1.56	0.78		0.78
Senecio triangularis												0.78
Smilacina racemosa							0.78	1.56	2.34	2.34	2.34	3.13
Stellaria sp.							1.56	2.34	2.34	1.56		
Streptopus amplexifolius	5.26		5.26	5.26	5.26	10.53	8.59	6.25	7.03	12.50	16.41	21.09
Streptopus roseus	10.53	5.26	5.26	5.26	15.79	10.53	66.41	46.88	63.28	64.84	58.59	75.00
Taraxacum officinale					5.26	15.79		0.78				
Tiarella trifoliata	15.79	15.79	10.53	26.32	26.32	47.37	82.03	60.94	64.84	70.31	70.31	76.56
Tiarella unifoliata				5.26	21.05	26.32	43.75	29.69	35.16	37.50	36.72	46.09
Urtica dioica			5.26	10.53	10.53	10.53		6.25	6.25	10.16	10.16	7.03
Vahlodea atropurpurea												0.78
Valeriana sitchensis												0.78
Veratrum viride						15.79	14.06	10.94	12.50	11.72	11.72	21.88
Viola sp.					5.26	5.26	11.72	8.59	10.16	13.28	18.75	24.22
Bryophytes and Lichens												
Aulacomnium palustre				5.26		5.26				0.78		13.28
Barbilophozia lycopodioides					5.26	5.26	0.78		0.78			
Brachythecium oedipodium												0.78
Brachythecium rivulare												0.78
Brachythecium salebrosum						21.05						9.38
Brachythecium sp.						57.89			2.34			78.13
Bryum caespiticium												4.69
Bryum pseudotriquetrum												0.78
Bryum weigelii						5.26						2.34
Bryum sp.			10.53	63.16	47.37	15.79			13.28	50.78	53.91	28.13
Ceratodon purpureus						15.79						20.31
Cladonia carneola						5.26						

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
	Pre-burn	Post-burn					Pre-burn	Post-burn				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Cladonia sp.												0.78
Cratoneuron commutatum												0.78
Dicranum sp.			5.26						3.13			
Leptobryum pyriforme						5.26						2.34
Unidentified lichen												0.78
Unidentfied liverwort										2.34		
Lophozia obtusa						15.79						1.56
Marchantia polifolia			26.32	42.11	21.05	15.79			35.16	41.41	36.72	21.09
Mnium glabrescens									0.78	0.78	0.78	
Mnium sp.				10.53	5.26	10.53	32.81			2.34	1.56	2.34
Unidentified moss			36.84	5.26	31.58		1.56	0.78	38.28	15.63	17.97	
Peltigera canina						10.53						3.13
Peltigera sp.												1.56
Philonotis fontana						5.26						0.78
Philonotis sp.						5.26						0.78
Plagiomnium ciliare												2.34
Plagiomnium drummondii												0.78
Plagiomnium ellipticum						10.53						14.06
Plagiomnium medium						5.26						3.13
Plagiomnium sp.						21.05						26.56
Pleurozium schreberi						5.26	3.91			0.78	0.78	3.91
Pogonatum urnigerum						15.79						
Pohlia nutans												0.78
Polytrichum commune												0.78
Polytrichum juniperinum						63.16						59.38
Polytrichum sp.			31.58	68.42	68.42		0.78		35.16	43.75	51.56	8.59
Pottiaceae												0.78
Ptilium crista-castrensis			5.26	5.26			2.34			0.78		2.34
Racomitrium sp.							0.78					
Rhizomnium gracile												0.78
Rhizomnium nudum												2.34
Rhizomnium punctatum												3.13
Rhizomnium sp.						5.26						3.91
Rhytidiadelphus squarrosus						5.26	3.91					3.13
Rhytidiadelphus sp.												0.78
Roellia roellii						5.26						

Appendix 2 (Concluded)

	Mineral soil plots (n = 19)						**Forest floor plots (n = 128)**					
	Pre-burn	**Post-burn**					**Pre-burn**	**Post-burn**				
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
HERBS			26.32	84.21	89.47	100.0			61.72	99.22	100.00	100.00
MOSSES AND LICHENS					94.74						96.09	
ROCK												4.69
SHRUBS		26.32	78.95	89.47	100.0			61.72	99.22	100.00	99.22	
TOTAL	100.0	100.0	100.0	57.89	89.47	100.0	100.00	100.00	99.22	55.47	100.00	100.00
WATER												0.78
WOOD						5.26						21.88

