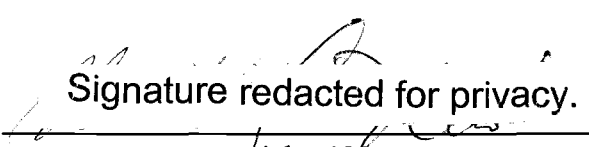


AN ABSTRACT OF THE THESIS OF

Tina V. Boucher for the degree of Master of Science in Forest Science presented on April 12, 2001. Title: Vegetation Response to Prescribed Fire in the Kenai Mountains, Alaska.

Abstract approved:  Signature redacted for privacy.

Michael Newton

The Chugach National Forest has been using prescribed fire as a wildlife habitat management tool since 1977. Between 1977 and 1997 about 4,000 hectares have been burned on the Kenai Peninsula to promote regeneration of woody plant species used by moose (*Alces alces*). Browse species include paper birch (*Betula papyrifera*), cottonwood (*Populus balsamifera* subsp. *balsamifera* and *Populus balsamifera* subsp. *trichocarpa*), aspen (*Populus tremuloides*), Scouler willow (*Salix scouleriana*), Barclay willow (*Salix barclayi*) and other tall shrub willows (*Salix* spp.). The purpose of this study was to evaluate the results of 20 years of prescribed fire in order to assess vegetation response to burning and provide managers with information on future prescribed burn planning. This analysis evaluated relationships among initial vegetation composition, physical site characteristics, browse species abundance, competitive herbaceous vegetation, and fire severity. With few exceptions, browse species increased in abundance after burning where they were present in the initial composition (measurements were made 15 to 20 years post-burn). Early successional grasses and forbs such as *Epilobium angustifolium* and *Calamagrostis canadensis* also tended to increase. Late successional species and forest associated species tended to decrease; these species include conifer seedlings, saplings, and trees (*Tsuga mertensiana* and *Picea x lutzii*), *Rubus pedatus*, *Linnaea borealis*, *Dryopteris dilatata*, and *Menziesia ferruginea*. Dwarf shrubs such as *Vaccinium uliginosum*, *V. vitis-idaea*, and *Empetrum nigrum* tended to decrease. Browse species abundance was inversely related to *C. canadensis* abundance. *C. canadensis* abundance increases with increasing depth of loamy mineral soil and increasing moisture (but *C. canadensis* does not occur abundantly on boggy sites with organic soils). Soils with deep loamy surface horizons tend to occur on depositional slopes such as fluvial valley bottoms and toe slopes. Sites with these features generally

show large increases in *C. canadensis* cover after prescribed burning, even when *C. canadensis* cover is low (3%) prior to burning. The most important pre-burn variables for predicting post-burn browse species abundance are pre-burn *C. canadensis* cover and type of surficial deposit. Site conditions that are favorable to *C. canadensis* may be problematic for successful regeneration of browse species, especially if browse species are not present in the initial composition.

Vegetation Response to Prescribed Fire in the Kenai Mountains, Alaska

by

Tina V. Boucher

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

**Presented April 12, 2001
Commencement June 2002**

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Tina V. Boucher, Author

ACKNOWLEDGEMENTS

I would like to thank Michael Newton for serving as my major advisor, providing financial support, enduring countless consulting sessions, and reviewing this manuscript. I am grateful to committee members Ted Dyrness, Jerry O. Wolff, and J. Boone Kauffman for their reviews and valuable suggestions.

The Chugach National Forest provided funding for this study. I would like to thank the staff of the Seward Ranger District for continued support and funding of this long-term study. I would particularly like to thank Susan Howell and Bill Shuster of the Seward Ranger District for their support of the prescribed fire monitoring program. I am grateful to Rob L. DeVelice and Dean Davidson of the Chugach National Forest for reviewing the manuscript and providing valuable insights and suggestions.

I would like to thank Wendy Bryden and Nathan Figley for their excellent work both in the field and office.

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VEGETATION RESPONSE TO PRESCRIBED FIRE IN THE KENAI MOUNTAINS, ALASKA

1 INTRODUCTION

Fire is the major disturbance force responsible for creating favorable moose habitat on the Kenai Peninsula, Alaska. Moose (*Alces alces*) on the Kenai depend on early seral hardwood stands for winter browse (Spencer and Halaka, 1964; Oldemeyer, 1983). Concern over declining moose habitat conditions on the Chugach National Forest resulted in efforts to enhance winter range in key areas. Winter range in the region occurs from 100 to 400 m elevation and is considered the most limiting factor for survival and vigor of the moose population (Weixelman et al., 1998). In 1977, the Chugach National Forest initiated a prescribed burning program designed to improve the condition and abundance of winter moose range. Since the initiation of the program, about 4,000 ha have been burned on the eastern portion of the Kenai Peninsula to promote the regeneration of moose browse species.

Fire in Alaska tends to improve range conditions for moose by improving the quality and availability of deciduous woody plants such as paper birch (*Betula papyrifera*), cottonwood (*Populus balsamifera* subsp. *balsamifera* and *Populus balsamifera* subsp. *trichocarpa*), aspen (*Populus tremuloides*), Scouler willow (*Salix scouleriana*), Barclay willow (*Salix barclayi*) and other tall shrub willows (*Salix* spp.) (Spencer and Halaka, 1964). There is evidence that the moose population on the Kenai has fluctuated over the past 150 years (Lutz, 1960), likely as a result of fire occurrence. Several authors have reported moose population peaks on the Kenai Peninsula associated with large burns (Chatelain, 1952; Spencer and Chatelain, 1953; LeResche et al., 1974). Widespread fires burned between 1871 and 1910 creating favorable, but transient, moose browse on the Kenai Peninsula (Spencer and Halaka, 1964). The abundance and distribution of moose and wildfire on the Kenai Peninsula prior to 1900 is not well documented, though it is likely that moose populations varied with abundance and availability of high quality habitat (Lutz, 1960). This study will not attempt to address

moose population fluctuation or fire history of the Kenai, rather it will address the effects of prescribed fire on vegetation composition and browse species abundance. Quantifying the effects of prescribed fire on vegetation will allow managers to use fire to meet habitat improvement objectives more efficiently.

The Seward Ranger District of the Chugach National Forest has an interest in evaluating the short- and long-term effects of prescribed burning and has conducted intensive vegetation monitoring in prescribed fire units since the inception of the burn program in 1977. This analysis represents the first comprehensive summary of these data. An analysis of these data will provide information regarding the interrelationships among browse abundance, site characteristics, fire severity, and competing vegetation across burned areas. This study will facilitate the development of a predictive tool for habitat management and aid in the future implementation of the prescribed burn program.

Initial progress reports suggest that, in general, browse production has increased on prescribed burn units. Some vegetation types, however, did not respond well to burning (Weixelman, 1987). A wide range of results may be achieved depending on a number of variables including initial vegetation cover and severity of burn (Viereck and Schandelmeier, 1980). Identification of factors that limit or promote browse species abundance will enable more effective prescribed burn planning and implementation. Species such as bluejoint reedgrass (*Calamagrostis canadensis*) may negatively affect the establishment and survival of desired browse species such as willow (*Salix* spp.) and birch (*Betula papyrifera*) through competitive interactions (Holsten et al. 1995, USDI Fish and Wildlife Service, 1996) and microsite modification, specifically, changes in the soil thermal regime (Cater and Chapin, 2000; Hogg and Lieffers, 1991). Seasonal date of burn and fire severity (including lighting technique and pre-burn fuel treatment) are variables that can be manipulated to achieve desired fire effects on a given site (USDI Fish and Wildlife Service, 1996). Understanding the nature of these relationships will enable managers to plan for and reduce the effects of competition and soil insulation on browse production.

The purpose of this analysis is to synthesize the results of twenty years of prescribed burning in order to provide systematic information to managers regarding the use of fire for habitat enhancement and landscape-level planning. This analysis evaluates

the relationships among initial vegetation composition, physical site characteristics, browse abundance, competitive herbaceous vegetation, and fire severity. I hypothesized that post-burn vegetation composition is strongly influenced by pre-burn vegetation composition, and vegetation response to fire is influenced by disturbance severity, abundance of *Calamagrostis canadensis*, and site characteristics such as landtype, surficial deposit, and soil depth. Development of predictive equations for post-burn browse abundance using pre-burn vegetation indicators and site characteristics will facilitate future management of vegetation and moose habitat.

1.1 Autecology of selected species

Vegetation development after fire is a result of many factors relating to the pre-burn vegetation composition and the severity of burn. Factors addressed in this review include the autecology of browse species, major competitive herbaceous species, selected site indicator species, and the effect of fire severity on vegetation. This review will summarize literature pertaining to the objectives of this study which include assessing the relationships among browse response, fire severity, competitive herbaceous species, and selected indicator species.

1.1.1 Browse species autecology

The major browse species under consideration for this study include *Populus tremuloides*, *Populus balsamifera* subsp. *balsamifera* and *Populus balsamifera* subsp. *trichocarpa*), *Betula papyrifera*, *Salix scouleriana*, *Salix barclayi*, and other tall shrub *Salix* spp. The reproductive strategy of individual browse species plays a significant role in determining their responses to fire. The ability of a species to establish and persist after disturbance determines the successional development of the stand. In general, these species regenerate most successfully in large openings under full sunlight (Collins, 1996). Each has the capacity to resprout vigorously after fire (Table 1). Additional information for each species is listed below.

Betula papyrifera seed requires mineral soil for germination, but organic matter nearby enhances seedling survival and growth (Haeussler and Coates 1986; Safford et al., 1990). The ability of birch to resprout from the trunk declines with age (Viereck and Schandelmeier; 1980). *B. papyrifera* occurs on a wide variety of site types, but grows most abundantly on upland terrain (Foster and King, 1986; Haeussler and Coates, 1986; Safford et al., 1990).

Populus tremuloides produces large quantities of light tufted seeds, though reproduction is generally through sprouts from lateral roots (Viereck and Schandelmeier, 1980). Root suckering is most successful when the entire clone is top-killed (Collins, 1996), and is strongly linked to soil temperature (Zasada and Schier, 1973), though sucker growth tends to decrease with increasing fire severity (Perala, 1974). Within the study area the distribution of *P. tremuloides* is patchy and is concentrated on warmer, south-facing slopes.

Populus balsamifera also produces large quantities of light tufted seeds and is capable of producing root suckers and sprouting from the stem. Suckering is considered the primary means of expansion, but not necessarily the primary means of recovery after disturbance (Haeussler and Coates, 1986; Krasny et al., 1988.). Fire stimulates root suckering where *P. balsamifera* is present in a stand in any successional stage (Haeussler and Coates, 1986). Zasada et al. (1981) found sucker production after logging was most common where mineral soil had been exposed. *P. balsamifera* has high nutrient requirements and displays optimal growth on deep alluvial soils (Haeussler and Coates, 1986).

Salix spp. produce large quantities of light-tufted seeds in early summer and crown sprout prolifically even when plants are mature to decadent (Viereck and Schandelmeier; 1980). Seven species of willow occurred in the study sites: *S. scouleriana*, *S. alaxensis*, *S. bebbiana*, *S. commutata*, *S. sitchensis*, *Salix barclayi*, and *Salix pulchra*. Of these seven, *S. barclayi* and *S. scouleriana* were dominant. *S. barclayi* occurs on a variety of habitats, but in the study area it can often be found in continuous thickets in moist, poorly drained sites with fine-textured soils in association with *S. pulchra* (Collette, 1996). The remaining willows sampled in the study occur across a range of habitats from moist riparian to upland, but, in general, they occur on sites that are not poorly drained

(Collette, 1996; Argus, 1973). Of the willows in the study area, *S. scouleriana* is most common on upland slope positions and often occurs in association with birch and aspen (Viereck and Little, 1972; Collette, 1996; Argus, 1973).

Betula nana and *Betula glandulosa* both occurred in the study area are used by moose, but are not preferred browse species in the study area. Since *B. nana* and *B. glandulosa* are reported to hybridize where the ranges overlap (Hulten, 1968; Viereck and Little, 1972), the two species were grouped together as *B. nana* for data analysis. In Alaska, both *B. nana* and *B. glandulosa* occur on poorly drained soils and sites underlain with permafrost (Moss, 1953; Pojar et al., 1984), but can also occur on dry, stony slopes (Viereck and Little, 1972). Both species have low nutrient requirements (Krajina, et al. 1982) and commonly occur in the understory of many black and white spruce taiga communities of Alaska and Canada (Foote, 1983; Viereck and Little, 1972). Both *B. nana* and *B. glandulosa* produce prolific seed crops, but vegetative regeneration by layering is more common. When aboveground plant parts of *B. nana* and *B. glandulosa* are killed by fire, they often sprout from the base of the stem (Parminter, J. 1983).

1.1.2 Autecology of dwarf ericaceous shrubs

Within the study area, dwarf ericaceous shrubs consistently occurred on certain site types and were taken as a group to indicate site conditions. The following dwarf and low ericaceous shrubs were encountered in the study area: *Vaccinium uliginosum*, *Vaccinium caespitosum*, *Vaccinium vitis-idaea*, and *Ledum palustre*. *Empetrum nigrum* also occurred in the study area and will be included with the ericaceous group due to its similar growth form and ecology. Taken as a group, these shrubs can be used to indicate site quality. *Vaccinium* species thrive on acid soils and can grow on relatively infertile, nitrogen-poor sites (Korcak, 1988). Subtle differences among these shrubs in rooting structure and depth may help explain why dwarf ericaceous shrubs did not always respond similarly to burning. For example, cover of *E. nigrum* and *V. uliginosum* generally decreased after burning, while cover of *V. caespitosum* generally increased.

Vaccinium uliginosum and *Empetrum nigrum* have wide ecological amplitude and occur on well drained to poorly drained sites. Both have low nutrient requirements and

are often found on cold, nitrogen-poor sites (Klinka et al., 1989; Henry et al., 1990). Both *V. uliginosum* and *E. nigrum* root in the organic layer or near the soil surface and sprout from rhizomes or rootstocks following fire (Lutz, 1956; Parminter, 1983; Viereck, 1983). Post-fire regeneration is most successful where the organic layer is not consumed (Chapin and Van Cleve, 1981). In the Wickersham Dome Fire near Fairbanks, Alaska, fire severity impacted the post-burn regeneration of these shrubs. Five severity classes were assigned to indicate the degree to which the organic layer was removed: (1) Heavily burned-deep ash layer present, organic material in the soil consumed or nearly so to mineral soil, (2) moderately burned-organic layer partially consumed, shallow ash layer present, parts of woody twigs remaining, (3) lightly burned-plants charred but original form of mosses and twigs visible, (4) scorched-moss and other plants brown or yellow but species usually identifiable, and (5) unburned-plant parts green and unchanged (Viereck et al., 1979). Severe fires tended to suppress post-burn recovery of *V. uliginosum* and *E. nigrum*. Four years after the Wickersham Dome Fire near Fairbanks, Alaska, *V. uliginosum* recovery in black spruce stands was higher in lightly burned stands than in heavily burned stands. Percent cover of *E. nigrum* was slightly less in lightly burned stands than in the control for four years following the burn, whereas, in severely burned stands, *E. nigrum* was absent for four years following the burn (Viereck and Dyrness, 1979).

Like the other dwarf huckleberries, *Vaccinium caespitosum* has low nutrient requirements (Korcak, 1988). Rhizomes are relatively shallow in the soil allowing *V. caespitosum* to survive most light to moderate fires, however, severe fires may be extremely damaging to the species (Hungerford, 1986).

Vaccinium vitis-idaea often grows on low fertility sites (Holloway, 1981). Rooting is shallow, though rhizomes may penetrate to mineral soil and plants may possess a taproot (Smith, 1962). Like *V. caespitosum*, *V. vitis-idaea* often survives light to moderate fires, but underground propagules may be killed in severe fires (Viereck and Schandelmeier, 1980). Four years after the Wickersham Dome Fire near Fairbanks, Alaska, *V. vitis-idaea* recovery in black spruce stands was higher in lightly burned stands than in heavily burned stands (Viereck and Dyrness, 1979).

1.1.3 Autecology of competitive herbaceous vegetation

Calamagrostis canadensis and *Epilobium angustifolium* are herbaceous perennials that reproduce clonally from shallow underground rhizomes. Both survive in mid-seral spruce-hardwood forests and mature spruce forests, but often increase greatly in vigor when the overstory is removed (Lieffers and Stadt, 1994).

Calamagrostis canadensis is common throughout the study area. Its range in Alaska extends from the southcentral region throughout the interior and northern regions. Throughout its range, it has been reported to occur on a variety of sites, but within the study area *C. canadensis* generally prefers moist fine-textured soils (Mueller-Dombois and Sims, 1966). Mitchell and Evans (1966) report that *C. canadensis* will readily recolonize logged-over areas in the boreal forest, reducing the occurrence of hardwood seed germination. A dense mat of *C. canadensis* may compete with tree seedlings for resources or change the thermal regime of the soil, reducing the potential for seedling establishment and growth (Cater and Chapin, 2000). Tree seedlings may also be subjected to shading and smothering effects of the grass, which often reaches heights of 1 to 2 m (Mitchell and Evans, 1966). Lieffers et al. (1993) found that where *C. canadensis* occurs abundantly prior to disturbance (i. e., in every square meter), rapid post-disturbance recolonization can be expected unless the clones are killed by a deep burn or through other site treatment. According to Sims and Mueller-Dombois (1968) most of the rhizome growth occurs within 4-5 cm of the surface of the mineral soil.

Calamagrostis canadensis is a prolific seed producer, though regeneration via underground rhizomes is the most common form of spread except in areas of severe burning (Viereck and Schandelmeier, 1980). *C. canadensis* propagates in May or June from rhizomes or seeds, which mature in late September. Conn (1990) found that buried seeds retained 9% viability after 4.7 years.

Epilobium angustifolium is an early seral species that occurs abundantly after fire, but generally becomes sparse in mature forests (Foote, 1983). *E. angustifolium* produces prolific, light seeds and can readily invade severely burned areas. Rhizomes are shallow (2 to 4 cm deep in the soil) and are often killed in fires of moderate to high intensity (Moss, 1936). On burned sites, invasion by seed is considered more common than

vegetative reproduction, although rhizomes can invade a burned area from nearby (Viereck and Schandelmeier, 1980). *E. angustifolium* litter is less persistent than that of *C. canadensis* (Hogg and Lieffers, 1991). In a comparison of soil thermal regimes under *C. canadensis* cover and *E. angustifolium* cover, warmer soils occurred under *E. angustifolium* (Hogg and Lieffers, 1991). Eis (1981) suggested that *E. angustifolium* is not as great an inhibitor of white spruce seedlings as *C. canadensis*.

Table 1. Seed, seedbed, and vegetative reproduction variables for paper birch, aspen, balsam poplar, and willow in Alaska (adapted from Zasada, 1971, Zasada, 1986, Viereck, 1973, Viereck and Schandelmeier, 1980)

* data not available for Alaska

Variable	Paper birch	Quaking aspen	Cottonwood	Scouler willow
Seed production to tree age relationship in natural stands:				
--First abundant production	15 years*	20 years*	*	Sprouts bear in 2-3 years
--Period of optimum prod.	45-100+ years	50-70 years*	*	*
Seed ripening	Maybe as early as Jul, but most commonly Aug-Sep*	June*	May or June*	end of May
Dispersal:				
--Initial	Jul-Sep*	June*	Early June*	as early as end of May
--Duration	90% by Dec	June-July*	June*	*
Seed quantity (seeds/acre)	2.2-300 million	Up to 200 million*	*	*
Seed quality (% total crop)	1-42% (average 17%)	Maybe very high (98%) viability of short duration under natural conditions*	*	*
Dispersal distance	At least 2-3 tree heights, greater distance on snow	Long distance*	Long distance*	Long distance
Periodicity of maximum seed crops	2-4 years	4-5 years*	Large quantities every year*	*
Viable seed:seedling ratio:				
--Mineral soil	20-400*	Probably many thousands*	Approaching many thousands*	*
--Organic matter	400+*	Rare*	Rare*	*
Seedbed requirements (i.e., believed most optimal under Alaska conditions)	Mineral soil*	Mineral soil*	Mineral soil*	Mineral soil
Vegetative reproduction:				
--Type	Sprouting of dormant buds	Root suckers	Root suckers	Sprouting of dormant buds
--Capacity	Common under some conditions*	Very common in fire-killed aspen stands	Common*	Common
Duration of seed viability	*	Short lived	Short lived	Short lived

1.2 Study area

1.2.1 Topography, geology, and geomorphology

The upper Kenai Peninsula can be divided into two distinct physiographic areas, the Kenai Lowlands on the western side of the Peninsula and the Kenai Mountains on the eastern side. The study area is in the Chugach National Forest portion of the Kenai Mountains excluding the eastern coastal mountains bordering Prince William Sound (Figure 1 and Figure 2). The Kenai Mountains feature rugged alpine terrain dissected by glacially carved valleys. Elevations range from sea level to 1900 m. The main geologic process involved in mountain formation is uplifting of sedimentary rock during the late Cretaceous Period. More recently, periods of glaciation have shaped the landscape. The lithology consists of meta-sedimentary rock with minor occurrences of limestone (DeVelice et al., 1999).

The general site of the study is the forested lower slopes and valley bottoms of the Kenai Mountains region. Six landtype associations (ECOMAP, 1993) have been described in the Kenai Mountains (Davidson, 1998) and are listed below in Table 2. Landtype associations are defined based upon "similarities in geomorphic process, geologic rock type, soil complexes...and plant associations" (ECOMAP, 1993). These slopes have been shaped by glaciation and depositional processes. Surficial deposits (the soil parent material) are either glacial or non-glacial. Glacial deposits include ablation till deposited on the sideslopes, hills, and valley bottoms, and glacial outwash; non-glacial deposits include alluvium and colluvium (material eroded from mountain side slopes by gravity and running water accumulating in concave lower slopes and toe slopes); inclusions of bedrock are also common. These deposits have a strong influence on the hydrology, geomorphology, and soil forming processes of the valley bottom and lower slopes, and subsequently, on vegetation development on each site. West of the Kenai Mountains, the Kenai Lowlands feature deep deposits of loess originating from floodplains of glacial streams and deposits of volcanic ash from the Aleutian Mountain

Range (Gallant et al., 1995). Ash deposits in the Kenai Mountains vary in depth and are not consistent throughout the area. Loess deposits occur sporadically.

Soils developed on glacial deposits feature unsorted gravel and cobbles in the upper profile. These soils can be well drained, but somewhat compacted water restricting layers are often present in the lower profile. Soils developed on glacial deposits generally lack a layer of deep, loamy soil in the upper horizon. Soils developed on alluvial and lower slope colluvial deposits are generally deep and have a sandy to loamy soil textures and a wide range of stoniness (Davis et al, 1980; Davidson, 1989).

Landtype, surficial deposit and soil variables for the 17 prescribed burns are listed in Table 3 and Table 4.

Table 2. Landtype associations and characteristic soils of the Kenai Mountains (Davidson, 1998).

