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EFFECTS OF FIRE ON THE SUBALPINE RANGE OF ROCKY MOUNTAIN BIGHORN SHEEP IN ALBERTA

by

© JERRY A. BENTZ

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

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IN

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ABSTRACT

A study was conducted to determine the effects of fire on the subalpine range of Rocky Mountain bighorn sheep in Alberta. The central objective of the study was to assess the ecological feasibility of using prescribed burning to create or maintain bighorn sheep range in the subalpine zone. Specific study objectives were: 1) to determine differences in the quantity and quality of available forage between burned and adjacent unburned forest sites, 2) to assess the factors which may limit or contribute to the use of fire-disturbed sites by bighorn sheep, and 3) to assess the effects of burning on the establishment and growth of important range plants commonly utilized by bighorn sheep.

Four study areas were selected (Ghost River, Rock Creek, Ram Mountain, Cadomin Mountain) to investigate differences in plant species composition and abundance and levels of bighorn sheep utilization between burned and adjacent unburned sites. The years that fires occurred on the burned study sites were: 1970 for Ghost River and Rock Creek, 1921 for Ram Mountain, and 1919 for Cadomin Mountain.

Mean tree stem densities in the burned sites at Ram Mountain and Cadomin Mountain were lowest in areas closest to treeline, and increased with distance downslope from treeline. Lodgepole pine was the dominant regenerating tree species at Ghost River and Rock Creek.

Species richness of vascular plants was generally higher in the burned sites of the four study areas. Most plant species recorded in sample plots in each study area were common to both burned and unburned sites. Total mean cover of graminoids, forbs-dwarf shrubs, and tall shrubs was generally higher in the burned sites.

Duff depths were significantly lower in the burned sites of all the study areas. Concentrations of N,P and K (kg/ha) were higher in the soil samples collected in the burned sites of all the study areas. Soil pH was also somewhat higher in the burned sites.

Bighorn sheep pellet group densities were higher in the burned sites of all four study areas. Discriminant analysis, using ten range-related variables measured in the study, identified distance downslope from treeline, tree density, and percent cover of bryophytes as the most important correlates of site utilization by bighorn sheep, as indicated by pellet group distributions.

The results of the study indicated that burning has resulted in site conditions which favour utilization by bighorn sheep, compared to utilization of adjacent unburned sites. The reduction or elimination of tree cover appeared to be the primary benefit of burning, with increased cover of herbaceous and shrubby forage of secondary importance.

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1. INTRODUCTION

1.1 General

It is generally accepted that fire has played a significant role in modifying and shaping wildland plant communities in many forest ecosystems in North America. In recent years resource management agencies have realized the need to incorporate fire management concepts and practices into integrated wildland management programs (Lotan 1979, Egging and Barney 1979). The use of fire for wildlife habitat enhancement is one important component of fire management. It is imperative, however, that wildlife habitat managers have sound ecological information on the impact of fire before attempting to use it as a tool for habitat manipulation.

1.2 Problem

The eastern slopes of the Rocky Mountains in Alberta provide range for the largest remaining population of Rocky Mountain bighorn sheep (*Ovis canadensis canadensis* Shaw) in North America. The capability of this range to support bighorn sheep is primarily governed by the amount and quality of forage available during the season of greatest scarcity (Wishart 1978). This is generally the winter season. Therefore, the quality and extent of available winter range is of vital importance in determining bighorn sheep population levels. In addition, the quality and extent of spring and fall range is also important in determining the overall utilization pressure on the winter range and therefore the carrying capacity of the range during the critical winter period.

Forest encroachment on the subalpine wintering grasslands and forest closure resulting from fire suppression programs and natural vegetation succession are regarded as important factors in lowering range availability and utilization (Cowan 1946, Pfeiffer 1948, Wishart 1958, 1978, Flook 1964, Stelfox 1971, 1976, Elliott 1978). In many areas dense tree cover not only limits the growing space available for more desirable grasses, forbs and shrubs but creates a visual barrier thus restricting the use of subalpine areas by bighorn sheep. Much of the present subalpine seral grassland habitat is the result of wildfires which burned in the mid and late 1800's and early 1900's before efficient fire suppression programs were initiated (Flook 1964, Stelfox 1976, Wishart 1978). Many of these areas are now reverting to forest cover and hence the available area for bighorn sheep range is declining.

Pre[illegible] fire has been proposed as a possible management [illegible] for the establishment or maintenance of subalpine [illegible] sheep range. Prescribed burning may provide a[illegible]al way of converting existing subalpine forest land, [illegible] esent [illegible] of low productive value for bighorn sheep [illegible] available and palatable understory plant association. The use of prescribed burning for wildlife habitat manipulation requires that scientists and managers be able to predict the effects burning may have on the habitat prior to ignition. Information must therefore be available not only on the probable response of the plant community but on factors which may limit or contribute to the utilization of fire-disturbed sites by target wildlife populations.

At present, little is known about the effects of fire in subalpine habitats on the east slopes of the Rocky Mountains in Alberta. Less is known about the utilization patterns of bighorn sheep on fire-disturbed sites. This study therefore attempts to provide some information which can be used to assess the ecological benefits and risks of prescribed burning subalpine forest land to create or maintain bighorn sheep range.

1.3 Study Design and Objectives

A study of the effects of fire on bighorn sheep range requires an understanding of the interrelated factors which: 1) constitute favourable bighorn sheep range, 2) may limit sheep population numbers or impact on population fitness, and 3) could be improved or suitably altered by burning. The literature review addresses the first and second topics. The third topic forms the basis of this study. Table 1 provides a preliminary outline of the possible effects that fire may

Table 1. Summary of the effects of fire on the major components of Rocky Mountain bighorn sheep range and the primary study parameters.

HABITAT NEEDS	MAJOR COMPONENTS		FIRE EFFECTS	STUDY DIRECTION
FOOD RESOURCES (subalpine)	FORAGE QUANTITY	YES	plant species abundance, and availability	measured percent cover of herbaceous and shrubs, plant species on burned and unburned subalpine sites
	FORAGE QUALITY	YES	plant species composition, phenology, nutrient content, and palatability	determined plant species composition on burned and unburned sites
	SEASONAL DISTRIBUTION	YES	plant species availability modified by changes in forest cover	measured utilization of browse species on burned and unburned sites
SAFETY AND MOBILITY	ESCAPE TERRAIN	NO	physical feature of landscape, major determining factor in range suitability	evaluated in terms of site utilization
	TREE COVER AND DISPERSION	YES	subordinate plant species composition and abundance, range utilization patterns	measured tree and snag densities on burned and unburned sites evaluated in terms of site utilization
	SNOW PACK	YES	vegetation height and type effects snow retention, dispersal, sublimation	not studied
	WOODY FUEL COMPLEX	YES	quantity, size distribution, and arrangement of fuel particles	measured weights of wood, fuels on burned and unburned sites, evaluated in terms of site utilization
	PREDATION	POSSIBLE	predator detection	not studied
	HUNTING AND DISTURBANCE	POSSIBLE	accessibility and ease of detection	not studied
	DISEASES AND PARASITES	POSSIBLE	herd fitness and susceptibility, destruction of pathogens or intermediate parasite hosts	not studied

have on the major components of Rocky Mountain bighorn sheep range. A brief outline of the study design as related to these components is also provided.

Since an extensive experimental prescribed burning program could not have been undertaken within the scope of this project, data were collected on four existing fire-disturbed sites in Alberta which are known to be utilized by bighorn sheep. The primary objectives of the study were:

1. To determine differences in the quantity of available forage between burned and adjacent unburned forest sites.
2. To determine differences in the quality of available forage between burned and adjacent unburned forest sites.
3. To assess the factors which may limit or contribute to the use of fire-disturbed sites by bighorn sheep.
4. To assess the effects of burning on the establishment and growth of important range plants commonly utilized by bighorn sheep.

2. LITERATURE REVIEW

2.1 Bighorn Sheep Ecology

2.1.1 General

In Canada, Rocky Mountain bighorn sheep are found primarily on the east slopes of the Rocky Mountains between latitudes 51°N and 55°N, and on both east and west slopes south of latitude 51°N (Cowan 1940). There is approximately 34,965 km² of potential bighorn sheep range in Alberta; 18,047 km² controlled by National Parks and 16,918 on provincial lands (Stelfox 1971). The bighorn's range essentially constitutes a strip of alpine and subalpine habitat approximately 48 by 724 km in size (Stelfox 1971).

In Alberta, ecology studies of bighorn sheep range have centred primarily in the national parks (Cowan 1945, 1947, Pfeiffer 1948, Green 1949, Tanner, 1950, Flook 1964, Geist 1971, Stelfox 1976). Several studies have also been conducted on provincial ranges (Wishart 1958, Johnson 1975). In the East Kootenays of British Columbia a number of range related studies were conducted in response to the serious bighorn die-offs which occurred in the mid 1960's (Demarchi 1965, 1968, Demarchi and Demarchi 1967, Hudson et al. 1972, Hebert 1973). In the United States, bighorn range ecology studies were accomplished by Packard (1946), Smith (1954), McCann (1956), Buechner (1960), Schallenberger (1965).

Oldemeyer et al. (1971), Constan (1972), and Matthews (1973).

2.1.2 Patterns of Range Use and Selection

Typical bighorn sheep habitat is semi-open and open alpine and subalpine habitat types consisting of grasses and shrubs in close proximity to rugged escape terrain. Winter ranges are generally at lower elevation (1050 to 2100 m) and confined primarily to southern exposures or windblown slopes adjacent to escape terrain (Stelfox 1976). Snow depth is very important in determining forage availability for bighorn sheep (Geist 1971, Stelfox 1976). Bighorn sheep are not well adapted to deep or crusted snow and generally only paw or dig for food in the absence of alternative feeding sites (Geist 1971). They tend to prefer feeding on open ridges and slopes cleared of snow by wind, snowslides, or avalanches.

Bighorn sheep show distinct seasonal changes in range use patterns in response to their seasonally changing environment. Stelfox (1976) described the general spring to fall distribution patterns exhibited by the bighorn populations in Banff and Jasper National Parks. He found that bighorn sheep basically forage upward along slopes facing south and east in May and June until they reach the subalpine and alpine grasslands. In July and August they forage on south and west slopes at the highest vegetated elevations and along alpine valley bottoms as snowfields recede. By late August and early September foraging shifts to north facing grasslands and open forests where snow melts the latest, and where herbaceous forage remains succulent and nutritious late into the fall.

Geist (1971) reported that bighorn sheep have several seasonal home ranges, as many as six or seven for rams and four for ewes. He found that some rams may utilize at most a pre-rut range, a rutting range, a midwinter range, a late winter range, a spring range, a salt lick range, and a summer range. Ewes may have a winter home range, a spring range, a lambing range and a summer range.

Escape terrain appears to be the most important habitat criterion of bighorn sheep. The availability of such terrain features as rocky outcrops, ledges, cliffs and steep rocky slopes in close proximity to available forage of suitable quality is the major determinant of potential range use. Shannon et al. (1975) found that distribution of bighorn sheep was strongly correlated with proximity to escape terrain regardless of season. Oldemeyer et al. (1971) noted that most feeding activity occurred within 100 yards of escape terrain. McCann (1956) stated that the most important requirement of mountain sheep habitat is "broken, craggy conditions" irrespective of elevation.

Bighorn sheep generally do not utilize heavily forested areas. Shannon et al. (1975) found that distribution of bighorn sheep was negatively related to forest crown closure. McCann (1956) reported that "mountain sheep seem to possess an inborn fear of extensive, heavily timbered conditions".

2.1.3 Food Habits

Bighorns are adaptable feeders and eat a wide variety of plant species native to the montane-alpine zones. Diet selection appears to be quite variable depending on the plant species composition, range conditions, and season. Bighorns tend to consume succulent new forage as it sprouts. Many researchers have stated that forage succulence is more important, or as important, as specific plants (Todd 1972). Stelfox (1976) stated that four factors are important in analysing seasonal forage qualities and preferences:

1. Green, young vegetation is more nutritious, palatable, and digestible than dormant, dry vegetation (Cook and Harris 1950, McCann 1956, Capp 1967, Dietz 1970, Hebert 1973)
2. Alpine vegetation is nutritionally superior to low elevation forage when similar species are compared (Johnson et al. 1968, Hebert 1973).
3. Free ranging sheep maximize nutrient intake by pursuing areas of "green-up" which occur on various exposures and elevations throughout the growing season.
4. Forage quality is strongly influenced by climate through its effect on seasonal variability in plant nutrient content, the periods of commencement and cessation of growth, and the seasonal availability of forage.

In winter, food intake by bighorn sheep depends directly on the rate of passage of food, which is in turn directly related to food quality (Geist 1971). Dietz (1970) defines high quality forage as forage that has high palatability, optimum levels of various nutrients, high digestibility of nutrient components, volatile fatty acids in optimum proportions for efficient energy production, adequate levels of minerals, vitamins, and trace elements, and efficient convertibility into components necessary for the animal body over sustained periods. The amount of energy available to a sheep for maintenance in severe cold or for reproduction and growth is directly related to the quality of available forage. Therefore, under extremely cold winter conditions, bighorn sheep cannot compensate for energy loss by eating more of the same food, but only by eating better food. This is usually forage with a higher protein content (Geist 1971).

A number of researchers have studied or reviewed the food habits of bighorn sheep. They include Cowan (1947), Smith (1954), Wishart (1958), Buechner (1960), Flook (1964), Schallenberger (1965), Capp (1967), Oldemeyer et al. (1971), Constan (1972), Todd (1972), Johnson (1975), and Stelfox (1976).

2.1.4 Population Dynamics

Stelfox (1974), in a study of range conditions, disease-parasitism, and population dynamics of ungulates on bighorn sheep ranges in Jasper, Banff, Waterton and Kootenay National Parks from 1966 to 1972, did not find an effective density-dependent, self regulating mechanism in bighorn sheep populations. He states:

"Bighorn sheep populations tend to increase in number until the condition of their winter ranges declines from overstocking. As the proportion of forage per sheep declines, endoparasite loads and juvenile mortality increases, while animal condition decreases. However, the ewes continue to produce lambs at a normal rate so that the population continues to increase, but at a decreasing rate. Increased parasitism is accompanied by increases in the incidence of lungworms which weaken the lungs and permit the invasion of pneumonia bacteria. As physiological stress increases under more pronounced malnutrition and increased parasite burdens the sheep become more susceptible to both the intrinsic pressure of disease-parasitism and the extrinsic pressure of weather. Severe winter and [illegible] spring weather is then capable of initiating a pneumonia-lungworm syndrome which effects a major die-off, thus releasing the heavy grazing pressure of the range."

The population dynamics of bighorn sheep were also reviewed by Buechner (1960); Streeter (1970) and Wishart (1978) who found similar relationships between the various intrinsic and extrinsic factors limiting sheep numbers.

2.2 Bighorn Sheep in Alberta

2.2.1 Past History and Present Status

Since the early 1800's bighorn sheep pupulations on the eastern slopes of the Canadian Rockies have undergone a series of dramatic fluctuations in numbers (Stelfox 1971). The period from 1800 to 1860 was generally one of abundance for bighorn sheep; their numbers are estimated to have exceeded 10,000. The period from 1860 to 1910 was generally one of population decline in which bighorn sheep numbers fell from about 10,000 to 2,600. Among the major causes of this decline were the indiscriminate hunting with firearms by resident Indians, and an influx of traders, explorers, settlers, railway builders and miners. Also of importance were inter-specific forage competition by large numbers of horses and cattle, as well as an increased incidence of man-caused fires, railway and mining construction, and adverse weather conditions.

After 1910, an extensive preservation program was instituted and a total of over 28,500 square kilometers along the eastern slopes was closed to hunting. In addition a general improvement in range conditions resulting from previous forest fires and low numbers of sheep and elk allowed bighorn sheep populations to increase to about 8,500 in 1936 (Stelfox 1971).

Between 1937 and 1949, a series of major die-offs, attributed to a pneumonia-lungworm disease, deteriorated ranges, heavy elk and livestock competition, a general decrease in grassland ranges caused by forest succession, and a series of severe winters reduced populations to about 2,500 by 1950. After 1950, populations again increased to a high of 10,000 in 1966 because of improved range conditions resulting from light ungulate stocking rates, generally good weather conditions, absence of serious diseases, and low predator populations.

A major die-off began in B.C.'s Kootenay National Park in 1966, and the bighorn population declined from about 175 to 40. Populations in both the National Parks and the provincial ranges in Alberta were as high as they had been at any time during this century (Stelfox 1971). General range deterioration was observed in the national parks during the period of 1966 to 1970 because of very large bighorn populations as well as large populations of elk and deer. Trefethen (1975) estimated the 1974 bighorn population in Alberta to be 7,100 to 7,900.

2.2.2 Harvest

The first game regulations passed in Alberta with regard to bighorn sheep were in 1887 (Wishart 1979). Bag limits of six head per season were introduced in 1893 and reduced to three in 1899. Hunting of females and lambs was prohibited in 1903. In 1921, regulations were changed permitting shooting of only one male sheep during the period from the first of September to the end of October. This regulation continued until 1945. Due to large die-offs, hunting was prohibited in the area south of the Bow River in 1946 and the hunting season restricted to one month in northern regions. Wishart (1979) outlined the major changes in bighorn ram regulations since 1950:

1) trophy seasons were introduced under the 3/4 curl restriction in 1956.

2) the 3/4 curl was increased to 4/5 curl restriction in 1968.

3) extended November seasons or "rut" seasons were tried from 1965 to 1968.

4) compulsory registration of rams was introduced in 1971.

5) restriction of non-resident sheep hunters to a draw system began in 1972, and

6) a waiting period for successful trophy hunters of four calendar years for non-resident aliens and one calendar year for residents and non-residents was introduced in 1974.

In 1966, the first non-trophy season was introduced in Alberta to try to avert major die-offs because of over-populated ranges. Sheep numbers on provincial ranges had increased from about 1,500 in 1950 to 5,500 in 1966 (Stelfox, 1971). The criterion set for harvest was any bighorn with horns less than 12 inches in length. However, since males were selectively chosen over females, the regulations were changed in 1968 to include ewes and lambs only. In the period 1950-1978 the recorded legal kill of rams averaged about 175 rams per year and in the period 1966-77 the recorded non-trophy sheep kill averaged about 108 per year (Wishart 1979).

2.2.3 Predation

Natural predators of bighorn sheep include wolves, coyotes, cougars, lynx, wolverines and eagles. Bighorn sheep effectively avoid excessive predation by escaping to protective cliffs and extremely rocky habitats, as well as by possessing exceptional eyesight and climbing ability. Predator control, therefore, is not generally considered necessary to enhance bighorn populations (Wishart 1978). In fact, some forms of predator protection may prove beneficial on ranges that are less accessible to hunting pressure by maintaining bighorn populations at acceptable levels, thereby controlling grazing pressure and parasite loads.

2.2.4 Fire and Bighorn Sheep Range

Throughout the literature on bighorn sheep range studies in Alberta there are references to the role of past fires in the creation of bighorn sheep range and to the impact of forest encroachment on the reduction of fire-induced ranges (Cowan 1946, Pfeiffer 1948, Tanner 1950, Rowan 1952, Banfield 1958, Wishart 1958, 1978, Stelfox 1971, 1976). In a discussion of the range relationships of ungulates in Banff and Jasper National Parks, Flook (1964) noted that much of the subalpine range had been produced by fire. He also noted, however, that spruce was gradually reestablishing and consequently was reducing the available range land. He noted a corresponding decline in the numbers of elk, moose, deer and bighorn sheep. Geist (1971) reported that along the Cascade Valley in Banff National Park bighorns lived primarily on ranges which were created by past forest fires, but that the grasslands produced were slowly reverting to forest. Stelfox (1976) noted that fires and forest succession strongly influenced the carrying capacity of the national parks for bighorn sheep. Yet it is interesting to note that to date research has neglected to test the importance or role of fire in maintaining or producing Rocky Mountain bighorn sheep range.

2.3 Fire in the Subalpine Zone

2.3.1 General

The subalpine zone of the northern Rocky Mountains as designated by Daubenmire (1943), has been investigated by Rydberg (1915), Larson (1930), Cormack (1953), Horton (1956), Patten (1963), Beil (1966), Ogilvie (1969), Krajina and Brooke (1970), Day (1972), Lowery (1972), Rowe (1972) and Franklin and Dyrness (1973), and La Roi and Hnatiuk

(1980). Fire is, and has been, an important force in determining plant species distribution and vegetation patterns in the subalpine zone. Some of the studies which review or document the importance of fire in high elevation areas include Clements (1910), Stahelin (1943), Fonda and Bliss (1969), Douglas and Ballard (1971), Habeck and Mutch (1973), Loope and Gruell (1973), Mogren and Barth (1974), and Dube (1976).

2.3.2 Fire History Studies

The specific influence of a fire on an ecosystem and the scale of its effects depend on the fire regime, which is the characteristic periodicity, extent, and severity of fires (Tande 1979). Fire history studies have tried to describe or document the natural historic fire regime for different forest ecosystems in western and northern North America. Fire history studies in the Rocky Mountains of the United States have been conducted by Houston (1973) in Yellowstone National Park, Loope and Gruell (1973) in the Jackson Hole area of northwest Wyoming, Clagg (1975) in Rocky Mountain National Park, Colorado, Arno (1976) in the Bitterroot Mountains of Montana, and Sneck (1977) in the Coram Experimental Forest, Montana.

A number of studies have also been conducted in the Canadian Rocky Mountains in recent years. MacKenzie (1973) used stand age data to approximate dates of fire origin for the forests of Waterton Lakes National Park. Byrne (1968) used historical literature in describing landscape change attributed to fire in Banff National Park. Tande (1977, 1979) used fire-scar analysis and stand age data to describe the historical fire regime of Jasper National Park. Hawkes (1979) used similar techniques to document the fire history of Kananaskis Provincial Park in Alberta.

Arno (1980) provided a state-of-knowledge summary of recent forest fire history studies in the Northern Rockies. Alexander (1979) compiled a bibliography containing 307 references dating back to 1900, and a list of 2 [illegible]rent studies on forest and rangeland fire history.

2.3.3 <u>Fire History Techniques</u>

Recent fire history studies have used dendrochronological techniques of fire-scar analysis and forest age-class analysis as well as historical records and fire agency records to determine past fire regimes in wildland areas. Clements (1910) first described many of the techniques now in use. Stokes and Smiley (1968) provided information on the basic principles and methods of dendrochronology or tree-ring dating, which form the basis of most fire history studies. Fritts (1971), Arno and Sneck (1977) and Tande (1977) describe the process of aging and correlating dates from fire scars on trees and identifying fire-initiated age classes of trees.

It is pertinent to outline some of the problems or drawbacks inherent in fire history studies and in the information obtained from these studies. Many forested areas are characterized by fire regimes that include periodic large, stand-destroying fires with intervening smaller, less destructive fires. Fire history studies are generally able to document past large fires but smaller fires may go undetected. Reasons for this include the destruction of evidence such as fire-scarred trees and regenerating trees by the larger fires, or simply the sensitivity of the sampling design. In addition, surface fires of low intensity may leave no obvious evidence of their existence if trees were not scarred or killed. Evidence of past fires becomes increasingly difficult to obtain and interpret as the time span involved increases.

Dates of fire occurrence are often based on age-class distributions of trees established following fire (e.g. lodgepole pine). This type of analysis often assumes that most post-fire tree recruitment initiates the year of, or immediately following, the fire year. This may be an accurate assumption in some cases but could lead to inaccurate or misleading results in others. Woodard (1977) found a recruitment lag, for lodgepole pine in the Table Mountain area of Washington, of 15 years between the year disturbance took place and the date of initial establishment. Mason (1915) and Horton (1953, 1955) found that stand regeneration by the major subalpine tree species usually occurred within 6-8 years following burning. Stahelin (1943) found natural recruitment periods of 50-100 years subsequent to wildfires were normal for subalpine sites in Colorado and southern Wyoming.

Fire history studies often use the terms fire-free interval (Arno 1976) or fire-return interval (Tande 1979) to describe the characteristic fire regime for a specific geographic area, stand type, or forest series. Arno (1980) defined mean fire-free interval as the estimated mean number of years between fires occurring within small stands (about 40 hectares). He noted that fire-free intervals at a given point within a stand would normally be somewhat longer. Maximum and minimum fire-free intervals may vary considerably from the mean. When interpreting this type of data it is therefore important to note the size of the area referred to, as well as stand characteristics such as elevation, exposure, topography and climate, all of which may influence the characteristic fire regime of stands with similar species composition.

A common justification or objective for conducting fire history studies is to provide land managers information from which they can.develop habitat manipulation prescriptions involving fire (prescribed burning, "let-burn" policies, "controlled wildfire" policies). The information may often be too generalized or speculative, however, to relate to specific sites or problem areas. For example, if land managers want to "duplicate" the "natural" fire regime for an area by prescribed burning at periodic intervals, they will have to decide among the mean, maximum or minimum fire-free intervals as guidelines. As previously mentioned, these values may vary considerably or may not even be pertinent to the particular site in question. General fire history studies should therefore be interpreted in the context for which they were designed, and not necessarily as management guidelines. They can, however, be very valuable in providing basic ecological information or as aids in understanding plant community dynamics and successional relationships.

2.4 Effects of Fire on Vegetation

2.4.1 Subalpine Forest Succession

Important factors which control stand establishment and development in subalpine forests include climate (length of growing season, diurnal and seasonal fluctuation in temperature, seasonal precipitation patterns), soils (moisture and nutrient status), physiographic features (elevation, slope, aspect) and availability of germplasm. Agents of disturbance such as avalanches, snowslides, ungulate grazing, wind, diseases, and insects also play a role in forest structure. In recent years the perception of the role of fire in forest ecosystems has changed fro being an unnatural agent of disturbance to a natural ecosystem process. Heinselman (1970) perhaps epitomizes the "pro-fire" viewpoint in his statement, "...fire was the key environmental factor that initiated new successions, controlled the species composition and age structure of the forests, and produced the vegetation patterns upon which the animal components of the ecosystem also depended." The term "fire-dependent" is now often used to describe many of the plant and animal components of forest ecosystems. Although this may be an oversimplification in many cases, the recent body of literature suggests that fire is often one of the more important factors influencing forest succession and plant and animal distribution (Lutz 1956, Daubenmire 1968, Vogl 1970, 1974, Habeck and Mutch 1973, Kozlowski and Ahlgren 1974, Kelsall et al. 1977, Gruell 1980).

A number of factors have been found to influence plant regeneration and stand development on burned areas. Woodard (1977) emphasized the importance of the thermal environment (fire intensity and total heat output) which occurs during the combustion process, as well as variables such as the original stand, amount of destruction wrought, seed source availability, soil, topography, seedbed suitability, age since disturbance, and changes in microclimatology. The exact nature and magnitude of importance of many of these factors have yet to be quantified in many fire-influenced plant communities. Variations in geographic location, plant species composition, landform, and climatic and edaphic features make generalization difficult. A number of workers, however, have attempted to develop ecological models which describe or predict pla successional patterns subsequent to burning (Wills 1928, Stahelin 1943, Cormack 1953, Lyons 1971, Habeck 1972, Martin et al. 1976, Lyon and Stickney 1976, Cattelino et al. 1979, Davis et al. 1980). Many of these models, however, tend to oversimplify the mechanisms involved and do not account for the variability inherent in plant succession following disturbance by fire.

2.4.2 Plant Adaptations to Fire

The study of adaptations of live plants to fire is often separated into two classes; 1) adaptations which increase the fire resistance of plants, and 2) adaptations which enable plants to re-establish in burned areas (Hawkes 1979). Brown and Davis (1973) outline nine factors which may affect the susceptibility of trees and forests to heat damage. These are: 1) the initial temperature of the vegetation, 2) the size of the critical tree portion exposed and its morphology, 3) the thickness and character of the bark, 4) the branching and growth habit, 5) the rooting habit, 6) the depth and character of the organic mantle covering the mineral soil, 7) the flammability of the foliage, 8) the stand habit, and 9) the season and stage of growth cycle. The above factors are important in that they affect the likelihood of plant tissue reaching lethal temperatures. The period of exposure to high temperature is also of great importance in determining the degree of damage to plant tissue (Hare 1961, Martin 1963, Kayll 1968, Wright 1970, Woodard 1977).

A number of researchers have attempted to categorize plant species on the basis of their mode of persistence in fire-disturbed habitats. Rowe (1979) revised an approach by Noble and Slatyer (1977), and proposed a classification scheme applicable to boreal plant species. He classified plants as:

1. Invaders; highly dispersive, pioneering fugitives with short-lived disseminules.
2. Evaders; species with relatively long-lived propagules that are stored in the soil or canopy.
3. Avoiders; tolerant species that slowly reinvade burned areas, late successional, often with symbiotic requirements.
4. Resisters; intolerant species whose adult stages can survive low severity fires.
5. Endurers; resprouting species, intolerant or tolerant, with shallow or deep-buried perennating buds.

The mode of persistence of the first three species types is disseminule-based with propagation primarily by diaspores. The mode of persistence of types four and five is vegetative based with propagation primarily by horizontal and vertical extension (Rowe 1979).

Stickney (pers. comm.)[1] has also developed a system of classifying plants based on their method of reestablishment following burning. He separates plant species into two broad

[1] Peter Stickney, Associate Plant Ecologist, Forestry Sciences Laboratory, Missoula, Montana, personal communication, 1981.

categories, survivors and colonizers. Survivor species are those present on the site prior to burning and capable of re-establishment from on-site surviving plant parts (root crowns, rhizomes, underground stems). Colonizer species may be of three types:

1. Residual colonizers; species with on-site seed of long viability stored in the soil or canopy.
2. Initial off-site colonizers; species with easily dispersed airborne seed or fruit that invade and establish on the burned sites soon after the fire.
3. Secondary off-site colonizers; species with less dispersive seed or fruit that generally colonize burned sites after some site amelioration has taken place.

Classification schemes of fire-plant relationships and plant adaptations to fire such as the ones outlined above, should be interpreted with care. Lumping of plant species into specific categories based on structural-functional criteria may often be misleading and unproductive when assessing successional trends and relationships. As Rowe (1979) points out, "phenotypic plasticity of perennial species complicates the categorization of plants as single structural-functional types. Species frequently display two or more strategems between perturbations." Classification schemes such as those described above, generally tend to mask causes and emphasize symptoms.

Forest trees, because of their dominant role in forest ecosystems and economic importance, have received much of the focus of research work on plant adaptations to fire (Lutz 1956, Ahlgren and Ahlgren 1960, Wellner 1970, Brown and Davis 1973).The autecological relationship of shrub species to fire has been reviewed or studied by Lutz (1956), Ahlgren and Ahlgren (1960), Buckman (1964), Ahlgren (1974), Wright (1974), and Miller (1977). Very little quantitative information is available on the effects of fire on subordinate plant species (grasses, sedges, forbs and dwarf shrubs). Some of the better review articles available include Ahlgren (1960), Ahlgren and Ahlgren (1960), Daubenmire (1968), McLean (1969), Vogl (1974), Lyon and Stickney (1976), and Wright and Bailey (1980).

2.5 Fire and Wildlife Management

2.5.1 General

In recent years there has been a growing interest in the study of the effects of fire on wildlife populations. The realization that fire has been an important influence in many forest and grassland communities has prompted numerous studies on the use of fire as a habitat management tool. However, the ability to predict or interpret cause and effect relationships between the action of fire and the response of animals is often hampered by inadequate knowledge of the characteristics of the fire. This has often led to contradictory results when assessing the effects of fire on specific wildlife species. Fires may vary in intensity, duration, frequency, location, shape, and extent. Fire effects may differ with season, nature of fuel, and properties of site and soil (Bendell 1974). The effects of prescribed fire may also differ from those of wildfire. It is necessary, therefore, when interpreting the findings of other workers to comprehend the inherent variability of fire and the subsequent effect it may have on wildlife populations.

Much of the literature on fire pertains only indirectly or speculatively to its effect on wildlife. For present purposes, this study will review only recent work pertaining to the effect of fire on ungulates in the Rocky Mountains. For information on the effects of fire on invertebrates, fish, small mammals, and birds the reader is referred to articles by Bendell (1974), Roppe and Hein (1976), Kelsall et al. (1977), and Lyon et al. (1978).

2.5.2 Natural Fire and Ungulate Populations

In general, most large herbivores benefit from forest fires (Lyon 1971, Bendell 1974, Leege 1974, Roppe and Hein 1976, Kelsall et al. 1977, Lyon et al. 1978). The impact of wildfire on ungulate populations, however, depends on many factors; size of the burn, interspersion of burned and unburned areas, successional stage of the pre-burn vegetation, intensity of the fire, post-burn vegetation response, and the competitive relationships of the resident ungulate species.

The size of the burn has been shown to affect ungulate site utilization (Lyon 1971, Roppe and Hein 1976). A large fire may decrease the interspersion of food and cover by increasing the uniformity of the vegetation. In addition, larger fires may lower the ratio of edge to burned area which may limit the use of the interior portions of the burn by wildlife (Roppe and Hein 1976). Several authors have suggested that fires of less than 20 hectares are most beneficial to wildlife (Biswell 1960, Harper 1969, Lyon 1971, Dealy 1974). However, fires rarely burn evenly and often create patterns of burned and unburned clumps of vegetation which provide the necessary interspersion of cover types for wildlife.

Many investigators have reported an increase in the quantity and availability of forage after fire. Lyon (1966) reported that early stages of succession maintained a greater abundance of wildlife than did mature stages of forest succession. Pengelly (1961) found that fire altered plant succession and increased forage for elk and deer in Idaho. Vogl and Beck (1970) found that burning made new growth available after vegetation had grown out of reach of white-tailed deer. Leege (1968, 1974) found that prescribed burning increased browse availability, nutrient levels, and palatability of new growth. Leege and Hickey (1971) noted that shrubs sprouted prolifically after both spring and fall burns in Idaho.

A number of workers have reported an increase in the nutrient content of forage species after fire, presumably because of an increased uptake of nutrients released in the ash. However, there is no simple relationship among burning, release of nutrients, uptake by plants, and utilization by animals (Bendell 1974). Lay (1967) and Dewitt and Derby (1955) reported a significant increase in utilization of burned areas and increased protein in browse plants for several years after a burn. Miller (19[illegible]) found that after burning, nutrient values of browse improved with increases in crude protein and phosphoric acid. Cowan et al. (1950) found that the contents of ascorbic acid, ether extracts, carbohydrates, and protein in moose forage in young fire-altered forest were superior to that in older stands. Bendell (1974) reviewed several published reports on the nutrient content of deer foods subsequent to burning. He found that protein levels appeared to increase after fire but there was little evidence of change in the amount of phosphorus or magnesium and that calcium levels appeared to decrease. He concluded that increases in nutrient levels, if any, were generally short-lived (1 to 20 years), and that levels of nutrients in browse plants remain relatively constant despite variations in mineral supply.

Moose and deer appear to benefit most from the early successional plant growth subsequent to fire. Kelsall et al. (1977) concluded that the optimal successional stages for moose occur between 11 and 30 years after burning. Edwards

(1954) described the dramatic increase in moose and deer numbers with the burning of mature conifer forest and subsequent growth of herbs and shrubs in Wells Gray Park, British Columbia. Peek (1974) reported an increase in the density of moose in northeastern Minnesota from less than 0.5 per square mile before burning to 2 per square mile following fire.

There are very few references to the effect of fire on bighorn sheep populations in Canada. Elliott (1978) studied the effect of fire on Stone sheep (<u>Ovis dalli</u>) range in northeastern British Columbia. He found subalpine ranges which had been altered by fire supported five times the density and absolute population size of sheep. In addition, he found these ranges averaged 75 percent more lambs in late winter than on unaltered ranges. Also, rams of the same age had horns about three inches longer. Peek et al. (1979) found after prescribed burning of a big sage brush (<u>Artemisia tridentala</u> Nutt.)/bluebunch wheatgrass (<u>Agropyron spicatum</u> (Pursh) Seribn. and Smith) bighorn sheep rangeland in the Salmon River area of Idaho, that utilization of bluebunch wheatgrass was greater on burned sites than on adjacent unburned sites four years after the burn. The utilization remained higher even after grass production had leveled off.

There is little quantitative evidence in the literature to demonstrate that ungulate populations actually increase as a result of burning. Many studies speculate that increased utilization of burned sites by ungulates or forage increases are indications of ungulate population increases. Local population shifts likely account for many apparent population increases (Allen 1971, Lyon 1971). To fully document the response of ungulate populations to burning it is therefore necessary that studies include an evaluation of population levels prior to, and after burning. Otherwise, it is very difficult to determine the long term impact that burning may have on ungulate population numbers.

2.5.3 Prescribed Burning and Wildlife Management

Prescribed burning has been defined by the Canadian Committee on Forest Fire Control (Anon. 1976) as follows:

> "The burning of forest fuels on a specific area under pre-determined conditions so that the fire is confined to that area to fulfill silvicultural, wildlife management, sanitary or hazard reduction requirements."

and by the Society of American Foresters' Task Force on Prescribed Burning (Martin et al. 1977) as:

> "the controlled application of fire to fuels in either their natural or modified state, under such conditions of weather, fuel moisture, soil moisture, etc., factors as allow the fire to be confined to a predetermined area and at the same time to produce the intensity of heat and rate of spread required to further certain management objectives."

