THE INITIAL RESPONSE OF SEVERAL FORAGE SPECIES TO PRESCRIBED BURNING IN SOUTHEASTERN BRITISH COLUMBIA

by

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ABSTRACT

This study was initiated in 1985 to assess the response of seven key forage and browse species to prescribed burning for wildlife habitat and range improvement in the East Kootenay region of British Columbia. The species studied were *Agropyron spicatum* (bluebunch wheatgrass), *Amelanchier alnifolia* (saskatoon), *Ceanothus velutinus* (snowbrush), *Festuca scabrella* (rough fescue), *Purshia tridentata* (bitterbrush), *Stipa occidentalis* (stiff needlegrass), and *Symphoricarpos albus* (common snowberry).

The primary objective of the study was to determine how these species respond to burning in terms of percent cover and current annual growth. There were two approaches to this study. First, experimentally burned plots were established on two sites. Spring and fall burning were carried out on one site and fall burning on a second site. Second, five previously operationally burned areas were compared with immediately adjacent unburned areas to assess differences in the percent cover of all the species and in the sprouting response of bitterbrush. Three of the sites were sampled in the first postburn growing season, one site was sampled in the second postburn growing season, and one site was sampled in the fourth postburn growing season.

The total preburn fuel load on these sites ranged from 1.2 to 2.0 kg/m^2. Total fuel consumption varied from 53 to 91% on the experimentally burned plots. The variability of each fuel load component was high.

In the first growing season following fall and spring burning, and the second growing season following fall burning, there were no significant differences in the percent cover of all species except bitterbrush and stiff needlegrass between burned and unburned plots. There was significantly less bitterbrush following both spring and fall burning. By the second growing season, bitterbrush had recovered slightly following fall burning. There was significantly more (33%) percent cover of stiff needlegrass on the fall burned plots both in the first and second growing season following burning.

The only species for which there was a significant difference in the current annual growth on fall burned plots compared with control plots, were bitterbrush and saskatoon. There was 71% less current annual growth of bitterbrush the first growing season following fall burning. Saskatoon had 48% less current annual growth on the fall burned plots compared with the control plots.

The results for percent cover were similar on the operationally burned areas. At all but the four-year-old operationally burned site, there was significantly less percent cover of bitterbrush on the burned plots compared with unburned plots. The percent decrease varied from 76 to 90%.

At a two-year-old operationally burned site, there was 58% less snowberry on burned plots compared with unburned plots. At the same site there was less rough fescue (94%) but this represented only a 2% decrease in the percent cover. There was 58% more percent cover of stiff needlegrass on one of the one-year-old operationally burned sites.

On these sites the postfire survival adaptation of all these species was by resprouting from either buds at the surface or the base of the plant, or from underground rhizomes. Some graminoid species seeded in from off-site seed sources.

This study shows that where bitterbrush is the focus of enhancement, prescribed burning may have initial detrimental effects regardless of the timing of burning. The effects appear to be more variable and less dramatic for the other species studied.

The implications of the response of these forage species to current prescribed burning practices are discussed and recommendations on future research are made.

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1 INTRODUCTION

Fire has been an important natural force in many ecosystems, affecting the distribution and form of plant species, as well as the species composition of the vegetation (Daubenmire 1968). Past fire management efforts have focused on the suppression and control of wildfires, both natural and human-caused, but it is now recognized that fire has an important role in maintaining particular plant communities while suppressing others, thus having a role in initiating secondary succession. Certain plant communities require periodic fires for their perpetuation (Mutch 1970).

Generally defined, prescribed burning is the deliberate use of fire for constructive purposes and according to a specific management plan (Eastman 1977). Lotti (1962) defined prescribed burning more precisely as "the skillful application of fire to natural fuels under conditions of weather, fuel moisture and soil moisture that will allow confinement of the fire to a predetermined area and at the same time will produce the intensity of heat and rate of spread required to accomplish certain planned benefits to one or more objectives of silviculture, livestock and wildlife management or hazard reduction."

In British Columbia, the history of fire use by humans begins with aboriginal people, who reportedly burned meadows for fire control purposes, for the maintenance of browse and grazing areas for game and stock animals, and to maintain berry patches. More recently humans have burned sloughs, marshes and stream courses to increase the availability and abundance of fur-bearing animals, burned deadfall/windfall in forests to prevent potential wildfires, burned to improve settlement areas and campsites, burned to create and maintain trails, and burned for aesthetic and religious purposes (Lewis 1982; Foote 1983).

Prescribed burning is currently used for a number of purposes in a wide variety of vegetative communities. These purposes include the removal of unpalatable and unproductive growth of forage plant species with the intention of increasing palatability and productivity, the control of disease and insects, the control of the encroachment by conifers, or development of undesired plant species and the promotion of desirable food plants, the control of animal distribution on a particular area, the removal of fuels which have accumulated naturally or as a result of logging, and the preparation of seedbeds for seeding and planting (Kayll 1974)

Prescribed burning for the improvement of wildlife habitat and range is a common practice. For wildlife purposes, fire is used to maintain a diversity of plant communities, in particular early seral stages of plant succession, which are important as habitat for food and sometimes as shelter to large populations of wildlife species (Kayll 1974). For range management purposes, fire is often used to rejuvenate grassland communities and to prevent the encroachment of conifers into these communities.

While B.C. has a wide variety of wildlife species, most public attention is focused on the big game species. It is the critical winter ranges of these wildlife species as well as cattle range which are being lost, due to both a diminishing land base and the vegetational changes occurring on this land base (Eastman 1977). There has been increased alienation of very productive lands for wildlife and livestock due to activities such as settlement, and the development of hydro reservoir impoundments, power line right-of-ways and strip mines (Demarchi and Demarchi 1987). Prescribed burning is one management tool currently being used by the Ministries of Environment and Forests in an attempt to restore and enhance important browse areas.

Prescribed burning by government resource managers to enhance habitat for wildlife in B.C. was first initiated in Wells Gray Park during the period 1965 to 1973 to enhance moose habitat (Fish and Wildlife Branch 1977). The use of prescribed burning for wildlife habitat improvement in B.C. has generally increased over the eleven-year period from 1977 to 1987, compared with the use of other habitat enhancement techniques such as mechanical cutting or thinning, and selective logging (Figure 1). In 1987, prescribed burning in B.C. for enhancement purposes was conducted on 55 967 hectares (Halladay 1988).

The East Kootenay region of B.C. is ecologically diverse and hence particularly important for its capacity to support a wide variety of ungulates in large numbers (Demarchi 1986). This region is also valuable for forestry, mining, hydroelectricity, ranching, and outdoor recreation. Alienation and/or alteration of wildlife habitat has resulted both directly and indirectly from the conflicting demands for these natural resources (Demarchi 1986).

A key determinant of the numbers and diversity of wildlife populations in the southern East Kootenay is the presence of the Rocky Mountain Trench, which provides low elevation habitat adjacent to the Purcell and Rocky Mountains. These lower elevation areas have lower snowfall, and therefore provide easy movement and access to low-growing plants during winter months (Tipper 1988). They are also in close proximity to high elevation summer ranges. These winter ranges are in early seral stages, providing shrub-dominated plant communities which are important as forage to Rocky Mountain elk (*Cervus elaphus nelsoni*), mule deer (*Odocoileus hemionus*) and white-tailed deer (*Odocoileus virginianus ochourus*).

Most of the winter ranges in the Rocky Mountain Trench have burned in this century. Early seral plant communities replaced mature Ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), and Douglas-fir (*Pseudotsuga menziesii*) forests following widespread wildfires in the early 1930's. These high-intensity wildfires were partially the result of large accumulations of fuel and debris following logging (Demarchi 1986; Tipper 1988). Fire suppression since the 1930's has largely eliminated wildfires in these areas, resulting in increased conifer encroachment onto wildlife habitat and range (Tipper 1979). Fire history records show that the natural fire frequency in similar ecosystems is 6 to 13 years (Cooper

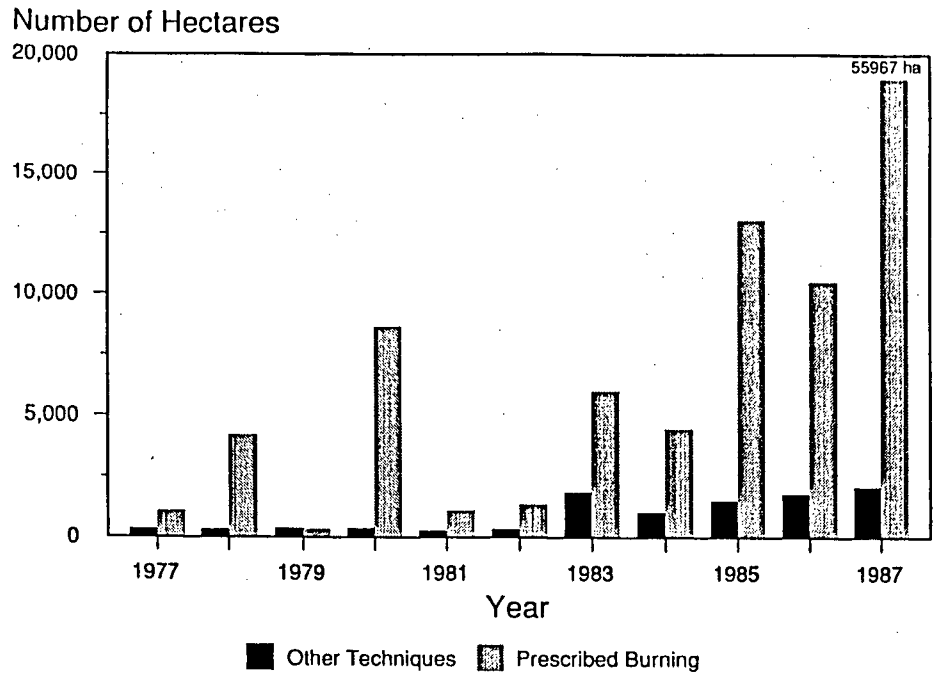


Figure 1. Prescribed burning compared with other habitat enhancement techniques in British Columbia.[1]

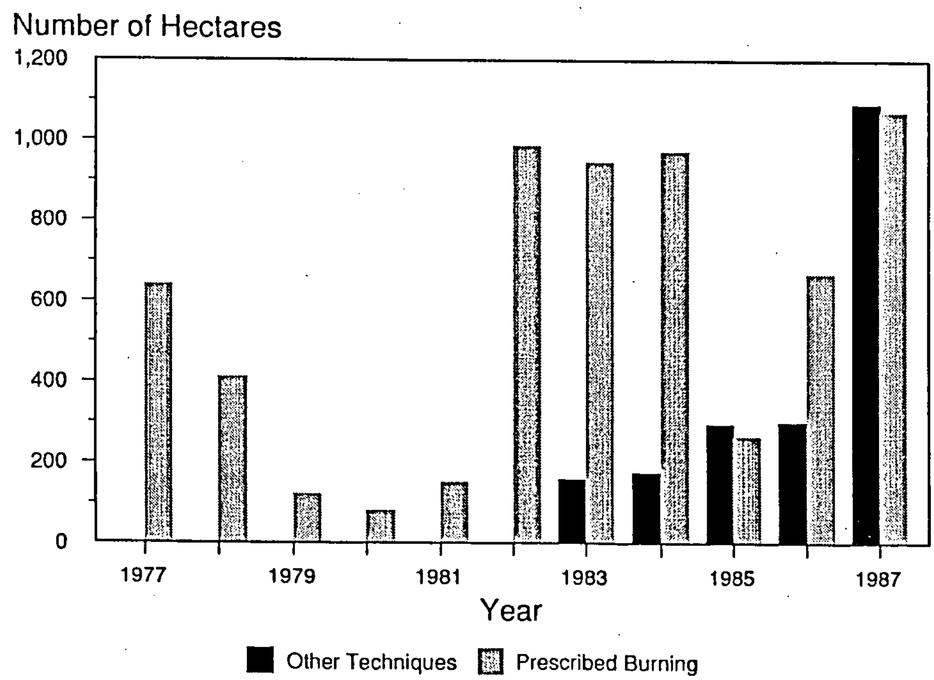


Figure 2. Prescribed burning compared with other habitat enhancement techniques in the East Kootenay.[1]

[1] Source: Halladay (1988)

1961).

Major prescribed burning activities to enhance wildlife habitat and range were initiated in 1975 by the provincial Ministry of Environment (Fish and Wildlife Branch) in cooperation with the Ministry of Forests (Range Branch). This activity is partially funded by the Habitat Conservation Fund, whose target species are primarily elk, but also mule deer, bighorn sheep (*Ovis canadensis canadensis*) and white-tailed deer. Since 1977, prescribed burning has increased in the East Kootenay, especially in the period since 1981 (Figure 2) (Halladay 1988; Tipper 1988). The main objectives of burning are to recondition and rejuvenate existing big game winter ranges, to enhance range for cattle, and to thin and prevent encroachment by regenerating forests. These prescribed burns have largely occurred in the spring, but attempts are now being made to burn in the late summer and early fall (Tipper 1988).

Observations have suggested that the vegetative response to these prescribed burns has been resprouting of important browse and grass species, which has been accompanied by increased animal use (Eastman 1977). Previous East Kootenay studies into the effects of these prescribed burns on vegetation have suggested that the response of the vegetation to fire is highly variable (Demarchi and Lofts 1985; Davidson in prep.). The successful use of prescribed fire as a vegetation management tool depends on the knowledge and understanding of a complex of factors and their interactions. These factors include site characteristics such as fuel loading, topography, aspect, elevation and plant species composition, weather conditions prior to, during and following burning, fire characteristics such as the severity and rate of spread, and the timing of the burn.

Wikeem and Strang (1983) stressed that there is "a lack of information necessary to conduct prescribed burning or to predict the effects for most objectives of forage, habitat and range management in B.C." They go as far as to say that "the art of prescribed burning is not yet well developed here, indeed many of the burns presently called "prescribed" might be defined as "controlled"." Given the complexity of fire and the lack of quantitative knowledge available on the effects of prescribed burning, particularly in the southern Rocky Mountain Trench, a study was initiated in 1985 to assess the effects on vegetation of prescribed burning for wildlife habitat improvement.

There are four important questions which required answers:

(1) How do key browse and forage species respond to burning?

(2) What is the quantity of fuel on these sites and how much fuel is consumed by burning? Is this related to the vegetation response?

(3) What effects do time of burning and fire weather conditions (i.e., burning prescriptions) have on fuel consumption and vegetative response?

(4) Does prescribed burning achieve management objectives, and how long are the effects of prescribed burning maintained?

There were two main approaches to this research project. The first approach was to conduct an extensive inventory of the operational prescribed burning activity in the southern Rocky Mountain Trench. This inventory was intended to collect relevant information on past burns that would better enable managers to determine the most suitable prescriptions from the viewpoint of promoting desired plant species. The second approach to this project was to conduct detailed sampling of experimentally burned plots to attempt to determine the optimal burning conditions for promoting several plant species of particular importance as food to ungulates and cattle, as well as to quantify consumption of fuel in these ecosystems.

The seven plant species selected were of interest to local wildlife managers in this area. These were three grasses (bluebunch wheatgrass (*Agropyron spicatum*), rough fescue (*Festuca scabrella*), and stiff needlegrass (*Stipa occidentalis*)), and four shrubs (saskatoon (*Amelanchier alnifolia*), snowbrush (*Ceanothus velutinus*), bitterbrush (*Purshia tridentata*), and common snowberry (*Symphoricarpos albus*)). All are important forage species to ungulates and cattle in the East Kootenay.

The primary focus of this research project was to study the response of these seven species to spring and fall burning and response was measured in terms of percent cover and current annual growth. Experimental plots were established on two sites with the purpose of comparing spring and fall burning. The experimental burns were characterized by quantifying fuel changes, observing fire behaviour characteristics and correlating changes in fuel to fire weather variables and Fire Weather Index System codes and indices.

The response of the selected species (measured by percent cover) was also studied on several operational burns over a wider range of years since burning. The fire severity achieved on the operational burns was assessed using percent sprouting of bitterbrush.

The management implications and recommendations resulting from this study are also proposed.

2 STUDY AREA DESCRIPTION

2.1 Location

The study sites are located within the southern Rocky Mountain Trench in the East Kootenay region of southeastern British Columbia (see Figure 3). The Pickering Hills range unit is located east of the Kootenay River and south of the Bull River, approximately 2 km east of Wardner, B.C. The Power Plant range unit is located immediately north of the Bull River. The Newgate range unit is located approximately 2 km north of the international border at Newgate, B.C., on the west bank of Koocanusa Reservoir. The Luckhurst range unit is located 3 km northwest of Skookumchuk, B.C. All study sites occur at elevations between 850 and 950 m.

2.2 Topography and Terrain

The East Kootenay region can be divided into three broad physiographic regions: the Purcell Mountains, the Rocky Mountains and the Rocky Mountain Trench (Ryder 1981). The study sites are located within the Rocky Mountain Trench, and therefore discussion will be limited to this region. The Rocky Mountain Trench is a major topographic feature bounded by the Rocky Mountains on the eastern front and extending some 1500 km, from northwestern Montana to 59 degrees latitude north (Ryder 1981).

Holland (1976) describes the Rocky Mountain Trench as a structurally controlled valley 8 to 25 km wide, varying between 760 and 1060 m in elevation, which was considerably modified by erosion and by glaciation during the Pleistocene period. The Trench consists of surficial materials commonly derived from the calcareous bedrock of the Rockies, and consisting primarily of large areas of hilly moraine (till). Gravelly glaciofluvial meltwater channel deposits, terraces and fans are interspersed between the hills. Silty and clayey

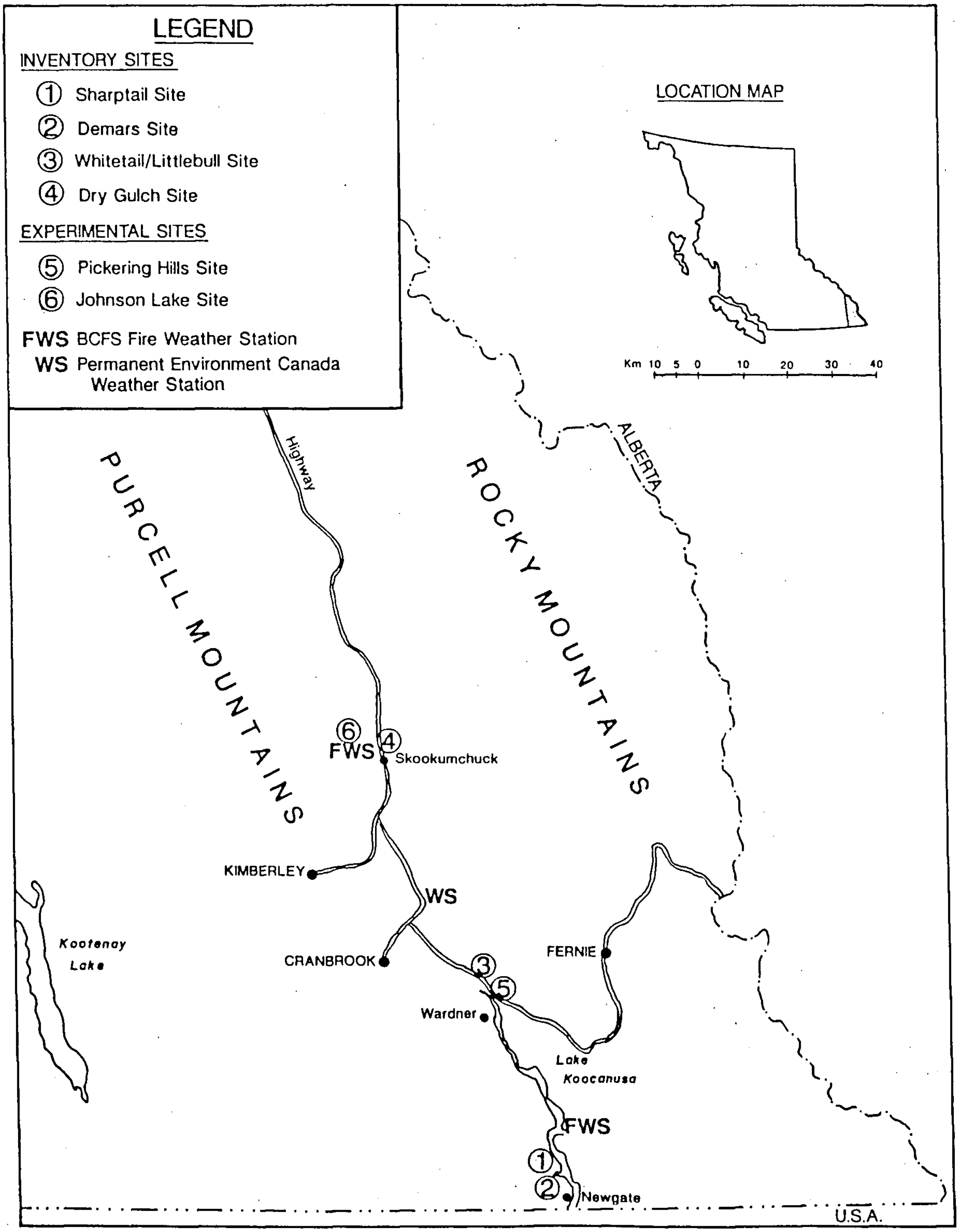


Figure 3. Location of the study sites in the Rocky Mountain Trench, southeastern B.C.

textured glaciolacustrine deposits occur where glacial lakes developed between valley glacier and valley walls (Demarchi 1986). The study sites generally occur at lower elevations in the Trench on large glaciofluvial terraces and morainal deposits, having either south-facing slopes or flat terraces. Table 1 provides the elevation, aspect, slope and dominant parent materials at each study site.

2.3 Soils

The soils in the study area are highly calcareous, derived from limestone parent material (Demarchi and Lofts 1985). Soil development is classified as Orthic Eutric Brunisol according to Lacelle (1990) (Table 1). The soil physical and chemical properties are largely influenced by the types of surficial material from which they have weathered (Lea *et al.* 1990). The soil texture varies locally but is generally gravelly silt loam (Table 1). The moisture regime of these sites is very xeric to xeric and the nutrient regime is generally mesotrophic to permesotrophic (Utzig *et al.* 1986).

2.4 Climate

The southern Rocky Mountain Trench is located in a rainshadow leeward of the Columbia Mountains. It has an upland continental-type climate with well defined seasons (Marsh 1986). Cold arctic air flows down the Trench during the winter and early spring resulting in cold winters with light snowfall. The summer is characteristically very warm and dry (Utzig *et al.* 1986). Low precipitation and high temperatures in July and August result in drought conditions during this period (Marsh 1986).

Local climate can change markedly over short distances depending on such factors as relief, elevation, aspect and slope position. Most importantly, precipitation and

Table 1. Summary of topographic features[1], soil characteristics[2], and wildlife capability[3] for all study sites.

Study Site	Plots	Aspect	Elevation (m)	Slope (%)	Major Terrain Parent Material	Soil Description (Soil Classification)	Most Common Texture	Drainage Class	Wildlife Capability
Pickering Hills	All	South	960	25	thick, morainal material (till)	Orthic Eutric Brunisol (Marmalade)	gravelly silt loam	well drained	High W.R. Elk, White-tailed deer; Moderate W.R. Mule deer
Johnson Lake	All	Flat	854	0	Glacio-fluvial material	Orthic Eutric Brunisol (Fishertown)	gravelly sandy loam	rapidly drained	Moderate W.R. - Elk, Mule and White-tailed Deer; Moderate S.R. -Moose
Upper Sharptail	1-5	Flat	854	5	Lacustrine material	Orthic Eutric Brunisol (Kayook)	silty to gravelly sandy loam	well drained	High W.R.- Elk, Mule and White-tailed deer
Lower Sharptail	6-10	Southwest	793	10-15	Lacustrine material	"	"	"	"
Demars	All	Southeast	854	0-10	Glacio-fluvial material	Orthic Eutric Brunisol (Sahal)	fine sandy loam/ gravelly sandy loam	well drained	High W.R.- Elk, White-tailed deer Moderate W.R.- Mule deer

Table 1. Summary of topographic features[1], soil characteristics[2], and wildlife capability[3] for all study sites (continued).

Study Site	Plots	Aspect	Elevation (m)	Slope (%)	Major Terrain Parent Material	Soil Description (Soil Classification)	Most Common Texture	Drainage Class	Wildlife Capability
Dry Gulch	All	Flat	885	0-3	Morainal material (till)	Orthic Eutric Brunisol (Wycliffe)	gravelly silt loam	well drained	High W.R.- Elk Moderate W.R.- Mule and White-tailed deer
White-tail/ Little Bull	1	South	915	50	Morainal material	Orthic Eutric Brunisol (Wycliffe)	gravelly silt loam	rapidly drained	High W.R.- Elk Mule and Whitetailed Deer and Bighorn Sheep
	2-4	South	915	5-10	"	"	"	well drained	"
	5	Flat	854	0	Glacio-fluvial material	Orthic Eutric Brunisol (Saha)	fine sandy loam	well drained	"

[1] Source: Ryder (1981)
[2] Source: Lacelle (1990)
[3] Source: Demarchi *et al.* (1983)
[4] W.R.= Winter range; S.R.= Summer range

precipitation/evaporation ratios can be highly variable. Table 2 summarizes the average climate data for the nearest long-term weather station located at Cranbrook (elevation 918 m) over a thirty-year period. Annual precipitation averages 399 mm, with the majority of this falling as rain from May to September (Atmospheric Environment Service 1982a). Mean daily temperatures range from a low of 8.6 °C in January to a high of 18.4 °C in July (Atmospheric Environment Service 1982b). Table 3 gives the number of growing degree days at the Cranbrook weather station (Atmospheric Environment Service 1982c).