Landtype association	Characteristic soils
Glaciers	no soil (rock and ice dominate)
Mountain Summits	shallow, coarse textured soil with moderate amounts of coarse fragments
Depositional Slopes	a. deep, well drained, medium textured soil with variable amounts of coarse fragments b. areas of fine textured soil that pond water and form wetlands
Moraines	a. glacial till featuring poorly to well drained soils with coarse fragments consisting of non-sorted gravel, cobbles, and stones in a moderate to fine textured matrix b. glacial outwash
Fluvial Valley Bottoms	a. dominated by deep, stratified soils with rounded coarse fragments b. may pond water or form wetlands on fine textured soil c. commonly have high water table
Hills	a. usually coarse to medium textured soil with 15-65% coarse fragments b. usually organic soils in basins between hills where organic material rests on glacial till or bedrock

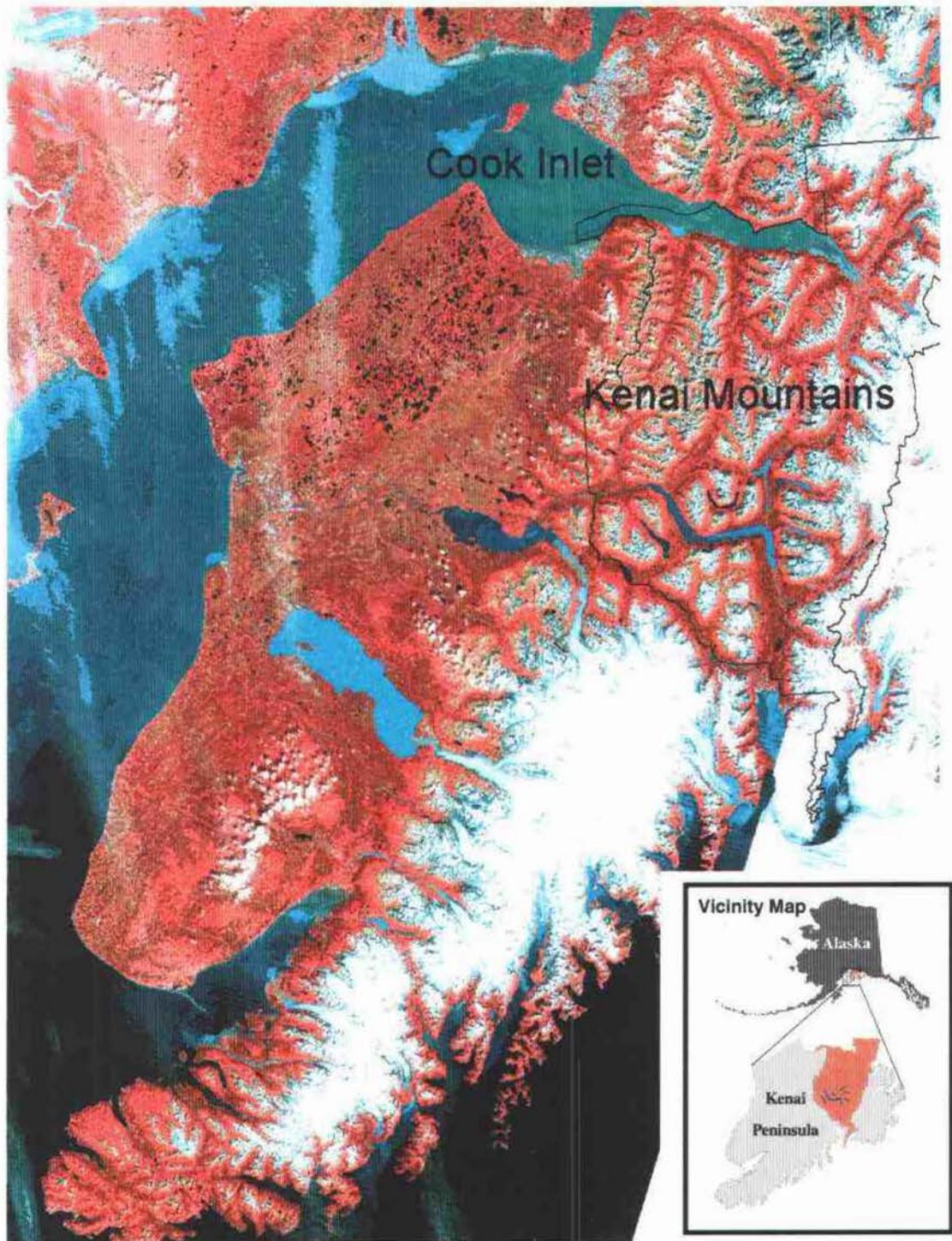


Figure 1. 1989 landsat image of the Kenai Peninsula, Alaska. The Kenai Mountains portion of the Chugach National Forest is outlined in black and highlighted in red in the inset. Coniferous (dark red) or broadleaf (red) forest occupy the valley bottoms; sideslopes are generally shrub (red) or herbaceous (pink) vegetation, and alpine summits are dominated by rock (blue), and ice and snow (white).

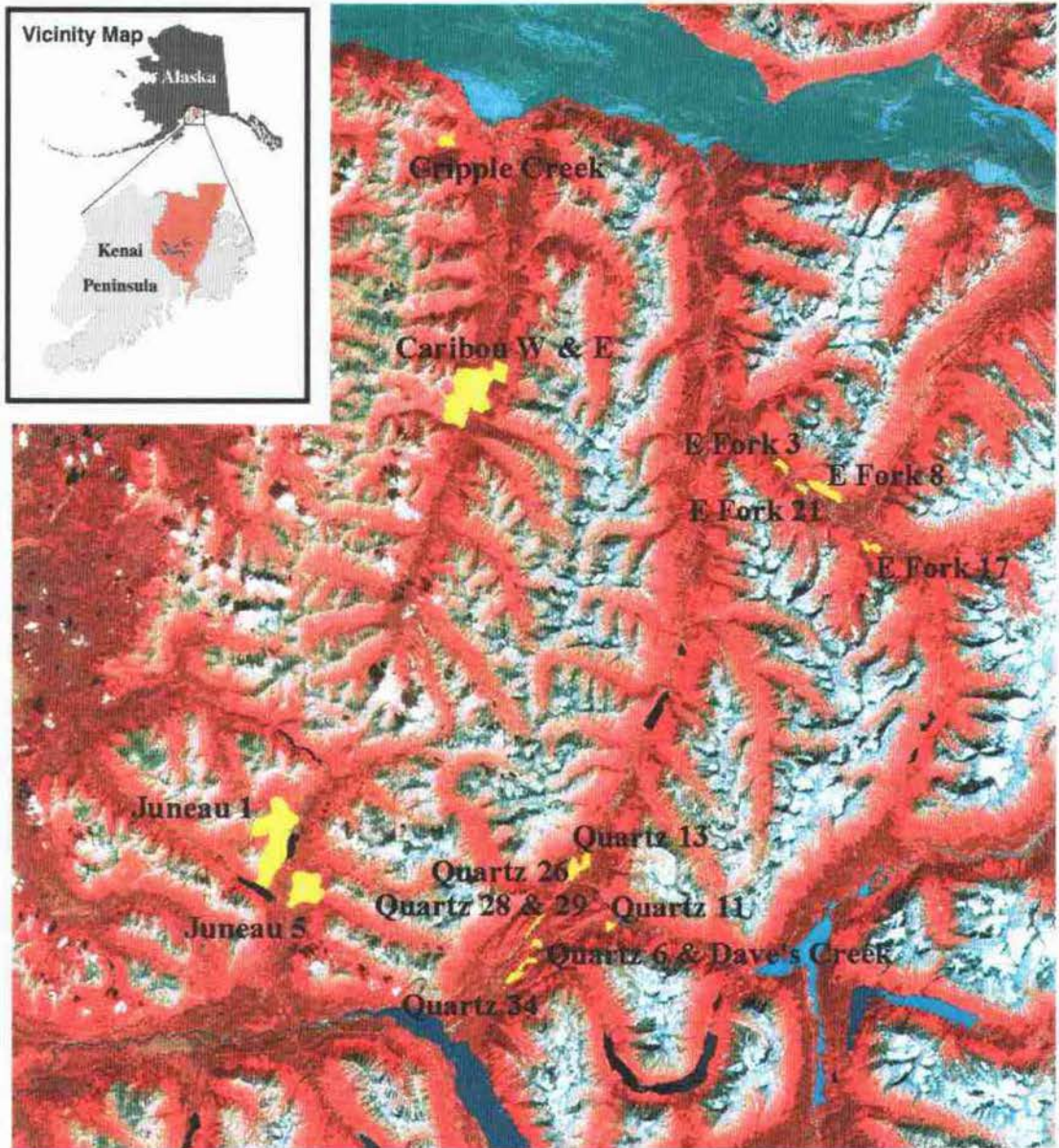


Figure 2. 1989 landsat image of the Kenai Mountains with prescribed burn study units highlighted in yellow. Inset shows Kenai Mountains portion of the Chugach National Forest highlighted in red.

Table 3. List of study sites, date of burn, size of burn, pre-burn fuel treatment, and type of ignition.

Unit Name	Abbr.	Burn Date	Hectares	Slope %	Aspect (true N)	Elevation (m)	Soil Depth (cm)	Fuel Treatment	Ignition
Quartz Creek 11	Q11	5/11/84	15	6	330	200	11	partial slash	manual
Quartz Creek 6	Q6	5/-/79	13	0	flat	200	54	full slash	manual
Juneau 1	J1	5/13/83	324	25	102	425	38	no slash	helitorch
Caribou E	CE	5/15-17/84	215	17	296	365	57	no slash	helitorch
Caribou W	CW	5/15-17/84	648	15	123	365	59	no slash	escape
Cripple Creek	CC	5/9/84	46	33	180	305	44	no slash	helitorch
Quartz Creek 29	Q29	5/9/81	24	2	200	180	32	full slash	manual
East Fork 17	EF17	8/27-28/81	41	10	324	230	21	partial slash	manual
Dave's Creek Test	DC	7/14/76	1	20	1	180	21	partial slash	manual
Quartz Creek 28	Q28	5/8/81	24	8	142	245	39	full slash	manual
Quartz Creek 13	Q13	8/2/78	36	5	280	305	18	full slash	manual
Quartz Creek 26	Q26	5/16/81	73	19	129	305	19	full slash	manual
Juneau 5	J5	5/30/82	278	3	268	395	36	no slash	helitorch
East Fork 3	EF3	8/1/78	11	0	flat	165	47	full slash	manual
East Fork 8	EF8	8/25/78	45	2	278	180	23	full slash	manual
East Fork 21	EF21	8/24/79	24	0	flat	180	10	full slash	manual
Quartz Creek 34	Q34	6/12/81	97	17	190	260	18	full slash	manual

Table 4. List of study sites, plant community type (unburned), landtype, surficial deposit, and source of surficial deposit (glacial or non-glacial).

Unit Name	Pre-Burn Plant Community Type	Landtype	Surficial deposit	Glacial/ non-glacial
Quartz Creek 11	Lutz spruce-black cottonwood / Sitka alder	Depositional slope	Alluvium	NG
Quartz Creek 6	Lutz spruce-paper birch / common horsetail	Fluvial valley bottom	Alluvium	NG
Juneau 1	Lutz spruce / barclay willow	Depositional slope	Colluvium	NG
Caribou E	Lutz spruce / Sitka alder	Depositional slope	Colluvium	NG
Caribou W	Lutz spruce-paper birch / rusty menziesia	Depositional slope	Colluvium	NG
Cripple Creek	Lutz spruce-paper birch / rusty menziesia / sparse	Mountain sideslope	Colluvium	NG
Quartz Creek 29	Quaking aspen (-Lutz spruce) / lowbush cranberry	Fluvial valley bottom	Glacial outwash	G
East Fork 17	Lutz spruce / lowbush cranberry	Hills	Glacial till	G
Dave's Creek Test	Lutz spruce-paper birch / lowbush cranberry	Hills	Glacial till	G
Quartz Creek 28	Lutz spruce (-mountain hemlock) / lowbush cranberry	Moraine	Glacial till	G
Quartz Creek 13	Lutz spruce / lowbush cranberry	Moraine	Glacial till	G
Quartz Creek 26	Mountain hemlock-paper birch / stiff clubmoss	Moraine	Glacial till	G
Juneau 5	Lutz spruce / barclay willow	Outwash plain	Glacial till	G
East Fork 3	Lutz spruce / lowbush cranberry	Outwash plain	Glacial till	G
East Fork 8	Lutz spruce / lowbush cranberry	Outwash plain	Glacial till	G
East Fork 21	Lutz spruce / lowbush cranberry	Outwash plain	Glacial till	G
Quartz Creek 34A	Lutz spruce-paper birch / lowbush cranberry	Hills	Residuum & till	G

1.2.2 Climate

The climate in the Kenai Mountains is transitional between maritime and continental. The mean annual temperature is 3.9°C at low elevations and -6.7°C at high elevations (Blanchet, 1983). Annual precipitation ranges from 500 mm to 1500 mm, with June having the lowest average monthly precipitation (DeVelice et al., 1999). Annual precipitation increases from west to east across the Kenai Mountains. In the western portion of the Kenai Mountains annual precipitation varies from 500 mm in the lowlands to 1500 mm in the mountains, while in the eastern mountains, the range is from 1000 mm in the lowlands to 2000 mm in the mountains. The coastal Kenai Mountains adjacent to Prince William Sound and Kenai Fjords can receive up to 5500 mm of precipitation per year (Blanchet, 1983).

1.2.3 Vegetation

Forests of the Kenai Mountains are fragmented by mountain ranges, ravines, and avalanche slopes. Much of the area is non-vegetated (rock and ice) in alpine zones. Tree line varies, but forests generally do not occur above 600 m. Less than 20 % of the Kenai Mountains region is forested.

Characteristic needleleaf trees in the study area include *Picea X lutzii* (Lutz spruce), a hybrid between *Picea glauca* and *Picea sitchensis* described by Viereck and Little (1986), *Tsuga mertensiana* (mountain hemlock), and *Picea mariana* (black spruce, a minor forest component). *Betula papyrifera* (paper birch) is the dominant broadleaf tree species; other common broadleaf species include *Populus balsamifera* subsp. *trichocarpa* (black cottonwood), *Populus tremuloides* (quaking aspen), and *Salix scouleriana* (Scouler willow). *Alnus crsipia* subsp. *sinuata* dominates the tall scrubland of the mountain sideslopes. Scrublands dominated by willow (particularly *Salix barclayi* and *Salix alaxensis*) are common in the valley bottoms. Undergrowth species occurring in the forest zone include *Calamagrostis canadensis* (bluejoint reedgrass), *Menziesia ferruginea*

(rusty menziesia), *Echinopanax horridum* (devil's club), *Dryopteris dilatata* (wood fern), *Vaccinium vitis-idaea* (lowbush cranberry), *Empetrum nigrum* (crowberry), *Pleurozium schreberi* (Schreber feathermoss), and *Hylecomium splendens* (splendid feathermoss).

1.3 Effect of fire on vegetation

1.3.1 Fire severity vs. fire intensity

Vegetation succession in response to fire in Alaska is related to a number of factors, including severity of burn, pre-burn vegetation composition, fuel load, weather, and season of burn. These factors interact to create fires of different intensities and severities. Fire intensity refers to rate of energy released per unit area per unit time (Viereck and Schandelmeier, 1980; Romme, 1980; Van Wagner, 1983) and fire severity refers to "the effect of the fire on the ecosystem, whether it affects the forest floor, tree canopy, or some other part of the ecosystem" (Viereck and Schandelmeier, 1980). Fire severity can be an important factor in determining post-burn successional pathways. A severe burn that removes most of the organic layer is likely to also kill most of the underground reproductive parts of resprouting vegetation as well as seeds buried in the soil. The mineral soil, however, provides an ideal seedbed for most of the species that arrive by seed. A light burn that leaves the organic layer intact will favor those species that reproduce from rhizomes, crown sprouts, or root sprouts (Viereck and Schandelmeier 1980). Dyrness and Norum (1983) found that a light burn in black spruce forests favored recolonization by *Calamagrostis canadensis*, while a severe burn favored recolonization by *Epilobium angustifolium*.

1.3.2 Soil temperature

The depth of the forest floor organic layer, which includes moss, litter, and the organic soil horizons, influences soil temperature and site productivity. Fire can reduce or remove the organic layer, reducing the insulating properties of the forest floor,

increasing soil temperatures and changing the soil thermal regime (Brown, 1983). Increased soil temperatures are directly related to the amount of reduction in depth of the organic layer (Vioreck et al., 1979; Vioreck and Dyrness, 1979; Dyrness, 1982; Vioreck, 1982).

1.3.3 Vegetation succession and fire regime

In boreal forests, tree establishment generally occurs in the first few years after fire (Vioreck, 1973). Therefore, factors affecting tree regeneration could have a long-term effect on forest succession. Foote (1983) and Payette (1992) describe post-fire forest succession in boreal forests as generally returning to the pre-disturbance forest cover type, thus, white spruce forests, after fire, generally return to white spruce in the absence of additional disturbance, but the rate of change and species composition can vary (Foote, 1983; Payette, 1992). Post-fire vegetation succession depends on a number of factors including initial vegetation state, fire severity, and post-fire conditions such as (1) presence of seeds and resprouting buds, (2) seedbed quality, and (3) climate and weather conditions (Foote, 1983). A generalized post-fire successional model to mature forest for spruce stands in interior Alaska would likely pass through the following stages (1) moss-herb stage with seedlings of woody species (if seeds are available and seedbed conditions are favorable for establishment) immediately following disturbance, (2) tall shrub-sapling stage, assuming sprouts and/or seeds are available and seedbed conditions are favorable, (3) dense tree stage (either hardwoods or conifers), if hardwoods are present the stand passes into (4) hardwood stage, if no hardwoods are present the stand progresses to (5) spruce stage. In forests of interior Alaska, the age of mature spruce trees is generally less than 300 yrs. A divergent or delayed successional pathway may be caused by several conditions: catastrophic fire events, fire events that are not sufficiently severe to create a mineral seedbed, or recurrent fire events that change the rate or pathway of forest development (Payette, 1992). For example, if seedlings and shrubs are not established due to lack of seeds or suitable seedbed, the herbaceous phase may dominate for an extended period of time. Herbivory is an additional factor that impacts the successional

sequence and rate of vegetation composition change, selectively reducing or eliminating certain species (Foote, 1983).

Though fire is considered an important disturbance force in boreal forests, few fire history studies have been completed in Alaska (Yarie, 19881; Gabriel and Tande 1983; Viereck and Schandelmeier, 1980; De Volder, 1999; Gracz, 199?). Reconstructing fire history is impeded by lack of long-term historical records and lack of fire scarring on boreal tree species. The goal of many fire history studies is to produce an estimate of the fire interval (the number of years between two successive fire events in a given area) and/or fire cycle (the average stand age of a forest whose age distribution fits a mathematical distribution) (Agee, 1993; Romme 1980). In the Porcupine River drainage in interior Alaska, Yarie (1981) described a fire cycle and fire return interval of 105 and 113 years, respectively for *Picea glauca*; and 36 and 43 years, respectively for *Picea mariana*. De Volder (1999) described a fire cycle for lowland *Picea mariana* on the Kenai National Wildlife Refuge (KNWR), which borders the Chugach National Forest to the west, between 42 and 56 years. An increase in fires was noted after 1828 coincident with European settlement of the Kenai. Given the rarity of lightning on the Kenai Peninsula, European settlement likely lead to increased human ignition and a more frequent fire cycle and return interval.

Gracz et al. (1995) conducted a fire history study *Picea glauca* forests of the KNWR. In this study, one fire with an approximate burn date of 1883, accounted for most of the area burned. The mean age of oldest spruce trees in the remaining area was 234 years. The dominance of a single fire within the historic time frame of the study suggests that 234 years is too brief a period in which to determine a fire return interval for *Picea glauca* forests of KNWR. Both De Volder (1999) and Gracz et al. (1995) suggest that current fire regimes on the Kenai Peninsula are influenced by human ignitions and fluctuating climatic conditions.

The Chugach National Forest portion of the Kenai Mountains is more strongly influenced by the maritime climate of Prince William Sound and Kenai Fjords than the forests of KNWR, resulting in cooler mean summer temperatures and higher precipitation. The fragmented nature of the forests of the Kenai Mountains potentially limits the spread of fire. The combination of these factors would likely result in a fire

return interval on the Chugach National Forest portion of the Kenai Peninsula longer than that of the KNWR. Prior to European settlement, forests were predominantly in late successional stages (Languille, 1904; Holbrook, 1924). Anthropogenic fires associated with mining and railroad activity burned over 30,000 ha on the National Forest from 1914 to 1997 (Potkin, 1997). Prior to European settlement, it is likely that fires were less frequent. Charcoal buried in the soil profile of these forests has been dated between 500 and 3,000 years (Potkin, 1997), indicating that fire played a role in forest development during this time. Charcoal found at the surface of the mineral soil, below the organic layer was not dated, but suggests that many of these forests burned at some time and may have originated after fire. Although it is clear that forest development has been influenced by fire, there is insufficient information to propose a fire return interval for *Picea lutzii* forests of the Kenai Mountains.

1.4 Related studies

The response of browse species and competitive vegetation to fire on the Kenai Peninsula has not been well documented. A study addressing the effects of fire and bark beetles on vegetation was conducted within the study area (within the Caribou West prescribed burn) between 1980 and 1996 (Holsten et al., 1995; Schulz, 2000). The 1984 prescribed fire burned about half of the study plots. Cover of *Calamagrostis canadensis* was high prior to burning, and the organic layer remained intact after burning with no mineral soil exposed. Seven years after the burn, it was found that *C. canadensis* and *Epilobium angustifolium* increased significantly in the beetle impacted stands in both the burned and unburned plots. By the 1996 reading, birch seedlings were more common in the burned plots than in the unburned plots, however, spruce seedlings were more common in the unburned plots. Twelve years after the burn *C. canadensis* levels had fallen since the previous reading, possibly indicating a loss of vigor due to the reported self-limiting nature of the species (Lieffers et al., 1993).

From 1974 to 1981 a study was conducted on the Kenai National Wildlife Refuge (west of the study area in the Kenai Lowlands region) addressing the effects of fire and management practices on browse production (Oldemeyer and Regelin, 1987). They

compared browse response to disturbance on different soil types and found that different browse species were associated with different soil conditions. In general, loamy soils on rolling terrain produced the greatest density of willow browse. The highest density of birch browse occurred hilly to steep loamy soils. Aspen dominated stands occurred on moraines on gravelly soils; however, browse density was only 57% of that on the loamy soils (Oldemeyer and Regelin, 1987). Loamy soils were clearly more productive than glacial moraine and glacial outwash soils. Competition from *Calamagrostis canadensis* was not reported to have interfered with woody regeneration within the lowlands study area. Topography and soil development of the Kenai Lowlands differs from the Kenai Mountains region. The Kenai Lowlands features rolling to flat terrain with glacial and alluvial surficial deposits overlain by a mantle of loess (Oldemeyer and Regelin, 1987). The Kenai Mountains region features a wide range of landtypes from mountain slopes to valley bottoms and generally lacks the loess mantle found on the lowlands. Productive sites featuring deep loamy soils are restricted to landtypes associated with alluvial deposits and toe slopes of mountain landtypes.

To summarize, browse species in the study area are adapted to fire and have the ability to reproduce vegetatively by resprouting or root suckering. All are also prolific seed producers that have the ability to disperse seed over a great distance. Severity of disturbance to the forest floor impacts browse establishment and vegetation succession by affecting seedbed, buried seed, and vegetative propagules. *Calamagrostis canadensis* and *Epilobium angustifolium* are also effective colonizers of disturbed sites, either by seed or by vegetative means. This analysis will evaluate the relationships between pre-burn vegetation composition and post-burn browse abundance. The influence of competitive vegetation (*C. canadensis*), fire severity, landtype, surficial deposit, and soil conditions on browse abundance and vegetation development will be assessed. It is hypothesized that pre-burn species composition and site characteristics can be used to estimate post-burn species composition and browse production. It is further hypothesized that pre-burn browse abundance can be used to predict post-burn browse abundance, given fire severity and abundance of *C. canadensis*. It is proposed that increased fire severity is associated with increased mineral seedbed, increased browse species recruitment, and decreased post-burn *C. canadensis* abundance.

Establishing relationships among pre- and post-burn browse production, vegetation composition, physical site characteristics, and fire severity will facilitate the development of management guidelines allowing estimation of browse species response to fire and designating criteria for site selection, season of burn, and severity of burn.

2 METHODS

2.1 Selection of study units

At each burn site, permanent transects (300 m long) were established by vegetation type in burned and unburned areas of similar pre-burn species composition and density. Pre-burn data from permanent transects were used where the transect had been established prior to burning. Vegetation types were mapped on aerial photographs prior to burning, and transects were placed within types which represented the target winter range for moose. Transect location was random within vegetation types, however, in most cases, the 300-m transect had to be broken up to fit within the vegetation type.

In order for a burn to be selected for this study, the target vegetation must have burned. A sample size of 17 burns remained after several burns were eliminated from consideration due to lack of evidence of fire in the target vegetation.

2.2 Field methods

The purpose of vegetation sampling was to characterize burned and unburned vegetation composition and site characteristics in order to compare vegetation development after burning across various vegetation and site types and burn severities. Data were collected along permanent 300 m long transects with 30 sampling points at 10 m intervals (Figure 3). At each sampling point, a nested design of a 1 m X 1 m plot within a 1 m X 5 m plot was used to estimate cover of herbaceous and woody vegetation. Within the 1 m X 1 m plot, percent cover was estimated by species for all herbs and dwarf shrubs. Within the 1 m X 5 m plot, percent cover was estimated for all shrubs and tree seedlings and saplings; additionally, height and number of stems were recorded for browse species, tree seedlings and saplings. Tree density, cover, and height were collected by species at four fixed-radius plots along the transect. Fixed radius plots were positioned along the transect so that plots would not overlap in units where the transect had to be split to fit within the vegetation type (see Figure 3). Radius length was

determined by tree cover and stand homogeneity; three sizes were used: small plots (8.9 m radius, 0.025 ha) were used in homogeneous stands with tree cover > 40 %, medium plots (12.6 m radius, 0.05 ha) were used where tree cover was 10 % - 40 %, and large plots (17.8 m radius, 0.1 ha) were used where tree cover was sparse (< 10 % cover). Radius length was selected based on the entire transect area and remained constant for each of the 4 plots per transect.

Soil depth was measured at each of the thirty points with a 0.5-inch diameter soil probe. The probe was able to penetrate loamy and sandy soils, but not loamy-skeletal, sandy-skeletal, or fragmental soils. This measurement provided an estimate of the depth of loamy soil or sandy soil. These particle size classes are defined by the Soil Survey Staff (1992) as follows: loamy—in the fine earth fraction, a texture of loamy very fine sand, very fine sand, or finer, including less than 35 percent (by volume) rock fragments; sandy—in the fine earth fraction, a texture of sand or loamy sand, including less than 35 percent rock fragments; loamy skeletal—35 percent or more rock fragments with a texture of loamy very fine sand, very fine sand, or finer; sandy skeletal—35 percent or more rock fragments with a texture of sand or loamy sand; fragmental—90 percent or more rock fragments.

