THE UNIVERSITY OF ALBERTA

PRESCRIBED CROWN FIRE EFFECTS ON A SUBALPINE BIGHORN SHEEP RANGE AT RAM MOUNTAIN, ALBERTA, CANADA

by

SUSAN J. MICHALSKY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled PRESCRIBED CROWN FIRE EFFECTS ON A SUBALPINE BIGHORN SHEEP RANGE AT RAM MOUNTAIN, ALBERTA, CANADA submitted by SUSAN J. MICHALSKY in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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Date NOV - 6 1986

ABSTRACT

A prescribed fire was ignited using an aerial drip torch on May 31, 1983 as part of the Ram Mountain bighorn sheep habitat improvement program. An assessment of the effects of burning is presented in two parts: the changes in fuel and plant cover and the utilization of that burned community by an indigenous bighorn sheep herd.

The fire reduced surface fuels from 20.9 t/ha to 6.5 t/ha. However, loadings increased to 25.3 t/ha within one year following burning due to fallen trees and the deposition of dead branches. Postburn plant cover did not correlate well with fuel reduction. Most plants on site recovered following burning with the exception of trees and some shrubs. Sorensen's Index of Similarity was 47.6 one month after the May fire, but rose to 71.2 one year later indicating a rapid recovery to the preburn subordinate plant species composition. Grass and sedge cover increased from preburn levels. Forb cover decreased immediately following fire but had nearly recovered to preburn levels by 1984.

Duff depths were reduced from an average of 5.3 cm in 1979 to 2.3 cm in 1983 as a direct result of burning, but did not change significantly during the year following the fire. Most soil parameters (pH, %C, %N, K, Na, and conductivity) analyzed in the mineral soil profiles rapidly returned to preburn levels with the exception of %P which increased slightly and SO_4 which remained unchanged.

Pellet group counts indicate bighorn sheep use of the burned site was significantly increased. An average of 400 sheep pellet groups per hectare had been deposited on the site in the year following burning. In addition, the deposition of sheep pellets in the burned area was 5 times that for an adjacent control area for the same period. Although the deposition of pellets would suggest sheep are frequenting the burned area, browsing by animals has not increased significantly. Only *Elymus innovatus*, *Bromus inermis* ssp *pumpellianus*, *Hedysarum alpinum*, *Astragalus alpinus*, and *Zigadenus elegans* of the 15 species found in the exclosure plots showed signs of animal utilization.

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Lastly, I would like to acknowledge the Recreation, Parks, and Wildlife Foundation, and the Canadian Forestry Service who provided financial support for this project.

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A. GENERAL INTRODUCTION

A prescribed crown fire was aerially ignited in a subalpine spruce - fir community on Ram Mountain, Alberta on May 31, 1983. The fire was ignited by experienced personnel from the Alberta Forest Service as part of a Rocky Mountain bighorn sheep habitat improvement project initiated by the Habitat Section of the Alberta Fish and Wildlife Division and the Fire Science personnel from the Department of Forest Science at the University of Alberta. The objective was to create or improve bighorn sheep habitat which could be used in spring or fall in an attempt to lessen utilization pressure on critical winter range. This thesis project was designed to assess the effects of the 1983 prescribed crown fire on:

(1) the postburn succession of a subalpine plant community, and

(2) the response of an indigenous Rocky Mountain bighorn sheep population to conditions on the site subsequent to burning.

The thesis has been divided into two separate chapters because of the two distinct objectives. The effect of the fire and the changes in physical site properties (soils and fuel loadings) on plant succession are the central theme of chapter one. The second chapter describes use of the site by ungulates, particularily bighorn sheep, after the fire. The effects of grazing on the dominant grasses and forbs are also investigated in the second chapter.

I. CHAPTER I: POSTFIRE SUCCESSION OF A SUBALPINE PLANT COMMUNITY

A. INTRODUCTION

Fire is an important abiotic factor in determining the structure and composition of subalpine plant communities in the Rocky Mountains (Day 1972; Bollinger 1973; Alexander 1974; Peet 1981; Ives and Hanson-Bristow 1983; Shankman 1984), yet, little information exists on how individual plant species or associations in subalpine spruce - fir communities respond to fire disturbance levels. Without such information it will be difficult to accurately forecast the feasibility of using prescribed burning for habitat improvement programs or to assess values at risk when determining economic and ecologic trade-offs between natural fire regimes (Kilgore 1976; Sando 1978) and conventional total suppression policies.

The objective of this study was to document the response of a subalpine forest community to a fire. Two years of postburn vegetation and soil characteristics are compared to preburn conditions, in light of knowledge of the fire severity, in an attempt to determine how subalpine forest communities in the Rocky Mountains of Alberta respond to disturbance by fire.

B. STUDY SITE

The 18 ha study site was located on Ram Mountain (52°22'N, 115°48'W) approximately 60 km west of Rocky Mountain House, Alberta, and 25 km southeast of Nordegg, Alberta, Canada. The uppermost elevation of the burn was 1950 m, slightly below the tree limit, and the elevation at the lowest position was 1740 m. The slope gradient averaged 42% and the aspect was predominantly southwestern (Figure I.1). Soils were derived from calcareous shale and resistant Paleozoic limestones of marine origin (Erdman 1950), and were well drained owing to the slope steepness, type of parent material and the shallow organic profile of humus and partially decayed litter. The thickness of the organic soil layer varied considerably throughout the study site (Woodard *et al*. 1983). The thickest organic profiles were found under mature timber at the base of the slope. The thinnest profiles were found consistently at treeline and on microsites within the centre of the area where shale rock was exposed.

Mean monthly temperature and precipitation at 2 m above ground level for the growing season (May through September), as measured at 2100 m elevation at Kiska Lookout (approximately 28 km west of Ram Mountain), were 12°C and 71 mm, respectively (Bentz 1981). The area was characterized by extreme fluctuations in seasonal temperatures and precipitation (Ogilvie 1969). July was the only frost-free month of the year. As a result of these climatic conditions,

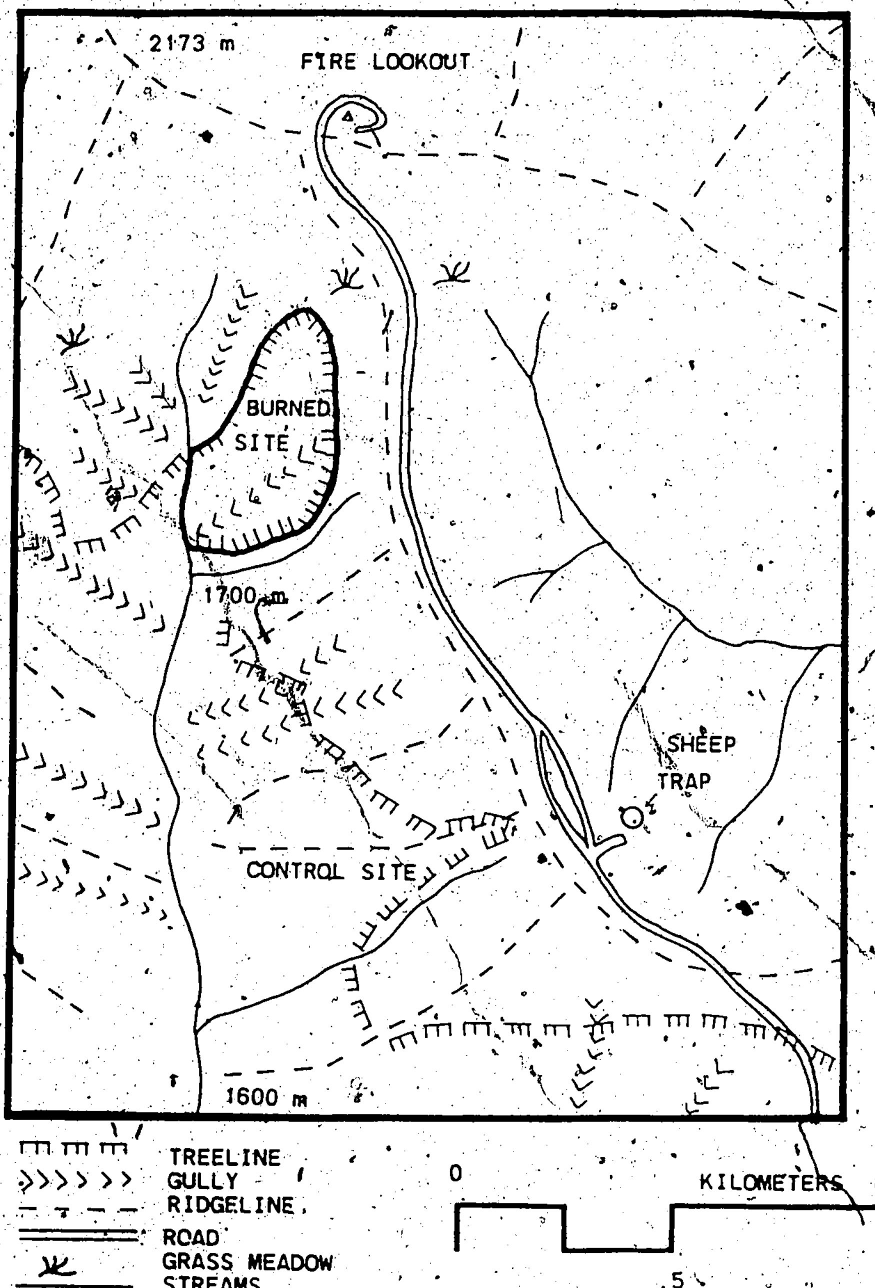

Figure 1.1. Ram Mountain study area and location of burned and control sites (extracted from Bentz 1979). Scale = 1:15,000.

the annual growth for trees was slow.

The site was dominated by white spruce (*Picea glauca*[1]) and subalpine fir (*Abies lasiocarpa*) tree cover prior to burning. The average ages of the white spruce and subalpine fir were 256 and 156 years, respectively (Bentz 1981). No fire scarred trees were found to indicate the preburn stand had originated after a fire (Bentz, 1981). The preburn surface vegetation was very sparse, covering approximately 20% of the ground area. *Elymus innovatus*, and shrub species such as: *Shepherdia canadensis*, *Potentilla fruticosa*, *Arctostaphylos uva-ursi*, *Rosa acicularis*, and *Juniperus scopulorum* contributed most to the understory cover (Bentz 1981).

The preburn and immediate postburn fuel loading, continuity and condition have been measured and described by Woodard *et al.* (1983). In general, preburn surface fuel loadings were highest in the lower 40% of the unit, where past winds had blown down a large proportion of the tree cover. Surface fuel loadings were judged not continuous or sufficiently abundant to support a crown fire. Highly flammable ladder fuels (dead needles and twigs) were absent, but live tree branches did extend almost to the ground on most stems. The actual and prescribed weather data at the time of the fire, as well as the prescription strategy and the resultant fire behavior, have been described by Woodard *et al.* (1983).

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[1] The nomenclature for vascular flora follows Moss (1983).

C. METHODS

In 1979, Bentz (1981) located three permanent baseline transects on the site burned in 1983. Two baseline transects were located on the adjacent control site in 1984. The topographic distance of the baseline transects varied from 400 to 600 m depending on the distance from treeline to the valley bottom fuel break (Rough Creek). The baseline transect locations were initially determined using aerial photographs (1:21,200; dated 05-09-73) but were slightly modified in the field due to changes in plant growth between 1973 and 1979. Criteria for locating baselines were based on a visual estimate of the uniformity of the snag and tree density and the topographic variation from treeline to valley bottom. Areas with abnormal variations in topography or distinct differences in ground cover (large rock outcrops, cliffs or talus slopes) were not sampled. The primary objective in locating baseline transects was to sample areas as uniform as possible within the study area. The length of the baseline transects and the distance between plot locations were measured using a Topoquick range finder without correction for slope angle.

Each baseline transect was divided into five segments of equal length. A secondary belt transect was then located perpendicular to the baseline in each segment using a restricted random sampling method (Figure I.2). This restriction does not bias the essential feature of this sampling procedure (Greig-Smith 1983), thus allowing the

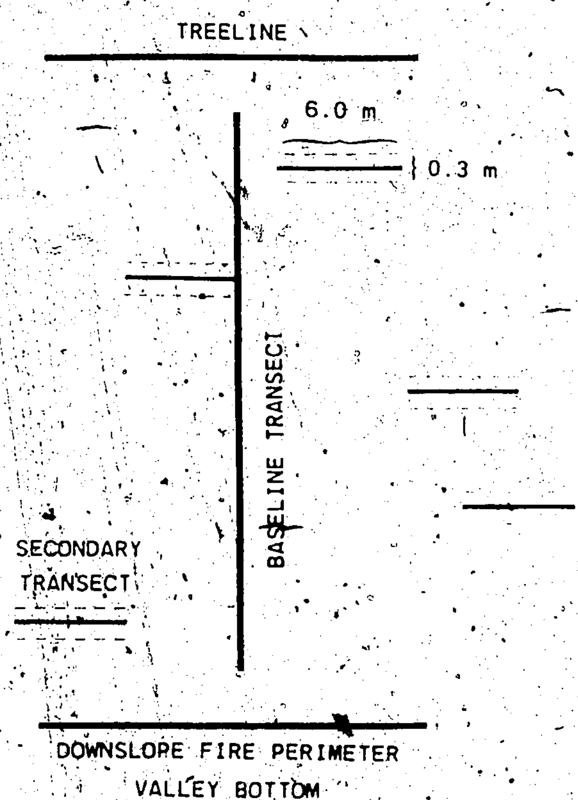

Figure I.2. Example of stratified random location of secondary transects along baseline transects.

observed variance of the data to be used as the basis of significance testing. 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 belt transect within each segment along the baseline was determined using random numbers. 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 placed to the right of the baseline. The size of each of the secondary belt transects was 0.3 by 6.0 m (Figure I.2).