Two permanent fire weather stations are located at Kikomun Creek (elevation 866 m), 22 km from the Pickering Hills study site, 19.5 km from the Sharptail study site, 21 km from the Demars study site, and 27 km from the White-tail/Little Bull study site, and at the Johnson Lake study site (elevation 854 m), which is approximately 400 m from the Dry Gulch study site. All weather station locations are indicated in Figure 3. A fire weather station was located on-site at Pickering Hills for the 3 weeks prior to fall burning but was not set up for the spring burns. On-site fire weather data is important due to local variability, but logistically is often not possible. Appendix A provides graphs that compare the weather on-site at Pickering Hills, and Kikomun Creek and Cranbrook fire weather stations for this period prior to fall burning.

2.5 Vegetation

All study sites are located within the Kootenay-Columbia Dry Cordilleran Interior Douglas-fir Subzone (IDFdm3) of the biogeoclimatic ecosystem classification (Utzig *et al.* 1986). Within this subzone, the study sites are classified within the drier *Purshia* - *Arctostaphylos* site series (IDFdm3/02) (see Figure 4). The zonal climax tree species is Rocky Mountain Douglas-fir (*Pseudotsuga menziesii*), but on drier sites Ponderosa pine (*Pinus*

Table 2. 30-year average weather data for Cranbrook A station (1952 to 1982).[1]

	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Daily Max Temp. (°C)	11.2	-4.5	1.4	5.5	11.7	17.4	21.4	25.9	25.0	19.2	11.7	2.0	-2.2
Daily Min Temp. (°C)	-0.3	-12.6	-8.2	-5.1	-0.3	4.4	8.1	10.5	9.9	5.4	0.2	-5.7	-9.8
Mean Daily Temp. (°C)	5.5	-8.6	-3.5	0.1	5.8	11.1	14.7	18.4	17.4	12.3	5.9	-1.8	-6.1
Rainfall (mm)	228.0	4.2	3.8	3.9	18.4	35.9	44.4	24.6	32.1	25.1	15.4	14.1	6.1
Snowfall (mm)	170.8	53.9	25.7	15.1	5.3	0.5	0	0	0	1.0	3.3	24.3	41.7
Days with measurable rainfall	62	1	2	3	6	8	10	7	7	7	5	4	2
Days with measurable snowfall	47	10	8	6	4	0	0	0	0	0	2	6	11

[1] Source: Atmospheric Environment Service 1982a, 1982b, 1982d, and 1982e.

Table 3. Number of growing degree days (30 year average) above various threshold temperatures at Cranbrook A weather station (1952 to 1982).[1]

Temperature (°C)	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
24.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	1.0	0.0	0.0	0.0	0.0	3.2
18.0	0.0	0.0	0.0	0.0	0.9	13.5	53.3	42.3	4.4	0.0	0.0	0.0	114.4
10.0	0.0	0.0	0.2	7.0	66.2	153.4	262.7	236.7	97.8	12.6	0.1	0.0	836.7
5.0	0.1	1.1	6.9	53.6	193.4	301.2	417.6	391.2	227.4	72.1	3.3	0.5	1668.4
0.0	8.9	22.3	63.9	174.3	346.9	451.3	572.4	546.3	375.8	192.2	36.7	11.6	2803.5
< 0.0	269.4	121.0	60.3	3.1	0.0	0.0	0.0	0.0	0.0	3.2	92.7	190.9	740.5

[1] Source: Atmospheric Environment Service 1982c.

Figure 4. Photograph showing a typical grass/shrubland community of the drier *Purshia/Arctostaphylos* site series (IDFdm3/02).

ponderosa) is also a dominant climax tree (Utzig *et al.* 1986). The biophysical classification system considers these sites as early seral stages of the Ponderosa Pine subzone within the Interior Rocky Mountain Douglas-fir zone (Lea 1984).

The vegetation on the study sites consists of moderately dense stands of shrubs dominated by bitterbrush and saskatoon, with varying amounts of common snowberry and prickly rose (*Rosa acicularis*). Kinnickinnick (*Arctostaphylos uva-ursi*) can be dominant on drier sites. The grass and forb layers are dominated by Kentucky bluegrass (*Poa pratensis*), *Stipa* spp., junegrass (*Koeleria macrantha*), and *Antennaria* spp. with varying amounts of bluebunch wheatgrass, rough fescue, cheatgrass (*Bromus tectorum*), and Canada bluegrass (*Poa compressa*). Species composition appears to differ among sites depending on several site factors, in particular, the degree of grazing and browsing pressure. Cheatgrass and Canada bluegrass tend to dominate after overgrazing. Snowbrush appears at Pickering Hills, particularly in areas where browsing has been prevented (ie., within the exclosures).

The plant communities on these sites represent early seral stages and succession proceeds slowly due to the summer drought conditions (Lea 1984). They would be classified as a prolonged shrub-herb stage according to Hamilton (1987). The existing plant communities are the result of disturbance in the form of logging followed by wildfire in the early 1930's, and prescribed fire over the past 20 years. Historically, the forests prior to disturbance consisted of Douglas-fir and western larch (*Larix occidentalis*) with some Ponderosa pine and lodgepole pine (*Pinus contorta*).

On some sites, relict Ponderosa pine trees remain, while on others an open forest of immature Douglas-fir and Ponderosa pine exists. Minor differences in plant species abundance and composition occur between sites, owing to a number of factors. The variation is due in part to differences in local topography and parent material, but largely reflects the intensity and time since the most recent fire disturbance and the degree of utilization as range and wildlife habitat.

2.6 Fire History

The existence of these early seral shrub/grassland ecosystems is the result of summer wildfires following logging in the early 1930's which burned throughout the entire Rocky Mountain Trench. A study by Dorey (1979) determined an average fire periodicity of 6.4 years (ranging from 2 to 12 years) for similar ecosystems in the Tobacco Plains area, based on tree ring data from 1813 to 1940. Cooper (1961) reports natural fire frequencies of 6 to 13 years in similar ecosystems. These ecosystems have since been maintained by the use of prescribed fire. Table 4 provides a history of the prescribed burning at each site.

2.7 Grazing History

Since the increase in potentially productive grazing lands on Crown land following the wildfires in the 1930's, the number of domestic cattle grazing on Crown lands has increased steadily (Demarchi 1986).

These highly productive wild ungulate winter ranges provide forage for summer grazing cattle. The common grazing system used in the Rocky Mountain Trench is rest-rotation, in which pastures within range units are grazed during different portions of the season on a rotational basis from year to year, and included in the rotation is at least one year of no grazing ("rest") (McLean 1979). While this type of grazing system was the same on each study site, the timing and sequence of this grazing cycle was not. Within a pasture, differences in the intensity of grazing and wildlife use occur depending on such factors as proximity to salt/mineral licks and cover. Therefore, grazing records which provide AUM's

Table 4. Summary of recent site history and sampling dates for all study sites.

Study Site	Recent Burn History	Sampling Dates	Number of plots
Operational Burns			
Upper Sharptail	Burned - April 1986	July/Aug. 1986, 1987	5
Lower Sharptail	Burned - April 1986	July 1986	5
Demars	Burned - April 1983	July/Aug. 1986	4
White-tail/Little Bull	Burned - April 1976 Burned - April 1985	August 1986	5
Dry Gulch	Burned - April 1986	August 1985, 1986, 1989	6
Experimental Burns			
Pickering Hills	Oper. Burn - April 1978 Burned - October 1986, April 1988	June/July/August 1985, 1986, 1987, 1988 October 1986	3
Johnson Lake	Burned - October 1987	October 1987 July/August 1985, 1987 1988	3

(animal unit month) for a given area were not considered useful indicators of range use. Minor differences in species abundance and composition may be due in part to differences in range trend and condition.

Range condition, which is defined as the state or health of range in relation to its potential, depends on the response of plant species and soils to grazing practices. Plant species can be classified according to their response to grazing intensity and are loosely classed as decreasers (defined as those species in the community which decrease in abundance under prolonged grazing and generally the dominant species in an ecosystem not overgrazed), increasers (those species which increase following moderate overuse but, eventually decrease with continued heavy use) and invaders (those species which are not usually members of the original community but invade as the range deteriorates). Range trend is defined as a change in the range condition (McLean 1979).

Species such as cheatgrass and Canada bluegrass are considered invaders on these sites, and their presence indicates overgrazing. The Johnson Lake site was heavily overgrazed, as indicated by the abundance of these species. The Pickering Hills experimental plots were established within exclosures which had prevented grazing for a few years prior to the study. They were therefore considered in good range condition.

For the operational burn sites, paired plots were established within the same pasture when possible. At the Dry Gulch and upper Sharptail sites the entire pasture was burned, so the unburned plots were established within the pasture immediately adjacent. Therefore at these sites, the timing and sequence of the grazing regime may have been different between pastures. It was assumed that utilization would be fairly similar, since a single rancher generally uses a single range unit.

2.8 Wildlife

The East Kootenay region is ecologically diverse, owing to the interaction of two different climatic regimes with a close proximity to a range of topographic features (e.g., floodplains, terraces and mountain slopes). This diversity makes this region unique in British Columbia for its ability to support an equally diverse number of wildlife species, many of which share the same winter range. These include seven ungulate species (Rocky Mountain elk, mule deer, white-tailed deer, moose (*Alces alces andersoni* and *A. a. shirasi*), Rocky Mountain bighorn sheep, mountain goat (*Oreamnos americanus*), and woodland caribou (*Rangifer tarandus caribou*), as well as grizzly and black bear (*Ursus arctos* and *U. americanus*) and numerous furbearing species and birds (Demarchi 1986).

The dry shrub-dominated ecosystems in which the study sites are located are particularly important for nesting birds such as the kingbird, western flycatcher, Lewis's woodpecker, and the western and mountain bluebird (Schwab 1979). Badger and Columbia ground squirrel are also numerous (D.Demarchi, Habitat Classification Specialist, Wildlife Branch, Ministry of Environment, pers. comm.).

At lower elevations in the Rocky Mountain Trench, the low snowfall allows easier movement, and low-growing forage and browse species are more accessible. Slope and aspect are important in terms of solar radiation, with southfacing slopes being exposed to the winter sun, further decreasing snow depth. The availability of adjacent forested draws or ridgetops is important for providing cover during adverse weather conditions or as a refuge from predators. The shrub/grassland communities provide key wintering habitat for white-tailed and mule deer, elk and bighorn sheep (Tipper 1988).

Demarchi (1986) has classified the East Kootenay region according to its capability for supporting ungulate species. Table 1 provides the capability rating for ungulate species on each study site.

The study areas have generally moderate to very high capability of supporting elk and mule deer during the winter months. The Pickering Hills range unit is one of the most productive areas for wintering elk, white-tailed and mule deer in the Rocky Mountain Trench (Demarchi and Lofts 1985). The Power Plant range unit, with its steep terrace slopes has a high capability for supporting bighorn sheep populations (D. Demarchi, pers. comm.).

3 METHODS

3.1 Plot Layout and Sampling

3.1.1 Experimental Burn Plots

3.1.1.1 Treatment Plot Layout

Two sites were selected for the experimental treatments - the Pickering Hills and Johnson Lake range pastures. At the Pickering Hills study site, experimental plots were located in June 1985 within three existing exclosures. The exclosures (henceforth called "Blocks") were established as part of a study initiated by the Fish and Wildlife Branch in 1961 (Demarchi 1966). Figure 5 shows a diagram of the layout of these exclosures and the treatment plots at this site. Blocks 1 and 2 were located within exclosures that were previously cattle-proof, and Block 3 was located in an exclosure that was previously both wildlife- and cattle-proof. Some cattle grazing was evident within Blocks 1 and 2 and there were obvious signs of wildlife browsing within all three blocks.

At the Johnson Lake study site, the experimental plots were located in a portion of the pasture receiving minimal use by cattle (G. Tipper, Wildlife Biologist, Ministry of Environment, pers. comm.). Three blocks were located side-by-side, and fenced within a single exclosure in the fall of 1986 (Figure 6).

The experiment consisted of a randomized complete block design, with each block divided equally into three plots. Each of three treatments (fall burn, spring burn and control, or unburned) were randomly assigned to one of three plots within each block for a total of three replications of each treatment and a total of nine plots on each site. At Pickering Hills, each plot was 14 x 40 m (.056 hectares), with a 1 meter fireguard between each plot (Figure 7). At Johnson Lake, each plot was 25 x 50 m (.125 hectares) with a 2 meter fireguard between each plot (similar to Figure 7).

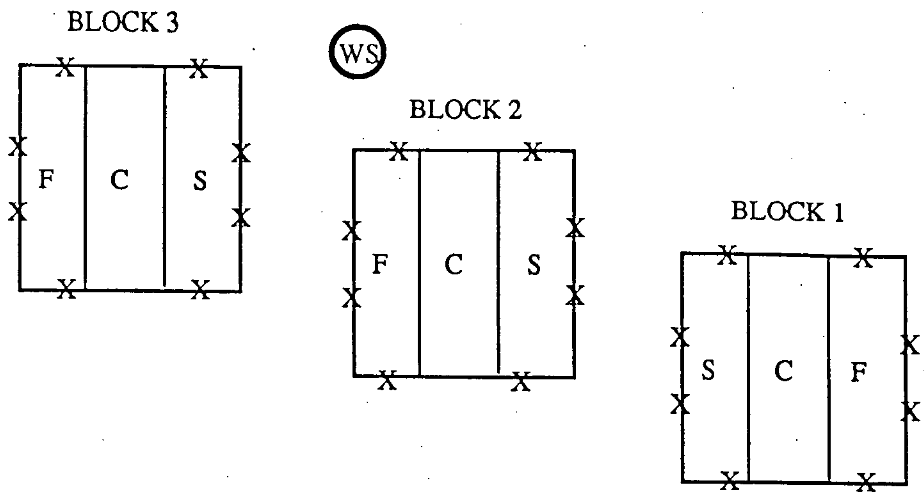


Figure 5. Diagram of the exclosure layout at the Pickering Hills experimental site. (Note: WS=Fire Weather Station; F=Fall burn, C=Control, and S=Spring burn)

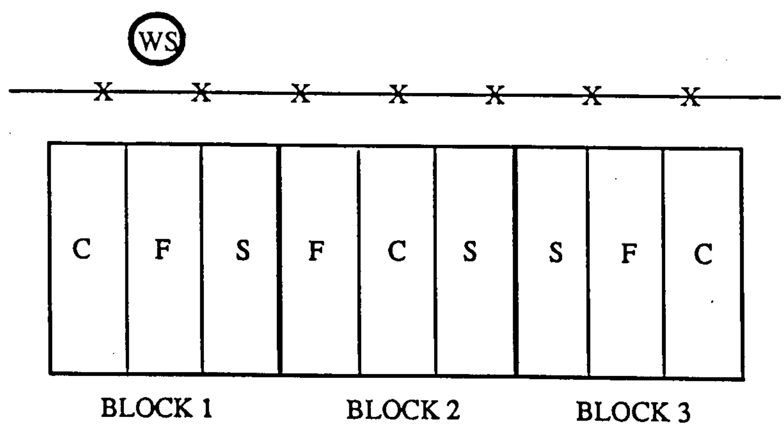


Figure 6. Diagram of the exclosure layout at the Johnson Lake experimental site. (Note: WS=Fire Weather Station; F=Fall burn, C=Control, and S=Spring burn)

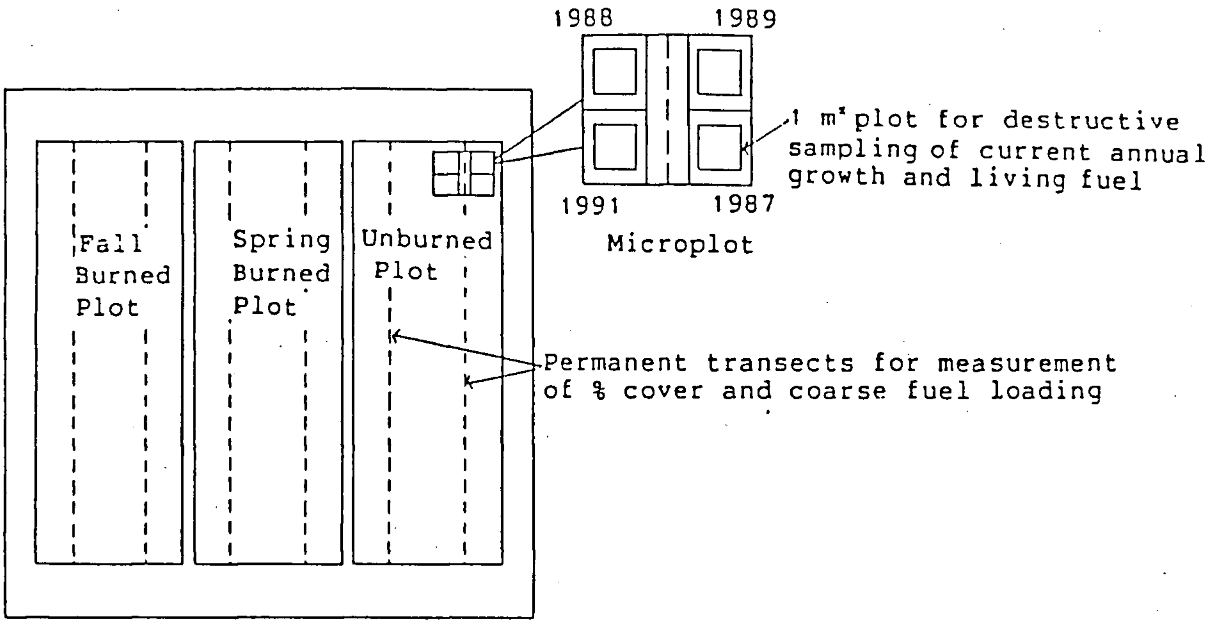


Figure 7. Treatment plot layout (fall burn, spring burn and control plots) at the Pickering Hills and Johnson Lake experimental study sites.

Poor weather conditions and other factors prevented burning of the treatment plots when originally scheduled. Consequently, the experimental design at Johnson Lake consisted of fall burn and control plots. The experimental design at Pickering Hills consisted of fall burn, spring burn and control plots. The first postburn growing season for the fall and spring burning treatments at this site cannot be compared directly, since they represent different years (1987 and 1988, respectively) therefore each treatment was compared to the control for the respective year.

Two line transects were located within each plot (Figure 7) and oriented parallel to the long axis of each plot. At Pickering Hills the transects were perpendicular to the direction of the slope. These transects were used for vegetation and fuel load sampling. Each line transect was divided into ten regular intervals and a subplot located at each (for a total of 20 subplots per treatment plot). At Pickering Hills, each subplot was 4 x 6 m in size. At Johnson Lake, each subplot was 5 x 6 m in size. At least ten subplots were randomly chosen from each treatment plot for sampling current annual growth (CAG). The original intention was to sample all the subplots but lack of time reduced the number sampled. Consequently, the sample size varies between blocks (Table 5). Each subplot was divided into four quadrants (2 m^2) and a 1 m^2 microplot was located in the centre of each. The plot layout was designed so that future sampling could take place at four different times. A 2 meter wide strip was located down the centre of each subplot to act as a buffer strip for the line transects (Figure 7). One of the four quadrants was randomly selected for sampling during this study.

Detailed plots were sampled pretreatment at several areas scheduled for operational burning. Only the operational burn at Dry Gulch occurred during the course of my study. Three detailed plots were located at this site. Two transects were located in each of these

Table 5. Sample size for each fuel component and current annual growth estimation pre-and postburn on each experimental treatment plot.

Site	Fuel Component	Sample Size (n) Preburn	Postburn
Pickering Hills	Shrubs	5	5
	Grasses	5	5
	Fine Fuels	5	10
	Current Annual Growth	-	10-20
Johnson Lake	Shrubs	5	5
	Grasses	5	5
	Fine Fuels	5	20
Dry Gulch	Shrubs	5	5
	Grasses	5	5
	Fine Fuels	5	10

plots in a similar manner to the treatment plots at Pickering Hills and Johnson Lake (Figure 7). These plots were sampled prior to burning, and during the first and second growing seasons following burning. The coarse and fine fuel loads were measured pre- and postburn. Since accurate preburn information and fire weather data were available for this site, and similar methods were used to sample the fuels and vegetation, the results for this site will be discussed with the results of the experimental burns. At this site an additional three paired plots were also sampled on the southeast corner of the same operational burn, using the methods described for the operational burn plots (ie., burned and unburned plots located adjacent to each other). The results from this operational-type sampling will be discussed under the operational burn results. To avoid greater confusion, these two sets of plots will be referred to as the Dry Gulch experimental burn plots and the Dry Gulch operational burn plots.

3.1.1.2 Vegetation Sampling

The percent cover of all plant species was determined using the line intercept method (Chambers and Brown 1983) (Figure 8). A total of 80 meters were sampled for each treatment plot at Pickering Hills, 100 meters for each treatment plot at Johnson Lake, and 60 meters for each experimental plot at Dry Gulch. All preburn plant measurements, were recorded to the nearest 10 cm, but this was refined to the nearest 1 cm for all postburn sampling.

Preburn vegetation sampling occurred in July and August 1985 and postburn vegetation sampling occurred in July 1987 and 1988 at Pickering Hills, in July 1988 at Johnson Lake, and in August 1986 and 1987 at Dry Gulch (Table 4).

A plant species list is located in Appendix B. Scientific names are according to Taylor and MacBryde (1977). Vernacular names used in the text are according to Meidinger (1987)

Figure 8. Photograph showing the line intercept method used for sampling vegetation percent cover and dead woody material.

and Hitchcock and Cronquist (1973) with the exception of bitterbrush which is a locally common name. It was very difficult to distinguish between *Poa pratensis* and *P. sandbergii* so these species were combined for this study.

Financial and time constraints warranted sampling the CAG only in the first growing season following fall burning at Pickering Hills site. The CAG of the seven key plant species, as well as miscellaneous shrub, forb and miscellaneous grass categories were determined using the harvest method (Chambers and Brown 1983) on 1 m^2 plots projected vertically (Figure 7). Current annual growth consisted of the leaves and twigs of the current year for each species. The CAG of annual herbs and grasses was assumed to be equal to all above-ground material. All samples were sorted by species into paper bags, air-dried for approximately 5 to 7 weeks, and oven-dried at 70 °C for 48 hours. All masses were recorded to the nearest 0.01 gram.

3.1.1.3 Fuel Load Sampling

The total fuel load was comprised of coarse fuel (woody fuel > 1 cm diameter), fine fuel (includes woody fuel < 1 cm diameter, dead vegetative material lying on the soil surface and ungulate pellets), standing shrubs and standing grasses. The coarse fuel load was estimated pre- and postburn and the difference between the two values was used to calculate fuel change, both absolute and a percentage of the preburn fuel load. The coarse fuel load on each treatment plot was estimated using the line intersect method (Van Wagner 1968) on the same two transects used for vegetation sampling. This fuel component did not include any dead branches of shrubs unless they were lying on the soil surface. The coarse fuels were measured in the year prior to and the year following burning of the treatment plots. The fine fuel load was estimated by collecting material from within ten 30 x 30 cm microplots randomly located within each treatment plot.

At Pickering Hills, the standing shrub and grass components were measured on randomly located 1 m^2 plots projected vertically within each treatment plot, and included all dead and living above-ground vegetation. The number of samples collected for each treatment plot for all fuel components is given in Table 5. All samples were oven-dried at 70 °C, and weighed as previously described.

At Johnson Lake, the shrub density was much lower and consequently with wider spacing so it was initially proposed to sample the standing shrub component using estimations derived from the biomass regression equations. Although intensive sampling occurred to develop these regression equations, it was later decided to maintain continuity and sample the standing shrub component by the destructive sampling method used at Pickering Hills (Thomson 1990).

Preburn fine and coarse fuel load sampling occurred in August 1986, and sampling of the shrubs and grasses, as well as additional fine fuel load sampling occurred in August 1987. As a result of postponement of some of the burning to a later date, unequal sample sizes were used in sampling the fuels. At Pickering Hills, postburn fuel sampling occurred immediately following the fall burning (October 1986) and in the summer following spring burning (June 1988). At Johnson Lake, postburn fuel sampling occurred immediately following fall burning (October 1987). At Dry Gulch, postburn fuel sampling occurred in the summer following spring burning. Table 4 outlines the sampling dates at each site.

3.1.1.4 Fire Weather and Fire Behaviour

Flame height and fire rate of spread were visually estimated only during the fall burning at Pickering Hills. A fire weather station was set up at both sites for the two weeks prior to the fall burning. Unfortunately it was not possible to have the station on-site for the spring burning at Pickering Hills. Relative humidity, air temperature, wind speed and direction and daily precipitation were measured, and Fire Weather Index System codes and indices were calculated using the Canadian Fire Weather Index System (Canadian Forestry Service 1984).

3.1.1.5 Burning Treatment

The fall burning at Pickering Hills occurred October 13, 1986 and the spring burning occurred April 14 and 15, 1988. The fall burning at Johnson Lake occurred October 9, 1987. The Dry Gulch operational burn occurred April 8, 1986.

All experimental plots were burned as strip headfires, ignited using hand-held drip torches (Figure 9).

3.1.2 Operational Burn Plots

3.1.2.1 Site Selection

Within the drier *Purshia-Arctostaphylos* site series of the IDFdm3 subzone, all areas which had been burned operationally over the 5 year period between 1980 to 1985 were assessed in terms of their suitability for establishing paired plots to monitor the effects of the operational burning on vegetation. A site was suitable for studying if it had an unburned area immediately adjacent to it of suitable size (allowing at least three paired plots for sampling), with a similar plant community, site canopy cover, topography, elevation, aspect, slope, soil classification, and grazing regime to that of the burned area (Figure 10). Of the fourteen areas assessed, only four met these criteria.