Fire severity indices were developed for each transect based on fire effects data, photographs, and narratives recorded the year of the burn. Burn severity information included always included photographs and written descriptions, and often included pre- and post-burn fuel loadings and measurements of reduction of the organic layer. Sites that had all of the above severity information collected were used to calibrate the photographs for those sites with less complete information. Four severity classes were developed to characterize degree of disturbance to the forest floor (1) heavily burned—deep ash layer present, organic layer consumed or nearly so to mineral soil, mostly gray ash (2) moderately burned—organic layer partially consumed, ash layer mostly black, parts of woody twigs remaining, (3) lightly burned—plants charred or scorched, but original form of ground cover still discernable, and (4) unburned (adapted from Viereck et al., 1979).

Percent cover, stems, and soil depth were averaged by transect. Averages by transect were used for analysis. Site characteristics were recorded by transect.

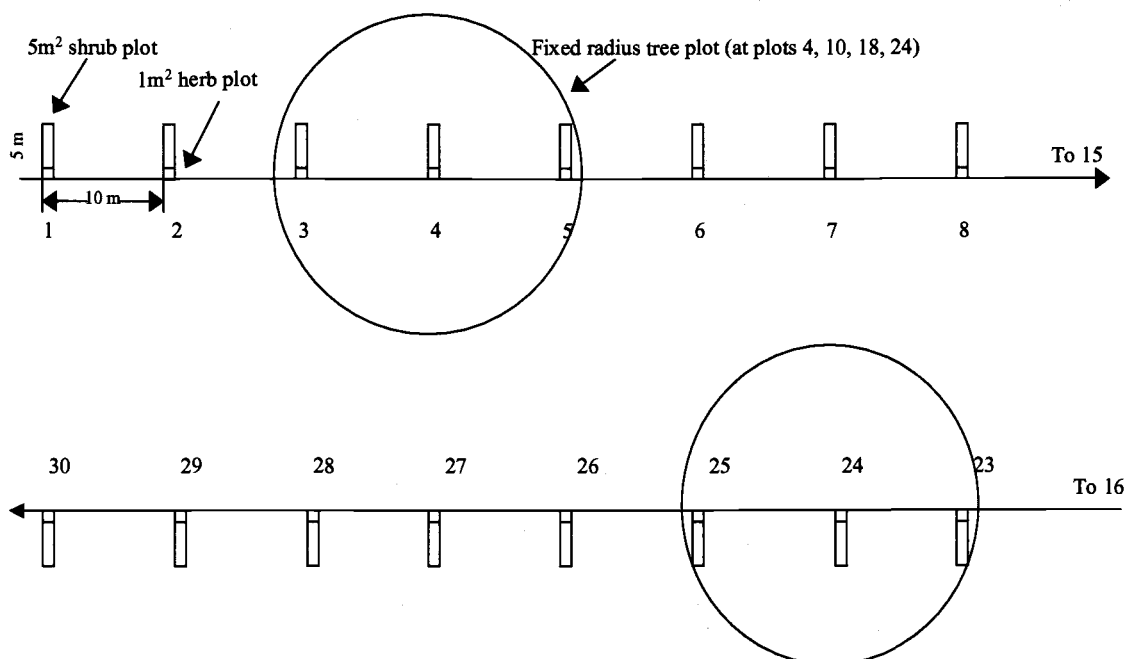


Figure 3. Burn monitoring transect diagram.

The source of the unburned plot data was either a pre-burn transect within the burn unit or a control transect adjacent to the unit. Controls were selected based on similarity of vegetation, slope, aspect, and landtype. Many of the pre-established controls were rejected due to non-conformity with the selection criteria; in these cases, controls were re-established in a type more similar to the burn transect, and control data were collected 15-20 years after burning. Pre-burn aerial photography, site visits, pre-burn vegetation descriptions and photographs were used to determine whether site conditions at the control adequately represented site conditions at the burn transect site. Table 14 in Appendix 3 summarizes the sources of unburned transect data. Since some control data were collected 15-20 years after burning, a comparison was made between controls read near the date of burn and controls read 15-20 years after the date of burn to evaluate forest change in the 15-20 years after burning. On six sites, controls were read near the date of burn (within five years); on two of these, sites controls were also read 15-20 years post-burn. These two sites were used to evaluate change in the control stands since the date of burn. A summary of this comparison is described in Appendix 3. Based on

Figure 14 in Appendix 3 (an ordination of all plots including the two plots that were read near the time of burn and 15-20 years after burning), it can be concluded that the controls read 15-20 years after burning provide an adequate representation of the forest condition at the time of burn.

2.3 Data preparation and analysis

Indirect gradient analysis using ordination was selected as a means of interpreting patterns in the data since it is a useful tool when the underlying factors are thought to vary continuously (McCune, 1999). Ordination allows the number of variables to be reduced to a few synthetic variables that can be represented as axes, in order to assess relationships among sample units. Axes represent ordination gradients, and can be related to measurable environmental variables. Indirect gradient analysis was used to position sample units according to association among species (sample units in species space). Sample unit positions in the ordination are determined by calculating the distance among them in a multi-dimensional space. Ordination allows the analyst to select among multiple factors and separate strong from weak patterns. Unforeseen patterns or processes are often revealed.

Plant community data are generally not well suited to analysis methods that rely on assumptions of normal distributions. In a typical plant community data matrix, there are many zero values; the matrix is said to be sparse—the more heterogeneous the data, the more sparse the matrix. Abundance values along a species response curve are expressed as positive values. Once a species becomes absent, the value is zero; a zero value gives no information about how unfavorable the environment is for a given species, and many methods of assessing distance among sample units (such as correlation and chi-squared distance) recognize shared zeros as a positive relationship. This causes significant distortion in the ordination gradient. Opposite ends of a gradient appear to have a positive relationship due to shared zeros and the ends of the gradient are drawn toward each other, resulting in a horse shoe-shaped curve.

Nonmetric Multidimensional Scaling (NMS; Mather 1976 and Kruskal 1964) is a nonparametric technique that avoids assumptions of normality and linear relationships

among variables. NMS using Sorensen similarity as a distance measure was used to ordinate sample units in species space and to assess the dimensionality of the data set. A Monte Carlo test was used to test whether the final three-dimensional solution was better than would be expected by chance.

NMS was selected as the most appropriate ordination technique due to its suitability for community data and its proven performance with heterogeneous samples (Minchin, 1987). Since species scores are based on ranked distances, distortions associated with community heterogeneity are relieved. PCORD version 4.28 (McCune and Mefford, 1999) was used for all multivariate analyses.

Data were arranged in two matrices, a matrix of species abundance and a matrix of site characteristics. The matrix of species abundance contains 14 sample units (seven paired plots; rows) and 129 species (columns). As displayed in Table 5, the average coefficient of variation (CV) was high in the raw species abundance data. Species data were relativized by species maxima, reducing the CV to an acceptable level. Relativization by species maximum equalizes the weight given to common and uncommon species (McCune and Mefford, 1999):

$$b_{ij} = x_{ij}/x_{\max_j}$$

where rows (i) are samples and columns (j) are species, x_{\max_j} is the largest value in the matrix for species j . Rare species, those that occurred in only one sample unit, were deleted, reducing the number of species from 129 to 104, lowering both the CV and beta diversity (the amount of compositional variation in a sample).

Table 5. Effect of data transformations on the coefficient of variation and beta diversity.

	Raw	Relativized by spp max	Relativized and reduced
Rows (sample units)			
Beta diversity	2.8	2.8	2.3
CV of sums*	35.53	31.37	29.25
Columns (species)			
CV of sums	203.81	52.59	47.2

*CV = Coefficient of variation = 100*standard deviation/mean

The second matrix contains site characteristics (quantitative and categorical) for 34 sample units. Variables include slope (percent), solar insolation (Urban, 1990), elevation, treatment (burned vs. unburned), landtype, surficial deposit, soil depth, burn severity, season of burn, and time since burn. The following combined vegetation variables were also included in the second matrix: total browse species cover, combined seedling and sapling cover for browse trees, and combined ericaceous shrub cover.

Two methods were used to interpret the ordination axes: (1) Correlation of environmental variables and species to ordination axes and (2) overlays of species and site variables on ordination points (sample units). Correlation coefficients between variables (species abundance or size of environmental variable) and sample unit position along ordination axes express the linear relationship of a variable with the ordination axis. Overlays can be used to assess whether a variable is patterned on an ordination. Each point on the ordination is replaced with a symbol whose size represents abundance of the variable (for continuous variables) or a symbol or color (for categorical variables). Overlays provide a more flexible means of examining the relationship of variables to the ordination than correlation coefficients since patterns are not limited to linear relationships.

The SAS System (version 8) was used to develop regression equations to model post-burn browse species abundance. A suite of candidate models was identified prior to analysis, including a global model consisting of all variables considered influential in estimating post-burn browse abundance. Akaike's Information Criterion (AIC)

(Burnham and Anderson, 1998) was used to evaluate candidate models and provide a measure of the discrepancy of fit between the data and the model in question. Additional factors such as overall fit of the model, variance explained, and p-values of parameters were considered in selecting the final models.

3 RESULTS

3.1 Species responses

Several species show consistent trends across all prescribed burns in the study area (Figure 4). However, the amount of increase or decrease in abundance varies widely depending on initial vegetation and site factors such as landtype, hydrology, surficial deposit, soil depth, and severity of burn.

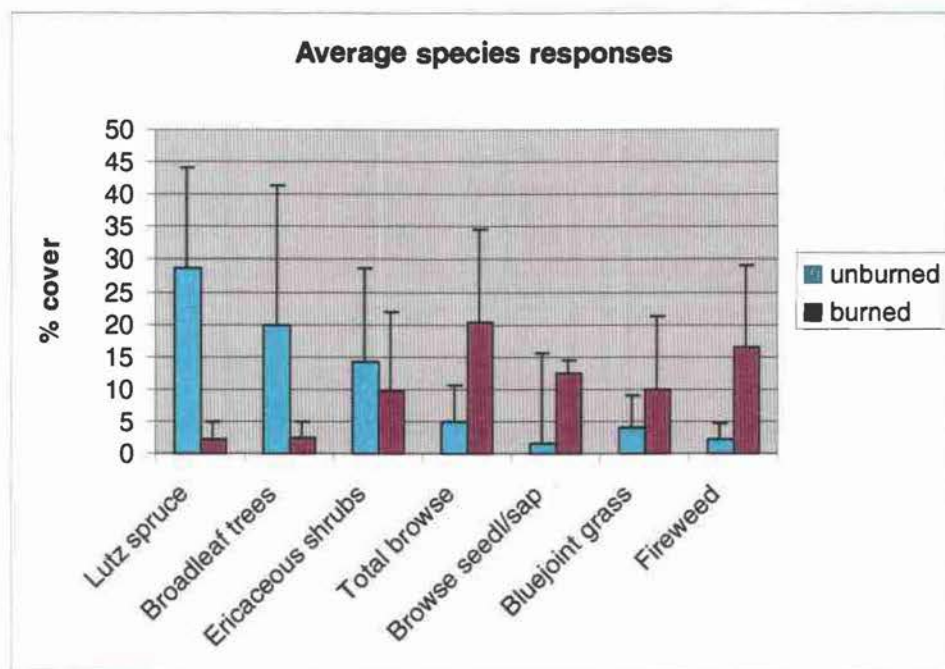


Figure 4. Average cover and standard error of selected species in burned and unburned plots across all burns (n=17). “Ericaceous shrubs” include *Vaccinium uliginosum*, *Vaccinium caespitosum*, *Vaccinium vitis-idaea*, *Ledum palustre*, and *Empetrum nigrum*. “Total browse” includes shrub willows as well as seedlings and saplings of browse trees.

After burning, browse species such as *Salix barclayi*, *Salix sitchensis*, and *Betula papyrifera* seedlings and saplings tended to increase where they were present in the initial composition. Early successional forbs and grasses such as *Epilobium angustifolium*,

Equisetum arvense, and *Calamagrostis canadensis* also tended to increase. Late successional and forest associated species tended to decrease; these species include conifer seedlings, saplings, and trees (*Tsuga mertensiana* and *Picea lutzii*), *Rubus pedatus*, *Linnaea borealis*, *Dryopteris dilatata*, and *Menziesia ferruginea*. Dwarf shrubs such as *Vaccinium uliginosum*, *Vaccinium vitis-idaea*, and *Empetrum nigrum* tended to decrease after burning. Selected species responses by site are listed in Table 6 (a full table of species responses is given in Appendix 2).

In general, browse species abundance after burning increased, but variation in browse species response was high among sites. Patterns of species responses can be explained using gradient analysis to compare pre-burn vegetation composition to post-burn vegetation composition and evaluate site conditions and fire severity.

Table 6. Change in percent cover values in burned and unburned transects (burned minus unburned) for selected species by site (column). Site names are cross-referenced with abbreviations in Table 3. Full list of species responses, including pre- and post-burn percent cover, in Appendix 2.

	CW	CE	Q11	J1	Q6	Q29	Q28	Q26	Q13	Q34	EF17	DC	EF8	EF21	EF3	J5	CC	AVE
Ferns and Fern Allies																		
<i>Atherium filix-femina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0
<i>Dryopteris dilatata</i>	-35	-31	0	-3	0	0	0	0	0	0	0	0	0	0	0	0	0	-4
<i>Equisetum arvense</i>	34	-9	1	25	-22	-2	0	9	0	0	0	0	0	0	0	-2	11	3
<i>Equisetum pratense</i>	1	0	5	1	-3	-1	0	1	0	0	0	0	3	0	0	0	0	0
<i>Equisetum silvaticum</i>	0	18	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	-1	1
<i>Gymnocarpium dryopteris</i>	7	14	-3	-7	-21	-5	0	13	0	0	3	0	0	1	0	0	3	0
<i>Lycopodium annotinum</i>	-6	-9	-4	0	0	-1	-1	-14	-1	0	-2	-3	0	0	0	0	-5	-3
<i>Lycopodium clavatum</i>	0	0	0	0	0	0	0	0	0	0	-1	0	0	-1	-1	0	0	0
<i>Lycopodium complanatum</i>	0	0	0	0	0	0	0	0	-5	-3	-4	0	0	1	0	0	-1	-1
Forbs																		
<i>Cornus canadensis</i>	-3	-2	1	-5	-3	-8	7	-3	4	-4	-13	26	-5	-3	-1	0	13	0
<i>Epilobium angustifolium</i>	25	29	44	11	31	6	15	23	12	3	3	3	8	3	6	-1	22	14
<i>Geocaulon lividum</i>	0	0	-1	1	0	0	2	-4	-1	3	-1	-6	-4	-6	0	0	0	-1
<i>Lupinus nootkatensis</i>	0	0	0	0	0	0	2	1	1	5	2	0	0	0	0	0	0	1
<i>Rubus arcticus</i>	0	-15	0	0	3	1	0	0	0	0	0	0	2	1	-4	-4	0	-1
<i>Rubus chaemorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0
<i>Rubus pedatus</i>	-13	0	-6	0	0	0	-1	-5	0	0	-1	-3	0	0	0	0	0	-2
Graminoids																		
<i>Calamagrostis canadensis</i>	16	26	9	3	11	7	5	7	4	0	1	1	0	2	2	0	8	6
<i>Festuca altaica</i>	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	7	9	0	1
Shrubs																		
<i>Alnus crispa sinuata</i>	6	-8	-37	7	-1	0	7	0	0	2	0	0	0	0	0	0	-1	-1
<i>Betula nana</i>	0	0	0	1	0	0	0	0	4	0	7	0	-4	3	10	6	0	2
<i>Echinopanax horridum</i>	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	0
<i>Empetrum nigrum</i>	0	0	-2	1	0	0	-14	-3	-8	-8	9	6	-32	-9	-11	0	0	-4
<i>Ledum palustre</i>	0	0	0	1	0	0	-8	0	0	0	0	1	0	-1	0	0	0	0
<i>Linnaea borealis</i>	-7	-4	-3	-1	0	-1	-2	-4	-3	-2	-1	0	0	-1	0	0	0	-2

Table 6, Continued.

	CW	CE	Q11	J1	Q6	Q29	Q28	Q26	Q13	Q34	EF17	DC	EF8	EF21	EF3	J5	CC	AVE
<i>Menziesia ferruginea</i>	-21	-12	0	0	0	0	5	0	0	0	0	-6	0	0	0	0	-6	-2
<i>Ribes sp.</i>	-7	0	-19	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	-2
<i>Rosa acicularis</i>	0	-1	-18	8	-4	1	0	0	0	0	0	0	0	0	0	0	1	-1
<i>Rubus idaeus</i>	-1	-2	3	2	4	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix barclayi</i>	1	0	-3	23	11	1	0	2	0	0	3	0	3	3	10	11	0	4
<i>Salix planifolia</i>	0	0	0	0	0	0	0	0	0	0	0	4	0	-1	0	2	0	0
<i>Salix sitchensis</i>	0	0	0	0	0	4	0	0	1	5	0	0	0	0	0	1	0	1
<i>Sambucus racemosa</i>	0	-5	-2	-2	1	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Vaccinium caespitosum</i>	0	0	0	-5	0	0	0	2	7	0	1	0	1	0	0	2	0	0
<i>Vaccinium uliginosum</i>	0	0	0	0	0	1	0	0	-12	0	4	0	0	-6	1	-1	0	-1
<i>Vaccinium vitis-idaea</i>	0	0	-1	2	0	0	5	1	3	-8	-3	15	-6	-4	-5	-2	0	0
Trees																		
<i>Betula papyrifera (sapl.)</i>	12	0	1	2	0	10	17	1	2	23	0	5	1	10	0	0	1	5
<i>Betula papyrifera (seedl.)</i>	0	0	0	3	1	12	6	1	2	8	0	16	-4	1	0	0	3	3
<i>Betula papyrifera (tree)</i>	-12	-6	-2	0	-42	-9	-1	-10	-1	-10	-1	-23	0	0	0	0	-34	-9
<i>Picea lutzii (sapl.)</i>	-3	0	0	1	0	0	0	0	2	1	1	0	0	-2	-2	0	-1	0
<i>Picea lutzii (seedl.)</i>	0	0	-2	0	0	-1	0	0	-3	0	0	0	-1	-1	-1	0	0	0
<i>Picea lutzii (tree)</i>	-22	-31	-50	-10	-56	-7	-15	-39	-28	-17	-15	-25	-50	-34	-43	0	-10	-27
<i>Populus balsamifera (sapl.)</i>	0	0	0	0	0	0	0	0	0	2	0	0	3	0	0	0	0	0
<i>Populus balsamifera (seedl.)</i>	0	0	-3	0	0	1	0	0	0	12	0	0	0	0	0	0	0	1
<i>Populus balsamifera (tree)</i>	0	0	-65	0	2	-2	0	0	-2	-4	0	0	2	0	0	0	0	-4
<i>Populus tremuloides (sapl.)</i>	0	0	0	0	0	2	0	0	0	0	0	0	0	-1	0	0	0	0
<i>Populus tremuloides (seedl.)</i>	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
<i>Populus tremuloides (tree)</i>	0	0	0	0	0	-24	1	-9	0	-4	0	0	0	-1	0	0	0	-2
<i>Salix scouleriana (sapl.)</i>	-1	0	0	0	0	7	3	-1	6	0	2	1	4	4	0	0	0	2
<i>Salix scouleriana (seedl.)</i>	0	0	0	0	0	0	1	0	1	1	1	1	-4	0	0	0	-1	0
<i>Salix scouleriana (tree)</i>	0	0	0	-3	0	-16	-4	-8	0	-3	1	-4	0	-1	0	0	-1	-2
<i>Tsuga mertensiana (sapl.)</i>	0	0	0	0	0	0	-3	-4	0	0	0	-1	0	-1	0	0	-2	-1
<i>Tsuga mertensiana (seedl.)</i>	0	0	0	0	0	0	-8	-2	-1	0	0	0	0	0	0	0	0	-1
<i>Tsuga mertensiana (tree)</i>	0	0	0	0	0	0	-15	-24	0	0	-2	-4	0	0	0	0	0	-3

3.2 Gradient analysis results

The dimensionality of the dataset was assessed by requesting a 6-dimensional ordination using Non-metric Multidimensional Scaling (NMS). The first three axes captured 80 % of the variance among sample units (Table 7). Additional dimensions contributed little to the model. The proportion of variance explained by each of the first three axes is based on the r-squared between ordination distances and distances in the original space.

Table 7. Proportion of variance explained by each of the first three axes. NMS ordination of plots in species space.

Axis	Axis Descriptor	Increment	Cumulative
1	Moisture	.21	.21
2	Site Quality	.29	.50
3	Succession	.30	.80

The three major compositional gradients captured in the ordination can be described according to their proximity to environmental gradients. Axis-1 represents a moisture gradient related to drainage, Axis-2 represents a gradient that can be described by surficial deposit and hydrology, and Axis-3 represents a successional gradient described by time since burn. Descriptions of the gradients will be presented using species correlations with the three axes defined by NMS and overlays of individual species and site variables. Although the selected solution was 3-dimensional, the results will be presented as two, 2-dimensional ordinations. Gradients illustrated in Axis-2 versus Axis-3 will be presented, followed by gradients illustrated in Axis-1 versus Axis-2.

3.2.1 Axis-2 vs. Axis-3

A projection of Axis-2 vs. Axis-3 displays 59% of the variance in species composition in the dataset (Figure 5a). Plots were arranged vertically along Axis-3 by time since burn with unburned plots consistently occurring above their burned counterparts. Time since burn was positively correlated with Axis-3 ($r = 0.67$; Table 9 and Figure 5b). The critical value for statistical significance of correlation coefficients at $\alpha = 0.05$ for a sample size of 34 is ± 0.33 from a table of critical values for correlation coefficients (Zar, 1984). Vectors linking burned and unburned plots were roughly parallel, and the direction of change after burning was consistent, although vector length showed considerable variation (Figure 5a). Site codes followed by "A" are unburned plots.