APPENDIX 3

Mean height (cm) of vegetation before and 1, 2, 3, 5, and 10 years after burning by species, layer, year, and substrate type

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Trees												
Abies lasiocarpa						2	80					3
Alnus crispa ssp. *sinuata*	1			P	49	139	157			75	156	145
Betula papyrifera											70	200
Picea glauca × engelmannii			20			119			15	57	61	84
Populus balsamifera						28						
Thuja plicata												10
Shrubs												
Lonicera involucrata							25	30	73	L	85	56
Menziesia ferruginea						2	48	15	40	45	83	39
Oplopanax horridus	6	5	15	20	30	30	39	12	28	33	33	26
Ribes glandulosum						20						20
Ribes lacustre		5	11	16	16	15	31	6	12	17	22	19
Ribes laxiflorum		5	14	16	22	15	37	9	18	23	27	20
Rubus idaeus		8	19	35	31	35	39	12	31	37	31	26
Rubus parviflorus	3	10	23	39	40	50	42	21	44	51	51	33
Salix sp.					23	60	15					60
Sambucus racemosa		10	34	46	32	25	28	11	28	30	20	15
Sorbus scopulina												10
Vaccinium membranaceum			15	15	30	50	15	L	8	15	42	60
Vaccinium ovalifolium		5				8	37	14	23	39	45	40
Vaccinium sp.						3						1
Herbs												
Actaea rubra									P	L	13	18
Agrostis scabra					55	P						
Agrostis sp.										70	85	P
Anaphalis margaritacea					50	30				P	40	50
Aruncus dioicus						5	60	28	103	77	46	36
Athyrium filix-femina	40	33	53	73	55	43	55	43	69	72	75	50
Botrychium sp.									5	2	L	P
Calamagrostis canadensis						100						
Calamagrostis stricta ssp. *inexpansa*												60
Calamagrostis sp.												90
Chrysosplenium tetrandrum									7	L	L	P
Cinna latifolia					65	62	20	75	72	150	112	68
Circaea alpina	P	L	P	P	P	P	P	P	6	P	P	P
Clintonia uniflora							P	P	10	P	P	P
Cornus canadensis	P	P	P	P	P	P	P	P	7	P	18	P
Dryopteris expansa	25	12	32	27	18	30	40	23	31	30	32	32

Appendix 3 (Continued)

	Mineral soil plots (n = 19)						Forest floor plots (n = 128)					
Species	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**	**1986**	**1987**	**1988**	**1989**	**1991**	**1996**
Epilobium angustifolium		20	65	77	85	84	49	30	64	83	96	86
Epilobium ciliatum		11	29	18	39	5		70	60	22	42	8
Epilobium sp.			1	P			80	P	1	P	P	
Equisetum arvense		4	15	37	45	35			41	46	50	36
Equisetum sylvaticum			18	20	30	37			32	39	41	29
Festuca occidentalis												20
Galium triflorum		P	P	P	P	P			14	21	20	P
Gymnocarpium dryopteris	1	P	7	12	18	P	12	P	12	17	18	15
Phleum alpinum												10
Phleum pratensis												60
Phleum sp.												50
Platanthera sp.						5			50	P	90	P
Poa palustris											120	87
Poa sp.					55							
Poaceae					P	80	P	65	P	100	P	
Rubus pedatus	P	P	P	P	P	P	3	P	2	P	P	P
Rubus pubescens								P	5	P	L	P
Smilacina racemosa							P	P	63	63	62	58
Streptopus amplexifolius	P	L	P	60	50	60	32	P	50	38	51	45
Streptopus roseus	P	P	P	P	10	P	P	P	14	15	22	10
Tiarella trifoliata	1	P	P	P	P	P	P	P	6	10	15	P
Tiarella unifoliata				P	10	P	P	P	6	P	P	P
Urtica dioica			50	50	40	100		P	35	53	55	17
Veratrum viride						27	63	67	102	82	74	52
Viola sp.				P	P	P	P	6	1	P	P	
Total Herbs (average height)			39	47	61	61			50	58	52	52
Total Shrubs (average height)			14	43	31	73			45	48	39	39
Total Vegetation (average height)	4	15	43	38	63	66	40	25	50	58	68	52

P = Known to be present, however no height was recorded.
L = Likely present, but overlooked in sampling and no height recorded.