The burning and sampling dates for the operational burns studied are given in Table 4.

Figure 9. Photograph showing burning of the fall treatment plots at Pickering Hills (October 13, 1986) using hand held drip torches.

3.1.2.2 Sample Plot Location

The number of paired sample plots established at each site varied depending upon the size of the burned area and adjacent unburned area, and the site variability. Paired plots were therefore established following a general reconnaissance around the perimeter of each burned area. The number of paired plots per site varied from three to ten.

Within a given stratified area, paired plot centres were determined by randomly selecting a distance at right angles to the burn boundary. All plot centres were located at least 40 m from the boundary to prevent sampling an 'edge area'. Plot centres were marked with metal stakes. Each pair of plots was located immediately adjacent to one another, at an equal distance on either side of the burn boundary.

3.1.2.3 Vegetation Sampling

At each plot centre, two 30 m line transects were located at right angles to one another with the first transect angled in a random direction (Figure 11). Where an environmental gradient was obvious (e.g., the presence of a slope), the first transect was established at right angles to the gradient (i.e., downslope).

The percent cover of all plant species present was estimated using the line intercept method as previously described. On the burned areas, the proportion of resprouting bitterbrush plants was determined by tallying the number of sprouting, nonsprouting and unburned plants, on a 1 m wide transect located along the percent cover transects (Figure 11). The centre point of each sample plot was used to establish a circular plot of 5 m^2 area. The number of sprouts or branches of each shrub species present arising from at or beneath the soil surface was counted.

Figure 10. The upper Sharptail operational burn site showing the burned area (upper left square) and the adjacent unburned area. Paired plots were sampled on either side of the fenceline.

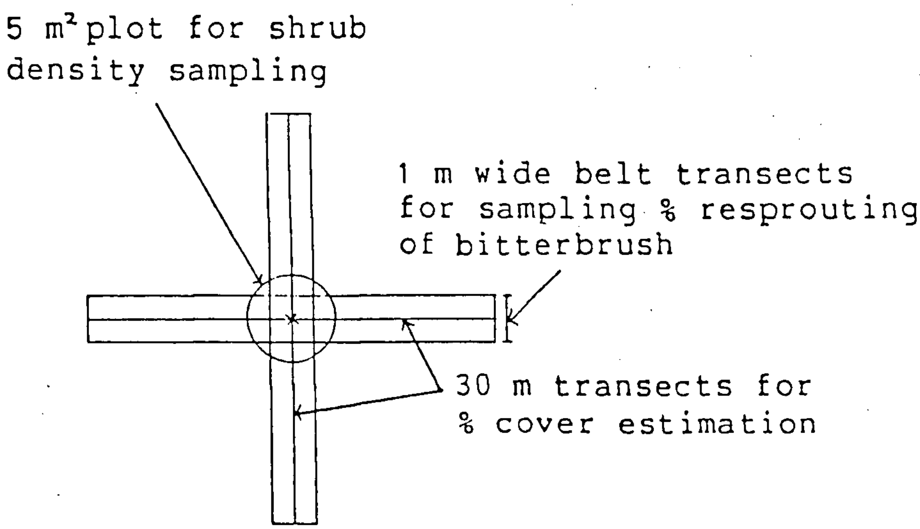


Figure 11. Operational burning plot sampling layout.

3.1.2.4 Fire Severity Estimation

Canadian Fire Weather Index System codes and indices were calculated for the day of each operational burn using data taken from the nearest weather stations, since no fire weather stations were set up on-site for burning. Fire intensity (defined here as the amount of heat released per unit time per unit length of fire front) is difficult to measure, and is usually estimated indirectly from measurements of fuel consumption, rate of spread, and flame height. None of these measurements and observations were available for these operational burns. Scorch height of trees is another indirect measurement of fire intensity in that it approximates flame height. These sites had very few trees present. Given this lack of information, very little can be said about the fire intensity on the operational burns.

Fire severity, which relates to the heat pulse down into the soil, is generally a more important indicator of fire effects on plants. The proportion of bitterbrush plants that resprouted following burning was measured and used as a relative index of fire severity on the operational burns. This information was used to qualitatively compare the fire severity of the burns. Since sampling took place at different times after operational burning at each site, the usefulness of the proportion of bitterbrush resprouting was limited, but can still indicate relative fire severity in terms of shrub response.

3.2 Data Analysis

3.2.1 Experimental Burn Plots

The design for this part of the study was a one-way experimental treatment in a randomized complete block design, with subsampling (Milliken and Johnson 1984). At Pickering Hills, there were three treatments (spring burn, fall burn, and control or unburned) located once in each of three blocks. The fall burn treatment plots were sampled in the first and second postburn growing seasons, and the spring burn treatment plots were sampled in the first postburn growing season. At Johnson Lake the fall burn treatment plots were sampled in the first postburn growing season.

At the Pickering Hills site, the treatment plots were established and sampled prior to the scheduling of the first burn in the fall 1985. The first experimental burning did not take place, however, until the fall of 1986. During the summer of 1986, a heavy infestation of tent caterpillars occurred on this site. The tent caterpillar infestation was confined to the Pickering Hills / Bull River area and did not occur at Johnson Lake or Dry Gulch. This infestation occurred on all the plots as demonstrated by the control plots, where large decreases in the percent cover of bitterbrush and saskatoon occurred (Table 6).

The experiment was originally designed to compare preburn and postburn for each treatment. A preliminary analysis of the data showed that there were no significant differences between the treatments prior to burning. It was assumed that the degree of reduction in the quantity of bitterbrush and saskatoon due to tent caterpillars was uniform across all treatments. This was a valid assumption given that the experiment was blocked and the treatments randomly allocated to each plot. The data were analyzed so as to compare each treatment with the control data for the appropriate year rather than with the preburn data for that treatment. The preburn data will not be discussed further.

Table 6. Mean percent cover of all key plant species on the Pickering Hills experimental control plots showing the reduction due to tent caterpillar damage (standard error in parentheses).

	Year		
Species	**1985**	**1987**	**1988**
Agropyron spicatum	0.2 (0.2)	1.3 (0.6)	1.4 (0.5)
Amelanchier alnifolia	25.7 (8.4)	9.9 (2.5)	10.1 (1.7)
Ceanothus velutinus	0.1 (0.1)	0.1 (0.1)	0.4 (0.3)
Festuca scabrella	0.7 (0.3)	1.2 (0.5)	1.1 (0.6)
Purshia tridentata	60.1 (3.5)	27.9 (2.8)	28.7 (2.9)
Stipa occidentalis	1.0 (0.6)	4.2 (1.1)	5.4 (1.4)
Symphoricarpos albus	4.0 (1.8)	1.7 (0.7)	2.0 (0.9)

Tests for normality of the data were performed using the Shapiro-Wilk statistic, W (SAS Institute Inc. 1988) and by looking at probability plots. In most cases, the assumption of normality of the data was not met, therefore nonparametric statistics were used for all analyses. Nonparametric statistics are often not available for all tests. Conover and Iman (1981) suggest ranking the data then performing the usual ANOVA, which is what was done in my study.

The two main questions and the associated statistical hypotheses for the experimental treatments were:

1) What is the vegetative response to burning these plant communities in two different seasons - spring and fall?

> H_{o1}: Fall and spring burning do not significantly affect the percent cover of each key plant species in the first postburn growing season.
>
> H_{o2}: Fall burning does not significantly affect the percent cover of each key plant species in the second postburn growing season.
>
> H_{o3}: Fall burning does not significantly affect the current annual growth of each key plant species in the first postburn growing season.

For Johnson Lake, the hypotheses were the same, but the vegetative response to fall burning in terms of the percent cover of key plant species was only assessed in the first postburn growing season.

2) Is there a difference in the consumption of fuel between the four experimental burns at Pickering Hills, Johnson Lake and Dry Gulch?

> H_o: There is no significant difference in fuel consumption (preburn fuel load - postburn fuel load) of fine fuel, coarse fuel, grass biomass and shrub biomass between the burning treatments at all sites (Pickering Hills spring and fall burns; Johnson Lake fall burn; and fine and coarse fuel on the Dry Gulch experimental burn plots).

A separate analysis of variance was done for each year to test for differences in the percent cover of each species between a burning treatment and the control (Table 7a for Pickering Hills and 7b for Johnson Lake). Because the sample sizes were unequal for the current annual growth, mean values were calculated for each treatment and analyzed using an ANOVA (Table 7c).

The preburn fuel data were tested for differences between sites and found to be the same. Therefore, for the fuel consumption data, the differences between pre- and postburn fuel load were analyzed using an ANOVA to test for differences in fuel consumption between site treatments. Fuel load data were used as a single value for each treatment plot. Tukey's multiple comparison test was used for all tests of differences between means (SAS Institute Inc. 1988).

For the Dry Gulch experimental plots, the Wilcoxin signed-rank test was used to test for differences between the percent cover preburn and the percent cover in the first or second postburn growing season using SYSTAT (Wilkinson 1988).

3.2.2 Operational Burn Plots

The plots on the operationally burned sites were sampled in pairs and were selected to minimize differences in environmental features. A comparison of operational burn areas with adjacent unburned areas was done to determine whether there was a difference in the vegetative response of the key plant species following burning. The test hypotheses for this part of the study were:

H_{o1}: There is no significant difference between paired burned and unburned plots in the percent cover of each of the key plant species.

H_{o2}: There is no significant difference between paired burned and unburned plots in the number of sprouts per 5 m^2 plots for each of the key plant species.

Statistical analysis of these data, therefore, required a paired comparison t-test.

Table 7. Sources of variation for all analysis of variance tests, with subsampling using ranked data.

a) Pickering Hills - for each year:

Source	**Df**		**F**
Block (B_i)	i-1	2	MS_B/MS_t
Treatment (T_j)	j-1	1	MS_T/MS_t
Transect (t(BT))	ij(k-1)	6	MS_t/MS_e
Error (e(tBT))	(i-1)(j-1)(k-1)	2	
TOTAL	BTt-1	11	

b) Johnson Lake - for each year:

Source	Df		F
Block (B_i)	i-1	2	MS_B/MS_t
Treatment (T_j)	j-1	1	MS_B/MS_t
Transect (t(BT))	ij(k-1)	6	MS_t/MS_e
Error (e(tBT))	(i-1)(j-1)(k-1)	2	
TOTAL	BTt-1	11	

Table 7. Sources of variation for all analysis of variance tests, with subsampling using ranked data (continued).

c) Pickering Hills - Current Annual Growth, using mean values of subsamples:

Source	Df		F
Block (Bi)	i-1	2	MS_B/MS_e
Treatment (Tj)	j-1	1	MS_T/MS_e
Error (e(BT))	(i-1)(j-1)	2	
TOTAL	ij-1	5	

d) Fuel Consumption (Preburn-Postburn):

Source	Df		F
Block (B_i)	i-1	2	MS_B/MS_t
Treatments (T_j)	i-1	3	MS_T/MS_e
Error (e(T))	(i-1)(j-1)	6	
TOTAL		11	

Because of the non-normality of the data, the Wilcoxin signed-rank test was used for all analyses of paired plot percent cover and sprout density data using SYSTAT (Wilkinson 1988).

4 FUEL CONSUMPTION ON THE EXPERIMENTAL BURN PLOTS

4.1 Results

4.1.1 Fire Weather and Behaviour

The weather conditions at the time of both fall burns were not considered ideal. The relative humidity was rather high, particularly at Pickering Hills and the air temperatures were fairly low (Table 8). The spring burns at Dry Gulch and Pickering Hills took place under more favourable burning conditions, with relatively high air temperatures for April and low relative humidities compared to the fall burns. The wind speeds were low for all burns, with no wind occurring during the Johnson Lake fall burn. The fall burn at Pickering Hills occurred with a continual light breeze which picked up during the burning of Block 3. This was reflected in higher rates of spread and flame heights achieved during the burning of this block, compared with Blocks 1 and 2.

The differences in the relative humidity and air temperatures between burns were reflected in the Fine Fuel Moisture Codes (FFMC). Higher FFMC values occurred for the spring burns. The Drought Codes (DC) were high for both of the fall burns, particularly at Johnson Lake. The rate of spread for the Pickering Hills fall burn plots ranged from 0.1 to 0.9 m per minute. Flame heights ranged from 0.2 to 1.7 m, with a maximum flame height of 2.5 m.

4.1.2 Fuel Consumption

The quantity of all fuel components on these sites appeared extremely variable. The total preburn fuel load at Pickering Hills averaged 1.96 kg/m^2 for the spring burn treatment plots and 1.18 kg/m^2 for the fall burn treatment plots, compared with 1.60 kg/m^2 on the fall burn treatment plots at Johnson Lake (Table 9). Although the total fuel loads were essentially the same, those at Pickering Hills consisted largely of downed woody material and living

Table 8. Weather parameters and Fire Weather Index System codes and indices for the days of burning at the Pickering Hills and Johnson Lake experimental burn sites and the Dry Gulch experimental burn plots.[1]

Site	Date of Burn	Weather Parameter R.H. (%)	Temp. (°C)	Wind (km/h)	Fire Weather Index System Codes and Indices FFMC	DMC	DC	BUI	ISI	FWI
Pickering	14/04/88	22	22	5	94	27	134	36	9	17
Hills	15/04/88	23	23	2	94	32	139	40	8	17
	08/10/86	70	13	8	77	6	378	11	0.9	1
Johnson Lake	09/10/87	38	10	0	89	61	691	101	3.7	15
Dry Gulch	08/04/86	31	22	9	90	29	81	31	6.8	13

[1] Weather data for the Pickering Hills spring burn taken from the nearest weather station at Kikomun Creek at 1300 hours; all other weather data were taken on-site at the time of burning.

Table 9. Total pre- and postburn fuel load (kg/m²) and percent of total fuel load at each site.

Fuel Component	Pickering Hills								Johnson Lake			
	Spring				Fall				Fall			
	Pre		Post		Pre		Post		Pre		Post	
Coarse Fuel	1.21	(62%)	.13	(26%)	.39	(33%)	.13	(23%)	1.43	(89%)	.01	(6%)
Fine Fuel	.05	(2%)	.05	(10%)	.07	(6%)	.06	(11%)	.02	(1%)	.02	(14%)
Grasses	.02	(1%)	.00	(0%)	.02	(2%)	.00	(0%)	.09	(6%)	.01	(7%)
Shrubs	.68	(35%)	.32	(64%)	.70	(59%)	.37	(66%)	.06	(4%)	.11	(73%)
TOTAL	1.96		0.50		1.18		0.56		1.60		0.15	

shrubs, with minor components of fine fuel and grasses. Those at Johnson Lake, consisted almost entirely of downed woody materials, with only minor amounts of grasses, shrubs and fine fuels. Figure 12 shows the changes in the proportions of the fuel components by burning treatment.

For many of the coarse fuel diameter classes, consumption was 100% (Table 10), although none of the differences between pre- and postburn fuel loads were statistically significant. In such cases it can be assumed that the fuels were consumed but that sampling was not sufficient and the variability was too high to detect statistically significant differences. Total coarse fuel consumption varied from 66 to 100%. The fall burn at Johnson Lake had almost 100% consumption of all diameter classes, while the fall burn at Pickering Hills had the lowest consumption for most diameter classes.

There were statistically significant differences between the pre- and postburn shrub and grass biomass on the Pickering Hills fall and spring burns. There was a decrease in the shrub biomass (by 46% and 53%) and in the grass biomass (by 90% and 100%) on the Pickering Hills spring and fall burns, respectively (Table 11).

The shrub, grass and fine fuel consumption appeared to be different on the Johnson Lake fall burn plots, compared with the Pickering Hills spring and fall burn plots (Table 11). There was an apparent increase in the shrub component (40%) and in the fine fuels (7%) following burning at Johnson Lake, although these differences between pre- and postburn were not statistically significant. Grass consumption was 87% at the Johnson Lake site, which was significantly different than grass consumption on the Pickering Hills fall and spring burns (95 and 100% respectively).

The shrub and grass components were not sampled for the Dry Gulch spring burn.

Figure 12. Proportion of the coarse fuel, fine fuel, grasses and shrubs which make up the total fuel load on the experimental burn plots pre- and postburn at Pickering Hills and Johnson Lake.

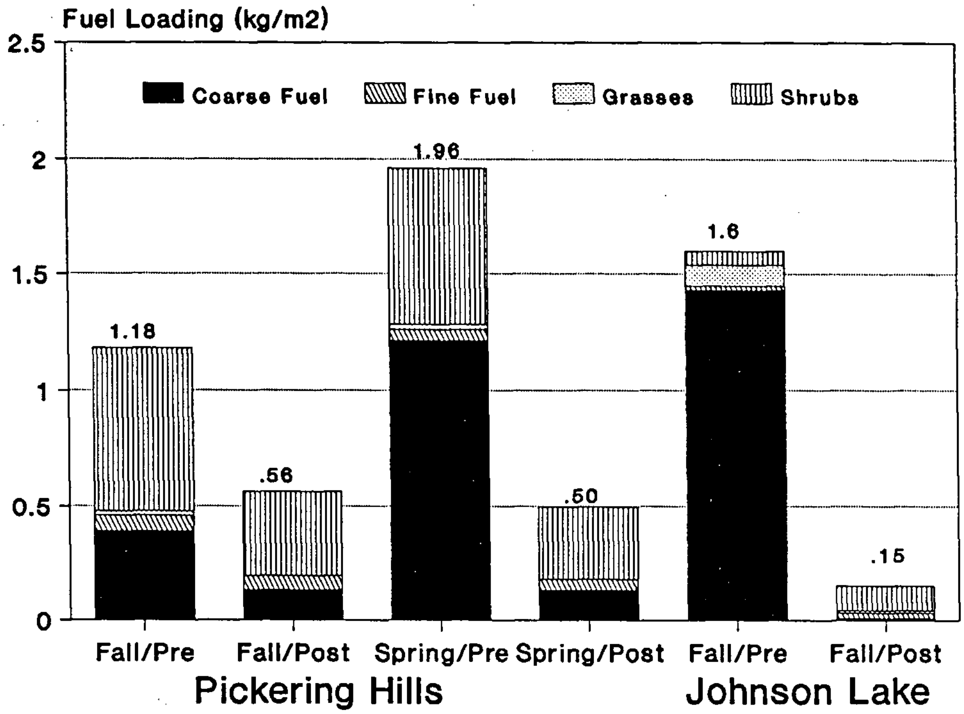


Table 10. Average pre- and postburn coarse fuel loads (kg/m^2) by diameter size classes (cm) for each of the experimental burns and the Dry Gulch operational burn plots (standard error in parentheses).[1]

Site	Treatment	Diameter Size Class (cm)																	
		1 - 3			3.1 - 5			5.1 - 7			7.1 - 12			>12			Total		
		Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change	Pre	Post	Change
PIC	Fall	.05	.03	-.02	.04	.01	-.03	.03	.01	-.02	.06	.03	-.03	.21	.05	-.16	.39	.13	-.26
		(.01)	(.01)		(.01)	(.01)		(.02)	(.01)		(.03)	(.03)		(.12)	(.05)		(.13)	(.05)	
PIC	Spring	.05	.01	-.04	.04	.03	-.01	.03	.03	+.00	.12	.06	-.06	.98	0.0	-.98	1.21	.13	-1.08
		(.02)	(.01)		(.02)	(.01)		(.01)	(.02)		(.08)	(.03)		(.98)	(0.0)		(.93)	(.05)	
JL	Fall	.043	0.0	-.04	.04	0.0	-.04	.03	0.0	-.03	.09	.01	-.08	1.22	0.0	-1.21	1.43	.01	-1.42
		(.02)	(.01)		(.02)	(.00)		(.02)	(.00)		(.04)	(.01)		(.85)	(.00)		(.80)	(.01)	
DG	Spring	.01	.01	0	.09	.05	-.04	.18	.05	-.13	.10	.06	-.04	1.26	.18	-1.08	1.63	.35	-1.28
		(.00)	(.00)		(.04)	(.01)		(.11)	(.02)		(.07)	(.04)		(.98)	(.18)		(.93)	(.15)	

[1] PIC=Pickering Hills, JL=Johnson Lake, DG=Dry Gulch. There were no significant differences between pre and postburn fuel load for any diameter classes for each site and treatment (rows), and no statistically significant differences between all 4 treatments in preburn and postburn loadings for fuel consumption (preburn-postburn fuel load) (α=0.05).

Table 11. Mean pre- and postburn shrub, grass and fine fuel biomass (kg/m^2) and percent change (standard error in parentheses).[1]

Site	Treatment	Shrubs				Grasses				Fine Fuels			
		Pre	Post	Change Actual	Change %	Pre	Post	Change Actual	Change %	Pre	Post	Change Actual	Change %
Pickering Hills	Fall	.70a (.09)	.37[2] (.08)	-.33a	-46	.02a (.00)	.00[2] (.00)	-.02a	-90	.07 (.01)	.06 (.005)	-.01a	-12
	Spring	.68a (.14)	.32[2] (.05)	-.34a	-53	.02a (.00)	0.0 (0)	-.02a	-100	.05 (.12)	.05 (.004)	-.00a	0
Johnson Lake	Fall	.06b (.02)	.11 (.03)	+.05b	+40	.09b (.01)	.01[2] (.00)	-.08b	-87	.02 (.01)	.02 (.00)	+.00b	+7

[1] Different letters denote a significant difference between treatments (columns), $\alpha = 0.05$; apparent discrepancies are due to rounding errors.

[2] Indicates a significant difference between pre- and postburn.

4.2 Discussion

4.2.1 Fire Weather and Behaviour

The FFMC represents the moisture content of the L layer and fine surface fuels generally less than 1.0 cm diameter. The drying time lag of this type of fuel is 0.7 days (Feller 1987). The FFMC values for the Pickering Hills spring burn were high relative to those which would normally be considered if burning logging slash in the interior of B.C. (Feller 1987). The DMC represents the moisture content of the 5 to 10 cm deep FH layers. The DC represents the moisture content of the 25 cm deep FH layer. All of these codes and indices were developed for Jack pine (*Pinus banksiana*) slash in eastern Canada.

The study sites have only a very thin to negligible L layer and since very little coarse woody material occurs on these sites, the DMC and DC may not be very relevant to describing the burns and developing burning prescriptions for these ecosystems. They may only be of value as indices of long term drought, and as a crude index of large woody fuel moisture content. The FFMC is the most useful of the Fire Weather Index System codes and indices, on sites where grasses and other fine fuels are the major component of the fuel load and where the continuity and abundance of this fuel determines whether a fire will be carried or not (G. Tipper, pers. comm.). Grasses are far more sensitive to diurnal changes in weather parameters. Hourly on-site weather data may be important in recognizing potential burning windows. Correlation of local atmospheric changes to changes in the grass moisture content would be useful for prescribed fire prescriptions in these types of ecosystems and could possibly lead to the development of a grass moisture code. The FFMC likely reflects the moisture content of materials such as dead woody shrub material on these sites well.

Kilgore and Curtis (1987), in their guide to understory burning in Ponderosa Pine-Larch-Douglas-fir forests, provided an example of a chart which integrates fuel moisture, relative humidity, and temperature into prescription windows suitable for burning. Higher temperatures can compensate for higher relative humidities and vice-versa, and prescriptions would be modified accordingly, depending on the fuel moisture. The authors stress that these charts must be site-specific to be effective. Their guide provides the prescriptions which are presently being used for spring and fall understory burning of Ponderosa pine, with grass and/or brush in Montana. These prescriptions call for midflame windspeeds of 10 to 25 km/hour, relative humidities of 25 to 35%, and temperatures of 15 to 21° C. The quantity and characteristics of the fuel must also be considered and compensated for when using charts such as these.

Based on their guidelines, the relative humidities for the fall burns in this study would have been too high and the temperatures too low for successful burning. The wind speeds would have been insufficient for all of the experimental burns.

Sinton and Bailey (1980) recommended relative humidities of 25 to 38% and air temperatures of 9 to 26 °C when burning rough fescue rangeland.

Noste *et al.* (1987) studied saskatoon response to five fire treatments. They reported rates of spread ranging from 0.12 m/min for a moderate severity/slow duration fire treatment to 4.05 m/min for a moderate severity/fast duration fire treatment. The rates of spread observed in my study were comparable to those for the range of fire treatments in their study, with the exception of the moderate severity/fast duration fire treatment. They reported flame heights ranging from 0.21 to 1.42 dm. The flame heights in my study correspond to the moderate severity/fast duration fire treatment.

Adams (1980) observed flame lengths of 1.5 to 4.6 m and rates of spread of 3.5 to 7 m/min in older stands of bitterbrush, much higher than those measured in this study. These observations by Adams were for denser stands with a larger quantity of dead material.

4.2.2 Fuel Load and Consumption

Fuel composition differed between the Johnson Lake and Pickering Hills sites. This can be attributed to several possible factors, particularly those which contribute to the structure and productivity of the plant community. Environmental characteristics, such as slope (Pickering Hills has a 25% slope, and Johnson Lake has virtually no slope), or soil texture, will influence the species composition and productivity due to their influence on available nutrients and moisture. Site history will affect the fuel abundance and composition quite significantly. Species indicative of overgrazing were abundant at Johnson Lake. Canada bluegrass and cheatgrass contributed significantly to the grass component, which was almost six times greater than that at Pickering Hills. Sites that had not been burned recently should have a greater accumulation of fuel. The Pickering Hills site had been prescribed burned only 11 years prior to this study, therefore it would be expected that the quantity of downed woody material would be less than that at Johnson Lake, which has no recent fire record (P. Burk, R.O. Range, Ministry of Forests, pers. comm.).