DOWN AND DEAD ROUNDWOOD FUEL ANALYSIS

Estimates of down and dead roundwood fuel loadings on burned and unburned sites for all surveys were obtained using the planar intersect method (Brown 1974). Fuel loadings were determined for five roundwood diameter classes (0-0.64 cm, 0.65-2.5 cm, 2.6-7.6 cm, 7.6 cm rotten, and > 7.6 cm solid). Fuel loading estimates were obtained for each 0.3 by 0.3 m subplot by counting the number of fuel intercepts by size class for each of the twenty 0.3 m wide subplots along the 6 m plane. Oven-dry fuel weights per unit area (tonnes/ha) were calculated using the constants and equations proposed by Brown (1974) and the total number of intercepts by individual size classes < 7.6 cm in diameter (0 - 7.6 cm dia. classes) or fuel diameter (> 7.6 cm dia. classes) measurements for roundwood > 7.6 cm in diameter which were recorded along the 6 m transect. Duff/litter depths were measured at 0.3 m, 1.5 m, 3.0 m, 4.5 m, and 6.0 m along each transect.

FIRE SEVERITY

Fire severity was estimated within each of the 20 subplots by Woodard *et al.* (1983) by multiplying the total and available surface fuel loading in kg/m^2 (Byram 1959) by a heat yield value of 18,830 kJ/kg to derive potential and actual heat output values (kJ/m^2), respectively. The available surface fuel weight was calculated by subtracting the immediate postburn fuel loading estimate from the preburn fuel loading estimate (Byram 1959). Although heat yield values vary within and between fuel species, the value used in this thesis is consistent with average values proposed by Byram (1959) and Van Wagner (1972, 1973). The frontal fire intensity for the whole treatment area was calculated using flame lengths reported in Woodard *et al.* (1983) and procedures proposed by Byram (1959) or more recently by Alexander (1982).

VEGETATION ANALYSIS

Four vegetation field surveys were completed as part of this study. The first survey (preburn; Survey I) was conducted in July-August 1979 by Bentz (1981). Survey II (immediate postburn) was completed in June, 1983, with an additional survey in July-August 1983 (Survey III). The last survey was taken in July/August 1984 (Survey IV). Each vegetation survey consisted of estimating the percent cover of vascular plants by species, lichens, moss and large diameter (> 7.6 cm dia.) roundwood within each of the twenty 0.3 m by 0.3 m subplots nested within the 0.3 x 6.0 m transects (Figure I.3).

Also the percent cover of trees by height classes 0-30 cm, 31-60 cm, 61-100 cm, and 101-200 cm were also recorded within these subplots. A 0.3 by 0.3 m sampling frame divided into 50%, 25%, 15% and 10% areas was used for all surveys to estimate the percent cover of these parameters for all surveys.

Sorensen's (1948) Index of Similarity (I.S.) was used to estimate the similarity in plant species composition between surveys.

$$I.S. = (2C/A+B) \times 100 \qquad [1]$$

where: C is the number of plant species common to both surveys,

A is the total number of plant species in the first survey, and

B is the total number of plant species in the second survey.

Information pertaining to cover, frequency and prominence values, before and after burning, was used to identify which species invaded, increased, decreased and disappeared from the site after burning. The prominence value (P.V.) (Stringer and LaRoi 1970; Dube 1976) was

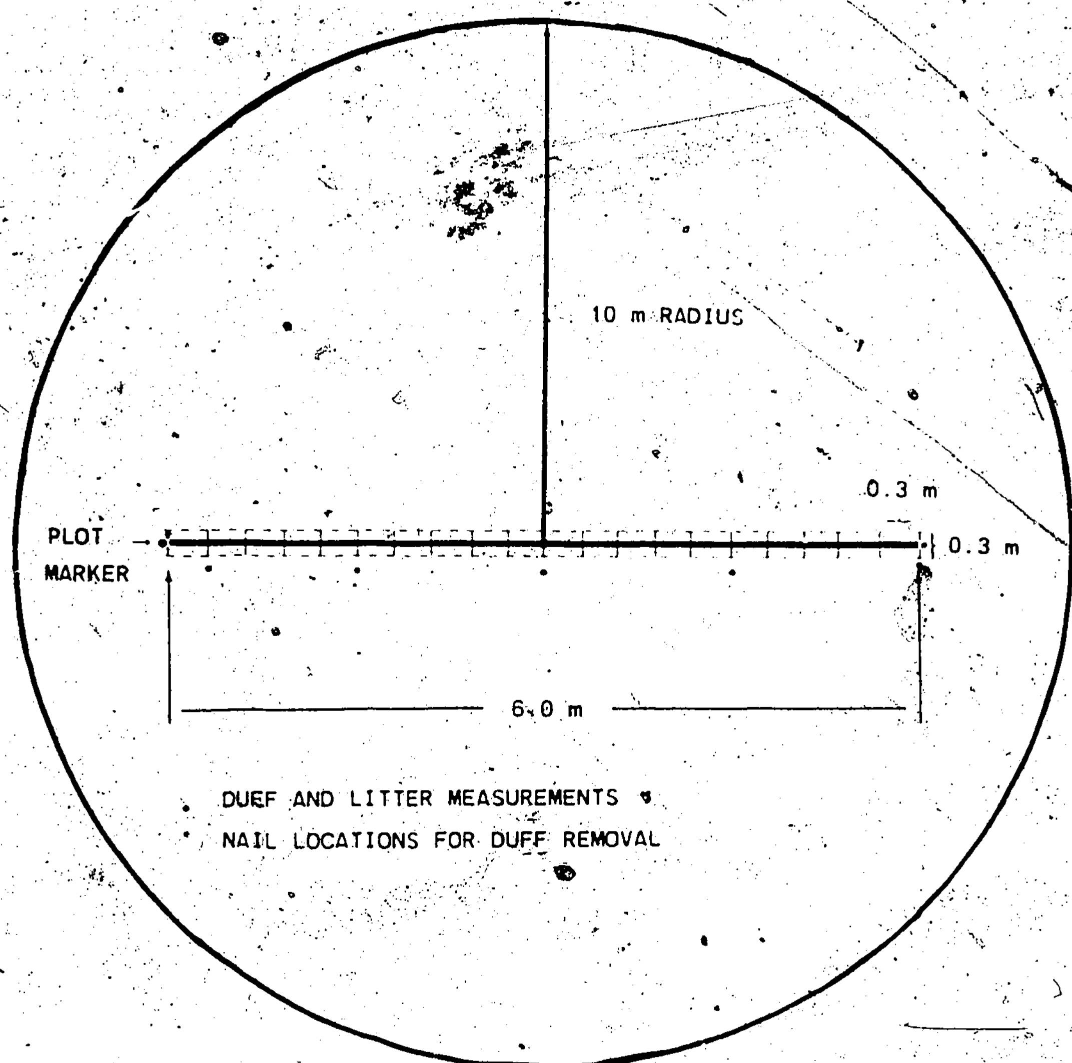

Figure I.3. Subplot and fixed radius plot layout in relation to secondary transects.

calculated for each species using the equation:

$$P.V. = \text{Mean Cover}(\%) \times \sqrt{\text{Frequency}(\%)} \quad [2]$$

Live tree and snag (dead standing tree) density (number of stems >2m in height per hectare) were measured in a 0.03 ha circular plot; the centre of which is concurrent with the centre point of each transect (Figure I.3). Live basal area per hectare by species was also calculated following standard forest mensuration procedures (Husch *et al*. 1972).

SOIL ANALYSIS

Ash and mineral soil samples were taken at each secondary transect during Surveys II and IV and analyzed for available nitrogen (N), phosphorus (P), potassium (K), soil reaction (pH), conductivity (E.C.), total carbon (C), sodium (Na) and sulfate (SO_4). Procedures described by McKeague (1976) were used in collecting soil samples. Laboratory technicians in the Department of Soil Science at the University of Alberta analyzed the soil samples using the following techniques.

McKeague (1976) for pH and E.C., using a 1:25 mixing ratio of soil:water, Technicon Industrial Method No. 334-74A/A for % N and % P (Kjeldahl digestion using a Block Digester and analysis using a Technicon Auto Analyzer; Black (1965) for K (meq/L) using the ammonium acetate extractable method, and for Na (meq/L) using semi-quantitative (low to high scale) estimate for this element, Technicon Industrial Method No. 226-72W) for SO_4 (meq/L). Total carbon (C) was calculated as a percentage using an instrument which measured the amount of C in the CO_2 gas when the soil sample was combusted in a Leco Furnace (Ball 1964).

The amount of soil data collected by Bentz (1981) during Survey I was insufficient to allow for comparison with data collected during the other surveys. Therefore, postburn soil results for 1983 and 1984 were compared to 1984 data from soil samples collected from the control site.

STATISTICAL ANALYSIS

The Wilcoxon nonparametric test (Conover 1980) was used to test for significant differences in paired preburn and postburn observations of cover values for all plant species. Student's t-test was used to determine significant differences between preburn and postburn fuel loadings, duff and litter depths and soil parameters. All differences are significant at the $\alpha=.05$ level unless otherwise stated in the text. Changes in fuel loadings by size class were regressed against individual species' cover changes using the SPSSX computer package (Nie *et al*. 1975).

D. RESULTS

FUELS

The total weight of down and dead roundwood fuels significantly decreased immediately after burning (20.9 t/ha in 1979 versus 6.5 t/ha in 1983; Survey II) but exceeded preburn levels by the 1984 field season (25.3 t/ha). The weight of roundwood fuels within all size classes contributed to the total increase, but roundwood fuels within the 2.6 - 7.6cm and >7.6cm (solid) diameter classes accounted for almost 73% of the total surface fuel loading (Figure I.4).

There was a significant reduction in duff depth as a direct result of burning (5.3 ± 2.8 to 2.3 ± 1.4) (Figure I.5). The duff was completely oxidized on only 11 of the 75 subplots sampled. Measurements of duff depth during the 1984 field season suggest the duff depth was not further reduced between 1983 (2.3 ± 1.4) and 1984 (2.3 ± 1.7). Little evidence of erosion was noted.

FIRE SEVERITY

Fire severity was analyzed from two perspectives: (1) a frontal fireline intensity which represents the average for the stand was calculated, and (2) an estimate of the potential and actual heat output was calculated for individual 0.3 m x 0.3 m microsites using potential and actual fuel consumption.

Flame lengths ranged from 15 - 27m (1 to 1.5 times the height of individual trees) (Woodard *et al.* 1983) and as a result, the estimated frontal fire intensity ranged from 82,000 to 306,000 kW/m indicating a very high intensity fire. Most crown fires fall within the range of 10,000 to 30,000 kW/m, and rarely exceed 50,000 kW/m (Alexander 1982).