Prescribed burning as a management tool has been used for hazard reduction, slash disposal, silvicultural site preparation, disease and insect control, range improvement, improvement of accessibility or aesthetics, and wildlife habitat manipulation (Kiil 1969, Alexander and Hawksworth 1975, Martin 1976, 1977, Bailey 1977, Fischer 1978, Martin and Dell 1978, McRae 1979, McRae et al. 1979, and Wright and Bailey 1980). Prescribed burning objectives for wildlife habitat management include rejuvenating decadent shrubs, increasing browse availability, increasing nutrient levels and palatability of browse and herbage, providing a seedbed for grasses, eliminating excessive litter buildup, manipulating plant species composition, and maintaining grasslands subject to tree or shrub encroachment (Leege 1968, Leege and Hickey 1971, Wright 1974, Gordon 1[illegible] Nelson 1976, Bailey 1977, Martin and Dell 1978, and [illegible] et al. 1979).

Elliott (1978) stated that the primary benefit of burning high elevation Stone sheep range would be an increase in the available forage. He also noted that secondary benefits might include increased dispersal or sublimation of snow, facilitation of predator detection, maintenance of herd contact, and increased ve[illegible] displacement of year-round available range. Peek et al. (1979) stated that fire can be a useful tool in bighorn habitat management by: 1) retarding successional advance of seral grasslands towards conifer climax, and 2) improving the production and palatability of important forage species.

3. STUDY AREAS

3.1 Study Area Selection

Suitable study areas were identified through an analysis of provincial fire incidence records and personal communication with Alberta Fish and Wildlife and Forest Service personnel. The following criteria were used in selecting specific burned study sites:

1. The burn site was located in the subalpine zone of the Rocky Mountains in Alberta.
2. The burn site was located within a documented bighorn sheep range.
3. The burn site was known to be utilized by bighorn sheep.
4. The burn site was 10 ha or larger in size.
5. The burn extended from valley bottom up to or beyond tree line.
6. The overstory tree canopy was killed in a major portion of the burn area.

Four study areas which met all of the above criteria were identified. Preliminary assessments of plant species composition and fire histories were obtained during the 1979 summer field season. The study areas sampled are referred to as: Ghost River, Rock Creek, Ram Mountain and Cadomin Mountain (Figure 1).

Suitable adjacent unburned sites were also identified and served as controls. Black and white aerial photographs

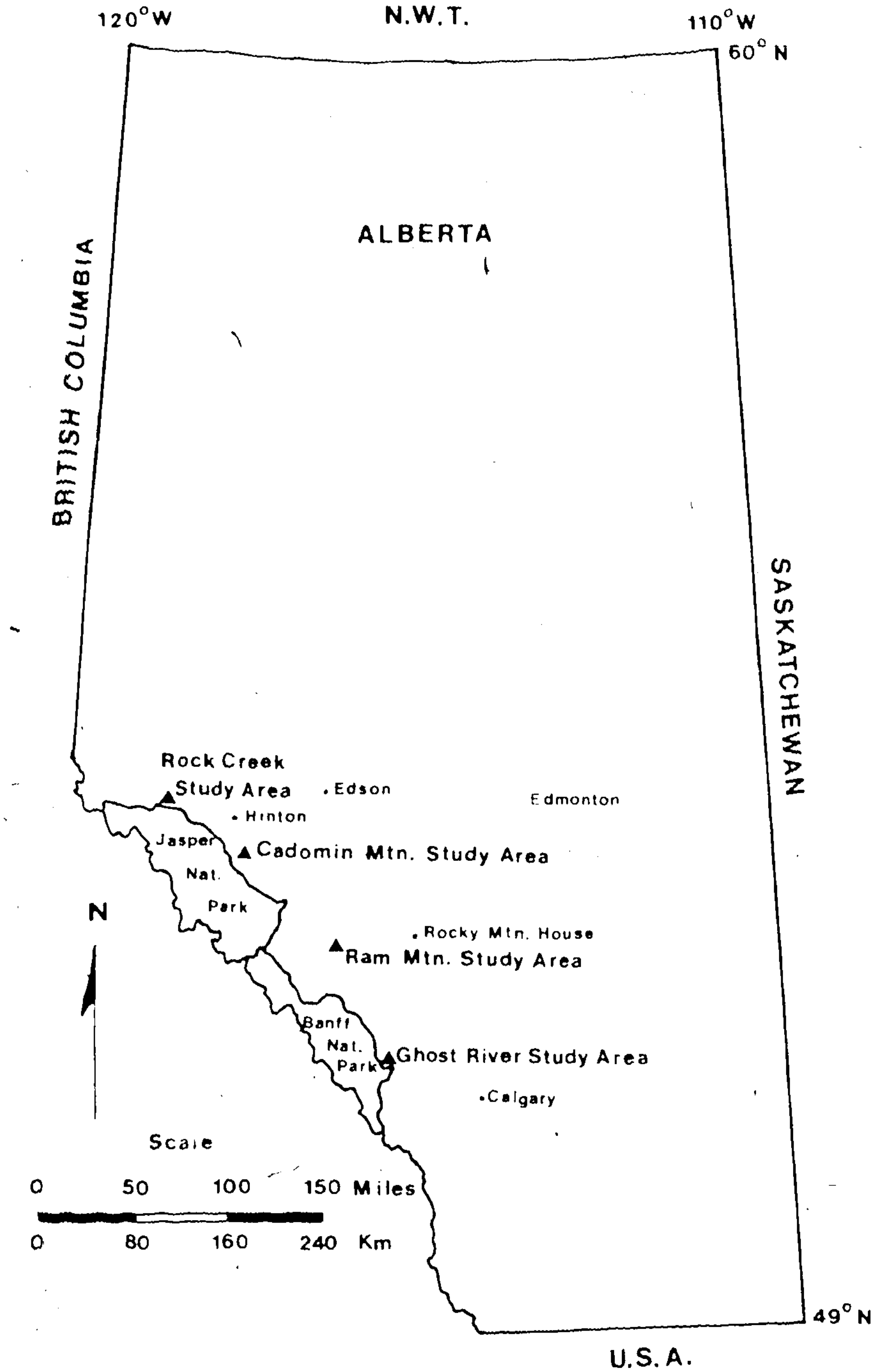

Figure 1. Location of study areas.

(1:21,120) were initially used for identification of adjacent unburned sites in each study area. Similarities in aspect, slope, topographic relief, and vegetation structure between burned and unburned sites were used as criteria. Unburned sites immediately adjacent to the burned sites were selected if possible.

3.2 Description of Study Areas

3.2.1 Location of Study Areas

3.2.1.1 Ghost River Study Area

The Ghost River study area is located within the boundaries of the Ghost River Wilderness Area which is located approximately 80 km northwest of Calgary, Alberta, via Highway 1A and the Forestry Trunk Road. The west and south boundaries of the Wilderness Area border Banff National Park. Access to the Ghost River Wilderness is limited. Vehicles can approach within only six to ten km of the easte boundary along the Ghost River Valley. The geographic location of the study area is 51°21′N latitude and 115°24′W longitude.

3.2.1.2 Rock Creek Study Area

The Rock Creek study area is within the boundaries of the Willmore Wilderness Area which is located immediately north and adjacent to Jasper National Park. The geographic location of the study area is 53°29′N latitude and 118°? W longitude. Vehicle traffic in the Willmore Wilderness Area is restricted. The closest road access to the study area is at Rock Lake, approximately 45 km northwest of Hinton, Alberta.

3.2.1.3 Ram Mountain Study Area

Ram Mountain, which comprises the southernmost extent of the Brazeau Range, is located approximately 60 km west of Rocky Mountain House and 25 km southeast of Nordegg, Alberta. Access is provided via Secondary Highways 940 and 752 from Nordegg and Rocky Mountain House, respectively. Access to the Ram Mountain Lookout is provided by a restricted-use Forest Service road. The geographic location of Ram Mountain is 52°20′ - 52°25′ N latitude and 115°41′ - 115°55′ W longitude.

3.2.1.4 Cadomin Mountain Study Area

Cadomin Mountain, together with a series of lesser mountains, comprise the Red Cap Range in west-central Alberta. The village of Cadomin is located at the extreme west end of Cadomin Mountain. The town of Edson is located approximately 100 km to the northeast and the town of Hinton approximately 65 km to the northwest. Access is provided via Secondary Highways 47 and 40 from Edson and Hinton, respectively. The east boundary of Jasper National Park is approximately 12 km west of Cadomin Mountain. The geographic location of Cadomin Mountain summit is 52°59′ N latitude and

117°17′ W longitude.

3.2.2 Climate

All of the study sites lie in the Front Ranges of the Rocky Mountains which have a continental boreal-like climate characterized by extreme differences in seasonal temperatures and a summer-high, winter-low distribution of precipitation (Ogilvie 1969). Temperatures generally decrease with an increase in elevation at a rate of 3°F for every 1000 feet rise in elevation (Ogilvie 1969). Nocturnal temperature inversions are also fairly common in mountain valleys.

No climatological data are available for the immediate vicinity of the study areas. Weather records from Alberta Forest Service weather stations were reviewed, however, and temperature (Stashko 1971a) and precipitation (Stashko 1971b) data recorded at weather stations nearest to the study areas are shown in Table 2.

3.2.3 Geology and Geomorphology

Much of the geological strata of the Front Ranges is sedimentary, comprised of limestones, dolomites, sandstones and shales. Many of the soil-forming materials are calcareous in nature, derived either from bedrock weathered in place or transported glacial and alluvial materials (Ogilvie 1969).

Table . Temperature and precipitation data recorded at Alberta Forest Service weather stations located nearest to the four study areas.

Study Area	Weather Station	Distance From Study Area (km.)	Elevation (m.)	Probable 30 year (1931-1960) mean maximum temperatures (°C) May	July	September	Mean monthly precipitation (mm) (1963-1970, May to September)
Ghost River	Ghost Ranger Station	30-E	1433	13.9	21.1	15.0	83
	Mockingbird Hill	25-NE	1902	11.7	18.3	12.2	76
Rock Creek	Moberly Lookout	42-E	1647	11.1	17.2	11.7	61
	Adams Creek Lookout	27-N	2210	7.2	13.3	7.8	58
Ram Mountain	Nordegg Ranger Station	25-NW	1326	14.4	21.7	16.1	76
	Kiska Lookout	28-W	2073	8.9	16.1	10.6	71
Cadomin Mountain	Grave Flats Lookout	16-E	2074	7.8	15.0	9.4	79

The Ghost River Wilderness Area lies in the Palliser Range formed by Devonian and Mississippian strata. The Ghost River flows southeasterly along a syncline containing Mesozoic strata. East of the Ghost River the mountains are mainly Mississippian carbonates with older Devonian beds on the Wilderness Area boundary (Hume 1936).

The Rock Creek study area lies in the Persimmon Range of the Front Ranges. The Persimmon Range extends for approximately 80 km from its southeastern end at Rock Creek Valley to its northwestern extremity just west of longitude 119°00′ where it loses its identity as a separate structural unit (Irish 1965). The Persimmon Range is underlain by Devonian and Mississippian strata which have been thrust relatively northeast over Cretaceous formations on a major southwest-dipping thrust called the Rocky Pass fault. The southwestern slope of the Persimmon Range, which includes the Rock Creek study area, is largely underlain by Triassic strata folded into numerous small sub-parallel anticlines and synclines (Irish 1965). The crest of each successive anticline becomes progressively lower in altitude from the summit of the range southwesterly toward the valley occupied by the Sulphur River and the upper part of Rock Creek. Mississippian and Devonian formations are composed of limestone and dolomite of marine origin as well as calcareous shales of the Banff formation.

The geology of the Ram Mountain area was studied by Erdman (1950) in the late 1940's for the Geological Survey of Canada. The Brazeau Range is composed of resistant Paleozoic limestones and softer shales which are well exposed above an elevation of 1818 m. The Paleozoic formations present in the study area consist of shales, limestones and dolomites of marine origin. The differential resistance to erosion of exposed strata is in part a controlling factor in determining the nature of the topography. The exposed upthrust mountain strata in the immediate study area are composed of marine sediments of Upper Devonian to Lower Mississippian age.

Cadomin Mountain forms part of the easternmost extremity of the Nikanassin Range in the Front Ranges of the Rocky Mountains. The Nikannassin Range is a series of northwestern-trending ranges and valleys composed of overthrust strata lying between southwesterly dipping faults (Roed 1968). The Nikanassin Range is composed largely of Palaeozoic formations, mostly shales, dolomites and fine limestones. Detailed descriptions of the local geological strata and exposures can be found in MacKay (1929a, 1929b), Leeson (1959), and Williams (1966).

3.2.4 Soils

Soil development in all the study areas is generally poor, with thin, immature profiles. Soil profile development is highly variable because of differences in microtopography, slope, elevation, vegetation cover, and parent material. Chemical and microbial soil-forming processes are retarded by low temperatures and short frost-free periods. The main soil groups present in the Rocky Mountains are Brunisols, Podsols, Regosols and Gleysols (Ogilvie 1969). Brunisolic soils generally have weakly developed horizons and occur in the drier habitats at lower elevations, usually under forest cover. Podsolic soils typically occur in coarse to medium textured acid or calcareous parent materials, under forest or heath vegetation, in cool or very cold humid climates (Canada Soil Survey Committee 1978). Podsolic soils are generally found at higher elevations under more mesic conditions. Regosolic soils are generally weakly developed and are generally rapidly to imperfectly drained. They are commonly found at higher elevations on scree slopes and in shallow deposits over rock ourcrops, or at low elevations where soil movement prevents horizon development. Gleysolic soils are uncommon in mountainous areas and are generally limited to flood plain sites, shallow depressions, or level lowlands that are frequently saturated with water (Canada Soil Survey Committee 1978).

Dumanski et al. (1972) conducted a soil survey of the Edson-Hinton area. In the mountainous areas, Luvisolic soils and Eutric and Dystric Brunisols are found below treeline. Above treeline, Alpine Eutric and Alpine Dystric Brunisols are common. The results of chemical soil analysis for the specific study areas are presented in a later section.

3.2.5 Bighorn Sheep Populations

3.2.5.1 Ghost River

There is very little information available concerning the size and movements of the bighorn sheep population in the Ghost River Wilderness Area. The most recent aerial census conducted by the Alberta Fish and Wildlife Division in the Wilderness Area reports a total population of 58 bighorn sheep (Cook 1978). This number, however, may fluctuate somewhat because of movements of sheep between Banff National Park and the Wilderness Area (Allan Cook pers. comm.). Sheep from the Wilderness Area are also thought to migrate into and out of the Burnt Timber bighorn sheep range located immediately to the north of the Ghost River Wilderness Area. The bighorn population size in the Burnt Timber range was 24 as recorded in the last aerial census (Froggart 1980).

3.2.5.2 Rock Creek

The Rock Creek study area is not located within a specific bighorn sheep winter range as designated by the Alberta Fish and Wildlife Division (Bibaud and Dielman 1980). Bighorn sheep from Jasper National Park are known to migrate to the area at certain times of the year.

3.2.5.3 Ram Mountain

A comprehensive study of the Ram Mountain bighorn sheep population was initiated in 1971 by the Wildlife Research

Section of the Alberta Fish and Wildlife Division (Hoffman 1971) and is continuing at the present time. Ram Mountain forms an essentially geographically isolated sheep range. The area is bounded on the north by the North Saskatchewan River, and undulating forested foothill terrain isolates the mountain on the other three flanks. The Fish and Wildlife Division maintains a research station on Ram Mountain and has constructed a permanent sheep trap. The sheep are trapped throughout the summer. Current year's lambs are tagged, and the growth and status of all the sheep in the population are monitored. Movement and range utilization patterns in the area are also monitored. The bighorn sheep population size has been maintained at approximately 100 animals for the past several years (Jorgenson 1981).

3.2.5.4 Cadomin Mountain

The Red Cap bighorn sheep range has been closed to bighorn sheep hunting since 1969. The closure came as a response to serious declines in the sheep population, particularly legal rams, in the late 1960's (Lynch 1971, Lynch and Wishart 1975). A research program was initiated in 1972 by the Alberta Fish and Wildlife Division to investigate the possible migration of rams into Jasper National Park. Preliminary results suggested that although some sheep moved into and out of Jasper National Park, hunting may have been the major factor which resulted in the decline in the number of legal rams (Smith and Lynch 1974, Smith et al. 1977). The latest aerial census conducted by the Alberta Fish and Wildlife Division (Bibaud and Dielman 1980) reported a total population of 143 sheep on the Red Cap Range.

4. METHODS

4.1 Sampling Scheme

Three baseline transects were established within each burned site at Ghost River, Ram Mountain and Cadomin Mountain and within each unburned site at Ghost River, Rock Creek and Ram Mountin. Four baseline transects were established in the burned site at Rock Creek. Only two baseline transects were established in the unburned site at Cadomin Mountain because of difficulty in locating a suitable location for a third transect.

The baseline transects ran downslope from treeline to the lower perimeter of the burn in the burned sites. In the adjacent unburned sites, the baseline transects ran from treeline downslope to valley botton (Figure 2). The lengths of the baseline transects varied from 400 to 600 meters depending on the slope distance from treeline to burn margin or valley bottom.

The locations of the baseline transects were initially determined using aerial photographs (1:21,120) and modified when necessary in the field. Criteria for locating baseline transects within each burned or unburned site were based on a visual estimate of the uniformity of the snag or tree density and the topographic variation from treeline to valley bottom. Areas which had large variations in topography (large rock outcrops, cliffs or talus slopes) or

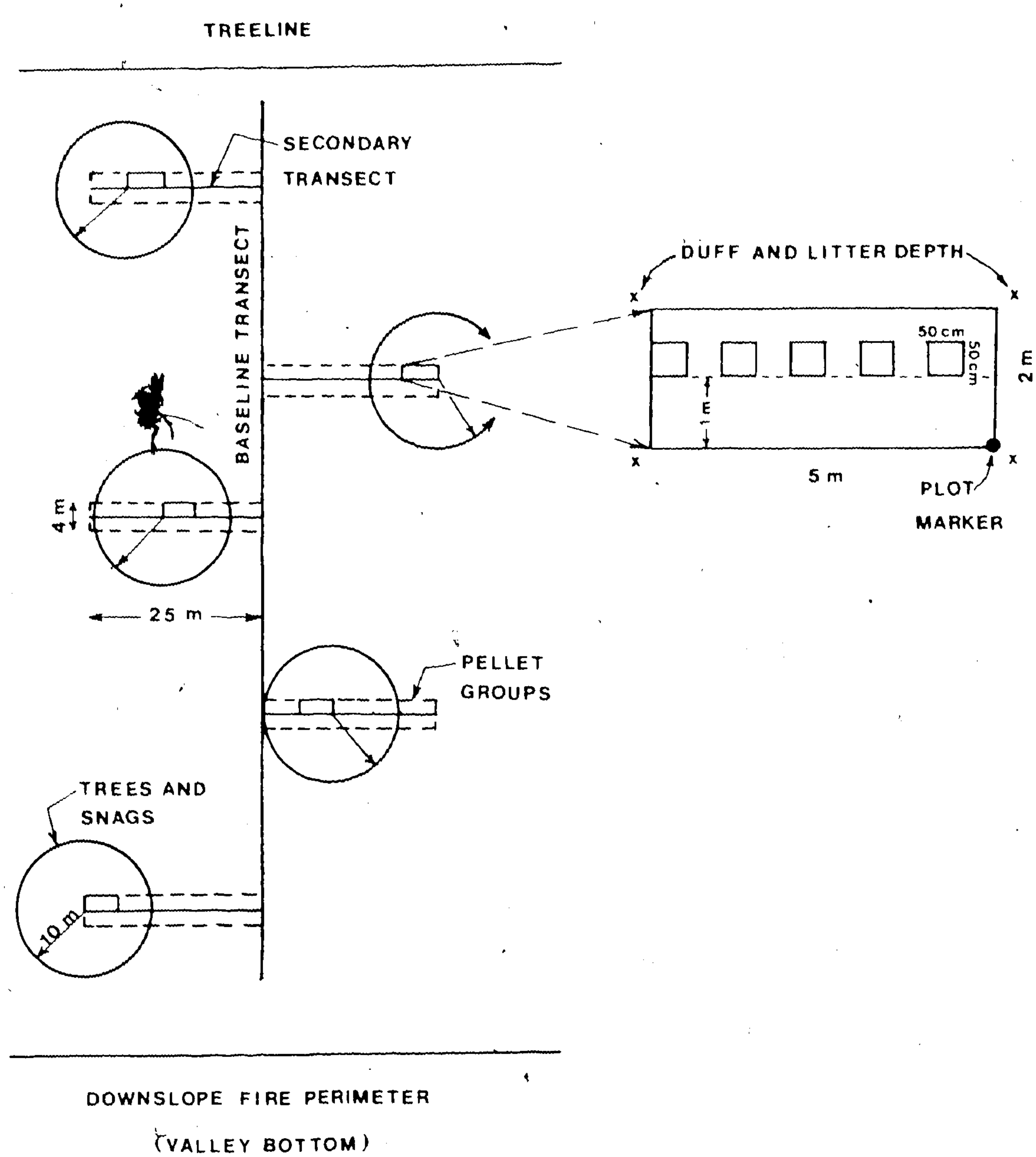

Figure 2. Diagrammatic representation of the plot and transect layout along one baseline transect.

distinct differences in ground cover from the rest of the site were not sampled. The primary objective in locating baseline transects was to sample areas that were as uniform as possible within a particular site and between burned and unburned sites in each study area. The lengths of the baseline transects were measured using a Topoquick range finder.

Each b[illegible] transect was divided into five segments of equal [illegible] secondary transect was then located perpendicu[illegible] the baseline in each segment using a restricted [illegible]m sampling method (Figure 2). This restriction does not bias the essential feature of sampling (Greig-Smith 1964) which allows the observed variance of the data to be used as the basis of tests of significance. Any point along a baseline transect within a belt 50 m wide had an equal chance of being represented in the samples.

The exact position of the secondary transect within each segment was determined using a random numbers table. If the random number was odd, the secondary transect was located to the left of the baseline. If the random number selected was even, the secondary transect was located to the right of the baseline. The length of each of the secondary transects was 25 m (Figure 2).

One 2 x 5 m plot was randomly located along each of the secondary transects (Figure 2). The 2 x 5 m plots were always located on the upslope side of the secondary transects. The plot marker pin was always located at the outside lower corner of the plot when viewed from downslope to upslope. The downslope five meter side of the plot was always located along the secondary transect, perpendicular to the baseline, and generally along the contour of the slope.

Five 0.5 x 0.5 m plots were systematically nested within each of the 2 x 5 m plots (Figure 2). A circular plot (r = 10 m) was established with a centre point at the plot marker pin.

4.2 Vegetation Analysis

The percent cover by species of subordinate vegetation (grasses, sedges, forbs, mosses, liverworts, lichens, and dwarf shrubs) and tree seedlings less than [illegible]0 cm in height was estimated to the nearest 1% in each of the five 0.5 x 0.5 m plots nested within each 2 x 5 m plot. The five intermediate percent cover values for each species were then averaged to obtain a percent cover value by species for each 2 x 5 m plot.

Vascular and non-vascular plant species recorded in plots in the four study areas were collected for verification of field identifications. Nomenclature follows Moss (1959) for vascular plants, Hale and Culberson (1970) for lichens, Ireland et al. (1980) for mosses, and Stotler and Crandall-Stotler (1977) for liverworts. Nomenclature for the moss *Dicranum brevifolium* (Lindb.) Lindb. follows

Peterson (1979). Voucher collections are deposited in the Department of Botany herbarium at the University of Alberta.

The foliar (crown) diameter (cm) was measured for all shrubs rooted in each 2 x 5 m plot. The foliar diameter measurements were then converted to a percent (crown) cover value for each shrub species present. Tree seedlings less than 2 m in height located in the 2 x 5 m plots were counted and assigned to one of four height classes (0 - 30 cm, 31 - 60 cm, 61 - 100 cm, 101 - 200 cm).

Stem densities (stems/ha) were recorded for standing trees and snags greater than 2 m in height in each circular plot (r = 10 m). Live trees were recorded by species but snags were not.

The percent frequency (number of plots of occurrence expressed as a percentage of the total number of plots per site) and percent mean cover of each herb, dwarf shrub, and shrub species were calculated for each burned and unburned site in the four study areas. These values were converted to Prominence Values (P.V.) using the formula P.V. = % Cover x $\sqrt{\%\ \text{Frequency}}$ (Beals 1960, La Roi 1964, Stringer and La Roi 1970, Dube 1976).

4.3 Range Utilization

4.3.1 Browse Analysis

Browsing intensity of shrubs located within each 2 x 5 m plot was measured by a percent estimate of browsed twigs (current annual growth) on two individuals of each shrub species present. The two individual shrub plants of each species were selected on the basis of their proximity to the plot marker pin. If only one individual was present within the 2 x 5 m plot, a second individual shrub plant located closest to the plot marker pin was selected from outside the plot. The estimates for browsing intensity of shrubs were not specific for bighorn sheep since it was not possible to differentiate browsing by bighorn sheep from that of other ungulate species. The data, however, provide a measure of the relative utilization of shrubs by ungulates in the burned and unburned sites of each study area.

4.3.2 Fecal Pellet Group Counts

Bighorn sheep fecal pellet groups were counted in belt transects 4 x 25 m in size (Figure 2). The belt transects were located along the length of the 25 m secondary transects and 2 m on either side. Fecal pellet groups of elk, deer and moose were also recorded when encountered.

Some difficulty was encountered in differentiating between bighorn sheep and deer pellet groups. Size and shape of individual pellets were generally used as the criteria for differentiating between the two species. Habitat type was used as the deciding factor in cases where other indicators were not conclusive.

4.4 Non-plant Ground Cover

Non-vascular plant ground surface cover (%) was estimated by cover type in each of the 0.5 x 0.5 m plots. A mean value for each 2 x 5 m plot was then calculated. The cover types recognized were; mosses, lichens, litter (conifer needles, twigs, branches, cured vascular pla material), larger diameter woody material, mineral soil, and rock.

4.5 Stand Age

Increment cores were taken from a number of the dominant live trees located adjacent to each plot location in the unburned sites to determine approximate stand ages. Coring height was approximately 30 cm on the downslope side of the bole. Increment cores were also taken from regenerating trees in the older burned sites at Ram Mountain and Cadomin Mountain to determine the year of burning. Fire-scarred cross sections were also taken from surviving trees in the above two sites to aid in determinating fire years.

The increment cores were stored in plastic drinking straws in the field and then transferred to mounting boards in the lab. They were then air dried and sanded to make the annual rings more distinct. A variable-power binocular microscope was used to obtain accurate ring counts (Stokes and Smiley 1968, Arno and Sneck 1977).

4.6 Down and Dead Woody Fuel Analysis

Estimates of down and dead woody fuel loadings on burned and unburned sites were obtained using Brown's (1974) line intersect method. A line 10 m long was randomly located in one of six predetermined directions from the plot marker pin. Fuel loadings were determined for the five roundwood diameter size class fuels (0.0 - 0.64 cm, 0.65 - 2.5 cm, 2.6 - 7.6 cm, 7.6 + cm Rotten, and 7.6 + cm Solid). All weights per unit area were calculated using Brown's (1974) proposed constants and equations. All weights are expressed in metric units (tonnes/hectare) on an oven-dry basis.

4.7 Physiographic Analysis

Measurements of percent slope and aspect were made at each plot. Percent slope was determined with a clinometer across plot centre. Aspect was determined with a hand held compass. Elevation was determined from topographic maps.

Measurements of duff and litter depths were made at each corner of the 2 x 5 m plots. An average duff and litter depth for each plot was then calculated.

4.8 Soil Analysis

Soil cores were taken at the down, mid and upslope locations along each baseline transect in each burned and unburned site. Because of poor soil development and variations in soil depth in the study areas, it was not possible to obtain cores of the same depth consistently. This often resulted in a relatively small soil sample size. Therefore, to simplify the soil analysis, composite samples were prepared. The three soils cores from each of the three slope position sampling locations in the burned sites were combined resulting in a total of three soil samples from each burned study site. Soil cores from unburned areas were first separated into organic (duff and litter) and mineral soil sections and then combined as above. This resulted in a total of six samples (three of organic and three of mineral soil) from each of the unburned study areas.

The Alberta Soil and Feed Testing Laboratory analysed the less than 2 mm fraction which included tests for available nitrogen (N) (Technicon Auto Analyser Method, Hodgins and Leitch 1977), phosphorus (P) (Technicon Auto Analyser Method, Hodgins and Leitch 1977), potassium (K) (ammonium acetate extractable method, Black 1965), soil reaction (pH), and conductivity (mhos.) (one to two soil water ratio method, McKeague 1976), and sulphur (S) (Technicon Industrial Method No. 226-72 W, modified by Alberta Soil and Feed Testing Lab). Semi-quantitative (low to high scale) estimates of sodium (Na) (Black 1965) and sulfate (SO_4) (Technicon Industrial Method No. 226-72W) were also determined. Organic matter was determined by the loss on ignition method (Ball 1964). Soil texture range (1 to 6 rating from very course-sand and loamy sand to organic) was also determined.

5. RESULTS AND DISCUSSION

5.1 Fire History and Stand Ages of Study Areas

5.1.1 Ghost River Burned Site

The fire that occurred on the Ghost River burn site was detected on August 30, 1970 and was reported controlled on September 2, 1970. The following account of the fire parameters and suppression activities is taken from the Alberta Forest Service Individual Fire Report (Form FP 48 (AFS-135), Fire No. DB7-6-70).

The final size of the fire was reported as 214.1 ha (529 acres). The area burned consisted primarily of 133.5 ha (330 acres) of unmerchantable white spruce (*Picea glauca*)/lodgepole pine (*Pinus contorta* var. *latifolia*.) forest. Other vegetation types burned included 32.4 ha (80 acres) of merchantable white spruce, 26.3 ha (65 acres) of potentially productive young growth or stunted timber and brushland, and 21.9 ha (54 acres) of untreed area above timberline. The ignition source of the fire was thought to have been an unextinguished campfire.

The peak fire period was reported as being from 1130 hr on August 30 to 1700 hr on August 31. The prevailing wind direction was from the south at an average speed of 32 km/hr on August 30 and 40 km/hr on August 31. Gusts up to 50 km/hr occurred on both days. Average forward rate of spread during the peak fire periods was 6.7 m/min (20 chains per hour) on August 30 and 3.4 m/min (10 chains per hour) on August 31. The duff moisture conditions were reported as being very dry. The fire was generally quite difficult to control because of the mountainous terrain which varied from 0-70%, and the highly variable winds which changed direction and speed frequently. These conditions were further aggravated by extremely dry fuel conditions and lack of water for suppression activities on some portions of the fire area.

Figure 3 shows the location of the burned site in the Ghost River Wilderness Area, topographic and physical features of the study area, and the locations of the baseline transects in both the burned and unburned sites. Plate 1 illustrates the general features of a portion of the burned site.

5.1.2 Ghost River Unburned Site

White spruce and lodgepole pine were both constituents of the unburned stands adjacent to the burned site. White spruce was most prevalent but generally lower in height than lodgepole pine. A total of 18 increment cores were taken from dominant and co-dominant trees adjacent to the plot locations. The 12 lodgepole pine trees sampled had a mean age of 81 years with a range of 40 to 101 years. The six white spruce trees sampled had a mean age of 61 years with a range of 41 to 80 years.

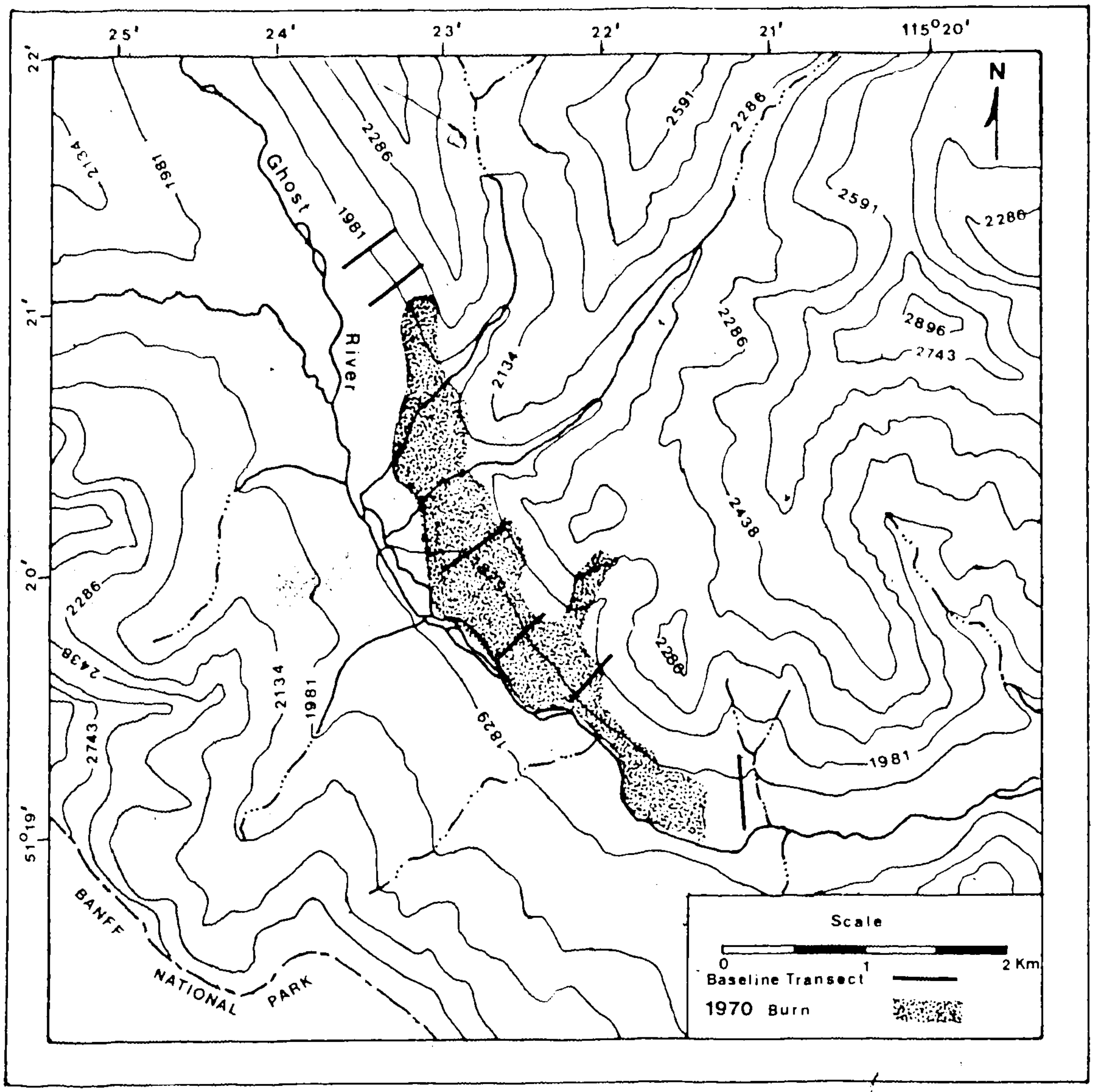

Figure 3. Location of Ghost River study area.

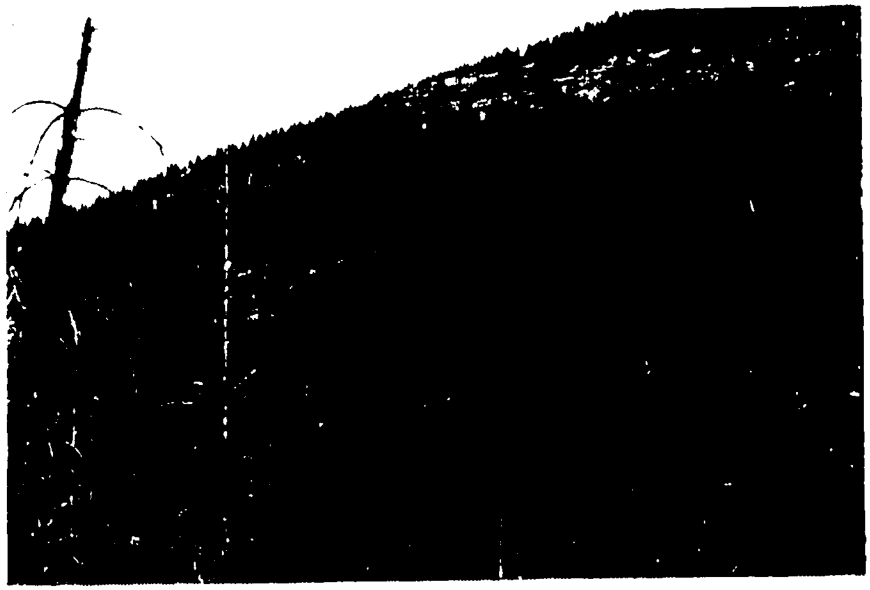

Plate 1. Ghost River burned study site (southwest aspect, photo date, June 1980).

Plate 2. Ghost River unburned study site (southwest aspect, photo date, June 1980).

The stand composition and age structure of the adjacent forested areas suggests the area may have been burned approximately 100 to 120 years ago. Since no fire-scarred trees were found, however, fire history determination was not possible. Plate 2 illustrates the vegetation cover and physical features of the unburned area sampled.