The greater quantity of shrubs at Pickering Hills compared with Johnson Lake may be due to greater site productivity, or to a difference in browsing intensity which would partially be attributable to the exclusion of wildlife and cattle for a short period. There was a very marked difference in the abundance of shrubs on either side of the exclosure fenceline. At Johnson Lake, the shrub component consisted mostly of bitterbrush whereas at Pickering Hills bitterbrush was dominant, but was mixed with a large quantity of common snowberry and saskatoon.

The fine fuel load was somewhat different between sites. The quantity of fine fuels at Johnson Lake was very low and consisted mostly of dead grass and animal pellets. The Pickering Hills site had approximately three times more fine fuel, which also consisted of dead grass, and animal pellets, but included Ponderosa pine needles. The amount of dead grass was also much higher at this site, a consequence of no grazing.

Table 12 compares the fuel load on my sites with that of various plant communities in western North America. Comparisons such as this are difficult to make largely because of inconsistent and incomplete descriptions of the fuel sampling methods employed. Many others factors will affect the characteristics and composition of the fuel load on any given site, and these factors result in a wide range of potential fuel loads. Some of these will be discussed further. For this discussion, 'litter' in the table will be considered equivalent to the fine fuels in my study.

The quantity of standing grass on my sites was much less compared with most of the grass-dominated plant communities in western North America (Table 12). It is more or less comparable to Ponderosa Pine/cheatgrass stands in Arizona (Harrington 1987). Many of the papers that studied shrub-dominated plant communities did not give values for the grass component.

The quantity of grass on a site will be extremely variable and will depend on the plant species composition. An abundance of annual grasses such as cheatgrass will result in large year-to-year fluctuations in above-ground biomass depending on seed production in the year prior to measurement. Growing season weather conditions will also affect the seed production and germination of annuals, and the above-ground production of both annual and perennial grasses. Above-ground production will also vary depending on the grazing history and intensity.

The maximum shrub biomass on my site is comparable to that on the grass-dominated plant communities, but is much lower than that of most of the shrub-dominated communities (Table 12). It is most comparable to the mixed forest stands. The shrub biomass on the

Table 12. A comparison of fuel loads (kg/ha) for various plant communities in western North America.

Plant Community	Fuel Load Grass	Shrub	Total[1]	Source
Grass Dominated:				
Df - Idaho fescue grassland (Df seedling stage)	3 340	2 175	-	Gruell *et al.* (1986)
Df - Idaho fescue Grassland (Df sapling stage)	5 672[2]	942	-	Gruell *et al.* (1986)
Ponderosa Pine/ Cheatgrass	448[3]	-	-	Harrington (1987)
Ponderosa Pine/ Grass/Forb Site	283	-	-	Mitchell *et al.* (1987)
Shrub Dominated:				
This Study	200 - 900	600 - 7 000	1 700 - 7 900	
Artemesia frigida/ Stipa occidentalis Habitat Type	-	-	600	Tiedemann (1986)
Sagebrush/Grassland	-	10 400[4]	-	Tiedemann (1986)

Table 12. A comparison of fuel loads (kg/ha) for various plant communities in western North America (continued).

Plant Community	Fuel Load Grass	Fuel Load Shrub	Fuel Load Total[1]	Source
California Chaparral	-	30 394	-	Debano and Conrad (1978)
Ponderosa Pine/ Shrub	175	-	-	Mitchell *et al.* (1987)
Northern California Brush Sites - Snowbrush	-	50 300 - 91 640	-	Countryman (1982)
- Manzanita	-	47 400 - 100 800	-	"
California Brush Sites - Light	-	13 440 - 32 032	-	Nord and Countryman (1972)
- Heavy	-	40 900 - 193 500	-	"

Table 12. A comparison of fuel loads (kg/ha) for various plant communities in western North America (continued).

Plant Community	Fuel Load Grass	Fuel Load Shrub	Fuel Load Total[1]	Source
Mixed Shrub/Forest:				
Aspen Stands				
Mixed Shrubs	-	2 780 - 4 040	-	Brown and Simmerman (1986)
Aspen/Shrubs	-	1 098 - 6 700	-	"
Mature Df/Lw Stand	261 - 2 460	291 - 2 750	12 280 - 110 570	Norum (1974)

[1] Total fuel load does not include coarse fuel.
[2] Grasses and litter combined.
[3] Cheatgrass only.
[4] Stems only.

study sites was much less than in California chaparral and sagebrush grasslands. California chaparral stands are very dense, with many years accumulation of biomass due to fire suppression.

The abundance of shrubs on a site depends on many site history factors, including site productivity and fire frequency, as well as fluctuations caused by insect defoliation or wildlife browsing.

The quantity of fine fuels was very low on my study sites compared to other sites (Table 13). There was very little accumulation of organic material on my study sites due to recent fire occurrence, intensive grazing by cattle and browsing by wildlife, as well as a lack of input from a forest stand.

The coarse fuels were much more difficult to compare with other studies. The use of the line intersect method to measurement fuel loads (Van Wagner 1968 as modified by Trowbridge *et al.* 1986) is increasing on cut-over sites in B.C., but is still not a routine practice for wildlife prescribed burning in shrubland communities or for underburning. Therefore, comparable data to these communities are not available. However, a comparison of the total coarse fuel loads from my study sites with those from other forested and cut-over sites (Table 13), emphasizes how little coarse woody material there is on my study sites. Again, this is primarily due to the history of fire occurrence and the nature of these communities. It has been a number of years since trees have been present on these sites to provide input to the coarse fuel component.

Fuel consumption will be influenced by a number of factors, particularly fuel characteristics. The moisture content of the dead and living fuels at the time of burning is important, and is governed by very different factors. Dead fuels respond to weather conditions, in particular relative humidity, precipitation and temperature. Rice (1983) noted that

Table 13. A comparison of woody fuel load (kg/ha) for plant communities in western North America.

Plant Community	Fuel Load			Source
	Fine Fuel	Coarse Fuel	Total	
Ponderosa Pine/Grasses and Forbs - Mature Forest (Openings)	-	-	17.1	Vose and White (1987)
- Mature Forest (Closed)	-	-	145.9	"
Mixed Conifer Forests (Sierra Nevada) - Low Productivity Site	-	-	75 - 102	Kauffman and Martin (1989)
- Moderate Productivity Site	-	-	125 - 177	"
Mature Df/Lw Stand	520 - 1 480	-	12 280 - 110 570	Norum (1974)
Ponderosa Pine/ White Pine Open	64 300	10 750	-	Harrington (1982)
Closed	52 420	24 400	-	"

the dead fuel associated with bitterbrush is usually 1 to 2 cm in diameter, and reaches a moisture equilibrium with the atmosphere in 1 hour. The moisture content of the living fuels is species-specific, varying with respect to physiological activity and the growth stage of the plant, as well as site conditions. All of these factors will vary depending on the timing of the burn.

The living fuels, particularly those greater than 1 cm in diameter, are not usually consumed entirely because of their relatively high moisture content. In fall, shrubs often contain less moisture than during the spring, particularly if they have undergone a long summer drought period. On the contrary, in early spring, shrubs will have gone through a long period of dormancy, with no physiological activity throughout the winter, and consequently no water uptake. Therefore, they will also contain little moisture.

The ratio of dead to living fuels, and the arrangement of those dead fuels will therefore be important in determining how much of the living shrubs are consumed. As the dead fuel burns, it provides the necessary heat to dry the living fuels to their ignition point (Nord and Countryman 1972). The bitterbrush plants on my sites had a high ratio of dead to living fuels, with much of the dead material accumulating within the shrub itself, particularly at Pickering Hills, where large portions of the bitterbrush plants had been damaged by tent caterpillars. This is likely the reason that the majority of these plants were consumed during burning. Other species such as common snowberry and saskatoon had much less dead material and were not observed to be consumed as completely.

The net increase of 40% observed for the living shrub component at Johnson Lake was probably due to sampling error. The dead material within a shrub was included in the coarse or fine fuel component when sampling took place prior to burning, and this included material which was standing within a plant. Following burning, sampling of the standing shrub component included all material (branches) which was not down on the ground. Therefore it would have included any previously 'standing' dead material in error. There was not an increase in living shrubs at Pickering Hills, but perhaps this is simply because more of the standing material was consumed on this site. Also, the shrub density was much lower at Johnson Lake. Therefore, a random location of plots resulted in sampling many plots with no shrubs, which greatly increased the standard error. I can only surmise that the variability and problems associated with sampling may have masked a potential reduction in the quantity of shrubs on these sites.

The spring burn at Pickering Hills consumed 100% of the grasses, which may have been due to the low moisture content of the dormant grasses at the time of burning (reflected by a high FFMC). The grass moisture content will be particularly sensitive to relative humidity and air temperature (McArthur 1966), with changes occurring on an hourly basis. The degree of curing and the moisture content of grasses is very important in determining whether these types of prescribed burns will occur (G. Tipper, pers. comm.). The FFMC is the most useful of the codes and indices in the Canadian Fire Weather Index System for predicting whether effective burning can take place on sites which have a major component of grass for fuel. The total preburn quantity of grass at Johnson Lake was approximately four times that at Pickering Hills, but there was little difference in the percent consumption occurring between all the burns. This implies that most quantities of grass will ignite and burn quickly, given sufficiently high FFMC values. Unburned grasses were likely not due to differences in the fire severity between burns but rather, due to microsite differences which may prevent some plants from burning completely (e.g., shading which could prevent adequate drying and curing). This can only be substantiated with further burning under a wider range of FFMC values.

There was no statistically significant reduction in the quantity of fine fuel on my study sites. This can also be explained by the highly variable accumulation of litter on the sites. Most of the fine fuels occurred under shrubs, where grasses are often not grazed, and have accumulated. Consequently, there were two types of microsites with respect to fuel accumulation - those beneath the shrubs and those in the interspaces between shrubs. A variable shrub distribution can therefore produce a variable fine fuel distribution.

The quantity of coarse fuels on these study sites was very low, due to the recent fire history and the lack of overstory contribution to the downed woody material. The number of pieces of fuel occurring on the transects was low, and almost entirely of the smaller diameter classes. These fuel pieces are susceptible to disturbance by small and large mammals, and by air currents during a fire. As a result, they may be missed when relocating the transects. This will also add to the apparently high variability of these fuel components.

4.2.3 General Trends Occurring Between Fuel Consumption and Fire Weather Codes, Indices and Weather Parameters

Correlation between fuel changes on the different burns and Canadian Fire Weather Index System codes and indices and weather parameters could not be determined, because the sample size was too small. Instead all the data were graphed to look for possible trends and relationships. Very few trends were apparent, and often those which did occur had no logical explanation.

The fall burn plots generally had the highest grass consumption, which was related to temperature. Generally, as temperature decreased, grass consumption increased, which was not the trend which would be expected. It was also observed that as temperature decreased, consumption of the 5 - 7 cm and 7 - 12 cm diameter size class of coarse fuel increased. None of these trends have any logical explanation.

There were no trends observed for the FFMC, except that as the FFMC increased, fuel consumption of the 7 - 12 cm diameter size class of dead woody fuel increased. This would not be expected since the FFMC should be more closely related to the fine fuel component. The consumption of this size class increased as the DMC and DC increased, which is to be expected. There were no apparent trends in fuel consumption with changes in the FWI or the relative humidity.

A greater number of burns over a much wider range of fire weather conditions is required in order to establish any logical and consistent trends in fuel consumption.

5 EFFECTS OF PRESCRIBED BURNING ON KEY PLANT SPECIES

5.1 Results

5.1.1 Experimental Burn Plots

5.1.1.1 Changes in Percent Cover of Key Species

Statistical analysis of the percent cover data tested for differences between treatments (control, and fall or spring burning) within each year at each site (Tables 14 and 15). The mean percent cover of all species preburn, and the first and second growing seasons following the Dry Gulch experimental spring burn are also discussed in this section (Table 16). The results are presented separately for each species.

5.1.1.1.1 *Agropyron spicatum*

There was no statistically significant difference in the percent cover of bluebunch wheatgrass between the spring burn or the fall burn and control plots in the first postburn growing season (Table 14). There was no significant difference between the fall burn and control plots in the second postburn growing season.

There was also no difference in the percent cover between fall burn and control plots at the Johnson Lake site (Table 15).

5.1.1.1.2 *Amelanchier alnifolia*

There appeared to be a greater percent cover of saskatoon on the spring burn plots at Pickering Hills in the first postburn growing season compared with the control plots, but this was not statistically significant (Table 14). There appeared to be less saskatoon on the fall burn plots compared with the control plots, but again this was not statistically significant.

At Johnson Lake there was no difference in the percent cover between fall burn and control plots (Table 15). There was also no significant difference between preburn and the first and second years following spring burning on the Dry Gulch experimental plots (Table 16).

Table 14. Mean percent cover for all key species on the Pickering Hills experimental burn plots (standard error in parentheses).[1]

Species	Year 1 Control	Year 1 Fall	Year 2 Control	Year 2 Fall	Year 1 Control	Year 1 Spring
Agropyron spicatum	1.3 (0.6)	1.3 (0.3)	1.4 (0.5)	2.1 (0.5)	1.4 (0.5)	1.0 (0.4)
Amelanchier alnifolia	9.9 (2.5)	6.1 (1.5)	10.1 (1.7)	7.7 (1.9)	10.1 (1.7)	13.9 (3.9)
Ceanothus veultinus	0.1 (0.1)	1.1 (0.7)	0.4 (0.3)	1.0 (0.6)	0.4 (0.3)	0.0 (0.0)
Festuca scabrella	1.2 (0.5)	0.6 (0.4)	1.1 (0.6)	1.0 (0.6)	1.1 (0.6)	0.2 (0.1)
Purshia tridentata	27.9a (1.8)	5.9b (1.2)	28.7a (2.9)	11.3b (1.7)	28.7a (2.9)	0.5b (0.2)
Stipa occidentalis	4.2a (1.1)	6.3b (1.6)	5.4a (1.4)	8.1b (1.2)	5.4 (1.4)	5.8 (2.2)
Symphoricarpos albus	1.7 (0.7)	2.1 (0.7)	2.0 (0.9)	2.9 (2.0)	2.0 (0.9)	1.5 (0.3)

[1] Different letters indicate significantly different values between a treatment and control within each year ($\alpha = .05$); where no letters occur there were no significant differences.

Table 15. Mean percent cover for key species at Johnson Lake for the first postburn growing season (standard error in parentheses).[1]

Species	Control	Fall
Agropyron spicatum	0.6 (0.6)	0.5 (0.4)
Amelanchier alnifolia	2.0 (1.2)	2.6 (0.8)
Festuca scabrella	0.6 (0.2)	2.3 (1.1)
Purshia tridentata	1.6 (0.7)	3.4 (1.8)
Stipa occidentalis	3.9 (1.5)	3.4 (2.2)

[1] There were no significant differences between treatments for all species (α = .05).

Table 16. Mean percent cover for key species on the Dry Gulch expermental burn plots (standard error in parentheses).[1]

Species	Preburn	Year 1	Year 2
Amelanchier alnifolia	2.6	1.1	0.7
	(1.6)	(0.7)	(0.5)
Festuca scabrella	5.2	3.3	2.6
	(2.3)	(1.0)	(0.7)
Purshia tridentata	3.3a	0.7b	0.9b
	(0.9)	(0.3)	(0.3)
Stipa occidentalis	1.4	2.3	1.9
	(0.4)	(0.7)	(0.6)

[1] Different letters indicate significantly different values between each postburn year and the preburn year (α = 0.05); where no letters occur there are no significant differences.

5.1.1.1.3 *Ceanothus velutinus*

Snowbrush was only present at Pickering Hills, and the percent cover was highly variable (as can be seen by the relatively high standard error values (Table 14)). The distribution is patchy, and it was more abundant in Block 3, which had been enclosed in a wildlife-proof fence for a number of years prior to the study. There was no statistically significant difference between either the spring or fall burn treatment and the control in the first postburn growing season, or between the fall burn and the control in the second postburn growing season.

5.1.1.1.4 *Festuca scabrella*

At Pickering Hills there were no differences in the percent cover of rough fescue between the control and either the fall or spring burn treatment in the first growing season following spring and fall burning or in the second growing season following fall burning (Table 14).

At Johnson Lake there appeared to be an increase in the percent cover on the fall burns, but it was not statistically significant (Table 15). There was no significant difference in the percent cover between preburn and the first or second growing seasons postburn at Dry Gulch (Table 16).

5.1.1.1.5 *Purshia tridentata*

At Pickering Hills, in the first postburn growing season, there was significantly less percent cover of bitterbrush both on the spring and the fall burns compared with the controls. Bitterbrush was almost eliminated following spring burning (Table 14). There appeared to be less bitterbrush following spring burning compared to the fall burns but this was not tested statistically (Table 14). By the second growing season following the fall burn, bitterbrush had begun to recover, showing a doubling in percent cover over the first growing season, but it was still 50% less than that on the control plots.

At Dry Gulch there was a significant decrease in the percent cover in the first postburn growing season (80% less than preburn) and by the second growing season bitterbrush had only recovered slightly (74% less than preburn).

5.1.1.1.6 *Stipa occidentalis*

At Pickering Hills, there was a significant increase in the percent cover of stiff needlegrass in both the first and second growing seasons (33% both years) following fall burning (Table 14). There appeared to be an increase in percent cover from the first to the second growing season on the fall burn plots (24%) (Table 14) but this was not tested statistically. There was no significant difference in percent cover between fall burn and control plots at Johnson Lake or between preburn and the first and second growing seasons following spring burning at Dry Gulch (Tables 15 and 16).

5.1.1.1.7 *Symphoricarpos albus*

At Pickering Hills, there was no significant difference in the percent cover of common snowberry between both treatments and the control plots in the first and second postburn growing seasons (Tables 14 and 15).

Common snowberry was not present on the Johnson Lake site.

5.1.1.2 Differences in the Current Annual Growth of Key Species on the Pickering Hills Fall Burn Plots

Despite the relatively large sample sizes used, the CAG measurements were highly variable for all species (Table 17). In the first growing season following fall burning, no significant differences in CAG between fall burn and control plots were detected for any species, with the exception of bitterbrush and saskatoon. CAG was 71% lower for bitterbrush and 48% lower for saskatoon on the fall burn plots compared to the control plots.

Table 17. Mean current annual growth (g/m²) for all key species on the Pickering Hills fall burn and control plots (standard error in parentheses).

Species	Control	Fall Burn
Agropyron spicatum	3.6 (1.8)	4.0 (1.6)
Amelanchier alnifolia	26.4a (18.3)	13.8b (4.8)
Ceanothus velutinus	0.0 (0.0)	1.4 (1.4)
Festuca scabrella	1.1 (0.5)	0.6 (0.3)
Purshia tridentata	41.8a (8.4)	12.1b (3.5)
Stipa occidentalis	8.7 (1.1)	8.0 (1.8)
Symphoricarpos albus	2.0 (1.3)	2.7 (1.2)

[1] Different letters indicate significantly different values between fall burn and control plots ($\alpha = .05$); where no letters occur, there are no significant differences.

5.1.2 Operational Burn Plots

5.1.2.1 Fire Severity Estimation

The number of bitterbrush plants resprouting on the burned plots was recorded to attempt to estimate fire severity on the operational burns. The percentage of bitterbrush plants which had sprouted ranged from 40% at Dry Gulch in the first growing season following burning, to 78% at Demars in the 4th growing season following burning (Table 18). At Dry Gulch, upper Sharptail, and lower Sharptail, some bitterbrush plants remained intact and living following burning.

5.1.2.2 Changes in Percent Cover of Key Species

Some differences in environmental characteristics occurred between operational burn sites (Table 1). These differences were reflected by variations in plant species composition and abundance from site to site. The time since burning at each site ranged from 1 to 4 years at the time of sampling (Table 4).

The percent cover was highly variable between plots within a site, which is reflected in the high standard errors (Table 19). There was no snowbrush present on any of the operational burn plots.

5.1.2.2.1 *Agropyron spicatum*

The percent cover of bluebunch wheatgrass on the unburned areas varied from 4.9% at White-tail/Little Bull, to 0% at Dry Gulch (Table 19). There were no statistically significant differences in the percent cover of bluebunch wheatgrass between burned and unburned areas at any sites. At upper Sharptail and White-tail/Little Bull, there was less cover (49% and 63%, respectively), but the variability was too high to detect any statistically significant differences.

Table 18. The proportion of bitterbrush resprouting on operational burns (standard error in parentheses).

Site	No. Years Since Burned	Sprouted	Nonsprouted	Unburned
Dry Gulch	1	41 (8)	47 (5)	13 (9)
Lower Sharptail	1	48 (4)	43 (3)	9 (4)
Upper Sharptail	1	61 (9)	29 (6)	10 (5)
Demars[1]	4	78 (15)	22 (4)	0 (0)
Whitetail/Littlebull	2	40 (8)	60 (3)	0 (0)

[1] On this site it was not possible to distinguish between sprouted and unburned shrubs.

Table 19. Mean percent cover for key species on burned and adjacent unburned plots at the operational burn sites (standard error in parentheses).[1]

a) Dry Gulch

Species	Unburned	Burned
Amelanchier alnifolia	6.5 (1.4)	5.0 (1.0)
Festuca scabrella	3.8 (1.2)	4.7 (0.8)
Purshia tridentata	12.2a (1.7)	0.5b (0.3)
Stipa occidentalis	0.3 (0.2)	0 (0)

b) Lower Sharptail

Species	Unburned	Burned
Agropyron spicatum	0.1 (0.1)	0.2 (0.1)
Amelanchier alnifolia	0.5 (0.3)	0.0 (0.0)
Festuca scabrella	3.3 (0.9)	1.9 (0.4)
Purshia tridentata	7.1a (1.8)	0.8b (0.3)
Stipa occidentalis	2.7a (0.6)	6.4b (0.9)
Symphoricarpos albus	0.4 (0.3)	0.0 (0.0)

c) Upper Sharptail

Species	Unburned	Burned
Agropyron spicatum	2.9 (1.4)	1.5 (0.5)
Amelanchier alnifolia	1.5 (0.8)	1.1 (0.6)
Festuca scabrella	1.9 (0.9)	2.0 (0.5)
Purshia tridentata	10.7a (1.9)	2.4b (1.3)
Stipa occidentalis	4.2 (0.7)	3.0 (0.6)
Symphoricarpos albus	2.7 (1.6)	0.8 (0.4)

d) Demars

Species	Unburned	Burned
Agropyron spicatum	0.1 (0.1)	0.1 (0.1)
Purshia tridentata	5.3 (2.4)	7.9 (1.8)
Symphoricarpos albus	2.6 (1.2)	2.7 (1.3)

e) **White-tail/Little Bull**

Species	Unburned	Burned
Agropyron spicatum	4.9 (2.2)	1.8 (0.7)
Amelanchier alnifolia	4.7 (1.8)	8.3 (2.4)
Festuca scabrella	2.4a (1.1)	0.6b (0.3)
Purshia tridentata	16.4a (2.1)	3.9b (0.6)
Stipa occidentalis	0.4 (0.1)	0.4 (0.2)
Symphoricarpos albus	14.8a (5.8)	6.3b (2.4)

[1] Different letters indicate significantly different values for unburned and burned areas (α = .05); where no letters occur there were no significant differences.

5.1.2.2.2 *Amelanchier alnifolia*

The percent cover of saskatoon on the unburned sites varied from 6.5% at Dry Gulch to 0% at Demars (Table 19). There were no statistically significant differences in percent cover between burned and unburned areas at any site, although there appeared to be more saskatoon (43%) on the burned plots compared with the unburned plots at White-tail/Little Bull in the second growing season following burning.

5.1.2.2.3 *Festuca scabrella*

The percent cover of rough fescue on the unburned sites varied from 3.8% at Dry Gulch to 0% at Demars. At White-tail/Little Bull, there was significantly less rough fescue on the burned plots compared with the unburned plots (94%), but this difference only represented approximately a 2 percentage point difference in cover.

5.1.2.2.4 *Purshia tridentata*

Bitterbrush was the dominant shrub species on almost all of the operationally burned sites. The unburned sites ranged in percent cover from 5% at Demars to 16% at White-tail/Little Bull. On almost all the sites, burned plots had significantly lower percent cover than unburned plots (Table 19; Figure 13). In the first growing season following burning at Dry Gulch, there was a 96% difference between unburned and burned plots (Table 19a). This compares with a 90% and 77% difference respectively, between unburned and burned plots on the lower and upper Sharptail sites in the first postburn growing season (Tables 19b and 19c). There was a 76% difference in bitterbrush percent cover on burned compared with unburned plots at White-tail/Little Bull in the second postburn growing season. At Demars, there was no significant difference between burned and unburned plots in the fourth postburn growing season (Table 19d).