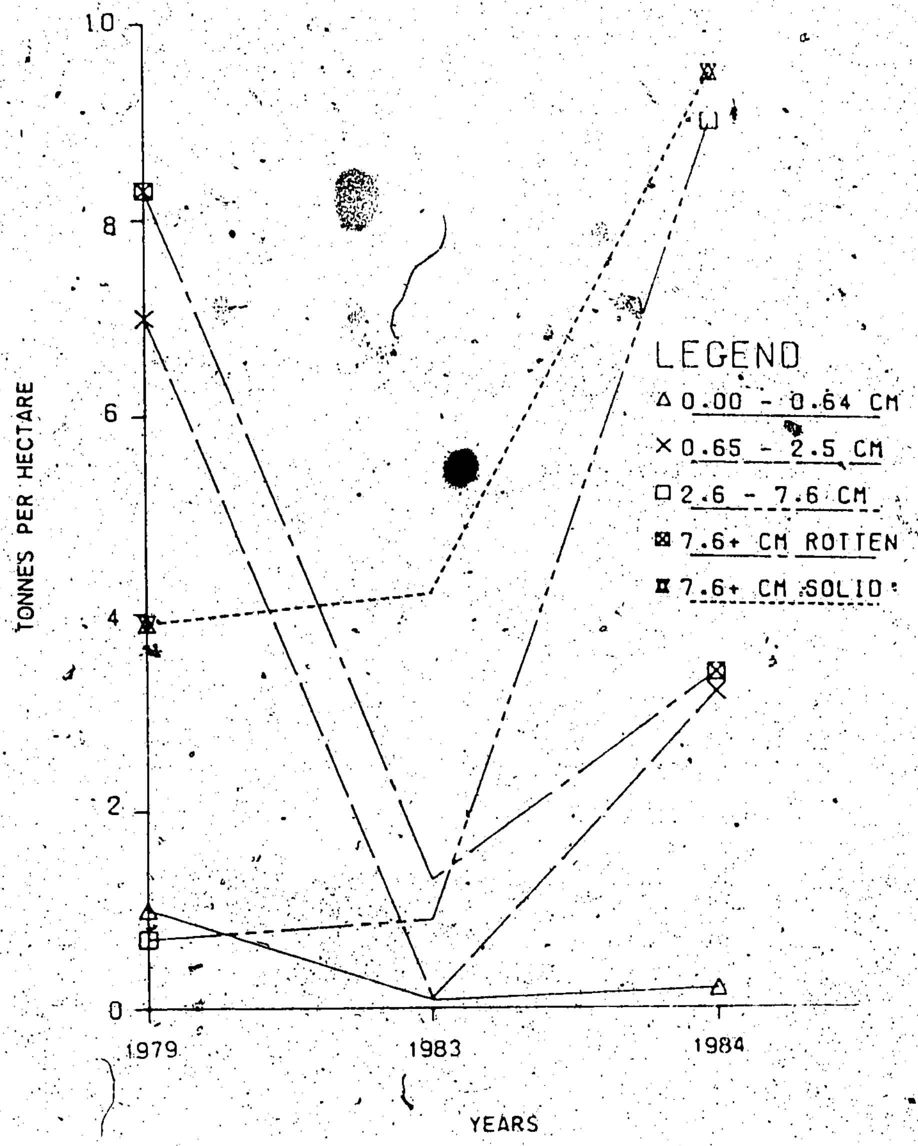

Figure I.4. Average oven-dry down and dead roundwood fuel weights by size classes (tonnes/ha O.D.W.) for preburn and postburn surveys.

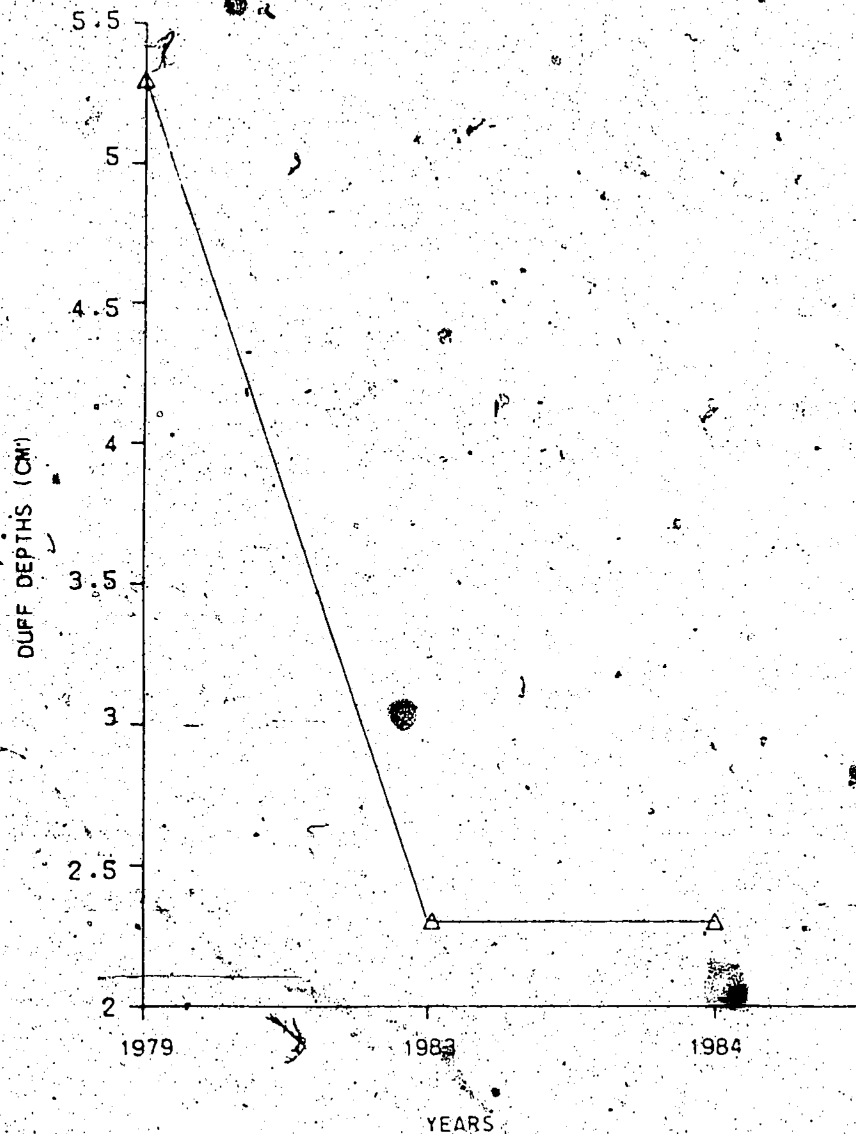

Figure I.5. Changes in average duff depths (cm) from preburn (1979) to postburn (1983, 1984) surveys.

Actual heat output, as indicated by the reduction of fuel loading by the fire, ranged from 0, due to a lack of roundwood fuels, to 11,273,031 kJ/m^2.

Graphs of preburn percent plant cover versus potential heat output (Figures I.6 and I.7), do not suggest preburn fuel loading is restricting plant cover. Postburn plant cover was greatest on subplots which were subjected to lower actual heat outputs (Figures I.8 and I.9). This relationship was not statistically tested due to insufficient samples and the lack of continuity in data over the complete range of heat output values. Shrub dominated subplots were associated only with low potential heat outputs (Figure I.6). Cover on these subplots was reduced to zero. It should be noted that the range of actual heat outputs did not differ greatly from that of potential heat outputs since most litter and small diameter fuels were consumed.

Regression analysis failed to show significant relationships between between heat output and changes in the absolute cover of plant species. *Elymus innovatus*, *Carex* spp and *Zigadenus elegans* (Figures I.10, I.11, and I.12) are illustrated here as examples of different relationships with total heat output.

Percent cover of *Elymus innovatus* varied greatly across the complete range of heat outputs in both pre and postburn surveys (Figure I.10). Although the plant cover of *Elymus innovatus* was reduced to zero on many subplots, it does not appear these results were due to higher heat outputs.

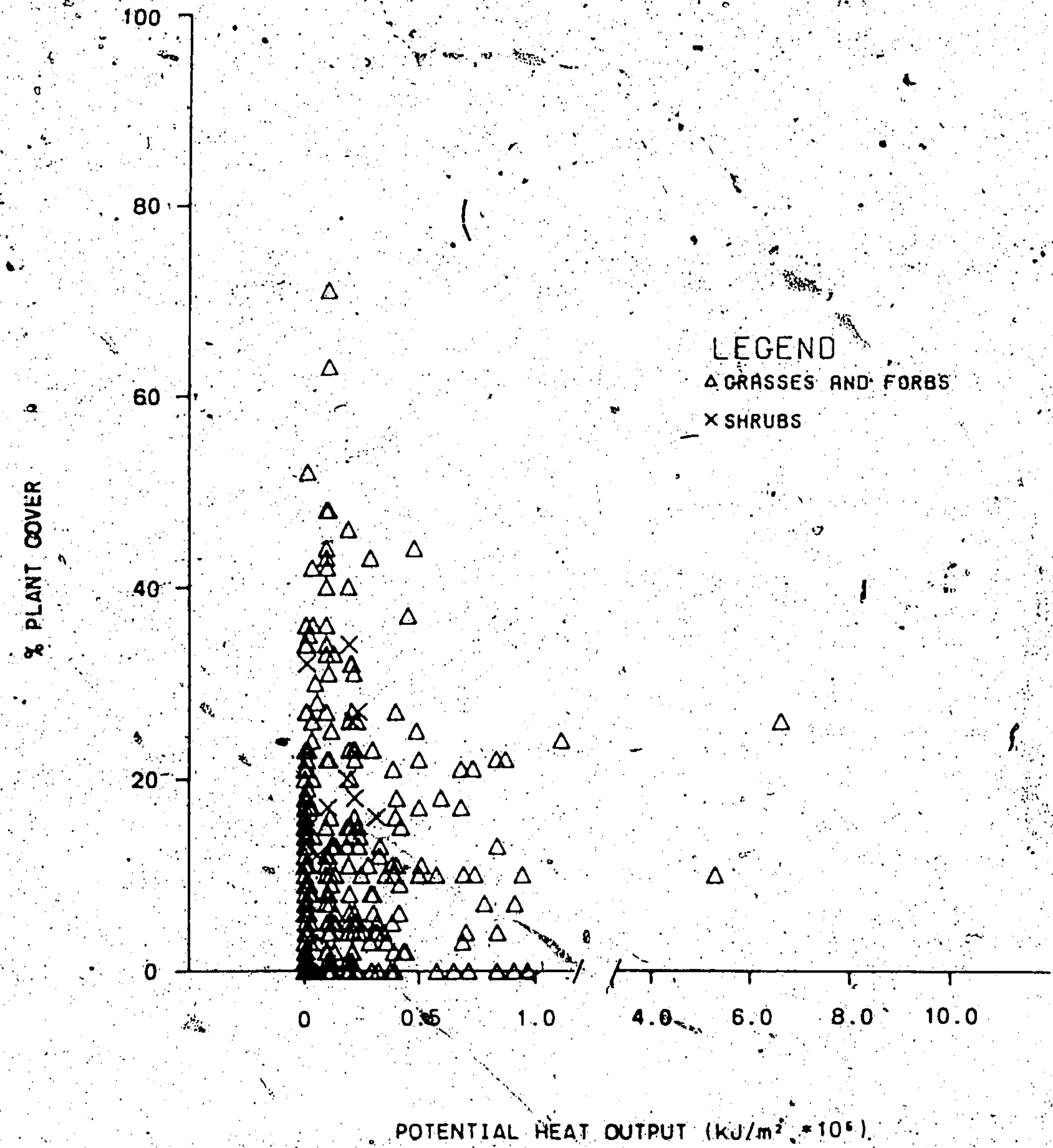

Figure I.6. Preburn vegetation cover for grasses, forbs and shrubs on subplots where the potential heat outputs ranged from 0 to 1,000,000 kJ/m^2.

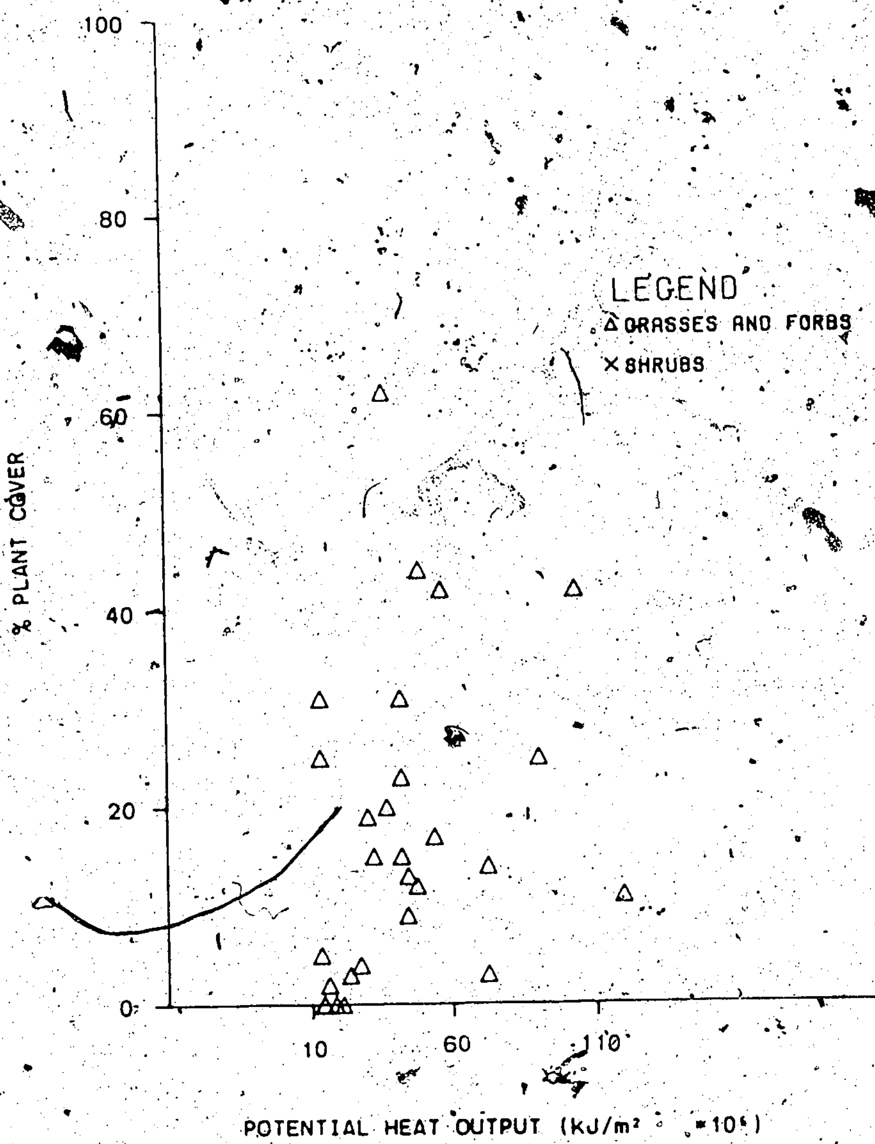

Figure I.7. Preburn vegetation cover for grasses, forbs and shrubs on subplots where the potential heat output range was greater than 1,000,000 kJ/m^2.