5.1.3 Rock Creek Burned Site

The fire that occurred at the Rock Creek burn site was detected on October 2, 1970 and was reported controlled on October 6, 1970. The following account of the fire parameters and suppression activities is taken from the Alberta Forest Service Individual Fire Report (Form FP 48 (AFS 135), Fire No. DE2-13-70).

The final size of the fire was reported as 169.5 ha (419 acres). The area burned consisted of 105.2 ha (260 acres) of merchantable white spruce/lodgepole pine forest. 21.0 ha (52 acres) of potentially productive young growth or stunted timber and brushland, and 43.3 ha (107 acres) of untreed area above treeline. The ignition source was an unextinguished campfire left by outfitters.

The peak fire period was reported as being from 1200 hr on October 3 to 0600 hr on October 4. The initial action crew arrived on the site at 1120 hr on October 3. At that time the fire was approximately 3.2 ha in size. Direct action was taken on the southern edge of the fire. Wind speed was approximately 16 km/hr from the north. At approximately 1200 hr the wind switched to the south-southwest at speeds of about 64 to 80 km/hr. The fire spread up the mountain side to the north and northeast. The high winds persisted until 1600 hr and then decreased. A moderate south wind persisted until 0600 hr on October 4 when light snow showers in the area essentially extinguished the fire.

The maximum and average forward rates of spread on October 3 were 3.4 m/min (10 chains per hour) and 26.8 m/min (80 chains per hour), respectively. The duff moisture conditions were reported as being very dry. The Buildup Index (BUI) and Spread Index (SI) measured at Moberly Lookout, 42 km east of the fire site, were 56 and 52, respectively.

Figure 4 shows the location of the burned site, topographic and physical features of the study area, and the locations of the baseline transects in both the burned and unburned sites. Plate 3 illustrates the general features of a portion of the burned site.

5.1.4 Rock Creek Unburned Site

A total of 28 increment cores were taken from dominant and co-dominant trees in the adjacent unburned forest at Rock Creek. White spruce was most prevalent in the unburned stands. Lodgepole pine were present at lower elevations but were lower in density than spruce. The mean age of 20 white spruce trees sampled was 170 years with a range of 91 to 279

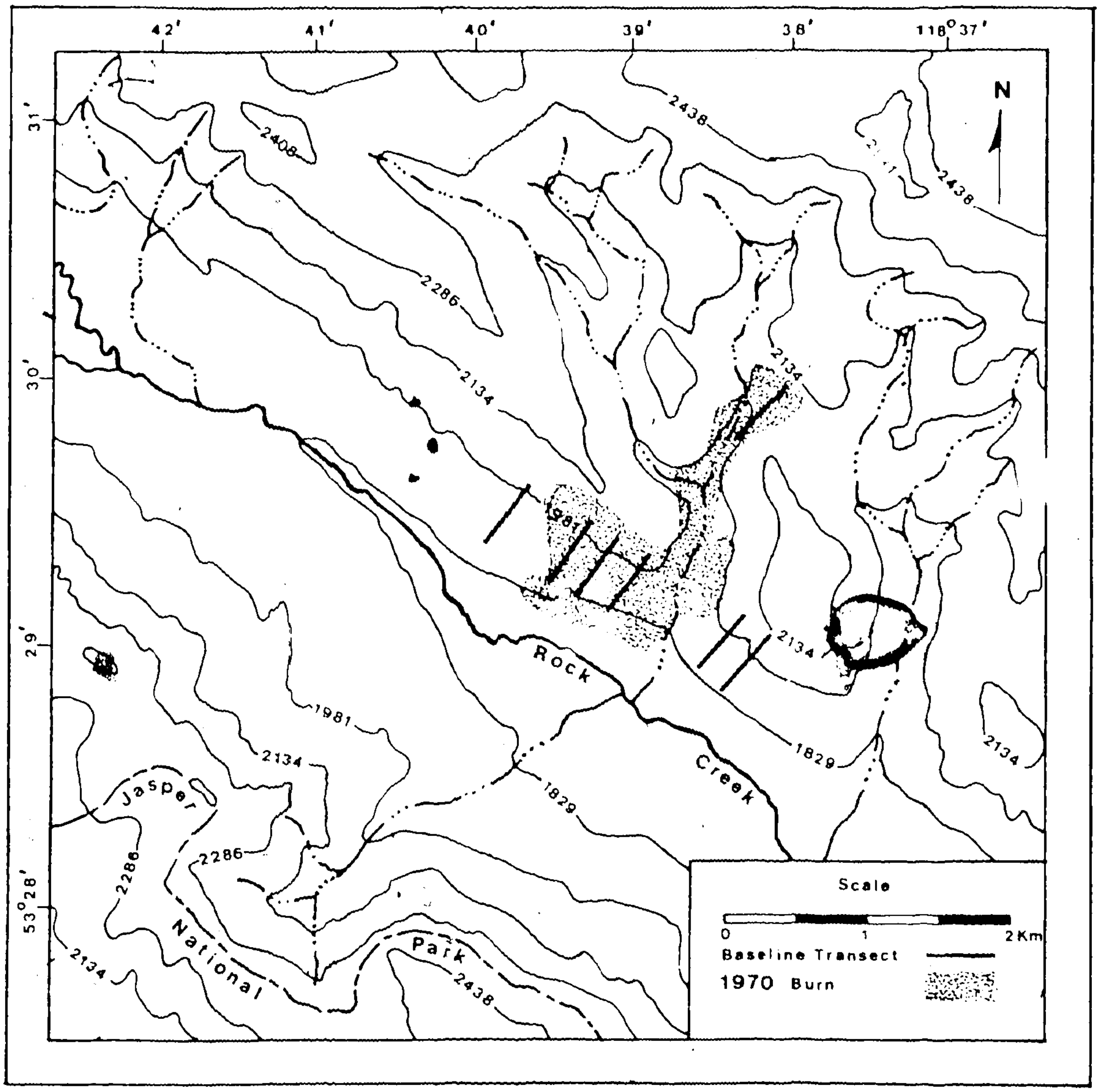

Figure 4. Location of Rock Creek study area.

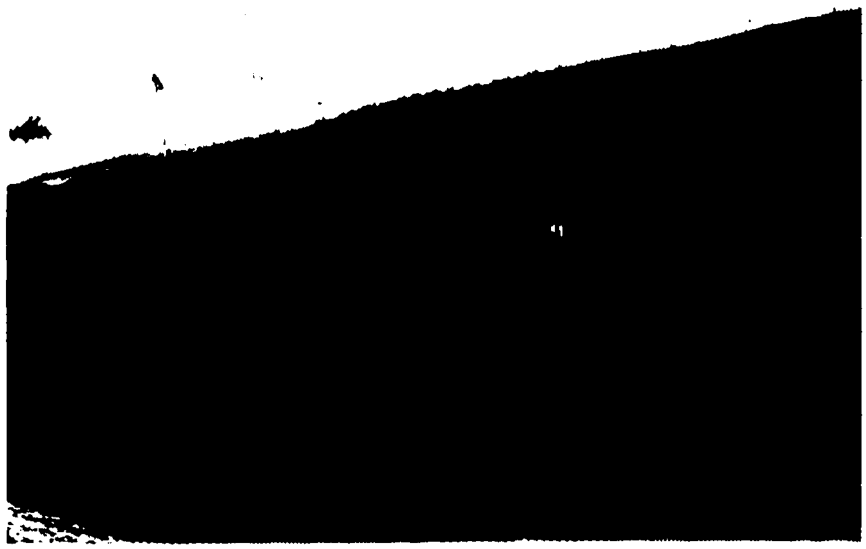

Plate 3. Rock Creek burned study site. (southwest aspect, photo date, July 1980).

Plate 4. Rock Creek unburned study site. (southwest aspect, photo date, July 1980).

years. The mean age of eight lodgepole pine trees sampled was 143 years with a range of 78 to 207 years. No direct evidence was found to indicate that the unburned stands were of fire origin. Any major fire in these stands would have occurred at least 300 years ago. Plate 4 illustrates the vegetation cover and physical features [illegible] e unburned area sampled.

5.1.5 Ram Mountain Burned Site

There are a number of areas on Ram Mountain that show evidence of past fires (Hoffman 1971, Johnson 1975). In most cases it appears these fires started at lower elevations and burned upslope to treeline. The specific burned site studied on Ram Mountain is located in the upper reaches of a small valley drained by a tributary of Rough Creek (Figure 5). The fire extended over several hundred hectares at lower elevations in the Rough Creek drainage area and on slopes to the east and west of the study site. Dense stands of lodgepole pine are present at lower elevations. At higher elevations, such as the area of the study site, the density of lodgepole pine is reduced, producing a semi-open herb/shrub plant community.

Increment cores were taken from 37 lodgepole pine trees in the burned site to determine the year of burning. Figure 6 shows the age frequency distribution of the sampled trees. The maximum age recorded was 55 years for seven of the trees. The mean age of the sampled trees was 48 years with a

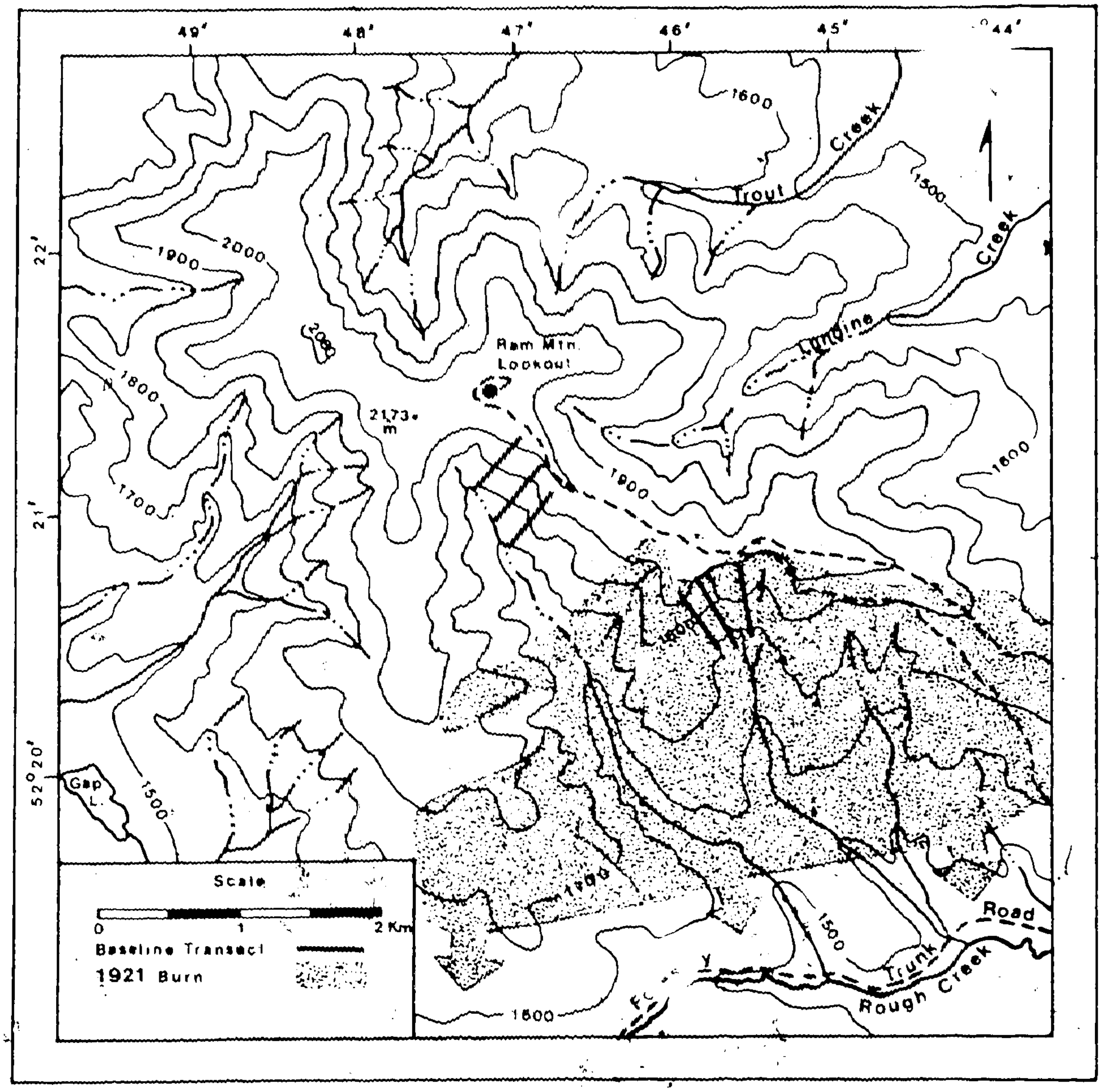

Figure 5. Location of Ram Mountain study area.

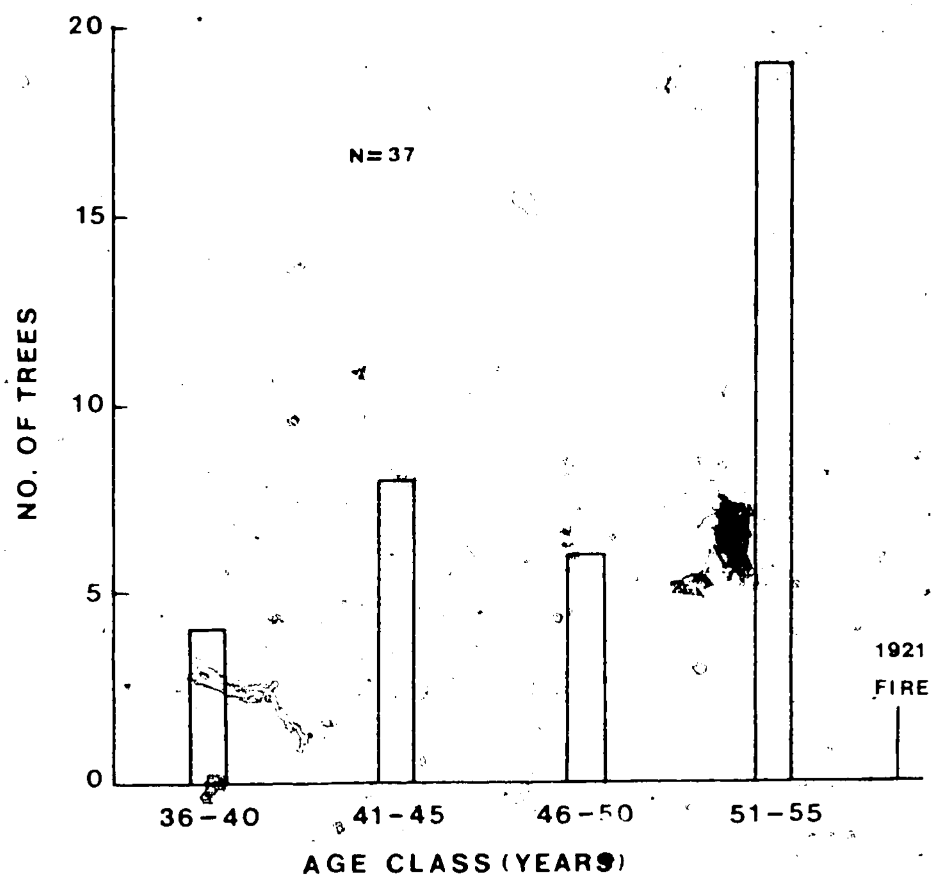

Figure 6. Age class distribution of lodgepole pine trees sampled in the Ram Mountain burned study site.

range of 36 to 55 years. Tande (1977) calculated a mean age-correction factor for lodgepole pine in Jasper National Park of 4 (±2) years to reach a coring height of 30 cm. Applying this correction factor to the maximum tree age recorded of 55 years gives a fire date of 1921 (± 2 years). No fire records are available to confirm this fire date so it is given only as the probable year of the fire. For the purpose of this study the degree of accuracy is considered sufficient given the proposed objectives. Plate 5 illustrates the vegetation cover and physical features of the Ram Mountain burned site.

5.1.6 <u>Ram Mountain Unburned Site</u>

The unburned study site at Ram Mountain is located in the upper reaches of the valley drained by the headwaters of Rough Creek (Figure 5). Increment cores were taken from 11 white spruce trees and one subalpine fir (<u>Abies lasiocarpa</u>). The mean age of the white spruce trees sampled was 256 years with a range of 168 to 299 years. The age of the subalpine fir tree sampled was 156 years. The site had not been burned for at least 300 years and no evidence was found to indicate the stand was of fire origin.

Fire scar cross sections were taken from two remnant lodgepole pine trees located in the same valley but on the opposite slope and to the south of the unburned study site. Aging of the fire scars showed that a fire had burned in that part of the valley in 1826. It was not possible,

Plate 5. Ram Mountain burned study site. (south-southwest aspect, photo date, Aug. 1980).

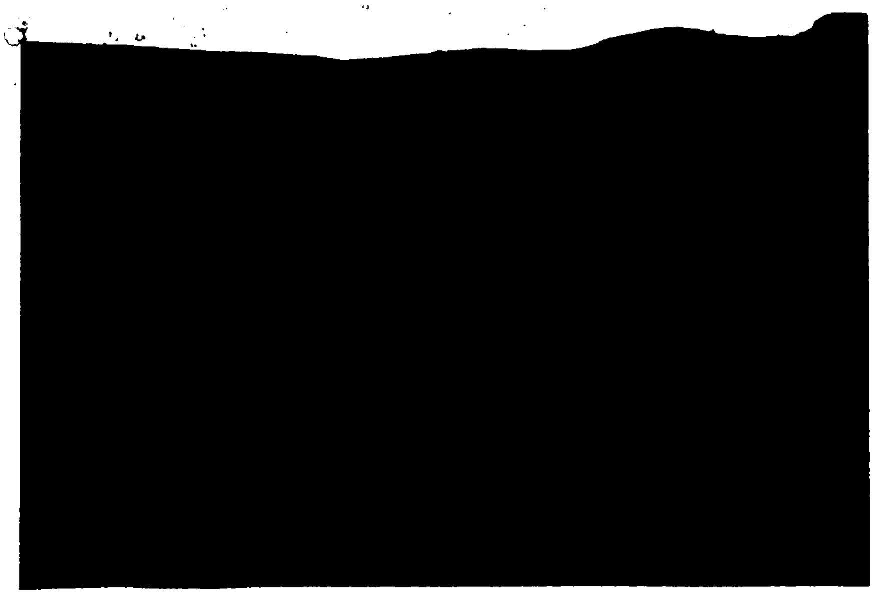

Plate 6. Ram Mountain unburned study site. (south-southwest aspect, photo date, Aug. 1980).

however, to document the extent of the fire because other fire-scar evidence, if present, had been destroyed by the 192' fire described earlier. The ages of the two lodgepole pi... trees were 411 and 422 years (confirmed by the fire ...earch staff at the Northern Forest Research Centre, ...monton, Alberta).

Plate 6 illustrates the vegetation cover and physical features of the Ram Mountain unburned study site.

5.1.7 Cadomin Mountain Burned Site

The burned study site at Cadomin Mountain is located in the upper reaches of a valley drained by an unnamed tributary of the McLeod River (Figure 7). The fire that burned on the study site extended over several hundred hectares in the valley and on slopes to the east and west of the study site. Lodgepole pine is the dominant tree species present in the burned site but white spruce occur sporadically at higher elevations. The density of lodgepole pine is quite variable depending on slope exposure and elevation.

Increment cores were taken from a total of 25 trees (21 lodgepole pine and 4 white spruce) in the study site to determine the year of the fire. Figure 8 shows the age frequency distribution of the lodgepole pine trees sampled. The maximum tree age recorded was 59 years. A cross section was also taken from a remnant fire-scarred lodgepole pine adjacent to the study site. Aging of the fire scar showed a

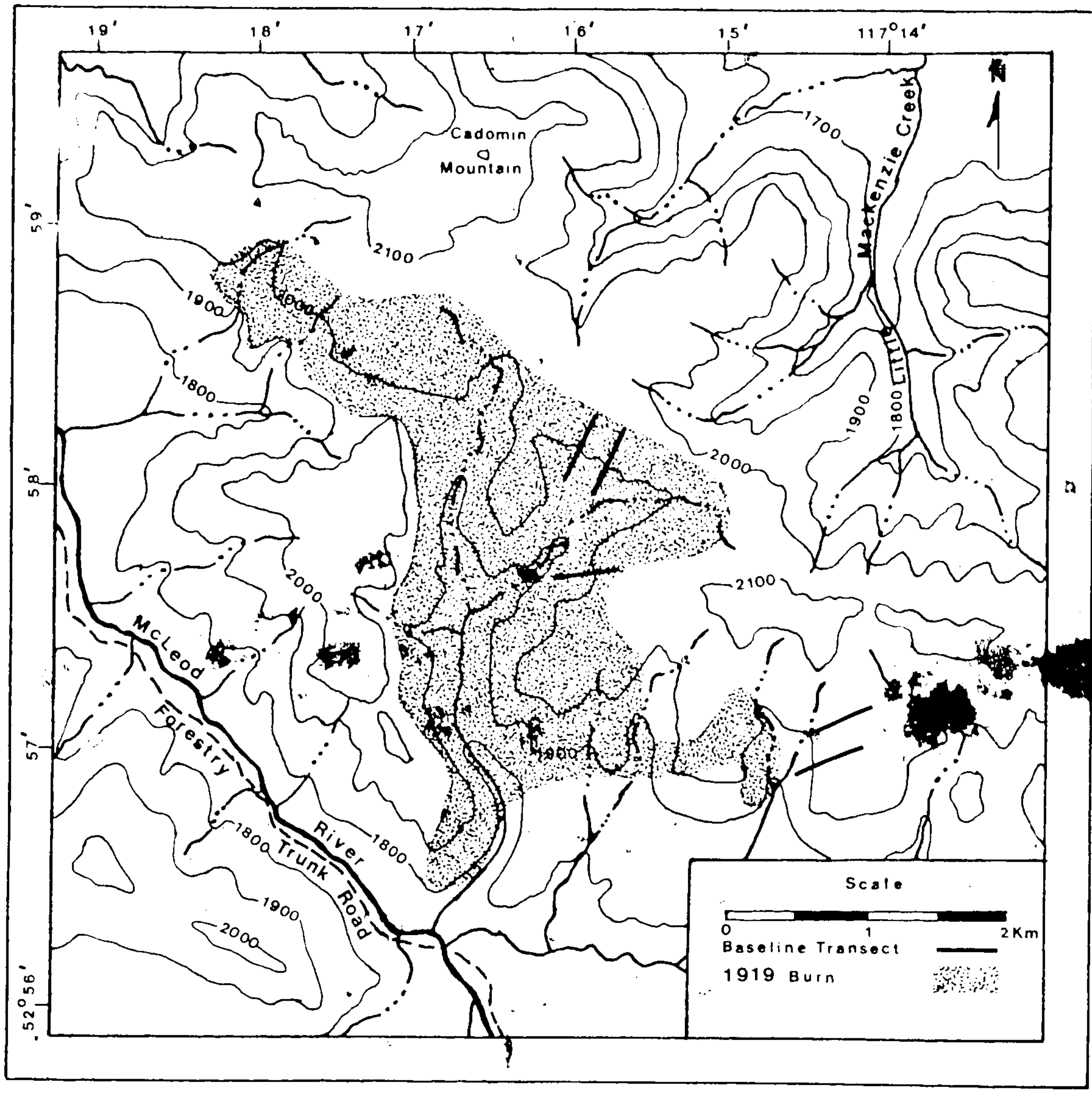

Figure 7. Location of Cadomin Mountain study area.

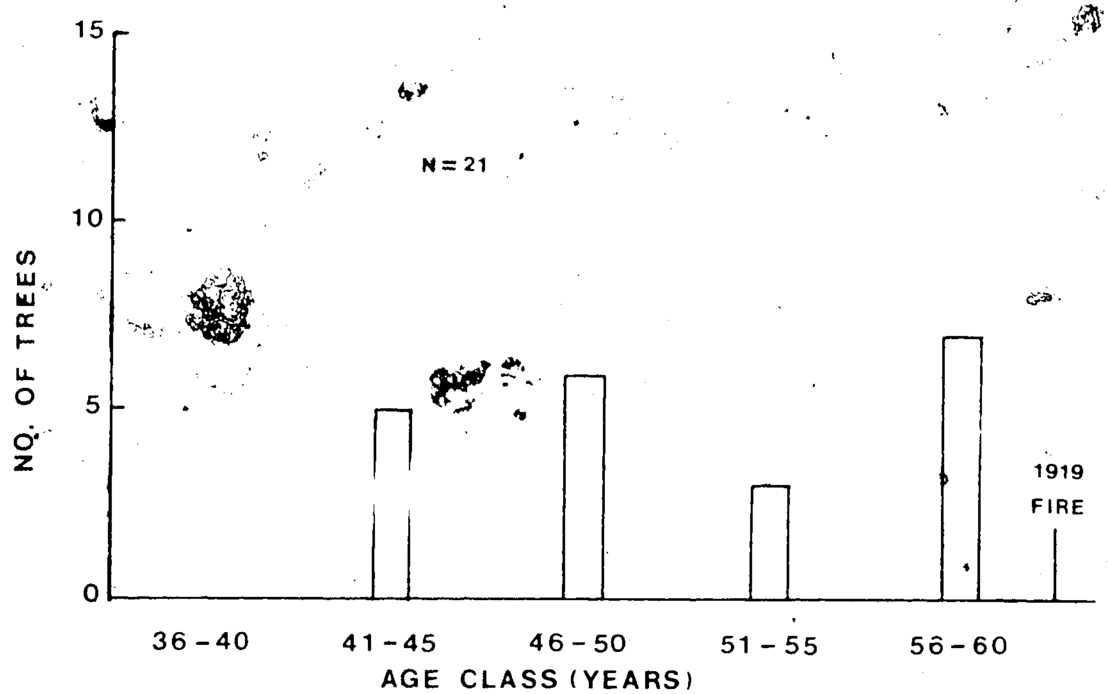

Figure 8. Age class distribution of lodgepole pine trees sampled in the Cadomin Mountain burned study site

fire date of 1919, 61 years ago. The mean age of the 21 lodgepole pine trees sampled was 51 years, with a range of 42 to 59 years. The mean age of the four white spruce trees sampled was 40 years, with range of 26 to 46 years.

Fire records were not available to confirm the fire date of 1919. However, the maximum tree age recorded, 59 years, falls within the limits that Tande (1977) used as an age-correction factor (4 ±2 years) for lodgepole pine in Jasper. Plate 7 illustrates the vegetation cover and topographic features of a portion of the Cadomin Mountain burned site.

5.1.8 Cadomin Mountain Unburned Site

The unburned study site at Cadomin Mountain is located in the upper reaches of a small valley to the southeast of the burned site (Figure 7). Increment cores were taken from eight white spruce and four lodgepole pine trees. The mean age of the white spruce trees sampled was 129 years, with a range of 103 to 151 years. The mean age of the lodgepole pine trees sampled was 165 years, with a range of 150 to 192 years. No fire-scarred trees were found on the unburned study site, but it is possible the stand was of fire origin. This conclusion is based on the fairly high density of lodgepole pine present. Plate 8 illustrates the vegetation cover and topographic features of the unburned study site at Cadomin Mountain.

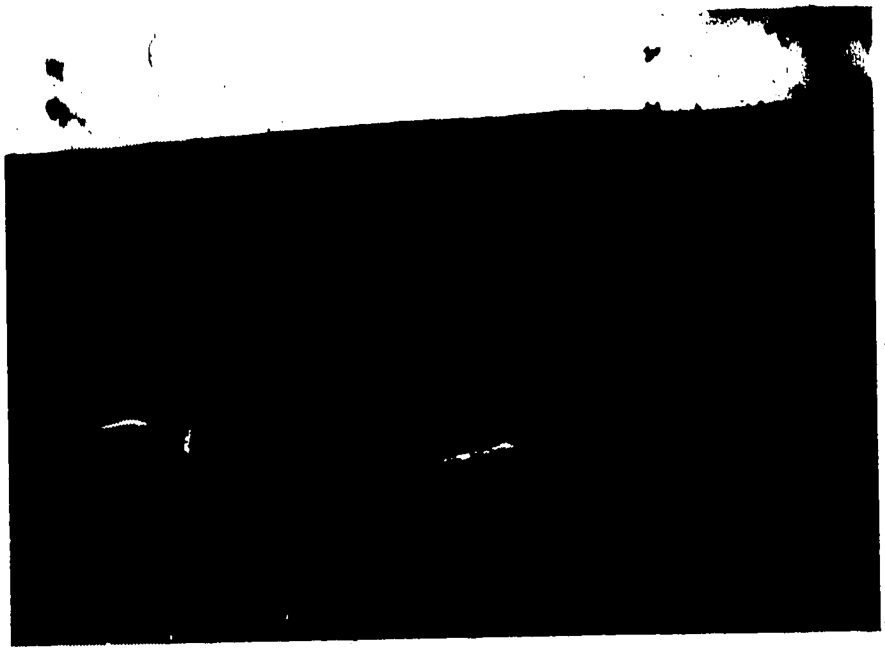

Plate 7. Cadomin Mountain burned study site.
(south-southwest aspect, photo date, Aug. 1980).

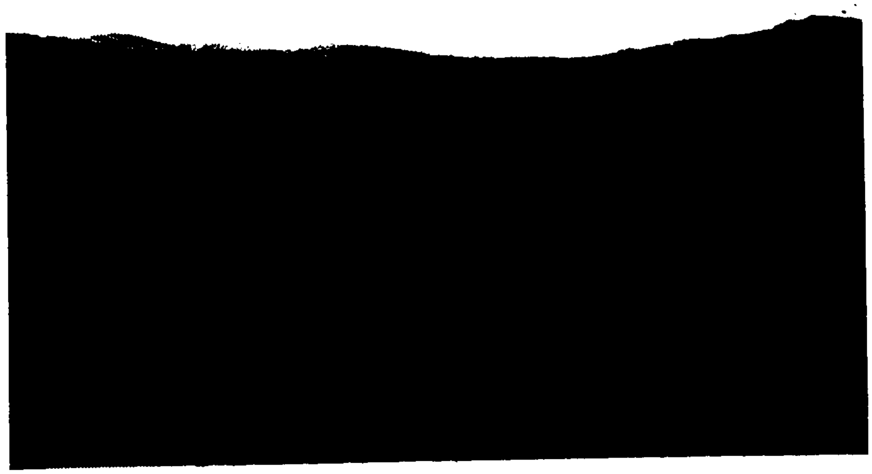

Plate 8. Cadomin Mountain unburned study site.
(west-southwest aspect, photo date, Aug. 1980).

5.2 Vegetation Analysis

5.2.1 Tree and Snag Stem Densities

The numbers of live trees (greater than two meters in height) and standing snags were recorded in fixed area (r = 10 m) circular plots with a centre point at the plot marker pin. The number of trees and/or snags in each plot was then converted to a stems/ha value, and a mean stem density value was calculated for each burned and unburned site (Table 3). The tree species composition (%) for each site is presented in Table 4.

Standing snag density was still relatively high in the 10 year old burn sites at Ghost River and Rock Creek (966 and 981 stems/ha, respectively). At Ram Mountain and Cadomin Mountain, however, most of the snags had fallen over and were in various stages of decomposition on the ground.

White spruce was the most prevalent tree species in the unburned sites of the four study areas. Lodgepole pine was less abundant, with a percent composition of approximately 40% in all the unburned sites except the Ram Mountain site, where only white spruce (98.3%) and subalpine fir (1.7%) were present.

Figure 9 shows the relationship between tree and snag densities in the study sites and the distance downslope from treeline. The individual plotted values represent the mean of all stem density values recorded for plots located within each 100 m distance interval. Mean tree stem densities were

Table 3. Mean tree and snag stem densities (stems/ha) and standard deviations (in parentheses) for burned and unburned sites in the four study areas.

	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		CADOMIN MOUNTAIN	
	BURNED SITE (*n* = 15)	UNBURNED SITE (*n* = 15)	BURNED SITE (*n* = 20)	UNBURNED SITE (*n* = 15)	BURNED SITE (*n* = 15)	UNBURNED SITE (*n* = 15)	BURNED SITE (*n* = 15)	UNBURNED SITE (*n* = 10)
TREE DENSITY (stems/ha)	-- --	968 (± 536)	-- --	314 (± 265)	1157 (± 1556)	1010 (± 505)	463 (± 600)	1092 (± 547)
SNAG DENSITY (stems/ha)	966 (± 896)	-- --	981 (± 1892)	-- --	23 (± 28)	144 (± 86)	212 (± 146)	73 (± 81)

Table 4. Tree species composition (%) in the burned and unburned sites of the four study areas.[1]

SPECIES	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		CADOMIN MOUNTAIN	
	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE
White spruce	--	61.2	--	61.1	11.4	98.3	2.7	51.3
Lodgepole pine	--	38.2	--	38.9	88.6	--	97.3	41.7
Subalpine fir	--	--	--	[illegible]	--	1.7	--	7.0
Trembling aspen	--	0.6	--	[illegible]	--	--	--	--

1 - Ghost River - 1970 burn, maximum recorded tree age in unburned site was 101 years

Rock Creek - 1970 burn, maximum recorded tree age in unburned site was 279 years

Ram Mountain - 1921 burn, maximum recorded tree age in unburned site was 299 years

Cadomin Mountain - 1919 burn, maximum recorded tree age in unburned site was 192 years

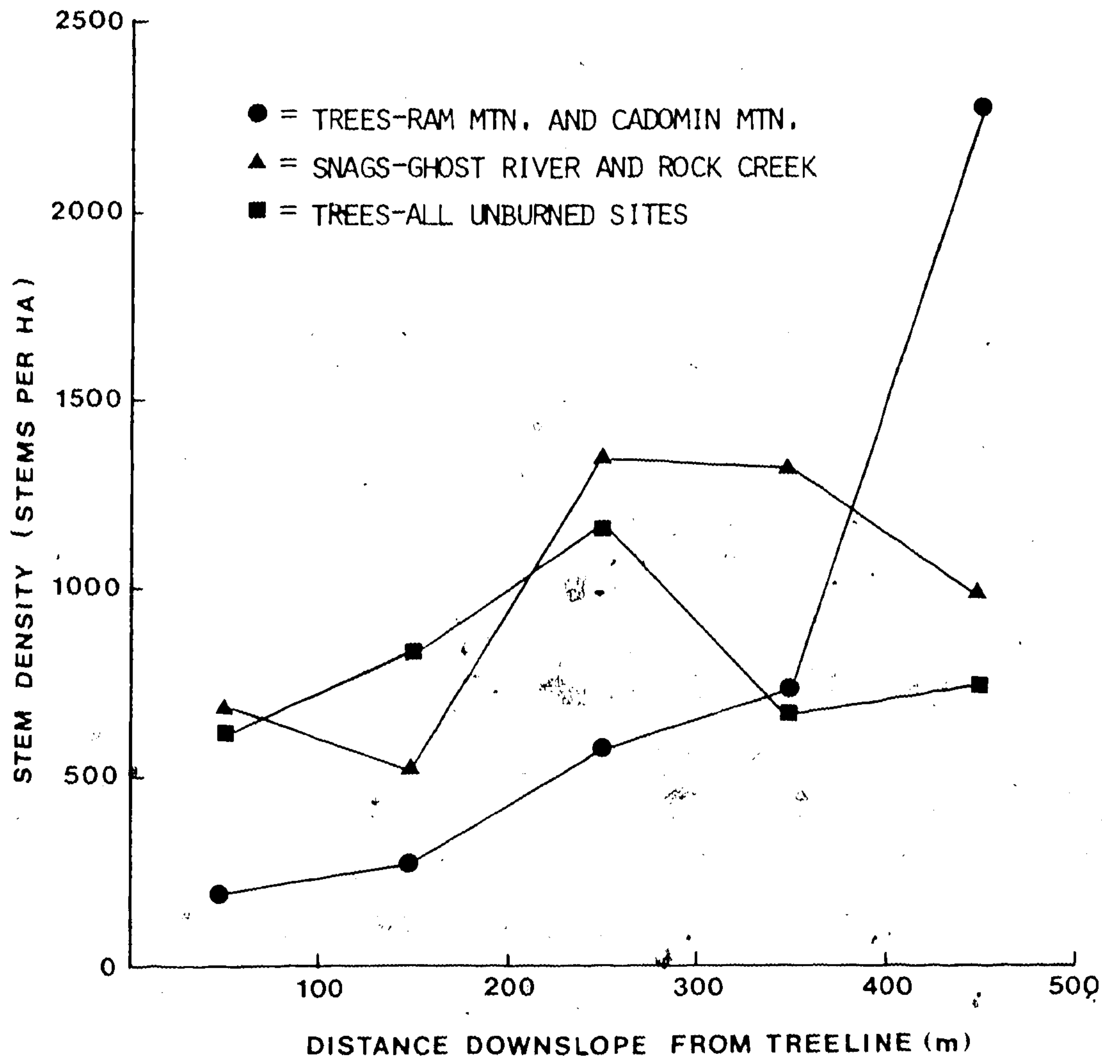

Figure 9. Tree and snag densities (stems/ha) in relation to distance downslope (meters) from treeline. Plotted values represent mean stem densities for all plots located within each 100 meter distance interval, shown at the midpoint of the interval.

highest in the midslope (200-300 m) locations of the unburned study sites. This was also the case for standing snag densities in the 10-year-old burn sites at Ghost River and Rock Creek. Mean tree stem densities in the burned sites at Ram Mountain and Cadomin Mountain were lowest in areas closest to treeline and increased as the distance downslope from tree line increased. This has important implications in terms of bighorn sheep site utilization, as will be shown in later sections.