Along Axis-2, plots are arranged according to topographic position and surficial deposit. Percent slope is negatively correlated with Axis-2 ($r = -.52$) with steeper slopes generally occurring on the left side of the gradient and flatter slopes generally occurring on the right side of the gradient. Percent slope alone, however, does not adequately describe this gradient. The gradient appears to be strongly influenced by surficial deposit with sites featuring alluvial and colluvial deposits occupying the left-hand portion of the gradient, and glacial deposits (moraines and outwash terraces) occupying the right-hand portion of the gradient. Sites with alluvial and/or colluvial deposits (non-glacial deposits) were negatively correlated with Axis 2 ($r = -0.65$; Table 9). Colluvial and alluvial deposits occurred on the following landtypes: depositional slopes (alluvial fans and toe slopes), fluvial valley bottoms, and mountain side slopes (lower slopes) and share a hydrologic pattern associated with runoff from alpine snow pack, and thus have a continuous supply of moisture throughout the growing season. Landtypes associated with glacial deposits include moraines, hills, and glacial outwash terraces. The hydrology of these sites is controlled largely by onsite precipitation. These sites are not characterized by continuous runoff throughout the growing season and the shallow soils are developed on coarse glacial till. For the purposes of this discussion, Axis-2 will be referred to as a "site quality" gradient since units on the extreme left are characterized by

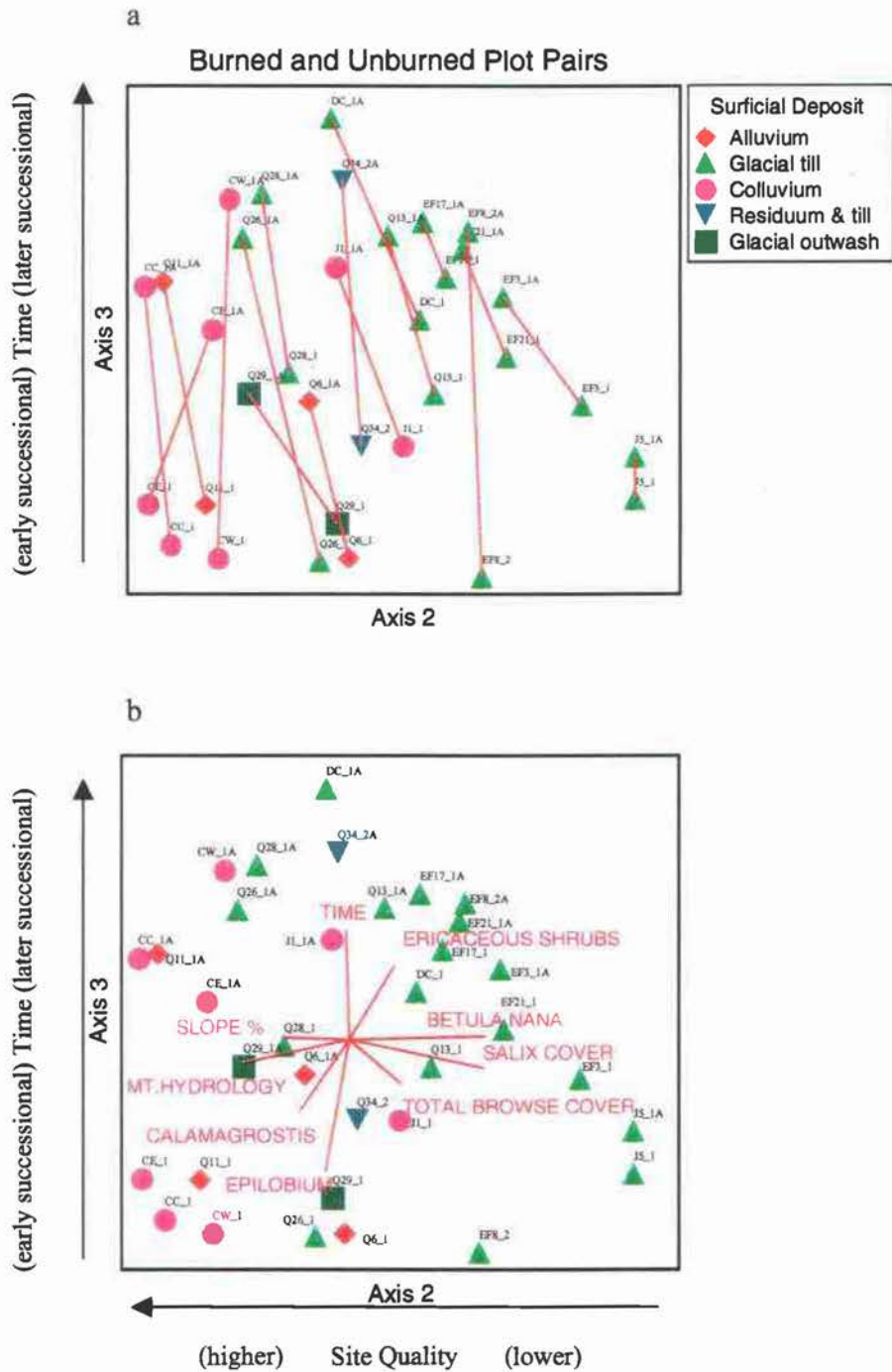


Figure 5. NMS ordination of Axis-2 (site quality) versus Axis-3 (time). Points represent plots in species space and the same configuration is displayed in both (a) and (b). Symbols represent type of surficial deposit. (a) vectors link burned and unburned sample unit pairs. (b) vectors represent direction of positive correlation with site variables and selected species. Length of vector indicates strength of correlation. “A” appended to site code indicates unburned.

toe slope and alluvial fan landtypes, those in the middle of the gradient occur on hills and moraines, and those on the far right occur on glacial outwash terraces. Species correlations with Axis-2 follow a pattern consistent with a gradient in site quality or productive capacity, with those species with low nutrient requirements positively associated with Axis-2 and those with high nutrient requirements negatively associated with Axis-2. A complete list of species correlations by axis is given in Table 8.

3.2.2 Species correlations

Early successional species such as *Epilobium angustifolium* and *Calamagrostis canadensis* were negatively correlated with Axis-3 while species associated with mature forests such as *Picea lutzii* (tree), *Geocaulon lividum* (Dyrness and Grigal, 1979; Reynolds, 1990), and *Empetrum nigrum* (Viereck, 1982; Lutz, 1956), and were positively correlated with Axis-3. Along the horizontal gradient, species associated with high site quality and deep soils such as *Viburnum edule* (Haeussler et al., 1990; Dyrness et al., 1989), *Streptopus amplexifolius* (DeVelice et al., 1999; DeMeo et al., 1992), and *C. canadensis* (Mueller-Dombois and Sims, 1966) were negatively correlated with Axis-2, while those associated with lower site quality such as *Potentilla fruticosa*, *Salix barclayi* (Argus, 1973; Collet, 1996), and *Betula nana* (Krajina, et al. 1982) were positively correlated with Axis-2. A complete list of species correlations for each Axis is given in Table 8. Species are ordered from most strongly negative correlation to most strongly positive correlation for each Axis.

Table 8. Species correlations with Axes 1 (moisture), 2 (site quality), and 3 (time). Species are ordered from most strongly negative correlation to most strongly positive correlation for each Axis.

Axis-1		Axis-2		Axis-3	
Species	r	Species	r	Species	r
<i>Rubus idaeus</i>	-0.61	<i>Viburnum edule</i>	-0.60	<i>Epilobium angustifolium</i>	-0.73
<i>Calamagrostis canadensis</i>	-0.61	<i>Streptopus amplexifolius</i>	-0.49	<i>Stellaria sp.</i>	-0.55
<i>Mertensia paniculata</i>	-0.54	<i>Calamagrostis canadensis</i>	-0.45	<i>Calamagrostis canadensis</i>	-0.54
<i>Equisetum arvense</i>	-0.51	<i>Lycopodium annotinum</i>	-0.41	<i>Moehringia lateriflora</i>	-0.51
<i>Viburnum edule</i>	-0.46	<i>Gymnocarpium dryopteris</i>	-0.41	<i>Rhinanthus minor</i>	-0.41
<i>Sambucus racemosa</i>	-0.44	<i>Linnaea borealis</i>	-0.41	<i>Equisetum arvense</i>	-0.39
<i>Equisetum silvaticum</i>	-0.43	<i>Alnus crispa sinuata</i>	-0.40	<i>Taraxacum officinale</i>	-0.37
<i>Alnus crispa sinuata</i>	-0.42	<i>Rubus idaeus</i>	-0.40	<i>Thalictrum sp.</i>	-0.37
<i>Gymnocarpium dryopteris</i>	-0.41	<i>Galium triflorum</i>	-0.40	<i>Phleum alpinum</i>	-0.36
<i>Cadamine umbellata</i>	-0.40	<i>Sambucus racemosa</i>	-0.39	<i>Populus balsamifera (sapl.)</i>	-0.36
<i>Rubus arcticus</i>	-0.38	<i>Echinopanax horridum</i>	-0.39	<i>Equisetum scirpoides</i>	-0.36
<i>Epilobium angustifolium</i>	-0.37	<i>Actea rubra</i>	-0.37	<i>Carex deweyana</i>	-0.35
<i>Thalictrum sp.</i>	-0.33	<i>Pyrola asarifolia</i>	-0.36	<i>Sanguisorba stipulata</i>	-0.35
<i>Carex deweyana</i>	-0.32	<i>Rosa acicularis</i>	-0.36	<i>Castilleja unalaschcensis</i>	-0.35
<i>Rosa acicularis</i>	-0.32	<i>Menziesia ferruginea</i>	-0.36	<i>Equisetum pratense</i>	-0.34
<i>Dryopteris dilatata</i>	-0.31	<i>Ribes sp.</i>	-0.35	<i>Aconitum delphinifolium</i>	-0.33
<i>Sanguisorba stipulata</i>	-0.31	<i>Betula papyrifera (tree)</i>	-0.34	<i>Geranium erianthum</i>	-0.33
<i>Equisetum pratense</i>	-0.30	<i>Epilobium angustifolium</i>	-0.31	<i>Heracleum lanatum</i>	-0.33
<i>Ribes sp.</i>	-0.28	<i>Equisetum silvaticum</i>	-0.31	<i>Gymnocarpium dryopteris</i>	-0.32
<i>Carex sp.</i>	-0.27	<i>Dryopteris dilatata</i>	-0.29	<i>Salix barclayi</i>	-0.32
<i>Valeriana sitchensis</i>	-0.27	<i>Rubus pedatus</i>	-0.29	<i>Achillea borealis</i>	-0.31
<i>Salix barclayi</i>	-0.26	<i>Moneses uniflora</i>	-0.28	<i>Angelica lucida</i>	-0.30
<i>Polemonium acutifolium</i>	-0.26	<i>Equisetum pratense</i>	-0.28	<i>Agrostis sp.</i>	-0.30
<i>Viola sp.</i>	-0.21	<i>Salix scouleriana (tree)</i>	-0.26	<i>Poa sp.</i>	-0.29
<i>Streptopus amplexifolius</i>	-0.20	<i>Populus balsamifera</i>	-0.26	<i>Rubus idaeus</i>	-0.27
<i>Sorbus scopulina</i>	-0.20	<i>Athyrium filix-femina</i>	-0.26	<i>Betula papyrifera (sapl.)</i>	-0.27
<i>Moehringia lateriflora</i>	-0.20	<i>Equisetum arvense</i>	-0.25	<i>Salix sitchensis</i>	-0.27
<i>Potentilla fruticosa</i>	-0.20	<i>Angelica lucida</i>	-0.25	<i>Viola sp.</i>	-0.27
<i>Rumex sp.</i>	-0.20	<i>Heracleum lanatum</i>	-0.23	<i>Athyrium filix-femina</i>	-0.26
<i>Swertia perennis</i>	-0.19	<i>Castilleja unalaschcensis</i>	-0.23	<i>Campanula rotundifolia</i>	-0.26
<i>Rubus chamaemorus</i>	-0.19	<i>Shepherdia canadensis</i>	-0.23	<i>Equisetum silvaticum</i>	-0.25
<i>Solidago multiradiata</i>	-0.17	<i>Sorbus scopulina</i>	-0.20	<i>Valeriana sitchensis</i>	-0.25
<i>Pyrola asarifolia</i>	-0.16	<i>Tsuga mertensiana (sapl.)</i>	-0.20	<i>Carex sp.</i>	-0.25
<i>Aconitum delphinifolium</i>	-0.15	<i>Tsuga mertensiana (tree)</i>	-0.19	<i>Polemonium acutifolium</i>	-0.24
<i>Picea lutzii (tree)</i>	-0.15	<i>Listera cordata</i>	-0.19	<i>Cinna latifolia</i>	-0.23
<i>Populus balsamifera</i>	-0.15	<i>Pyrola chlorantha</i>	-0.18	<i>Viburnum edule</i>	-0.23
<i>Moneses uniflora</i>	-0.15	<i>Phleum alpinum</i>	-0.17	<i>Potentilla fruticosa</i>	-0.22
<i>Festuca altaica</i>	-0.14	<i>Populus tremuloides (tree)</i>	-0.16	<i>Cadamine umbellata</i>	-0.22
<i>Spirea beauverdiana</i>	-0.13	<i>Tsuga mertensiana (seedl.)</i>	-0.15	<i>Festuca altaica</i>	-0.20
<i>Pyrola secunda</i>	-0.13	<i>Pyrola secunda</i>	-0.15	<i>Populus tremuloides (sapl.)</i>	-0.18
<i>Anemone richardsonii</i>	-0.13	<i>Thalictrum sp.</i>	-0.13	<i>Populus tremuloides (seedl.)</i>	-0.17

Table 8, Continued

Species	r	Species	r	Species	r
<i>Betula papyrifera</i> (tree)	-0.10	<i>Vaccinium ovalifolium</i>	-0.12	<i>Mertensia paniculata</i>	-0.16
<i>Rubus pedatus</i>	-0.09	<i>Corydalis sempervirens</i>	-0.12	<i>Betula papyrifera</i> (seedl.)	-0.16
<i>Juncus</i> sp.	-0.07	<i>Mertensia paniculata</i>	-0.11	<i>Swertia perennis</i>	-0.15
<i>Menziesia ferruginea</i>	-0.07	<i>Sorbus sitchensis</i>	-0.11	<i>Galium triflorum</i>	-0.15
<i>Lycopodium annotinum</i>	-0.06	<i>Picea lutzii</i> (tree)	-0.10	<i>Luzula parviflora</i>	-0.15
<i>Achillea borealis</i>	-0.06	<i>Valeriana sitchensis</i>	-0.08	<i>Arctostaphylos uva-ursi</i>	-0.15
<i>Cinna latifolia</i>	-0.05	<i>Ledum palustre</i>	-0.06	<i>Solidago multiradiata</i>	-0.14
<i>Stellaria</i> sp.	-0.04	<i>Populus balsamifera</i> (seedl.)	-0.05	<i>Rumex</i> sp.	-0.13
<i>Sheperdia canadensis</i>	-0.01	<i>Cadamine umbellata</i>	-0.05	<i>Salix alaxensis</i>	-0.12
<i>Trientalis europa</i>	0.02	<i>Viola</i> sp.	-0.05	<i>Populus balsamifera</i> (seedl.)	-0.12
<i>Phleum alpinum</i>	0.04	<i>Cornus canadensis</i>	-0.05	<i>Rubus arcticus</i>	-0.12
<i>Heracleum lanatum</i>	0.04	<i>Betula papyrifera</i> (sapl.)	-0.04	<i>Actea rubra</i>	-0.11
<i>Athyrium filix-femina</i>	0.05	<i>Festuca saximontana</i>	-0.02	<i>Rubus chamaemorus</i>	-0.11
<i>Angelica lucida</i>	0.06	<i>Anemone richardsonii</i>	-0.02	<i>Juncus</i> sp.	-0.11
<i>Taraxacum officinale</i>	0.06	<i>Rhinanthus minor</i>	-0.02	<i>Sorbus scopulina</i>	-0.10
<i>Castilleja unalascensis</i>	0.06	<i>Populus tremuloides</i> (seedl.)	0.01	<i>Srteptopus amplexifolius</i>	-0.08
<i>Galium triflorum</i>	0.07	<i>Betula papyrifera</i> (seedl.)	0.03	<i>Salix scouleriana</i> (sapl.)	-0.08
<i>Campanula rotundifolia</i>	0.07	<i>Populus tremuloides</i> (sapl.)	0.05	<i>Anemone richardsonii</i>	-0.08
<i>Geranium erianthum</i>	0.07	<i>Salix sitchensis</i>	0.05	<i>Trisetum spicatum</i>	-0.07
<i>Echinopanax horridum</i>	0.08	<i>Moehringia lateriflora</i>	0.05	<i>Rosa acicularis</i>	-0.07
<i>Populus tremuloides</i> (tree)	0.10	<i>Geranium erianthum</i>	0.05	<i>Lupinus nootkatensis</i>	-0.04
<i>Actea rubra</i>	0.11	<i>Trientalis europa</i>	0.06	<i>Festuca saximontana</i>	-0.04
<i>Vaccinium caespitosum</i>	0.12	<i>Poa</i> sp.	0.06	<i>Salix planifolia</i>	-0.04
<i>Equisetum scirpoides</i>	0.13	<i>Lupinus nootkatensis</i>	0.07	<i>Echinopanax horridum</i>	-0.02
<i>Lycopodium alpinum</i>	0.13	<i>Lycopodium complanatum</i>	0.08	<i>Sambucus racemosa</i>	0.01
<i>Betula nana</i>	0.14	<i>Salix alaxensis</i>	0.09	<i>Alnus crispa sinuata</i>	0.02
<i>Poa</i> sp.	0.14	<i>Arctostaphylos uva-ursi</i>	0.09	<i>Pyrola asarifolia</i>	0.05
<i>Salix bebbiana</i>	0.15	<i>Swertia perennis</i>	0.10	<i>Populus tremuloides</i> (tree)	0.08
<i>Rhinanthus minor</i>	0.15	<i>Salix scouleriana</i> (seedl.)	0.10	<i>Salix bebbiana</i>	0.09
<i>Salix planifolia</i>	0.16	<i>Lycopodium alpinum</i>	0.10	<i>Sheperdia canadensis</i>	0.10
<i>Salix scouleriana</i> (tree)	0.17	<i>Equisetum scirpoides</i>	0.11	<i>Moneses uniflora</i>	0.10
<i>Linnaea borealis</i>	0.18	<i>Populus balsamifera</i> (sapl.)	0.11	<i>Trientalis europa</i>	0.10
<i>Lycopodium clavatum</i>	0.18	<i>Geocaulon lividum</i>	0.11	<i>Populus balsamifera</i>	0.11
<i>Agrostis</i> sp.	0.19	<i>Stellaria</i> sp.	0.13	<i>Vaccinium caespitosum</i>	0.11
<i>Salix alaxensis</i>	0.19	<i>Trisetum spicatum</i>	0.13	<i>Betula nana</i>	0.11
<i>Trisetum spicatum</i>	0.20	<i>Salix bebbiana</i>	0.14	<i>Cornus canadensis</i>	0.12
<i>Populus tremuloides</i> (sapl.)	0.21	<i>Luzula parviflora</i>	0.15	<i>Spirea beauverdiana</i>	0.13
<i>Luzula parviflora</i>	0.21	<i>Picea lutzii</i> (seedl.)	0.16	<i>Ribes</i> sp.	0.15
<i>Pyrola chlorantha</i>	0.23	<i>Picea lutzii</i> (sapl.)	0.18	<i>Dryopteris dilatata</i>	0.19

Table 8, Continued.

Axis-1		Axis-2		Axis-3	
Species	r	Species	r	Species	r
<i>Vaccinium ovalifolium</i>	0.23	<i>Taraxacum officinale</i>	0.20	<i>Salix scouleriana</i> (seedl.)	0.19
<i>Corydalis sempervirens</i>	0.24	<i>Salix scouleriana</i> (sapl.)	0.21	<i>Salix scouleriana</i> (tree)	0.19
<i>Tsuga mertensiana</i> (tree)	0.24	<i>Spirea beauverdiana</i>	0.21	<i>Lycopodium alpinum</i>	0.20
<i>Sorbus sitchensis</i>	0.26	<i>Agrostis</i> sp.	0.21	<i>Vaccinium ovalifolium</i>	0.21
<i>Tsuga mertensiana</i> (seedl.)	0.28	<i>Campanula rotundifolia</i>	0.21	<i>Sorbus sitchensis</i>	0.22
<i>Populus balsamifera</i> (sapl.)	0.28	<i>Rubus arcticus</i>	0.23	<i>Corydalis sempervirens</i>	0.23
<i>Vaccinium uliginosum</i>	0.31	<i>Carex deweyana</i>	0.24	<i>Pyrola secunda</i>	0.23
<i>Listera cordata</i>	0.31	<i>Sanguisorba stipulata</i>	0.25	<i>Pyrola chlorantha</i>	0.29
<i>Lycopodium complanatum</i>	0.33	<i>Lycopodium clavatum</i>	0.26	<i>Lycopodium clavatum</i>	0.29
<i>Picea lutzii</i> (seedl.)	0.34	<i>Vaccinium vitis-idaea</i>	0.28	<i>Betula papyrifera</i> (tree)	0.30
<i>Ledum palustre</i>	0.35	<i>Empetrum nigrum</i>	0.29	<i>Ledum palustre</i>	0.31
<i>Tsuga mertensiana</i> (sapl.)	0.35	<i>Vaccinium uliginosum</i>	0.32	<i>Tsuga mertensiana</i> (seedl.)	0.32
<i>Populus balsamifera</i> (seedl.)	0.36	<i>Achillea borealis</i>	0.34	<i>Vaccinium uliginosum</i>	0.33
<i>Salix scouleriana</i> (seedl.)	0.36	<i>Cinna latifolia</i>	0.36	<i>Vaccinium vitis-idaea</i>	0.34
<i>Picea lutzii</i> (sapl.)	0.37	<i>Rumex</i> sp.	0.38	<i>Menziesia ferruginea</i>	0.34
<i>Betula papyrifera</i> (sapl.)	0.39	<i>Rubus chamaemorus</i>	0.38	<i>Tsuga mertensiana</i> (tree)	0.35
<i>Salix sitchensis</i>	0.40	<i>Aconitum delphinifolium</i>	0.40	<i>Listera cordata</i>	0.36
<i>Arctostaphylos uva-ursi</i>	0.42	<i>Juncus</i> sp.	0.41	<i>Lycopodium complanatum</i>	0.36
<i>Salix scouleriana</i> (sapl.)	0.44	<i>Vaccinium caespitosum</i>	0.44	<i>Picea lutzii</i> (sapl.)	0.39
<i>Cornus canadensis</i>	0.44	<i>Polemonium acutifolium</i>	0.46	<i>Lycopodium annotinum</i>	0.41
<i>Empetrum nigrum</i>	0.44	<i>Solidago multiradiata</i>	0.46	<i>Rubus pedatus</i>	0.41
<i>Festuca saximontana</i>	0.45	<i>Salix planifolia</i>	0.49	<i>Linnaea borealis</i>	0.42
<i>Betula papyrifera</i> (seedl.)	0.45	<i>Carex</i> sp.	0.52	<i>Tsuga mertensiana</i> (sapl.)	0.47
<i>Lupinus nootkatensis</i>	0.52	<i>Potentilla fruticosa</i>	0.54	<i>Picea lutzii</i> (seedl.)	0.49
<i>Populus tremuloides</i> (seedl.)	0.53	<i>Festuca altaica</i>	0.60	<i>Empetrum nigrum</i>	0.56
<i>Vaccinium vitis-idaea</i>	0.59	<i>Salix barclayi</i>	0.71	<i>Geocaulon lividum</i>	0.59
<i>Geocaulon lividum</i>	0.63	<i>Betula nana</i>	0.74	<i>Picea lutzii</i> (tree)	0.62

Both abundance of combined browse species and total abundance of *Calamagrostis canadensis* are negatively correlated with Axis-3 ($r = -0.42$ and $r = -0.54$, respectively; Table 9 and Figure 6), indicating both are more abundant in post-burn plots, however, total browse is positively correlated with Axis-2, while *C. canadensis* abundance is negatively correlated with Axis-2. The occurrence of *C. canadensis* can be described by the landscape features correlated with Axis-2. Figure 6 illustrates the ordination positions and relative abundance of browse species and *C. canadensis*. In general, *C. canadensis* occurs most abundantly on alluvial and colluvial deposits overlain with deep fine soil, while browse species occur most abundantly on glacial deposits (moraines and outwash plains) and residuum. The exception to this trend is Juneau 1 (J1_1); although classified as a site with colluvial surficial deposits, it also features a layer of glacial till and outwash. In Figure 6, Juneau 1 appears in an intermediate position between the alluvial/colluvial deposits and the glacial deposits. *C. canadensis* cover increased only slightly on this site after burning (from 3% to 6%). The dominant browse species at J1_1 is *Salix barclayi*; this species often occurs with *C. canadensis*, and its ability to resprout does not appear to be severely impeded by the presence of *C. canadensis*.

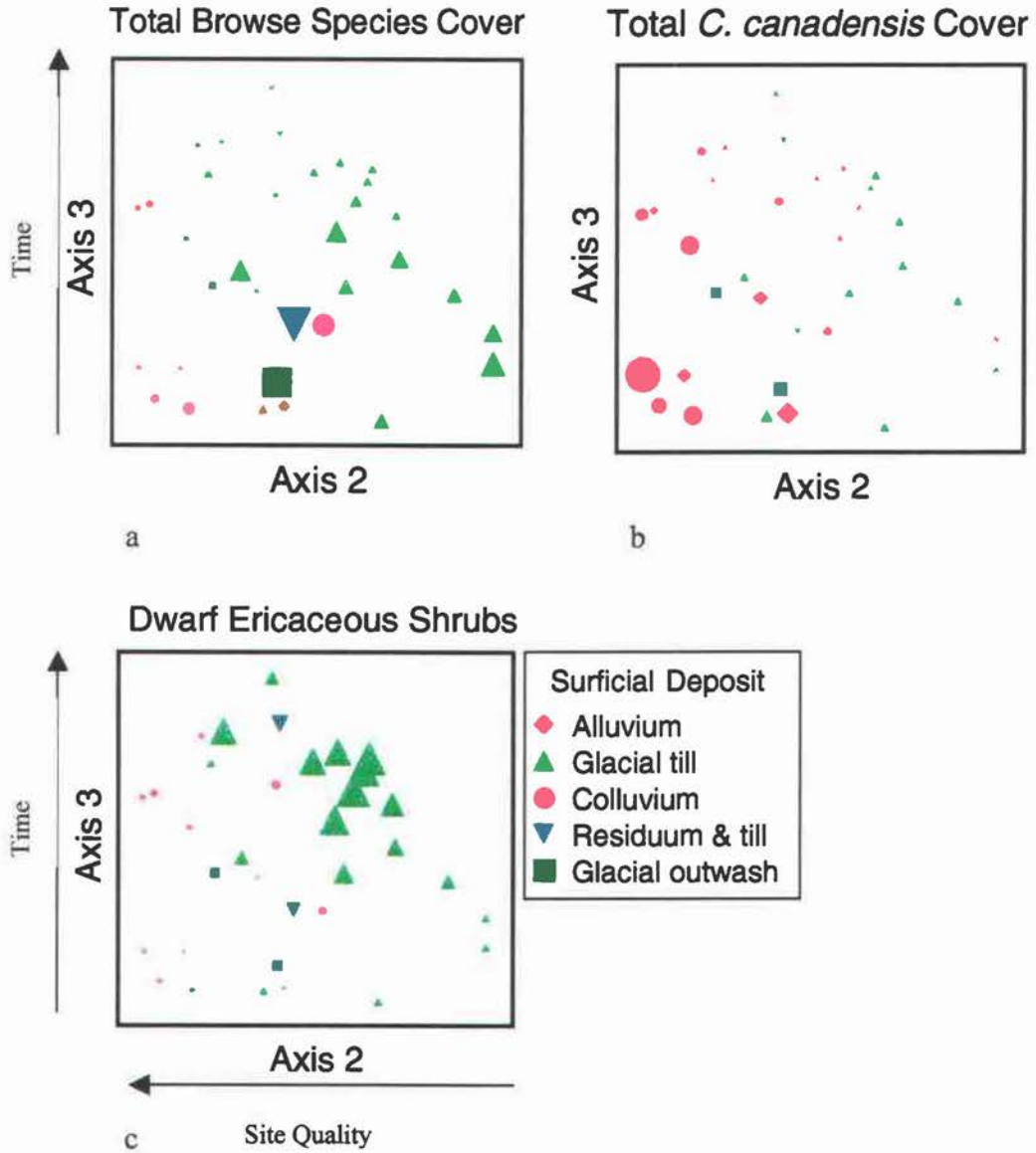


Figure 6. NMS ordination of Axis-2 (site quality) versus Axis-3 (time). Symbols represent surficial deposit. (a) Size of symbol reflects abundance of browse species (% cover). (b) Size of symbol represents abundance (% cover) of *Calamagrostis canadensis*. (c) Size of symbol represents combined abundance (% cover) of ericaceous shrubs.