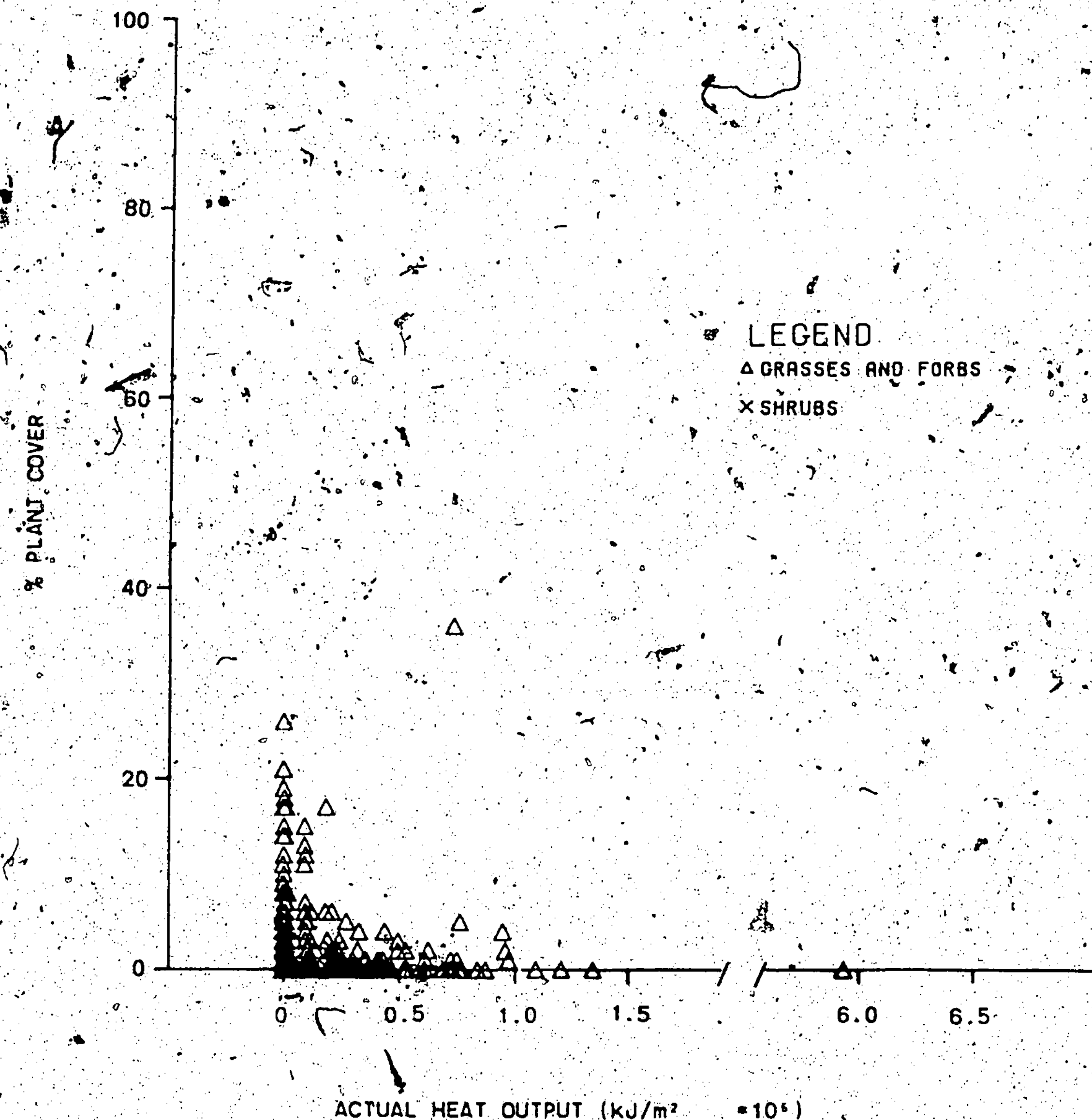

Figure I.8. Postburn vegetation cover for grasses, forbs and shrubs on subplots where the actual heat outputs ranged from 0 to 1,000,000 kJ/m^2.

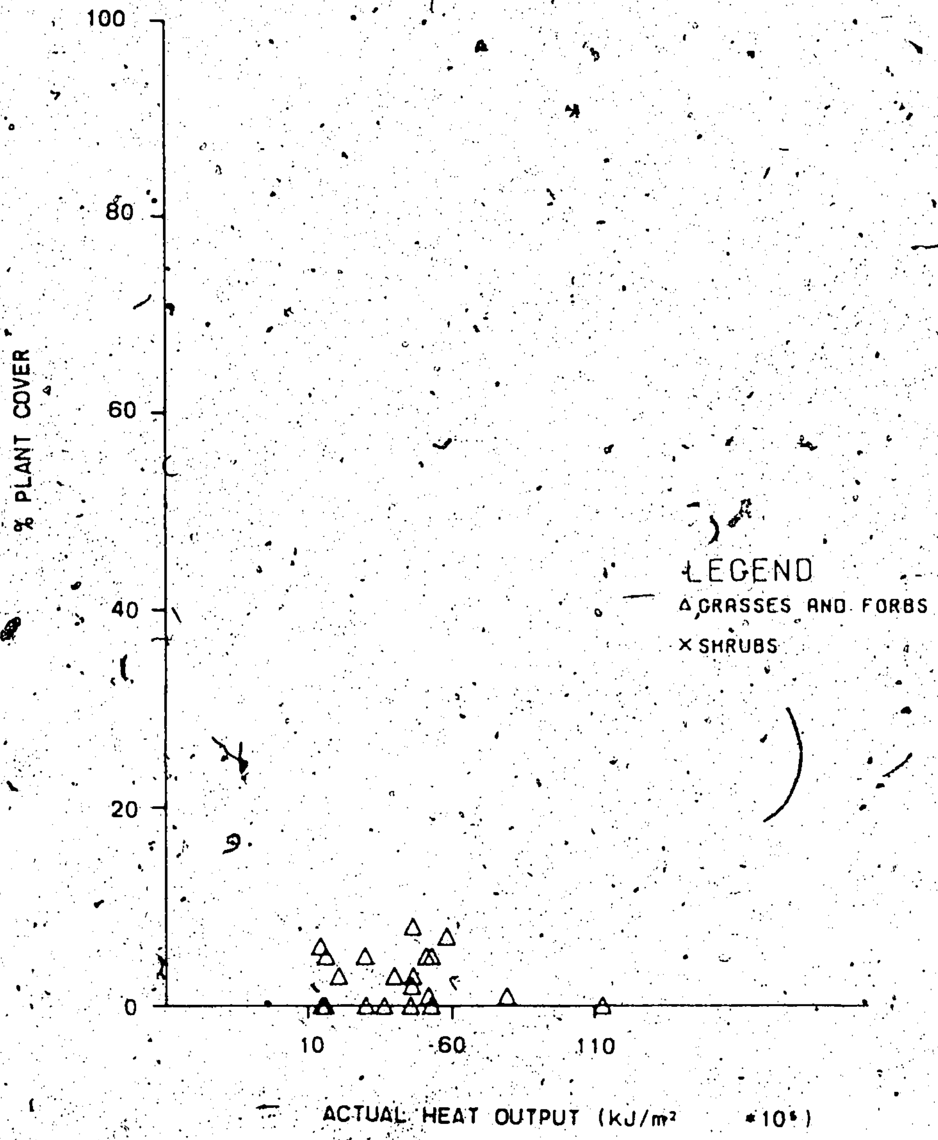

Figure I.9. Postburn vegetation cover for grasses, forbs and shrubs on subplots where the actual heat output range was greater than 1,000,000 kJ/m^2.

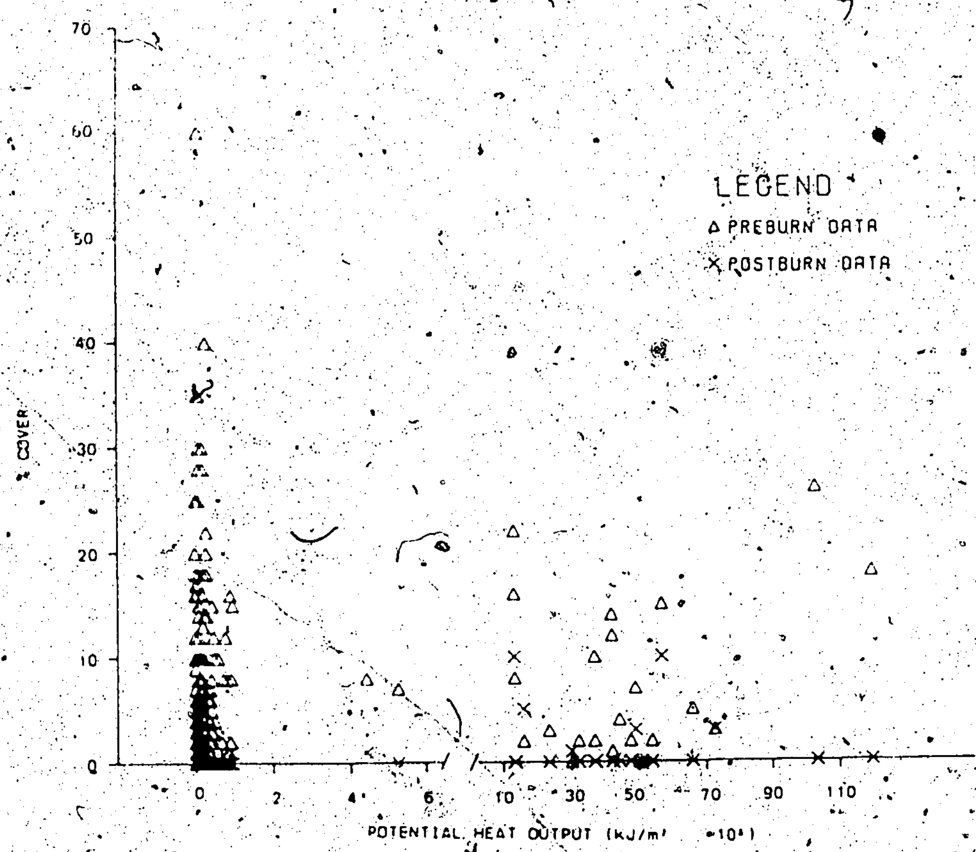

Figure I.10. Preburn and postburn percent cover values of *Elymus innovatus* relative to the range in potential heat output values (kJ/m^2).

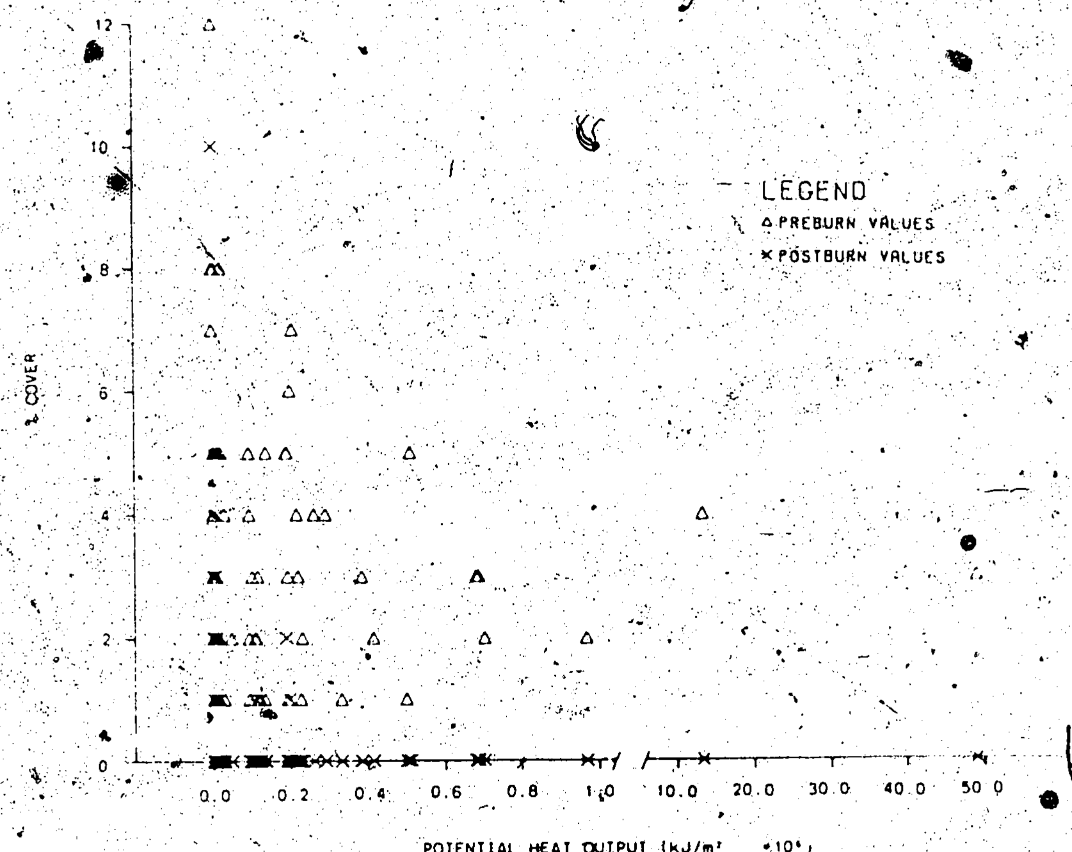

Figure I.11. Preburn and postburn percent cover values of *Carex* spp. relative to the range in potential heat output values (kJ/m^2).