5.2.2 Conifer Seedling Densities

The numbers of conifer tree seedlings (by species and height class) less than two meters in height were recorded in each 2 x 5 m plot. These values were then converted to per hectare values, and mean seedling densities (by height class) were calculated for each burned and unburned site (Table 5). Table 6 shows the species distribution (%) of conifer seedlings in each study site.

Seedling recruitment was very low in the burned site at Rock Creek as compared to that in the burned site at Ghost River. This is very interesting since the unburned sites in both areas had very similar tree species compositions, approximately 40% of which consisted of lodgepole pine. The low regeneration success of lodgepole pine in the Rock Creek burned site is difficult to interpret based on the information available at the time of sampling. Serotinous cones in the crowns of fire-killed lodgepole pine are

Table 5. Mean conifer seedling densities (No./ha) by height class in burned and unburned sites of the four study areas.

HEIGHT CLASS	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		CADOMIN MOUNTAIN	
	BURNED SITE (n = 15)	UNBURNED SITE (n = 15)	BURNED SITE (n = 20)	UNBURNED SITE (n = 15)	BURNED SITE (n = 15)	UNBURNED SITE (n = 15)	BURNED SITE (n = 15)	UNBURNED SITE (n = 10)
0 - 30 cm	867	800	--	1200	733	1400	1667	9700
31 - 60 cm	1800	333	100	133	67	400	333	--
61 - 100 cm	800	133	--	67	67	867	--	--
101 - 200 cm	--	67	--	67	267	333	67	300
TOTAL	3467	1333	100	1467	1134	3000	2067	10000

Table 6. Percent composition by species of conifer seedlings in the burned and unburned sites of the four study areas.[1]

SPECIES	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		CADOMIN MOUNTAIN	
	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE
White spruce	9.6	40.0	--	68.2	41.2	53.3	25.8	16.0
Lodgepole pine	90.4	55.0	100.0	27.3	58.8	--	74.2	[illegible]
Subalpine fir	--	5.0	--	4.5	--	46.7	--	[illegible]

1 - Ghost River - 1970 burn, maximum recorded tree age in unburned site was 101 years

Rock Creek - 1970 burn, maximum recorded tree age in unburned site was 279 years

Ram Mountain - 1921 burn, maximum recorded tree age in unburned site was 239 years

Cadomin Mountain - 1919 burn, maximum recorded tree age in unburned site was 192 years generally considered to provide the primary on-site seed source for conifer regeneration subsequent to fire (Clements 1910, Horton 1956, Lotan 1973). Cone serotiny, although a fairly common characteristic of lodgepole pine in the Rocky Mountains, has been shown to vary with stand age, previous fire history of individual stands, and geographic location (Brown 1973, Lotan 1973). One explanat[illegible] therefore be related to the possible lack of seed be[illegible] otinous cones and subsequent loss of seeds in the lodgepole pine present on the site prior to burning. Other factors known to adversely affect lodgepole pine seedling germination and establishment following fire include: depth and chemical content of the ash (Woodard 1977), high surface temperatures and desiccation as a result of increased solar radiation on the blackened soil (Crossley 1956), fungus and other pathogen infections (Baranyary and Stevenson 1964), adverse weather conditions at the time of seedling emergence, and competition from other plant species (Clements 1910). Browsing by ungulates and rodents has also been shown to affect the density and vigor of conifer seedlings (Baranyary and Stevenson 1964).

Spruce and fir regeneration following fire is usually dependent on a residual on-site seed source (surviving trees or unburned seedbeds) or on seed dispersed from adjacent unburned stands (Alexander 1958, Horton 1959). Spruce seedlings accounted for 9.6% (Table 6) of the total seedling population on the burned site at Ghost River, but no spruce seedlings were recorded on the burned site at Rock Creek. In most cases the spruce seedlings were located in upslope areas at Ghost River and likely originated from seed dispersed from surviving trees at treeline. Spruce seedlings were more abundant in the older burn sites at Ram Mountain an tomin Mountain, primarily in the upslope areas of the sites. Subalpine fir seedlings were not found in any of the burned sites but were present in all of the unburned sites sampled (Table 6). Subalpine fir regeneration is characteristic of older spruce-fir stands in the Rocky Mountains, where shading and relatively high duff and litter accumulations create unsuitable seedbed conditions for spruce and lodgepole pine seedling establishment (Alexander 1958).

Figure 10 illustrates the relationship between conifer seedling density and the distance downslope from treeline in the burned sites of the four study areas. Individual plotted values represent the mean seedling density for all plots located within each 100 meter distance interval (shown at the midpoint of each interval). The results show that seedling densities were generally highest in the mid to lower slope positions in all the study sites. Dube (1976) found that the numbers of pine seedlings decreased with increasing elevation and slope steepness in the Vermilion Pass burn in Kootenay National Park. Horton (1953) also found that the steepest slopes were least stocked with pine seedlings in high elevation areas in Alberta. The decrease

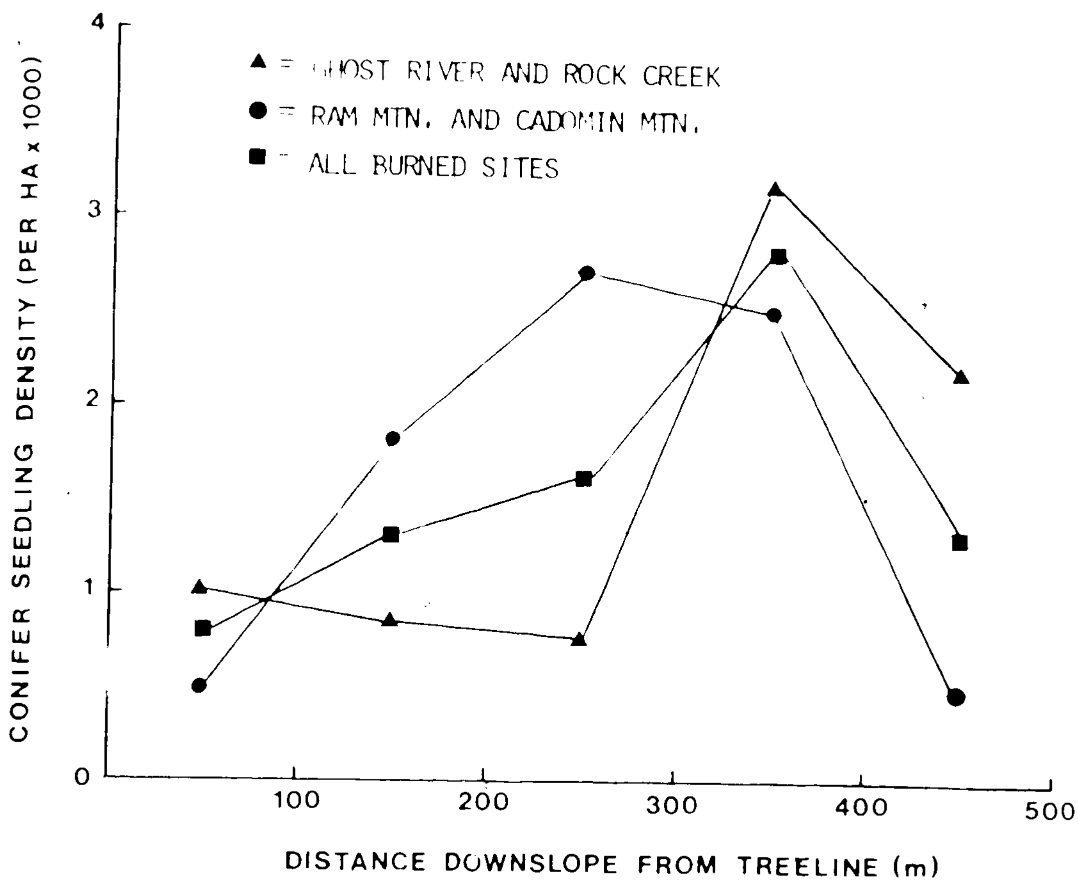

Figure 10. Conifer seedling density in burned study sites in relation to distance downslope from treeline. Plotted values represent the mean seedling density for all plots located within each 100 meter distance interval, shown at the midpoint of each interval.

in seedling density with increase in elevation and slope angle was attributed by Dube (1976) to elevationally correlated temperature and moisture gradients unfavorable to pine establishment and growth. A reduction in the available seed source, or unsuitable seedbed conditions, may also have been in part responsible for the apparent unsuccessful regeneration of the upslope areas by tree seedlings.

A reduction in seedling and tree densities, particularly in upslope areas, is very beneficial in terms of bighorn sheep range improvement. As discussed previously, bighorn sheep generally tend to avoid areas with high tree cover. Low seedling recruitment on burned sites could, therefore, potentially result in more favourable long-term range conditions.

5.2.3 Species Diversity of the Vascular Flora

A total of 135 vascular plant species were identified in sample plots in the burned and unburned sites of the four study areas. No attempt was made to identify and record the entire vascular flora in the study areas. The plant species recorded in sample plots, however, were found to be very representative of the vascular flora observed in the immediate vicinity of the study areas.

It should be noted that the differences in species numbers between burned and unburned sites reported here were not based on pre- and post-burn samples. It is assumed that species richness in the burned sites would have been similar to that in the adjacent unburned sites if the sites had not been disturbed by fire.

Table 7 shows the numbers of vascular plant species recorded in each of the burned and unburned sites of the four study areas. The results indicate that the burned sites in all of the study areas, except Ghost River, had a greater number of species than the adjacent unburned sites. The differences in species numbers are greatest in the two study areas with older burned sites, Ram Mountain and Cadomin Mountain; 59 and 61 years since disturbance, respectively. The burned site in the Rock Creek study area showed a net increase of seven plant species. This net increase consisted of increases of eight graminoid species and three forb species, and decreases of three tree species and one shrub species. In the Ram Mountain study area there was a net increase of ten vascular plant species in the burned site, consisting of five shrubs, two dwarf shrubs, and three forb species. The Cadomin Mountain study area had a net increase of 26 plant species in the burned site. This total consisted of increases of three shrubs, one dwarf shrub, eight graminoid species, and 15 forb species.

Sorensen's (1948) index of Similarity was used to illustrate the similarity in plant species composition between the burned and unburned sites in each study area (Table 7). The number of plant species common to both study sites in the Ghost River, Rock Creek, Ram Mountain and Cadomin Mountain study areas was 29, 37, 36, and 26,

Table 7. Numbers of vascular plant species recorded in sample plots in the burned and unburned sites of the four study areas

	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		[illegible] MOUNTAIN	
	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE	BURNED SITE	UNBURNED SITE
Trees	2	1		3	[illegible]	[illegible]	[illegible]	3
Shrubs[2]	7	7	5	6	[illegible]	4	[illegible]	2
Dwarf Shrubs	3	3	5	5	5	3	[illegible]	8
Graminoids	4	4	13	5	[illegible]	[illegible]	[illegible]	4
Forbs	22	23	38	35	31	28	32	[illegible]
TOTAL	38	38	61	54	51	44	[illegible]	34
Index of Similarity (IS)[3]	76		[illegible]		73		55	

1 Conifer seedlings less than 30 cm in height

2 Includes suckers of <u>Populus</u> <u>balsamifera</u> and <u>P.</u> <u>tremuloides</u> less than 2 m in height

3 $IS = \frac{2C}{A + B} \times 100$

where C = number of species common to both sites
A = total number of species in burned site
B = total number of species in unburned site
IS = Sorensen's (1948) Index of Similarity (Community Coefficient)

respectively. The Ghost River study area showed the highest floristic similarity between the burned and unburned sites (IS=76). The unburned study site at Ghost River also had the lowest recorded maximum tree age (101 years) of the four study areas. However, the Cadomin Mountain study area had the lowest index of similarity value (IS=55) even though the maximum recorded tree age of the unburned site was 192 years, considerably lower than the tree ages recorded in the unburned study sites at Rock Creek and Ram Mountain (279 and 290 years, respectively). Stand age, therefore, did not appear to significantly influence similarity index values in the areas studied. Of special note, is the pattern of relatively high similarity index values in all the study areas. This suggests that the plant species composition in subalpine areas is relatively stable even after disturbance by fire.

Increases in species diversity following fire in subalpine areas have been reported in a number of studies. Dube (1976) found that four years after the Vermilion Pass fire in Kootenay National Park, nearly twice as many species were present in the burned forest as in the surrounding unburned forest. This was attributed to the invasion of a large number of herbaceous species, coupled with a large number of resprouting woody residual plants. Dyrness (1973) reported a 50% increase (48 to 72) in the numbers of vascular plant species six years after logging and slash burning in a Douglas fir forest in the western Cascade

Mountains of Oregon. Invading herbaceous species provided a majority of the cover two to four years after burning, but residual species regained dominance by the fifth year.

The results of this study indicate that residual species accounted for the majority of the plant species present in the burned sites. However, additional species not present in the unburned sites were consistently higher in number in the burned sites. In terms of species richness, therefore, the burned sites were superior to the unburned sites. Although species richness cannot be directly related to forage quantity or quality, the potential for increases in forage availability is enhanced as a result of greater numbers of plant species being present on the burned sites.

5.2.4 General Vegetation Response

The mean percent cover of each of the major plant cover types in each burned and unburned site of the four study areas is presented in Table 8. The cover values represent the total mean cover for each particular cover type over all the sample plots in each site. A Student's t-test was used to test for significant differences between mean cover values ($p < .05$) in the burned and unburned site of each study area.

There were no significant differences between mean percent cover of the major cover types in the burned and unburned sites of the Ghost River study area. Both graminoid and shrub mean cover were higher in the burned site (7.5%

Table 8. Percent mean [illegible] and standard deviation (in parentheses) [illegible] burned and unburned sites of the [illegible] areas

COVER TYPE	GHOST RIVER		[illegible] CREEK		RAM M[illegible]		[illegible] M[illegible]	
	BURNED SITE (n = 15)	UNBURNED SITE (n = 15)	BURNED SITE (n [illegible])	UNBURNED [illegible] (n = 15)	BURNED SITE (n [illegible])	UNBURNED SITE [illegible]	BURNED SITE [illegible]	UNBURNED SITE [illegible]
Graminoids	[illegible]a (± [illegible])	6.4a (± [illegible])	[illegible]	6.[illegible] (± 4.[illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Forbs and dwarf shrubs	[illegible] (± 8.3)	[illegible]a (± 1[illegible].5)	[illegible]	[illegible]a (± [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Shrubs	[illegible]a (± 8.[illegible])	6.4a (± 5.2)	[illegible]	8.2a (± 6.7)	[illegible]	[illegible]	[illegible]	[illegible]
Bryoids	[illegible]a (± 17.4)	14.[illegible]a (± 16.5)	[illegible]	[illegible]8a (± [illegible])	[illegible]	[illegible]	[illegible]	[illegible]
Non-plant	[illegible]a (± [illegible])	58.[illegible]a (± [illegible])	[illegible]	49.[illegible]a (± 13.[illegible])	[illegible]	[illegible]	[illegible]	[illegible]

a,b Mean values for burned and unburned sites [illegible] individual study areas [illegible] letters are [illegible] different at the [illegible] vs. 6.4%) and 7.7% vs. 4.4%) at Ghost River. Forb-dwarf shrub cover was higher in the unburned site (19.0% vs. 12.8%). Non-plant cover (litter, rotten wood, bare mineral soil, and rock) accounted for 62.7% and 58.9% of the ground cover in the burned and unburned sites, respectively.

In the Rock Creek study area, graminoid cover was significantly higher in the burned site ([illegible].4% vs. 6.7%). Forb-dwarf shrub cover and non-plant cover were also higher in the burned site but the differences were not significant. Both shrub and bryoid cover were higher in the unburned site at Rock Creek (8.2% vs. 2.[illegible]% and 17.8% vs. 10.9%) but again, the differences were not found to be significant.

In the Ram Mountain study area, both forb-dwarf shrub cover and tall shrub cover were significantly higher in the burned site (23.7% vs. 7.3% and 9.8% vs. 3.6%). Graminoid cover was also higher in the burned site (7.9% vs. 6.5%) but the difference was not significant. Bryoid cover was significantly higher in the unburned site (11.5% vs. 2.3%). There was no significant difference in non-plant cover between the two Ram Mountain study sites.

In the Cadomin Mountain study area, shrub cover was significantly higher in the burned site (2.6% vs. 0.8%). Both graminoid and forb-dwarf shrub cover were also higher in the burned site (3.7% vs. 2.7% and 27.6% vs. 19.0%) but the differences were not significant. Bryoid cover was significantly higher in the unburned site but a significant difference in non-plant cover was not found between the two

Cadomin Mountain study sites.

On the basis of the above data, a number of general trends were evident. Total mean graminoid cover tended to be higher in all of the burned sites of the four study areas. Forb dwarf shrub cover was higher in the burned sites of all the study areas except Ghost River. Shrub cover was higher in the burned sites of all the study areas except Rock Creek. Bryoid cover tended to be higher in unburned sites. Non plant cover was generally high in all study sites but tended to be somewhat higher in the burned sites.

Higher cover of graminoids, forb dwarf shrubs, and tall shrubs in the burned sites suggests available forage for bighorn sheep is greater in quantity in these sites. The results also represent a measure of the difference in the quality of available forage between burned and unburned sites. Since bighorn sheep are primarily grazers, an increase in the cover of graminoids, forbs and dwarf shrubs in the burned sites suggests a more desirable species composition in terms of forage preference. Although nutrient contents of forage species were not measured in this study, it has been shown that forest vegetation is generally of lower quality than alpine vegetation, because of reduced illumination and slightly lower temperatures slowing the growth rate and hence lowering the nutritive quality of the forage (Klein 1970, Hebert 1973). The phenology of herbaceous species in the burned sites may also reflect increases in forage quality since commencement of growth in the spring would be somewhat sooner because of increased solar radiation at ground level.

5.2.5 Analysis of Shrub Stratum

The crown diameter of individual tall shrubs encountered in each 2 x 5m plot was measured (to the nearest cm) and then converted to a percent cover value. The total percent cover of all individuals of each shrub species encountered was then calculated for individual plots and the plot values averaged to obtain a mean percent cover for each site. Table 9 shows the frequency (%), mean cover (%), and prominence values (P.V. = Mean Cover (%) x √Frequency (%)) of the 10 tall shrub species identified in the burned and unburned sites of the four study areas.

Alnus crispa and *Amelanchier alnifolia* were found only in the burned site at Ram Mountain. Both species are common constituents of early successional subalpine forest types (Moss 1959) and are capable of vegetative reproduction from root crowns following fire (Ahlgren 1960, Rowe 1979, Wright et al. 1979). *Betula glandulosa* was found in the burned sites at Rock Creek and Cadomin Mountain and in the unburned sites at Ghost River and Rock Creek. It was usually found in the lower slope positions under relatively mesic conditions. Percent cover was one percent or less in all the sites in which it was recorded.

Juniperus communis appeared to be adversely affected by fire in all the study areas. Mean cover, frequency, and

Table 9. Frequency (%)[1], mean cover (%), and prominence value (P.V.)[2] of tall shrubs found in the burned and unburned sites of the four study areas.

SPECIES	STUDY[3] AREA	BURNED SITES FREQUENCY (%)	BURNED SITES MEAN COVER (%)	BURNED SITES P.V.	UNBURNED SITES FREQUENCY (%)	UNBURNED SITES MEAN COVER (%)	UNBURNED SITES P.V.
Alnus crispa	GR		--	--	--	--	--
	[illegible]	-	--	--	--	--	--
		20	3.8	17.0	--	--	--
	M	-	--	--	--	--	--
Amelanchier alnifolia	[illegible]	-	-	--	--	--	--
	RC	--	--	--	--	--	--
	RM	20.0	0.1	0.4	--	-	--
	CM	--	--	--	--	--	--
Betula glandulosa	GR	--	--	--	13.0	0.1	0.1
	RC	10.0	1.0	3.2	20.0	0.8	3.6
	RM	--	--	--	--	--	--
	CM	20.0	0.6	2.7	--	--	--
Juniperus communis	GR	13.3	0.4	1.5	40.0	1.6	10.1
	RC	--	--	--	60.0	1.8	13.9
	RM	40.0	0.6	4.0	66.7	1.9	15.6
	CM	26.7	0.1	0.7	70.0	0.4	3.0
Populus balsamifera	GR	6.7	0.1	0.3	--	--	--
	RC	--	--	--	--	--	--
	RM	13.3	0.2	0.7	--	--	--
	CM	--	--	--	--	--	--
Populus tremuloides	GR	46.7	0.5	3.1	6.7	0.5	1.3
	RC	5.0	0.1	0.2	--	--	--
	RM	10.0	0.1	0.4	--	--	--
	CM	6.7	0.1	0.1	--	--	--

Table 9. (continued)

SPECIES	STUDY[3] AREA	BURNED SITES FREQUENCY (%)			UNBURNED SITES FREQUENCY (%)		
		FREQUENCY (%)	MEAN COVER (%)	P.V.[2]	FREQUENCY (%)	MEAN COVER (%)	P.V.
Potentilla fruticosa	GR	13.3	0.4	1.5	33.3	1.0	5.5
	RC	--	--	--	6.7	0.6	1.6
	RM	53.3	0.7	4.7	66.7	0.2	1.9
	CM	6.7	0.1	0.1	--	--	--
Rosa acicularis	GR	53.3	1.0	7.2	33.3	0.2	1.0
	RC	5.0	0.1	0.2	5.0	0.1	0.2
	RM	60.0	0.2	1.2	6.7	0.1	0.1
	CM	--	--	--	--	--	--
Salix spp.	GR	20.0	0.1	0.4	40.0	0.9	5.4
	RC	20.0	1.3	5.8	26.7	0.4	1.9
	RM	46.7	1.2	8.4	--	--	--
	CM	73.3	2.1	17.6	10.0	0.2	0.6
Shepherdia canadensis	GR	66.7	5.4	[illegible]	46.7	2.3	15.6
	RC	30.0	0.4	1.9	35.0	2.5	15.0
	RM	53.3	2.7	19.9	73.3	1.4	12.2
	CM	--	--	--	--	--	--

1 - Percentage occurrence in plots per site.
2 - P.V. = Mean Cover (%) x $\sqrt{\text{Frequency (\%)}}$.
3 - GR = Ghost River, RC = Rock Creek, RM = Ram Mountain, CM = Cadomin Mountain.

prominence values were all lower in the burned sites. A combination of factors, including high flammability of the foliage, low trailing grow..n form, and an inability to reproduce vegetatively from rootstocks (Wright et al. 1979) likely contributed to the observed lower frequency and cover values in the burned sites.

Populus balsamifera and Populus tremuloides suckers (less than 2 m in height) were much more prevalent in the burned sites. Populus balsamifera suckers were found in the Ghost River and Ram Mountain burned sites but were not present in any of the unburned sites. Populus tremuloides suckers were found in all four of the burned sites but had very low cover values (0.1% to 0.5%). Of the unburned sites, the Ghost River site had the only record of occurrence of Populus tremuloides. Both Populus species are capable of reproduction from seed or vegetatively from rootstocks (Lutz 1956, Ahlgren 1960, Lyon and Stickney 1976). Both suckers and seedlings were found in the Ghost River and Rock Creek burned sites. It was not possible, however, to determine the mode of reproduction of Populus tremuloides in the two older burned sites at Ram Mountain and Cadomin Mountain.

Potentilla fruticosa occurred in all of the burned sites except Rock Creek, but had mean cover values of less than 1.0%. It was also present in all of the unburned sites except Cadomin Mountain. Rosa acicularis was not found in either the burned or unburned site at Cadomin Mountain but was present in all the other study sites. Mean cover values were generally low (1.0% or less), but with higher frequency, mean cover and prominence values in the burned sites at Ghost River and Ram Mountain. The above ground portions of Potentilla fruticosa and Rosa acicularis are easily killed by fire but both species are capable of regenerating from root crowns (Ahlgren 1960, Wright et al. 1979).

The various Salix species encountered were grouped because of difficulties in identificating individual plants in the field. A species list was later compiled from voucher collections. The following species were identified: Salix glauca, S. bebbiana, S. brachycarpa, S. myrtillifolia, S. discolor, and S. vestita. The most common species encountered was Salix glauca, which was present in all of the study areas. The most common method of re-establishment of Salix species following fire is by resprouting from underground rootstocks (Lutz 1956). Salix species also produce light, wind-disseminated seed which germinate well on exposed mineral soil. Salix seedlings were observed occasionally in the burned sites at Ghost River and Rock Creek, but most of the willows encountered appeared to be of vegetative origin.

Shepherdia canadensis was found in all of the study sites except those at Cadomin Mountain. The frequency, mean cover, and prominence value were all higher in the burned site at Ghost River but lower in the burned site at Rock Creek. At Ram Mountain, the mean cover and prominence value were higher in the burned site, but percent frequency was lower. Shepherdia canadensis is regarded as moderately fire-tolerant by McLean (1969). Lyon and Stickney (1976) reported that it is able to resprout vegetatively from the root crown following fire. Rowe (1979) describes Shepherdia canadensis as a semi-tolerant evader species which is able to re-establish from seed maintained in a viable state in the soil for extended periods of time. Most of the individual specimens examined in the burned sites at Ghost River and Rock Creek, however, had re-established vegetatively.

In summary, shrub species which generally increased in importance in the burned sites were Populus balsamifera, Populus tremuloides, Rosa acicularis, Salix spp., and Shepherdia canadensis. Juniperus communis showed a marked decrease in importance in the burned sites of all four study areas. Potentilla fruticosa decreased in importance in the more recently burned sites at Ghost River and Rock Creek but increased in importance in the older burn sites at Ram Mountain and Cadomin Mountain. No trends were evident for Alnus crispa, Amelanchier alnifolia or Betula glandulosa. All of the shrub species, with the exception of Juniperus communis, are capable of re-establishment by vegetative means if the above-ground portions are killed or damaged by fire. In addition, several of the shrub species are capable of invading fire-disturbed sites by means of light, wind disseminated seed (Populus spp., Salix spp.). Generally, however, the shrub species composition on burned sites in subalpine areas would be expected to be very similar to that on the sites prior to burning. Moderate increases in abundance of some shrub species could be expected, but based on the sites studied in this project, and the shrub species involved, large increases in shrub cover would likely not occur.

5.2.6 Analysis of Herbs and Dwarf Shrubs

Frequency (%) and mean cover (%) of each herb and dwarf shrub species were converted to Prominence Values (P.V.), where P.V. = Mean Cover (%) x $\sqrt{\text{Frequency (\%)}}$. The frequency, mean cover, P.V.'s and individual plot cover values for all vascular species identified in the burned and unburned sites of the four study areas are given in Appendix 1. The P.V.'s are synthetic expressions reflecting the relative importance of each plant species in each study site. Tables 10 to 17 list the ten major subordinate vascular plant species in each burned and unburned site of the four study areas. The individual species listed in each table are ranked according to their associated P.V.'s, from highest to lowest.

The ten major subordinate plant species and their associated P.V.'s for the burned and unburned sites of Ghost River study area are listed in Table 10 and 11, respectively. It is interesting to note that eight of the species were common to both sites. Of the eight species, three had higher P.V.'s in the burned site (Elymus

Table 10. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the burned site of the Ghost River study area.

SPECIES	PROMINENCE VALUE
Elymus innovatus	70.9
Epilobium angustifolium	22.5
Arctostaphylos uva-ursi	20.5
Hedysarum sulphurescens	11.7
Linnaea borealis	8.4
Solidago multiradiata	4.8
Aster spp.	3.1
Arnica cordifolia	2.6
Achillea millefolium	2.6
Vaccinium scoparium	0.9

Table 11. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the unburned site of the Ghost River study area.

SPECIES	PROMINENCE VALUE
Arctostaphylos uva-ursi	67.2
Elymus innovatus	54.3
Hedysarum sulphurescens	19.5
Linnaea borealis	15.2
Arnica cordifolia	4.9
Zygadenus elegans	3.5
Carex rossii	3.1
Aster spp.	2.8
Solidago multiradiata	2.7
Vaccinium scoparium	2.3

innovatus, Solidago multiradiata, and Aster spp.). The other five species (Arctostaphylos uva-ursi, Hedysarum sulphurescens, Linnaea borealis, Arnica cordifolia, and Vaccinium scoparium) all had higher P.V.'s in the unburned site. Epilobium angustifolium was the most abundant forb species in the burned site (P.V. = 22.5) but had a P.V. of only 1.7 in the unburned site (Appendix 1). Carex rossii was fairly prevalent in the unburned site (P.V. = 3.1), but had a P.V. of 1.6 in the burned site. Zygadenus elegans was also more abundant in the unburned site.

The high degree of similarity between the species composition in the burned and unburned sites suggests that many of the species are capable of re-establishment from surviving underground plant parts subsequent to burning. Elymus innovatus, the major graminoid species present in all of the study sites, is able to resprout from underground rhizomes (Moss 1959). Other rhizomatous species reported as being capable of vegetative reproduction following fire include Solidago multiradiata (Wright et al. 1979), Aster spp. (Wright et al. 1979), Achillea millefolium (McLean 1969, Lyon and Stickney 1976), and Vaccinium scoparium (McLean 1969, Miller 1977). Hedysarum sulphurescens has a deep rooted woody caudex (Moss 1959), which is relatively unaffected by even fairly severe fires.

Epilobium angustifolium, the most prevalent herb species on the Ghost River burned site, is probably the most widely recognized perennial fire species (Lutz 1956, Lyon and Stickney 1976). This species generally colonizes recently burned sites by means of light, wind disseminated seed (Ahlgren 1960), but it also has the capability of vegetative reproduction from fibrous roots and rhizomes (Moss 1936, Mclean 1969). Arnica cordifolia is also an early colonizer of burn sites by means of windborne seeds as well as vegetatively from subterranean plant parts (McLean 1969, Dube 1976, Lyon and Stickney 1976).

Reports on the response of Arctostaphylos uva-ursi to fire are quite variable. Some researchers regard it as very susceptible to fire because of its fibrous roots and stolons (McLean 1969), and incapable of vegetative reproduction (Lutz 1956). However, Rowe (1979) observed that in northern Saskatchewan the species sprouts from basal burls (lignotubers) in the mineral soil. Scotter (1972) also observed sprouting of the species following fire. The results of this study suggest that this species has some capability of vegetative reproduction based on its relatively high prominence in the burned sites.

Linnaea borealis is another species subject to contrasting reports as to its response following fire. McLean (1969) stated that because of its shallow fibrous roots and stolons, it was very susceptible to fire injury. Lutz (1956) reported that the species was severely damaged by fire and that unburned areas usually served as centres from which the plants spread. Ahlgren (1960), however, stated that it was fairly common on burned areas and was capable of reproducing by vegetative means. Dyrness (1973) also found increases in the cover of Linnaea borealis after slash burning in the Western Cascades of Oregon. The results of this study showed that Linnaea borealis was generally lower in abundance in the burned sites but was still one of the major species present, suggesting some capability for vegetative reproduction.

Lyon and Stickney (1976) noted that Carex rossii may reestablish, following fire, from viable seeds present in the soil. Keown (1978) observed that Zygadenus elegans was generally not harmed by low intensity fires as long as the tunicated underground bulbs were not damaged.

Tables 12 and 13 list the ten major subordinate plant species in the burned and unburned sites of the Rock Creek study area. Seven of the species listed were common to both sites. Of these seven species, four had higher P.V.'s in the burned site (Epilobium angustifolium, Elymus innovatus, Achillea millefolium, and Aster spp.), and three species had higher P.V.'s in the unburned site (Hedysarum alpinum, Linnaea borealis, and Arnica cordifolia).

Agoseris glauca, which showed a dramatic increase in prominence in the burned site (P.V. = 17.4 vs. 1.9 in the unburned site), is capable of reproducing vegetatively from a woody taproot [illegible] sexually from light windborne seeds (Budd 1979). Stellaria longipes and Bromus pumpellianus, both increasers in the burned site, have extensive branching rootstocks and rhizomes. Fragaria virginiana, which had a

Table 12. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the burned site of the Rock Creek study area.

SPECIES	PROMINENCE VALUE
Epilobium angustifolium	74.6
Elymus innovatus	71.1
Agoseris glauca	17.4
Achillea millefolium	15.7
Hedysarum alpinum	9.7
Linnaea borealis	9.3
Aster spp.	8.8
Bromus pumpellianus	7.7
Stellaria longipes	7.1
Arnica cordifolia	4.6

Table 13. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the unburned site of the Rock Creek study area.

SPECIES	PROMINENCE VALUE
Elymus innovatus	46.8
Arctostaphylos uva-ursi	43.5
Hedysarum alpinum	18.9
Linnaea borealis	13.3
Epilobium angustifolium	11.8
Fragaria virginiana	11.4
Arnica cordifolia	10.3
Achillea millefolium	9.3
Aster alpinus	6.4
Oxytropis splendens	5.5

higher P.V. in the unburned site (11.4 vs. 1.7 in the burned site), was described by McLean (1969) as being very susceptible to fire injury because of its shallow fibrous roots and stolons. Hooker and Tisdale (1974) noted that this species may increase after low-intensity fires but is easily killed in high-intensity fires.

Tables 14 and 15 list the ten major subordinate plant species in the burned and unburned sites of the Ram Mountain study area. Seven of the species listed were common to both sites. Of these seven species, four had higher P.V.'s in the burned site (*Arctostaphylos uva-ursi*, *Aster alpinus*, *Kobresia bellardii*, and *Galium boreale*), and three species had higher P.V.'s in the unburned site (*Elymus innovatus*, *Hedysarum alpinum*, and *Solidago multiradiata*).

The ten major subordinate plant species recorded in the burned and unburned sites of the Cadomin Mountain study area are listed in Tables 16 and 17, respectively. Again, seven of the species listed were common to both sites. Of the seven species, four had higher P.V.'s in the burned site (*Dryas hookeriana*, *Cornus canadensis*, *Epilobium angustifolium*, and *Vaccinium vitis-idaea*), and three species had higher P.V.'s in the unburned site (*Vaccinium membranaceum*, *Elymus innovatus*, and *Linnaea borealis*).

Table 14. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the burned site of the Ram Mountain study area.

SPECIES	PROMINENCE VALUE
Arctostaphylos uva-ursi	63.0
Elymus innovatus	34.4
Aster alpinus	23.8
Kobresia bellardii	23.4
Zygadenus elegans	15.7
Dryas hookeriana	12.0
Galium boreale	11.6
Linnaea borealis	10.1
Hedysarum alpinum	9.3
Solidago multiradiata	7.8

Table 15. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the unburned site of the Ram Mountain study area.

SPECIES	PROMINENCE VALUE
Elymus innovatus	53.3
Hedysarum alpinum	14.5
Solidago multiradiata	9.6
Kobresia bellardii	8.0
Fragaria virginiana	6.4
Galium boreale	4.5
Androsace chamaejasme	3.9
Aster alpinus	2.4
Oxytropis sericea var. spicata	2.3
Arctostaphylos uva-ursi	1.6

Table 16. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the burned site of the Cadomin Mountain study area.

SPECIES	PROMINENCE VALUE
Dryas hookeriana	30.8
Cornus canadensis	26.0
Vaccinium membranaceum	19.9
Epilobium angustifolium	18.0
Arctostaphylos uva-ursi	15.8
Vaccinium vitis-idaea	15.2
Elymus innovatus	10.0
Arnica cordifolia	9.1
Carex rossii	6.0
Linnaea borealis	5.2

Table 17. Prominence Values (mean cover (%) x √frequency (%), max. = 1000) of the ten major subordinate vascular plant species in the unburned site of the Cadomin Mountain study area.

SPECIES	PROMINENCE VALUE
Vaccinium membranaceum	39.2
Linnaea borealis	18.8
Cornus canadensis	14.7
Elymus innovatus	13.2
Vaccinium vitis-idaea	11.2
Dryas hookeriana	9.0
Vaccinium caespitosum	6.4
Epilobium angustifolium	4.8
Kobresia bellardii	3.9
Phyllodoce glanduliflora	2.9

5.2.7 Successional Trends and Potential Utilization

Table 18 lists 118 plant species identified in the burned and unburned sites of the four study areas. Also shown is the occurrence of each species in burned and unburned sites, the relative change in mean cover of each species between burned and unburned sites, the estimated potential utilization of each species by bighorn sheep, and the probable seasons of prime importance of each species to bighorn sheep.

Relative change in mean cover is illustrated with the letters I, D and N which represent increase, decrease and no change, respectively. An increase or decrease in mean cover is specified if the difference in the mean cover values between burned and unburned sites for a particular species was 0.5% or greater. One should note that this is not a statistically-derived value but was chosen by the author for illustrative purposes. A more rigorous test of significance was not employed because of the nature of the data.

Information on the potential utilization of each species by bighorn sheep and its seasonal importance was obtained from the available literature on bighorn sheep food habits and range use patterns. Specific studies by Cowan (1947), Wishart (1958) Flook (1964), Oldemeyer et al. (1971), Todd (1972), Johnson (1975), and Stelfox (1976) were used as references.

A number of the species listed in table 18 show definite trends in terms of differences in mean cover

Table 18. Relative changes in mean cover (%) of vascular plant species between burned and unburned sites, potential estimates utilization by bighorn sheep, and seasonal preferences of plant species by bighorn sheep.