3.2.3 Axis-1 vs. Axis-2

A projection of Axis-1 vs. Axis-2 displays 50% of the variance in the dataset. This projection shows the relationship of site quality along Axis-2 to a moisture gradient along Axis-1 (Figure 7). Since the vectors do not show a directional trend (as in Axis-3) and the paired burned and unburned plots are relatively close to one another, the projection illustrates the variance explained by environment and site factors other than time-since-burn. In other words, it displays the variance among sites not explained by succession and burning. Landtype, combined with surficial deposit and depth of loamy soil, can be viewed as indicators of potential site quality and hydrology. Along Axis-2, high quality sites (depositional slopes with colluvial and alluvial deposits) are negatively correlated with Axis-2, and glacial outwash plains and terraces (sites with coarse glacial deposits) are positively correlated with Axis-2. Hill slopes and glacial moraines occupy the middle range of Axis-2. Along Axis-1, deep deposits of loamy soil (corresponding to fluvial valley bottoms and depositional slopes) are negatively correlated with Axis-1 ($r = -0.54$; Table 9 and Figure 7), while better-drained sites, corresponding to moraine and hill landtypes with relatively shallow soils, are positively correlated with Axis-1 (Figure 7). The wettest sites occupy the far left positions on Axis-1 (Quartz Creek 6 and Caribou East); and the best-drained site (Quartz Creek 34) occupies the far right position. Species correlations with Axis-1 are displayed in Table 8.

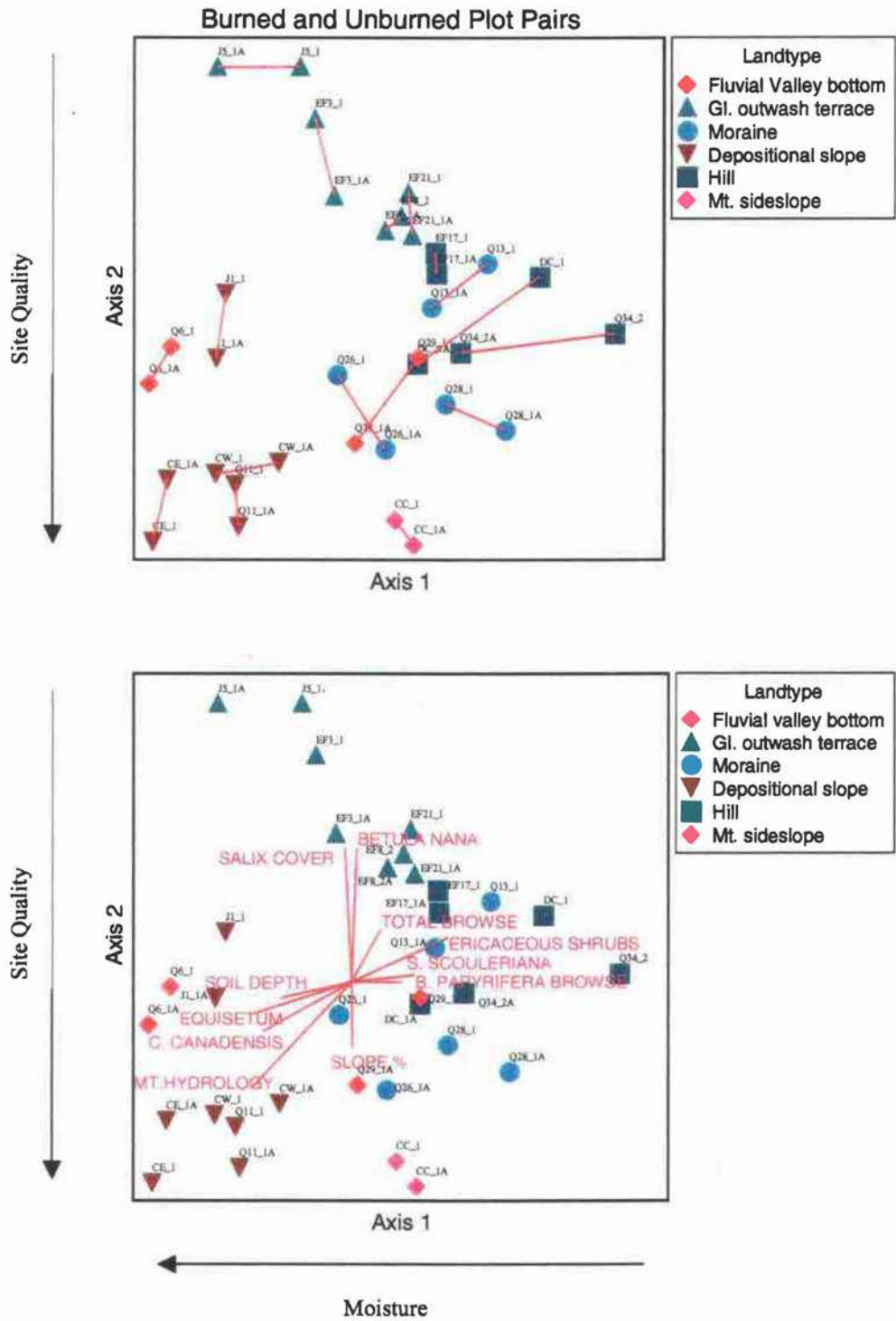


Figure 7. NMS ordination of Axis-1 (moisture) vs. Axis-2 (site quality). Points represent plots in species space; symbols represent landtype. (a) vectors link burned and unburned sample unit pairs. (b) vectors represent correlations with site variables and selected species. Direction of vector indicates direction of positive correlation and length indicates strength of correlation.

Calamagrostis canadensis and total browse abundance

The projection of Axis-1 vs. Axis-2, with abundance of browse species and *Calamagrostis canadensis* represented by size of symbol, (Figure 8) gives a clear picture of the relationship of browse abundance and *C. canadensis* to a moisture gradient (Axis-1) and landtype (Axis-2). While the projection of Axis-2 vs. Axis-3 illustrated the relationship of *C. canadensis* to surficial deposit and succession, the projection of Axis-1 vs. Axis-2 gives a clearer picture of the site conditions favored by selected species since the variation related to succession is not displayed. *C. canadensis* abundance increases with increasingly deeper soils and increasing moisture. Deeper soils tended to occur on fluvial valley bottoms and depositional slopes, such as toe slopes. Browse species abundance is inversely related to *C. canadensis* abundance. Total browse cover is positively correlated with both Axis-1 and Axis-2 (Figure 8 and Table 9), while *C. canadensis* cover is negatively correlated with both Axes (Figure 8 and Table 8). Total cover of browse species is generally higher on the hill and moraine landtypes on sites with shallow or stony soils. *Salix barclayi* is the exception to this trend, occurring most abundantly on poorly drained glacial deposits and depositional slopes (Figure 9).

Relationship of *Calamagrostis canadensis* to landtype and soil depth

Of the sites with over 3% cover *Calamagrostis canadensis* in the pre-burn or control plots, only those with specific landtype and soil conditions resulted in a high cover of *C. canadensis* after burning. Burn sites with deep non-stony soils (over 38 cm deep) on depositional slopes and fluvial valley bottoms produced abundant cover of *C. canadensis* (20% to 44%) after prescribed burning. Surficial deposits on these sites were alluvial and/or colluvial; *C. canadensis* did not occur abundantly on glacial till deposits before or after burning.

Browse trends by individual species

Salix scouleriana seedlings and saplings and *Betula papyrifera* seedlings and saplings occupy adjacent and overlapping regions of the ordination space (Figure 9). High cover values of *B. papyrifera* and *S. scouleriana* correspond to hill slope and glacial

moraine landtypes. Study sites on these landtypes tended to be well drained with coarse-textured soils.

Salix barclayi has a wide ecological amplitude, but tends to occur most abundantly on poorly drained soils, on both colluvial and glacial deposits (Figure 9). *S. barclayi* is positively correlated with Axis-2, indicating a tendency to occur on lower productivity sites, while *S. scouleriana* is positively correlated with Axis-1, indicating a tendency toward better-drained sites.

The occurrence of *Populus tremuloides* roughly coincides with the occurrence of *Betula papyrifera*. The pattern of occurrence of *Populus balsamifera* was less clear with low percentages occurring across the ordination. Quartz Creek 34, one of the most severe burns on a well-drained site, had the highest abundance of *P. balsamifera* (Figure 9).

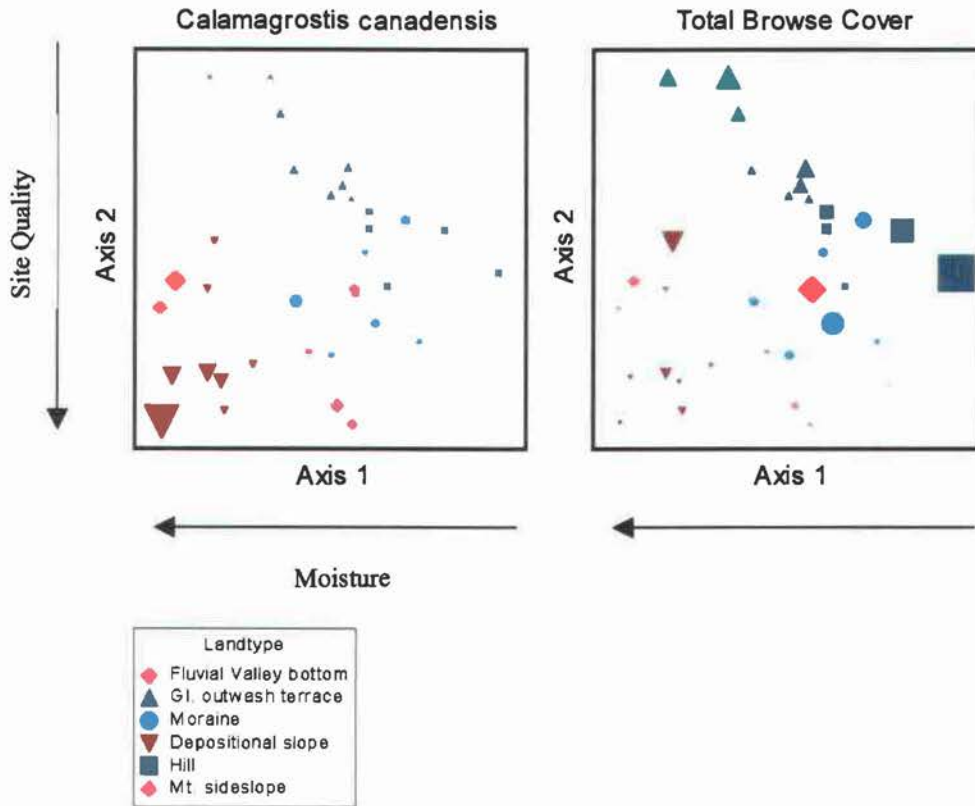


Figure 8. NMS ordination of Axis-1 (moisture) versus Axis-2 (site quality). Symbols represent landtype. Size of symbol represents abundance (% cover) of *C. canadensis* or total browse.

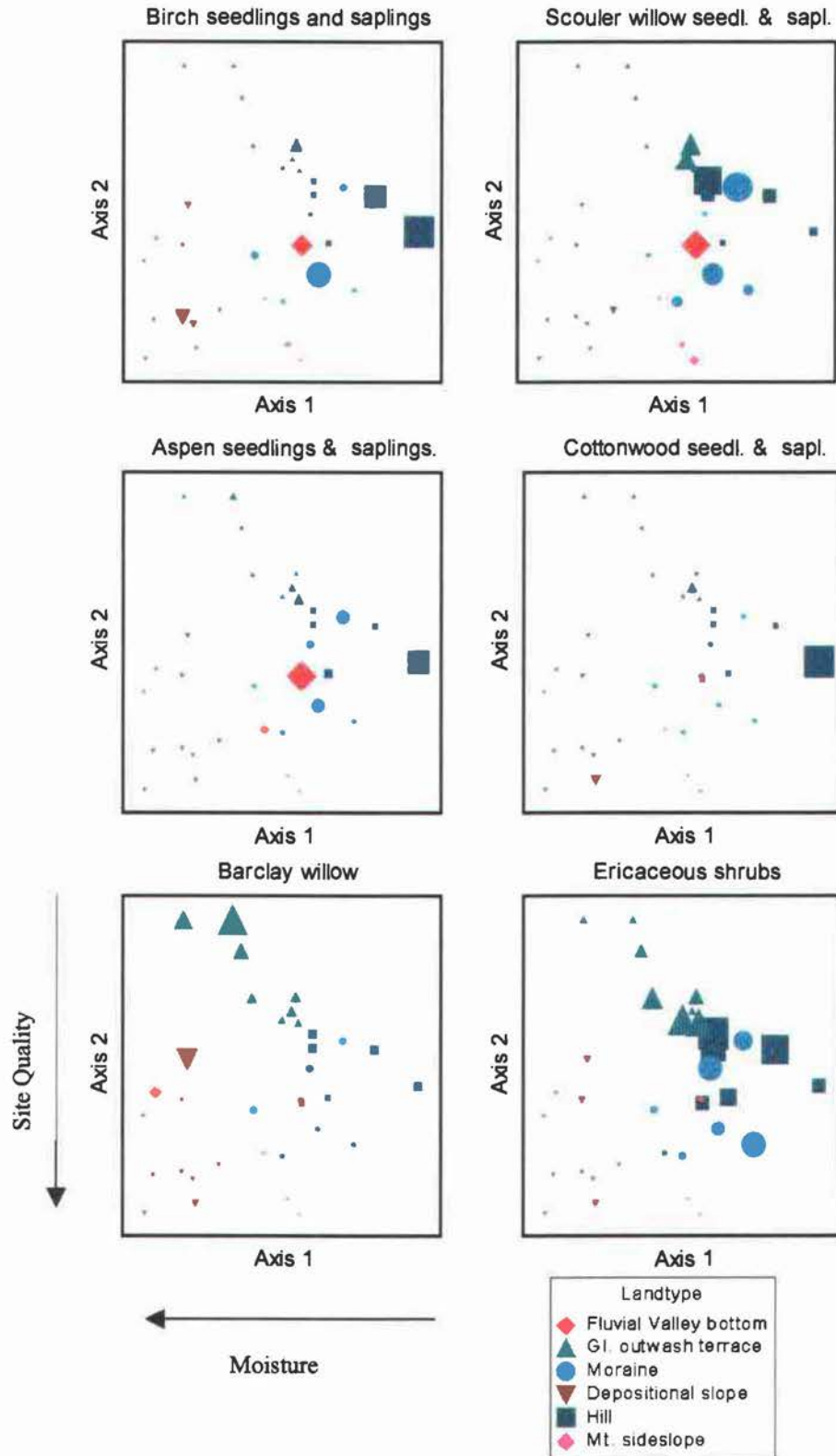


Figure 9. NMS ordination Axis-1 (moisture) versus Axis-2 (site quality). Symbols represent landtype. Size of symbol represents abundance (% cover) of indicated species.

Table 9. Correlations with Axes 1 (moisture), 2 (site quality), and 3 (time) for environmental variables and selected combined species.

Environmental variables	r Axis-1	r Axis-2	r Axis-3
Soil depth (cm)	-0.54	-0.26	-0.22
Percent slope	0.06	-0.52	0.08
Time since burn	-0.12	-0.12	0.67
Burned/unburned	0.07	0.13	-0.74
Solar insolation	0.09	-0.21	-0.19
Non-glacial deposit (mt. hydrology)	-0.65	-0.66	-0.31
Combined species cover			
Dwarf ericaceous shrubs	0.63	0.43	0.55
Combined <i>Equisetum</i>	-0.63	-0.36	-0.47
Combined <i>Salix</i> (excluding <i>Salix scouleriana</i>)	-0.17	0.74	-0.34
Combined <i>Betula papyrifera</i> seedlings and saplings	0.45	-0.02	-0.27
Combined <i>Populus balsamifera</i> seedlings and saplings	0.37	-0.02	-0.18
Combined <i>Populus tremuloides</i> seedlings and saplings	0.45	0.04	-0.22
Combined <i>Salix scouleriana</i> seedlings and saplings	0.51	0.17	-0.06
Combined cover of all browse species	0.35	0.46	-0.42
<i>Calamagrostis canadensis</i>	-0.61	-0.45	-0.54

3.3 Browse abundance models

The hypothesized model explaining browse abundance is post-burn browse abundance is a function of pre-burn browse abundance, *Calamagrostis canadensis* abundance, fire severity, type of surficial deposit, and interactions between surficial deposit and *C. canadensis*, and surficial deposit and pre-burn browse abundance. Subsets of this global model were tested to determine which models explained the variation in the data without over-fitting the model. Akaike's Information Criterion for small datasets (AIC_c) (Burnham and Anderson, 1998) was calculated for each equation and rescaled as a simple difference,

$$\Delta AIC_{ci} = AIC_{ci} - \min AIC_c .$$

where the lowest AIC_c value of all the models ($\min AIC_c$) is subtracted from the AIC_c value for each model (AIC_{ci}). The “best” model has the lowest ΔAIC_{ci} value. ΔAIC_{ci} values within 1-2 of the lowest value have considerable support, models with ΔAIC_c values from 3-7 have less support, and those with values greater than 10 have very little support (Burnham and Anderson, 1998). Regression variables are defined as follows:

LCALCAN = log-transformed pre-burn *Calamagrostis canadensis* cover

SEVERITY = burn severity, categorical variable with 3 levels: lightly burned, moderately burned, and severely burned

LPREBROWSE = log-transformed pre-burn browse species abundance, includes browse species trees, seedlings and saplings and shrub willows. (Pre-burn data include data from control plots on sites where pre-burn data were not available.)

MTHYDR = categorical landscape variable defining surficial deposit with 2 levels: M = alluvial/colluvial deposits (hydrology associated with mountain runoff); G = glacial deposits (hydrology not associated with mountain runoff). Because of the small size of the dataset, surficial deposits were grouped into these two categories based on their dominant process.

LPOSTBROWSE = log transformed post-burn browse species abundance, includes browse species seedlings, saplings and shrubs (response variable).

Global Model:

$$LPOSTBROWSE = LPREBROWSE + LCALCAN + SEVERITY + MTHYDR + LCALCAN * MTHYDR + LPREBROWSE * MTHYDR$$

Due to the high number of parameters in the global model, the ΔAIC_c value for model was 30.6, indicating it was not a useful model for describing variation in the data. Models with greater than 3 parameters had ΔAIC_c values of 8.5 or higher, indicating they have little support according to this criterion (Burnham and Anderson, 1998).

Based on the overall fit of the model, variance explained, p-value of parameters, and ΔAIC_c (Burnham and Anderson, 1998), the following two models were selected to explain post-burn browse species abundance:

- 1) $LPOSTBROWSE = \text{intercept} + LCALCAN, \Delta AIC_c = 0$
- 2) $LPOSTBROWSE = \text{intercept} + LCALCAN + MTHYDR + MTHYDR * LCALCAN, \Delta AIC_c = 3.6$

Model 1

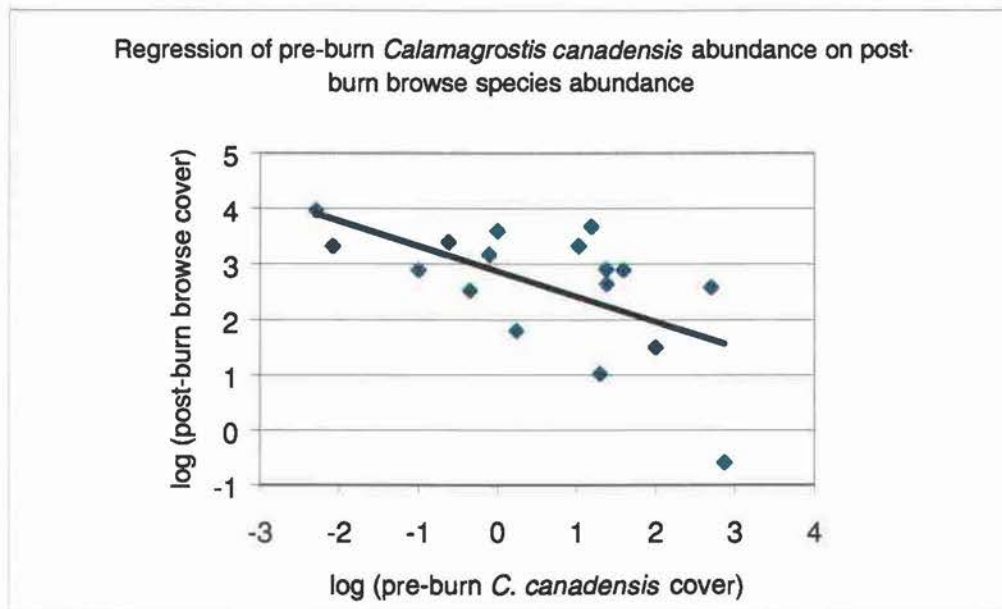
$$\text{LPOSTBROWSE} = \text{intercept} + \text{LCALCAN}, \quad r^2 = 0.36$$

$$\text{LPOSTBROWSE} = 2.87 - 0.45(\text{LCALCAN})$$

$$\quad \quad \quad (.24) \quad \quad (.16)$$

Table 10. Regression model coefficients and standard errors for model 1 (n = 17).

Parameter	Estimate	Standard Error	t Value	Pr > t
Intercept	2.87	0.24	11.74	<.0001
LCALCAN	-0.45	0.16	-2.87	0.0116

**Figure 10. Regression of pre-burn *Calamagrostis canadensis* abundance on post-burn browse species abundance (model 1).**

The first model described the underlying relationship of *Calamagrostis canadensis* prior to burning to post-burn browse abundance (Figure 10), indicating a significant inverse relationship between post-burn browse abundance and pre-burn *C. canadensis* cover (Figure 10, and Table 10), however, the model could be enhanced without over-fitting by allowing an interaction between *C. canadensis* and surficial deposit, as in the second model:

Model 2

$$\text{LPOSTBROWSE} = \text{intercept} + \text{LCALCAN} + \text{MTHYDR} + \text{MTHYDR} * \text{LCALCAN},$$

$$r^2 = 0.49$$

For MTHYDR = M (alluvial and colluvial deposits)

$$\text{LPOSTBROWSE} = 4.21 - 1.23(\text{LCALCAN})$$

(.94) (.49)

For MTHYDR = G (glacial deposits)

$$\text{LPOSTBROWSE} = 2.97 - 1.23(\text{LCALCAN}) + 1.00(\text{LCALCAN})$$

(1.8) (.49) (.54)

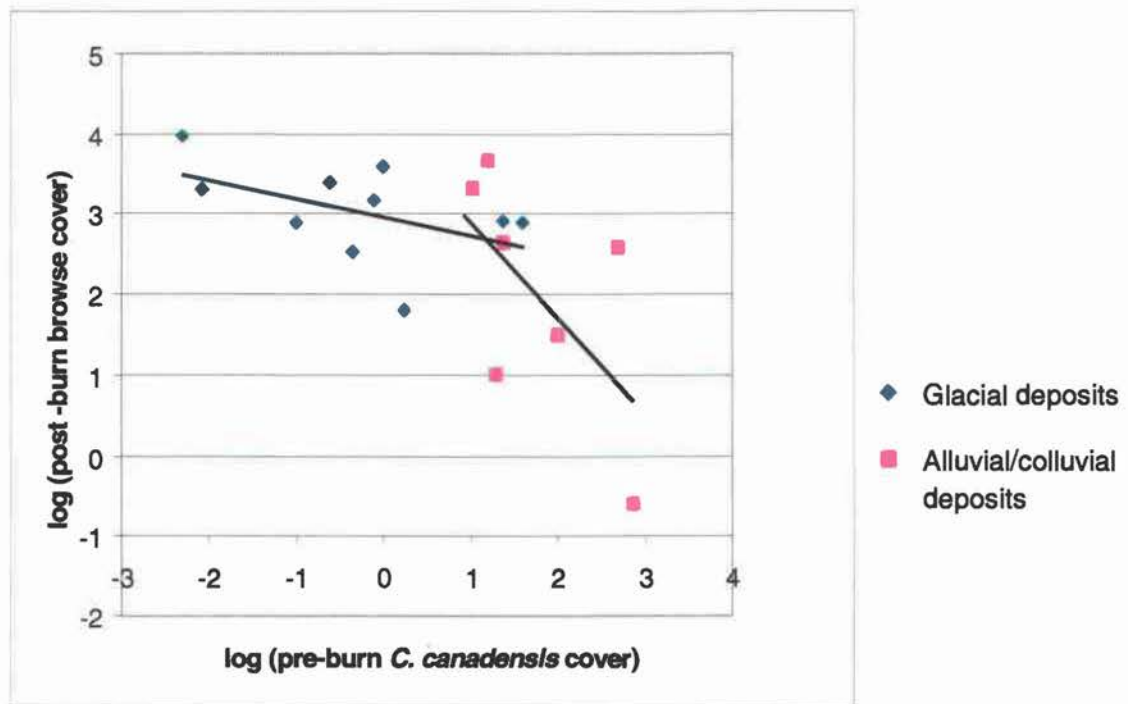


Figure 11. Regression of pre-burn *Calamagrostis canadensis* abundance on post-burn browse species abundance showing an interaction between *C. canadensis* and surficial deposit (model 2).