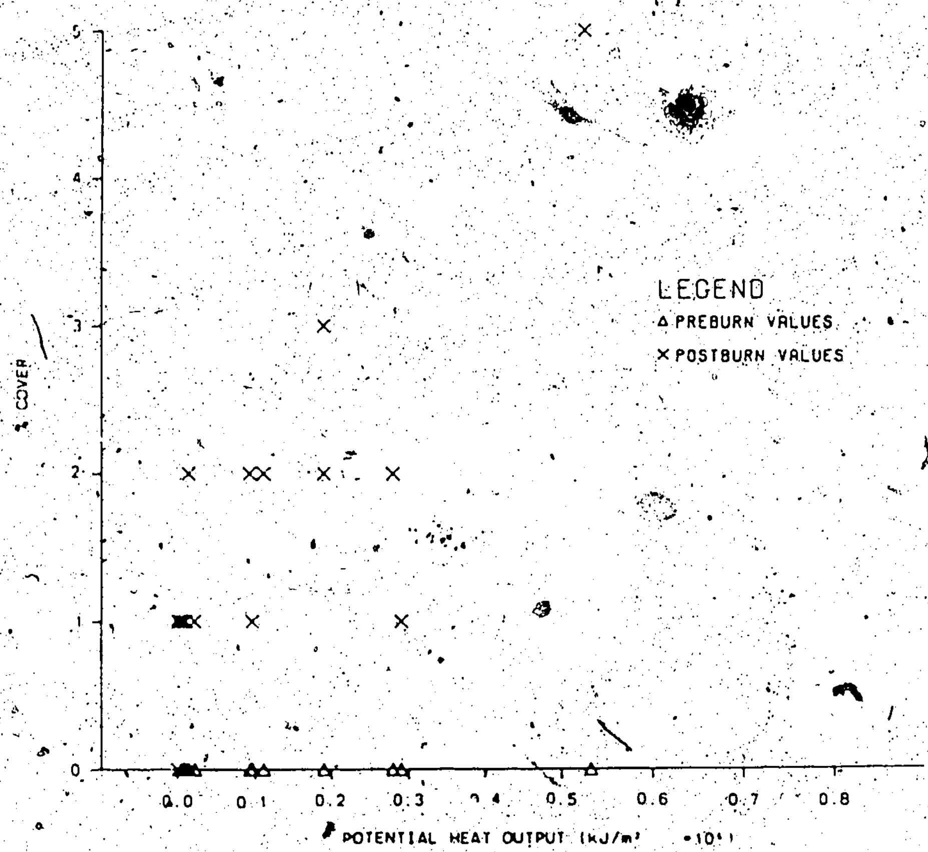

Figure I.12. Preburn and postburn percent cover values of *Zigadenus elegans* relative to the range in potential heat output values (kJ/m^2).

However, this relationship was not tested statistically because of a shortage of samples across the complete spectrum of fuel loadings (which are used to calculate potential heat outputs).

Carex spp. were most commonly found on subplots with lower fuel loadings (Figure I.11). In addition, the preburn sedge cover was relatively low compared to other species. The percent cover of *Carex* species decreased in all burned subplots, and there appears to be an inverse relationship between heat output level and postburn *Carex* cover. An increase in heat output consistently reduced the cover of this species.

Zigadenus elegans was found only on subplots with low potential heat outputs (Figure I.12). The percent cover of *Zigadenus elegans* increased on all subplots subjected to burning regardless of the heat output value for the subplot.

VEGETATION COVER

Immediately following the prescribed crown fire, the overstory canopy cover was reduced from 60% to 20% (visual estimate from photographs), and subordinate vegetation cover was reduced from 20% of ground area to 1.3% (Figure I.13). Grass and sedge cover was reduced from a preburn level of 6.5% to 0.8% within one month of burning, while forb cover went from 6.6% to 0.5% over the same period. By August 1983 (three months after burning), the ground area covered by grass and sedge species had nearly recovered to preburn

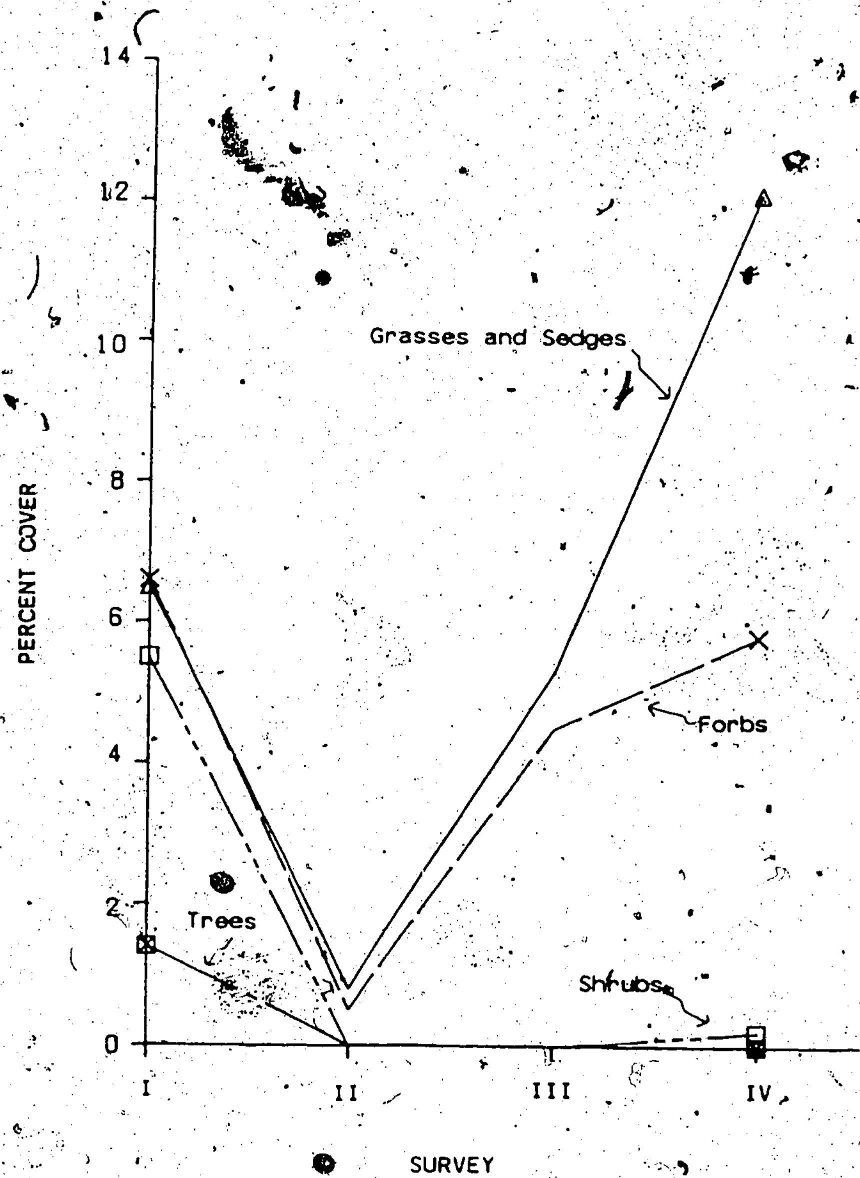

Figure I.13: Total understory cover changes between preburn (1979; I)and postburn surveys (June 1983; II, August 1983; III, and 1984; IV) by cover type.

levels and forbs were within 2/3 of the preburn cover values. By the end of the 1984 growing season, forb cover had almost recovered to preburn levels, while grass and sedge cover values were almost twice those prior to burning (12.1%).

Trees and shrubs were most adversely affected by the direct or indirect effects of burning. Trees have not re-established on any of the permanent plots and after two growing seasons shrub cover only amounts to 0.2% of the ground area. The percent cover, percent frequency and prominence values for all species in the burned site are presented in Tables I.1, I.2, and I.3, respectively.

Seventeen plant species were identified in the understory plant community immediately following burning (Survey II). This amount is half of the number of species found in the preburn community, but 12 of the 17 species found in the postburn plant community were also common to the preburn community for a similarity index value of 47.6 (Figure I.14), suggesting five plant species invaded after burning. By the end of the 1983 growing season (Survey III) this value had increased to 65.5, and by the end of the 1984 growing season (Survey IV) the index had climbed to 71.2. The similarity index between postburn surveys is even higher. The similarity index between Survey II and Survey III is 78.0, and between Surveys III and IV it is 81.5.

The cover of *Carex aurea* and *C. scirpoidea*, *Campanula rotundifolia*, *Galium boreale*, and *Zigadenus elegans*

Table I.1. Percent absolute cover [1] of subordinate vascular plant species in the 1979 preburn survey (Survey I), and three postburn surveys (June 1983; Survey II, August 1983; Survey III, and 1984; Survey IV) including species' life cycle (annual (A) vs perennial (P)).

Species	Life Cycle	Survey I	Survey II	Survey III	Survey IV
GRASSES AND SEDGES					
Agrostis scabra L.	P	0.0	0.0	0.0	0.[illegible]
Carex aurea Nutt. & *C. scirpoidea* Michx.	P	0.9	0.2	1.7**	0.5
Elymus innovatus Beal & *Bromus inermis* Leys ssp. *pumpellianus* Scribn.	P	5.5	0.5	3.4	11.9**
Poa spp. (mainly *P. alpina*) L.	P	[illegible]	0.1	0.2	0.1
FORBS					
Achillea millefolium	P	T	0.0	0.0	0.0
Agoseris aurantiaca (Hook.) Greene	A	[illegible]	0.0	0.0	T
Androsace chamaejasme Host	P	0.5	T	0.3	0.3
Antennaria alpina (L.) Gaertn.	P	T	T	T	T
Arenaria spp. L.	A,P	0.1	0.0	0.0	0.0

* = Significant decrease in cover from preburn (a = .05)

** = Significant increase in cover from preburn (a = .05)

T = Trace

Aster alpinus L.	P	0.4	0.0*	0.0	0.0
Campanula rotundifolia L.	P	0.1	0.1**	0.4**	0.3
Delphinium glaucum S. Wats.	P	T	0.0	0.0	0.0
Dryas hookeriana	P	0.1	0.0	0.0	0.0
Epilobium angustifolium L.	P	T	T	0.5	0.6
Fragaria virginiana L.	P	1.0	T*	0.1	0.3
Galium boreale L.	P	0.5	0.2	1.1**	1.4
Gentianella (Gentiana) amarella L.	A	0.1	0.0	T	0.0
Hedysarum alpinum L. & *Astragalus alpinus* L.	P	1.8	0.0*	0.1	1.0
Linnaea borealis L.	P	0.0	0.0	T	0.0
Mertensia paniculata (Ait.) G. Don	P	T	0.0	0.0	T
Moneses uniflora (L.) A. Gray	P	0.0	0.0	0.0	0.1
Orthilia (Pyrola) secunda (L.) House	P	T	0.0	T	0.0
Oxytropis spp. (D.C.)	P	0.3	0.1	0.6	T
Polygonum viviparum L.	A	T	0.0	T	T
Sedum rosea (L.) Scop.	P	T	0.0	T	T
Senecio spp. L.	P	0.2	0.0	0.0	0.2
Silene parryi (S. Wats.) C.L. Hitch & Maguire	P	T	0.0	0.0	0.0

Solidago spathulata (decumbens) D.C. & Aster	P	1.1	0.1	1.1	1.5
sibericus L.					
Stellaria longipes Goldie	P	0.0	T	T	0.1
Stenanthium occidentale A. Gray	P	0.1	0.0	0.0	T
Viola adunca J. E. Smith	P	0.0	0.0	0.1	0.1
Zygadenus elegans Pursh	P	T	T	0.2	0.1
SHRUBS					
Arctostaphylos uva-ursi (L.) Spreng.	P	0.3	0.0	0.0	0.0
Juniperus scopulorum Sarg.	P	3.1	0.0	0.0	0.0
Potentilla fruticosa L.	P	0.6	0.0	T	0.1
Rosa acicularis Lindl.	P	T	0.0	0.0	0.0
Shepherdia canadensis (L.) Nutt.	P	1.5	0.0	0.0	0.1
TREES					
Abies lasiocarpa (Hook.) Nutt.	P	0.2	0.0	0.0	0.0
Picea glauca (Moench) Voss	P	1.2	0.0	0.0	0.0

Table I.2. Percent frequency of subordinate vascular plant species in the 1979 preburn survey (Survey I), and three postburn surveys (June 1983; Survey II; August 1983; Survey III, and 1984; Survey IV).