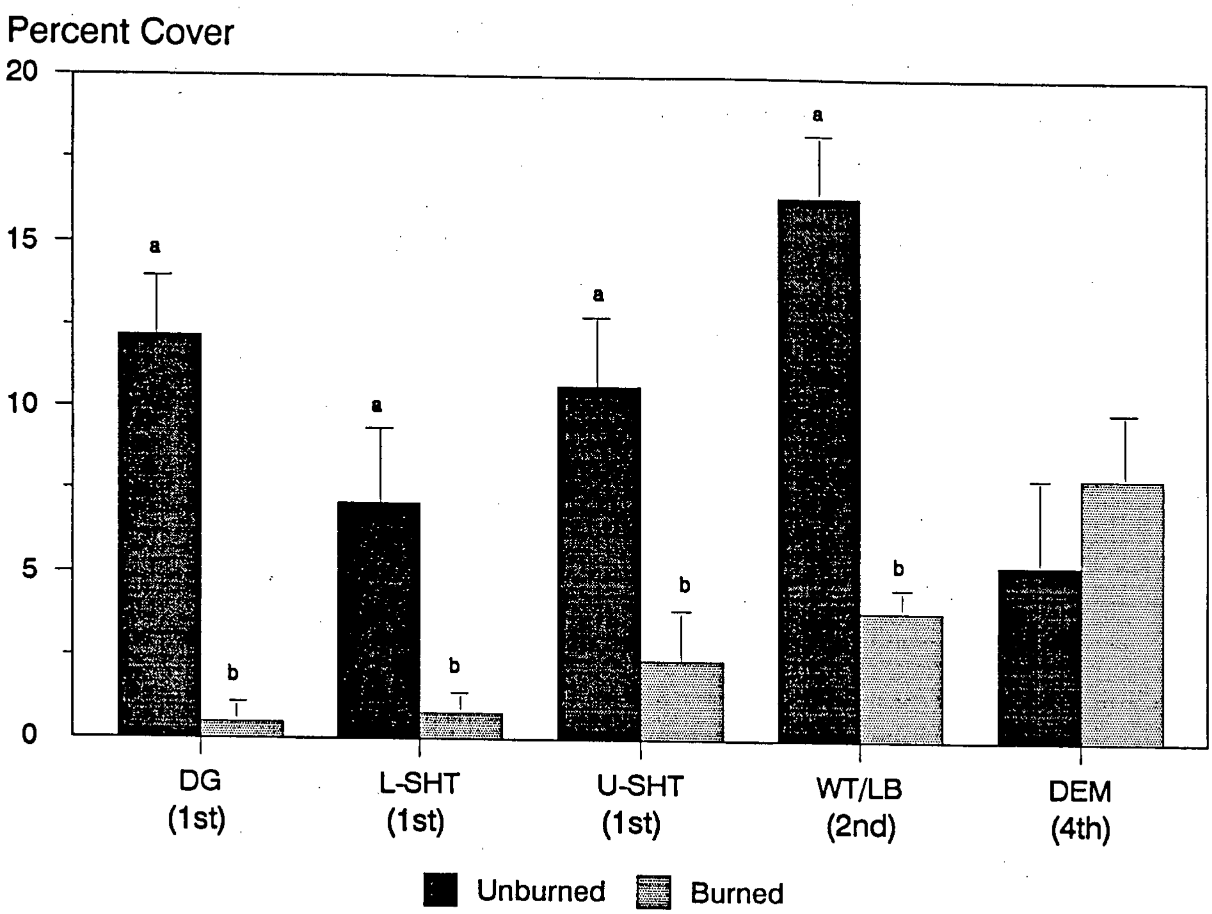


Figure 13. Mean percent cover of bitterbrush on unburned and burned plots for all operational burns. Error bars represent standard error and letters denote significant differnces between burned and unburned areas ($\alpha = 0.05$).

5.1.2.2.5 *Stipa occidentalis*

Stiff needlegrass ranged in percent cover from 0.3% at Dry Gulch to 4.2% at upper Sharptail (Table 19). At lower Sharptail there was 58% greater percent cover of stiff needlegrass on the burned plots compared with unburned plots. At all other sites there was no significant difference between burned and unburned plots.

5.1.2.2.6 *Symphoricarpos albus*

Common snowberry ranged in percent cover from 0% at Dry Gulch to 15% at White-tail/Little Bull. It was the second most abundant shrub species at White-tail/Little Bull. At this site, there was 58% less snowberry on burned plots in the second postburn growing season compared to unburned plots. There was no significant difference in percent cover at all other sites.

5.2 Discussion

5.2.1 Fire Severity Estimation

The characterization of prescribed fire is essential to understanding and predicting its effects and to the eventual development of burning prescriptions. The concept of fire severity attempts to characterize the ecological effects of a fire, with respect to the forest floor, soil, or plant community. Ryan and Noste (1985) best describe it as relating "to the degree that on-site plants survive a fire or reproduce from on-site meristematic tissue such as rhizomes, root crowns, underground stems, and seeds or the extent to which the site is invaded by seed from off-site plants (Lyon and Stickney 1976). Fire severity is also reflected by the amount and location of organic matter lost by burning, decreases in the protective forest floor, volatilization of nitrogen and other elements, and transformation of less volatile elements to soluble mineral forms (Wells *et al.* 1979)." It is characterized by the heat pulse down into the soil. While fire intensity can be quantified using the rate of spread and total fuel consumption, fire severity is usually assessed qualitatively. It is generally classified by the degree of organic matter consumption and soil heating.

There are problems in assessing the fire severity on a burn after it has occurred. Ryan and Noste (1985) propose a fire severity rating which combines ground char and flame length into a two-dimensional fire severity matrix. Observed ecological effects are then related to the different combinations of ground char and flame length in this matrix. In my study, these measurements were not taken during the operational burns, therefore a matrix such as this cannot be used.

Morgan and Neuenschwander (1988) used percent fuel consumption as an indication of fire severity, since the initial quantity and the degree of consumption of the organic matter on a site will influence the amount of heat reaching the soil. They used two general categories -

high severity burns were considered those with little unconsumed organic layers and dead woody material less than 7.5 cm in diameter remaining. Low severity burns were those with organic layers remaining intact and little mineral soil exposed. A classification such as theirs would not be a very useful indicator of fire severity for my study, considering the low fuel load on these sites.

The fire duration at any particular location was short because of the low quantity of fuel. The accumulation of fine fuel beneath shrubs such as bitterbrush may result in fires of longer duration at these spots which in turn may increase the temperatures reached at the growing points of the plants. Many of these classifications are only practical if assessment occurs pre- and postburn.

A more direct indicator of fire severity is the temperature reached at particular points in the soil. This gives a good indication of the temperatures experienced by below ground plant parts. Soil heating has two components, the maximum soil temperature reached and the duration of the maximum temperature. The temperature considered lethal to plant tissue is 60 °C (Daubenmire 1968). Only a few studies have measured the temperatures reached at different depths in the soil during fires.

Hamilton (1988) studied soil heating during slashburning in the Sub-Boreal Spruce zone in the central interior of British Columbia. She reported maximum soil temperatures of approximately 600 °C at the soil surface and the upper 2 cm, with a very sharp decrease in temperature occurring after 10 minutes. Temperatures at both depths were greater than 60 °C for almost 25 minutes. At a second site, temperatures at the soil surface were only above 120 °C for 25 minutes. The maximum soil temperature reached in the upper two centimetres was only 70 °C. The soil temperature increased gradually over 10 minutes, then levelled off, but it was maintained for 25 minutes. Soil temperatures four centimetres below the surface were not over 60 °C at either of the two sites she studied.

Bailey and Anderson (1980) found that the soil temperatures reached at the ground surface during burning were different in a grassland area compared to a shrub-dominated area or an aspen area. In the grassland area, maximum temperatures reached were 186 °C and on the shrub-dominated site, 398 °C. The fuel loads for Bailey and Anderson's (1980) study are given in Table 12.

In western Montana, Noste *et al.* (1987) used a range of artificially produced fuel loads to simulate natural fuel conditions in a Douglas-fir/Snowberry habitat type. They reported mean temperatures above 60 °C for 5 to 17 minutes in the top six centimetres of the soil. They did not report the maximum soil temperatures reached.

The fuel and fire characteristics of my study sites fell within the ranges of those characteristics studied by Noste *et al.* (1987). I will therefore extrapolate from their results and speculate that lethal temperatures were likely achieved on all of the experimentally and operationally burned areas. Given the relatively low quantity of fine fuels that occur on these sites, elevated temperatures were of short duration.

The degree of soil heating can be influenced by a number of fire characteristics such as duration, which is determined by the quantity of fuels and their moisture content. The degree of soil heating is also influenced by a number of site factors. The soil temperatures achieved will depend a great deal on soil properties such as coarse fragment content and the soil moisture content. Abundant soil moisture will confine high soil temperatures to the upper 1 cm. In my study, inadequate soil moisture may have been a problem at the time of the experimental fall burns because of summer drought. However, all of the operational burns and the experimental spring burn took place shortly after snowmelt, when soil moisture was adequate.

Soil texture on a site is important when discussing the fire severity, because of its influence on the transfer of heat through the soil. Finer-textured soil will have slower heat transfer, partly because of its high moisture-holding capacity. Heat transfer through water is much slower than through an air space. These air spaces are much more abundant in a coarse-textured soil (R. Trowbridge, Soil Scientist, B.C. Ministry of Forests, Smithers, pers. comm., 1990).

Coarse soils also allow fibrous bark and organic material in the upper soil horizon to burn. This causes increased temperatures and heating of the plant below-ground (Martin and Driver 1983). Finer-textured soils such as those occurring at Sharptail, Dry Gulch and Demars, have good soil moisture retention, which favours the sprouting of bitterbrush. However at the White-tail/Little Bull site, the soils are very rocky and gravelly.

The ability of resprouting plants to survive lethal temperatures depends largely on the location of their perennating organs. This is reflected in the varying responses of the shrub species observed in this study. Bitterbrush is the most susceptible shrub on these sites, because its perennating organs are located at or above the soil surface, where temperatures are highest. Common snowberry and saskatoon suffered almost no mortality following burning, because they both resprout from rhizomes located predominantly just beneath the organic layers in the upper few centimetres of mineral soil (Bradley 1984).

The percent of resprouting bitterbrush plants varied between sites. The lack of any unburned plants at the White-tail/Little Bull site, combined with the low resprouting on this site (40%) two years following burning indicates that this fire was probably more severe than the other operational burns. Due to the lack of on-site weather data for these operational burns, it is impossible to accurately relate bitterbrush mortality to fire weather conditions or fire behaviour characteristics.

Sampling of shrub density on small plots was attempted, but the variability was far too high given the small sample size, to detect differences in sprouting between burned and unburned areas. There did appear to be a greater number of saskatoon sprouts on most of the operational burns, compared with unburned areas but there were no statistically significant differences.

Leege and Hickey (1971) observed the same number of snowberry sprouts before and after burning of brushfields in Idaho. They did however, observe a greater number of saskatoon sprouts on burned areas compared to unburned areas, with spring burning producing a greater number of sprouts than fall burning.

Since my study sites were sampled only after being burned, sprouting of key browse plant species may be the only useful indicator of fire severity. Due to the abundance of bitterbrush on these sites, and its susceptibility to burning, the sprouting of this species is probably the most important indicator of fire severity.

The frequency of fire on a site will greatly affect the fire severity. The greater the length of time since burning, the greater the accumulation of organic material which will produce a fire of greater severity. Bradley (1984) also speculated that some shrub species which established from seedlings or new rhizome branches that had developed during a long fire-free interval, would generally do so above the mineral soil surface, and are therefore more susceptible to fire. This did not seem to be evident on the sites in this study. Bitterbrush mortality was greatest on the White-tail/Little Bull site and on the spring burn plots at Pickering Hills, both of which had been recently prescribed burned.

For simplicity and the sake of comparison, I have assumed that bitterbrush will not resprout after the first year from plants that are killed. Bitterbrush will be compared despite differences in the number of years since burning. Therefore, the fire severity on the operational burns rated from most severe to least would have been:

White-tail/Little Bull > Demars ≈ upper Sharptail > lower Sharptail ≈ Dry Gulch (Table 18).

The difficulty in quantifying fire severity after the fact on these prescribed burns is seen in the fact that there was a difference in the fire severity (as characterized by the percent of resprouting bitterbrush) between the upper and lower Sharptail burns, despite the fact that they were burned at essentially the same time under almost identical conditions.

5.2.2 Plant Species Response

The adaptiveness of a species, particularly in terms of a strategy for maintaining itself in an environment which is prone to disturbance, is difficult to discuss. Mutch (1970) hypothesized that plant species in areas where fire is frequent, will have adaptations which enhance the chance of an ecosystem burning naturally. This means the differentiation between plant species which have adaptations to survive fire and those which depend on fire to perpetuate themselves. According to Mutch's hypothesis, the heat content of a plant is one indicator of a plant adaptation which promotes burning within the community. Fire dependent plants have energy properties which make them highly flammable. The heat content of a plant depends on the fuel chemistry, or the total amount of energy available (which is correlated to the crude fat content) and its availability to the combustion process (which may be inhibited by certain inorganic constituents within the plant) (Mutch 1970). Bitterbrush is considered to have an average heat content which is less than that of many species in chaparral communities which sustain explosive fires (Rice 1983). I suspect that in the East Kootenay communities, the plant species may continue to perpetuate themselves without fire, but eventually other mechanisms will affect the community composition (e.g., encroachment and competition from conifers).

Any discussion on plant species response to fire must consider the historical significance of fire within the plant communities present and the evolutionary adaptations of each plant species to the disturbance. Following burning, almost all of the plant species on the study sites regenerated by sprouting from remnant underground plant parts. The evolutionary and ecological significance of this response by these drier plant communities as a whole indicates that fire has a natural role as a frequent disturbance mechanism in these types of communities (Mutch 1970).

On dry open sites, fire usually results in a lesser amount of each species but not a major compositional change in the plant community (Fischer and Bradley 1987), which was also apparent in the plant communities that I studied.

5.2.2.1 Shrubs

The following discussion will focus on the fire survival strategies of the four shrub species studied, comparing the different regenerating mechanisms of each.

5.2.2.1.1 *Amelanchier alnifolia*

Saskatoon is a moderately important browse species for big game species throughout its range but in the East Kootenay it is readily sought after and consumed throughout the year by both ungulates and cattle. It is largely utilized in the winter months by elk, moose, and mule deer (Watson *et al.* 1980; Hemmer 1975 as cited in Noste and Bushey 1987). It is moderately to highly palatable (Blauer *et al.* 1975; Watson *et al.* 1980) and is readily browsed by cattle when more palatable species have dried out. The berries of saskatoon are utilized by a wide variety of birds and small mammals as well as bear (Mace and Bissell 1986). It is a long-lived many-stemmed deciduous perennial shrub or small tree reportedly living a maximum age of 86 years (Watson *et al.* 1980; Noste and Bushey 1987).

Saskatoon survives fire almost completely by resprouting from deeply located rhizomes, which are usually oriented both vertically and horizontally, largely just below the mineral soil.

Bradley (1984) describes the rhizomes as "root crowns" but only to give a better perception of the robustness of the below-ground structure. Regenerating stems come from the portion of the root crown closest to the soil surface usually within 1.5 m of the main plant (Hemmer 1975 as cited in Noste and Bushey 1987). Saskatoon is very immune to fire injury both because the rhizomes are located primarily below the soil surface and because it is afforded protection by its woodiness (Bradley 1984). Lonner (1972) as cited by Bradley (1984), found that the roots of the plant ranged from 10 to 36 years older than the above-ground stem.

On my study sites, saskatoon regenerated from shoots arising from below the soil surface (Figure 14). Most plants were observed to have survived burning on both the operational and experimental burns.

At the Pickering Hills fall burn, there was significantly less (48%) CAG on the burned plots (Table 17) although there was no statistically significant difference in percent cover between the fall burn and the control. This is likely due to resprouting of all the burned shrubs, but greatly reduced height and branching of the shoots, compared with unburned shrubs. Presumably as the new sprouts branch and increase in size the percent cover will increase over time to perhaps exceed that of the unburned areas.

Other authors have found variable results both in terms of cover and current annual growth. Bradley (1984) points out that following burning, saskatoon resprouts very well

Figure 14. Resprouting of *Amelanchier alnifolia* (saskatoon) from underground rhizomes in the first growing season following fall burning at Pickering Hills.

to burning but is not likely to increase in frequency. Asherin (1976) found the opposite to my results; he found that the maximum crown height was reduced in the first three years following burning, but CAG increased compared with unburned areas. Merrill *et al.* (1982) found that CAG of saskatoon did not vary between burned and unburned areas over a four year period. Davidson (in prep.) reported a decrease in the percent cover of saskatoon in the second growing season following spring burning in similar ecosystems to my study.

Others have found that stem heights equalled those of unburned areas by the end of the first growing season (Merrill *et al.* 1982). In the Sub-boreal Spruce zone of British Columbia saskatoon is considered to have slow recovery following slashburning of cutover areas (Hamilton and Yearsley 1988).

In my study season of burn had no significant effect on plant response. All the above-ground stems were killed regardless of the timing of burning. Noste *et al.* (1987) also found only a weak relationship between sprouting response and season of burning (phenology). Leege and Hickey (1971) found that there were a greater number of sprouts following spring burning compared with fall burning but that the reverse was true for shrub height.

In my study there did not appear to be a difference in sprouting ability due to fire frequency, since saskatoon resprouted following all of the operational burns studied regardless of the time interval since burning. Leege (1979) burned brushfields during the spring at 3 to 5 year intervals and observed saskatoon resprouting after each burn. Noste *et al.* (1987) found that the sprouting response did not appear to be related to plant size, despite the fact that decadent saskatoon shrubs have a high proportion of dead stems within the plant.

No seedlings of saskatoon were observed on my experimental study sites. Seed production tends to be low in saskatoon, with good seed crops being produced only every 3-5 years (Blauer *et al.* 1975). Seed dispersal is mainly by birds and bears that pass consumed seeds through their digestive tracts (Noste and Bushey 1987). Saskatoon can produce fruit as early as the second growing season following burning (Crane *et al.* 1983). Abundant seed production has been observed in burned areas in similar plant communities in the East Kootenay.

Other factors such as browsing pressure also affect saskatoon response. Following a wildfire, Crane *et al.* (1983) observed heavy damage of saskatoon after a wildfire due to browsing.

5.2.2.1.2 *Ceanothus velutinus*

Snowbrush is a highly valued evergreen browse species utilized as winter forage by deer and elk (Miles and Meikle 1974; Conard *et al.* 1985; Noste and Bushey 1987). It occurs on the driest sites, generally with south-facing aspects (Miles and Meikle 1974). It occurs at Pickering Hills but is very heavily browsed, where it has not been protected by exclosures. On Block 3 (enclosed within a wildlife-proof exclosure), it was very healthy and robust.

Snowbrush is considered a residual colonizer and fire dependent, germinating from on-site ground-stored seed (Stickney 1982) requiring heat stratification to germinate (Dyrness 1973; Miles and Meikle 1974; Conard *et al.* 1985). Seeds are long-lived, often remaining viable on a site for more than 200 years (Gratowski 1962 as cited in Conard *et al.* 1985). Although not abundant on my study sites, this species was selected for study because of its importance to wildlife and because of the potential for enhancing the plant due to its seed-banking abilities and its requirement for heat stratification.

Seeds generally remain close to the parent plant when released. They are dispersed by mechanical expulsion and by small mammals (Noste and Bushey 1987).

In the first growing season following fall burning at Pickering Hills, no snowbrush seedlings were observed to have germinated from stored seed sources. Seed production and storage is usually considered high for this species. In Oregon, sites have been found with up to 2.5 X 10^6 seeds/ha stored in the duff (Quick 1956). Germination is better following fall burning rather than spring burning because of the higher soil temperatures during fall burning followed by a cold/wet stratification occurring in winter weather (Conard *et al.* 1985). The absence of snowbrush germinants on the Pickering Hills study site could be due to one or more of the following factors: firstly, this site had been browsed heavily for a number of years, which may have prevented the plants from producing seed. There is a possibility that the seedlings were overlooked in sampling, although they certainly could not have been abundant. Lastly, the temperatures achieved during burning or the duration of those maximum temperatures may not have been sufficient to stratify the seed.

The results from the experimental burning may suggest that snowbrush is not abundant on this site, and has therefore not accumulated a large quantity of stored seed, so the use of fire to encourage germination should not be recommended without further assessment of the seed bank on these sites.

Snowbrush has moderately good resprouting ability, generally resprouting from the root crown following total crown kill by fire, excessive injury or other mechanical injury (Miles and Meikle 1974; Noste and Bushey 1987).

Those plants which were present on-site were not eliminated following burning. Plants were observed to have resprouted and appeared very lush and green, even without exclusion from wildlife browsing. These plants will probably not increase on this site unless they can flower and produce seed.

5.2.2.1.3 *Purshia tridentata*

Bitterbrush has a wide distribution in the drier ecosystems of intermontane western North America. It is the dominant shrub species on elk and mule deer winter ranges in the Rocky Mountain Trench south of Canal Flats. Bitterbrush is considered a very important browse species for both livestock and wildlife species. In the East Kootenay it provides excellent browse for deer in the winter (Demarchi, pers. comm., 1990), is heavily used by elk, especially during the winter months (Mueggler and Stewart 1980) and is consumed in lesser amounts by bighorn sheep in the spring (Gullion 1964). It also provides food and cover for small mammals and birds (Fischer 1988).

Bitterbrush is a long-lived deciduous shrub with numerous ecotypes which vary in growth form continuously from decumbent plants with multiple stems to upright plants with a single stem (Nord 1965; Blauer *et al.* 1975). It is a deep-rooted species, with its root system reaching depths of 4.0 to 5.8 m (McConnell 1961; Giunta *et al.* 1978).

Much literature exists on the response of bitterbrush to disturbance, particularly fire (Nord 1965; Martin and Driver 1983). It survives fire largely by resprouting from existing plants, but also from on-site seed caches present prior to the fire, and by seeding in from off-site sources (Fischer and Bradley 1987). In many plant communities it is considered a weak sprouter. It varies greatly in its ability, and in the mechanism used, to resprout following burning (Martin and Driver 1983). Sprouts have been observed to arise from dormant adventitious buds encircling the stem at ground level, from a callus of meristematic tissue formed beneath the bark following burning, from a lignotuber (a swelling in the main stem at or just below ground surface), and from buds below the soil surface (Blaisdell and Mueggler 1956; Martin and Driver 1983). On the experimental and operational burn plots in this study, all regeneration of bitterbrush was by resprouting. As bitterbrush has a number of ecotypic growth forms, genetic variation will often determine how sprouts are formed.

The decumbent growth form is generally considered a good resprouter following fire or top removal. Other ecotypes such as the columnar growth form, are more damaged by fire. The bitterbrush plants on my study sites had the decumbent growth form, and were therefore expected to have the ability to resprout following most fires.

In my study, bitterbrush sprouts were observed to arise at the basal portion of the main stem just above the soil surface (Figure 15). It is not known whether the sprouts arose from dormant buds triggered following burning or from meristematic tissue which formed after burning. Of greatest significance to my study is the location of this perennating tissue.

Martin and Driver (1983) have suggested a number of factors which affect the ability of bitterbrush to resprout. These factors interact and differ in their importance, depending on the ecotype of bitterbrush.

The season of burning is an important factor determining bitterbrush resprouting ability. Almost all the operational burning occurring in these communities in the East Kootenay has occurred in early spring, prior to green-up, and while soil moisture is still abundant after snowmelt. The response of bitterbrush to spring burning at Pickering Hills was quite different than that observed on the operational spring burns. On the experimental site in the first growing season there was almost no resprouting of bitterbrush observed in the spring burn plots. Bitterbrush may resprout anywhere from three weeks to thirteen months following burning (Martin and Driver 1983). Therefore, there is the possibility that these plants may still respond by the second growing season. Fischer and Bradley (1987) considered spring the best time to burn to enhance sprouting and fall burning the best time to burn to regenerate by seed. Most authors consider bitterbrush particularly susceptible to fire kill in the period from summer to early fall (Blaisdell and Mueggler 1956; Martin and Driver 1983). There has

Figure 15. Resprouting of *Purshia tridentata* (bitterbrush) from buds on the main stem just above the soil surface in the first growing season following fall burning at Pickering Hills.

been reluctance to burn during the fall in the East Kootenay because of this. The fall experimental burns at both sites occurred later in the season. They were low severity burns due to marginal weather conditions and may not be possible to duplicate operationally.

Soil moisture, both at the time of burning and in the first growing season following burning has been thought to be particularly important in determining whether bitterbrush will resprout. Clark *et al.* (1982) tested this by burning and clipping plants, with and without watering afterwards, but the high soil moisture following treatment did not have the highly beneficial effects that they had anticipated. In my study, precipitation was high following the fall burns. The spring burning occurred shortly after snowmelt, with adequate soil moisture. The growing season following spring burning at Pickering Hills was characteristically dry with precipitation occurring only eight days after burning. It is not possible to correlate soil moisture with sprouting on these sites.

The removal of the above-ground portion of the plants following burning must be separated into two factors which will affect the plant. First is the effect of removing the above-ground biomass, and second is the heating of the growing points during the fire. A few studies have attempted to isolate these two factors by comparing the response of bitterbrush to clipping and/or burning of plants. Clark *et al.* (1982) found that clipped plants had more frequent sprouting than burned plants. In my study, plants which had been clipped at ground level during August in order to create a fireguard, sprouted profusely the following growing season. This removal occurred at a time when carbohydrate reserves in the roots and basal stems should have been the lowest (Menke and Trlica 1981) and therefore the effects of top removal most damaging. This suggests that resprouting is greatly affected by fire and perhaps soil heating is more important.

Menke and Trlica (1981) studied seasonal changes in the concentration of total nonstructural carbohydrates (TNC) in different portions of bitterbrush plants. For bitterbrush these changes exhibited a typical U-shaped pattern. TNC moved from the taproots in early spring (May to June) and showed a maximum depletion in July and August. TNC reached its peak in the taproot and basal stem in the fall. Menke and Trlica felt that initial movement of TNC in the spring appeared to be related to rainfall, which when high, caused movement from the taproots to the new growth to begin later. Depending on the timing of burning in relation to carbohydrate depletion of the roots, removal of the above-ground biomass may leave the plant low on reserves and decrease the resprouting ability (Martin and Driver 1983).