Table 11. Regression model coefficients and standard errors for model 2 (n = 17).

Parameter		Estimate	Standard Error	t Value	Pr > t
Intercept		4.21	0.94	4.50	0.0006
MTHYDR	G	-1.24	0.98	-1.26	0.2303
MTHYDR	M	0.00.			
LCALCAN		-1.23	0.49	-2.51	0.0262
LCALCAN *MTHYDR	G	1.00	0.54	1.84	0.0886
LCALCAN *MTHYDR	M	0.00.			

Allowing the slopes and intercepts to differ illustrates how browse species response to burning depends on the type of surficial deposit and the abundance of *Calamagrostis canadensis* (Figure 11 and Table 11). On alluvial and colluvial deposits, as pre-burn *C. canadensis* cover increased, the effect on post-burn browse abundance was more strongly inverse. On glacial deposits, the effect of pre-burn *C. canadensis* cover on post-burn browse production was less negative. For example, at Caribou East (a burn on a colluvial deposits with the highest pre-burn *C. canadensis* cover of all the burn sites) *C. canadensis* increased from 18 to 44 % after burning and cover of browse species changed very little, from 0.1 to 0.5 % cover (Table 12, CE). At Quartz Creek 29 (a burn on alluvial deposits with relatively low pre-burn *C. canadensis* cover) *C. canadensis* increased from 3 to 11 % after burning and cover of browse species increased from 3 to 40 % (Table 12, Q29).

Table 12. Unburned and burned average cover values for selected species and groups of species by site. Cover values are for unburned transects unless preceded by "burned." Burn severity classes are as follows: 2=light, 3=moderate, 4=severe. "Total browse cover" includes shrub willows and seedlings and saplings of broadleaf trees. Site abbreviations can be cross-referenced with site names in Table 3.

Site abbreviation	soil depth (cm)	G=glacial; M=alluvial or colluvial deposit	Burn Severity	Calamagrostis canadensis	Burned C. canadensis	Total browse cover	Burned total browse cover	Empetrum nigrum	Burned E. nigrum	Vaccinium caespitosum	Burned V. caespitosum	Vaccinium uliginosum	burned V. uliginosum	Vaccinium vitis-idaea	Burned V. vitis-idaea	Ericaceous combined	Burned Ericaceous combined	Betula nana	Burned B. nana	Broadleaf tree cover
Q34	18	G	4	0	0	0	53	9	0	0	0	0	0	11	3	20	14	0	0	22
DC	21	G	3	0	1	1	28	5	12	0	0	2	2	4	19	13	35	0	0	29
Q13	18	G	3	0	5	5	18	11	4	3	9	16	4	2	5	33	23	4	7	8
Q28	39	G	2	1	5	2	30	20	6	0	0	0	0	5	10	33	16	0	0	7
EF17	21	G	2	1	1	6	13	17	25	5	6	5	8	4	1	30	41	14	21	6
EF21	10	G	3	1	3	6	24	16	7	0	0	10	4	9	5	36	18	19	22	2
J5	36	G	2	1	1	22	36	0	0	0	2	1	0	3	1	4	3	9	15	0
Q26	19	G	4	1	8	3	6	4	0	0	2	0	0	2	3	6	6	0	0	35
EF8	23	G	4	4	4	6	18	32	0	0	1	0	0	8	1	41	5	11	7	0
EF3	47	G	3	5	7	8	18	12	1	8	7	2	3	7	2	28	13	16	26	0
J1	38	M	2	3	6	0	28	0	1	5	0	0	0	0	2	5	4	0	1	4
Q29	32	M	3	3	11	3	40	0	0	0	0	0	1	5	4	5	5	0	0	57
Q11	11	M	2	4	13	7	3	2	0	0	0	0	0	1	0	2	0	0	0	68
CW	59	M	3	4	20	2	14	0	0	0	0	0	0	1	0	1	0	0	0	13
CC	44	M	3	7	16	1	5	0	0	0	0	0	0	0	0	0	0	0	0	40
Q6	54	M	2	15	26	1	13	0	0	0	0	0	0	0	0	0	0	0	0	43
CE	57	M	2	18	44	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6

4 DISCUSSION

4.1 Succession pattern

Figure 5 shows vectors linking unburned and burned plots aligning in a unidirectional and roughly parallel fashion. Axis-3 appears to represent vegetation change along a time gradient, and the direction of vegetation change after burning is consistent in the burn units in the study area, although the lengths of the vectors vary. If prescribed burning had influenced the direction of vegetation change, it is likely that the vectors would not be consistently parallel. This finding is consistent with previous studies on boreal forest dynamics, in which the direction of forest succession was altered only in cases of severe disturbance (Foote, 1983; Payette, 1992). The relatively parallel alignment of the plot-pair vectors in Figure 5 show that pre-burn species composition is a more important factor in predicting post-burn vegetation composition than burn severity, except possibly in cases of severe fires.

It likely that burn units in the study area did not encompass a sufficiently wide range of burn severities to display divergent successional pathways, or possibly the sample size (17 burns) was not large enough to show this range of responses. Length of vector represents the degree of dissimilarity between unburned and burned plot pairs, and there is considerable variation in vector lengths (Figure 12). Vectors between the severely burned sites and their unburned counterparts were relatively long (Figure 12), suggesting that severe burning caused a more pronounced change in plant composition than light burning, but the direction of change was consistent with that of the other burns. The pre-burn forest types within the burn dataset did not represent a complete range of the forest diversity in the study area. For example, mountain hemlock-dominated stands, which represent some of the most mature forests in the area, were not represented in the dataset. Burning forests at the mature end of the successional gradient could create conditions in which a divergence in direction of change would be more likely, since site conditions at the time of burning are very different from those conditions immediately after fire. Typical mature forests in the study area have developed deep organic layers on

the forest floor, lowering soil temperatures and productivity, creating site conditions very different from post-burn conditions. Less mature forest stands that have been burned more recently generally feature mixed tree cover of *Picea lutzii*, *Betula papyrifera* and possibly other broadleaf tree species such as *Populus tremuloides* and/or *Salix scouleriana*. These forests likely cycle back more rapidly to the pre-burn condition, since site conditions have not been altered as dramatically as in the more mature forest condition and the broadleaf tree cover propagates vegetatively.

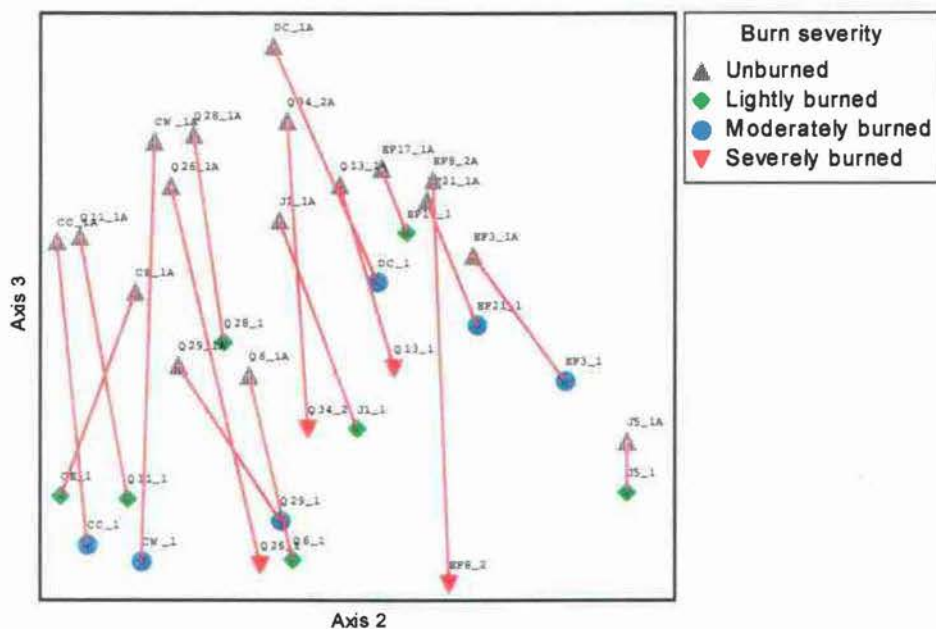


Figure 12. NMS ordination of Axis-2 (site quality) vs. Axis-3 (time). Points represent plots in species space. Symbol represents burn severity. Vectors link burned and unburned sample unit pairs. “A” appended to site name indicates unburned.

Sites dominated by *Calamagrostis canadensis* after burning, such as Caribou E, Caribou W, and Quartz 6, show the same general trend in direction of vector as the remaining burns (Figure 5), possibly indicating a that the successional direction of these sites was not altered by *C. canadensis*, although it is likely that the rate of succession has been slowed in these sites, caused by a delay in the recruitment of woody species. This explanation is supported by Schulz (2000); in a study within the Caribou West prescribed

burn site, cover of *C. canadensis* increased significantly 7 years after the burn, but 12 years after burning, *C. canadensis* cover had decreased to pre-burn levels.

4.2 Relationship of pre-burn seral stage and post-burn browse production

Forest seral stage may be more important than fire severity in predicting post-burn browse production on sites where broadleaf trees (all of which propagate vegetatively) are the dominant browse component (mid-seral forests). Fire severity may not play as significant a role in determining post-burn browse response as in late-seral forests. In other words, creating abundant post-burn browse from a forest dominated by birch is more likely than converting a mature conifer site to birch. The existing birch-dominated forests of the Kenai Mountains were established after wildfire and, in general, have shallower organic mats than mature conifer forests. This allows the litter and duff layers to dry earlier in the spring, and mineral seedbed may be more readily created after burning.

4.3 Fire severity

The dataset does not provide conclusive evidence on the role fire severity plays on post-burn vegetation composition. The highest frequency burn severity was “lightly burned” with 7 plots (Figure 12), followed by “moderately burned” with 6 plots, and finally “severely burned” with 4 plots. Since most of the burns were lightly to moderately burned, trends across burn severities may be difficult to detect due to a lack of samples in the “severely burned” category. Based on what is known of individual species traits, such as rooting habit, type of reproduction, and seedbed needs, assumptions can be made that are supported by trends observed in the data. Some of these trends are described below.

4.3.1 Effect of fire severity on dwarf ericaceous shrubs and browse species

Severe fires shift species composition and abundance by exposing mineral soil, thereby allowing recruitment of new species and/or removing species that, under less severe burn conditions, would resprout. For example, cover of *Vaccinium uliginosum*, *Ledum palustre*, and *Empetrum nigrum* tended to decrease after severe burns (Table 6), and browse species abundance tended to increase on the same sites (Figure 6 and Figure 12). This trend of decreasing ericaceous shrub cover and increasing browse species cover is illustrated in three of the four most severe burns: East Fork 8 (EF8), Quartz Creek 34 (Q34), and Quartz Creek 13 (Q13) (Figure 2 and Table 12). In the fourth burn, Quartz Creek 26 (Q26), ericaceous shrubs were not abundant in either the control or post-burn plots. The trend in ericaceous shrub cover on sites with light burns is less clear; of the two lightly burned sites with ericaceous cover, ericaceous shrubs increased after burning at East fork 17 (EF17) and decreased after burning at Quartz Creek 28 (Q28); browse species cover increased at Quartz Creek 28 and remained constant at East fork 17 (Table 12).

Ericaceous shrubs as a group did not respond consistently to fire. *Vaccinium caespitosum* increased after burning on six of eight sites where it occurred, and *Vaccinium vitis-idaea* showed a mixed response, decreasing on nine of 14 sites where it occurred. The variable response of the dwarf ericaceous shrubs could be related to their slight differences in rooting habit. All are shallowly rooted, but *V. caespitosum* and *V. vitis-idaea* rhizomes can penetrate mineral soil (Hungerford, 1986; Smith, 1962), and *V. vitis-idaea* may possess a taproot (Smith, 1962). Rhizomes of *Vaccinium uliginosum*, and *Empetrum nigrum* root in the organic layer or near the mineral soil surface, rendering these species more susceptible to damage from fire (Chapin and VanCleve, 1981).

4.3.2 Calamagrostis canadensis and browse species

Four burn units developed an abundant cover (16%-44%) of *Calamagrostis canadensis* after burning: Caribou East (CE), Caribou West (CW), Cripple Creek (CC), and Quartz Creek 6 (Q6); two of these burns were classified as moderately burned and

two were classified as lightly burned (Table 12). On sites with abundant *C. canadensis* there appears to be a slight trend of increasing browse cover with increasing fire severity; however, post-burn browse cover changed only slightly on these four sites. The two moderately burned sites showed increased browse abundance (Cripple Creek and Caribou West), while browse decreased in the remaining two sites (Caribou East and Quartz Creek 6), which were lightly burned (Table 12). Unfortunately, there were no burns classified as severely burned on sites with high cover of *C. canadensis*. Presumably, more severe fires would kill *C. canadensis* rhizomes and expose mineral soil providing seedbed for recruitment of browse species. It is likely that rootstocks of resprouting species generally persist after all but the most severe fires with little change to the pre-burn population.

4.3.3 Browse species response to burn severity

Populus balsamifera seedlings and saplings had the greatest increase in cover (from 0 % to 14%) after burning on the site with the highest severity burn (Quartz Creek 34) and presumably the highest exposure of mineral soil. Other studies in Alaska confirm that *P. balsamifera* regenerates abundantly by seed after severe disturbance to the organic layer (Newton and Cole, 2000). *Betula papyrifera* seedlings and saplings also had the greatest increase in cover in the Quartz Creek 34 burn (0 % to 23 %), however, *B. papyrifera* also increased dramatically in lightly to moderately burned sites: Quartz Creek 28 (0 % to 23 %), Quartz Creek 29 (0 % to 22 %), and Dave's Creek (0 % to 21 %). This suggests that the response of *B. papyrifera* is responsive to factors beyond burn severity, such as competition for seedbed space and/or pre-burn cover of *B. papyrifera* (trees). Of the four burns described above, none had abundant pre-burn or post-burn cover of *C. canadensis* (Table 12), pre-burn cover of *B. papyrifera* was greater than or equal to 10 percent on three of the four sites; Quartz Creek 28 a pre-burn *B. papyrifera* cover of 3 percent.

4.4 Influence of site quality on vegetation response

As described earlier, the terms “high quality” and “low quality” site have been used in this discussion to describe a suite of site characteristics that influences species composition and species response to disturbance. “High quality” sites include those found on depositional slope and valley bottom landtypes with alluvial or colluvial surficial deposits and deep loamy soils. “Low quality” sites include those found on hill and glacial moraine landtypes with glacial till surficial deposits and soils with a high percentage of coarse fragments in the surface layers. Competition for space is intense on “high quality” sites such as (such as Caribou East, Caribou West, and Quartz Creek 6), and as a result, there is high occupancy by competitive herbaceous species such as *Calamagrostis canadensis*, and less occupancy and recruitment by browse species and ericaceous shrubs (Figure 6 and Figure 8). The influence of surficial deposit on the inverse relationship of *C. canadensis* to browse species abundance also supported by regression equations in Figure 11. Browse species abundance after burning is more negatively impacted by *C. canadensis* on high quality sites (alluvial and colluvial deposits) than it is on sites with glacial deposits. A relatively small dataset precluded further refinement of the model. It is likely that pre-burn browse species abundance would explain additional variance not explained by *C. canadensis* and surficial deposit, however, additional explanatory variables in the model caused unacceptably high AIC_c values indicating over-fitting of the data.

It is likely that “high quality” sites would also be optimal for production of certain browse species in the absence of competition from herbaceous species. Woody perennials that resprout after fire will, in general, persist after disturbance, eventually shading the competitive herbaceous species. However, 15 to 20 years after burning the sites listed above, woody species have not yet emerged sufficiently from the herbaceous layer (*C. canadensis* grows to 2 m) to shade the competition. This maybe due to two factors: herbivory by moose prevents broadleaf tree species from escape and the resprouting capacity of birch (the most common broadleaf tree species on these sites) declines as trees mature.

In a projection of Axis-1 versus Axis-2 (Figure 8), which describes variance in species composition explained by factors other than time and succession, the location of browse species corresponds roughly to the location of ericaceous shrubs. Landtypes that support browse species and dwarf ericaceous shrubs include hill slopes, glacial moraines, and glacial outwash plains (Figure 9). Surficial deposits on these sites include glacial till and residuum and (Figure 6), and soils are generally stony. This pattern results in browse species occurring more abundantly on low productivity sites than on high productivity sites where competition from herbaceous species for space may be high. The understory composition on these sites generally features a combination of several of the following species: *Vaccinium vitis-idaea*, *V. caespitosum*, *V. uliginosum*, *Empetrum nigrum*, *Ledum palustre*, and *Betula nana*, all of which are capable of growing abundantly on sites with low nutrient availability (Korcak, 1988; Henry et al., 1990; Holloway, 1981; Klinka et al., 1989). The vegetation composition of sites such as Juneau 5, East Fork 3, 8, 21, and 17 suggests that these sites are lower quality than depositional sites such as Caribou East, Caribou West and Quartz Creek 6. East Fork and Juneau sites occupy the far right positions of Axis-2, while Caribou East, Caribou West and Quartz Creek 6 occupy the far left of Axis-2. Since site conditions on low quality sites can limit the abundance of highly competitive species, browse species abundance is inversely related to *C. canadensis* abundance.

4.5 Management recommendations

4.5.1 Overview of unit selection

Selecting areas to burn across the forest is a decision-making process that logically begins at the landscape level and works down to the unit level. In order to use fire successfully as a management tool across the landscape, decisions must be made regarding where to burn, how much and how frequently to burn, and finally how to burn a selected unit. Considerations for burn unit selection can be broken down into three general categories:

1. Management goals at the landscape level, considering habitat needs and present versus desired future condition. Questions about where to burn and how much to burn are addressed at this level.
2. Operational limitations such as proximity to natural fire breaks, development, highway, or power lines.
3. Burn planning guidelines for specific site types based on existing vegetation and site characteristics. Site-specific burn prescriptions, including information on fuels (moisture and abundance) and weather limitations, are developed at this level.

The following guidelines and burn planning flowchart (Figure 13) address the third component of burn unit selection. In forested lowlands, the primary goal of prescribed burning will likely be one or more of the following: regeneration of beetle-killed spruce forests, moose range enhancement (generally winter range), and/or fuel reduction. Burn planning will depend on the primary objective(s) of the burn. If moose range enhancement is the primary objective, then a burn plan designed to create optimal conditions for recruitment and/or resprouting of desired browse species will be required, considering the availability of seed source for browse species. If forest regeneration is the primary objective, then a burn plan designed to create the most favorable seedbed conditions for the desired conifer or broadleaf tree species will be needed, also considering availability of seed for targeted tree species. These two objectives can be accomplished together; however, the potential for successful restocking of tree species will be a higher priority if the main objective is forest regeneration. For all objectives, burn timing must be planned with seed dispersal for the target species for successful regeneration by seed (see Table 1 for duration of seed viability after dispersal by species).

Burn Planning Flow Chart—General Browse

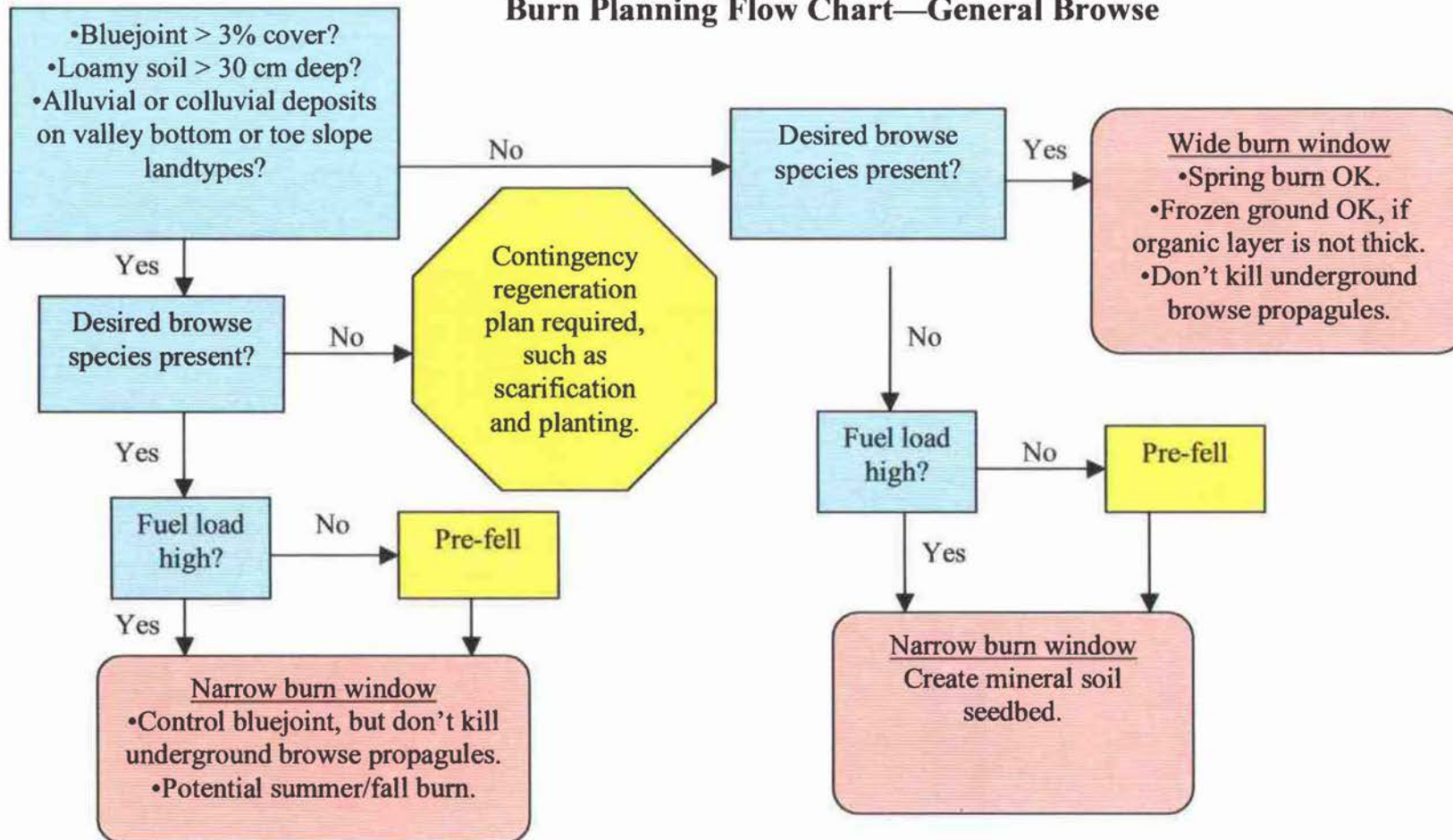


Figure 13. Prescribed burn planning flowchart, generalized for all browse species.