Species	Survey I	Survey II	Survey III	Survey IV
GRASSES AND SEDGES				
Agrostis scabra L.	0.0	0.0	0.0	2.6
Carex aurea Nutt. & *C. scirpoidea* Michx.	31.1	10.0	30.4	13.2
Elymus innovatus Beal & *Bromus inermis* Leys ssp *pumpellianus* Scribn.	66.8	22.5	[illegible]6	66.1
Poa spp. (mainly *P. alpina*) L.	5.7	14.1	6.8	3.9
FORBS				
Achillea millefolium L.	0.4	0.0	0.0	0.0
Agoseris aurantiaca (Hook.) Greene	2.5	0.0	0.0	1.1
Androsace chamaejasme Host.	26.4	1.8	12.1	15.0
Antennaria alpina (L.) Gaertn.	1.4	0.4	0.7	0.7
Arenaria spp. L.	3.2	0.0	0.0	0.0
Aster alpinus L.	16.8	0.0	0.0	0.0

T = Trace.

Campanula rotundifolia L.	6.4	3.2	12.5	14.3
Delphinium glaucum S. Wats	0.7	0.0	0.0	0.0
Dryas hookeriana	1.1	0.0	0.0	0.0
Epilobium angustifolium L.	0.4	3.2	3.9	11.1
Fragaria virginiana L.	18.2	1.4	4.6	1.4
Galium boreale L.	22.9	12.5	27.1	31.1
Gentianella (Gentiana) amarella L.	7.2	0.0	0.7	0.0
Hedysarum alpinum L. & *Astragalus alpinus* L.	36.8	0.0	5.0	33.9
Linnaea borealis L.	0.0	0.0	0.4	0.0
Mertensia paniculata (Ait.) G. Don	0.7	0.0	0.0	0.4
Moneses uniflora (L.) A. Gray	0.0	0.0	0.0	2.9
Orthilia (Pyrola) secunda (L.) House	1.6	0.0	0.4	0.0
Oxytropis spp. (D.C.)	16.4	6.9	20.4	4.3
Polygonum viviparum L.	1.4	0.0	1.4	0.4
Sedum rosea (L.) Scop.	0.7	0.0	1.4	0.4
Senecio spp. L.	5.4	0.0	0.0	0.4
Silene [illegible] (S. Wats) [illegible] Hitch & Maguire	0.4	0.0	0.0	0.0
Solidago [illegible] & *Aster sibiricus*	31.4	7.9	31.1	30.4

Stellaria longipes Goldie	0.0	0.4	0.4	2.5
Stenanthium occidentale A. Gray	1.1	0.0	0.0	0.4
Viola adunca J.E. Smith	0.0	0.0	[illegible]	1.4
Zigadenus elegans Pursh.	1.8	3.2	3.9	4.3
SHRUBS				
Arctostaphylos uva-ursi (L.) Spreng.	4.3	0.0	0.0	0.0
Juniperus scopulorum Sarg.	10.4	0.0	0.0	0.0
Potentilla fruticosa L.	7.9	0.0	1.1	2.5
Rosa acicularis Lindl.	0.4	0.0	0.0	0.0
Shepherdia canadensis (L.) Nutt.	9.6	0.0	0.0	2.5
TREES				
Abies lasiocarpa (Hook.) Nutt.	1.4	0.0	0.0	0.0
Picea glauca (Moench) Voss.	3.9	0.0	0.0	0.0

Table I.3. Prominence values of subordinate vascular plant species in the 1979 preburn survey (Survey I), and in three postburn surveys (June 1983; Survey II, August 1983; Survey III, and 1984; Survey IV).

Species	Survey I	Survey II	Survey III	Survey IV
GRASSES AND SEDGES				
Agrostis scabra L.	0.0	0.0	0.0	0.1
Carex aurea Nutt. & *C. scirpoidea* Michx.	4.8	0.7	9.5	6.8
Elymus innovatus Beal & *Bromus inermis* Leys ssp *pumpellianus* Scribn.	46.0	2.6	22.7	96.6
Poa spp. (mainly *P. alpina*) L.	0.3	0.5	0.5	0.3
FORBS				
Achillea millefolium L.	T	0.0	0.0	0.0
Agoseris aurantiaca (Hook.) Greene	0.1	0.0	0.0	T
Androsace chamaejasme Host.	2.3	T	1.1	1.1
Antennaria alpina (L.) Gaertn.	T	T	T	T
Arenaria spp. L.	0.1	0.0	0.0	0.0
Aster alpinus L.	1.6	0.0	0.0	0.0
Campanula rotundifolia L.	0.2	0.1	1.5	1.2

T=Trace

Delphinium glaucum S. Wats.	T	0.0	0.0	0.0
Dryas hookeriana	0.1	0.0	0.0	0.0
Epilobium angustifolium L.	T	0.1	0.9	2.0
Fragaria virginiana L.	4.1	T	0.2	0.1
Galium boreale L.	2.4	0.6	5.7	7.7
Gentianella (Gentiana) amarella L.	0.2	0.0	T	0.0
Hedysarum alpinum L. & *Astragalus alpinus* L.	10.7	0.0	0.3	5.7
Linnaea borealis L.	0.0	0.0	T	0.0
Mertensia paniculata (Ait.) G. Don	T	0.0	0.0	T
Moneses uniflora (L.) A. Gray	0.0	0.0	0.0	0.1
Orthilia (Pyrola) secunda (L.) House	0.1	0.0	T	0.0
Oxytropis spp. (D.C.)	1.4	0.3	2.7	0.1
Polygonum viviparum L.	T	0.0	T	T
Sedum rosea (L.) Scop.	T	0.0	T	T
Senecio spp. L.	0.6	0.0	0.0	0.1
Silene parryi (S. Wats.) C.L. Hitch & Maguire	T	0.0	0.0	0.0
Solidago spathulata (decumbens) D.C. & *Aster sibericus* L.	5.9	0.2	6.2	8.0
Stellaria longipes Goldie	0.0	T	T	0.1

Stenanthium occidentale A. Gray	0.1	0.0	0.0	T
Viola adunca J.E. Smith	0.0	0.0	0.1	0.1
Zigadenus elegans Pursh	T	0.2	0.3	0.1
SHRUBS				
Arctostaphylos uva-ursi (L.) Spreng.	0.6	0.0	0.0	0.0
Juniperus scopulorum Sarg.	10.0	0.0	0.0	0.0
Potentilla fruticosa L.	1.8	0.0	T	0.1
Rosa acicularis Lindl.	0.6	0.0	0.0	0.0
Shepherdia canadensis (L.) Nutt.	4.6	0.0	0.0	0.1
TREES				
Abies lasiocarpa (Hook.) Nutt.	0.2	0.0	0.0	0.0
Picea glauca (Moench) Voss	2.4	0.0	0.0	0.0

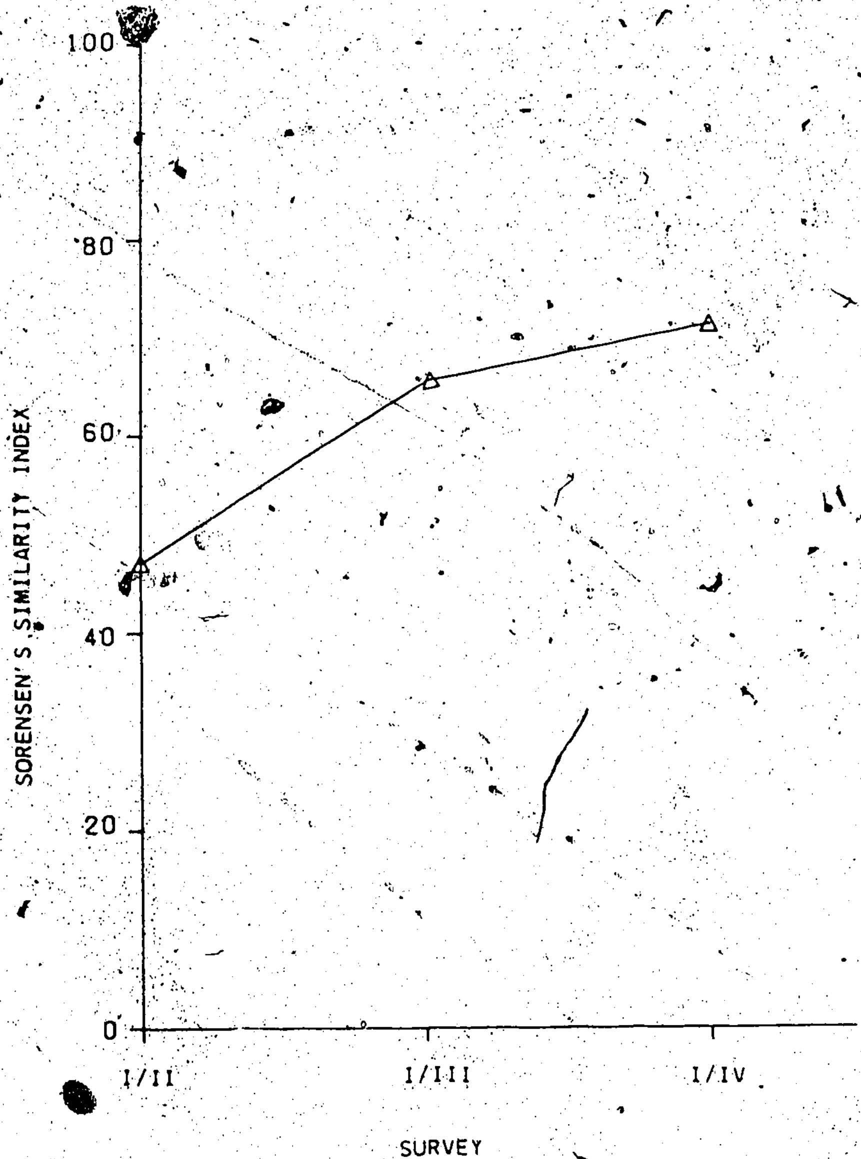

Figure I.14. Species composition comparisons between preburn (1979; I)and postburn surveys (June 1983; II, August 1983; III, and 1984; IV) using Sorensen's Index of Similarity.

displayed a significant increase over preburn values by the end of the first growing season (Table I.1). *Elymus innovatus* and *Bromus inermis* spp *pumpellianus* also showed a significant increase from preburn cover but only by the end of the 1984 growing season (Table I.1).

Immediately following burning the cover of *Androsace chamaejasme*, *Aster alpinus*, *Fragaria virginiana*, *Hedysarum alpinun* and *Astragalus alpinus*, *Arctostaphylos uva-ursi*, *Juniperus scopulorum*, *Potentilla fruticosa*, *Rosa acicularis*, *Shepherdia canadensis*, and *Picea glauca* (under 2m in height) showed significant decreases when compared to preburn values (Table I.1). Subsequent to Survey II there were no further decreases in the cover of these species.

Elymus innovatus was the most prominent species on the site in all surveys (Table I.3). *Bromus inermis* spp. *pumpellianus* was grouped with *Elymus innovatus* due to the difficulty in distinguishing between the two species in juvenile stages. However, it was possible to identify the separate species when they were mature. *Bromus inermis* spp. *pumpellianus* was found to exist on only one plot on the burned site and therefore did not constitute a major portion of the grass cover on the site.

Trees survived in only 4 out of the 14 burned plots resulting in a large decrease in basal area of live stems. Prior to burning (1979), Bentz (1981) estimated the live tree density to be 1012 (± 525) stems/ha and snag density at 136 (± 83). Subsequent to burning tree and snag densities were changed to 73 (± 172) and 1449 (± 771) stems/ha, respectively. The slight increase in total stem density likely a result of individual tree seedlings growing into the size class >2m which was used to distinguish between subordinate versus overstory tree cover. Some of the discrepancy may also be due to sampling error. Live tree seedlings were not identified on any subplots during the two field seasons following burning.

SOILS

Preburn soil samples collected and analyzed by Bentz (1981) were not used in the analysis of fire effects on soils because of the limited sample size. Instead, the pH, conductivity, carbon, nitrogen, phosphorus, potassium, sodium, and sulfates of soil samples collected in 1983 and 1984 in the burned area were compared to soil samples taken from the adjacent control site (Table I.4). Temporary significant increases existed for conductivity, potassium and sodium between the 1984 control and 1983 burn surveys. These three parameters decreased between 1983 and 1984 surveys. The sulfate concentration in soil increased between the 1983 and 1984 surveys.