On the Pickering Hills site, there was 79% less percent cover on the fall burns in the first year, compared with the controls and only 71% less CAG between fall burned and control plots. Differences in the above-ground CAG of plants are difficult to interpret, since it is unknown what is occurring below-ground. Resource allocation in the large unburned shrubs on the control plots would be primarily towards maximizing resources for the maintenance of the shrub as well as the production of new growth. It is speculated that the plants on the burned areas will be putting most of their resources into new growth, although it is not known what proportion is allocated to the production of below-ground biomass (J. Pojar, Research Ecologist, B.C. Min. For., Smithers, pers. comm., 1990). The amount of stored below-ground carbohydrates will vary more depending on the time of burning. During the fall burn, the root system was probably storing carbohydrates and not likely affected by fire. At the time of the spring burn, carbohydrates will be moving from the below-ground parts and stems to new growth and therefore burning at this time may be critical.

Defoliation by tent caterpillars may seriously damage and kill bitterbrush plants leaving the remaining portions in a weakened state (Hormay 1943 as cited in Martin and Driver 1983). The fall burning at Pickering Hills took place after the growing season during which defoliation by tent caterpillars occurred. The bitterbrush plants on the spring burn plots had an additional growing season to recover before being burned. Perhaps tent caterpillar defoliation followed by a second defoliation by fire did not cause further damage when done in the fall, but the spring burned plants had begun to recover in the first year following defoliation, and then were hit by a second defoliation by fire in the next year.

Plant age is important. Shrubs less than five-years and greater than 65-years-old do not sprout well following fire (Rice 1983; Fischer 1988). This is partially a reflection of the root crown size at the time of burning. Younger shrubs have a smaller root crown, therefore heat damage of buds is more likely to occur. It is also thought that young shrubs may not have yet formed buds or meristematic tissue. With the exception of White-tail/Little Bull and Pickering Hills, most of the sites had not had a fire occurrence since the wildfires in the 1930's. The Pickering Hills had been operationally burned 11 years before the experimental burning and the White-tail/Little Bull site had been operationally burned 9 years before the second operational burning.

Bitterbrush had slow recovery after two years at White-tail/Little Bull. Resprouting was quite low (40%) and after two years, the percent cover was still 76% less than that on unburned plots. Perhaps nine years was too short a return interval on this site to promote sprouting.

Sprout mortality is an important consideration with bitterbrush. Clark *et al.* (1982) reported high winter mortality of sprouts after the first growing season.

The recovery of bitterbrush to preburn levels is generally considered slow, taking as long as 10 or 15 years (Martin and Driver 1983). The Dry Gulch operational burn and the fall experimental burn at Pickering Hills, sampled in the first and second postburn growing seasons, showed some recovery of bitterbrush over the two year period, although it was not remarkable and certainly not near preburn levels. At the Demars site, bitterbrush had recovered to preburn levels four years after burning. Davidson (in prep.) observed less cover of bitterbrush on burned compared with unburned areas two years following burning of a comparable winter range in the East Kootenay.

It is tempting to interpret the response of the operational burning at Demars as being indicative of a return to preburn levels by four years. The sites varied, particularly with respect to soil texture characteristics, but also fuel load, recent fire history, and burning conditions of the prescribed burns and therefore is not possible to extrapolate the results from the Demars site elsewhere. This site was much sandier and somewhat more disturbed with very low species diversity suggesting that site characteristics were different.

The between-site differences in the percent cover of bitterbrush prior to burning were likely a result of several factors, including fire frequency. More important, are probably site factors which will determine the potential of the site to produce bitterbrush. Pickering Hills had a very dense cover of bitterbrush before burning in 1976. A rancher described the site at that time as "being so dense you couldn't ride a horse through the shrubs". The shrubs at Johnson Lake, Dry Gulch and Sharptail were much older, not having been burned for about 45 years, but they were much smaller than those at Pickering Hills indicating differences in site productivity.

Bitterbrush will also regenerate following burning from seed which survives on-site, or from off-site seed sources. In the first growing seasons following burning at Pickering Hills no seedlings were observed in the burned plots but seedlings were occasionally present on unburned plots in the area. Bitterbrush plants do not reach seed-bearing age until 8 to 20 years depending on site conditions (Nord 1965; Giunta *et al.* 1978). Bitterbrush seed is fairly heavy, and falls close to the parent plant (Nord 1965). Rodents play an important role in the bitterbrush reproductive process by transporting seed from off-site sources. They also remove a papery covering which inhibits germination.

Bitterbrush plants at the Pickering Hills and White-tail/Little Bull sites would not have had sufficient time to produce seed, but at the other sites the bitterbrush should have been of sufficient age. At all my study sites, off-site seed sources were available. The Pickering Hills site had a very high population of rodents therefore seed caching on the site is likely to have occurred. The seed of bitterbrush does not withstand burning well.

Seedling establishment appears to be correlated with fuel consumption. Bitterbrush plant mortality is high with increased seedling establishment when fuel consumption is high, and bitterbrush plant mortality is low, with low seedling establishment when fuel consumption is low (Britton and Clark 1985). Seedling establishment of bitterbrush depends on the degree of competition from neighbouring species (Rice 1983). Ferguson (1962) found that bitterbrush seedlings seldom survived except where no competing vegetation was present within a 0.3 to 1.0 m radius. Competition is likely not a problem on my study sites.

5.2.2.1.4 *Symphoricarpos albus*

Common snowberry is considered an important browse species for deer in the East Kootenay with most use occurring in the late fall, winter and early spring (D. Demarchi, pers. comm.). Elk may use it occasionally and bighorn sheep consume it regularly at this time. The fruit of common snowberry is used by various bird species in the winter (Watson *et al.* 1980).

Common snowberry is a long-lived perennial plant (Watson *et al.* 1980) and is clonal, spreading by horizontal rhizomes, largely found below the mineral surface (Lyon and Stickney 1976; Bradley 1984).

Following fire, common snowberry regenerates from slender rhizomes located primarily within the mineral soil. Rhizomes may run horizontally for some distance and from each, a single above-ground stem is produced (Lyon and Stickney 1976; Bradley 1984). It is speculated that these stems become independent after the first growing season (Pelton 1953).

Common snowberry is considered to be a very fire resistant plant species. It survives vegetatively by means of rhizomes and reproductively, by means of on-site seed of short viability and by transport of off-site seed (Lyon and Stickney 1976).

On the Pickering Hills experimental burn plots, common snowberry was a prolific resprouter from rhizomes beneath the soil surface. Despite the profusion of resprouting stems, there was no statistically significant difference in percent cover between burned and unburned areas for all of the experimental and operational burn plots, except White-tail/Little Bull. At this site, it was reduced significantly, two years after burning.

The response of common snowberry to prescribed fire is highly variable (Noste and Bushey 1987). Vegetative regrowth can occur even following severe stand-replacing wildfires (Stickney 1985). Most studies indicate that snowberry benefits from low severity fire (Hooker and Tisdale 1974), but it usually takes a few years to recover (Crane *et al.* 1983; Morgan and Neuenschwander 1988). In my study, stems sprouted from portions of rhizomes with small burned remainders of stems attached. It was observed that there were more sprouts on the burned plots, than on the control plots, although this was not measured. Stem density can be variable in the first growing season postfire. In one study it was found to be the same (Leege and Hickey 1971) and in another it was higher (Merrill *et al.* 1982) than before burning. If sprout survival is high on my sites, then the potential for expansion by this species should be good.

Davidson (in prep.) found significantly more cover of snowberry two growing seasons after burning than before burning in ecosystems similar to those of my study in the East Kootenay. In Montana, Gordon (1976) found that the percent cover and biomass were generally greater than the preburn levels after two growing seasons following spring burning, and Morgan and Neuenschwander (1988) found that common snowberry had reached its maximum cover, which was five times higher than preburn levels by the third to fifth year following a low severity burn. They found cover was not affected by burn age or burn severity. Common snowberry increased until year five, though it was virtually gone after 15 years, probably due to competition and canopy closure.

There was no difference in the current annual growth between the fall burned plots and the control plots. This is consistent with the data of Merrill *et al.* (1982) who found that fire had no effect on CAG, for the first four years after burning.

Fruit production can occur in the first postfire year, with seed being transported primarily by birds (Crane *et al.* 1983). No berry production was observed on the experimental burn plots in the first and second growing seasons following burning in this study.

5.2.2.2 Graminoids

Fire is not the only factor contributing to the response of the grass species on these sites. Heavy grazing during the growing season by cattle and during the dormant season by big game is prevalent and therefore complicates interpretation of the effects of fire. Differences in grazing history existed between the sites. Johnson Lake had been heavily grazed for a number of years before the exclosure was built and the fall burn treatments took place. Grazing had been excluded from the Pickering Hills plots for a number of years, although the wires had come down on the fences, and there was some evidence of grazing. The operational burn areas in most cases, had a year of "rest" from grazing before burning, then had continued grazing beginning in the fall following burning.

While grazing history must be considered a factor influencing the response of the vegetation, it was impossible to isolate, let alone quantify in my study. First of all, very little information is available on utilization of my sites. The number of AUM's (animal unit months) and the grazing regime can be determined, but this does not provide specific quantitative information about utilization. Range trend can be only be inferred from the grass species present. The Johnson Lake site was obviously overgrazed, and so the response of the species on this site to fire were confounded with the response to overgrazing. Differences between sites in terms of species composition is not just a reflection of range condition, but also of site factors such as soil texture and local climate. The response of any community to a disturbance, be it fire or grazing, will ultimately depend on the physiological state or the condition of the plants within the community (Menke and Trlica 1981).

Grass species require adaptations which will allow them to persist in ecosystems which may be subjected to grazing, fire, drought conditions, and frequently, large temperature extremes (Risser 1985). Many of the physiological and morphological traits of graminoid species which allow postfire survival are similar to those of the shrubs on these sites. Grasses may have meristematic tissue protected from burning, and they may have the potential for rapid regrowth, especially in response to elevated temperatures which occur following burning. Increased seed production has been observed to occur and this too is a response to the elevated temperatures (Risser 1985). Grasses will also respond to the increased light and nutrients following the removal of large woody shrubs by burning.

5.2.2.2.2 *Agropyron spicatum*

Bluebunch wheatgrass is an important year-round forage species for livestock and wildlife species, including elk, mule deer and bighorn sheep year-round (Quinton *et al.* 1982). In healthy stands, the presence of bluebunch wheatgrass indicates proper grazing and good range condition (McLean 1979). It is highly palatable, except where it has not been grazed for one or two years, resulting in ranky, tough older growth (McLean 1979). In general, bluebunch wheatgrass withstands grazing well, although it is sensitive to heavy grazing during its short growing season of late May and June (Miller *et al.* 1986).

Bluebunch wheatgrass is a perennial, cool-season short rhizomatous or nonrhizomatous bunchgrass (McLean 1979). The rhizomatous form usually dominates under relatively moist conditions.

The postfire survival strategy of bluebunch wheatgrass is predominantly by seed germination from off-site sources, with some resprouting from basal buds at the rootcrowns (Antos *et al.* 1983; Bradley 1986; Fischer and Bradley 1987; McMurray 1987). It is generally only slightly damaged by fire (Schmisseur and Miller 1985; Fischer and Bradley 1987), although the percent cover may be reduced for a few years (Mueggler and Blaisdell 1958; Daubenmire 1975). Morphological traits make it much less likely to sustain prolonged fire. It has coarse leaves and large stems, so that little material accumulates at the base of the plant to act as fuel, and prolong a fire (Antos *et al.* 1983). The leaves and stems burn quickly so the flame front has a short residence time and little heat is transferred into the soil and to the growing points (Wright 1985; Antos *et al.* 1983).

No statistically significant differences in the percent cover of bluebunch wheatgrass occurred between burned and unburned areas at all my study sites. There appeared to be a decrease in percent cover at White-tail/Little Bull and both Sharptail sites, which may be significant from a management perspective, but the variability was too high to detect a statistically significant difference. Most other authors have found a decrease in the percent cover of bluebunch wheatgrass in the first few years following burning (Daubenmire 1975; Mueggler and Blaisdell 1958; Uresk *et al.* 1976). Daubenmire (1975) found a significant reduction in canopy cover. He also found a 50% reduction in the current annual growth in the first year following burning. Recovery had begun to occur by the second and third year, although values were still less than preburn levels. Mueggler and Blaisdell (1958) found 56% less bluebunch wheatgrass three years after burning. Uresk *et al.* (1976) on the other hand, found a greater quantity of CAG and a greater number of flowering culms for the three years following a wildfire in late summer.

In my study there appeared to be no difference in the percent cover of bluebunch wheatgrass between fall and spring burning although season of burning is considered to be one of the most important factors in determining the effect of fire on this species (Miller *et al.* 1986). Miller *et al.* (1986) reviewed the ecology and management of bluebunch wheatgrass and, in summarizing the effects of season on fire response, stated that fall burning causes little or no mortality of plants whereas spring and summer burning decrease the basal area often resulting in high mortality. Willms *et al.* (1980a and 1980b) found that fall burning resulted in a decrease in the rate of tiller elongation in the following spring. Miller *et al.* (1986) suggested four reasons for the results of Willms *et al.* (1980a and b): 1) destruction of the fall regrowth which thereby reduces the photosynthetic surface, 2) exposure of meristematic tissue to extreme temperatures, 3) increased soil temperatures which cause a moisture deficit, and 4) greater evaporative cooling from the blackened soil surface. Strang and Johnson (1988) observed a decrease in basal area of bluebunch wheatgrass initially with recovery in the third year postfire following burning in different seasons.

Miller *et al.* (1986) suggested that bluebunch wheatgrass response to burning depends on the vigour of the plant before burning, the burning conditions, and the growing conditions, particularly soil moisture, following fire. The effects of burning can also depend on the proximity of plants to shrubs with greater litter accumulations. Many of the bluebunch wheatgrass plants at Pickering Hills were located within the bitterbrush shrubs, suggesting that cattle and wildlife cannot graze these plants. Litter accumulations near these bluebunch wheatgrass plants, however, might have acted to increase fire severity compared to what would have been experienced by the grasses in the absence of shrubs.

Bluebunch wheatgrass is sensitive to grazing, particularly in the first year following burning. Miller *et al.* (1986) suggested allowing a full uninterrupted growth cycle following burning. On the East Kootenay sites, it is common to allow some grazing in the fall of the first year following burning.

Seeds of bluebunch wheatgrass have low viability, with reported germination rates of 53% in the laboratory and 16% in the field (Harris 1967). Seeds germinate during the fall and sometimes overwinter to germinate in the spring. Initial seedling growth is slow and often less vigorous than competing species such as cheatgrass (Harris 1967).

Seedling establishment following burning will depend to a large extent on soil moisture

(Risser 1985), and on competition from surrounding species. Burning reduces the size of shrubs, allowing establishment of bluebunch wheatgrass seedlings. Annual grasses and forbs such as cheatgrass (*Bromus tectorum*) generally increase in percent cover following burning which is an important consideration when burning areas with a large component of cheatgrass. In the present study however, cheatgrass was not particularly abundant before burning except possibly at Johnson Lake but did not appear to increase significantly in the first year after burning. Cheatgrass is considered a major competitor to bluebunch wheatgrass seedling development (Harris 1967).

5.2.2.2.1 *Festuca scabrella*

Rough fescue was not very abundant at any of the sites, possibly due to overgrazing. The postfire survival strategy of this grass is predominantly resprouting of surviving residual plants, and germination from off-site wind-carried seed (Wright and Bailey 1980; Fischer and Bradley 1987).

Rough fescue exhibited both strategies following burning of the study sites. In the first year following burning during either spring or fall, it resprouted from perennating buds within the base of the plant (Figure 15). The smaller plants observed at White-tail/Little Bull may have been produced from regenerated plants but were more likely from off-site seed sources. The rough fescue plants within the Pickering Hills exclosure were particularly "wolfy"-looking before burning, with a heavy accumulation of litter.

Most studies have shown that rough fescue is initially damaged following burning (Wright and Bailey 1980; Sinton and Bailey 1980; Strang and Johnson 1988). Recovery appears to be related to the severity of the fire, and the frequency of fire occurrence. Under low severity fires, the densely packed stubble accumulations will act to insulate the perennating

Figure 16. Resprouting of *Festuca scabrella* (rough fescue) in the first growing season following fall burning at Pickering Hills.

buds located near the ground surface (Johnston and McDonald 1967). Under very dry burning conditions and more intense fires, and where fuel has accumulated, plant survival is inhibited because the dense stubble accumulations generate high severity fires which can burn down into the crowns and increase below-ground soil temperatures causing damage to below-ground tissue (Fischer 1988).

Recovery of preburn cover and production usually occurs within two to three years (Wright and Bailey 1980). The plants in my study were damaged initially, although the only statistically significant effect occurred at the White-tail/Little Bull site where cover was reduced by the fire (Table 19).

All of the operational burning in my study was done in the spring, with no significant effect on the percent cover of rough fescue. Bailey and Anderson (1978) found a decrease in the percent cover following both spring and fall burning but by the third year, the percent cover had reached preburn levels. They felt that spring burning was more detrimental than fall burning due to the elevated growing points which occur at that time. There may also be increased soil moisture during fall burning (Jourdannis and Bendunah 1986). Sinton and Bailey (1980) found that fall burning caused earlier growth in the spring and earlier flowering due to the higher soil temperatures resulting from increased absorption of heat by the blackened surface.

My study found no significant difference in the CAG following fall burning compared to the control plots. Sinton and Bailey (1980) found a reduction in CAG following all burning (spring, summer and fall), but burning in late spring caused the greatest reduction. In their study, fall burning caused only a slight reduction in CAG.

Seed production in rough fescue is erratic, and the factors responsible for this are presently unknown, although environmental factors can have a significant impact (Stout *et al.*

1981). Bailey and Anderson (1978) observed a decrease in seed production following spring burning, but no change in seed production following fall burning. This was explained by the fact that rough fescue begins floral initiation in the fall, prior to winter dormancy. Thus, burning in the spring could adversely affect development of the inflorescence.

5.2.2.2.3 *Stipa occidentalis*

Stiff needlegrass is a long-lived perennial grass which is palatable to livestock and wildlife species in the early stages of growth, prior to seed maturation. It is considered to have a fair energy value but is high in crude protein until the leaf stage (McLean 1979). It provides some cover to small birds and mammals. It withstands grazing well, being one of the last species to disappear following overgrazing and the first to reappear when the range condition improves (Tiemenstein 1987).

The postfire survival strategy of stiff needlegrass is through vegetative tillering, as well as off-site seed establishment (Fischer 1988). Needle and thread grasses (*Stipa* spp.) are considered the least resistant of the bunchgrasses to fire (Stubbendieck *et al.* 1986). The accumulation of the finer leaves and culms of the plant allow a greater transfer of heat into the soil, and cause subsequently greater damage. Plant size appears to be particularly important in determining the response of stiff needlegrass to burning. Plants with smaller basal diameters more often survive fire than do plants with larger basal diameters (Wright and Klemmedson 1965), probably due to the higher subsurface temperatures generated by greater amounts of dead material (Fischer 1988).

There was an apparent increase in the percent cover of stiff needlegrass in the second year following fall burning at Pickering Hills although it was not statistically significant. There was also 2.5 times greater percent cover on burned areas at White-tail/Little Bull in the second postburn growing season. At that site this increase may have been a response to decreased shrub cover, but this was not reflected in a similar increase in the cover of the other grasses.

Most other researchers have found significant reductions in the cover of stiff needlegrass, with variable lengths of recovery periods following fire. Wright and Klemmedson (1965) found a reduction in the percent cover for a long period after burning, but they only studied a high intensity burn where subsurface charring had occurred. Wright *et al.* (1979) found that three to five years was required to achieve preburn levels. Zschaechner (1985) found that plants in burned areas were 1.6 times taller than those in unburned areas four years after burning. He concluded that abundant precipitation following burning enhances survival and that the proximity of shrub fuels can decrease the survival of stiff needlegrass. He also concluded that removal of competing shrubs (in his study - big sagebrush (*Artemesia tridentata*)) may enhance survival after fire. Blaisdell (1953) found that after 12 years there was no difference in stiff needlegrass productivity between burned and unburned areas. No other studies have apparently considered the effects of burning on CAG in the first few years after fire.

7 CONCLUSIONS AND MANAGEMENT IMPLICATIONS

7.1 CONCLUSIONS

The total preburn fuel load ranged from 1.2 to 2.0 kg/m^2 on the experimentally burned plots. Much of this consisted of coarse woody material, but the fine fuels, particularly cured grasses although not abundant by mass, are considered more important to prescribed burning in these particular ecosystems. The coarse woody material only represented a few pieces of fuel, whereas the fine fuels determine whether a burn will occur. Where an abundance of annual grasses occurred on a site, the quantity of grass and fine fuels were greatly increased. The quantity of fuels observed in this study were within the average range observed in other similar North American grass and shrub-dominated communities.

Coarse fuel consumption was almost 100% for many of the diameter classes. Grass consumption averaged 94% on the fall and spring burned plots. Fuel consumption should generally be sensitive to weather parameters, but due to the limited number of sites studied no relationships were found between consumption and fire weather and Canadian Fire Weather Index System codes and indices. Given the high proportion of fuels consumed on these sites, some concern is raised over the depletion of nutrients in these ecosystems.

The response of the seven forage species on these sites was variable. On the experimental burns, there were no statistically significant differences in percent cover between fall or spring burned and control plots for most species with the exception of stiff needlegrass and bitterbrush. There was significantly more stiff needlegrass on the fall burned plots in both the first and second growing postburn growing seasons, although this was not reflected in the current annual growth. There was also more stiff needlegrass on a one year old operational burn.

Bitterbrush decreased significantly in the first growing season after both the spring and fall experimental burns. By the second postburn year, bitterbrush had recovered slightly, although it was still less than half the cover of that on the control plots. There was a corresponding decrease in the current annual growth in the first postburn growing season. On the operational burns there was also a consistent decrease in bitterbrush percent cover for all the sites except the four year old burn.

Saskatoon showed no significant difference in percent cover, but showed a 48% decrease in current annual growth in the first growing season. On a two year old burn, rough fescue and snowberry also had significantly less percent cover on the unburned areas compared with the burned areas.

The dominant postfire survival strategy of all the shrubs was by resprouting, either from buds on the stem at the soil surface as in bitterbrush, or sprouting from rhizomes as in snowberry and saskatoon. The graminoids on this site also resprouted from the bases of the plants, but seeded in from off-site seed sources as well.

7.2 MANAGEMENT IMPLICATIONS

This study has looked at the effects of a commonly practised management tool on the response of plant species in the initial years following treatment. Speculation about the use of prescribed fire based on this study alone is limited by the lack of longer-term data. The following recommendations are based on the results of this study, together with a review of current literature. Some of the recommendations pertain to the use of prescribed fire as a habitat enhancement tool in these specific plant communities, and others pertain to the research project itself assuming that the importance of continuing this study is recognized. Some suggestions are made regarding methods for future sampling of operational burns. Lastly, knowledge gaps and future research needs are mentioned.

The following recommendations are made regarding the use of prescribed fire in these early seral communities:

1. The choice of burning season for a site can only be decided after weighing the site-specific advantages and disadvantages of both spring and fall burning. Early spring has been the most common time of year to burn operationally in the past, but based on the experimental results alone it is recommended that a late fall (early October) operational burn be attempted, to determine whether the severity of fire achieved at the two experimental sites can be duplicated operationally, with a similar vegetative response. Spring burning has the advantage of providing forage in the winter following treatment but it is obvious from this study that if bitterbrush is the dominant shrub on a site and is a species being managed for, then lower severity burns are required. Where saskatoon and common snowberry are predominant, neither spring nor fall burning appear to have detrimental effects in the first year following burning.

2. A fire return interval of no less than 20 years should be used, particularly where bitterbrush is the dominant shrub in the community. This provides sufficient time for bitterbrush to set seed and for seeded plants to mature. Although it was not addressed specifically in the present study, there could be a concern about depletion of site nutrients, particularly given the low quantity of organic material on these sites. Repeated burning, which can consume a large percentage of the fine fuels, when compounded with the usual practice of heavy grazing in the interval between fires, may cause a depletion of nutrients and a decline in the fertility of these sites over the long-term. Other consequences of too frequent a fire interval include a loss of seed source. There must also be sufficient time to accumulate enough fuel to allow burning to occur again.

3. The vigour of the vegetation on the site prior to treatment is particularly important in predicting its response to burning. A year of rest before burning is necessary, as is a full uninterrupted year without grazing following burning. Plants weakened by heavy grazing will respond less favourably to burning than those which have not been grazed. Factors such as insect invasion will also influence shrub response. The grass species on these sites are all considered particularly sensitive to burning following an extreme drought year, therefore greater attention should be given to weather conditions in the year prior to burning.

4. This study should be continued for a longer term than has been done to date. The results presented here only consider the effects of experimental spring burning on one site, and experimental fall burning on two sites in the first and second growing seasons following treatment. The results have shown very few significant differences in the percent cover and current annual growth for most species, except for a decrease at all sites and the practical

elimination of bitterbrush following spring burning at Pickering Hills. Based on these initial findings it would appear that prescribed burning in these ecosystems is not particularly beneficial, and has some detrimental effects in the short-term, the long-term effects have yet to be determined for these sites. Long-term monitoring of these experimental sites is extremely important to determine whether or not the short-term detrimental effects give way to long-term beneficial ones as suggested by some other studies.

5. The plots at Johnson Lake should be burned during the spring to complete the experimental design. It is recommended that all the experimental plots be evaluated and assessed at least every two years for the next five years and perhaps at five year intervals thereafter.

6. It is recommended that estimation of the percent cover be done using a number of small plots rather than using the line intercept method when sampling forbs and grasses in the future. Rather than percent cover, a three-dimensional measure such as plant volume may provide more useful information. Productivity measurements are more desirable, as they better reflect the plant vigour and growth as well as available browse.