General guidelines for burn planning for moose range enhancement are outlined in a burn-planning flowchart (Figure 13). Site characteristics such as geomorphology and soil depth influence initial vegetation as well as potential post-burn vegetation development. Site conditions that favor competitive herbaceous vegetation, such as *Calamagrostis canadensis*, may be problematic for successful regeneration of woody species. A proposed burn site on a valley bottom or toe slope landtype with alluvial or colluvial deposits and deep (>30 cm), loamy soil would be likely to support *C. canadensis* and will require stringent guidelines when planning a prescribed burn. Under these conditions, low pre-burn cover values of *C. canadensis* can increase substantially after burning. For example, within the study area, a pre-burn *C. canadensis* cover of 4 % was remeasured at 20 % fifteen years after burning, at another site a pre-burn value of 18% increased to 44% after burning. Given a proposed burn unit with the conditions described above, there may still be options for successful burning and regeneration of woody species. If the desired browse species are present and fuel load is high (i.e. dead spruce on the ground), the burn plan should be designed to control grass by burning the rhizomes in the organic layer and expose mineral soil to promote recruitment of woody species. These requirements result in a narrow window of burn opportunity. The organic layer (not just the thatch on the surface) must be sufficiently dry to carry a fire; generally, the organic layer will not be sufficiently dry during the droughty period (May-June) to ensure removal of the organic layer. A burn on this type of site would be most likely to be successful if conducted as a late summer or fall burn if the weather conditions allowed sufficient drying of the organic layer (such weather conditions do not typically occur every year). If desired browse species are present, but the fuel load is low, pre-felling of standing fuels may be required. If desired browse species are not present prior to burning on a site with the above characteristics, a contingency plan for regeneration of woody species will likely be required. Site treatments such as scarification, seeding, or planting may be necessary. A prescribed burn on such a site that does not result in duff removal and exposure of mineral soil will incur ongoing costs associated with alternative methods of regeneration of woody species.

If a proposed burn unit is not on a valley bottom or toe slope landtype with alluvial or colluvial deposits and deep (>30 cm) loamy soil, and desired browse species are

present, then the potential burn window is wide. These sites will often occur on glacial moraines, hill, and mid-mountain slope landtypes. If resprouting stems from existing browse species will result in sufficient stocking, then burning can take place across a wide range of conditions, including a spring burn on frozen ground. However, if new recruitment of woody species is required to meet desired stocking, then exposure of mineral soil will be necessary to provide a favorable seedbed. The burn should be severe enough to expose mineral soil, but not so severe as to kill underground propagules of desired browse species. Pre-felling should be considered if the fuel load is not sufficient to create the desired burn severity.

Where feasible, pre-felling can be used as a tool to widen the burn window, not only by increasing the fuel load, but also through opening the canopy allowing earlier drying of the fuel bed. A burn unit that has been pre-felled will dry more rapidly and be more flammable than the surrounding forest.

The allocation of resources required to successfully regenerate a burn unit to the target species will be different depending on site quality and objective of burn. Regenerating a high quality site with deep, fine soils on alluvial or colluvial deposits may require a higher allocation of resources than regenerating a site of lesser quality (i.e., glacial moraine with coarse textured soils) due to competition from *Calamagrostis canadensis*. If moose browse production is the primary objective, then concentrating on lower quality sites will be more cost effective. Given the current spruce bark beetle epidemic, regenerating forests on high quality sites will likely also be a priority in a prescribed fire program. Careful burn planning along with contingency plans for regeneration will be needed to ensure successful forest regeneration.

Since post-burn browse production is positively correlated with the abundance of browse species in the pre-burn conditions, post-burn browse production will be maximized by targeting early- to mid-seral forests where browse species are already abundant in the pre-burn condition. Selection and execution of prescribed burn units will vary depending on the motivation for burning. Where browse production, particularly birch and/or aspen, is the highest priority, mid-seral stands with a birch and/or aspen component should be targeted. Where regenerating beetle-killed spruce forests is the highest priority, available burn units will likely be in later seral stages dominated by

spruce or mountain hemlock-spruce. Availability of a viable seed source of target regeneration species and creation of favorable seedbed conditions should be a high priority if relying on natural regeneration.

Preparing multiple units with different requirements for burning will increase chances of conducting burns given average seasons with often short and unpredictable windows of favorable burn weather.

4.5.2 Future direction

Continuing fire effects monitoring will increase knowledge regarding the influence of fire across a wider range of fire severities and vegetation types. Information is lacking on the effects of severe fires on all vegetation types and the effect of fire on later successional Lutz spruce-mountain hemlock stands. In order to conduct successful fire effects monitoring, the burn monitoring protocol must be strictly adhered to. It is essential to have permanent, well-monumented pre-burn vegetation and fuel load monitoring transects in the vegetation types of interest at each burn. Documentation of fire severity, including reduction of organic layer and amount of mineral soil exposed, is particularly important. Monitoring should be conducted the year prior to burning, the first three years following the burn, and at five-year intervals thereafter. Fire effects data should be collected as soon as practical after the burn.

This study developed guidelines for burn planning at the level of the burn unit. Guidelines should be developed for landscape-level planning, addressing the question of how much of the landscape should be burned and at what frequency. The historic range of variation (not yet defined for the area) could be used as a guide.

5 CONCLUSIONS

Pre-burn vegetation composition explains the majority of the variance in vegetation and browse species response to fire in the Kenai Mountains (Figure 5). Vegetation composition is influenced by physical site characteristics such as landtype, surficial deposit, and soil depth (Figure 7). These site characteristics, combined with initial vegetation, can be used to predict the effect of prescribed burning on a given site. In addition to initial vegetation composition, specific species indicators, such as dwarf ericaceous shrubs, *Calamagrostis canadensis*, and *Betula nana*, can be used as indicators of site quality and provide information regarding potential post-burn browse production. Severity of burn can be manipulated to influence post-burn vegetation development by affecting seedbed conditions and allowing new species recruitment, as well as reducing underground propagules of species such as *C. canadensis* that compete with new recruitment for seedbed space and possibly site resources. Burn severity is a higher concern on certain site types, for example, those that might support abundant *C. canadensis* after burning and those sites with a deep organic layer. Failure to execute a sufficiently severe prescribed burn on a site that supports abundant *C. canadensis* will likely result in failure to meet woody regeneration targets.

Calamagrostis canadensis occurred on each of the seventeen sites on both unburned and burned plots, and abundance increased after burning on every site; however, percent cover varied greatly across site types after burning (from 0.1 % to 48%). *C. canadensis* occurs most abundantly on moist sites with deep, loamy soil, on landtypes including lower mountain slopes (toe slopes) and alluvial valley bottoms. Sites with these features generally show large increases in *C. canadensis* cover after prescribed burning, even when *C. canadensis* cover is low (3%) prior to burning. *C. canadensis* is generally not abundant on hill and glacial moraine landtypes, which often feature shallow, stony soils. On these site types, *C. canadensis* cover generally does not increase dramatically after burning.

Browse abundance was inversely related to *Calamagrostis canadensis* abundance after burning, and browse abundance can be linked to site type. Total browse abundance

was generally higher after burning on sites where browse species were present prior to burning and competition from *C. canadensis* was not a factor. Landtypes that support these conditions include glacial moraines, hills, and mid-mountain slopes.

Within the prescribed burns of the study area, vegetation succession followed predictable pathways indicated by the direction of change on the ordination gradient representing time. Although factors such as severity, pre-burn vegetation composition, and landscape position varied across the 17 burns, the direction of succession after burning was relatively consistent. The rate of succession, however, may have been impacted by large increases in *Calamagrostis canadensis* after burning on certain sites, impeding recruitment of tree species.

Timing and severity of burn can be manipulated to increase the probability of achieving desired burn results. Burn planning guidelines developed in this study based on site type and existing vegetation composition will assist managers in successfully meeting habitat enhancement and forest regeneration objectives.

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APPENDICES

Appendix 1: Species codes and scientific names

Chugach

Code

Scientific Name

TREES

BETPAP	<i>Betula papyrifera</i> Marsh.
BETPAPSA	<i>Betula papyrifera</i> sapling
BETPAPSE	<i>Betula papyrifera</i> seedling
PICLUT	<i>Picea X lutzii</i> Little
PICLUTSA	<i>Picea X lutzii</i> sapling
PICLUTSE	<i>Picea X lutzii</i> seedling
POPBALT	<i>Populus balsamifera</i> ssp. <i>trichocarpa</i> (Torr. & Gray ex Hook.) Brayshaw
POPBALTSA	<i>Populus balsamifera</i> ssp. <i>trichocarpa</i> sapling
POPBALTSE	<i>Populus balsamifera</i> ssp. <i>trichocarpa</i> seedling
POPTRE	<i>Populus tremuloides</i> Michx.
POPTRESA	<i>Populus tremuloides</i> Michx. sapling
POPTRESE	<i>Populus tremuloides</i> Michx. seedling
SALSCO	<i>Salix scouleriana</i> Barratt ex Hook.
SALSCOSA	<i>Salix scouleriana</i> sapling
SALSCOSE	<i>Salix scouleriana</i> seedling
TSUMER	<i>Tsuga mertensiana</i> (Bong.) Carr.
TSUMERSA	<i>Tsuga mertensiana</i> sapling
TSUMERSE	<i>Tsuga mertensiana</i> seedling

TALL SHRUBS

ALNCRIS	<i>Alnus crispa</i> ssp. <i>sinuata</i> (Regel) Hulten
BETNAN	<i>Betula nana</i> L.
BETGLA	<i>Betula glandulosa</i> Michx.
ECHHOR	<i>Echinopanax horridum</i> (Sm.) Dcne. & Planch.
MENFER	<i>Menziesia ferruginea</i> Sm.
POTFRU	<i>Potentilla fruticosa</i> auct. non L.
RIBES	<i>Ribes</i> L.
RIBBRA	<i>Ribes bracteosum</i> Dougl. ex Hook.
RIBGLA	<i>Ribes glandulosum</i> Grauer
RIBHUD	<i>Ribes hudsonianum</i> Richards.
RIBLAC	<i>Ribes lacustre</i> (Pers.) Poir.
RIBLAX	<i>Ribes laxiflorum</i> Pursh
RIBTRI	<i>Ribes triste</i> Pallas
ROSACI	<i>Rosa acicularis</i> Lindl.
RUBIDA	<i>Rubus idaeus</i> L.
SALIX	<i>Salix</i> L.
SALALA	<i>Salix alaxensis</i> (Anderss.) Coville
SALBAR	<i>Salix barclayi</i> Anderss.
SALCOM	<i>Salix commutata</i> Bebb

Chugach**Code**

SALPUL
SALSIT
SAMRAC
SHECAN
SORSCO
SORSIT
VACOVA
VIBEDU

Scientific Name

Salix pulchra Cham.
Salix sitchensis Sanson ex Bong.
Sambucus racemosa L.
Shepherdia canadensis (L.) Nutt.
Sorbus scopulina Greene
Sorbus sitchensis M. Roemer
Vaccinium ovalifolium Sm.
Viburnum edule (Michx.) Raf.

LOW AND SUBSHRUBS

ANDPOL
ARCALP
ARCRUB
ARCUVA
EMPNIG
JUNCOM
LEDPAL
LINBOR
LOIPRO
OXYMIC
SPIBEA
VACCAE
VACULI
VACVIT

Andromeda polifolia L.
Arctostaphylos alpina (L.) Spreng.
Arctostaphylos rubra (Rehd. & Wilson) Fern.
Arctostaphylos uva-ursi (L.) Spreng.
Empetrum nigrum L.
Juniperus communis L.
Ledum palustre L.
Linnaea borealis L.
Loiseleuria procumbens (L.) Desv.
Oxycoccus microcarpus Turcz. ex Rupr
Spiraea beauverdiana auct. non Schneid.
Vaccinium caespitosum Michx.
Vaccinium uliginosum L.
Vaccinium vitis-idaea L.

FORBS

ACHBOR
ACODEL
ACTRUB
ANERIC
ARABIS
ARNICA
ARNLAT
BOSROS
CAMROT
CARUMB
CASUNA
CERBEE
CHRTET
DELGLA
EPIANG
GALIUM
GALBOR
GALTRIL
GEOLIV
GERERI
GEUMAC

Achillea borealis Bong.
Aconitum delphiniifolium DC.
Actaea rubra (Ait.) Willd.
Anemone richardsonii Hook.
Arabis L.
Arnica L.
Arnica latifolia Bong.
Boschniakia rossica (Cham. & Schlecht.) Fedtsch.
Campanula rotundifolia L.
Cardamine umbellata Greene
Castilleja unalaschcensis (Cham. & Schlecht.) Malte
Cerastium beeringianum Cham. & Schlecht.
Chrysosplenium tetrandrum (Lund ex Malmgr.) Th. Fries
Delphinium glaucum S. Wats.
Epilobium angustifolium L.
Galium L.
Galium boreale L.
Galium triflorum Michx.
Geocaulon lividum (Richards.) Fern.
Geranium erianthum DC.
Geum macrophyllum Willd.

Chugach**Code****Scientific Name**

HERLAN	<i>Heracleum lanatum</i> Michx.
LISCOR	<i>Listera cordata</i> (L.) R. Br. ex Ait. f.
LUPNOO	<i>Lupinus nootkatensis</i> Donn ex Sims
MERPAN	<i>Mertensia paniculata</i> (Ait.) G. Don
MIMGUT	<i>Mimulus guttatus</i> DC.
MITELL	<i>Mitella</i> L.
MOELAT	<i>Moehringia lateriflora</i> (L.) Fenzl
MONUNI	<i>Moneses uniflora</i> (L.) Gray
OSMORH	<i>Osmorhiza</i> Raf.
PARPAL	<i>Parnassia palustris</i> L.
PEDICU	<i>Pedicularis</i> L.
PETASI	<i>Petasites</i> P. Mill.
PETHYP	<i>Petasites hyperboreus</i> Rydb.
PLADIL	<i>Platanthera dilatata</i> (Pursh) Lindl. ex Beck
POLACU	<i>Polemonium acutiflorum</i> Willd. ex Roemer & J.A. Schultes
POLAVI	<i>Polygonum bistorta</i> ssp. <i>plumosum</i> (Small) Hult.
POLVIV	<i>Polygonum viviparum</i> L.
PYROLA	<i>Pyrola</i> L.
PYRASA	<i>Pyrola asarifolia</i> Michx.
PYRCHL	<i>Pyrola chlorantha</i> Sw.
PYRGRA	<i>Pyrola grandiflora</i> Radius
PYRMIN	<i>Pyrola minor</i> L.
PYRSEC	<i>Pyrola secunda</i> L.
RANUNC	<i>Ranunculus</i> L.
RHIMIN	<i>Rhinanthus minor</i> L.
RUBARC	<i>Rubus arcticus</i> L.
RUBCHA	<i>Rubus chamaemorus</i> L.
RUBPED	<i>Rubus pedatus</i> Sm.
RUMEX	<i>Rumex</i> L.
SANSTI	<i>Sanguisorba stipulata</i> Raf.
SENECI	<i>Senecio</i> L.
SOLMUL	<i>Solidago multiradiata</i> Ait.
STELLA	<i>Stellaria</i> L.
STRAMP	<i>Streptopus amplexifolius</i> (L.) DC.
SWEPER	<i>Swertia perennis</i> L.
TARAXA	<i>Taraxacum</i> G.H. Weber ex Wiggers
THALIC	<i>Thalictrum</i> L.
TRIEUR	<i>Trientalis europaea</i> L.
VALSIT	<i>Valeriana sitchensis</i> Bong.
VERVIR	<i>Veratrum viride</i> Ait.
VIOLA	<i>Viola</i> L.

GRAMINOIDS

AGRSPI	<i>Agropyron spicatum</i> Scribn. & Merr.
AGROST	<i>Agrostis</i> L.
CALCAN	<i>Calamagrostis canadensis</i> (Michx.) Beauv.
CAREX	<i>Carex</i> L.

Chugach**Code****Scientific Name**

CARDEW	<i>Carex deweyana</i> Schwein.
CARINT	<i>Carex interior</i> Bailey
CARLAE	<i>Carex laeviculmis</i> Meinsh.
CARMACH	<i>Carex macrochaeta</i> C.A. Mey.
CARPHY	<i>Carex phyllomanica</i> W. Boott
CARPYR	<i>Carex pyrenaica</i> Wahlenb.
CARRHY	<i>Carex rhynchosphysa</i> Fisch., C.A. Mey. & Ave-Lall.
CINLAT	<i>Cinna latifolia</i> (Trev. ex Goepp.) Griseb.
DANINT	<i>Danthonia intermedia</i> Vasey
FESTUC	<i>Festuca</i> L.
FESALT	<i>Festuca altaica</i> Trin.
FESRUB	<i>Festuca rubra</i> L.
FESSAX	<i>Festuca saximontana</i> Rydb.
HIEALP	<i>Hierochloe alpina</i> (Sw. ex Willd.) Roemer & J.A. Schultes
JUNCUS	<i>Juncus</i> L.
LUZPAR	<i>Luzula parviflora</i> (Ehrh.) Desv.
PHLEUM	<i>Phleum</i> L.
PHLALP	<i>Phleum sspinum</i> L.
POA	<i>Poa</i> L.
TRISPI	<i>Trisetum spicatum</i> (L.) Richter

FERNS AND ALLIES

ATHFIL	<i>Athyrium filix-femina</i> (L.) Roth
CYSMON	<i>Cystopteris montana</i> (Lam.) Bernh. ex Desv.
DRYDIL	<i>Dryopteris dilatata</i> auct. non (Hoffmann) Gray
EQUISE	<i>Equisetum</i> L.
EQUARV	<i>Equisetum arvense</i> L.
EQUpra	<i>Equisetum pratense</i> Ehrh.
EQUsci	<i>Equisetum scirpoides</i> Michx.
EQUsil	<i>Equisetum sylvaticum</i> L.
EQUvar	<i>Equisetum variegatum</i> Schleich. ex F. Weber & D.M.H. Mohr
GYMDRY	<i>Gymnocarpium dryopteris</i> (L.) Newman
LYCOPO	<i>Lycopodium</i> L.
LYCALP	<i>Lycopodium alpinum</i> L.
LYCANN	<i>Lycopodium annotinum</i> L.
LYCCLA	<i>Lycopodium clavatum</i> L.
LYCCOM	<i>Lycopodium complanatum</i> L.

Appendix 2: Table of species responses by burn unit

Table 13. Changes in percent cover on burned and unburned transects for all species by burn unit. "A" appended to transect abbreviation indicates pre-burn or control.

Species	CW_1A	CW_1	CW change	CE_1A	CE_1	CE change	Q11_1A	Q11_1	Q11 change	J1_1A	J1_1	J1 change	Q6_1A	Q6_1	Q6 change	Q29_1A	Q29_1	Q29 change	Q28_1A	Q28_1	Q28 change
Ferns and Allies																					
<i>Atherium filix-femina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cystopteris montana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dryopteris dilatata</i>	35	0	-35	35	4	-31	1	0	0	3	0	-3	0	0	0	0	0	0	0	0	0
<i>Equisetum arvense</i>	6	40	34	10	1	-9	0	1	1	0	25	25	32	10	-22	4	2	-2	0	0	0
<i>Equisetum pratense</i>	0	1	1	0	0	0	3	8	5	0	1	1	4	0	-3	3	2	-1	0	0	0
<i>Equisetum scirpoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum silvaticum</i>	0	0	0	1	19	18	0	1	1	0	0	0	5	4	-1	0	0	0	0	0	0
<i>Gymnocarpium dryopteris</i>	0	7	7	0	14	14	6	2	-3	7	0	-7	25	4	-21	7	2	-5	0	1	0
<i>Lycopodium alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lycopodium annotinum</i>	6	0	-6	9	0	-9	4	0	-4	0	0	0	0	0	0	1	0	-1	2	1	-1
<i>Lycopodium clavatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lycopodium complanatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Forbs																					
<i>Achillea borealis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0
<i>Aconitum delphinifolium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0
<i>Actea rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anemone richarsonii</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0
<i>Angelica lucida</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arabis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amica latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Amica sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia arctica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemisia tilesii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boschniakia rossica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Campanula rotundifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cardamine umbellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja unalaschensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cerastium beeringianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	CW_1A	CW_1	CW change	CE_1A	CE_1	CE change	Q11_1A	Q11_1	Q11 change	J1_1A	J1_1	J1 change	Q6_1A	Q6_1	Q6 change	Q29_1A	Q29_1	Q29 change	Q28_1A	Q28_1	Q28 change
<i>Chrysosplenium tetrandrum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cornus canadensis</i>	4	1	-3	2	0	-2	1	2	1	0	4	3	4	0	-3	15	7	-8	4	11	7
<i>Corydalis sempervirens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Delphinium glauca</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epilobium angustifolium</i>	1	26	25	5	34	29	0	44	44	1	13	11	1	32	31	8	15	6	4	18	15
<i>Galium boreale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Galium triflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gentiana amarella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geocaulon lividum</i>	0	0	0	0	0	0	1	0	-1	0	1	1	0	0	0	0	0	0	5	7	2
<i>Geranium erianthum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geum macrophyllum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heracleum lanatum</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Listera cordata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus nootkatensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2
<i>Mertensia paniculata</i>	0	1	1	4	0	-4	0	0	0	3	5	2	1	2	1	0	0	0	0	0	0
<i>Mimulus guttatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mitella sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moehringia lateriflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moneses uniflora</i>	0	0	0	0	0	0	1	0	-1	0	0	0	0	0	0	1	0	-1	0	0	0
<i>Osmorhiza sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parnassia palustris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pedicularis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Petasites hyperboreus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Platanthera dilatata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polemnium acutiflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
<i>Polygonum bistorta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polygonum viviparum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola chlorantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola minor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola secunda</i>	0	0	0	0	0	0	4	0	-4	1	0	-1	0	0	0	0	0	0	1	0	0
<i>Pyrola sp.</i>	0	0	0	0	0	0	11	1	-10	0	0	0	0	0	0	2	0	-2	0	0	0

Species	CW_1A	CW_1	CW change	CE_1A	CE_1	CE change	Q11_1A	Q11_1	Q11 change	J1_1A	J1_1	J1 change	Q6_1A	Q6_1	Q6 change	Q29_1A	Q29_1	Q29 change	Q28_1A	Q28_1	Q28 change
<i>Ranunculus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhinanthus minor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
<i>Rubus arcticus</i>	0	0	0	15	0	-15	0	0	0	1	1	0	-1	4	3	1	2	1	0	0	0
<i>Rubus chamaemorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus pedatus</i>	13	0	-13	0	0	0	6	0	-6	0	0	0	0	0	0	0	0	0	1	0	-1
<i>Rumex sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sanguisorba stipulata</i>	0	4	4	0	0	0	0	0	0	1	14	13	1	1	0	0	0	0	0	0	0
<i>Senecio sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Solidago multiradiata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Stellaria sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Streptopus amplexifolius</i>	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Swertia perennis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Taraxacum officinale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Thalictrum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trientalis europa</i>	1	0	-1	0	0	0	1	1	0	0	0	0	1	1	0	3	0	-3	0	0	0
<i>Valeriana sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Veratrum viride</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	-2	0	0	0
Graminoids																					
<i>Agropyron spicatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agrostis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calamagrostis canadensis</i>	4	20	16	18	44	26	4	13	9	3	6	3	15	26	11	3	11	7	1	5	5
<i>Carex deweyana</i>	0	0	0	0	0	0	0	0	0	0	2	2	0	3	3	0	0	0	0	0	0
<i>Carex machrochaeta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carex sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cinna latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Danthonia intermedia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Deschampsia beringensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca altaica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca saximontana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	CW_1A	CW_1	CW change	CE_1A	CE_1	CE change	Q11_1A	Q11_1	Q11 change	J1_1A	J1_1	J1 change	Q6_1A	Q6_1	Q6 change	Q29_1A	Q29_1	Q29 change	Q28_1A	Q28_1	Q28 change
<i>Festuca sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hierochloa alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Luzula parviflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phleum alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phleum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0	0	0
<i>Trisetum spicatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dwarf Shrubs																					
<i>Andromeda polifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos rubra</i>	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos uva-ursi</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Empetrum nigrum</i>	0	0	0	0	0	0	2	0	-2	0	1	1	0	0	0	0	0	0	20	6	-14
<i>Juniperus communis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ledum palustre</i>	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	8	0	-8
<i>Linnaea borealis</i>	7	0	-7	4	0	-4	3	0	-3	1	1	-1	0	0	0	4	3	-1	6	4	-2
<i>Oxycoccus microcarpus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium caespitosum</i>	0	0	0	0	0	0	0	0	0	5	0	-5	0	0	0	0	0	0	0	0	0
<i>Vaccinium uliginosum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
<i>Vaccinium vitis-idaea</i>	1	0	0	0	0	0	1	0	-1	0	2	2	0	0	0	5	4	0	5	10	5
Tall and Low Shrubs																					
<i>Potentilla fruticosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spiraea beauverdiana</i>	0	1	0	3	1	-2	3	2	-1	0	4	4	0	2	2	0	0	0	0	2	1
<i>Alnus crispa subsp. sinuata</i>	0	6	6	21	14	-8	37	0	-37	8	15	7	1	0	-1	0	0	0	2	10	7
<i>Betula nana</i>	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Echinopanax horridum</i>	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Menziesia ferruginea</i>	22	2	-21	12	0	-12	0	0	0	0	0	0	0	0	0	0	0	0	5	9	5
<i>Ribes sp.</i>	9	2	-7	1	1	0	22	3	-19	1	1	0	1	0	-1	0	0	0	0	0	0
<i>Rosa acicularis</i>	3	3	0	1	0	-1	22	4	-18	1	9	8	5	1	-4	6	7	1	0	0	0
<i>Rubus idaeus</i>	3	1	-1	7	6	-2	0	3	3	0	2	2	0	5	4	0	1	1	0	0	0
<i>Salix alaxensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	CW_1A	CW_1	CW change	CE_1A	CE_1	CE change	Q11_1A	Q11_1	Q11 change	J1_1A	J1_1	J1 change	Q6_1A	Q6_1	Q6 change	Q29_1A	Q29_1	Q29 change	Q28_1A	Q28_1	Q28 change
<i>Salix barclayi</i>	0	1	1	0	0	0	3	0	3	0	23	23	1	12	11	0	1	1	0	0	0
<i>Salix bebbiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix commutata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix planifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	4	0	0	0
<i>Sambucus racemosa</i>	0	0	0	7	2	-5	2	0	-2	2	0	-2	0	1	1	0	0	0	0	0	0
<i>Shepherdia canadensis</i>	0	0	0	0	0	0	2	0	-2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorbus scopulina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorbus sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium ovalifolium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viburnum edule</i>	0	1	1	1	2	0	2	1	-1	0	0	0	1	0	0	1	1	0	0	1	1
Trees																					
<i>Betula papyrifera (seedl.)</i>	0	1	0	0	0	0	1	1	0	0	3	3	0	1	1	0	12	12	0	6	6
<i>Betula papyrifera (sapl.)</i>	1	13	12	0	0	0	0	1	1	0	2	2	0	0	0	0	10	10	0	17	17
<i>Betula papyrifera (tree)</i>	13	2	-12	6	0	-6	3	1	-2	0	0	0	43	0	-42	10	1	-9	3	2	-1
<i>Picea lutzii (sapl.)</i>	3	0	-3	0	0	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0
<i>Picea lutzii (seedl.)</i>	0	0	0	0	0	0	2	0	-2	0	0	0	0	0	0	1	0	-1	0	1	0
<i>Picea lutzii (tree)</i>	22	0	-22	31	0	-31	50	0	-50	21	11	-10	56	1	-56	8	1	-7	19	4	-15
<i>Populus balsamifera (sapl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
<i>Populus balsamifera (seedl.)</i>	0	0	0	0	0	0	3	0	-3	0	0	0	0	0	0	0	1	1	0	0	0
<i>Populus balsamifera (tree)</i>	0	0	0	0	0	0	66	1	-65	0	0	0	0	2	2	5	3	-2	0	0	0
<i>Populus tremuloides (sapl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0
<i>Populus tremuloides (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1
<i>Populus tremuloides (tree)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	-24	0	1	1
<i>Salix scouleriana (sapl.)</i>	1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	1	4	3
<i>Salix scouleriana (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
<i>Salix scouleriana (tree)</i>	0	0	0	0	0	0	0	0	0	4	1	-3	0	0	0	17	1	-16	4	0	-4
<i>Tsuga mertensiana (sapl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	-3
<i>Tsuga mertensiana (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	-8
<i>Tsuga mertensiana (tree)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	3	-15