Table I.4. Comparison of soil parameters between control and burn sites (1983, 1984).

Parameter	Control 1984	Burned 1983	Site 1984
pH	7.2	6.8	7.4
E.C.	0.62	**1.55	0.66
% C	8.58	11.46	8.10
% N	0.4	0.5	0.4
% P	0.06	0.10	0.09
K(meq/L)	0.2	**0.8	0.3
Na(meq/L)	0.04	**0.28	0.03
SO (meq/L)	1.6	1.6	**1.9

** - Significant increase (= 0.5)
* - Significant decrease (=0.05)

E. DISCUSSION

FUELS

Most smaller diameter roundwood fuels (<7.6 cm) and most large diameter (>7.6cm) rotten fuels, on the ground and standing, were consumed by the fire (Woodard et al. 1983), accounting for the reduction in fuel loading from 1979 to 1983. The 18.8 t/ha increase in the surface fuel loading subsequent to burning is probably due to fallen trees which were killed by the fire and perhaps overturned by the wind. It should be noted that although surface fuel loadings now exceed preburn levels, the absence of live and dead aerial fuels, and the poor continuity of surface fuels, particularly in the small diameter classes, will prevent this area from supporting a wild or prescribed fire for some time in the future.

The fire consumed almost 60% of the duff (from 5.3 cm in 1979 to 2.3 cm in 1983). However, underground plant parts would likely survive in areas where duff removal was less than complete (Flinn and Wein 1977). Therefore, it is highly likely that subterranean plant parts which will be able to recover quickly from the effects of this disturbance, especially since there was little evidence of erosion if they are capable of vegetative reproduction.

FIRE SEVERITY

On most subplots the actual heat output equalled the potential heat output, suggesting that most fuels, regardless of size and location, were consumed by the fire. The large variation in total heat outputs (from 0 to 11,273,031 KJ/m^2) is largely due to the microsite variability in fuel loadings prior to burning. As previously discussed, a large portion of the preburn site was covered with over turned trees, whereas undisturbed areas had very little down and dead fuel (Bentz 1981).

Small diameter down and dead roundwood fuels would be expected to be more abundant on subplots dominated by shrub cover than on those where forbs and grasses were dominant because of the number of fine woody fuels. However, fire fuel loadings were lowest on shrub dominated subplots suggesting that most of these twigs were retained on the plant. This result may also be due to the slow growing nature of these individuals, animal browsing, rapid decomposition or perhaps even the young age of these plants.

High preburn fuel loadings were concentrated in the "blowdown" portion of the stand where plant cover was lowest. Therefore, large reductions in the percent cover of grasses, forbs or shrubs was not due to higher heat output values. There appears to be a relationship between fuel loading and preburn plant cover, but this relationship was not tested statistically because of a lack of samples. A similar relationship was found by Woodard (1977).

The variation in distribution of plant cover and fuel loading across the site, and the amount of residual organic material, may be the reason no significant relationships were found between heat output and changes in cover for any plant species. This relationship might also be confounded by such strongly rhizomatous species as *Elymus innovatus* which have the ability to resprout from subterranean reproductive tissue. These species may not be affected by even extremely high heat outputs when sheltered by duff materials. Rhizomatous plants will most likely regenerate if the layer of organic matter is thick enough to protect the reproductive tissue (Flinn and Wein 1977). For example, the sedge species on the burned site exhibit weakly rhizomatous tendencies, and therefore, did not recover as rapidly as *Elymus innovatus*, thus accounting for the more apparent inverse relationship with heat output. *Carex* spp. have the ability to cast light seed in abundance and this is, perhaps, their survival strategy (Rowe 1983). However, the spring burn may have destroyed the available seed, thus accounting for the low carex cover in the postburn community.

Zigadenus elegans, increased in cover regardless of heat output. Most plants likely originated on subplots where seed had been stored or transported since this species was found on many subplots where it had not been previously observed.

"Total heat output" (kJ/m^2) is not a measure of the fire temperature nor the length of time it took to burn the fuel on any given subplot. These parameters were not measured at the time of the fire, but that information may have made the interpretation of plant responses noted easier and more accurate.

VEGETATION COVER

Preburn subordinate plant cover was sparse, likely due in a large part to the density of the overstory tree canopy which would likely affect surface temperatures and available light, and perhaps even available soil nutrients. Immediately following the fire the overstory canopy was reduced from 60% cover to 20% due largely to the consumption of live tree foliage. Although, the understory plant cover was reduced to very low levels (1.3% of ground area) immediately following burning, it seems to be recovering rapidly.

The relatively high Sorensen's Index of Similarity values suggest the fire had little impact on subordinate plant composition. By 1984, 24 of the plant species found in the burned area were common to the preburn, but this value fails to explain the presence or absence of individual plant species. Therefore, the species found on this site are discussed relative to their regeneration strategies and/or morphological adaptations in light of published theories by Lyon and Stickney (1976), Cattelino *et al.* (1979) and

Chapman and Crow (1981). These theories may enable the study to account for individual species response to effects of burning.

GRASSES AND SEDGES

Percent cover of the two sedges, *Carex aurea* and *C. scirpoidea* increased significantly by the end of the 1983 growing season (Survey III) but decreased in cover the following year (Table I.1). *Carex* was the second most prominent genus on the site (Table I.3) until 1984. These species are mainly caespitose and have short rhizomes on Ram Mountain. The decline in the cover of these two species may be attributed to sheep use or to fire induced changes in the physical or chemical environment. Previous studies of sites where *Carex* species were present prior to burning all agree that the ground cover of this genus generally increases after fire (Dyrness 1973; Miller and Miller 1976; Archibold 1979, 1980). These studies suggest increases in frequency of sedges are due to seed cast rather than vegetative reproduction.

Poa species tend to be strongly caespitose to stoloniferous (Porsild 1979), and thus, would be expected to have a response pattern similar to that of the sedges, since reproduction would be expected to come from seed rather than vegetatively, particularily on sites where all organic material is burned. The genus did show a slight increase in frequency in Survey II, but cover values did not change during that time period due to the size of these individuals at the time of sampling. Thus, *Poa* contributed very little to the total plant cover on site after burning.

Agrostis scabra is a perennial grass with fibrous root sytems, and it occasionally has short rhizomes. Representatives of this species did not appear on the the site until 1984, and has invaded the site in low numbers (Table 1.2). The presence of this species is likely the result of seed migration onto the site due to wind or animals.

The cover values of *Elymus innovatus* and *Bromus inermis* ssp. *pumpellianus* were combined because of difficulties in distinguishing between them in their juvenile stages. Both species are strongly rhizomatous, perhaps accounting for their rapid recovery immediately after the fire. Seedlings were also observed in 1984. *Bromus inermis* is known to increase in abundance after fire (Mogren and Barth 1974; Crane *et al*. 1983). The response of *Elymus innovatus* to burning has not been widely studied, but one would expect it to react similarly to *Bromus inermis* because of their similar growth habits and morphological characteristics. These two species increased substantially following the burn and have been the most prominent species on the site in all surveys.

FORBS

Achillea millefolium was found in low abundance prior to burning and disappeared from the site after the fire. This species has shallow, horizontal rootstocks and rhizomes that are located in the duff layer, and would likely be destroyed if burning oxidized the duff layer in the areas where it grew.

Gentianella amarella and *Agoseris aurantiaca* are annuals that disappeared from the site until 1984. The absence of these species is probably due to a shortage of seeds which were killed by the fire.

Epilobium angustifolium is well known as an invader or increaser on disturbed sites, particularily burned sites. Schmidt and Lotan (1980) stated that the increase shown by this species subsequent to burning was associated with increases in soil nutrients following fire. The species commonly propagates from seeds and rhizomes (Shafi and Yarranton 1973; Dyrness 1973; Lyon and Stickney 1976; Crane *et al.* 1983). The rhizomes of this species are located 1.5 to 5.0 cm below the top of the mineral soil (McLean 1968), thus giving them a good chance to survive fire. In the event that they do survive, the live roots are able to capture nutrients as they percolate through the soil profile possibly giving those roots a competitive advantage. In this study, the percent cover of *Epilobium angustifolium* did increase, but the increases were not statistically significant, perhaps owing to its relatively low distribution in the preburn stand.

Fragaria virginiana is not noted for significant cover changes after fire, but it did decrease significantly on this site. Alghren (1960) reported the species is capable of sexual and asexual reproduction after burning. Data from Noste (1982) and Antos and Shearer (1980) showed the percent cover of wild strawberry increases slightly immediately after burning but then returns to preburn levels.

Galium boreale showed a significant increase in cover following the burn, but the available information on this species is conflicting. Archibold (1980) reported invasion following fire, whereas Mogren and Barth (1974) and White (1983) found the species decreased in cover subsequent to burning. This species is a light seeded perennial capable of some vegetative reproduction, and its response to fire would likely depend on the available seed source.

Hedysarum alpinum and *Astragalus alpinus* decreased significantly in cover on the site following the burn, but are experiencing slow but steady recovery. Both species have woody taproots and creeping rhizomes, and are also capable of reproducing by seed. Therefore, it is highly probable these species will contribute significantly to the future plant cover on this site if they can tolerate the new environment created by the fire.

These species were grouped because of the difficulty of distinguishing between them without flowers or fruits and because of their similar phenologies and regenerative strategies, which should lead to a similar response to fire.

Solidago spathulata and *Aster sibiricus* were positively identified during the postburn survey, although at times it was too difficult, without flowers, to distinguish between immature specimens. These two species have similar leaf shapes and arrangements, and therefore, they were grouped into one cover type. *Aster sibiricus* was not reported in the preburn plant community but the apparent absence of this species may be due to misidentification during that survey. These species showed no significant changes in cover but have increased in prominence. Thus they constitute a major portion of the relative vegetative cover on the site. Both recovered quickly during the first growing season following the fire.

Zigadenus elegans rarely occurs in abundance on any plots on the site. It reproduces by seed and has a perennial bulb which is usually located well into mineral soil possibly enabling it to survive a fire. It was widespread on the site and, although cover values were low, it showed a significant increase in frequency and cover after burning.

Little autecological information is available for *Androsace chamaejasme*, *Antennaria alpina*, *Orthilia secunda*, *Aster alpinus*, *Delphinium glaucum*, *Dryas hookeriana*, *Campanula rotundifolia*, *Moneses uniflora*, *Viola adunca*, *Silene parryi*, *Arenaria* spp., *Oxytropis* spp., and *Stellaria longipes* so it is difficult to interpret their reaction to fire. These species do not contribute significantly to the understory plant cover (Table I.1).

SHRUBS AND TREES

All shrubs within the treatment area showed significant decreases in cover following burning. Postburn shrub cover emerged from root collars of shrubs on site prior to burning. *Arctostaphylos uva-ursi* has trailing rooting stems and stolons but also reproduces by seed. It has not yet returned to the site, suggesting the roots, rhizomes and seeds may have been destroyed by fire. The literature is conflicting, suggesting the percent cover of this species may increase (Rowe 1983; Miller and Miller 1976), decrease (Noste 1982) or show no change (Mogren and Barth 1974) after fire.

Neither *Juniperus scopulorum* nor *Rosa acicularis* have yet returned to the site. These species, especially *Juniperus scopulorum*, do not readily reproduce vegetatively and may take longer to recover on the site depending on the natural mechanisms required to relocate the viable seed.

Potentilla fruticosa and *Shepherdia canadensis* both reproduce vegetatively and by seed (Moss 1983). They were identified in the burned area during the 1984 survey, recovering by means of root collar sprouts after the parent plant was entirely top-killed by the fire.

Abies lasiocarpa and *Picea glauca* have been almost eliminated from the burned site in those areas where crowning occurred.

SOILS

In general, most soil parameters (electrical conductivity, carbon, phosphorus, potassium, sodium, and sulfates) followed trends reported in the literature (White *et al*. 1973; Lewis 1974; DeByle 1976; Stark 1979; Wells *et al*. 1979). The most striking anomaly was that nitrogen in the soil samples did not decrease after burning (Table I.4) before decreasing in 1984. Also, immediately after burning the pH decreased before it increased in 1984. The absence of precipitation during the period between the burn and survey II could account for these results since leaching of nutrients into mineral soil might not yet have occurred. It appears the critical temperature limit, above which major losses in nitrogen can be expected, is 300°C (Ahlgren and Ahlgren 1960; Knight 1965, 1966; Baker 1966). In addition, Baker (1968) found that soils that were lightly burned had nitrogen values similar to preburn conditions while Raiso

(1979) suggested that nitrogen, particularly nitrate compounds, may increase in the soil if temperatures were less than 500 - 600°C. Therefore, low surface temperatures at the time of burning may also explain these apparent anomalies. Any one, or combination of, the following factors may be responsible for the response of nitrogen on this site: (1) the ash generated by the high intensity crown fire may have been blown off site (Lewis 1974), (2) the organic matter burned only at low temperatures, and (3) precipitation may not have leached the available elements into the mineral soil.