SPECIES	BURNED[1] SITES				UNBURNED SITES				CHANGE IN MEAN COVER[2]				UTILIZATION[3]	SEASON[4]
	1	2	3	4	1	2	3	4	1	2	3	4		
Trees														
Abies lasiocarpa	-	-	-	-	-	X	X	X	-	N	N	N	3	Sp,S
Picea engelmannii and glauca	X	-	X	Y	X	X	X	X	N	N	D	N	2	Sp,S
Pinus contorta	X	-			-	X	-	X	I	N	I	I	4	A
Shrubs														
Alnus crispa	-	-	X	-	-	-	-	-	-	-	I	-	3	Sp,F
Amelanchier alnifolia	-	-	X	-	-	-	-	-	-	-	N	-	2	Sp
Betula glandulosa	-	X	-	X	X	X	-	-	N	N	-	I	3	Sp
Juniperus communis	X	-	X	X	X	X	X	X	D	D	D	N	5	U
Populus balsamifera	X	-	X	-	-	-	-	-	N	-	N	-	3	Sp
Populus tremuloides	X	X	X	X	X	-	-	-	N	N	N	N	2	Sp,S,F
Potentilla fruticosa	X	-	X	X	X	X	X	-	D	D	N	N	3	S
Rosa acicularis	X	X	X	-	X	X	X	-	I	N	N	-	4	Sp
Salix glauca	X	-	-	-	X	-	-	-	D	-	-	-	1	A
Salix spp.	-	X	X	X	-	X	-	X	-	I	I	I	1	A
Shepherdia canadensis	X	X	X	-	X	X	X	-	I	D	I	-	2	S,F
Dwarf Shrubs														
Arctostaphylos uva-ursi	X	X	X	X	X	X	X	-	D	D	I	I	3	Sp,F,W
Cassiope tetragona	-	-	-	X	-	-	-	-	-	-	-	N	4	U
Cornus canadensis	-	X	-	X	-	-	-	X	-	N	-	I	3	U
Dryas hookeriana	-	-	X	X	-	X	X	X	-	D	I	I	1	A
Empetrum nigrum	-	-	-	X	-	X	-	-	-	N	-	N	4	U
Linnaea borealis	X	X	X	X	X	X	Y	X	D	N	I	D	4	U
Phyllodoce glanduliflora	-		-	-	-	-	-	X	-	-	-	D	3	Sp,F
Salix arctica			-	X	-	-	-	X	-	-	-	N	2	F,W
Vaccinium caespitosum			X	-	-	X	-	X	-	N	N	D	4	S
Vaccinium membranaceum			-	X	-	-	-	X	-	-	-	D	4	J
Vaccinium scoparium	X	X	-	-	X	-	-	-	N	N	-	-	4	U
Vaccinium vitis-idaea	-	-	-	X	-	-	-	X	-	-	-	I	4	U
Vaccinium sp.	-	-	X	-	-	-	-	-		-	N	-	4	U

Table 18. (continued)

SPECIES	BURNED[1] SITES				UNBURNED SITES				CHANGE IN MEAN COVER[3]				UTILIZATION[2]	SEASON[4]
	1	2	3	4	1	2	3	4	1	2	3	4		
Graminoids														
Agrostis scabra	-	-	-	X	-	-	-	-	-	-	-	N	3	Sp
Agrostis variabilis	-	-	-	X	-	-	-	-	-	-	-	N	3	Sp
Bromus pumpellianus	-	X	X	-	X	-	-	-	N	I	N	-	4	Sp
Calamagrostis inexpansa	-	-	X	-	-	-	-	-	-	-	N	-	3	Sp,S
Calamagrostis lapponica	-	-	-	X	-	-	-	-	-	-	-	N	3	Sp,S
Carex atrosquama	-	-	-	-	-	-	X	-	-	-	N	-	2	A
Carex concinna	X	X	-	-	-	X	-	-	N	N	-	-	3	A
Carex rossii	X	X	-	X	X	-	-	-	N	I	-	I	2	A
Carex scirpoidea	-	-	X	-	X	-	X	-	N	-	N	-	2	A
Elymus innovatus	X	X	X	X	X	X	X	X	I	I	D	N	4	Sp
Festuca brachypylla	-	-	-	X	-	-	X	-	-	-	N	N	3	S
Kobresia bellardii	-	-	X	X	-	X	X	X	-	I	I	D	1	A
Poa alpina	-	X	X	-	-	X	X	-	-	N	N	N	1	S
Poa arctica	-	X	-	-	-	-	-	X	-	N	-	N	1	S
Poa canbyi	-	X	-	-	-	-	-	-	-	I	-	-	1	S
Poa interior	-	X	-	X	-	X	-	-	-	N	-	N	1	S
Poa palustris	-	-	X	-	-	-	X	-	-	-	N	-	1	S
Trisetum spicatum	-	X	-	X	-	-	-	X	-	N	-	I	2	S
Forbs and pteridophytes														
Achillea millefolium	X	X	X	X	X	X	X	-	N	I	N	N	3	S
Aconitum delphinifolium	-	X	-	X	-	-	-	-	-	N	-	N	4	U
Agoseris glauca	X	X	X	X	X	X	X	-	N	I	N	N	4	S
Androsace chamaejasme	X	-	X	-	X	-	X	-	N	-	N	-	5	U
Anemone multifida	X	X	X	-	X	X	-	-	N	N	N	-	4	Sp
Anemone parviflora	-	-	X	-	-	-	-	-	-	-	N	-	4	U
Antennaria racemosa	-	X	-	-	-	X	-	-	-	N	-	-	4	Sp
Antennaria rosea	X	X	-	X	X	X	-	-	N	N	-	I	4	Sp
Antennaria umbrinella	-	-	X	-	-	-	X	-	-	-	N	-	4	Sp
Aquilleja flavescens	-	X	-	-	-	-	-	-	-	N	-	-	4	U
Arenaria rubella	-	X	X	X	-	X	X	-	-	N	N	N	4	U
Arnica alpina	-	-	-	X	-	-	-	-	-	-	-	N	3	S
Arnica cordifolia	X	X	X	X	X	X	X	X	N	D	N	I	3	S
Arnica latifolia	X	-	-	-	-	-	-	-	N	-	-	-	3	S
Artemesia campestris	-	X	-	-	-	-	-	-	-	I	-	-	4	U
Artemesia norvegica	-	-	-	X	-	-	-	X	-	-	-	N	4	U

Table 18. (continued)

SPECIES	BURNED[1] SITES				UNBURNED SITES				CHANGE IN MEAN COVER[2]				UTILIZATION[3]	SEASON[4]
	1	2	3	4	1	2	3	4	1	2	3	4		
Forbs and pteridophytes cont.														
Aster alpinus	-	-	X	-	-		X	-	-	-	I	-	2	S
Aster sp.	X	X	-	X	X	X	-	-	N	N	-	N	2	S
Botrychium lunaria	-	X	-	X	-	X	-	-	-	N	-	N	5	U
Campanula lasiocarpa	-	-	-	X	-	-	-	X	-	-	-	N	4	S
Campanula rotundifolia	X	X	X	X	X	X	X	-	N	N	N	N	3	S
Castilleja miniata	X	-	-	X	-	X	-	-	N	N	-	N	3	S
Castilleja occidentalis	-	-	X	-	-	X	-	-	-	N	N	-	3	S
Clematis columbiana	-	-	X	-	-	-	-	-	-	-	N	-	5	U
Delphinium glaucum		X	-	-	-	-	X	-	-	N	N	-	2	Sp,S
Draba aurea	-	X	-	-	X	X	-	-	N	N	-	-	4	U
Epilobium angustifolium	X	X	X	X	X	X	X	X	I	I	N	I	3	S
Equisetum arvense	-	-	-	-	-	X	-	-	-	N	-	-	4	U
Equisetum scirpoides	X	X	-	-	X	X	-	-	N	N	-	-	4	U
Erigeron peregrinus	-	X	-	X	-	X	-	-	-	N	-	N	4	S
Fragaria virginiana	X	X	X	X	X	X	X	-	N	D	N	N	3	Sp
Galium boreale	-	X	X	-	-	X	X	-	-	N	I	-	2	Sp,S
Gentianella amarella	X	-	X	X	-	-	X	X	N	-	N	N	4	U
Gentianella sp.	-	X	-	-	-	-	-	-	-	N	-	-	4	U
Habenaria viridis	-	-	X	-	-	-	-	-	-	-	N	-	4	U
Hedysarum alpinum	-	X	X	X	-	X	X	X	-	D	N	D	1	Sp,S
Hedysarum mackenzii	-	-	X	-	X	X	X	-	N	N	N	-	2	Sp,S
Hedysarum sulphurescens	X	-	-	-	X	-	-	-	D	-	-	-	1	Sp,S
Lycopodium alpinum	-	-	-	X	-	-	-	-	-	-	-	N	4	U
Mertensia paniculata	-	-	-	-	-	-	X	X	-	-	N	N	4	U
Minulus guttatus	-	-	X	-	-	-	-	-	-	-	N	-	4	U
Moneses uniflora	-	-	-	-	-	-	X	-	-	-	N	-	4	U
Myosotis alpestris	-	X	-	-	-	X	-	-	-	N	-	-	4	U
Oxytropis campestris	-	-	-	-	-	-	-	X	-	-	-	N	3	Sp,S
Oxytropis deflexa	-	-	-	-	-	-	X	-	-	-	N	-	2	Sp,S
Oxytropis sericea var. spicata	-	-	X	-	-	-	X	-	-	-	N	-	1	Sp,S
Oxytropis splendens	-	X	-	X	X	X	-	X	N	D	-	N	1	Sp,S
Pedicularis arctica	-	-	-	-	-	-	-	X	-	-	-	N	4	U
Penstemon confertus	-	-	-	-	X	-	-	-	N	-	-	-	4	S
Penstemon procerus	-	X	-	-	-	-	-	-	-	N	-	-	4	S
Petasites palmatus	-	-	-	-	-	X	-	-	-	N	-	-	4	U
Phacelia sericea	X	X	-	-	-	X	-	-	N	N	-	-	3	S
Polemonium pulcherrimum	-	X	-	-	-	-	-	-	-	N	-	-	4	U

Table 18. (continued)

SPECIES	BURNED[1] SITES				UNBURNED SITES				CHANGE IN MEAN COVER[2]				UTILIZATION[3]	SEASON[4]
	1	2	3	4	1	2	3	4	1	2	3	4		
Forbs, and pteridophytes cont.														
Polygonum viviparum	-	X	X	X	-			X	-	N	N	N	4	U
Potentilla diversifolia	-	X	-	-	-	-	-	-	-	N	-	-	2	S
Potentilla nivea	-	-	-	X	-	-	-	X	-	-	-	N	1	Sp,S,F
Pyrola asarifolia	-	X	-	-	-	-	-	-	-	N	-	-	4	U
Pyrola bractiata	-	-	-	-	X	X	-	-	N	N	-	-	4	U
Pyrola secunda	X	-	X	-	X	X	X	X	N	N	N	N	4	U
Rumex alpestris	-	X	-	-	-	-	-	-	-	N	-	-	5	U
Saxifraga tricuspidata	-	X	-	X	-	-	-	X	-	N	-	N	4	U
Saxifraga sp.	-	X	-	-	-	X	-	-	-	N	-	-	4	U
Sedum rosea	-	-	-	-	-	-	X	-	-	-	N	-	5	U
Sedum stenopetalum	-	-	-	X	-	X	-	-	-	N	-	N	5	U
Selaginella densa	-	X	X	X	-	-	-	-	-	N	N	N	4	U
Senecio canus	X	-	X	-	-	-	X	-	N	-	N	-	3	Sp,S,[illegible]
Senecio lugens	-	-	X	-	-	-	X	-	-	-	N	-	3	Sp,S
Silene acaulis	-	-	X	X	-	-	X	-	-	-	N	N	4	U
Solidago multiradiata	X	X	X	X	X	X	X	X	N	N	N	N	3	S
Stellaria longipes	-	X	-	-	-	X	-	-	-	I	-	-	4	U
Stellaria monantha	-	X	-	-	-	X	-	-	-	N	-	-	4	U
Stenanthium occidentale	-	-	X	-	X	-	X	-	N	-	N	-	4	U
Zygadenus elegans	X	X	X	X	X	X	X	X	D	D	I	N	1	Sp,S

1 - Burned Sites:

1 = Ghost River
2 = Rock Creek
3 = Ram Mountain
4 = Cadomin Mountain

2 - Change in mean cover

I = Increase
D = Decrease
N = No change (< 0.5%)

3 - Utilization

1 = Primary forage species
2 = Secondary forage species
3 = Little grazed species
4 = Incidental forage species
5 = Not grazed or unknown

4 - Season

Sp. = Spring
S = Summer
F = Fall
W = Winter
A = All seasons
U = Unknown

X = encountered in at least one sample plot per site.

between burned and unburned sites. Species which increased in cover in the burned sites of at least three of the study areas included Pinus contorta var. latifolia (seedlings), Salix spp., and Epilobium angustifolium. Carex rossii increased in cover in the burned sites of two of the study areas. Important forage species which showed an increase in cover in at least one burned site, with no change in mean cover between the other sites in which they occurred, included Alnus crispa, Betula glandulosa, Cornus canadensis, Poa canbyi, Trisetum spicatum, Achillea millefolium, Aster alpinus, and Galium boreale.

A number of species also had consistently lower mean cover values in the burned sites of the study areas. Juniperus communis decreased in cover in three of the burned sites. Hedysarum alpinum, an important forage species, decreased in cover in two of the burned sites. Important forage species which showed a decrease in cover in at least one burned site, with no change in mean cover between the other sites in which they occurred, included Salix glauca, Fragaria virginiana, Hedysarum sulphurescens, and Oxytropis splendens. As noted earlier, Arctostaphylos uva-ursi decreased in cover in the ten year old burned sites at Ghost River and Rock Creek, but showed higher mean cover values in the older burned sites at Ram Mountain and Cadomin Mountain. It appears that this species is initially adversely affected by burning, but eventually (after more than ten years) develops significantly higher cover in the semi-open, older burned areas. *Potentilla fruticosa* and *Zygadenus elegans* also appear to follow this type of response pattern to burning. *Elymus innovatus*, the dominant grass species in all the sites studied, had high cover values in the ten year old burned sites but generally decreased in cover in the older burned sites. Many of the other herbaceous species listed in Table 18 were too rare in occurrence to formulate any general conclusions with respect to their response to burning.

5.2.8 Non-Plant Ground Cover

In addition to subordinate vascular plant cover, the ground cover in the study sites comprised six major cover types; bryophytes, lichens, litter (conifer needles, cured plant material, twigs), woody material (down and dead snags and branches), mineral soil, and rock. Table 19 gives the frequency (%), mean cover (%), and prominence value (P.V.) of each of the above cover types in the burned and unburned sites of the four study areas. The cover of bryophytes and lichens was not determined for individual species. The values given represent total mean cover for the composite bryophyte and lichen complexes. Voucher specimens were collected, however, for later identification of the major species of bryophytes and lichens present in the study sites.

Percent cover of bryophytes was higher in the unburned sites of all the study areas except Ghost River (Table 19).

Table 19. Non-vascular plant ground cover (%) of the major cover types in the burned and unburned sites of the four study areas.

COVER TYPE	STUDY AREA[1]	BURNED SITES FREQUENCY (%)	BURNED SITES MEAN COVER (%)	BURNED SITES P.V.	UNBURNED SITES FREQUENCY (%)	UNBURNED SITES MEAN COVER (%)	UNBURNED SITES P.V.
Moss complex	GR	66.7	15.5	126.5	73.3	9.8	83.9
	RC	95.0	10.7	104.4	80.0	14.9	132.9
	RM	66.7	1.0	7.8	80.0	10.3	91.7
	CM	46.7	2.1	14.0	100.0	14.1	141.4
Lichen complex	GR	13.3	0.4	1.5	73.3	4.2	36.0
	RC	5.0	0.1	0.1	73.3	3.0	25.7
	RM	46.7	1.3	9.1	53.3	1.3	9.5
	CM	80.0	3.5	31.0	100.0	6.2	62.0
Litter	GR	100.0	31.0	309.5	100.0	50.3	502.7
	RC	100.0	23.7	236.9	100.0	33.0	330.3
	RM	100.0	29.0	290.0	100.0	41.0	410.1
	CM	93.3	24.7	238.8	100.0	37.9	378.6
Mineral Soil	GR	93.3	8.4	80.8	46.7	4.9	33.3
	RC	95.0	14.3	139.4	53.3	5.5	40.5
	RM	73.3	9.3	79.7	46.7	4.6	31.4
	CM	86.7	13.9	129.7	70.0	6.2	52.0
Rock	GR	93.3	20.7	199.5	66.7	3.7	30.5
	RC	85.0	10.7	98.4	73.3	3.4	28.9
	RM	86.7	13.1	121.8	86.7	12.3	114.0
	CM	86.7	19.1	178.0	60.0	1.7	13.5
Woody material	GR	13.3	0.8	2.8	--	--	--
	RC	60.0	3.4	26.5	80.0	7.0	63.0
	RM	86.7	10.0	93.5	80.0	12.0	107.2
	CM	73.3	3.4	28.9	70.0	4.1	34.5

1.- GR = Ghost River, RC = Rock Creek, RM = Ram Mountain,
CM = Cadomin Mountain

However, the species of bryophytes present in the burned site at Ghost River, as well as Rock Creek, were very different from those in the unburned sites of the two study areas. In the burned sites, the bryophyte complex was composed of species normally associated with disturbed, untreed sites; Bryum caespiticium, Barbula convoluta, Ceratadon purpureus, and Polytrichum juniperinum. These species are capable of reproducing by rhyzoids or spores and are common pioneering moss species on burned areas (Lutz 1956). They often formed a continuous, low growi[illegible]t directly on mineral soil. In the unburned sites t[illegible]or bryophyte species present were Dicranum spp., Hyloc[illegible]um splendens, Pleurozium schreberi, Pohlia nutans, and P[illegible] crista-castrensis. These species are normally associated with more mature subalpine forest stands (Lutz 1956). Moss cover was generally very low in the older burned sites at Ram Mountain and Cadomin Mountain (1.0% and 2.1%) but was considerably higher in the unburned sites (10.3% and 14.1%) of the two study areas.

Cover of lichens was generally very low in all of the burned sites, especially at Ghost River and Rock Creek (0.4% and 0.1%). Lichen cover was somewhat higher in the older burned sites at Ram Mountain and Cadomin Mountain (1.3% and 3.5%). The major lichen species identified in the burned sites were Cladonia spp. and Peltigera spuria. Both lichen mean cover and numbers of lichen species were higher in the unburned sites of the four study areas. The most common lichen species identified in the unburned sites included Cladina mitis, Cladonia cenotea, Cladonia gracilis, Cladonia pleurota, Hypogymnia physodes, Letharia vulpina, Peltigera aphthosa, and Usnea sp.

Lutz (1956) reported that reproduction of lichens may be either sexual or asexual, but fragmentation and production of soredia appeared to be the most common means of reproduction. Those species which appear earliest on burned areas are generally of low stature and probably regenerate from subterranean parts and bits of unburned thallus (Lutz 1956).

Cover of litter and down and dead woody material was higher in the unburned sites of all four study areas. Cover of bare mineral soil and rock was higher in the burned sites of all four study areas. These results are not suprising since the fires would have consumed much of the litter and woody material present on the ground at the time of burning, thus exposing more mineral soil and rock on the sites. Erosion or soil slumpage did not appear to be a problem in any of the burned sites studied even though slopes of 30% to 70% were common in the study areas.

5.2.9 Duff and Litter Depths

Table 20 presents mean duff and litter depths (cm) measured in the burned and unburned sites of the four study areas. A Student's t-test was used to test for significant differences ($p < .05$) between mean duff and litter depths in

Table 20. Mean duff and litter depths (cm) and standard deviations (in parentheses) in the burned and unburned sites of the four study areas.[1]

	GHOST RIVER		ROCK CREEK		RAM MOUNTAIN		CADOMIN MOUNTAIN	
	BURNED SITE (n = 15)	UNBURNED SITE (n = 15)	BURNED SITE (n = 20)	UNBURNED SITE (n = 15)	BURNED SITE (n = 15)	UNBURNED SITE (n = 15)	BURNED SITE (n = 15)	UNBURNED SITE (n = 10)
MEAN LITTER DEPTH	2.4a (± 1.3)	2.8a (± 2.0)	0.8a (± 0.6)	2.2b (± 1.5)	1.8a (± 1.3)	1.6a (± 0.9)	1.3a (± 0.8)	2.1b (± 0.9)
MEAN DUFF DEPTH	1.1a (± 0.8)	6.0b (± 3.4)	0.9a (± 1.3)	5.1b (± 7.1)	1.7a (± 1.1)	5.1b (± 4.4)	1.3a (± 0.9)	3.6b (± 1.6)

1 - Ghost River - 1970 burn, maximum recorded tree age in unburned site was 101 years

Rock Creek - 1970 burn, maximum recorded tree age in unburned site was 279 years

Ram Mountain - 1921 burn, maximum recorded tree age in unburned site was 299 years

Cadomin Mountain - 1919 burn, maximum recorded tree age in unburned site was 192 years

a,b - Values followed by different letters for individual study areas are significantly different at the .05 level.

burned and unburned sites of each study area. The results show that duff depths were significantly lower in the burned sites of all four study areas. Litter depths were significantly lower in the burned sites at Rock Creek and Cadomin Mountain but no significant differences were found in litter depths between burned and unburned sites at Ghost River and Ram Mountain.

Fires remove varying proportions of the organic layer overlying the mineral soil, the amount depending mainly on the moisture content of the organic layer at the time of the fire (Van Wagner 1979). The quality of the resultant seedbed and the fate of plants whose underground parts are located within or just below the organic layer are highly dependent on the depth of burn (McLean 1969, Rowe 1979, Van Wagner 1979).

Depth of burn may be independent of fire intensity, which is a measure of the fire's rate of energy release expressed as kilowatts per meter of fire front (Van Wagner 1972). Rowe (1979) stated that the term "fire severity" may be a more appropriate descriptor of the degree of organic material removal and of soil heating as related to the survival of perennating plant parts buried in the soil. Fires may be of low intensity (low rate of energy release) but may nevertheless be of high severity, if all the organic soil material is removed, and buried seed, rhizomes, and roots are killed. This situation may occur when duff moisture levels are very low and residence time (the length of time for the fire front to pass a point) is long. Since underground plant parts are usually located in the upper soil horizons, the combustion of the organic soil material will have a large impact on the survival of underground reproductive structures.

5.2.10 Down and Dead Woody Fuel Loading

Estimates of down and dead woody fuel loadings (tonnes/ha) by roundwood diameter size class for burned and unburned sites are presented in Table 21. Percent of total fuel weight per site of each roundwood diameter size class is also given. A Student's t-test was used to test for significant differences ($p < .5$) between total mean fuel loadings in the burned and unburned sites of each study area.

Total mean woody fuel loadings in the unburned sites at Ghost River and Ram Mountain were significantly higher than those in the burned sites of the two study areas. This relationship was reversed, however, for the Rock Creek and Cadomin Mountain study areas, where total mean fuel loadings were higher on the burned sites.

In the Rock Creek study area, the higher fuel loading on the burned site was primarily a result of the high loading of down and dead large diameter (7.6 + cm) solid fuel particles (24.023 tonnes/ha). These were generally recently fallen snags. Fewer snags had fallen in the Ghost River burned site where the loading of large diameter solid

Table 21. Mean down and dead fuel loading[1] (tonnes/ha) and percent loading[2] by roundwood diameter size class for burned and unburned sites[3]

ROUNDWOOD DIAMETER SIZE CLASS	GHOST RIVER (n = 15) BURNED SITE	GHOST RIVER (n = 15) UNBURNED SITE	ROCK CREEK (n = 20) BURNED SITE	ROCK CREEK (n = 15) UNBURNED SITE	RAM MOUNTAIN (n = 15) BURNED SITE	RAM MOUNTAIN (n = 15) UNBURNED SITE	CADOMIN MOUNTAIN (n = 15) BURNED SITE	CADOMIN MOUNTAIN (n = 10) UNBURNED SITE
0 - 0.64 cm.	0.053 (0.27)	0.728 (0.98)	0.019 (0.06)	0.345 (1.19)	0.151 (0.58)	1.072 (1.93)	0.093 (0.29)	0.573 (4.66)
0.65 - 2.54 cm	0.213 (6.28)	1.546 (.209)	0.462 (1.43)	0.579 (2.00)	1.990 (7.58)	5.472 (9.83)	1.554 (4.6[illegible])	1.242 (1[illegible])
2.55 - 7.6 cm	2.427 (12.57)	3.845 (5.19)	0.863 (2.67)	1.379 (4.76)	5.187 (19.76)	3.804 (6.84)	4.339 (1[illegible])	5.0[illegible] (4[illegible])
7.6 + cm. SOLID	9.710 (30.27)	3.812 (5.14)	24.023 (74.25)	13.798 (47.58)	3.484 (13.27)	18.855 (33.89)	4.183 (1[illegible])	-
7.6 + cm. ROTTEN	5.912 (30.61)	64.179 (86.60)	6.989 (21.60)	12.896 (44.47)	15.438 (58.81)	26.435 (47.51)	22.9[illegible] (67.9[illegible])	5.4[illegible] (44.54)
TOTAL	19.315a	74.110b	32.354a	28.997a	26.251a	55.639b	33.815a	12.2[illegible]b

1 number not in parenthesis, calculated using Brown's (1974) line intercept method

2 number in parenthesis

3 Ghost River - 1970 burn, maximum recorded tree age in unburned site was [illegible] years

Rock Creek - 1970 burn, maximum recorded tree age in unburned site was 279 years

Ram Mountain - 1921 burn, maximum recorded tree age in unburned site was 299 years

Cadomin Mountain - 1919 burn, maximum recorded tree age in unburned site was 192 years

a,b total mean fuel loading values for burned and unburned sites in each study area followed by different letters are significantly different at the .05 level fuel particles was 9.710 tonnes/ha. In the Cadomin Mountain study area, the higher fuel loading on the burned site was primarily a result of the high loading of large diameter rotten fuel particles. These were generally snags which had fallen a number of years previously and were partially decomposed.

Fahnestock (1976) found that in burned subalpine spruce-fir stands in northern Washington, few fire-killed trees fell within the first 10 years, and 20 or 30 years may elapse before appreciable downfall occurred. He found that typically, most of the snags fell within 25 to 40 years, and the mass of material remained essentially intact to at least 60 years after the fire. He estimated that fire-caused fuels became unimportant to fire spread and intensity in about 100 to 125 years.

An important consideration in prescribed burning is the amount and continuity of fuel available for combustion (Martin and Dell 1978). Although fire behavior and intensity can be manipulated through variations in ignition patterns and prescription parameters, it is essential that sufficient fuel be available to fulfill the objectives of the prescribed burn. In the sites studied, considerable variation existed in both the loading and the horizontal continuity of the down and dead fuel. Upslope areas tended to have much lower fuel loadings than mid and downslope areas. Therefore, both fuel loading and continuity should be considered if prescribed burning for bighorn sheep range improvement is contemplated.

5.2.11 Soil Analysis

The results of the soil chemical analysis conducted by the Alberta Soil and Feed Testing Laboratory are presented in Table 22. Nutrient levels are given for individual sample types. Separate analyses were conducted on the duff and mineral soil portions of the soil samples collected in the unburned sites. A total nutrient content value is also given for the soil samples collected in the unburned sites.

The methods of analyses employed by the Soil and Feed Testing Laboratory are standardized for agricultural mineral soil with a mean bulk density of 1.5 and a mean depth of 15 cm. Results for plant nutrients (N, P, K) expressed on a weight basis (kg/ha) were assumed to be accurate for the mineral soil samples collected in this study. The data for nutrient contents (kg/ha) in the organic portions of the soil samples were adjusted, however, using a bulk density of 0.3 gms/cc (D. Pluth pers. com.)[2] and the mean duff depth recorded for each unburned site.

The results show that concentrations of nitrogen (N), phosphorus (P), and potassium (K) were generally higher in the soil samples collected in the burned sites of all the study areas (Table 22). The effects of fire on soil nutrient levels reported in the literature are highly variable.

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[2] Dr. Don Pluth, Associate Professor, Department of Soil Science, University of Alberta.

Table 22. Physical and chemical soil properties in burned and unburned sites of the four study areas.

STUDY AREA	SITE	SAMPLE TYPE	kg per ha N	kg per ha P	kg per ha K	Sulfur (S) (ppm)	Soil Reaction (pH)	Conductivity (mm hos)	Organic1 Matter (%)	Texture2
GHOST RIVER	Burned	Total	62	32	278	8.8	7.3	0.63	14.6	5
	Unburned	Duff	1	2	27	9.4	5.9	0.43	H+	6
	Unburned	Mineral	1	4	161	5.9	6.2	0.25	16.7	5
	Total Unburned	Total	2	6	188	15.3	--	--	--	--
ROCK CREEK	Burned	Total	67	171	268	4.7	6.8	0.60	16.1	5
	Unburned	Duff	4	8	29	10.1	6.5	0.87	H+	6
	Unburned	Mineral	18	73	190	4.1	6.7	0.43	9.8	3
	Total Unburned	Total	22	81	219	14.2	--	--	--	--
RAM MTN.	Burned	Total	48	21	395	3.2	7.3	0.6[illegible]	21.5	3
	Unburned	Duff	1	4	27	5.2	6.5	0.53	H+	6
	Unburned	Mineral	12	39	289	2.9	6.9	0.47	34.2	5
	Total Unburned	Total	13	43	316	8.1	--	--	--	--
CADOMIN MTN.	Burned	Total	3	75	340	2.6	5.2	0.27	14.1	3
	Unburned	Duff	1	2	18	5.7	4.6	0.37	H+	6
	Unburned	Mineral	3	42	190	3.4	4.4	0.20	20.6	3
	Total Unburned	Total	4	44	208	9.1	--	--	--	--

1 - H+ = all organic.
2 - Hand texturing, 1 to 6 scale, 1 = sand and loamy sand, 6 = organic.

Generally, burning of the surface organic matter removes or decreases the organic mantle, volatilizes large amounts of nitrogen and small amounts of other elements, and transforms less volatile elements to soluble mineral forms that are more easily absorbed by plants (Wells et al. 1979). Conflicting reports, however, appear to result from site specific variations in fire intensity, fuel characteristics and loading, vegetation type and phenology, soil moisture and prior nutrient status, and climate (Wells et al. 1979).

Nutrient losses from burned sites may take place by wind and water erosion, leaching, or volatilization. Nutrient losses from erosion depend on the erosion mechanisms involved. Surface erosion removes those nutrients closely associated with organic matter, while mass erosion may remove the entire soil profile with its incorporated nutrient capital (Wells et al. 1979). Greater nutrient depletion will result from surface erosion than from mass erosion because of the greater area affected. Adequate post-fire plant cover to stabilize the soil surface appears to be the critical factor in avoiding unacceptable erosion rates following fire (MacLean et al. 1979, Wells et al. 1979). No evidence of mass erosion was found on the burned sites studied. Surface erosion may have occurred on the burned study sites to some extent in the first few years following burning, but did not appear to be a problem at the time of sampling.

Nitrogen and sulphur (S) are very susceptible to burning losses because they have low volatilization temperatures. Direct N losses from burning may be compensated for by surviving plants on the site capable of symbiotic N fixation. Several reports also indicate N is fixed by nonsymbiotic microorganisms following burning (Lutz 1956, Ahlgren and Ahlgren 1960, Wells et al. 1979).

Soil pH was generally somewhat higher in the burned sites of all the study areas. Soil acidity in surface soil layers is generally reduced by burning as a result of the basic cations released by combustion of organic matter and the chemical effects of heating on organic matter and minerals (Wells et al. 1979). Soil pH increases depend upon the amount of ash released, original soil pH, the chemical composition of the ash, and wetness of the climate (Lutz 1956, Wells 1971, Grier 1975).

The role of fire as a mineralizing agent which restores plant nutrients to circulation is thought to be very important in northern and high altitude forest ecosystems. (Rowe and Scotter 1973, MacLean et al. 1979, Raison 1979). Slow rates of organic matter decomposition tend to remove nutrients from circulation and the nutrient supply may ultimately become limiting to plant growth. Fire is viewed as a natural process which periodically releases mineral elements as ash from the living and dead organic substances burned. In addition, fires may indirectly release mineral elements through increased decomposition rates of remaining organic layers and other remains, leaching or erosion of mineral soils, and the physical spalling of rocks and subsequent breakdown of rock fragments (Wright and Heinselman 1973).

In summary, the results of this study indicate that concentrations of N, P, and K were generally higher in soil samples collected in the burned sites of the four study areas. Sulphur concentrations were generally somewhat lower in the burned sites. Soil pH and conductivity were generally somewhat higher in the burned sites.

5.3 Site Utilization

5.3.1 Browse Utilization

Results of browse utilization measurements are not specific to bighorn sheep, since other ungulate species were present in the study areas. It was not possible to determine shrub utilization by bighorn sheep as opposed to deer, elk, or moose. The results, therefore, indicate the relative degree of browse utilization by all the ungulates present in the study areas.

Table 23 gives the frequency (percentage of plots per site in which the shrub species was recorded), mean utilization (percentage of twigs browsed for all individuals of each shrub species recorded), and preference index value (mean utilization (%)/$\sqrt{\text{frequency (\%)}}$ for the ten tall shrub

Table 23. Frequency (%), mean utilization (%), and preference indices of shrubs in the burned and unburned sites of the four study areas.

SPECIES	STUDY AREA	BURNED SITES FREQUENCY (%)	BURNED SITES MEAN UTILIZATION (%)	BURNED SITES PREF. INDEX	UNBURNED SITES FREQUENCY (%)	UNBURNED SITES MEAN UTILIZATION (%)	UNBURNED SITES PREF. INDEX
Alnus crispa	GR	--	--	--	--	--	--
	RC	--	--	--	--	--	--
	RM	20.0	9.9	2.2	--	--	--
	CM	--	--	--	--	--	--
Amelanchier alnifolia	GR	--	--	--	--	--	--
	RC	--	--	--	--	--	--
	RM	20.0	0	0	--	--	--
	CM	--	--	--	--	--	--
Betula glandulosa	GR	--	--	--	13.0	18.8	5.2
	RC	10.0	9.5	3.0	20 [illegible]	6.3	1.4
	[illegible]	--	--	--	--	--	--
	CM	20.0	1.1	0.2		--	--
Juniperus communis	GR	13.3	0	0	4[illegible]	0.4	0.1
	RC	--	--	--	60.0	0	0
	RM	40.0	0	0	66.7	0	0
	CM	26.7	0	0	70 [illegible]	0	0
Populus balsamifera	GR	6.7	0	0	--	--	--
	RC	--	--	--	--	--	--
	RM	13.3	15.6	4.3	--	--	--
	CM	--	--	--	--	--	--
Populus tremuloides	GR	46.7	48.7	7.1	6.7	25.0	9.7
	RC	5.0	23.5	10.5	--	--	--
	RM	20.0	65.2	14.6	--	--	--
	CM	6.7	0	0	--	--	--

Table 23. (continued)

SPECIES	STUDY[1] AREA	BURNED SITES FREQUENCY (%)	BURNED SITES MEAN[2] UTILIZATION (%)	BURNED SITES PREF.[3] INDEX	UNBURNED SITES FREQUENCY (%)	UNBURNED SITES MEAN UTILIZATION (%)	UNBURNED SITES PREF. INDEX
Potentilla fruticosa	GR	13.3	5.9	1.6	33.3	0.6	0.1
	RC	--	--	--	6.7	0	0
	RM	53.3	3.7	0.5	66.7	0.7	0.1
	CM	6.7	5.6	2.2	--	--	--
Rosa acicularis	GR	53.3	28.8	3.9	33.3	5.4	0.9
	RC	5.0	11.0	4.9	6.7	0	0
	RM	60.0	2.1	0.3	6.7	0	0
	CM	--	--	--	--	--	--
Salix spp.	GR	20.0	23.5	5.3	40.0	20.8	3.3
	RC	20.0	8.6	1.9	26.7	15.2	2.9
	RM	46.7	33.2	4.9	--	--	--
	CM	73.3	25.2	2.9	10.0	19.1	6.0
Shepherdia canadensis	GR	66.7	9.2	1.1	46.7	9.5	1.4
	RC	30.0	5.7	1.0	46.7	2.0	0.3
	RM	53.3	0	0	73.3	23.5	2.7
	CM	--	--	--	--	--	--

1 - GR = Ghost River, RC = Rock Creek, RM = Ram Mountain, CM = Cadomin Mountain.
2 - Percent of twigs (current annual growth) browsed for all individuals of each species measured.
3 - Mean utilization (%) / $\sqrt{\text{frequency (\%)}}$.

species identified in the four study areas. The preference index value (P.I.) is a measure of the relative utilization of each shrub species. It is a modification of the preference index value used by Stelfox (1976).

The most preferred species in the burned sites was Populus tremuloides, with a mean P.I. value of 8.05 for the four study areas. Salix spp. also had relatively high P.I. values in all the study sites, both burned and unburned. Other species which showed high P.I. values included Rosa acicularis, Potentilla fruticosa, and Populus balsamifera. Juniperus communis and Shepherdia canadensis appeared to be the least preferred browse species.