Species	Q26_1A	Q26_1	Q26 change	Q13_1A	Q13_1	Q13 change	Q34_2A	Q34_2	Q34 change	EF17_1A	EF17_1	EF17 change	DC_1A	DC_1	DC change
Ferns and Allies															
<i>Atherium filix-femina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cystopteris montana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dryopteris dilatata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum arvense</i>	0	9	9	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum pratense</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum scirpoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum silvaticum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gymnocarpium dryopteris</i>	10	23	13	0	0	0	0	0	0	0	3	3	0	0	0
<i>Lycopodium alpinum</i>	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0
<i>Lycopodium annotium</i>	14	0	-14	1	0	-1	0	0	0	2	1	-2	3	0	-3
<i>Lycopodium clavatum</i>	0	0	0	0	0	0	0	0	0	1	0	-1	0	0	0
<i>Lycopodium complanatum</i>	0	0	0	6	2	-5	3	0	-3	4	0	-4	0	0	0
Forbs															
<i>Achillea borealis</i>	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
<i>Aconitum delphinifolium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Actea rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Anemone richarsonii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Angelica lucida</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arabis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemesia arctica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemesia tilesii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boschniakia rossica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Campanula rotundifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cardamine umbellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja unalaschensis</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cerastium beeringianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Q26_1A	Q26_1	Q26 change	Q13_1A	Q13_1	Q13 change	Q34_2A	Q34_2	Q34 change	EF17_1A	EF17_1	EF17 change	DC_1A	DC_1	DC change
<i>Chrysosplenium tetrandrum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cornus canadensis</i>	9	6	-3	3	7	4	7	2	-4	18	5	-13	0	26	26
<i>Corydalis sempervirens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Delphinium glauca</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epilobium angustifolium</i>	3	26	23	3	15	12	0	3	3	1	3	3	0	3	3
<i>Galium boreale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Galium triflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Gentiana amarella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geocaulon lividum</i>	4	0	-4	4	3	-1	3	6	3	7	6	-1	10	4	-6
<i>Geranium erianthum</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geum macrophyllum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heracleum lanatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Listera cordata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus nootkatensis</i>	0	1	1	2	2	1	0	5	5	0	3	2	0	0	0
<i>Mertensia paniculata</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mimulus guttatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mitella sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moehringia lateriflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moneses uniflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Osmorhiza sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Parnassia palustris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pedicularis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Petasites hyperboreus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Platanthera dilatata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polemnium acutiflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polygonum bistorta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polygonum viviparum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola chlorantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola minor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola secunda</i>	1	0	-1	0	0	0	1	0	-1	0	0	0	0	0	0
<i>Pyrola sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Q26_1A	Q26_1	Q26 change	Q13_1A	Q13_1	Q13 change	Q34_2A	Q34_2	Q34 change	EF17_1A	EF17_1	EF17 change	DC_1A	DC_1	DC change
<i>Ranunculus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhinanthus minor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus arcticus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus chamaemorus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus pedatus</i>	5	0	-5	0	0	0	0	0	0	1	1	-1	0	0	0
<i>Rumex sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sanguisorba stipulata</i>	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Senecio sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Solidago multiradiata</i>	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
<i>Stellaria sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Streptopus amplexifolius</i>	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Swertia perennis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Taraxacum officinale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Thalictrum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trientalis europa</i>	1	0	0	1	1	0	0	0	0	1	1	0	0	0	0
<i>Valeriana sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Veratrum viride</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Graminoids															
<i>Agropyron spicatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agrostis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calamagrostis canadensis</i>	1	8	7	0	5	4	0	0	0	1	1	1	0	1	1
<i>Carex deweyana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carex machrochaeta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carex sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cinna latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Danthonia intermedia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Deschampsia beringensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca altaica</i>	0	0	0	2	0	-1	0	0	0	0	0	0	0	0	0
<i>Festuca rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca saximontana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Q26_1A	Q26_1	Q26 change	Q13_1A	Q13_1	Q13 change	Q34_2A	Q34_2	Q34 change	EF17_1A	EF17_1	EF17 change	DC_1A	DC_1	DC change
<i>Festuca sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hierochloa alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Luzula parviflora</i>	0	0	0	0	3	3	0	0	0	0	0	0	0	0	0
<i>Phleum alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phleum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa sp.</i>	0	3	3	0	4	4	0	0	0	0	0	0	0	0	0
<i>Trisetum spicatum</i>	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0
Dwarf Shrubs															
<i>Andromeda polifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos uva-ursi</i>	0	0	0	0	0	0	1	11	10	0	0	0	0	0	0
<i>Empetrum nigrum</i>	4	0	-3	11	4	-8	9	0	-8	17	25	9	5	12	6
<i>Juniperus communis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ledum palustre</i>	0	0	0	0	0	0	0	0	0	0	0	0	2	3	1
<i>Linnaea borealis</i>	5	2	-4	6	3	-3	4	1	-2	1	1	-1	0	0	0
<i>Oxycoccus microcarpus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium caespitosum</i>	0	2	2	3	9	7	0	0	0	5	6	1	0	0	0
<i>Vaccinium uliginosum</i>	0	0	0	16	4	-12	0	0	0	5	8	4	2	2	0
<i>Vaccinium vitis-idaea</i>	2	3	1	2	5	3	11	3	-8	4	1	-3	4	19	15
Tall and Low Shrubs															
<i>Potentilla fruticosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Spiraea beauverdiana</i>	0	1	0	0	0	0	0	0	0	3	5	1	0	1	1
<i>Alnus crispa subsp. sinuata</i>	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
<i>Betula nana</i>	0	0	0	4	7	4	0	0	0	14	21	7	0	0	0
<i>Echinopanax horridum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Menziesia ferruginea</i>	1	1	0	0	0	0	0	0	0	0	0	0	7	0	-6
<i>Ribes sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rosa acicularis</i>	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus idaeus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix alaxensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	Q26_1A	Q26_1	Q26 change	Q13_1A	Q13_1	Q13 change	Q34_2A	Q34_2	Q34 change	EF17_1A	EF17_1	EF17 change	DC_1A	DC_1	DC change
<i>Salix barclayi</i>	2	4	2	4	4	0	0	0	0	3	6	3	0	0	0
<i>Salix bebbiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix commutata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix planifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
<i>Salix sitchensis</i>	0	0	0	0	1	1	0	5	5	0	0	0	0	0	0
<i>Sambucus racemosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Shepherdia canadensis</i>	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
<i>Sorbus scopulina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorbus sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium ovalifolium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viburnum edule</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees															
<i>Betula papyrifera (seedl.)</i>	0	1	1	0	2	2	0	8	8	0	0	0	0	16	16
<i>Betula papyrifera (sapl.)</i>	0	1	1	0	2	2	0	23	23	1	1	0	0	5	5
<i>Betula papyrifera (tree)</i>	10	0	-10	1	0	-1	11	1	-10	1	0	-1	25	2	-23
<i>Picea lutzii (sapl.)</i>	0	0	0	1	3	2	0	1	1	1	2	1	1	1	0
<i>Picea lutzii (seedl.)</i>	0	0	0	3	1	-3	1	1	0	2	2	0	0	1	0
<i>Picea lutzii (tree)</i>	39	0	-39	28	1	-28	17	0	-17	18	3	-15	30	5	-25
<i>Populus balsamifera (sapl.)</i>	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0
<i>Populus balsamifera (seedl.)</i>	0	0	0	0	0	0	0	12	12	0	0	0	0	0	0
<i>Populus balsamifera (tree)</i>	0	0	0	3	0	-2	4	0	-4	0	0	0	0	0	0
<i>Populus tremuloides (sapl.)</i>	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
<i>Populus tremuloides (seedl.)</i>	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0
<i>Populus tremuloides (tree)</i>	9	0	-9	3	3	0	4	0	-4	0	0	0	0	0	0
<i>Salix scouleriana (sapl.)</i>	1	1	-1	0	6	6	0	0	0	3	5	2	1	2	1
<i>Salix scouleriana (seedl.)</i>	0	0	0	0	1	1	0	1	1	0	1	1	0	1	1
<i>Salix scouleriana (tree)</i>	16	9	-8	1	1	0	3	0	-3	5	6	1	4	0	-4
<i>Tsuga mertensiana (sapl.)</i>	4	0	-4	0	0	0	0	0	0	2	2	0	1	0	-1
<i>Tsuga mertensiana (seedl.)</i>	2	0	-2	1	0	-1	0	0	0	1	0	0	0	0	0
<i>Tsuga mertensiana (tree)</i>	24	0	-24	0	0	0	0	0	0	3	1	-2	5	1	-4

Species	EF8_2A	EF8_2	EF8 change	EF21_ 1A	EF21_ 1	EF21 change	EF3_ 1A	EF3_ 1	EF3 change	J5_ 1A	J5_ 1	J5 change	CC_ 1A	CC_ 1	CC change
Ferns and Allies															
<i>Atherium filix-femina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
<i>Cystopteris montana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dryopteris dilatata</i>	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	0
<i>Equisetum arvense</i>	0	0	0	0	0	0	0	0	0	2	0	2	0	11	11
<i>Equisetum pratense</i>	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum scirpoides</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Equisetum silvaticum</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1
<i>Gymnocarpium dryopteris</i>	0	0	0	0	1	1	0	0	0	0	0	0	5	8	3
<i>Lycopodium alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lycopodium annotium</i>	0	0	0	0	0	0	0	0	0	0	0	0	5	0	-5
<i>Lycopodium clavatum</i>	0	0	0	1	0	-1	1	0	-1	0	0	0	0	0	0
<i>Lycopodium complanatum</i>	0	0	0	0	1	1	0	0	0	0	0	0	1	0	-1
Forbs															
<i>Achillea borealis</i>	0	1	1	0	0	0	0	0	0	5	1	-4	0	2	2
<i>Aconitum delphinifolium</i>	0	1	1	0	0	0	0	0	0	2	0	-1	0	0	0
<i>Actea rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	4	5	1
<i>Anemone richarsonii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Angelica lucida</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arabis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arnica sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemesia arctica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Artemesia tilesii</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boschniakia rossica</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Campanula rotundifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cardamine umbellata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Castilleja unalaschensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
<i>Cerastium beeringianum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	EF8_ 2A	EF8_ 2	EF8 change	EF21_ 1A	EF21_ 1	EF21 change	EF3_ 1A	EF3_ 1	EF3 change	J5_ 1A	J5_ 1	J5 change	CC_ 1A	CC_ 1	CC change
<i>Chrysosplenium tetrandrum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cornus canadensis</i>	10	5	-5	7	4	-3	4	3	-1	-1	-1	0	6	19	13
<i>Corydalis sempervirens</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Delphinium glauca</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epilobium angustifolium</i>	1	9	8	1	4	3	1	7	6	8	7	-1	1	23	22
<i>Galium boreale</i>	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Galium triflorum</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
<i>Gentiana amarella</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geocaulon lividum</i>	4	0	-4	7	1	-6	0	0	0	0	0	0	0	0	0
<i>Geranium erianthum</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Geum macrophyllum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Heracleum lanatum</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	3	3
<i>Listera cordata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Lupinus nootkatensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mertensia paniculata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mimulus guttatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Mitella sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moehringia lateriflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Moneses uniflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Osmorhiza sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1
<i>Parnassia palustris</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pedicularis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Petasites hyperboreus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Platanthera dilatata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polemnium acutiflorum</i>	0	0	0	0	0	0	0	0	0	5	1	-4	0	0	0
<i>Polygonum bistorta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Polygonum viviparum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola chlorantha</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola minor</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Pyrola secunda</i>	0	0	0	0	0	0	0	0	0	2	0	-2	0	0	0
<i>Pyrola sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1

Species	EF8_2A	EF8_2	EF8 change	EF21_1A	EF21_1	EF21 change	EF3_1A	EF3_1	EF3 change	J5_1A	J5_1	J5 change	CC_1A	CC_1	CC change
<i>Ranunculus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rhinanthus minor</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rubus arcticus</i>	3	5	2	0	1	1	7	3	-4	6	3	-4	0	0	0
<i>Rubus chamaemorus</i>	0	0	0	0	0	0	0	0	0	2	0	-2	0	0	0
<i>Rubus pedatus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rumex sp.</i>	0	0	0	0	0	0	0	0	0	2	0	-2	0	0	0
<i>Sanguisorba stipulata</i>	0	5	5	0	0	0	3	0	-3	5	1	-4	0	0	0
<i>Senecio sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Solidago multiradiata</i>	0	0	0	0	0	0	0	1	1	4	0	-4	0	0	0
<i>Stellaria sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Streptopus amplexifolius</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Swertia perennis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Taraxacum officinale</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Thalictrum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trientalis europa</i>	1	0	-1	1	2	1	2	1	-1	0	0	0	1	1	0
<i>Valeriana sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Veratrum viride</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viola sp.</i>	0	0	0	0	0	0	1	0	-1	0	0	0	0	1	1
Graminoids															
<i>Agropyron spicatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Agrostis sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Calamagrostis canadensis</i>	4	4	0	1	3	2	5	7	2	1	1	0	7	16	8
<i>Carex deweyana</i>	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0
<i>Carex macrochaeta</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Carex sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cinna latifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Danthonia intermedia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Deschampsia beringensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca altaica</i>	0	0	0	0	0	0	1	8	7	6	16	9	0	0	0
<i>Festuca rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Festuca saximontana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	EF8_2A	EF8_2	EF8 change	EF21_1A	EF21_1	EF21 change	EF3_1A	EF3_1	EF3 change	J5_1A	J5_1	J5 change	CC_1A	CC_1	CC change
<i>Festuca sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Hierochloa alpina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Juncus sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Luzula parviflora</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phleum alpinum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Phleum sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Poa sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Trisetum spicatum</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dwarf Shrubs															
<i>Andromeda polifolia</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos rubra</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Arctostaphylos uva-ursi</i>	1	3	2	0	1	1	0	0	0	0	0	0	0	0	0
<i>Empetrum nigrum</i>	32	0	-32	16	7	-9	12	1	-11	0	0	0	0	0	0
<i>Juniperus communis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Ledum palustre</i>	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0
<i>Linnaea borealis</i>	0	0	0	1	0	-1	0	0	0	0	0	0	0	1	0
<i>Oxycoccus microcarpus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium caespitosum</i>	0	1	1	0	0	0	8	7	0	0	2	2	0	0	0
<i>Vaccinium uliginosum</i>	0	0	0	10	4	-6	2	3	1	1	0	-1	0	0	0
<i>Vaccinium vitis-idaea</i>	8	1	-6	9	5	-4	7	2	-5	3	1	-2	0	0	0
Tall and Low Shrubs															
<i>Potentilla fruticosa</i>	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0
<i>Spirea beauverdiana</i>	0	0	0	5	4	-1	10	1	-9	0	0	0	0	0	0
<i>Alnus crispa subsp. sinuata</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-1
<i>Betula nana</i>	11	7	-4	19	22	3	16	26	10	9	15	6	0	0	0
<i>Echinopanax horridum</i>	0	0	0	0	0	0	0	0	0	0	0	0	9	5	-4
<i>Menziesia ferruginea</i>	0	0	0	0	0	0	0	0	0	0	0	0	6	0	-6
<i>Ribes sp.</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Rosa acicularis</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	2	1
<i>Rubus idaeus</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
<i>Salix alaxensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Species	EF8_2A	EF8_2	EF8 change	EF21_1A	EF21_1	EF21 change	EF3_1A	EF3_1	EF3 change	J5_1A	J5_1	J5 change	CC_1A	CC_1	CC change
<i>Salix barclayi</i>	6	9	3	3	6	3	8	18	10	21	32	11	0	0	0
<i>Salix bebbiana</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix commutata</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Salix planifolia</i>	0	0	0	2	2	-1	0	0	0	1	3	2	0	0	0
<i>Salix sitchensis</i>	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
<i>Sambucus racemosa</i>	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
<i>Shepherdia canadensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorbus scopulina</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Sorbus sitchensis</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Vaccinium ovalifolium</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Viburnum edule</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Trees															
<i>Betula papyrifera (seedl.)</i>	4	0	-4	0	2	1	0	0	0	0	0	0	0	3	3
<i>Betula papyrifera (sapl.)</i>	0	1	1	0	10	10	0	0	0	0	0	0	0	1	1
<i>Betula papyrifera (tree)</i>	0	0	0	0	0	0	0	0	0	0	0	0	35	1	-34
<i>Picea lutzii (sapl.)</i>	0	0	0	2	0	-2	2	0	-2	0	0	0	1	0	-1
<i>Picea lutzii (seedl.)</i>	2	0	-1	1	0	-1	1	0	-1	0	0	0	0	0	0
<i>Picea lutzii (tree)</i>	50	0	-50	39	5	-34	43	0	-43	4	4	0	13	3	-10
<i>Populus balsamifera (sapl.)</i>	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
<i>Populus balsamifera (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Populus balsamifera (tree)</i>	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Populus tremuloides (sapl.)</i>	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0
<i>Populus tremuloides (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Populus tremuloides (tree)</i>	0	0	0	1	0	-1	0	0	0	0	0	0	0	0	0
<i>Salix scouleriana (sapl.)</i>	0	4	4	0	5	4	0	0	0	0	0	0	0	0	0
<i>Salix scouleriana (seedl.)</i>	5	0	-4	0	0	0	0	0	0	0	0	0	1	1	-1
<i>Salix scouleriana (tree)</i>	0	0	0	1	0	-1	0	0	0	0	0	0	4	4	-1
<i>Tsuga mertensiana (sapl.)</i>	0	0	0	1	0	-1	0	0	0	0	0	0	2	0	-2
<i>Tsuga mertensiana (seedl.)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
<i>Tsuga mertensiana (tree)</i>	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3: Comparison of control and pre-burn data

Table 14. Comparison of control and pre-burn data for all units.

Unit Name	pre-burn transect in burn	control transect adjacent to burn, read w/i five years of burn	control transect adjacent to burn, read 15-20 years after burn
Quartz Creek 11	X		
Quartz Creek 6		X	X
Juneau 1	X		
Caribou E	X		
Caribou W		X	
Cripple Creek			X
Quartz Creek 29	X		
East Fork 17			X
Dave's Creek Test			X
Quartz Creek 28			X
Quartz Creek 13			X
Quartz Creek 26			X
Juneau 5		X	
East Fork 3			X
East Fork 8		X	
East Fork 21		X	X
Quartz Creek 34		X	X

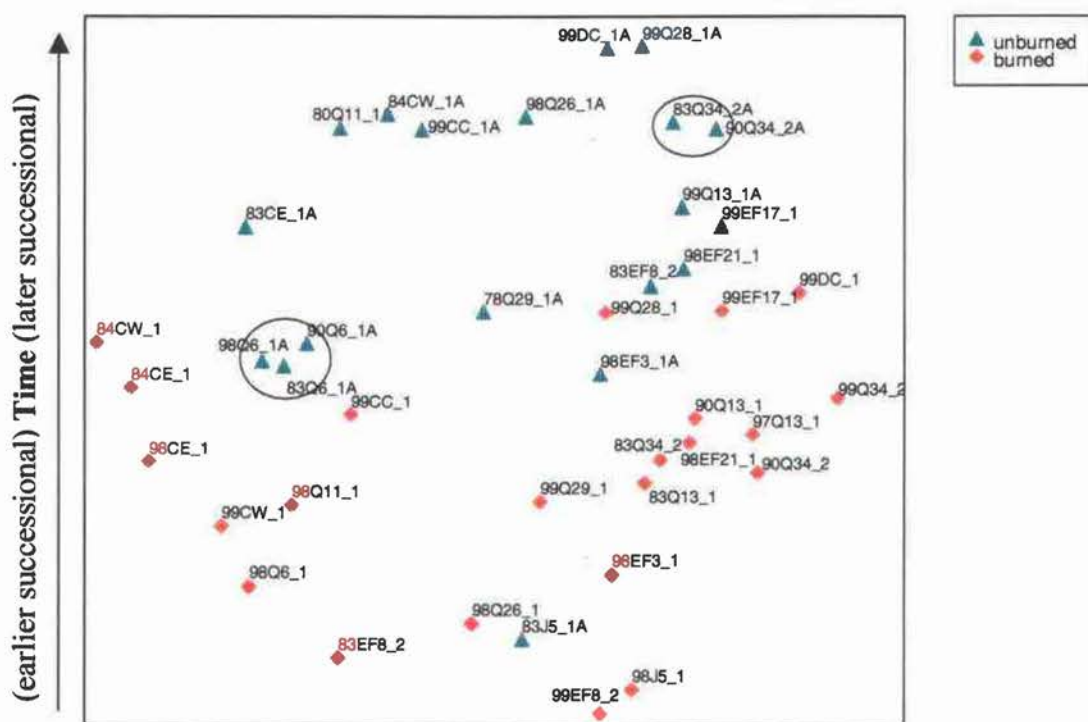


Figure 14. NMS ordination (Axis 2 vs. Axis 3) including multiple readings of two control plots, Quartz 6 1A (three plots) and Quartz 34 2A (two plots). Readings of plots at the same control point are circled.

Figure 14 shows the relationship in species space of control plots read at different times between 1983 and 1999. The control plot at Quartz 6 was read in 1983, 1990, and 1998. The proximity of the points in the ordination space indicates that there has been little change in species composition in the control plot over a 15-year period. The control plot at Quartz 34 was read in 1983 and in 1990. Again, there was little evidence of change in species composition. Although spruce bark beetles have caused considerable mortality in these plots, species composition has yet to show directional change. Spruce abundance has been considerably reduced by beetle mortality in these plots. Spruce mortality data were collected, and crown cover of recently killed spruce trees was added to the live spruce cover.