7. The development of regression equations which can relate readily measurable variables to biomass appear promising (Thomson 1990). For the grass species, measurements such as basal area and number of flowering culms are important. For the shrubs, measurements such as crown height and number of sprouts are more important than percent cover.

8. The value of photographic records can not be overstated, both for monitoring broad community changes and for detailed monitoring of individual plants over time.

9. Forage enhancement objectives should be quantifiable. It is not enough to state objectives of an enhancement technique as merely "to increase the quality and quantity of browse species" or "to prevent encroachment by conifers". These objectives must be quantified and must supply answers to the following questions:
a) How much of an increase in shrub productivity is desired for an enhancement technique to be considered effective (ie., a 20% increase in current annual growth?; a 30% increase in available browse?; or a 10% increase in berry production?) and,
b) Over what time-frame are these goals to be achieved (ie., is a decrease for the first five years followed by an increase over the next five adequate to justify the costs of using the techniques)?

10. A greater understanding of the objectives of prescribed burning and interactions of those objectives is required. Achievement of one objective may require a moderate to high severity burn (e.g., prevention of conifer encroachment) which may mean that a second goal (e.g., increasing shrub production) cannot be achieved because it requires a low severity burn. These objectives must specify the individual plant species being managed for given the variability in the response of shrub and grass species on these sites.

11. Forage enhancement objectives should be related more specifically to quantifiable fire prescriptions involving such as fire behaviour characteristics, fuel consumption objectives and fire severity impacts. This can only be achieved by routine measurement of these variables

on all operational burns until the effects can be predicted and related to environmental factors measurable before treatment.

12. When assessing the suitability of a habitat enhancement technique for a particular area the appropriate site factors must be clearly determined. It is very important that a pretreatment assessment be made which assesses fuel availability and continuity, and which determines the abundance and composition of all the plant species in the community.

The importance of site factors in determining the plant species response cannot be emphasized enough, particularly with respect to the potential of a site to produce vegetation. The present vegetation will be an important integrator of site factors, reflecting the fertility of the site. We must routinely evaluate the capability of the site with respect to its nutrient and moisture regime.

13. When monitoring operational burns it will be necessary to increase the number of plots sampled over that used in this study. This can be done by sampling a larger number of small plots rather than a few large plots such as those used in this study. This will increase the probability of detecting statistically significant differences. Monitoring of individual plants is particularly important to correlate variables such as plant age and height to postfire response (ie., resprouting ability). Pre- and postburn quantification of fuels should be done on all sites scheduled for operational burning. Sites should be stratified so that sampling occurs beneath and between shrubs. Again, variables other than percent cover that better indicate fire severity, such as crown height, number of sprouts and sprout survival, and scorch heights on trees, should be measured following burning. These variables are often simpler and less time-consuming to measure, but equally valuable for the information gained. Immediately following

burning a simple assessment of ash colour, degree of defoliation of shrubs, percent mineral soil exposure, and continuity of fuel consumption which will characterize the fire severity are important and simple observations to make. It is perhaps better to choose a typical site and study that in greater detail than sample many sites with inadequate information.

14. In burning these grass/shrubland areas, cured grasses are the most important component of the fuel, although not necessarily constituting the greatest weight. They are much more sensitive to diurnal weather changes and not likely well characterized by changes in the codes and indices of the Canadian Fire Weather Index System. The FFMC is perhaps important in predicting the moisture content of the dead material within the shrubs. The DC and DMC may be useful only in assessing the long-term drought on the site.

In order to develop a greater understanding of the relationship between FFMC and fire effects it will be important to routinely sample these variables on-site for all operational burns. Presently, the British Columbia Forest Service startup dates for the Canadian Fire Weather Index System calculations are not early enough in the season to be of use to operational spring burning in these grass/shrubland ecosystems. These burns usually take place in late March/early April. Perhaps the startup dates could begin earlier. On-site weather data for the period before, during and after operational burning is necessary to make adjustments for the location of the Fire Weather stations.

Several areas of knowledge require further investigation:

1. A literature review on the autecology of plant species which are of particular importance to wildlife and livestock is fundamental to understanding what is already known about the

responses of these species to habitat enhancement. This information should be made accessible to wildlife and range managers. A database should be established that allows input on individual habitat enhancement treatments currently taking place in British Columbia. More information that is specific to the ecotypes of species found in British Columbia, particularly for bitterbrush. This should include information on seed production and phenology, and age of maturity as well as production potential of species in these ecosystems. This would allow greater predictive capabilities. It would also establish priority areas for filling information gaps on particular species.

2. The interactive effects of livestock grazing, wildlife browsing and prescribed fire on these sites are not understood. It is difficult, if not impossible, to isolate the effects of grazing from those of fire without repeating the experiment on wildlife-proof enclosures and unenclosed areas. An additional study should be undertaken that would be more representative of operational conditions and study the effects of burning with grazing by livestock.

3. A quantitative study should be undertaken to determine how the changes in browse species following these treatments will affect the wildlife species being managed for, and to determine how these changes relate to wildlife productivity and density changes today and in the future. This type of study should also determine effects on small mammals, and birds, as well as non-target plant species. As an example, reducing the bitterbrush on these sites may alter habitat for small mammals and birds.

4. It is recommended that changes in the moisture content of grasses on these grass/shrubland sites be correlated to current fire weather indices. It may be useful to develop a grass

moisture code which will enable wildlife and range managers to more accurately determine burning windows. Currently, tools such as the prescribed fire predictor and the Canadian Fire Weather Index System are not very useful for grass/shrublands.

All these recommendations are suggested to improve prescribed fire planning and help managers better understand the relationships between fire effects and preburn environmental factors, such as fuel abundance, plant species composition and abundance, soil factors and moisture content of fuels, as well as fire behaviour characteristics.

Perhaps Mutch (1970) summarizes our understanding of fire best. "Considerable freedom is experienced in natural resource management, but with this freedom goes the responsibility to insure that management sustains the viability of ecosystems... Fire has been a part of certain biological balances over evolutionary periods of time. Man must wisely interpret fire's significance in ecosystems to develop balanced programs of fire protection and prescribed fire use".

8 REFERENCES

Adams, G.R. 1980. Results of range/wildlife prescribed burning on the Fort Rock Ranger District in central Oregon. R-6 Fuel Management Notes. Portland, OR: USDA For. Serv., Region 6.

Antos, J.A., B. McCune, and C. Bara. 1983. The effect of fire on an ungrazed western Montana grassland. Amer. Midl. Nat. 110:354-364.

Atmospheric Environment Service. 1982a. Canadian Climate Normals 1951-1980. Volume 3. Precipitation. Environment Canada.

Atmospheric Environment Service. 1982b. Canadian Climate Normals 1951-1980. Volume 2. Temperature. Environment Canada.

Atmospheric Environment Service. 1982c. Canadian Climate Normals 1951-1980. Volume 4. Degree Days. Environment Canada.

Atmospheric Environment Service. 1982d. Canadian Climate Normals 1951-1980. Volume 5. Wind. Environment Canada.

Atmospheric Environment Service. 1982e. Canadian Climate Normals 1951-1980. Volume 6. Frost. Environment Canada.

Bailey, A.W. and M.L. Anderson. 1978. Prescribed burning of a *Festuca-Stipa* grassland. J. Range Manage. 31(6):446-449.

Bailey, A.W. and M.L. Anderson. 1980. Fire temperatures in grass, shrub and aspen forest communities of central Alberta. J. Range Manage. 33(1):37-40.

Blaisdell, J.P. 1953. Ecological effects of planned burning of sagebrush-grass range on the Upper Snake River plains and their relationship to certain climatic factors. USDA For. Serv. Tech. Bull. 1190. 68 pp.

Blaisdell, J.P. and W.F. Mueggler. 1956. Sprouting of bitterbrush (*Purshia tridentata*) following burning or top removal. Ecology 37:365-369.

Blauer, A.C., A.P. Plummer, E.D. McArthur, R. Stevens, and B.C. Giunta. 1975. Characteristics and hybridization of important Intermountain shrubs. I. Rose family. USDA For. Serv. Research Paper INT-169. Ogden, UT.

Bradley, A.F. 1984. Rhizome morphology, soil distribution, and the potential fire survival of eight woody understory species in western Montana. MA thesis, Univ. Idaho.

Bradley, A.F. 1986. *Pseudoroegnaria spicata*. *In*: Fischer, W.C. (compiler). 1988. The fire effects information system (Database). Missoula, MT: USDA For. Serv., Intermountain Research Station, Intermountain Fire Science Laboratory. Magnetic tape reels.

Britton, C.M., and R.G. Clark. 1985. Effects of fire on sagebrush and bitterbrush. *In*: Sanders, K. and J. Durham (eds.) 1985. Rangeland fire effects: a symposium. U.S. Dept. Int., Bur. Land Manage. pp. 22-26.

Brown, J.K. and D.G. Simmerman. 1986. Appraising fuels and flammability in western aspen: a prescribed fire guide. USDA For. Serv. Gen. Tech. Rep. INT-205.

Canadian Forestry Service. 1984. Tables for the Canadian Forest Fire Weather Index System. For. Tech. Rep. 25 (4th Edition). Canadian Forestry Service, Environment Canada.

Chambers, J.C. and R.W. Brown. 1983. Methods for vegetation sampling and analysis on revegetated mined lands. USDA For. Serv. Gen. Tech. Rep. INT-151.

Clark, R.G., C.M. Britton, and F.A. Sneva. 1982. Mortality of bitterbrush after burning and clipping in eastern Oregon. J. Range Manage. 35(6):711-714.

Conard, S.G., A.E. Jaramillo, K. Cromack, Jr., and S. Rose. 1985. The role of the genus *Ceanothus* in western forest ecosystems. USDA For. Serv. Gen. Tech. Rep. INT-151.

Conover, W.J. and R.L. Iman. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. Amer. Stat. 35(3):124-129.

Cooper, C.F. 1961. The ecology of fire. Chapter 30 *In*: 39 Steps to Biology. 1968. Proceedings from Scientific American. W.F. Freeman and Co., San Francisco, CA.

Countryman, C.M. 1982. Physical characteristics of some northern California brush fuels. USDA For. Serv. Gen. Tech. Rep. PSW-61.

Crane, M.F., J.R. Habeck and W.C. Fischer. 1983. Early postfire revegetation in a western Montana Douglas-fir forest. USDA For. Serv. Res. Pap. INT-319.

Daubenmire, R. 1968. Ecology of fire in grasslands. Adv. Ecol. Res. 5:209-273.

Daubenmire, R. 1975. Plant succession on abandoned fields, and fire influences, in a steppe area in southeastern Washington. Northwest Science 49(1):36-48.

Davidson, P.W. In prep. The effects of grazing, burning and logging on bighorn sheep in the East Kootenay, B.C. Cranbrook Fish and Wildlife Branch, B.C. Min. Envir.

Debano, L.F. and C.E. Conrad. 1978. The effect of fire on nutrients in a chaparral ecosystem. Ecology 59(3):489-497.

Demarchi, D.A. 1966. The effects of excluding livestock and big game on a seral shrub community in the East Kootenay, British Columbia. BSc. thesis, Dept. Plant Sci. Univ. B.C.

Demarchi, D.A. 1986. Biophysical resources of the East Kootenay area: wildlife. MOE Tech. Rep. 22. B.C. Min. Envir., Victoria, B.C.

Demarchi, D.A. and R.A. Demarchi. 1987. Wildlife habitat - the impacts of settlement. Chapter 10. *In*: Murray, A. (ed.). Our Wildlife Heritage: 100 Years of Wildlife Management. The Centennial Wildlife Society of B.C., Victoria, B.C. 192 pp.

Demarchi, D.A. and S. Lofts. 1985. The effects of spring burning on the productivity and nutrient concentration of several shrub species in the southern Rocky Mountain Trench. MOE Tech. Rep. 19. B.C. Min. Envir., Victoria, B.C.

Demarchi, D.A., B. Fuhr, B.A. Pendergast and A.C. Stewart. 1983. Ecological (biophysical) land capability for wildlife (ungulates) in British Columbia. MOE Manual 4. British Col. Min. Envir. Victoria, B.C.

Dorey, R.J. 1979. A fire history investigation and the effects of fire exclusion on a Ponderosa pine forest. B.Sc. thesis. Fac. Forestry. Univ. B.C.

Dyrness C.T. 1973. Early stages of plant succession following logging and burning in the western Cascades of Oregon. Ecology 54:57-69.

Eastman, D. 1977. Prescribed burning for wildlife habitat in B.C. *In*: Dube, D.E. (compiler). Proceedings: Fire Ecology in Resource Management Workshop. Can. For. Serv. Info. Rep. NOR-X-210.

Feller, M.C. 1987. Forest fire science and management: course manual. Forestry 327. Faculty of For., Univ. British Columbia.

Ferguson, R.B. 1962. Growth of single bitterbrush plants vs. multiple groups established by direct seeding. USDA For. Serv. Intermountain Forest and Range Experimental Sation. Res. Note 90

Fischer, W.C. (compiler). 1988. The fire effects information system (Database). Missoula, MT: USDA For. Serv., Intermountain Research Station, Intermountain Fire Science Laboratory. Magnetic tape reels.

Fischer, W.C. and A.F. Bradley. 1987. Fire ecology of western Montana forest habitat types. USDA For. Serv. Gen. Tech. Rep. INT-223.

Fish and Wildlife Branch. 1977. Wildlife habitat management in Wells Grey Park. Progress and evaluation. B.C. Fish and Wildlife Branch. Internal Reports.

Foote, M.J. 1983. Classification, description, and dynamics of plant communities after fire in the taiga of interior Alaska. USDA For. Serv. Res. Pap. PNW-307.

Giunta, B.C., R. Stevens, K.R. Jorgensen, and A.P. Plummer. 1978. Antelope bitterbrush -an important wildland shrub. Utah State Division of Wildlife Resources. Publ. No. 78-12.

Gordon, F.A. 1976. Spring burning in an aspen-conifer stand for maintenance of moose habitat, West Boulder River, Montana. *In*: Proc., Tall Timbers Fire Ecology Conf. No. 14 and Intermountain Fire Research Council fire and land management symposium; 1974 Oct. 8-10; Missoula, MT.

Gratowski, H.J. 1962. Heat as a factor in germination of seeds of *Ceanothus velutinus* var. *laevigatus T.G.* Corvallis, OR: Oregon State Univ., PhD. thesis. 131 pp.

Gruell, G.E., J.K. Brown, and C.L. Bushey. 1986. Prescribed fire opportunities in grasslands invaded by Douglas-fir: state of the art guidelines. USDA For. Serv. Gen. Tech. Rep. INT-198.

Gullion, G.W. 1964. Wildlife use of Nevada plants. Contributions Toward a Flora of Nevada. No. 49. Beltsville, MD: USDA; Agr. Res. Serv., Plant Industry Station, Crops Research Div.

Halladay, D.R. 1988. An overview of wildlife prescribed burning in British Columbia. *In*: Feller, M.C. and S.M. Thomson (eds.). 1988. Wildlife and range prescribed burning workshop -proceedings. Univ. B.C., Fac. For. pp. 7-16.

Hamilton, E.H. 1987. A system for the classification of seral ecosystems within the biogeoclimatic ecosystem classification: First Approximation. B.C. Min. For. Lands Research Report. RR87004-HQ.

Hamilton, E.H. 1988. Impacts of prescribed burning on soil-vegetation relationships in the Sub-Boreal Spruce zone. *In*: Feller, M.C. and S.M. Thomson (eds.). Wildlife and range prescribed burning workshop proceedings. 1988. Fac. Forestry, Univ. B.C., Vancouver. pp. 171-184.

Hamilton, E.H. and H.K. Yearsley. 1988. Vegetation development after clearcutting and site preparation in the SBS zone. FRDA Rep. No. 018.

Harrington, M.G. 1982. Stand, fuel and potential fire behaviour characteristics in an irregular southeastern Arizona Ponderosa pine stand. USDA For. Serv. Res. Note RM-418.

Harrington, M.G. 1987. Predicting reduction of natural fuels by prescribed burning under Ponderosa pine in southeastern Arizona. USDA For. Serv. Res. Note RM-472.

Harris, G.A. 1967. Some competitive relationships between *Agropyron spicatum* and *Bromus tectorum*. Ecol. Monog. 37(2): 89-111.

Hemmer, D.M. 1975. Serviceberry: ecology, distribution, and relationships to big game. Missoula, MT: Univ. Montana, M.S. thesis.

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. An illustrated manual. University of Washington Press. Seattle, WA, USA. 730 pp.

Holland, S.S. 1976. Landforms of British Columbia. A physiographic outline. 2nd Edition. B.C. Dept. Mines and Min. Res. Bull. No. 48.

Hooker, L.L. and E.W. Tisdale. 1974. Effects of prescribed burning on a seral brush community in northern Idaho. Univ. Idaho. Forestry, Wildlife and Range Experimental Station Paper No. 14.

Hormay, A.L. 1943. Bitterbrush in California. USDA For. Serv. Res. Note 34. California Forest and Range Experiment Station.

Johnston, A. and M.D. MacDonald. 1967. Floral initiation and seed production in *Festuca scabrella* Torr. Can. J. Pl. Sci. 47:577-583.

Jourdonnais, C. and D. Bedunah. 1986. Burning issues on the Sun. Montana Outdoors 17(6):15-17.

Kauffman, J.B. and R.E. Martin. 1989. Fire behavior, fuel consumption, and forest-floor changes following prescribed burning understory fires in Sierra Nevada mixed conifer forests. Can. J. For. Res. 19:455-462.

Kayll, A.J. 1974. Heat tolerance of tree seedlings. Proc. Tall Timber Fire Ecology Conference 8: 89-105.

Kilgore, B.M. and G.A. Curtis. 1987. Guide to understory burning in Ponderosa Pine-Larch-Fir forests in the Intermountain West. USDA For. Serv. Gen. Tech. Rep. INT-233.

Lacelle, L.E.H. 1990. The biophysical resources of the East Kootenay area: soil. Report No. 20, B.C. Soil Survey, Wildlife Technical Monograph TM-1. Wildlife Branch, B.C. Min. Envir. 363 pp.

Lea, E.C. 1984. Biophysical resources of the East Kootenay area: vegetation. Assessment and Planning Division, Min. of Environment, Victoria, B.C.

Lea, E.C., D.A. Demarchi, and L.E.H. Lacelle. 1990. Biophysical analysis of the Sheep Mountain Wildlife Area. Working Report - Draft. B.C. Min. Envir., Victoria, B.C.

Leege, T.A. 1979. Effects of repeated prescribed burns on northern Idaho elk browse. Northwest Sci. 53(2):107-113.

Leege, T.A. and W.O. Hickey. 1971. Sprouting of northern Idaho shrubs after prescribed burning. J. Wildl. Manage. 35(3):508-515.

Lewis, H.T. 1982. A time for burning. Occasional Paper No. 17. Boreal Institute for Northern Studies, Univ. Alberta.

Lonner, T.N. 1972. Age distribution and some relationships of key browse plants on big game ranges in Montana. Montana Fish and Game Dept. Job Completion Rept. Proj. W-12--R-2-3. 79 pp.

Lotti, T. 1962. The use of prescribed fire in the silviculture of loblolly pine. Proc. Tall Timbers Fire Ecology Conference 1:109-120.

Lyon, L.J. and P.F. Stickney. 1976. Early vegetation succession following large northern Rocky Mountain wildfires. *In*: Proc. Tall Timbers Fire Ecology Conference and Intermountain Fire Research Council fire and land management symposium. 1974. Oct. 8-10. Missoula, MT.

Mace, R.D. and G.N. Bissell. 1986. Grizzly bear foods in the floodplains and avalanche chutes of the Bob Marshal Wilderness, Montana. *In*: Contreras, G.P. and K.E. Evans (compiler). 1986. Proceedings - grizzly bear habitat symposium; 1985, April 30 - May 2; Missoula, MT. USDA For. Serv. Gen. Tech. Rep. INT-207. pp. 78-91.

Marsh, R.D. 1986. Climate (of the East Kootenay area). *In*: Demarchi, D.A. 1986. Biophysical resources of the East Kootenay. MOE Tech. Rep. 19. British Columbia Min. Envir.

Martin, R.E. and C.H. Driver. 1983. Factors affecting antelope bitterbrush reestablishment following fire. *In*: Tiedemann, A.R. and K.L. Johnson. Research and management of bitterbrush and cliffrose in western North America. USDA For. Serv. Gen. Tech. Rep. INT-152. pp. 266-279

McArthur, A.G. 1966. Weather and grassland fire behaviour. For. Tim. Bur. Leaflet No. 100, Canberra, Aust. 23 pp.

McLean, A. 1979. Range management: handbook for British Columbia. Agriculture Canada. Research Station, Kamloops, B.C.

McMurray, N. 1987. *Festuca scabrella*. *In*: Fischer, W.C. (compiler). The Fire Effects Information System (Database). Missoula, MT: USDA For. Serv., Intermountain Research Station, Intermountain Fire Sciences Laboratory. Magnetic tape reels.

Meidinger, D. 1987. Recommended vernacular names for common plants of British Columbia. B.C. Min. For. Lands Res. Rep. RR37002-HQ.

Menke, J.W. and M.J. Trlica. 1981. Carbohydrate reserve, phenology, and growth cycles of nine Colorado range species. J. Range Manage. 34:269-277.

Merrill, E.H., H.F. Mayland, and J.M. Peek. 1982. Shrub responses after fire in an Idaho Ponderosa pine community. J. Wildl. Manage. 46(2):496-502.

Miles, J. and K. Meikle. 1974. A review and study of the ecology of *Ceanothus sanguineus* and *C. velutinus*. Report No. 3., Program UP-B-290, Agriculture Canada.

Miller, R.F., J.M. Seufert, and M.R. Haferkamp. 1986. The ecology and management of bluebunch wheatgrass (*Agropyron spicatum*): a review. Agriculture Experiment Station. Oregon State Univ., Corvallis, Station Bull. 669.

Milliken, G.A. and D.E. Johnson. 1984. Analysis of messy data. Volume 1. Designed experiments. Van Nostrand Reinhold Co., N.Y. pp. 50-54.

Mitchell, J.E., P.N.S. Bartling, and R. O'Brien. 1987. Understory cover-biomass relationships in the Front Range Ponderosa pine zone. USDA For. Serv. Res. Note RM-471.

Morgan, P. and L.F. Neuenschwander. 1988. Shrub response to high and low severity burns following clearcutting in northern Idaho. West. J. Appl. For. 3(1):5-9.

Mueggler, W.F. and J.P. Blaisdell. 1958. Effects on associated species of burning, rotobeating, spraying, and railing sagebrush. J. Range Manage. 11:61-66.

Mueggler, W.F. and W.L. Stewart. 1980. Grassland and shrubland types of western Montana. Gen. Tech. Rep. INT-166. USDA For. Serv.

Mutch, R.W. 1970. Wildland fires and ecosystems - a hypothesis. Ecology 51(6):1046-1051.

Nord, E.C. 1965. Autecology of bitterbrush in California. Ecol. Monog. 35(3):307-334.

Nord, E.C. and C.M. Countryman. 1972. Fire relations. *In*: McKell, C.M., J.P. Blaisdell, and J.R. Goodin. 1971. Wildland shrubs - their biology and utilization. An International Symposium. Utah State Univ. USDA For. Serv. Gen. Tech. Rep. INT-1. pp. 88-97.

Norum, R.A. 1974. Fire intensity - fuel reduction relationships associated with understory burning in Larch/Douglas-fir stands. Proc. Tall Timbers Fire Ecology Conference 14:559-572.

Noste, N.V. and C.L. Bushey. 1987. Fire response of dry forest habitat types in Montana and Idaho. USDA For. Serv. Gen. Tech. Rep. INT-239.

Noste, N.V. E.D. Reinhardt, and R.A. Wilson, Jr. 1987. Fire effects on *Amelanchier alnifolia* shrubs during phenological development stages. *In*: Wallace *et al.* (Comp.). Proceedings - symposium on shrub ecophysiology and biotechnology. USDA For. Serv. Gen. Tech. Rep. INT-258. pp. 158-163.

Pelton, J. 1953. Studies on the life history of *Symphoricarpos occidentalis* Hook. in Minnesota. Ecol. Monog. 23:17-39.

Quinton, D.A., A. McLean and D.G. Stout. 1982. Vegetative and reproductive growth of bluebunch wheatgrass in interior British Columbia. J. Range Manage. 35(1):45-46.

Quick, C.R. 1956. Viable seeds from the duff and soil of sugar pine forests. For. Sci. 2:36-42.

Rice, C.L. 1983. A literature review of the fire relationships of antelope bitterbrush. *In*: Tiedemann, A.R. and K.L. Johnson. 1983. Proceedings - Research and Management of Bitterbrush and Cliffrose in western North America. Salt Lake City, Utah. April 13-15 1982. USDA For. Serv. Gen. Tech. Rep. INT-152. pp. 256-265.

Risser, P.G. 1985. Chapter 11. Grasslands. *In*: Chabot, B.F. and H.A. Mooney. 1985. Physiological ecology of North American plant communities. Chapman and Hall.

Ryan, K.C. and N.V. Noste. 1985. Evaluating prescribed fires. *In*: Lotan, J.E., B.M. Kilgore, W.C. Fischer, and R.W. Mutch (eds.). Proceedings - Symposium and workshop on wilderness fire. Missoula, MT. USDA For. Serv. Gen. Tech. Rep. INT-182.

Ryder, J.M. 1981. Biophysical resources of the East Kootenay: terrain. Assessment and Planning Division, Bull. No. 7. Min. of Environment, Victoria, B.C.