Mean P.I. values of shrubs for the four study areas were generally lower in the unburned sites for all species except Betula glandulosa and Shepherdia canadensis. results indicate, therefore, that ungulate use of brow species is generally higher in the burned sites suggesting a preference for these sites over adjacent unburned sites.

5.3.2 Fecal Pellet Group Counts

Fecal pellet group counts were ade in 4 x 25 m plots located along each 25 m secondary transect in the burned and unburned sites of the four study areas. In add io to bighorn sheep pellet groups, the number of pellet grou of deer, elk and moose were also recorded. As re rted previously (Methods section), some difficulty was encountered in distinguishing between bighorn sheep and deer pellet groups in some instances. Although this problem was resolved in most cases by using shape, size, and texture of individual fecal pellets as criteria, it was necessary at times to make a somewhat subjective decision based on habitat type. One realizes the limitations of this procedure, but for the purpose of the data analysis employed and the objectives of the study, it was necessary to distinguish as accurately as possible between the pellet groups of bighorn sheep and deer.

Since the sample plots were not cleared of fecal matter prior to sampling, the numbers of pellet groups recorded in each plot represent an accumulation in excess of one year. The number of pellet groups recorded per plot, however, do indicate the relative utilization pressure on a particular site over several years, which is sufficient to fulfill the objectives of the study. No attempt was made to use the pellet group data to calculate range carrying capacities or ungulate densities in this study. The basic assumptions of the analyses used were: 1) pellet group densities were indicative of relative site utilization, and 2) the rate of decomposition of pellet groups was constant between burned and unburned sites and among study areas.

Pellet group densities (pellet groups/ha) for bighorn sheep, deer, elk and moose are shown for each burned and unburned site of the four study areas in Tables 24 to 27. To show the relationship between pellet group densities and slope position, mean pellet group densities were calculated

Table 24. Fecal pellet group densities (pellet groups/ha) of bighorn sheep, deer, elk and moose in the burned and unburned sites of the Ghost River study area.

DISTANCE FROM TREELINE (m)	BURNED SITE				DISTANCE FROM TREELINE (m)	UNBURNED SITE			
	BIGHORN SHEEP	DEER	ELK	MOOSE		BIGHORN SHEEP	DEER	ELK	MOOSE
0 - 100	133	0	0	0	0 - 100	67	33	0	0
100 - 200	133	0	0	0	100 - 200	0	100	0	0
200 - 300	67	67	0	0	200 - 300	0	167	0	0
300 - 400	33	33	0	0	300 - 400	0	167	0	33
400 - 500+	0	167	0	0	400 - 500	0	133	0	0
MEAN	73	53	0	0	MEAN	13	120	0	7

Table 25. Fecal pellet group densities (pellet groups/ha) of bighorn sheep, deer, elk and moose in the burned and unburned sites of the Rock Creek study area.

DISTANCE FROM TREELINE (m)	BURNED SITE				DISTANCE FROM TREELINE (m)	UNBURNED SITE			
	BIGHORN SHEEP	DEER	ELK	MOOSE		BIGHORN SHEEP	DEER	ELK	MOOSE
0 - 100	967	0	0	0	0 - 100	200	0	0	0
100 - 200	100	0	0	0	100 - 200	33	0	167	0
200 - 300	33	0	0	0	200 - 300	100	0	0	0
300 - 400	33	0	0	0	300 - 400	0	0	33	0
400 - 500+	33	0	0	0	400 - 500	0	33	0	0
MEAN	233	0	0	0	MEAN	67	7	40	0

Table 26. Fecal pellet group densities (pellet groups/ha) of bighorn sheep, deer, elk and moose in the burned and unburned sites of the Ram Mountain study area.

DISTANCE FROM TREELINE (m)	BURNED SITE				DISTANCE FROM TREELINE (m)	UNBURNED SITE			
	BIGHORN SHEEP	DEER	ELK	MOOSE		BIGHORN SHEEP	DEER	ELK	MOOSE
0 - 100	600	0	0	0	0 - 100	--	--	--	--
100 - 200	700	0	0	0	100 - 200	--	--	--	--
200 - 300	433	133	0	33	200 - 300	--	--	--	--
300 - 400	67	233	0	0	300 - 400	--	--	--	--
400 - 500+	0	200	0	67	400 - 500	--	--	--	--
MEAN	360	113	0	20	MEAN	--	--	--	--

Table 27. Fecal pellet group densities (pellet groups/ha) of bighorn sheep, deer, elk and moose in the burned and unburned sites of the Cadomin Mountain study area.

DISTANCE FROM TREELINE (m)	BURNED SITE				DISTANCE FROM TREELINE (m)	UNBURNED SITE			
	BIGHORN SHEEP	DEER	ELK	MOOSE		BIGHORN SHEEP	DEER	ELK	MOOSE
0 - 100	0	0	667	0	0 - 100	167	167	467	0
100 - 200	33	0	33	0	100 - 200	0	100	0	0
200 - 300	167	67	167	0	200 - 300	0	33	0	0
300 - 400	0	0	133	0	300 - 400	0	33	33	0
400 - 500+	33	167	67	0	400 - 500	0	0	233	0
MEAN	47	47	213	0	MEAN	33	67	147	0

for plots located within each 100 meter distance interval measured from treeline to the lower perimeter of the study site. Total mean pellet group densities are also given for each ungulate species in each burned and unburned site. As reported previously, pellet group counts were not conducted in the unburned site at Ram Mountain, so no data are available for that site.

Bighorn sheep mean pellet group densities were higher in the burned sites of all the study areas. Furthermore, pellet group densities were highest on the upslope areas, and decreased with increasing distance from treeline. This relationship is readily apparent in Table 28, which presents a summary of total mean pellet group densities in the burned and unburned sites of all four study areas. Figures 11 and 12 further illustrate the relationship between bighorn sheep, deer, and elk pellet group densities and distance downslope from treeline, in both the burned and unburned sites.

Deer pellet group densities were higher in all the unburned sites sampled. Deer pellet group densities were also generally higher in the downslope areas of the burned sites (Figure 11), but had a fairly even distribution with respect to slope position in the unburned sites (Figure 12).

Elk pellet groups were only recorded in the burned and unburned sites at Cadomin Mountain (Table 27) and in the unburned site at Rock Creek (Table 25). At Cadomin Mountain, elk mean pellet group density was higher in the burned site

Table 28. *Mean fecal pellet group densities (pellet groups/ha) of bighorn sheep, deer, elk and moose in the burned and unburned sites of the four study areas.*

DISTANCE FROM TREELINE (m)	BURNED SITES				DISTANCE FROM TREELINE (m)	UNBURNED SITES			
	BIGHORN SHEEP	DEER	ELK	MOOSE		BIGHORN SHEEP	DEER	ELK	MOOSE
0 - 100	425	0	167	0	0 - 100	108	50	117	0
100 - 200	242	0	8	0	100 - 200	8	92	0	0
200 - 300	175	67	42	8	200 - 300	25	50	0	0
300 - 400	33	67	33	0	300 - 400	0	58	8	8
400 - 500+	17	133	17	17	400 - 500	0	33	67	0
MEAN	178	53	53	5	MEAN	28	57	38	2

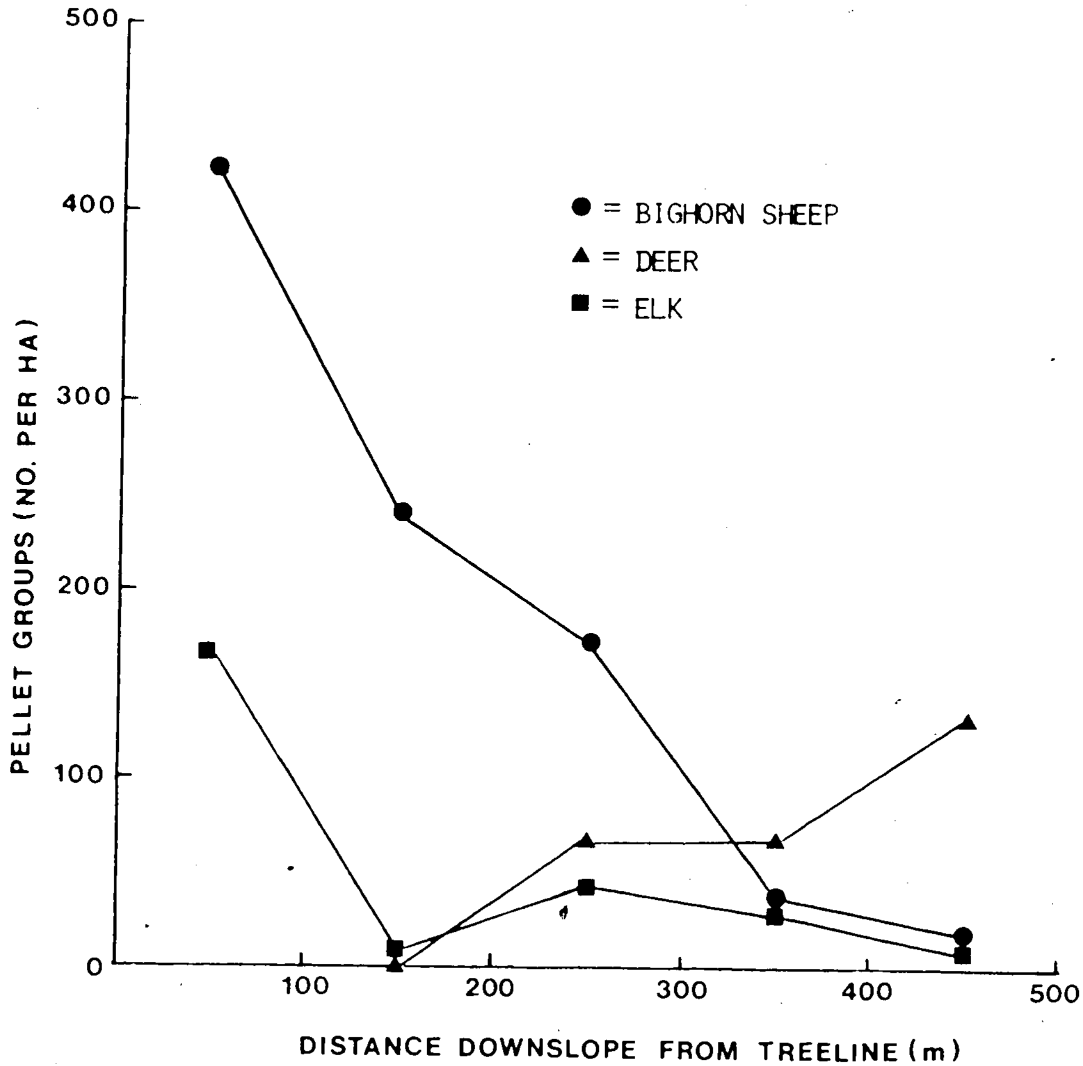

Figure 11. Mean number of pellet groups per hectare of bighorn sheep, deer and elk in relation to the distance downslope from treeline in the burned sites of the four study areas.

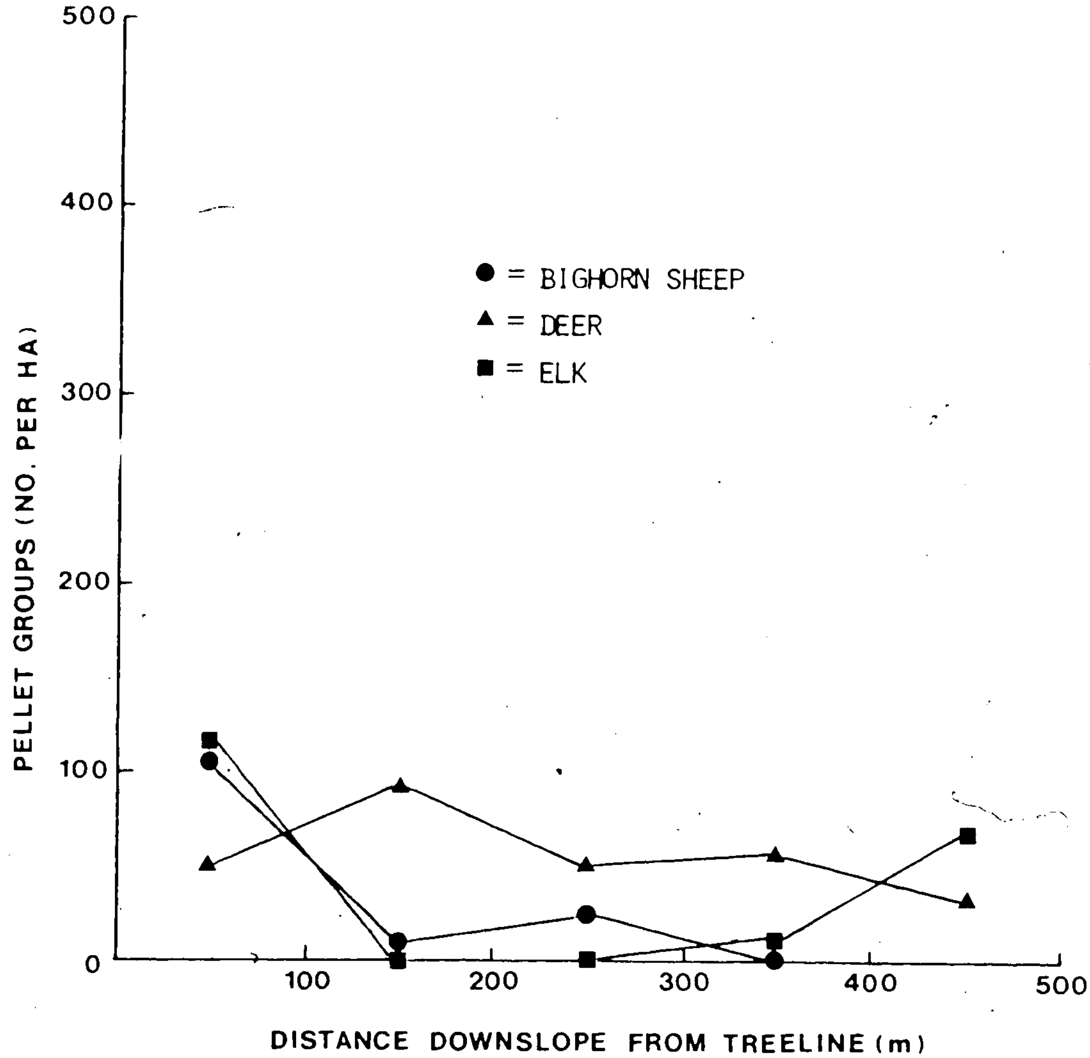

Figure 12. Mean number of pellet groups per hecta[illegible] of bighorn sheep, deer and elk in relation to the distance downslope from treeline in the unburned sites of the four study areas.

(213 vs. 147 pellet groups/ha). Elk appeared to be the most common ungulate species on both of the sites sampled. Upslope areas in both the burned and unburned sites appeared to be most heavily utilized by elk.

To determine if a relationship existed between bighorn sheep pellet group occurrence and site type, a 2 x 2 contingency table was constructed (Table 29), with data representing the numbers of plots in which bighorn sheep pellet groups were either present or absent in burned and unburned sites of the four study areas.

A Chi-square test was performed on the deviations of the observed from the expected frequencies which yielded $X^2 = 10.656$ ($p < .005$, d.f. = 1). The results indicate, therefore, that the occurence of bighorn sheep pellet groups was not independent of the site type. Conversely, the presence of bighorn sheep pellet groups was strongly associated with burned sites.

To determine if the previous results were consistent for the various study areas, Table 30 was constructed with data representing the numbers of plots in which bighorn sheep pellet groups were either present or absent in the burned and unburned site of each study area. Data for the Ram Mountain study area were not included because pellet group counts were not conducted in the unburned site.

A Chi-square test was carried out on the deviations of the observed from the expected frequencies which yielded $X^2 = 1.474$ ($0.1 < p < 0.5$, d.f. = 2). The results indicate,

Table 29. The observed frequencies of bighorn sheep pellet groups in plots in the burned and unburned sites of the four study areas.

	Burned Sites	Unburned Sites	Total
Present	30	6	36
Absent	35	34	69
Total	65	40	105

Table 30. The observed frequencies of bighorn sheep pellet groups in plots in the Ghost River, Rock Creek and Cadomin Mountain study areas.

	Ghost River	Rock Creek	Cadomin Mountain	Total
Present	9	12	5	26
Absent	21	23	20	64
Total	30	35	25	90

therefore, that the observed frequency of bighorn sheep pellet group occurrence was independent of study area location.

In summary, based on pellet group distribution measurements, the results show that bighorn sheep utilized burned sites to a greater extent than adjacent unburned sites and that this relationship was consistent for all the areas studied. It would appear, therefore, that burning has resulted in conditions which favour bighorn sheep site utilization over utilization of adjacent unburned sites.

5.3.3 Discriminant Analysis

Habitat selection and spatial distribution within specific habitat types is an expression of a complex response of animals to a number of often interdependent variables. These variables may be intrinsic, dependent on the physiological and behavioral status of the animal, or extrinsic, dependent on cues from abiotic and biotic features of the environment (Shannon et al. 1975). In previous sections it was argued, based on measurements of fecal pellet group densities, that bighorn sheep utilized burned sites to a greater extent than adjacent unburned sites. Specific conditions or factors which may influence this observed pattern of range use are difficult to isolate because of the interdependency of the range related variables involved.

Two-group discriminant analysis (Nie et al. 1975) was used, in an attempt to distinguish those variables which were most important in influencing the pattern of site utilization observed in this study. The purpose of discriminant analysis is to statistically distinguish between two or more groups of cases. Mathematically, the objective of discriminant analysis is to weight and linearly combine the discriminating variables in such fashion that the groups are forced to be as statistically distinct as possible. This is done by forming one or more linear combinations of the discriminating variables (Nie et al. 1975). A mathematical discussion of how the discriminant functions and coefficients are derived is beyond the scope of this study. Further information is available in multivariate statistics texts such as Cooley and Lohnes (1971), Harris (1975), and Green (1978).

The two groups of interest in this study were: 1) areas represented by plots in which no bighorn sheep pellet groups were found, and 2) areas represented by plots in which one or more bighorn sheep pellet groups were found. A total of 105 pellet group plots were sampled in the four study areas. Thirty-six plots contained one or more pellet groups, and 69 plots contained no bighorn sheep pellet groups.

The variables used in the discriminant analysis were: 1) distance (meters) downslope from treeline of each plot (SLOPED), 2) tree density in stems/ha (TREED), 3) snag density in stems/ha (SNAGD), 4) percent cover of graminoids (GRASSC), 5) percent cover of forbs and dwarf shrubs (FORBC), 6) percent cover of tall shrubs (SHRUBC), 7) percent cover of non-plant cover types (NPLANTC), 8) percent cover of bryoids (BRYOIDC), 9) conifer seedling density (No./ha) (SEEDLD), and 10) down and dead woody fuel loading (tonnes/ha) (FUEL). The resultant data set was an 11 x 105 matrix representing 11 variables measured on 105 plots, with bighorn sheep pellet group density as the dependent variable (Appendix 2). A summary of the statistical results associated with the discriminant function generated by the SPSS DISCRIMINANT subprogram (Nie et al. 1975) is presented in Table 31.

Table 31. Summary of the statistical results associated with the discriminant function generated by the SPSS DISCRIMINANT subprogram.

SUMMARY TABLE

STEP	ACTION ENTERED	ACTION REMOVED	VARS IN	WILKS' LAMBDA	SIG.	LABEL
1	SLOPED		1	0.847042	0.0000	
2	TREED		2	0.804310	0.0000	
3	BRYOIDC		3	0.776821	0.0000	

CLASSIFICATION FUNCTION COEFFICIENTS
(FISHER'S LINEAR DISCRIMINANT FUNCTIONS)

PELLETS =	0	1
SLOPED	0.1477782E-01	0.9728637E-02
TREED	0.8740275E-03	0.1412989E-03
BRYOIDC	0.3678403E-01	0.3792904E-02
(CONSTANT)	-3.472552	-1.588414

CANONICAL DISCRIMINANT FUNCTIONS

FUNCTION	EIGENVALUE	PERCENT OF VARIANCE	CUMULATIVE PERCENT	CANONICAL CORRELATION	:	AFTER FUNCTION	WILKS' LAMBDA	CHI-SQUARED	D.F.	SIGNIFICANCE
					:	0	0.7768207	25.633	3	0.0000
1*	0.28730	100.00	100.00	0.4724186	:					

* MARKS THE 1 CANONICAL DISCRIMINANT FUNCTION(S) TO BE USED IN THE REMAINING ANALYSIS.

STANDARDIZED CANONICAL DISCRIMINANT FUNCTION COEFFICIENTS

	FUNC 1
SLOPED	0.60508
TREED	0.51470
BRYOIDC	0.41475

CANONICAL DISCRIMINANT FUNCTIONS EVALUATED AT GROUPS MEANS (GROUP CENTROIDS)

GROUP	FUNC 1
0	0.38346
1	-0.73496

Of the variables analysed, those identified to be most important as correlates of relative site utilization (as indicated by pellet group distributions) were distance downslope from treeline (SLOPED), tree density (TREED), and percent cover of bryophytes (BRYOIDC). The statistical significance of the discriminating power of the derived function is shown by the chi-square statistic ($X^2 = 25.633$, d.f. = 3, $p < .001$) in Table 31.

The results indicate, therefore, that pellet group distribution, as a measure of relative site utilization, was dependent on distance from treeline, tree density, and bryophyte cover. The occurrence of pellet groups was highest in areas closest to treeline, with low tree density, and with low bryophyte cover. Conversely, pellet group occurrence was lowest in downslope areas, with high tree densities, and high bryophyte cover. The selection of distance downslope from treeline and tree density as discriminating variables is not surprising, given the results presented in previous sections, and reports in the literature on bighorn sheep range use patterns. Relative bryophyte cover, however is influenced by a number of variables such as overstory canopy cover, soil moisture and stand age. Relative bryophyte cover as a determinant of pellet group occurrence is, therefore, not independent of the other two discriminating variables identified. It is also probable that lower cover of herbaceous forage in areas with high bryophyte cover may have been a contributing factor in the observed distribution of pellet group occurrence.

It is not proposed that the variables used in the discriminant analysis were the only ones which could potentially influence the site utilization patterns observed in this study. Other factors such as traditional range use patterns, snow depth, distance to escape terrain, and seasonal changes in forage quality and palatability have also been shown to affect the levels and patterns of range use by bighorn sheep (Shannon et al. 1975, Stelfox 1976).

The primary benefit of fire in the areas studied appeared to be a reduction in tree density which made the sites more suitable for potential use by bighorn sheep. Other factors, such as decreased bryophyte cover and increased cover of herbaceous and shrubby vegetation, likely contributed to the increased utilization of the burned sites.

6. CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Fire has historically been an important factor in determining the quality and extent of Rocky Mountain bighorn sheep subalpine range in Alberta. Four study areas were selected (Ghost River, Rock Creek, Ram Mountain, Cadomin Mountain) to investigate differences in plant species composition and abundance and levels of bighorn sheep utilization between burned and adjacent unburned sites.

The years of the fires that occurred on the burned study sites were: 1970 for Ghost River and Rock Creek, 1921 for Ram Mountain, and 1919 for Cadomin Mountain. The maximum ages recorded for trees sampled in adjacent unburned stands were 101, 279, 299, and 192 years for the Ghost River, Rock Creek, Ram Mountain and Cadomin Mountain study areas, respectively. Available information indicates that all of the fires were of relatively high intensity, killing all of the trees present on the burned sites in each study area.

Standing snag density was still relatively high in the Ghost River and Rock Creek burned sites (1970 fires), suggesting a fairly long time interval between initial tree mortality and eventual decomposition. Most of the snags had fallen over in the older burned sites at Ram Mountain and Cadomin Mountain, but were only partially decomposed. Excessive localized concentrations of downed snags could potentially result in serious obstructions to ungulate movements for a number of years, although this was not directly observed in this study.

Mean tree stem densities in the burned sites at Ram Mountain and Cadomin Mountain were lowest in areas closest to treeline, and increased as the distance downslope from treeline increased. Mean tree densities in these two sites were considerably lower in upslope areas than in adjacent unburned sites, creating a potentially more-favorable situation for bighorn sheep site utilization. Bighorn sheep pellet group [illegible] measurements indicated that upslope areas were mo[illegible]ly utilized. It is recommended, therefore, if prescribed burning is used for bighorn sheep range improvement, that upslope areas (300 to 400 m from treeline) be the areas of primary concern. The results suggest that areas further downslope and in valley bottoms would likely not be utilized by bighorn sheep even if the tree cover was removed by burning. Distance from suitable escape terrain should be the primary factor in deciding which areas to burn and the extent of the burn downslope.

Lodgepole pine was the dominant regenerating tree species in the burned sites at Ghost River and Rock Creek. Spruce seedlings were more prevalent in the burned sites at Ram Mountain and Cadomin Mountain but were still subordinate in numbers to lodgepole pine. Low recruitment levels of conifer seedlings is generally beneficial in terms of bighorn sheep range improvement following burning, especially in mid- to upslope areas. Lodgepole pine seedling establishment is generally dependent on the presence of serotinous seed-bearing cones and the creation of suitable seedbed conditions (exposure of mineral soil). Subalpine stands with few or no lodgepole pine present in the overstory canopy, or with a large proportion of non-serotinous cones, would generally be expected to have much lower seedling recruitment levels following burning.

Species richness of vascular plants was generally higher in the burned sites of the four study areas. A large number of the plant species recorded in sample plots in each study area were common to both burned and unburned sites. The burned sites, however, always had more additional species than the unburned sites.

Total mean graminoid cover tended to be higher in all of the burned sites of the four study areas. Forb-dwarf shrub mean cover was higher in all the burned sites except Ghost River. Mean shrub cover was higher in the burned sites of all the study areas except Rock Creek. The results indicate, therefore, that available forage was generally greater in the burned sites than in adjacent unburned sites. The quality of available forage is also higher in the burned sites based on the species composition and relative abundance of preferred forage types. Although nutrient contents of forage were not measured in this study, available information suggests that forage plants growing in untreed or alpine areas are generally nutritionally superior to forage plants growing in forested areas.

All of the shrub species present in the sites studied are capable of vegetative reproduction following fire, with the exception of Juniperus communis. Shrub species which generally increased in importance included Populus balsamifera (suckers), Populus tremuloides (suckers), Rosa acicularis, Salix spp., and Shepherdia canadensis. Because of the high "survivor" component of the shrub flora, and the relatively low number of species encountered (10), it was not expected that shrub species composition would change significantly from the pre-burn species composition. Moderate increases in the abundance of some shrub species might be expected, but based on the results of this study, large increases in shrub cover would likely not occur following fire.

At least seven out of the ten most prominent herb-dwarf shrub species in each study area were common to both the burned and unburned sites. This suggests that many of the dominant plant species present in the subalpine areas studied are capable of re-establishment from surviving underground plant parts following fire. A number of species have the additional capability of invading burned sites by means of light, wind disseminated seed (Epilobium angustifolium, Arnica cordifolia). Species most susceptible to fire injury are those with shallow fibrous roots and stolons present in the surface organic mantle. Many of the important perennial forage species are deep rooted and are usually only temporarily reduced in abundance following fire. This suggests that burning will not have a serious affect on many of the dominant perennial forage species present in subalpine forest stands. In addition, burning creates conditions more suitable for the establishment and growth of herbaceous plant species which are endemic to subalpine areas but are most prevalent in open, untreed areas.

An important limitation of this study is the lack of a continuum of different aged burned sites. It was not possible to document plant species composition and abundance in a recently burned site or in sites which had been burned 10 to 60 years ago. This information would have been very helpful in providing a more thorough evaluation of both the short term and long term impacts of fire in subalpine areas. The study also was not able to determine under what conditions a burned site becomes an unburned site in terms of bighorn sheep utilization and vegetation characteristics. These problems must be left for future research.

Duff depths were significantly lower in the burned sites of all the study areas. Concentrations (kg/ha) of N, P and K, however, were higher in the soil samples collected in the burned sites of all the study areas. Soil pH was also somewhat higher in the burned sites. Reports in the literature generally indicate that nutrient gains resulting from ashing of the organic layer are usually fairly short-lived (1 to 3 years). The higher soil nutrient leve... reported in this study suggest that other factors such as increased mineralization of parent material may be responsible for the improved nutrient status in the burned sites. Surface erosion or soil slumpage did not appear to be a problem in any of the burned sites studied. However, because of the steep slopes typical in subalpine forested areas, and the relatively poor soil development, consideration of potential soil erosion problems may be necessary if prescribed burning is used in high elevation areas.

Ungulate utilization of shrubs was generally higher in the burned sites, suggesting a preference for these sit over adjacent unburned sites. The most preferred browse species were _Populus tremuloides_ and _Salix_ spp. Other shrub species which had high preference index values included _Rosa acicularis_, _Potentilla fruticosa_ and _Populus balsamifera_. _Juniperus communis_ and _Shepherdia canadensis_ appeared to be the least preferred browse species.

Bighorn sheep fecal pellet group densities were higher in the burned sites of all four study areas. Also, the occurrence of bighorn sheep pellet groups was strongly associated with burned sites, and this relationship was independent of study area location. Upslope areas (closest to treeline) had higher bighorn sheep pellet group densities in all the sites studied. These results indicate, therefore, that burning has resulted in conditions which favour bighorn sheep site utilization, compared to utilization of adjacent unburned sites.

Discriminant analysis, using ten range-related variables measured in this study, identified distance downslope from treeline, tree density, and percent cover of bryophytes as the most important correlates of bighorn sheep relative site utilization, as indicated by pellet group distributions. The results indicate that in the sites studied, relative site utilization by bighorn sheep was highest in areas closest to treeline, with low tree densities, and with low bryophyte cover.

The results of this study suggest that the primary benefit of fire in subalpine forest sites, in terms of bighorn sheep range improvement, is a reduction in the tree density, particularly in upslope areas. The reduction or elimination of tree cover introduces the potential for the use of these sites by bighorn sheep providing, that other habitat requirements such as proximity to escape terrain are present. Other contributing factors identified in this study, such as increased cover of herbaceous and shrubby forage, are viewed as secondary determinants influencing the degree of utilization of the fire-disturbed sites by bighorn sheep.

Detailed fire intensity measurements were not available for the fires that occurred on the burned study sites. Indirect evidence, however, suggests that the intensities attained by the fires were at or near the maximum probable fire intensities which occur in typical subalpine forest stands in Alberta. Prescribed fire, even under very hazardous conditions (high wind speed, high air temperature, low relative humidity, low fuel moisture content, low crown foliar moisture content) would likely not produce conditions more severe than those observed on the burned sites in this study. Therefore, the possibility of site sterilization or long term site degradation occurring as a result of prescribed burning is considered very remote providing appropriate fire prescription parameters are determined and followed.

The results of this study suggest, therefore, that prescribed burning could be an ecologically feasible tool for the establishment or maintenance of Rocky Mountain bighorn sheep range in Alberta. Large-scale burning of subalpine areas is not recommended, however, since bighorn sheep are relatively specific in their habitat requirements. Based on the results of this and other range use studies, the selection of subalpine forest sites for burning should be pursuant to the determination of specific management needs and objectives, within the perspective of the total habitat requirements of the particular bighorn sheep population.

7. FUTURE RESEARCH

This study was designed to provide ecological information about the effect of fire on the subalpine range of Rocky Mountain bighorn sheep in Alberta. Because of time and budget constraints, only four sites were studied. These constituted essentially two different times since burning, 10 years and approximately 60 years. One of the most obvious needs for future research is the documentation of vegetation and utilization parameters in fire-disturbed sites in the first years subsequent to burning. This would provide information on the initial response and availability of forage species and the degree and pattern of utilization exhibited by bighorn sheep and other ungulates present on the fire-disturbed sites. This information may be critical if justifications or guidelines for prescribed burning programs are required by land managers.

A future research program would ideally be one in which both wildlife and vegetation components were studied prior to, and after an experimental prescribed burn in a suitable subalpine site. This type of research program was initiated by the author during the course of this study. The unburned study site at Ram Mountain was selected by the author, in consultation with Alberta Fish and Wildlife and Forest Service personnel, to be prescribed burned and subsequently studied to determine both the short term and long term impacts of fire on forage quantity and quality, and the utilization patterns exhibited by the resident bighorn sheep population on Ram Mountain. The prescribed burn was initially scheduled for the fall, 1980, but unsuitable weather conditions at that time resulted in rescheduling the burn to 1981.

With so little known about the relationships between fire and its impact on bighorn sheep populations, research could progress in many directions. The most important objectives of future research, however, should be:

1. To define, document, and test the fire parameters and prescriptions most appropriate for creating or maintaining suitable high elevation subalpine bighorn sheep range.
2. To determine the effects of various heat treatments on the establishment and growth of important forage species.
3. To determine post-fire successional relationships of important forage plants and to relate these to the various direct and indirect impacts of fire on the site.
4. To document both short term and long term utilization levels and patterns exhibited by bighorn sheep and other ungulate populations on fire-disturbed sites, and to determine critical factors influencing these patterns.

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APPENDIX 1

Vegetation plot data for burned and unburned sites in each of the four study areas (Tables 1 - 8). Individual plot cover values for each species were determined by averaging the cover values recorded in each of the five, 0.5 x 0.5 m plots nested within each 2 x 5 m plot. Frequency (Freq.) represents the percentage occurrance of each species in plots per site. Mean cover (M.C.) represents the percent mean cover per site of each species. Prominence value (P.V.) was calculated using P.V. = Mean Cover (%) x $\sqrt{\text{Frequency (\%)}}$. Estimated mean cover values of less than 1% for individual species may be interpreted on the following scale: 0 - 0.10% = trace, 0.11 - 0.50% = rare, 0.51 - 1.0% = sparse.