SAS Institute Inc. 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, NC: SAS Institute Inc., 1028 pp.

Schmisseur, E. and R. Miller. 1985. Prescribed fire for eastern Oregon rangelands: management considerations. Circ. of Info. 699, Agric. Exp. Station, Oregon State Univ.

Schwab, F.E. 1979. Effect of vegetation structure on breeding bird communities in the dry zone Douglas-fir forest of southeastern British Columbia. M.Sc. thesis, Univ. B.C.

Sinton, H.M. and A.W. Bailey. 1980. Burning vs mowing: effects on rough fescue rangeland. Univ. Alberta Agriculture and Forestry Bulletin. pp. 70-73.

Stickney, P.F. 1982. Vegetation response to clearcutting and broadcast burning on north and south slopes at Newman Ridge. *In*: Site preparation and land management on steep terrain: Proceedings of a symposium. 1982 Feb 15-17; Spokane, WA. Pullman, WA: Washington State Univ. Cooperative Extension Services. pp 159-165.

Stickney, P.F. 1985. Data base for early postfire succession on the Sundance burn, northern Idaho. USDA For. Serv. Gen. Tech. Rep. INT 189.

Stout, D.G., A. McLean, and D.A. Quinton. 1981. Growth and phenological development of rough fescue in interior British Columbia. J. Range Manage. 34:455-459.

Strang, R.M. and A.H. Johnson. 1988. Prescribed burning trials on the Dewdrop Ranges, Kamloops - an interim report. *In*: Feller, M.C. and S.M. Thomson (eds.). 1988. Wildlife and range prescribed burning workshop proceedings. Fac. For., Univ. B.C., Vancouver. pp. 134-138.

Stubbendieck, J., S.L. Hatch, and K.J. Hirsch. 1986. North American range plants, Third Edition. Lincoln, NE: Univ. of Nebraska Press.

Taylor, R.L. and B. MacBryde. 1977. Vascular plants of British Columbia: a descriptive resource inventory. The University of British Columbia Press, Vancouver, B.C.

Thomson, S.M. 1990. Regression equations for estimating bitterbrush biomass (*Purshia tridentata*). Unpublished manuscript.

Tiedemann, A.R. 1986. Nutrient accumulations in Pinyon-Juniper ecosystems - managing for future site productivity. *In*: Everett, R.L. (comp.). Proceedings, Pinyon-juniper conference. 1986. USDA For. Serv. Gen. Tech. Rep. INT-215. pp. 352-359.

Tiemenstein, D. 1987. *Stipa columbiana. In*: Fischer, W.C. (compiler). 1988. The fire effects information system (Database). Missoula, MT: USDA For. Serv., Intermountain Research Station, Intermountain Fire Science Laboratory. Magnetic tape reels.

Tipper, G.K. 1979. Land use plan for the Southern Rocky Mountain Trench - WIldlife. B.C. Fish and Wildlife Branch, Cranbrook, B.C. Internal Report.

Tipper, G.K. 1988. Prescribed burning for wildlife in the southern East Kootenay. *In*: Feller, M.C. and S.M. Thomson (eds.). 1988. Wildlife and range prescribed burning workshop proceedings. Fac. Forestry, Univ. B.C., Vancouver. pp. 61-69.

Trowbridge, R., B. Hawkes, A. Macadam, and J. Parminter. 1986. Field handbook for prescribed fire assessments in British Columbia. B.C. Min. For., Land Manage. Handbook No. 11.

Uresk, D.W., J.F. Cline, and W.H. Rickard. 1976. Impact of wildfire on three perennial grasses in south-central Washington. J. Range Manage. 29:309-310.

Utzig, G.F., P.G. Comeau, D.L. MacDonald, M.V. Ketcheson, T.F. Braumandl, A.R. Warner, and G.W. Still. 1986. A field guide for identification and interpretation of ecosystems in the Nelson forest region. Research Section, Nelson Forest Region. B.C. Min. For.

Van Wagner, C.E. 1968. The line intersect method in forest fuel sampling. For. Sci. 14:20-26.

Vose, J.M. and A.S. White. 1987. Processes of understory seedling recruitment one year after prescribed fire in an Arizona Ponderosa pine community. Can. J. Bot. 65:2280-2290.

Watson, L.E., R.W. Parker and D.F. Polster. 1980. Manual of species suitability for reclamation in Alberta. Alberta Land Conserv. Reclamation Council Rep. No. RRTAC 80-5. 2 Vols.

Wells, C.G., R.E. Campbell and others. 1979. Effects of fire on soil: Forest Service national fire effects workshop. USDA For. Serv. Gen. Tech. Rep. WO-7.

Wikeem, B.M. and R.M. Strang. 1983. Prescribed burning on British Columbia rangelands: the state of the art. J. Range Manage. 36:3-8.

Wilkinson, L. 1988. SYSTAT: The system for statistics. Evanston, Il. Systat, Inc., USA.

Willms, W., A.W. Bailey, and A. McLean. 1980a. Effects of clipping and burning on some morphological characteristics of *Agropyron spicatum*. Can. J. Bot. 58:2309-2312.

Willms, W., A.W. Bailey, A. McLean and R. Tucker. 1980b. The effects of fall grazing and burning of bluebunch wheatgrass range in spring. Can. J. An. Sci. 80:113-122.

Wright, H.A. 1985. Effects of fire on grasses and forbs in sagebrush-grass communities. *In*: Sanders, K., and J. Durham (eds.). Rangeland fire effects: a symposium. US Dept. Int., Bur. Land Manage. pp. 12-21.

Wright, H.A. and A.W. Bailey. 1980. Fire ecology and prescribed burning in the great plains - a research review. USDA For. Serv. Gen. Tech. Rep. INT-77.

Wright, H.A., L.F. Neuenschwander, and C.M. Britton. 1979. The role and use of fire in sagebrush-grass and pinyon-juniper plant communities: a state-of-the-art review. USDA For. Serv. Gen. Tech. Rep. INT-58.

Zschaechner, G.A. 1985. Studying rangeland fire effects: a case study in Nevada. *In*: Sander, K. and J. Durham (eds.). Rangeland fire effects: a symposium. USDA Bureau Land Manage., Idaho State Office. pp. 66-84.

APPENDIX A. DAILY PRECIPITATION, RELATIVE HUMIDITY, TEMPERATURE AND FIRE WEATHER INDEX AT PICKERING HILLS, KIKOMUN CREEK AND CRANBROOK WEATHER STATIONS FOR A THREE WEEK PERIOD.

Figure 1. Daily average precipitation at Pickering Hills, Kikomun Creek and Cranbrook weather stations over a three week period.

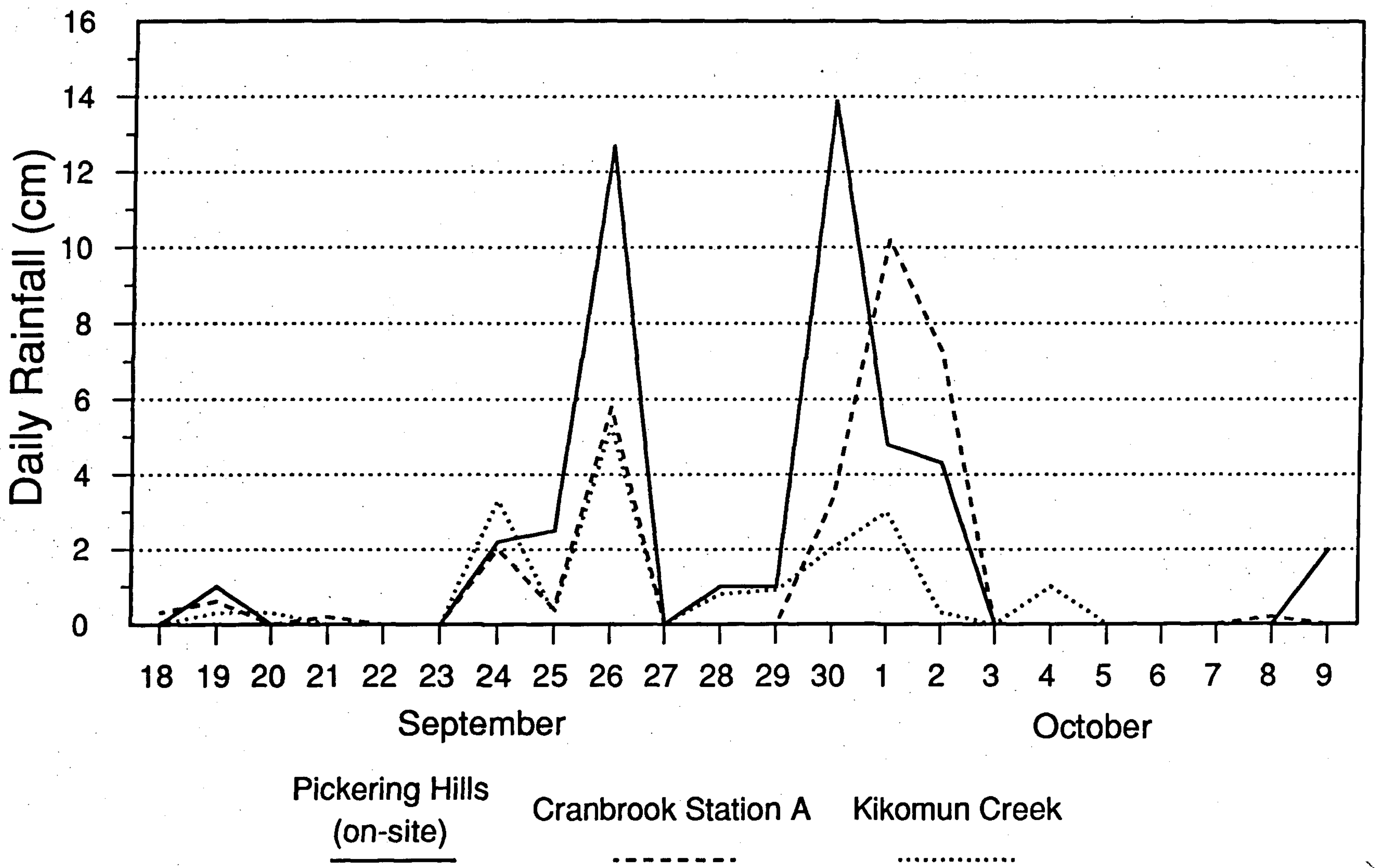


Figure 2. Daily relative humidity at Pickering Hills, Kikomun Creek and Cranbrook weather stations over a three week period.

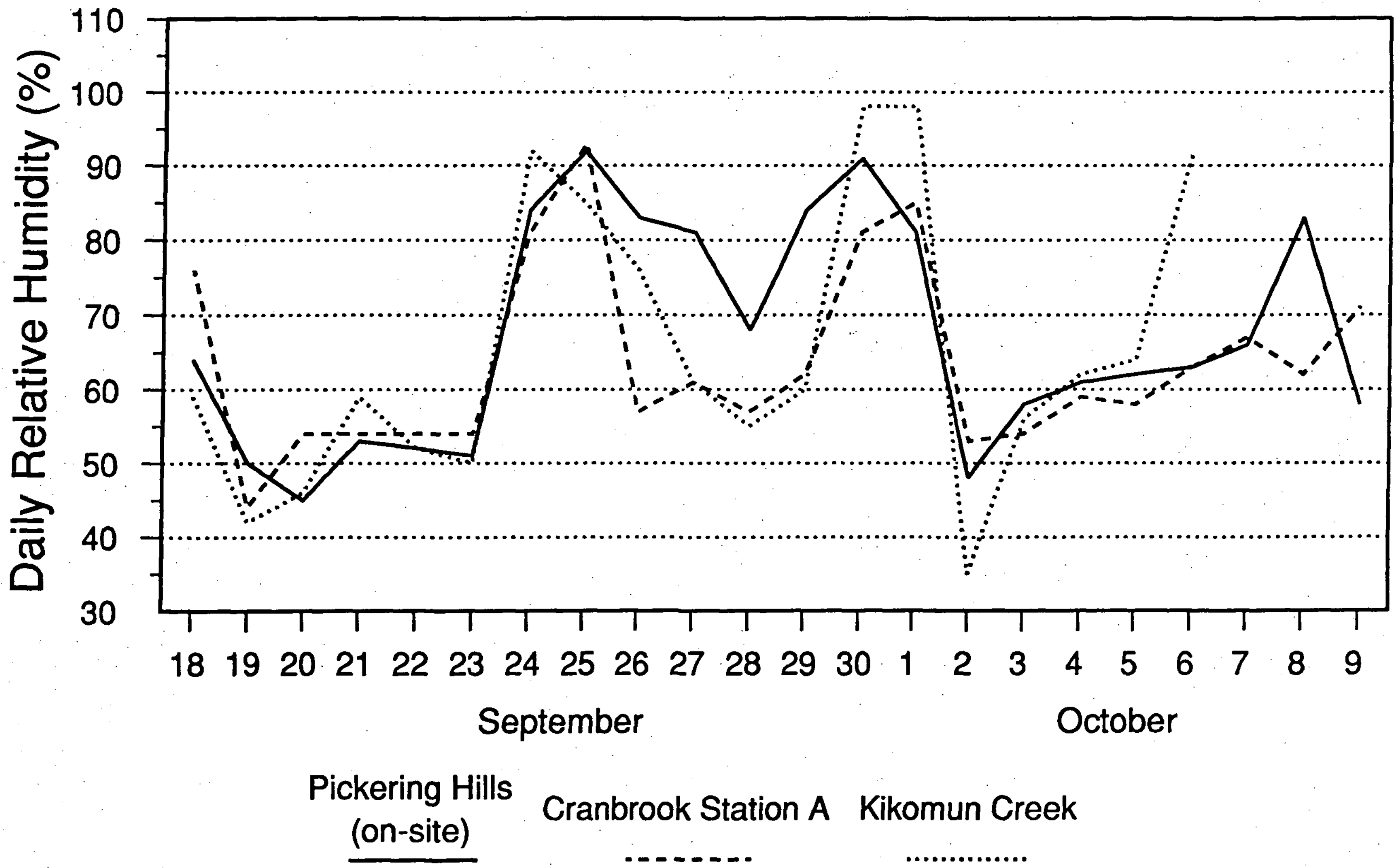


Figure 3. Daily temperature at Pickering Hills, Kikomun Creek and Cranbrook weather stations over a three week period.

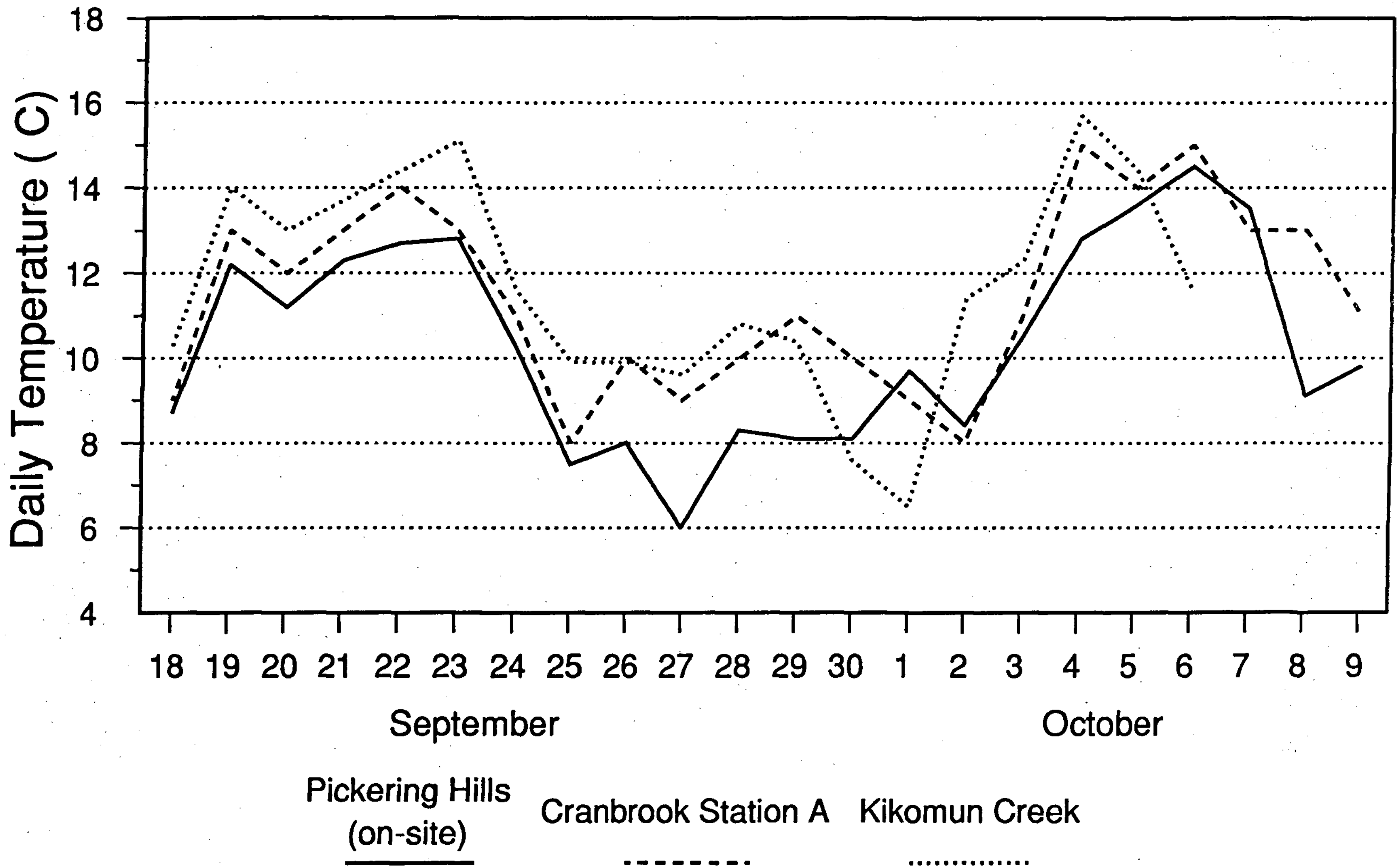
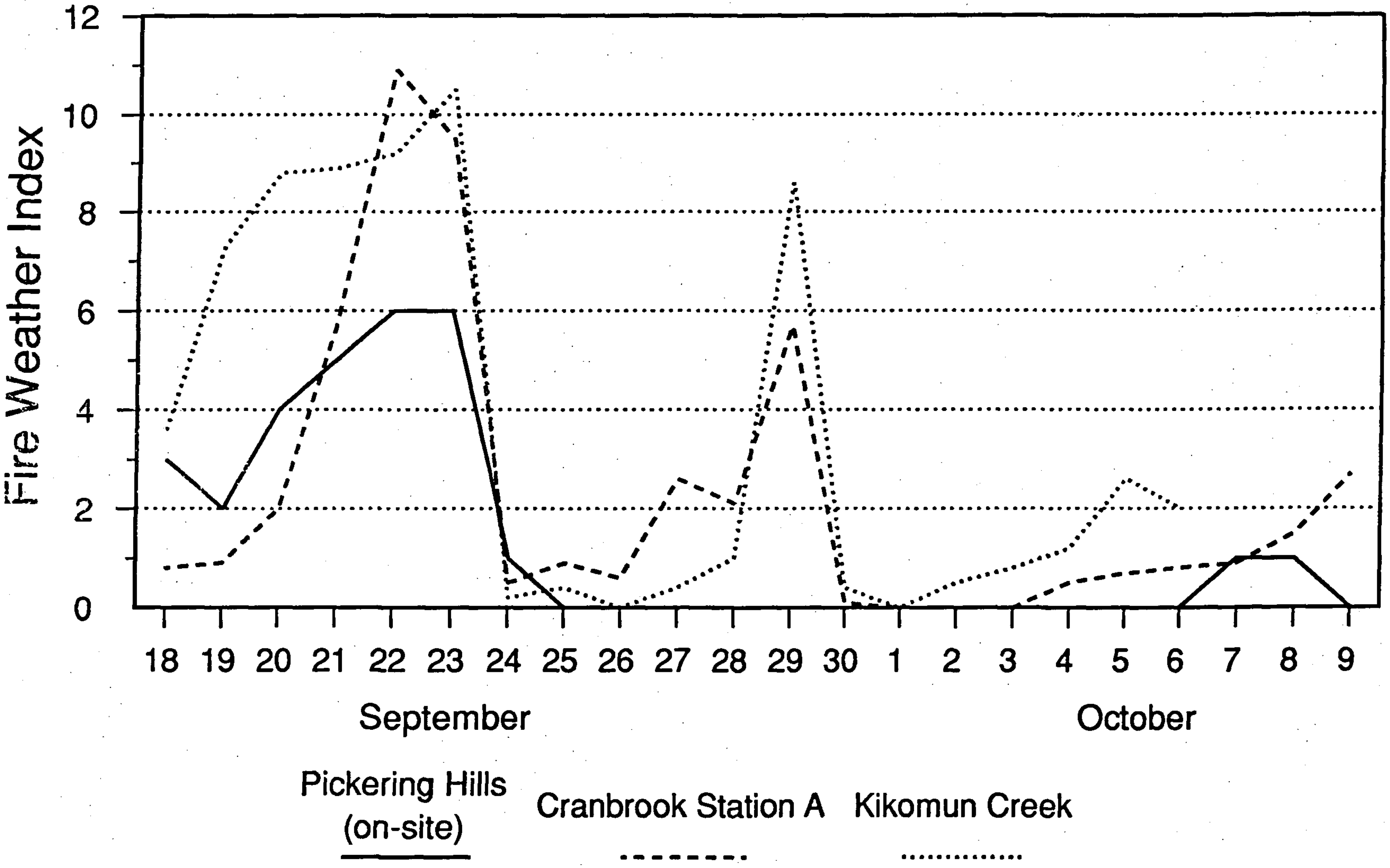


Figure 4. Fire weather indices at Pickering Hills, Kikomun Creek and Cranbrook weather stations over a three week period.



APPENDIX B. PLANT SPECIES LIST

Achillea millefolium	yarrow
Agoseris glauca	pale agoseris
Agropyron cristata	crested wheatgrass
Agropyron repens	quackgrass
Agropyron spicatum	bluebunch wheatgrass
Agropyron pauciflorum	slender wheatgrass
Agrostis stolonifera	creeping bentgrass
Allium cernuum	nodding onion
Amelanchier alnifolia	saskatoon
Anemone multifida	cut-leaved anemone
Antennaria microphylla	rosy pussytoes
Antennaria neglecta	field pussytoes
Antennaria umbrinella	umber pussytoes
Apocynum androsaemifolium	spreading dogbane
Arabis holboellii	Holboell's rockcress
Arctostaphylos uva-ursi	kinnikinnick
Arenaria serpyllifolia	thyme-leaved sandwort
Artemesia frigida	pasture sage
Aster subspicatus	Douglas' aster
Astragilis miser	timber milk-vetch
Balsamorhiza sagitta	arrow-leaved balsamroot
Bromus commutatus	meadow bromegrass
Bromus inermis	smooth brome
Bromus tectorum	cheatgrass
Calachortis macrocarpum	sagebrush mariposa lily
Calamagrostis rubescens	pinegrass
Campanula rotundifolia	common harebell
Carex spp.	sedge
Castelleja miniata	common red paintbrush
Castelleja sulphurea	sulphur paintbrush
Ceanothus velutinus	snowbrush
Chenepodium capitatum	strawberry-blite
Cirsium arvense	Canada thistle
Crepis atrabarba	slender hawksbeard
Epilobium angustifolium	fireweed
Epilobium paniculatum	tall annual willowherb
Erigeron compositus	cut-leaved daisy
Erigeron corymbosus	long-leaved fleabane
Erigeron linearis	line-leaved fleabane
Festuca idahoensis	Idaho fescue
Festuca occidentalis	western fescue
Festuca rubra	red fescue
Festuca scabrella	rough fescue
Filago arvense	field filago
Fragaria virginiana	wild strawberry

Gaillardia aristata	brown-eyed Susan
Galium boreale	northern bedstraw
Geum triflorum	large-leaved avens
Heuchera cylindrica	round-leaved alumroot
Heterotheca villosa	hairy golden-aster
Hieracium cynoglossoides	hound's tongue hawkweed
Koeleria macrantha	junegrass
Lactuca spp.	
Lithospermum ruderale	lemonweed
Lomatium triternaturm	narrow-leaved desert parsley
Lupinus sericea	silky lupine
Mahonia aquifolia	tall Oregon-grape
Medicago spp.	
Microseris spp.	microseris
Monarda fistulosa	wild bergamot
Penstemon confertus	yellow penstemon
Phacelia linearis	thread-leaved phacelia
Phleum pratense	timothy
Phlox hoodii	Hood's phlox
Pinus ponderosa	ponderosa pine
Poa compressa	Canada bluegrass
Poa pratensis	Kentucky bluegrass
Poa sandbergii	Sandberg's bluegrass
Populus tremuloides	trembling aspen
Potentilla gracilis	graceful cinquefoil
Prunus virginiana	choke cherry
Pseudotsuga menziesii	Douglas-fire
Purshia tridentata	bitterbrush
Ranunculus spp.	buttercup spp.
Rosa acicularis	baldhip rose
Silene douglasii	Douglas' campion
Solidago spathulata	spike-like goldenrod
Stipa occidentalis	stiff needlegrass
Stipa comata	needle-and-thread grass
Stipa richardsonii	spreading needlegrass
Stipa spartea	porcupinegrass
Symphoricarpos albus	common snowberry
Taraxacum officinale	common dandelion
Tragapogon dubius	yellow salsify
Trifolium spp.	clover
Verbascum thapsus	great mullein
Vicia americana	American vetch
Viola adunca	early blue violet
Zygadenus venenosa	meadow death-camas