Table 1. Vegetation plot data for the Ghost River burned study site

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9
Trees									
Picea engelmannii and glauca	-	-	-	-	-	-	0.2	-	-
Pinus contorta	-	-	-	-	3[illegible]	2	4.8	-	0.8
Shrubs									
Juniperus communis	-	-	-	-	-	-	-	-	-
Populus balsamifera	-	-	-	-	-	-	-	-	-
Populus tremuloides	-	0.6	-	0.2	-	-	2.9	0.6	-
Potentilla fruticosa	-	-	-	-	-	-	-	-	-
Rosa acicularis	-	-	3.1	1.8	-	-	-	-	3.0
Salix glauca	-	0.1	-	-	-	-	0.1	-	-
Shepherdia canadensis	14.5	5.3	-	4.2	33.8	-	-	-	3.5
Graminoids									
Carex concinna	-	0.[illegible]	-	-	-	-	-	0.4	-
Carex rossii	1.0	-	-	-	-	0.6	1.0	-	0.6
Elymus innovatus	24.6	12.6	9.8	9.8	5.8	4.2	1.8	2.0	6.4
Poa sp	-	-	-	0.6	-	-	-	-	-
Dwarf Shrubs									
Arctostaphylos uva-ursi	-	-	11.4	-	-	-	-	-	-
Linnaea borealis	-	0.8	-	5.8	3.4	-	-	1.2	3.0
Vaccinium scoparium	-	0.4	-	-	-	-	1.8	0.8	-
Forbs and pteridophytes									
Achillea millefolium	0.4	0.6	-	1.2	-	1.4	-	-	0.4
Agoseris glauca	0.2	-	-	-	-	-	-	-	-
Androsace chamaejasme	-	-	-	-	-	-	-	-	-
Anemone multifida	-	-	-	-	-	-	-	-	-
Antennaria rosea	-	-	-	-	-	-	-	-	-
Arnica cordifolia	-	-	-	1.0	0.2	-	2.0	1.8	-
Arnica latifolia	-	-	-	-	-	-	-	-	-
Aster sp	-	0.7	0.4	2.0	0.8	-	-	0.6	0.4
Campanula rotundifolia	-	-	-	-	-	-	-	-	-

Table 1 (continued)

SPECIES	PLOT NO 10	11	12	13	14	15	FREQ (%)	M.C (%)	P.V
Trees									
Picea engelmannii and glauca	-	-	-	-	-	-	7	0.01	0.03
Pinus contorta	-	2.8	-	-	-	-	3.3	0.84	4.85
Shrubs									
Juniperus communis	-	-	-	-	2.8	2.8	13	0.36	1.50
Populus balsamifera	-	-	-	-	-	1.6	7	0.11	0.30
Populus tremuloides	0.1	-	-	0.4	-	1.[illegible]	47	0.45	3.10
Potentilla fruticosa	-	-	-	-	[illegible]	3.[illegible]	[illegible]3	0.37	1.50
Rosa acicularis	5.3	-	0.7	0.1	0.4	0.2	[illegible]3	0.98	[illegible]7.20
Salix glauca	-	-	-	0.4	-	-	20	0.04	0.40
Shepherdia canadensis	2.6	6.4	5.5	4.4	1.4	-	67	5.44	44.40
Graminoids									
Carex concinna	0.6	-	-	-	-	-	13	0.07	0.28
Carex rossii	-	-	-	-	0.2	0.4	40	0.25	1.58
Elymus innovatus	5.6	4.2	6.4	10.8	2.0	0.6	100	7.10	70.80
Poa sp	-	-	-	-	0.8	-	13	0.09	0.33
Dwarf Shrubs									
Arctostaphylos uva-ursi	-	-	-	-	33.8	23.6	20	4.59	20.53
Linnaea borealis	3.8	-	-	0.4	-	-	47	1.23	8.40
Vaccinium scoparium	-	-	-	-	-	-	20	0.20	0.89
Forbs and pteridophytes									
Achillea millefolium	-	-	-	0.6	0.4	0.2	53	0.35	2.56
Agoseris glauca	-	-	-	-	-	-	7	0.01	0.03
Androsace chamaejasme	-	-	-	0.6	0.8	0.6	20	0.13	0.58
Anemone multifida	-	-	-	-	0.2	-	7	0.01	0.03
Antennaria rosea	-	-	-	-	0.2	-	7	0.01	0.03
Arnica cordifolia	-	-	-	1.8	-	-	33	0.45	2.60
Arnica latifolia	-	1.0	-	-	-	-	7	0.07	0.18
Aster sp	0.4	1.0	0.2	-	-	-	60	0.40	3.10
Campanula rotundifolia	-	-	-	-	-	0.4	7	0.03	0.08

Table 1 (continued)

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9
<u>Forbs and pteridophytes</u>									
Castilleja miniata	-	-	-	-	-	-	-	-	-
Compositae (1)	-	-	-	0.4	-	-		-	0.6
Compositae (2)	-	-	-	-	-	-	-	-	-
Epilobium angustifolium	1.4	2.0	-	5.0	0.4	3.4	7.8	6.4	0.6
Equisetum scirpoides		-	-			-	1.0		
Fragaria virginiana	-	-			-	2.0	-	-	
Gentianella amarella	-	-	0.6		-	-	0.8	-	-
Hedysarum sulphurescens	9.8	5.6	0.8		-	1.0	1.0	-	3.0
Phacelia sericea			-	-		-	-	-	
Pyrola secunda	-	-	-	-		-	-	-	-
Senecio canus	-	-	-	-	-	-	-	-	-
Solidago multiradiata		-	-	0.2	0.6	2.2	-	-	0.6
Zygadenus elegans	-	-	-	-		-		-	-

Table 1 (continued)

SPECIES	PLOT NO 10	11	12	13	14	15	FREQ (%)	M.C (%)	P.V
<u>Forbs and pteridophytes</u>									
Castilleja miniata	-	-	0.4	-	-	-	7	0.03	[illegible]
Compositae (1)	-	-	-	-	-	-	13	0.07	[illegible]
Compositae (2)	0.6	1.8	-	-	-	-	13	0.16	0.58
Epilobium angustifolium	2.4	4.4	-	5.6	-	-	73	2.[illegible]	22.82
Equisetum scirpoides	-	0.2	-	-	-	-	[illegible]	0.08	0.29
Fragaria virginiana	-	-	-	-	-	-	[illegible]	0.13	0.36
Gentianella amarella	-	-	-	-	-	-	13	0.08	0.33
Hedysarum sulphurescens	-	0.2	-	-	0.6	0.6	60	1.50	11.70
Phacelia sericea	-	-	0.2	-	-	-	7	0.01	0.03
Pyrola secunda	0.2	-	-	-	-	-	7	0.01	0.03
Senecio canus	[illegible]	-	0.2	-	0.4	-	13	0.04	0.15
Solidago multiradiata	0.[illegible]	0.2	2.4	1.2	0.4	0.2	67	0.59	4.82
Zygadenus elegans	-	-	-	-	0.2	-	7	0.01	0.03

Table 2 Vegetation plot data for the Ghost River unburned study si

SPECIES	16	17	18	19	20	21	22	23	24
Trees									
Picea engelmannii and glauca									
Shrubs									
Betula glandulosa	0.2					0.1			
Juniperus communis	8.3	2.9		6.8	3.8		1.6		
Populus tremuloides	7.[illegible]								
Potentilla fruticosa	1.9		6.6	0.5	0.7	4.5			3.0
Rosa acicularis	0.4		0.9	0.3					
Salix glauca						2.6	0.6	0.8	
Shepherdia canadensis	1.8	0.8			2.9		7.3	2.9	
Dwarf Shrubs									
Arctostaphylos uva-ursi	18.4	4.0			0.4	11.6	19.2		4.0
Linnaea borealis								22.8	
Vaccinium scoparium									
Graminoids									
Bromus pumpellianus									
Carex rossii	1.8	0.2	0.4	0.8	2.0	1.2	0.4		
Carex scirpoidea						4.0			
Elymus innovatus	4.2	7.6	3.0	3.6	4.2	6.0	8.4	2.0	8.6
Forbs and pteridophytes									
Achillea millefolium			0.4			0.8	0.6		
Agoseris glauca									
Androsace chamaejasme	0.6	0.8	0.6	0.4	0.8	1.2			
Anemone multifida		0.4							
Antennaria rosea							0.4	0.8	1.6
Arnica cordifolia							3.6	0.4	
Aster sp									
Campanula rotundifolia	0.4								
Compositae (1)								0.6	
Compositae (2)						4.4			0.6

Table 2 (continued)

SPECIES	25	26	27	28	29	30	FREQ (%)	M.C (%)	P.V
Trees									
Picea engelmannii and glauca	-	-	0.2	-	-	-	7	0.01	0.03
Shrubs									
Betula glandulosa	-	-	-	-	-	-	13	0.02	0.10
Juniperus communis	-	-	-	-	-	0.1	40	1.57	10.10
Populus tremuloides	-	-	-	-	-	-	7	0.51	1.30
Potentilla fruticosa	-	-	-	-	-	-	33	0.95	5.50
Rosa acicularis	0.4	-	-	-	-	0.6	33	0.17	1.00
Salix glauca	-	4.8	3.2	0.4	-	-	40	0.85	5.40
Shepherdia canadensis	-	-	-	10.2	-	8.5	47	2.29	15.60
Dwarf Shrubs									
Arctostaphylos uva-ursi	11.4	2.2	0.8	-	31.8	14.0	73	7.85	87.22
Linnaea borealis	-	10.6	3.2	7.6	-	-	27	2.95	15.23
Vaccinium scoparium	-	9.0	0.4	-	-	-	13	0.63	2.30
Graminoids									
Bromus pumpellianus	-	-	-	-	3.4	-	7	0.23	0.59
Carex rossii	-	-	-	-	-	-	47	0.45	3.07
Carex scirpoidea	-	-	-	-	-	-	7	0.27	0.70
Elymus innovatus	12.2	1.2	2.4	1.4	7.6	9.0	100	5.43	54.30
Forbs and pteridophytes									
Achillea millefolium	1.6	0.2	-	-	1.0	-	40	0.31	1.96
Agoseris glauca	-	-	1.0	-	2.4	-	13	0.23	0.84
Androsace chamaejasme	-	-	-	-	-	-	40	0.29	1.83
Anemone multifida	-	-	-	-	-	-	7	0.03	0.08
Antennaria rosea	-	2.0	3.4	2.2	-	0.4	7	0.04	0.10
Arnica cordifolia	-	0.6	-	-	1.2	1.4	47	0.72	4.82
Aster sp	-	-	-	-	-	-	33	0.48	2.77
Campanula rotundifolia	-	-	-	-	-	-	7	0.03	0.08
Compositae (1)	-	-	-	-	-	-	7	0.04	0.10
Compositae (2)	-	-	-	-	-	-	7	0.28	0.75

Table 2 (continued)

SPECIES	PLOT NO 16	17	18	19	20	21	22	23	24
<u>Forbs</u> <u>and</u> <u>pteridophytes</u>									
Draba aurea		-		-		-	-	-	-
Epilobium angustifolium		-	-	-	-	-	-	0.2	0.8
Equisetum scirpoides			-	-		-	-	1.2	1.8
Fragaria virginiana	-		-		0.2			-	-
Hedysarum mackenzii	-	-	-	0.8	5.2	-		-	-
Hedysarum sulphurescens	0.6	1.8		1.2	1.6	-	6.2	1.2	-
Oxytropis splendens	0.4			-	-	1.6		-	-
Penstemon confertus	-	-	-	-	-	-	0.2		-
Pyrola bracteata				-	-	-		2.4	-
Pyrola secunda	-	-	-	-		-	-	-	
Solidago multiradiata	2.0	2.2	1.8		0.6	-	-	-	-
Stenanthium occidentale	-	-		-	-	-	-	0.2	-
Zygadenus elegans	3.4	0.7	1.0	-	-	0.2	-	-	-

Table 2 (continued)

SPECIES	PLOT NO 25	26	27	28	29	30	FREQ (%)	M C (%)	P V
<u>Forbs</u> <u>and</u> <u>pteridophytes</u>									
Draba aurea	0.2	-	-	-	-	-	7	0.01	0.03
Epilobium angustifolium	-	0.8	1.4	1.2	-	-	33	0.29	1.67
Equisetum scirpoides	-	1.6	0.6	0.6	-	-	33	0.39	2.25
Fragaria virginiana	-	-	-	-	-	-	7	0.01	0.03
Hedysarum mackenzii	-	-	-	-	-	-	13	0.40	1.46
Hedysarum sulphurescens	6.8	0.4	-	-	5.8	10.2	67	2.39	19.51
Oxytropis splendens	-	-	-	-	-	-	13	0.13	0.47
Penstemon confertus	-	-	-	-	-	-	7	0.01	0.03
Pyrola bracteata	-	-	-	-	-	-	7	0.16	0.41
Pyrola secunda	-	-	-	2.4	-	-	7	0.16	0.41
Solidago multiradiata	-	-	-	-	0.4	-	33	0.47	2.71
Stenanthium occidentale	-	0.4	0.4	0.6	-	-	27	0.11	0.57
Zygadenus elegans	-	-	-	-	2.4	1.0	40	0.65	3.48

Table 3. Vegetation plot data for the Rock Creek burned study site

SPECIES	1	2	3	4	5	6	7	8	9	10	11	12
Trees												
Shrubs												
Betula glandulosa							0.2					
Populus tremoloides	0.3											
Rosa acicularis							0.4					
Salix glauca	0.3									0.7		
Shepherdia canadensis		0.8	0.3				2.8	1.3				1.8
Dwarf shrubs												
Arctostaphylos uva-ursi					1.0							
Cornus canadensis											5.6	
Linnaea borealis	27.0	3.2				0.4	5.0					
Vaccinium caespitosum												
Vaccinium scoparium											0.4	
Graminoids												
Bromus pumpellianus					4.8				1.8	3.6		
Carex concinna												
Carex rossii			3.0		0.4	1.6	3.6	1.2		0.8		
Carex sp												
Carex sp												
Elymus innovatus	[illegible]	6.4	14.4	5.6	5.4	6.8	3.8	9.2	19.0	12.4	-	15.0
Festuca sp												
Juncus sp												
Poa alpina										0.2		
Poa arctica						2.8						
Poa canbyi									1.4			
Poa interior	0.4				0.2			0.6	0.8			
Trisetum spicatum	0.4											
Forbs and pteridophytes												
Achillea millefolium			1.4	0.8	0.8		0.4	0.6	5.6	0.6	-	2.4
Aconitum delphinifolium												
Agoseris glauca		0.6	4.0	4.2	0.6			19.2	4.8			1.8
Anemone multifida												
Antennaria racemosa												
Antennaria rosea												

Table 3 (continued)

SPECIES	13	14	15	31	32	33	34	35	FREQ. (%)	M.C. (%)	P.V.
Trees											
Shrubs											
Betula glandulosa	-	-	-	-	-	8.6	11.6	-	10	1.01	3.19
Populus tremoloides	-	-	-	-	-	-	-	-	5	0.02	0.04
Rosa acicularis	-	-	-	-	-	-	-	-	5	0.02	0.04
Salix glauca	-	-	-	-	-	14.3	9.6	-	20	1.25	5.59
Shepherdia canadensis	0.1	-	-	-	-	-	-	-	30	0.35	1.92
Dwarf shrubs											
Arctostaphylos uva-ursi	-	-	-	3.4	6.0	-	-	0.6	20	0.55	2.46
Cornus canadensis	-	-	-	-	-	-	-	-	5	0.28	0.63
Linnaea borealis	-	-	-	-	-	1.4	-	-	25	1.85	9.25
Vaccinium caespitosum	-	-	-	-	-	3.8	2.2	-	10	0.30	0.95
Vaccinium scoparium	-	-	-	-	-	-	-	-	5	0.02	0.04
Graminoids											
Bromus pumpellianus	0.6	0.8	1.2	-	3.2	2.4	0.8	-	45	1.14	7.65
Carex concinna	-	-	-	0.2	-	0.8	-	-	10	0.05	0.16
Carex rossii	2.4	-	-	-	-	-	-	-	35	0.65	3.85
Carex sp	-	-	-	2.8	-	-	1.2	-	10	0.20	0.83
Carex sp	-	-	-	-	-	-	0.2	-	5	0.01	0.02
Elymus innovatus	9.8	4.8	4.4	3.2	5.4	8.2	6.0	5.0	95	7.28	71.05
Festuca sp	-	-	-	-	1.0	4.6	5.0	4.0	20	0.73	3.26
Juncus sp	-	-	-	-	-	-	0.2	-	5	0.01	0.02
Poa alpina	-	-	-	-	-	-	-	-	5	0.01	0.02
Poa arctica	-	-	-	2.0	-	-	-	-	10	0.24	0.78
Poa canbyi	-	10.0	-	1.8	-	-	-	-	15	0.66	2.56
Poa interior	-	2.6	1.2	-	-	-	-	0.6	35	0.32	1.89
Trisetum spicatum	-	-	0.8	-	-	-	-	-	10	0.06	0.19
Forbs and pteridophytes											
Achillea millefolium	3.2	13.2	3.2	-	0.2	0.8	[illegible]	1.8	75	1.81	15.88
Aconitum delphinifolium	-	-	-	-	-	1.4	0.6	0.6	15	0.14	0.54
Agoseris glauca	2.2	-	-	-	0.2	5.6	[illegible]	1.0	60	2.26	[illegible]
Anemone multifida	0.8	-	-	1.0	0.8	-	-	-	15	0.12	0.46
Antennaria racemosa	-	-	-	-	-	0.4	-	-	5	0.02	0.04
Antennaria rosea	-	-	-	-	-	-	0.8	-	5	0.04	0.09

Table 3. (continued)

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9	10	11	12
Forbs and pteridophytes												
Aquilleja flavescens	-	-	-	-	-	-	-	-	-	-	-	-
Arenaria rubella	-	-	-	-	-	-	-	-	0.4	-	-	-
Arnica cordifolia	0.2	0.2	-	-	-	0.6	-	1.0	-	-	1.8	-
Artemesia campestris	-	-	-	-	-	-	-	-	-	-	-	-
Aster sp	-	-	-	4.6	0.6	-	-	-	3.6	2.8	0.4	0.6
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	-	-	-	-	-	-	-	-	-	-	-
Delphinium glaucum	-	-	-	-	-	-	-	-	-	-	-	-
Draba aurea	-	-	-	-	0.2	-	-	-	-	-	-	-
Epilobium angustifolium	13.6	7.2	2.7	11.0	6.0	30.4	9.0	3.2	3.0	7.0	23.2	4.0
Equisetum scirpoides	1.0	-	-	-	-	-	-	-	-	-	-	-
Erigeron peregrinus	-	-	-	-	-	-	-	-	-	-	-	-
Fragaria virginiana	-	-	-	-	-	-	-	-	0.8	-	-	-
Galium boreale	-	-	-	1.2	0.2	-	-	-	2.2	1.8	-	-
Gentianella sp	-	-	0.4	-	0.8	-	0.2	1.0	-	-	-	-
Hedysarum alpinum	-	-	1.0	14.4	0.2	-	-	-	-	-	-	6.0
Myosotis alpestris	-	-	-	-	-	-	-	-	-	-	-	-
Oxytropis splendens	-	-	0.8	-	-	-	-	0.6	0.4	-	-	-
Penstemon procerus	-	-	-	-	-	-	-	-	-	-	-	1.0
Phacelia sericea	-	-	1.0	-	0.2	-	-	-	1.0	0.8	-	-
Polemonium pulcherrimum	-	-	-	0.2	-	-	-	-	-	-	-	-
Polygonum viviparum	-	-	-	-	-	-	-	-	-	-	-	-
Potentilla diversifolia	-	-	-	-	-	-	-	-	-	-	-	-
Pyrola asarifolia	-	-	-	-	-	-	-	-	-	-	-	-
Rumex alpestris	-	-	-	-	-	-	-	-	-	-	-	-
Saxifraga tricuspidata	-	-	-	-	-	-	-	-	-	-	-	-
Saxifraga sp	-	-	-	-	0.2	-	-	-	-	-	-	-
Selaginella densa	-	-	-	-	-	-	-	-	-	-	-	-
Solidago multiradiata	-	-	-	-	-	-	-	-	-	-	-	-
Stellaria longipes	-	-	-	-	2.8	-	-	-	2.2	6.6	-	-
Stellaria monantha	-	-	-	0.4	-	-	-	-	-	-	-	-
Zygadenus elegans	-	0.8	-	-	-	-	-	-	-	-	-	-

Table 3. (continued)

SPECIES	PLOT NO 13	14	15	31	32	33	34	35	FREQ (%)	M.C (%)	P.V
Forbs and pteridophytes											
Aquilleja flavescens	-	-	-	-	-	1.60	-	3.6	10	0.26	0.82
Arenaria rubella	-	-	2.4	0.8	0.6	-	-	-	20	0.21	0.94
Arnica cordifolia	0.4	-	-	-	-	7.2	1.2	1.4	45	0.89	4.83
Artemesia campestris	-	-	-	-	-	-	11.8	8.6	10	1.07	3.38
Aster sp.	1.8	0.8	1.0	4.8	0.8	-	1.2	-	60	1.13	8.75
Botrychium lunaria	-	-	-	-	-	-	-	0.2	5	0.01	0.02
Campanula rotundifolia	-	-	-	-	-	-	-	1.8	5	0.09	0.20
Delphinium glaucum	-	-	-	-	-	1.0	-	-	5	0.05	0.11
Draba aurea	-	-	-	-	-	-	-	-	5	0.01	0.02
Epilobium angustifolium	9.6	2.6	2.2	-	2.4	2.8	3.6	10.0	95	7.85	74.56
Equisetum scirpoides	-	-	-	-	-	-	-	-	5	0.05	0.11
Erigeron peregrinus	-	-	-	-	-	-	2.4	-	5	0.12	0.27
Fragaria virginiana	-	-	-	-	-	2.8	1.2	3.4	20	0.38	1.74
Galium boreale	0.2	-	-	-	-	-	-	-	25	0.27	1.35
Gentianella sp	-	-	-	-	-	-	0.4	0.2	30	0.14	0.77
Hedysarum alpinum	0.6	-	-	2.6	-	3.0	-	2.8	40	1.53	8.88
Myosotis alpestris	-	-	-	1.0	0.2	0.2	-	-	15	0.07	0.27
Oxytropis splendens	-	-	0.4	0.4	-	-	1.8	-	30	0.21	1.15
Penstemon procerus	-	-	-	-	-	-	-	-	5	0.05	0.11
Phacelia sericea	-	-	0.4	0.4	1.8	-	-	1.8	40	0.36	2.28
Polemonium pulcherrimum	-	-	-	-	-	-	-	1.0	10	0.08	0.19
Polygonum viviparum	-	-	-	-	-	0.8	0.4	0.8	15	0.10	0.39
Potentilla diversifolia	-	-	-	-	-	-	0.8	0.4	10	0.08	0.19
Pyrola asarifolia	-	-	-	-	-	-	0.8	-	5	0.04	0.09
Rumex alpestris	-	-	-	-	-	-	-	0.4	5	0.02	0.04
Saxifraga tricuspidata	-	-	-	2.0	-	-	-	-	5	0.10	0.22
Saxifraga sp	-	-	-	-	-	-	-	-	5	0.01	0.02
Selaginella densa	-	-	-	1.6	-	-	-	-	5	0.08	0.18
Solidago multiradiata	-	-	-	3.6	1.2	1.2	1.2	1.0	25	0.41	2.05
Stellaria longipes	-	4.2	5.4	0.6	-	-	0.4	0.4	40	1.12	7.08
Stellaria monantha	-	-	-	-	-	-	-	-	5	0.02	0.04
Zygadenus elegans	-	-	-	1.4	3.8	-	-	-	15	0.29	1.12

Table 4 Vegetation plot data for the Rock Creek unburned study site

SPECIES	16	17	18	19	20	21	22	23	24
				PLOT NO					
Trees									
Abies lasiocarpa	-	-	0.2	-	-	-	-	-	-
Picea engelmannii	1.0	-	0.2	-	0.4	-	0.2	-	-
Pinus contorta	-	-	0.2	-	-	-	-	-	-
Shrubs									
Betula glandulosa	-	-		-	0.4	8.6	2.5	-	-
Juniperus communis	-	0.4	-	0.7	8.0	-	1.3	3.0	8.9
Potentilla fruticosa	-	8.2	-	-	-	-	-	-	-
Rosa acicularis	-	-	-	-	-	-	-	-	-
Salix spp	-	0.4	-	-	0.2	4.2	0.7	-	-
Shepherdia canadensis	-	0.7	3.2	-	-			4.1	0.3
Dwarf Shrubs									
Arctostaphylos uva-ursi	-	5.0	1.4	-	18	1.2			3.8
Dryas hookeriana	-		-	-	0.	-	[illegible]		-
Empetrum nigrum		-	-	-			[illegible]		-
Linnaea borealis	4.0	-	8.0	-			[illegible]4	4	-
Vaccinium caespitosum	1.4	-	-	-		-	-		-
Graminoids									
Carex concinna	-	1.4	0.2	-	-			-	-
Elymus innovatus	3.8	8.2	4.4	4.2	4.4	11.6	3.8	2.6	4.8
Kobresia bellardii	-	-	-	-	-	1.6	-	-	-
Poa alpina	-	0.2	-	-	1.8	-	-	-	-
Poa interior	4.0	-	-	0.4	0.4	-	-	-	-
Forbs and pteridophytes									
Achillea millefolium	-	1.4	0.4	3.0	1.8	0.8	1.2	-	2.2
Agoseris glauca	-	-	-	-	-	7.0	0.8	-	-
Anemone multifida	-	2.0	0.6	-	0.8	1.4	-	-	0.4
Antennaria racemosa	-	-	-	-	-	-	-	-	-
Antennaria rosea	-	-	-	-	0.2	1.4	-	-	-
Arenaria rubella	-	0.4	-	0.4	-	-	-	-	-
Arnica cordifolia	-	-	13.4	-	-	-	1.0	1.2	-
Aster alpinus	-	-	-	2.4	1.8	1.0	1.0	-	1.4

Table 4 (continued)

SPECIES	25	26	27	28	29	30	FREQ (%)	M.C. (%)	P.V.
			PLOT NO						
Trees									
Abies lasiocarpa	-	-	-	-	-	-	7	0.01	0.02
Picea engelmannii	-	-	-	-	-	-	27	0.12	0.82
Pinus contorta	-	-	-	-	-	-	7	0.01	0.03
Shrubs									
Betula glandulosa	-	-	-	-	-	-	20	0.83	3.71
Juniperus communis	-	-	-	3.4	1.0	0.3	60	1.80	13.94
Potentilla fruticosa	-	-	-	-	-	-	7	0.61	1.61
Rosa acicularis	-	-	0.5	-	-	-	7	0.03	0.08
Salix spp.	-	-	-	-	-	-	27	0.37	1.82
Shepherdia canadensis	-	-	0.9	20.1	8.7	-	47	2.83	17.34
Dwarf Shrubs									
Arctostaphylos uva-ursi	26.0	-	27.8	-	-	5.8	53	5.95	43.45
Dryas hookeriana	11.0	-	-	-	-	-	13	0.76	2.78
Empetrum nigrum	-	-	-	1.4	-	-	7	0.09	0.23
Linnaea borealis	-	-	-	9.8	11.4	-	4 0	2.11	13.34
Vaccinium caespitosum	-	-	-	-	-	-	7	0.09	0.23
Graminoids									
Carex concinna	-	-	-	-	-	1.0	20	0.16	0.72
Elymus innovatus	0.6	1.6	6.0	2.8	5.8	7.6	100	2.68	46.80
Kobresia bellardii	12.2	-	-	-	-	0.2	20	0.93	4.16
Poa alpina	-	-	-	-	-	0.2	20	0.13	0.58
Poa interior	-	-	-	-	-	5.8	27	0.71	3.57
Forbs and pteridophytes									
Achillea millefolium	-	-	2.6	0.2	0.4	2.4	73	1.08	9.25
Agoseris glauca	-	-	1.0	-	-	2.6	27	0.36	1.86
Anemone multifida	-	-	-	-	-	-	33	0.36	2.02
Antennaria racemosa	-	-	-	0.8	3.8	-	13	0.31	1.13
Antennaria rosea	-	-	-	-	-	-	13	0.11	0.40
Arenaria rubella	-	-	-	-	-	-	13	0.05	0.18
Arnica cordifolia	-	-	-	4.8	3.2	0.6	40	1.63	TO 31
Aster alpinus	0.4	-	-	1.6	-	3.6	53	0.88	6.43

Table 4 (continued)

SPECIES	PLOT NO 16	17	18	19	20	21	22	23	24
Forbs and pteridophytes									
Botrychium lunaria	-	-	-	-	-	-	-	-	-
Campanula rotundifolia	-	0.8	-	-	0.2	-	-	-	-
Castilleja miniata		1.8		-		2.8	0.4	-	-
Castilleja occidentalis		-	0.8	-	0.2	-	-		-
Draba aurea		-	-	-	-	-	-	-	-
Delphinium glauca		-		-	-	0.8	-	-	-
Epilobium angustifolium	3.4		0.3	6.6	1.8	0.8	1.4	-	0.8
Equisetum arvense	-	-	-	-	-	-	-	-	-
Equistem scirpoides	0.4	-	-	-	-	-	-	-	-
Erigeron peregrinus	-	-	-	-	-	-	-	-	-
Fragaria virginiana		3.2	1.2	6.6	-	0.6	0.6	-	0.2
Galium boreale		0.6	-	1.8	0.2	-	-	-	1.6
Hedysarum alpinum	-	-	4.0	9.8	3.6	4.2	-	-	1.2
Hedysarum mackenzii	-			-	-	-		-	-
Myosotis alpestris		-	-	-	-	-	-	-	1.8
Oxytropis splendens	-	0.8		0.6	0.4	0.6	-	-	1.4
Pedicularis sp	-	-			-	-	-	-	-
Petasites palmatus	-	-			-	-	-	-	-
Phacelia sericea	-	2.0	-	-	-	-	-	-	-
Pyrola bracteata	-		-	-	-	0.2	-	-	-
Pyrola secunda	2.2	-	-	-	-		0.4	-	-
Saxifraga sp	-	-		-	-	-	-	-	-
Sedum stenopetalum	-	1.4	-	-	-	-	-	-	0.4
Solidago multiradiata	-	0.4	-	-	-	-	-	-	-
Stellaria longipes	-	0.8	-	-	-	-	-	-	0.8
Stellaria monantha	-		-	1.6	-	-	-	-	-
Zygadenus elegans	-	1.0	0.4	-	0.2	1.2	0.4	-	1.0

Table 4 (continued)

SPECIES	PLOT NO 25	26	27	28	29	30	FREQ (%)	M C (%)	P V
Forbs and pteridophytes									
Botrychium lunaria	-	-	-	-	0.2	-	7	0.01	0.03
Campanula rotundifolia	-	-	-	-	-	0.4	20	0.09	0.40
Castilleja miniata	-	-	-	-	-	-	20	0.33	1.48
Castilleja occidentalis	-	-	-	-	-	-	13	0.07	0.28
Draba aurea	-	-	-	-	-	-	7	0.01	0.03
Delphinium glauca	-	-	-	-	-	-	7	0.06	0.13
Epilobium angustifolium	-	3.6	-	-	0.4	2.4	87	1.48	11.84
Equisetum arvense	-	0.8	-	-	-	-	7	0.05	0.13
Equistem scirpoides	-	2.2	-	-	-	-	13	0.17	0.62
Erigeron peregrinus	-	-	-	-	1.4	-	7	0.09	0.23
Fragaria virginiana	-	-	1.4	0.2	3.4	3.4	87	1.38	11.35
Galium boreale	-	-	1.2	-	-	0.6	40	0.40	2.53
Hedysarum alpinum	2.2	-	2.8	2.4	3.6	0.8	67	2.31	18.88
Hedysarum mackenzii	3.6	-	-	-	-	-	7	0.24	0.82
Myosotis alpestris	-	-	-	-	-	0.4	13	0.08	0.16
Oxytropis splendens	1.8	-	0.6	-	-	5.0	53	0.76	5.48
Pedicularis sp	-	-	-	-	4.2	-	7	0.28	0.72
Petasites palmatus	-	1.0	-	-	-	-	7	0.07	0.18
Phacelia sericea	-	-	-	-	-	0.2	13	0.15	0.56
Pyrola bracteata	-	-	-	-	-	-	7	0.01	0.03
Pyrola secunda	-	-	-	-	-	-	13	0.17	0.62
Saxifraga sp	-	-	-	-	-	0.2	7	0.01	0.03
Sedum stenopetalum	-	-	-	-	-	-	13	0.12	0.44
Solidago multiradiata	0.6	-	6.4	-	-	-	20	0.49	2.19
Stellaria longipes	-	-	-	-	-	0.2	20	0.11	0.49
Stellaria monantha	-	-	-	-	-	-	7	0.11	0.28
Zygadenus elegans	0.4	-	2.6	-	-	-	53	0.48	3.51

Table 5 Vegetation plot data for the Ram Mountain burned study site

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9
Trees									
Picea engelmannii and glauca	-	-	-	0.2	-	-	-	-	-
Pinus contorta		-	-	-	-	-	-	0.4	-
Shrubs									
Alnus crispa	32.5	22.4	-	-	-	2.6	-	-	-
Amelanchier alnifolia	0.3	0.4	-	-	-	-	0.2	-	-
Juniperus communis		-	-	-	-	-	-	3.2	-
Populus balsamifera	-	-	-	-	-	-	3.5	-	-
Populus tremuloides	-	0.2	0.1	-	-	-	0.4	-	-
Potentilla fruticosa	0.3	-	-	1.1	2.3	-	-	-	-
Rosa acicularis	0.3	0.2	0.1	-	-	0.2	0.3	0.1	-
Salix spp	-	0.4	2.0	-	-	-	2.8	4.8	4.7
Shepherdia canadensis	-	-	5.4	-	-	1.0	1.1	4.4	0.1
Dwarf shrubs									
Arctostaphylos uva-ursi	-	5.2	-	0.4	0.4	-	5.4	2.4	-
Dryas hookeriana	-	-	-	22.0	3.6	-	-	-	0.8
Linnaea borealis	0.6	8.2	0.8	-	-	8.8	5.6	1.2	-
Vaccinium caespitosum	-	-	-	-	-	0.4	-	-	-
Vaccinium sp	-	-	-	-	-	2.4	-	-	-
Graminoids									
Bromus pumpellianus	-	2.4	-	-	-	-	-	-	1.4
Calamagrostis inexpansa	-	-	-	-	-	-	-	0.4	-
Carex scirpoidea	-	-	-	-	-	-	-	-	0.8
Elymus innovatus	4.5	8.8	4.2	2.0	0.4	17.2	0.6	2.8	-
Kobresia bellardii	-	1.4	-	6.2	8.4	2.0	1.0	1.8	2.2
Poa alpina	-	-	0.2	-	0.8	-	-	0.2	0.2
Poa palustris	-		0.4	-	-	-	-	0.4	1.0
Forbs and pteridophytes									
Achillea millefolium	-	0.8	0.8	-	-	0.2	0.2	0.4	0.2
Agoseris glauca	-	0.2	1.2	-	-	0.6	-	-	-

Table 5 (continued)

SPECIES	PLOT NO 10	11	12	13	14	15	FREQ (%)	M.C. (%)	P.V.
Trees									
Picea engelmannii and glauca	-	-	1.6	-	-	-	13	0.12	0.44
Pinus contorta	-	-	-	1.0	8.8	-	20	0.68	3.04
Shrubs									
Alnus crispa	-	-	-	-	-	-	20	3.83	12.66
Amelanchier alnifolia	-	-	-	-	-	-	20	0.06	0.27
Juniperus communis	-	0.3	2.2	2.1	1.6	0.1	40	0.63	3.08
Populus balsamifera	-	-	-	-	-	0.1	13	0.24	0.87
Populus tremuloides	-	-	-	-	-	-	20	0.05	0.22
Potentilla fruticosa	0.1	-	1.8	1.1	2.2	0.8	53	0.65	4.73
Rosa acicularis	-	0.7	0.1	0.3	-	-	60	0.16	1.24
Salix spp	-	-	3.2	-	1.0	-	47	1.23	8.43
Shepherdia canadensis	-	7.1	19.1	-	2.8	-	53	2.73	19.81
Dwarf shrubs									
Arctostaphylos uva-ursi	37.0	9.4	9.8	15.4	17.8	7.2	73	7.36	53.03
Dryas hookeriana	4.2	-	-	-	-	0.6	33	2.08	12.01
Linnaea borealis	-	-	-	-	-	-	40	1.55	10.06
Vaccinium caespitosum	-	-	-	-	-	-	7	0.03	0.08
Vaccinium sp	-	-	-	-	-	-	7	0.16	0.41
Graminoids									
Bromus pumpellianus	2.4	-	-	0.2	-	-	27	0.43	2.22
Calamagrostis inexpansa	-	-	-	-	-	-	7	0.03	0.08
Carex scirpoidea	1.2	-	-	-	-	-	13	0.13	0.47
Elymus innovatus	1.0	4.2	3.0	1.8	1.8	1.0	93	3.55	34.39
Kobresia bellardii	2.8	-	1.8	1.8	2.2	10.2	80	2.62	23.43
Poa alpina	0.2	-	-	-	-	-	33	0.11	0.64
Poa palustris	-	-	-	-	-	-	20	0.12	0.64
Forbs and pteridophytes									
Achillea millefolium	-	0.2	0.4	0.2	0.4	0.4	73	0.28	2.48
Agoseris glauca	-	-	0.8	-	-	-	27	0.17	0.88

Table 5 (continued)

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9
Forbs and pteridophytes									
Androsace chamaejasme	-	-	0.2	0.6	1.0	-	0.6	0.2	0.4
Anemone multifida	-	0.2	0.6	-	-	-	0.2	1.2	-
Anemone parviflora	-	-	-	0.4	-	-	0.4	-	0.6
Antennaria umbrinella	-	-	0.2	0.6	0.4	-	-	-	-
Arenaria sp.	-	-	-	-	-	-	0.2	-	0.2
Arnica cordifolia	1.6	-	-	-	-	1.6	-	-	-
Aster alpinus	4.6	10.8	5.4	1.8	-	3.8	2.4	-	-
Campanula rotundifolia	-	0.6	-	0.4	-	-	0.2	0.4	-
Castilleja occidentalis	-	-	-	0.2	-	-	-	0.6	-
Clematis columbiana	-	-	-	-	-	1.2	-	-	-
Epilobium angustifolium	2.0	-	-	-	-	-	-	-	-
Fragaria virginiana	-	0.2	1.2	3.0	-	2.4	-	2.0	-
Galium boreale	-	2.0	2.8	1.8	-	0.4	2.0	2.8	1.8
Gentianella amarella	-	0.2	-	-	-	0.2	-	-	-
Habenaria viridis	-	-	-	-	-	-	-	0.4	-
Hedysarum alpinum	-	0.2	6.2	2.8	1.0	-	-	2.8	-
Hedysarum mackenzii	-	-	-	-	1.2	-	-	-	-
Mimulus guttatus	-	-	-	0.2	0.2	-	0.2	-	-
Oxytropis sericea var. spicata	-	-	-	0.6	0.6	-	-	-	-
Polygonum viviparum	-	-	-	-	0.6	-	-	-	0.2
Pyrola secunda	0.4	-	-	-	-	0.4	-	-	-
Scrophulariaceae sp	-	-	-	0.6	-	-	-	0.2	-
Selaginella densa	-	-	-	-	1.0	-	-	-	1.0
Senecio canus	-	-	-	-	-	-	-	-	-
Senecio lugens	-	-	-	-	-	-	-	-	-
Silene acaulis	-	-	-	-	0.6	-	-	-	-
Solidago multiradiata	-	-	1.6	2.8	1.6	-	1.6	-	2.2
Stenanthium occidentale	-	-	-	-	-	0.4	-	-	-
Zygadenus elegans	1.4	4.0	1.0	2.8	1.4	2.2	2.8	1.2	0.8

Table 5 (continued)

SPECIES	PLOT NO 10	11	12	13	14	15	FREQ (%)	M.C. (%)	P.V
Forbs and pteridophytes									
Androsace chamaejasme	0.6	-	0.2	1.4	-	1.6	67	0.45	3.67
Anemone multifida	0.4	-	0.8	0.6	1.8	-	53	0.39	2.65
Anemone parviflora	-	-	-	-	-	-	20	0.09	0.40
Antennaria umbrinella	-	-	-	-	-	-	20	0.08	0.35
Arenaria sp.	0.2	-	-	-	-	0.4	27	0.07	0.38
Arnica cordifolia	-	-	-	-	-	-	13	0.21	0.77
Aster alpinus	-	4.2	4.8	2.8	3.4	-	67	2.81	23.78
Campanula rotundifolia	0.2	-	-	0.2	-	-	40	0.13	0.82
Castilleja occidentalis	-	-	-	-	-	-	13	0.05	0.18
Clematis columbiana	-	-	-	-	-	-	7	0.08	0.21
Epilobium angustifolium	-	-	-	-	-	-	7	0.13	0/34
Fragaria virginiana	0.2	-	-	-	-	0.2	47	0.81	4.17
Galium boreale	-	1.0	1.8	1.0	2.0	0.2	80	1.30	11.83
Gentianella amarella	0.2	-	0.4	-	-	-	27	0.07	0.36
Habenaria viridis	-	-	-	-	-	-	7	0.03	0.08
Hedysarum alpinum	-	1.6	1.6	-	3.0	-	53	1.27	9.27
Hedysarum mackenzii	1.6	-	-	0.8	-	-	20	0.24	1.07
Mimulus guttatus	-	-	-	-	-	-	20	0.04	0.18
Oxytropis sericea var. spicata	-	-	-	-	-	-	13	0.08	0.29
Polygonum viviparum	-	-	-	-	-	-	13	0.05	0.18
Pyrola secunda	-	-	-	-	-	-	13	0.05	0.18
Scrophulariaceae sp	0.4	-	-	-	-	-	20	0.08	0.36
Selaginella densa	-	-	-	-	-	2.2	20	0.28	1.25
Senecio canus	-	-	-	0.4	0.8	-	13	0.08	0.29
Senecio lugens	0.4	2.4	-	-	-	-	13	0.19	0.89
Silene acaulis	-	-	-	-	-	-	7	0.04	0.10
Solidago multiradiata	0.6	-	-	1.4	0.4	3.0	60	1.01	7.82
Stenanthium occidentale	-	-	-	-	-	-	7	0.03	0.08
Zygadenus elegans	0.8	-	3.2	-	2.4	1.8	87	1.69	15.73

Table 6. Vegetation plot data for the Ram Mountain unburned study site

SPECIES	16	17	18	19	20	21	22	23	24
				PLOT NO.					
Trees									
Abies lasiocarpa	-	-	-	-	-	-	1.8	-	-
Picea engelmannii and glauca	-	-	-	1.4	-	-	3.8	-	-
Shrubs									
Juniperus communis	-	2.3	2.1	-	-	2.6	0.8	-	2.5
Potentilla fruticosa	-	0.1	0.3	0.5	0.6	0.3	-	1.0	0.1
Rosa acicularis	-	-	-	-	-	-	0.1	-	-
Shepherdia canadensis	-	4.9	7.4	0.2	-	2.7	0.3	1.0	-
Dwarf Shrubs	-	-	-	-	2.6	0.8	0.9	-	
Arctostaphylos uva-ursi	-	-	-	0.3	-	-	-	0.5	1.9
Dryas hookeriana	-	-	-	-	-	-	-	-	-
Linnaea borealis	2.0	-	-	-	-	-	-	-	-
Graminoids									
Carex atrosquama	-	-	-	-	-	-	-	0.3	-
Carex scirpoidea	-	-	-	-	0.4	-	-	-	-
Elymus innovatus	7.2	1.7	3.0	22.3	2.5	0.5	12.2	-	3.0
Festuca brachyphylla	-	-	-	-	-	-	-	0.1	-
Kobresia bellardii	-	0.2	1.5	1.6	-	0.1	0.7	4.1	0.1
Poa alpina	-	-	-	-	-	-	-	-	-
Poa palustris	-	-	-	-	0.7	-	-	-	0.1
Forbs and pteridophytes									
Achillea millefolium	-	-	-	-	-	0.1	-	-	-
Agoseris glauca	-	-	-	-	-	-	-	-	0.3
Androsace chamaejasme	-	-	0.2	0.8	1.3	-	0.9	1.1	0.1
Antennaria umbrinella	-	-	-	-	0.5	-	-	-	-
Arenaria rubella	-	0.1	-	-	1.0	-	-	-	-
Arnica cordifolia	2.9	-	-	-	-	-	-	-	-
Aster alpinus	-	-	0.3	2.3	1.1	1.3	0.1	-	-
Campanula rotundifolia	-	-	-	-	-	-	-	0.7	0.1

Table 6 (continued)

SPECIES	25	26	27	28	29	30	FREQ (%)	M.C (%)	P.V
				PLOT NO.					
Trees									
Abies lasiocarpa	-	1.8	-	-	-	-	13	0.23	0.84
Picea engelmannii and glauca	-	-	-	-	11.6	-	20	1.12	5.01
Shrubs									
Juniperus communis	0.2	0.7	5.7	9.0	2.7	-	67	1.91	15.83
Potentilla fruticosa	0.1	-	0.2	-	0.3	-	67	0.23	1.88
Rosa acicularis	-	-	-	-	-	-	7	0.01	0.03
Shepherdia canadensis	0.3	0.7	3.1	0.8	0.1	-	73	1.43	12.22
Dwarf Shrubs	-	-	-	-	2.6	0.8	0.9	-	
Arctostaphylos uva-ursi	0.5	1.0	-	-	-	-	33	0.28	1.82
Dryas hookeriana	-	-	-	-	0.8	-	7	0.05	0.13
Linnaea borealis	-	-	-	-	-	-	7	0.13	0.34
Graminoids									
Carex atrosquama	-	-	-	-	-	-	7	0.02	0.05
Carex scirpoidea	-	-	-	-	-	-	7	0.03	0.08
Elymus innovatus	5.4	8.7	9.1	1.9	1.4	3.9	93	5.52	53.33
Festuca brachyphylla	-	-	-	-	-	-	7	0.01	0.03
Kobresia bellardii	-	0.8	0.2	1.2	1.8	1.0	80	0.89	7.96
Poa alpina	-	-	-	-	0.2	-	7	0.01	0.03
Poa palustris	-	-	-	-	-	-	13	0.05	0.18
Forbs and pteridophytes									
Achillea millefolium	-	-	-	-	-	-	7	0.01	0.02
Agoseris glauca	-	-	-	-	-	0.4	13	0.05	0.18
Androsace chamaejasme	-	0.9	0.1	0.1	0.7	0.5	73	0.46	3.85
Antennaria umbrinella	-	-	-	-	-	-	7	0.03	0.08
Arenaria rubella	-	-	-	-	0.2	-	20	0.09	0.40
Arnica cordifolia	-	-	-	-	-	-	7	0.19	0.49
Aster alpinus	-	-	0.4	-	-	-	40	0.37	2.34
Campanula rotundifolia	-	-	0.1	-	0.4	-	27	0.09	0.46

Table 6 (continued)

SPECIES	PLOT NO 16	17	18	19	20	21	22	23	24
Forbs and pteridophytes									
Delphinium glaucum	0.7	-	-	-	-	-	-	-	-
Epilobium angustifolium	2.4	-	-	-	-	-	-	-	-
Fragaria virginiana	0.4	-	-	0.2	-	1.4	4.5	0.1	-
Galium boreale	0.2	-	0.9	0.1	-	0.3	1.3	0.8	1.7
Gentianella amarella	-	-	-	0.1	-	-	0.2	-	-
Hedysarum alpinum	-	-	1.4	2.8	1.4	0.5	2.0	2.0	1.6
Hedysarum mackenzii	-	-	-	-	-	-	-	-	0.1
Mertensia paniculata	1.2	-	-	-	-	-	-	-	-
Moneses uniflora	0.3	-	-	-	-	-	-	-	-
Oxytropis deflexa	-	-	-	-	-	-	-	0.1	-
Oxytropid sericea var. spicata	-	-	0.1	0.5	1.3	-	-	1.5	0.3
Polygonum viviparum	-	-	-	-	-	-	-	0.3	-
Pyrola secunda	0.3	-	-	-	-	-	-	-	-
Sedum rosea	-	-	-	-	-	-	-	0.1	-
Senecio canus	-	-	-	-	-	-	-	-	-
Senecio lugens	1.9	-	-	-	-	-	-	-	-
Silene acaulis	-	-	-	-	-	-	-	0.1	-
Solidago multiradiata	-	0.1	0.8	0.3	2.3	0.2	1.2	2.8	2.1
Stenanthium occidentale	0.5	-	0.1	-	-	-	-	-	-
Zygadenus elegans	-	-	-	-	-	0.1	-	0.2	-

Table 6 (continued)

SPECIES	PLOT NO 25	26	27	28	29	30	FREQ (%)	M.C. (%)	P.V.
Forbs and pteridophytes									
Delphinium glaucum	-	-	0.3	-	-	-	13	0.07	0.25
Epilobium angustifolium	-	0.2	-	-	-	-	13	0.07	0.82
Fragaria virginiana	-	4.0	3.5	-	-	-	47	0.94	3.42
Galium boreale	0.1	1.2	0.4	0.3	-	0.2	80	0.50	4.47
Gentianella amarella	-	0.7	0.4	-	0.1	-	33	0.10	0.58
Hedysarum alpinum	0.5	0.8	0.4	2.3	5.7	2.4	87	[illegible].55	14.52
Hedysarum mackenzii	-	-	-	-	-	-	7	0.01	0.03
Mertensia paniculata	-	0.3	-	-	-	-	13	0.10	0.37
Moneses uniflora	-	-	-	-	-	-	7	0.02	0.05
Oxytropis deflexa	-	-	-	-	-	-	7	0.01	0.03
Oxytropid sericea var. spicata	-	-	-	0.2	1.1	-	47	0.33	2.25
Polygonum viviparum	-	-	-	-	-	-	7	0.02	0.03
Pyrola secunda	-	2.4	0.2	-	-	-	20	0.19	0.85
Sedum rosea	-	-	-	-	-	-	7	0.01	0.03
Senecio canus	-	1.0	2.4	-	-	-	13	0.23	0.84
Senecio lugens	-	-	-	-	-	-	7	0.13	0.34
Silene acaulis	-	-	-	-	-	-	7	0.01	0.03
Solidago multiradiata	1.2	-	0.2	0.9	-	4.2	80	1.07	9.57
Stenanthium occidentale	-	-	-	0.7	-	-	20	0.08	0.40
Zygadenus elegans	-	-	-	0.1	-	-	20	0.03	0.13

Table 7. Vegetation plot data for the Cadomin Mountain burned study site

SPECIES	1	2	3	4	5	6	7	8	9
Trees									
Picea engelmannii and glauca	-	-	-	-	-	-	-	-	-
Pinus contorta	4.0	13.6	-	2.0	-	0.4	-	0.4	-
Shrubs									
Betula glandulosa	-	-	-	-	4.8	-	-	-	-
Juniperus communis	-	-	1.2	0.1	-	-	0.6	0.2	-
Populus tremuloides	-	0.1	-	-	-	-	-	-	-
Potentilla fruticosa	-	-	-	-	-	-	-	-	-
Salix spp	3.3	-	1.1	8.6	1.0	4.2	0.8	1.2	2.4
Dwarf Shrubs									
Arctostaphylos uva-ursi	1.0	5.8	-	-	-	-	4.2	-	34.8
Cassiope tetragona	-	-	-	-	0.6	-	-	-	-
Cornus canadensis	-	0.8	1.8	-	-	3.8	4.0	0.2	-
Dryas hookeriana	-	-	-	-	15.0	-	-	-	-
Empetrum nigrum	3.2	-	-	-	-	-	-	-	-
Linnaea borealis	4.6	16.8	-	-	-	-	-	-	-
Salix arctica	-	-	-	-	1.6	-	-	-	-
Vaccinium membranaceum	-	3.2	0.8	-	-	0.4	8.2	1.6	0.4
Vaccinium vitis-idaea	-	1.0	8.8	10.6	13.8	1.8	-	-	-
Graminoids									
Agrostis scabra	-	-	-	-	-	0.2	-	-	-
Agrostis variabilis	-	-	0.4	-	-	-	-	0.2	0.2
Calamagrostis lapponica	-	-	-	-	-	0.2	-	1.8	-
Carex rossii	-	-	0.4	0.2	1.2	0.2	6.8	0.6	-
Gramineae (1)	-	-	-	-	0.4	-	-	-	-
Gramineae (2)	-	-	-	0.8	-	-	-	-	-
Gramineae (3)	-	-	-	-	-	-	-	-	0.4
Elymus innovatus	1.2	1.6	2.2	2.8	-	0.6	-	0.4	4.6
Festuca brachyphylla	-	-	0.2	-	-	2.0	1.2	0.8	0.8
Kobresia bellardii	-	-	-	-	-	-	-	-	-
Poa interior	-	-	-	-	-	1.2	0.2	-	-
Trisetum spicatum	-	-	-	-	-	0.4	1.8	1.0	1.2

Table 7. (continued)

SPECIES	25	26	27	28	29	30	FREQ (%)	M C (%)	P V
Trees									
Picea engelmannii and glauca	-	0.4	-	-	-	-	7	0.03	0.08
Pinus contorta	-	0.2	2.8	-	-	-	47	1.58	10.66
Shrubs									
Betula glandulosa	-	-	1.9	2.5	-	-	20	0.60	2.68
Juniperus communis	-	-	-	-	-	-	27	0.14	0.73
Populus tremuloides	-	-	-	-	-	-	7	0.01	0.02
Potentilla fruticosa	-	-	-	-	-	0.4	7	0.03	0.08
Salix spp	-	-	3.2	6.2	1.1	-	73	2.05	17.52
Dwarf Shrubs									
Arctostaphylos uva-ursi	-	-	-	-	-	-	27	3.05	15.78
Cassiope tetragona	-	-	-	-	-	-	7	0.04	0.10
Cornus canadensis	-	14.6	21.0	7.4	-	-	53	3.88	28.00
Dryas hookeriana	32.8	-	-	-	25.6	16.0	27	5.96	30.78
Empetrum nigrum	-	-	-	-	-	-	7	0.21	0.54
Linnaea borealis	-	-	-	-	-	-	13	1.43	5.22
Salix arctica	0.8	-	-	-	-	-	13	0.16	0.58
Vaccinium membranaceum	-	6.6	4.2	16.2	-	-	60	2.57	19.91
Vaccinium vitis-idaea	-	0.4	-	-	-	-	40	2.81	15.24
Graminoids									
Agrostis scabra	-	-	0.4	-	-	-	13	0.04	0.08
Agrostis variabilis	-	0.6	0.4	-	-	-	33	0.12	0.69
Calamagrostis lapponica	-	-	0.6	-	-	-	20	0.17	0.78
Carex rossii	0.8	-	0.2	1.2	-	-	60	0.77	5.96
Gramineae (1)	-	-	-	-	-	-	7	0.03	0.08
Gramineae (2)	-	-	-	-	-	-	7	0.05	0.13
Gramineae (3)	0.6	-	-	-	-	-	13	0.07	0.26
Elymus innovatus	-	1.2	-	2.2	0.2	0.8	73	1.17	10.02
Festuca brachyphylla	-	-	1.4	-	0.2	0.4	53	0.44	3.21
Kobresia bellardii	0.6	-	-	-	-	0.4	13	0.07	0.28
Poa interior	-	-	0.4	-	0.4	0.4	33	0.17	0.98
Trisetum spicatum	-	0.8	2.8	2.0	-	-	47	0.59	4.03

Table 7 (continued)

SPECIES	PLOT NO 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	FREQ (%)	M C (%)	P V
Forbs and pteridophytes																		
Achillea millefolium	-	-	-	0.6	-	0.8	1.0	0.2	0.8	-	0.8	0.8	1.6	-	-	53	0.44	3.21
Aconitum delphinifolium	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	7	0.01	0.03
Agoseris glauca	-	-	-	0.2	-	-	-	0.4	0.8	-	-	-	-	-	-	20	0.07	0.31
Antennaria rosea	-	-	-	0.4	-	1.2	2.8	0.8	[illegible]	0.2	0.2	0.6	2.2	-	-	60	0.65	5.03
Arenaria rubella	-	-	-	-	-	-	-	-	-	0.6	-	-	-	0.2	0.4	20	0.08	0.38
Arnica cordifolia	-	0.4	-	-	-	-	0.4	-	0.4	-	5.2	4.0	11.2	-	-	40	1.44	9.11
Arnica alpina	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-	-	7	0.03	0.08
Artemesia norvegica	-	-	-	-	-	0.4	-	-	0.6	0.8	-	0.8	-	-	-	27	0.17	0.88
Aster sp	-	-	-	0.8	-	1.0	0.4	-	2.4	0.2	0.8	0.6	0.4	-	-	53	0.44	3.21
Botrychium lunaria	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	7	0.01	0.03
Campanula lasiocarpa	-	-	-	-	-	0.8	-	-	0.2	-	-	0.2	-	-	-	20	0.08	0.36
Campanula rotundifolia	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	7	0.04	0.10
Castilleja miniata	-	-	-	-	-	-	0.6	-	-	-	-	1.0	0.8	-	-	20	0.18	0.72
Epilobium angustifolium	-	-	2.2	3.4	1.0	1.8	4.8	0.6	1.8	-	4.8	4.2	6.6	-	0.2	73	3.10	17.88
Erigeron peregrinus	-	-	-	0.3	-	-	-	-	-	-	0.2	-	0.2	-	-	20	0.08	0.36
Fragaria virginiana	-	-	-	-	-	-	-	-	-	0.4	-	0.8	0.8	-	-	20	0.13	0.58
Gentianella amarella	-	-	-	-	0.2	0.2	-	0.4	-	0.2	0.6	0.8	-	0.2	-	47	0.17	1.16
Hedysarum alpinum	-	-	-	-	-	-	-	-	1.2	-	-	-	-	-	-	7	0.08	0.21
Lycopodium alpinum	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	7	0.07	0.18
Oxytropis splendens	-	-	-	-	-	-	-	-	0.6	1.8	-	-	-	1.0	1.2	27	0.31	1.60
Oxytropis sp	-	-	-	-	-	-	-	-	-	1.6	-	-	-	-	0.2	13	0.12	0.44
Polygonum viviparum	-	-	-	-	1.6	-	-	-	0.2	1.0	-	-	0.2	0.4	0.6	40	0.25	1.58
Potentilla nivea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	7	0.07	0.18
Saxifraga tricuspidata	-	-	-	-	0.4	-	-	-	-	1.4	-	-	-	-	1.0	20	0.18	0.85
Scorphulariaceae sp	-	-	-	0.4	-	0.6	0.2	0.2	-	-	-	0.2	-	-	-	33	0.11	0.84
Sedum stenopetalum	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	0.2	13	0.05	0.18
Selaginella densa	-	-	-	-	-	-	-	-	-	0.4	-	-	-	-	-	7	0.03	0.08
Silene acaulis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	7	0.03	0.08
Solidago multiradiata	-	-	1.0	-	1.2	1.4	2.0	0.8	1.2	-	-	1.0	-	0.2	-	53	0.59	4.31
Solidago sp	-	-	-	1.8	-	-	-	-	-	-	-	-	-	-	-	7	0.12	0.31
Stellaria sp	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	7	0.03	0.08
Zygadenus elegans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	7	0.01	0.03

Table 8. Vegetation plot data for the Cadomin Mountain unburned study site

SPECIES	PLOT NO 16	17	18	19	20	21	22	23	[illegible]
Trees									
Abies lasiocarpa		-	0.8	-	0.9	-	0.4		
Picea engelmannii				-			2.0		
Pinus contorta		0.6							
Shrubs									
Juniperus communis	0.1	1.2	1.5	-	-	0.2	1.7	0.[illegible]	0.1
Salix glauca			-		-	2.8			
Dwarf shrubs									
Cornus canadensis	9.6	0.6	1.6	[illegible]	2.4	[illegible]	[illegible]		-
Dryas hookeriana				[illegible]		[illegible]	[illegible]		-
Linnaea borealis	0.8	-		[illegible]	2.8	[illegible]	[illegible]		-
Phyllodoce glanduliflora		-		8.0					-
Salix arctica	-		-	-					
Vaccinium caespitosum		-	-				7.4		6.8
Vaccinium membranaceum	19.0	4.0	[illegible]	7.8	[illegible]	[illegible]	8.2		-
Vaccinium vitis-idaea	0.8	[illegible]	[illegible]	-		[illegible]		2.8	5.4
Graminoids									
Elymus innovatus	2.0	0.2	1.[illegible]	1.6	1.0	[illegible]	0.2	2.2	1.8
Kobresia bellardii		-		-		-	-	-	-
Poa arctica		0.2		-		-	-	-	-
Trisetum spicatum				-	-	-		-	0.7
Forbs and pteridophytes									
Arnica cordifolia	-	-	0.2	1.4	0.2	0.4	-	-	0.8
Artemesia norvegica	-	-	-	-	-	-		-	-
Campanula lasiocarpa	-	-	-	-	-	-		0.4	-
Epilobium angustifolium	0.4	-	0.2	-	-	3.6		2.0	-
Gentianella amarella	-	-	-	-	-	-		-	-
Hedysarum alpinum	-	-	-	-	-	-		-	-
Mertensia paniculata	-	-	-	-	-	-	-	0.6	-
Oxytropis campestris		-	-	-	-	-		-	

Table 8. (continued)

SPECIES	PLOT NO 25	26	27	28	29	30	FREQ (%)	M C (%)	P V
Trees									
Abies lasiocarpa	-	-	-	-	-	-	30	0.29	1.59
Picea engelmannii	-	-	-	-	-	-	10	0.20	0.63
Pinus contorta	-	-	-	-	-	-	10	0.06	0.19
Shrubs									
Juniperus communis	-	-	-	-	-	-	70	0.36	3.01
Salix glauca	-	-	-	-	-	-	10	0.19	0.60
Dwarf shrubs									
Cornus canadensis	-	-	-	-	-	-	60	1.90	14.72
Dryas hookeriana	28.6	-	-	-	-	-	10	2.86	9.04
Linnaea borealis	-	-	-	-	-	-	50	2.66	18.81
Phyllodoce glanduliflora	-	-	-	-	-	-	10	0.90	2.85
Salix arctica	2.4	-	-	-	-	-	10	0.24	0.76
Vaccinium caespitosum	-	-	-	-	-	-	20	1.42	6.35
Vaccinium membranaceum	-	-	-	-	-	-	70	4.68	39.16
Vaccinium vitis-idaea	-	-	-	-	-	-	60	1.44	11.15
Graminoids									
Elymus innovatus	0.8	-	-	-	-	-	100	1.32	13.20
Kobresia bellardii	12.9	-	-	-	-	-	10	1.24	3.92
Poa arctica	-	-	-	-	-	-	10	0.02	0.06
Trisetum spicatum	0.6	-	-	-	-	-	20	0.08	0.36
Forbs and pteridophytes									
Arnica cordifolia	-	-	-	-	-	-	50	0.30	2.12
Artemesia norvegica	2.0	-	-	-	-	-	10	0.20	0.63
Campanula lasiocarpa	0.2	-	-	-	-	-	20	0.06	0.27
Epilobium angustifolium	0.4	-	-	-	-	-	50	0.66	4.81
Gentianella amarella	0.2	-	-	-	-	-	10	0.02	0.06
Hedysarum alpinum	5.8	-	-	-	-	-	10	0.58	1.83
Mertensia paniculata	-	-	-	-	-	-	10	0.06	0.19
Oxytropis campestris	0.6	-	-	-	-	-	10	0.06	0.19
Oxytropis splendens	1.4	-	-	-	-	-	10	0.14	0.44
Pedicularis arctica	0.4	-	-	-	-	-	10	0.04	0.13
Polygonum viviparum	5.4	-	-	-	-	-	10	0.54	1.71

Table 8 (continued)

SPECIES	PLOT NO 16	17	18	19	20	21	22	23	24
Forbs and pteridophytes									
Oxytropis splendens									
Pedicularis arctica									
Polygonum viviparum									
Potentilla nivea									
Pyrola secunda	-		-				0.4		
Saxifraga tricuspidata	-	-		-					
Senecio sp	-	-	0.4		-		-		
Solidago multiradiata	-				-		-	-	0.2
Zygadenus elegans									

Table 8 (continued)

SPECIES	PLOT NO 25	26	27	28	29	30	FREQ (%)	M C (%)	P V
Forbs and pteridophytes									
Oxytropis splendens	1.4	-	-	-	-	-	10	0.14	0.44
Pedicularis arctica	0.4	-	-	-	-	-	10	0.04	0.13
Polygonum viviperum	5.4	-	-	-	-	-	10	0.54	1.71
Potentilla nivea	0.8	-	-	-	-	-	10	0.08	0.25
Pyrola secunda	-	-	-	-	-	-	10	0.09	0.13
Saxifraga tricuspidata	0.8	-	-	-	-	-	10	0.08	0.25
Senecio sp	-	-	-	-	-	-	10	0.04	0.13
Solidago multiradiata	1.2	-	-	-	-	-	20	0.14	0.83
Zygadenus elegans	0.4	-	-	-	-	-	10	0.04	0.13

APPENDIX 2

Range variables measured in sample plots in the burned and unburned sites of the four study areas (Tables 1 to 4) and used in the two-group discriminant analysis. The key to the column headings is as follows:

SLOPED	=	distance downslope (meters) from treeline of each plot.
PELLETS	=	pellet groups per hectare of bighorn sheep (dependent variable).
TREED	=	tree density in stems/ha.
SNAGD	=	standing snag density in stems/ha.
GRASSC	=	total mean percent cover of graminoids.
FORBC	=	total mean percent cover of forbs and dwarf shrubs.
SHRUBC	=	total mean percent cover of tall shrubs.
NPLANTC	=	total mean percent cover of non-plant cover types.
BRYOIDC	=	total mean percent cover of mosses and lichens.
SEEDLD	=	conifer seedling density (number of seedlings per 2 x 5 m plot).
FUEL	=	total down and dead woody fuel loading (tonnes/ha).

Table 1. Range variables measured in the burned and unburned sites of the Ghost River study area.

SITE	PLOT	SLOPED	PELLETS	TREED	SNAGD	GRASSC	FORBC	SHRUBC	NPLANTC	BRYOIDC	SEEDLD	FUEL
Burned												
	01	444	0	0	382	25.6	11.8	14.5	62.6	0	1	62.23
	02	376	100	0	955	12.6	9.6	6.0	61.0	16.8	2	14.70
	03	268	0	0	764	9.8	13.2	3.1	74.0	0	0	16.96
	04	152	200	0	2324	10.2	15.6	5.2	62.2	12.0	3	46.81
	05	84	100	0	3533	3.8	5.4	33.8	59.4	16.4	4	14.38
	06	468	0	0	414	4.8	10.0	0	40.0	46.4	10	1.69
	07	320	0	0	1178	2.8	14.4	3.0	25.4	51.0	15	11.95
	08	276	0	0	1019	2.4	10.8	0.6	49.0	37.0	4	26.21
	09	160	100	0	700	7.0	8.6	6.5	78.0	3.2	3	2.80
	10	36	100	0	1050	6.2	8.2	8.0	51.6	27.6	3	1.27
	11	364	0	0	764	4.2	8.8	6.4	64.2	20.0	5	40.00
	12	272	0	0	286	6.4	3.4	6.2	89.2	0	0	4.96
	13	240	200	0	[illegible]91	10.8	10.2	5.3	69.0	9.0	2	22.34
	14	130	100	0	223	3.0	37.0	6.3	59.2	0	0	16.29
	15	56	200	0	0	1.0	25.6	10.2	70.2	0	0	7.27
Unburned												
	01	344	0	446	0	6.0	25.8	20.3	63.4	2.8	0	0.32
	02	240	0	1082	0	7.8	9.4	3.7	78.8	4.0	0	20.65
	03	178	0	1623	0	3.4	3.8	7.5	84.0	0	1	3.05
	04	104	0	796	0	4.4	2.4	7.3	71.2	20.0	0	5.89
	05	1[illegible]	0	1178	0	6.2	3.6	7.7	77.0	9.6	0	24.89
	06	450	0	445	0	11.2	25.0	7.2	40.4	20.0	2	4.40
	07	376	0	764	0	8.8	30.2	9.7	59.6	1.4	0	15.12
	08	244	0	1655	0	2.0	29.8	3.8	45.6	23.0	5	67.08
	09	150	0	1050	0	8.6	8.2	0	68.2	15.0	0	155.43
	10	52	200	64	0	12.2	20.6	0.4	66.2	0.6	0	101.17
	11	460	0	1719	0	1.2	27.8	[illegible].8	36.0	32.2	9	90.56
	12	400	0	1623	0	2.4	11.2	3.2	63.4	21.6	1	46.75
	13	244	0	1050	0	1.4	14.6	10.6	23.4	59.8	2	138.53
	14	176	0	191	0	11.0	45.0	0	44.0	0	0	389.77
	15	44	0	828	0	9.0	27.0	9.2	61.8	0.2	0	48.05

Table 2. Range variables measured in the burned and unburned sites of the Rock Creek study area.

SITE	PLOT	SLOPED	PELLETS	TREED	SNAGD	GRASSC	FORBC	SHRUBC	NPLANTC	BRYOIDC	SEEDLD	FUEL
Burned												
	01	550	0	0	3825	5.8	42.8	0.6	35.2	16.4	0	1.12
	02	470	0	0	5095	6.4	12.0	0.8	40.0	41.6	0	17.47
	03	310	0	0	6685	17.4	10.6	0.3	62.8	9.2	0	0
	04	200	0	0	286	5.6	36.8	0	49.6	8.0	0	1.26
	05	90	200	0	127	14.6	13.0	0	65.2	7.4	0	0.42
	06	560	0	0	573	11.2	31.4	0	36.2	21.2	0	190.80
	07	400	0	0	446	7.4	14.6	3.0	76.4	1.0	0	0
	08	320	100	0	541	8.0	25.4	1.3	64.6	1.6	0	93.72
	09	190	0	0	0	23.0	23.8	0	50.8	1.8	0	0
	10	80	900	0	32	17.0	19.2	0.7	60.4	1.0	0	2.06
	11	468	100	0	764	0	31.2	0	34.4	34.4	0	255.48
	12	360	100	0	446	15.0	15.6	1.8	46.8	22.6	0	4.13
	13	252	0	0	446	12.8	18.6	0.1	59.8	7.8	0	75.59
	14	152	200	0	0	18.2	20.8	0	58.8	2.4	0	0
	15	44	1800	0	0	7.6	15.0	0	76.4	1.0	0	0.43
	16	428	0	0	0	10.0	21.8	0	66.6	2.0	2	0.40
	17	352	0	0	266	9.6	17.6	0	51.6	21.2	0	2.01
	18	244	0	0	95	16.0	32.8	22.9	28.4	3.6	0	0.40
	19	160	100	0	0	12.2	34.4	21.2	42.4	8.2	0	1.83
	20	28	0	0	0	9.6	43.0	0	35.2	4.8	0	0
Unburned												
	01	484	0	700	0	7.8	11.4	0	41.2	38.6	2	8.69
	02	344	0	286	0	7.8	21.4	10.7	62.4	4.6	3	0.14
	03	276	0	509	0	4.6	27.0	3.2	34.8	31.2	7	0.49
	04	152	100	0	0	5.2	33.0	0.7	59.4	1.0	0	0.04
	05	60	0	95	0	6.4	29.4	8.6	48.2	16.0	1	13.76
	06	452	0	223	0	13.2	18.0	13.8	35.0	33.8	7	0.15
	07	384	0	223	0	3.8	17.6	4.5	30.6	55.6	2	1.21
	08	292	0	636	0	2.6	3.6	7.1	62.6	22.8	0	157.22
	09	168	0	32	0	4.8	16.0	9.2	64.2	11.8	0	11.31
	10	44	300	64	0	12.8	46.0	0	40.6	0	0	0
	11	460	0	414	0	1.6	7.6	0	71.4	19.4	0	184.63
	12	360	0	64	0	6.0	46.4	1.4	46.8	0	0	28.18
	13	236	300	827	0	2.8	20.8	23.5	56.2	6.0	0	23.71
	14	184	0	478	0	5.8	32.0	9.7	25.6	26.8	0	5.42
	15	84	300	159	0	14.8	28.8	0.3	55.6	0	0	0

Table 3. Range variables measured in the burned and unburned sites of the Ram Mountain study area.

SITE	PLOT	SLOPED	PELLETS	TREED	SNAGD	GRASSC	FORBC	SHRUBC	NPLANTC	BRYOIDC	SEEDLD	FUEL
Burned												
	01	452	0	3088	32	4.6	10.6	33.4	80.2	1.6	0	40.05
	02	353	0	668	0	12.6	33.6	23.6	45.2	4.6	0	24.41
	03	268	100	700	32	4.8	25.0	7.6	68.2	1.0	1	22.36
	04	144	800	637	0	8.2	40.6	1.1	45.2	3.8	2	19.28
	05	36	1000	987	0	7.6	13.6	2.3	74.8	3.4	0	0.99
	06	436	0	732	0	19.2	22.8	3.8	54.4	0	0	41.23
	07	352	200	128	64	1.6	21.6	8.1	68.1	1.2	2	11.29
	08	252	200	669	32	5.4	15.6	12.3	55.8	13.2	4	30.33
	09	144	900	191	32	5.6	8.2	4.8	78.8	1.8	0	22.32
	10	76	500	64	0	7.4	46.8	0.1	45.0	0	2	55.41
	11	420	0	5952	32	4.2	18.8	8.1	62.8	2.2	0	20.20
	12	344	0	2196	95	4.8	24.0	26.4	66.0	0.4	1	31.78
	13	244	1000	446	32	3.8	24.0	3.5	64.0	0	2	45.68
	14	168	400	796	0	4.0	32.0	7.6	44.2	0	2	4.77
	15	60	300	95	0	11.2	17.6	1.1	68.6	1.2	1	23.69
Unburned												
	01	548	-	987	255	7.2	12.9	0	31.5	49.3	14	99.66
	02	448	-	891	159	1.9	0.2	7.3	80.8	11.0	0	16.66
	03	356	-	1973	191	4.5	3.8	9.8	83.5	22.4	2	22.72
	04	184	-	478	255	23.9	7.3	0.7	64.5	3.6	11	87.07
	05	20	-	1082	64	3.6	8.9	0.6	84.1	0	0	45.76
	06	500	-	541	0	0.6	3.9	5.6	86.2	4.7	1	39.82
	07	388	-	606	127	12.9	10.2	1.2	55.3	0.6	8	75.05
	08	280	-	14532	64	4.5	10.4	2.0	72.1	12.6	1	0.41
	09	146	-	828	255	3.2	8.2	2.6	80.8	0	0	23.37
	10	60	-	1305	255	5.4	2.3	0.6	90.8	1.4	0	60.45
	11	480	-	286	95	9.5	12.3	1.4	61.4	15.3	1	128.81
	12	366	-	636	127	9.3	8.4	9.0	46.3	15.5	6	151.34
	13	224	-	987	64	3.1	4.6	9.8	67.0	24.6	1	38.99
	14	144	-	2005	64	3.4	9.0	3.1	67.3	0	0	2.48
	15	80	-	1114	191	4.9	7.7	0	75.9	12.1	0	41.39

Table 4. Range variables measured in the burned and unburned sites of the Cadomin Mountain study area.

SITE	PLOT	SLOPED	PELLETS	TREED	SNAGD	GRASSC	FORBC	SHRUBC	NPLANTC	BRYOIDC	SEEDLD	FUEL
Burned												
	01	[illegible]	0	1782	96	1.2	8.8	3.3	84.4	1.6	0	60.64
	02	[illegible]	0	637	191	1.6	28.0	0.1	56.8	0	0	38.66
	03	[illegible]	0	573	254	3.2	14.4	2.3	85.9	6.0	1	35.11
	04	160	0	64	223	3.6	19.6	6.6	51.8	15.0	3	8.60
	05	52	0	0	318	1.6	35.8	5.6	55.6	6.0	0	12.81
	06	436	100	255	191	4.8	14.0	4.2	55.4	16.6	2	54.29
	07	368	0	318	350	10.0	27.0	1.2	50.6	11.4	2	78.63
	08	276	100	286	223	4.6	5.8	1.4	78.2	8.8	8	5.73
	09	180	100	0	446	7.0	46.4	2.4	42.4	0	4	19.66
	10	52	0	0	0	2.0	42.2	0	55.0	0.8	0	0.39
	11	460	0	1814	223	2.6	34.2	0	57.6	5.0	1	46.30
	12	336	0	414	478	6.0	40.2	5.1	39.6	8.8	10	96.28
	13	268	200	796	159	4.4	48.0	8.7	41.8	4.0	0	49.96
	14	152	0	0	32	0.8	27.6	1.1	85.5	0.4	0	0
	15	68	200	0	0	2.0	21.4	0.4	76.6	0	0	0
Unburned												
	01	452	0	1145	64	2.0	26.6	0.1	30.4	38.8	8	2.51
	02	376	0	1209	127	0.4	7.8	1.2	65.0	26.4	2	11.98
	03	268	0	1241	32	1.2	8.4	1.5	50.2	38.4	32	51.36
	04	136	0	1560	64	1.6	26.8	0	42.2	29.4	6	2.08
	05	60	0	2100	223	1.0	11.0	0	72.2	6.8	0	6.74
	06	484	0	860	0	2.4	14.0	3.0	24.4	56.6	14	3.94
	07	352	0	764	191	0.2	28.0	1.7	43.6	20.8	37	21.14
	08	276	0	1178	32	2.2	5.8	0.6	61.2	5.4	1	14.80
	09	176	0	860	0	1.8	13.2	0.1	77.4	5.4	0	8.39
	10	52	500	0	0	13.8	48.2	0	32.8	3.8	0	0

END

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