F. CONCLUSIONS

Fire had a significant impact on fuel loadings. Down and dead roundwood fuels were reduced from 20.9 t/ha to 6.5 t/ha and duff depths were reduced from 5.3 cm to 2.3 cm.

The area was subjected to an extremely severe fire, as determined by flame lengths and the amount of down and dead roundwood consumed. Frontal fire intensities were estimated to range from 82,000 to 306,000 kW/m, while total heat output values ranged from 0, on subplots (0.3 m x 0.3 m) that did not burn, to 11,273,031 kJ/m^2 on subplots supporting the highest concentrations of surface fuels. However, most of the energy derived as a result of burning was concentrated in the tree crown strata of the fuelbed.

Preburn and postburn subordinate plant cover did not correlate well with preburn fuel loadings or amount of fuel consumed. *Elymus innovatus* was found across the complete spectrum of heat output before and after burning, whereas cover of *Carex* spp. seemed to be inversely related to heat output. Lastly, *Zigadenus elegans* increased in cover across the complete range of heat outputs subsequent to burning.

All species decreased in cover immediately following burning but within two years grasses and sedges had recovered to almost twice that of preburn levels, while forbs were within 2/3 of preburn cover values. Trees and shrubs were most adversely affected by burning. Trees have not reestablished on any of the permanent plots, and after two growing seasons and shrubs species cover only 0.2% of the total available ground area.

Sorensen's Index of Similarity suggested the postburn subordinate plant community immediately following fire was quite similar to preburn composition (47.6). By the end of the 1983 growing season this value had recovered to 65.5 and by the end of the 1984 growing season the index had climbed to 71.2.

Most plant species on the site were perennials and were capable of rapid vegetative reproduction or producing light weight, mobile seed. Very few of the perennial forb or graminoid species have disappeared from the site as a result of burning. This was not true for annuals.

In general, the response of anions and cations in the soil followed trends reported in the literature. The site appeared very stable as indicated by the rapid recovery of subordinate plant composition and soil parameters to preburn levels. There was little physical evidence of erosion.

G. LITERATURE CITED

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II. CHAPTER II: UTILIZATION OF A BURNED SUBALPINE COMMUNITY BY BIGHORN SHEEP

A. INTRODUCTION

The bighorn sheep (*Ovis canadensis canadensis*) is an important wildlife species in Alberta (Phillips and Adamowicz 1983). The size and quality of the sheep population in this province is greatly influenced by the amount and quality of available winter range. Fire exclusion policies are believed to have contributed to a reduction in carrying capacity of winter range due to an increase in tree cover (Cowan 1946; Pfeiffer 1948; Wishart 1958, 1978; Flook 1964; Stelfox 1971, 1976; Elliott 1978).

Prescribed burning may provide an economically efficient way of increasing the productive value of existing bighorn sheep winter range and perhaps even increasing the size of that range. Fire has been used successfully in the management of range for Dall's sheep in the Yukon (Hoefs 1980), stone sheep in British Columbia (Elliott 1978) and bighorn sheep in Colorado (Hobbs and Spowart 1984) and Wyoming (Peek *et al.* 1979). Although it is widely believed that fire can be implemented successfully in Alberta, little work has been done to substantiate this belief.

This study documented the results of a prescribed burn which was part of a bighorn sheep habitat improvement program. The strategy was to improve non-winter habitat by burning a southwest exposure in an attempt to keep animals off critical winter range for longer periods in spring and fall. The hypothesis associated with this objective is that the quantity and quality of forage, and therefore site utilization, would increase with a reduction in overstory tree canopy cover.

B. STUDY SITE

Ram Mountain, which comprises the southernmost end of the Brazeau range, supports a natural population of Rocky Mountain bighorn sheep. This population is somewhat isolated from adjacent populations due to the natural isolation of the Brazeau Range from the main Rocky Mountain ranges. Ram Mountain is located approximately 60 km west of Rocky Mountain House, Alberta and 25 km southeast of Nordegg, Alberta, Canada (52°22'N, 115°48'W). The study site was chosen for three principal reasons:

(1) the Alberta Fish and Wildlife Division have been monitoring individual sheep and group movement, population size, and vigor in the area for the past 11 years,

(2) a complete spectrum of seasonal sheep use ranges are found in the vicinity of the study area, and

(3) the actual 18 ha burn site was chosen because it was bordered on three sides by rock slope and at the base by a dry creek bed which provided adequate fuel breaks.

The elevations within the burn site and control area ranged from 1740 to 1950 m with an average slope of 42%. Soils were derived from calcareous shale and resistant

Paleozoic limestones of marine origin (Erdman 1950), and were thin, with immature profiles. Mean monthly temperature and precipitation for the growing season (May through September), measured at Kiska Lookout, approximately 28 km to the west of Ram Mountain, are 12°C and 71 mm, respectively. The area is characterized by extremes in seasonal temperatures and a summer-high, winter-low distribution of precipitation (Ogilvie 1969).

Tree cover, prior to burning, consisted mostly of white spruce (*Picea glauca*)[2] with some subalpine fir (*Abies lasiocarpa*). Average tree ages of 256 (range 159 to 299) and 156 years for white spruce and subablpine fir respectively, indicate that a fire had not occurred on the site in at least 300 years, and no evidence was found that indicated the stand was of fire origin (Bentz 1981). The understory was dominated by shrub species and had a sparse cover of grasses and forbs consisting predominantly of *Elymus innovatus* (Bentz 1981). Plant taxa known to be utilized by sheep; eg. *Potentilla fruticosa*, *Elymus innovatus*, *Zigadenus elegans*, *Hedysarum alpinum* and *Shepherdia canadensis* were common on the site (pers. comm. J. Jorgensen, Alta. Fish and Wildlife Div.).

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[2]Moss (1983) serves as the scientific authority for the nomenclature of vascular flora.

C. METHODS

A high intensity crown fire was ignited on May 31, 1983 and has been summarized by Woodard, Bentz and Van Nest (1983). Aerial application of gel-gasoline was used in igniting the stand in an attempt to reduce tree cover without significantly affecting the shallow soil and duff profiles, and therefore the surface vegetation. All burned plots on Ram Mountain, with the exception of exclosures, were permanently established by Bentz (1981) in 1979 and were re-sampled following burning. A control site was established in 1984 in an adjacent area to determine the extent of effects other than burning on the parameters measured. Immediate postburn measurements were recorded in June 1983 (Survey II), and subsequent surveys took place in August 1983 and July/August 1984 (Surveys III and IV, respectively).

VEGETATION AND FUEL ANALYSIS

The basic sampling design for vegetation and fuel was discussed in the previous chapter.

RANGE UTILIZATION

Pellet groups were counted in a 4 by 25 m plot located with its midpoint (12.5 m) at the headstake of the transect (Figure II.1). The plot runs at right angles to the secondary transect. Pellet groups were recorded by species (bighorn sheep, moose, elk and deer) and converted to pellet

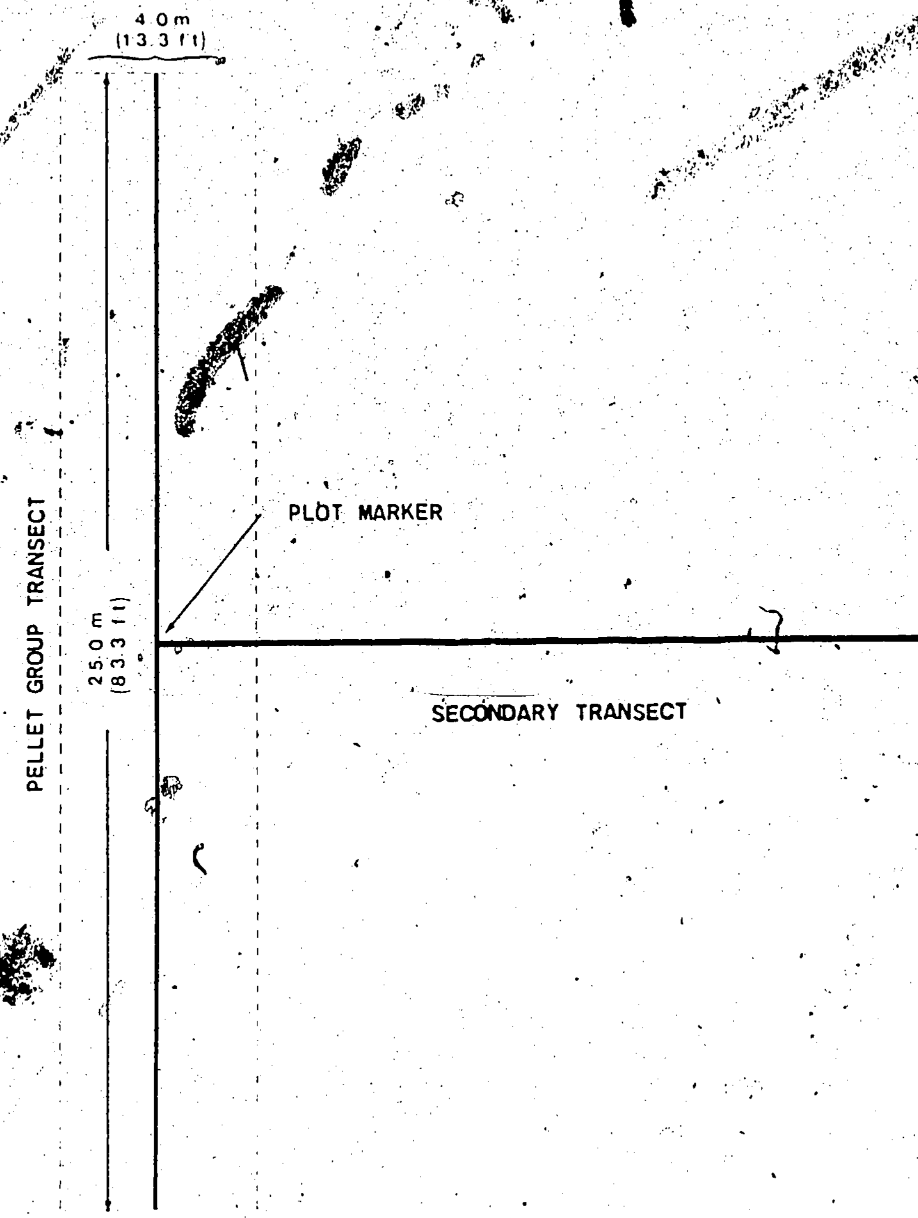

Figure II.1. Plot layout of pellet group transects adjacent to secondary transects.

groups per hectare. Plots were not swept clear between surveys.

Some difficulty was encountered in differentiating between deer and bighorn sheep pellets. Size and shape of individual pellets were generally used as the criteria for differentiating between the two species. The analysis of the shrub species included estimating the percent of current annual growth that had been browsed. The two individual shrubs (of each species) nearest the centre point (3m) of the transect were selected to be sampled. These measurements were not taken on the immediate postburn surveys due to the absence of shrubs, and no shrubs were browsed in 1984.

Six exclosures were located on the burned site and six on the control site in 1984. The exclosures are cage designs enclosing just over one square metre of ground area. Two exclosures were placed at each of three different slope locations, upper, middle, and lower, on both the burned and control sites. Exclosures were located on the inside of the two outer primary transects on the burn site while on the control site they were located on the opposite side of the primary transect to the secondary transect. The exact placement of the exclosures was dependant on the amount of vegetative cover. When possible, exclosures were placed where cover of *Elymus innovatus* was abundant in an attempt to sample as many plants of this species as possible. Adjacent to each exclosure was a square meter of ground area with a vegetation pattern similar to the interior of the exclosure. This provided the 'open' or grazed sample.

In each square metre, grazed and ungrazed, the number of plants of each major species and the number of grazed plants were counted and recorded. The number of tillers, rather than number of plants, were counted for graminoid species, as plants were difficult to distinguish between without utilizing destructive sampling procedures.

Elymus innovatus was chosen for an in depth utilization study for two reasons: (1) it was the most common subordinate plant species on the site, and (2) its distribution was relatively uniform over the entire study area in comparison with other plant species. It is also a plant species known to be used by sheep. Total number of tillers, number of tillers utilized and number of seedheads were recorded for the entire square metre area. The square metre was then divided into four equal parts and a grid placed over each segment. Two plants were randomly chosen, using random number tables to locate the plants on the 50 by 50 cm grid. The plants were extracted from each segment using destructive sampling, and each plant was separated into above ground (shoots) and below ground (roots with rhizomes) parts, and seedheads. These parts were oven dried and the weights were recorded and analyzed. The number of tillers per plant was also recorded.

STATISTICAL ANALYSIS

Analysis of variance was used to test for relationships between parameters measured on *Elymus innovatus* (number of tillers per plant, number of seedheads per square metre, and biomass data) and three independant variables including grazing, slope position and burning (treatment). Student's t-test was used to test differences between preburn and postburn pellet group counts, and between grazed and ungrazed parameters. All tests were performed at the $\alpha=.05$ level.

D. RESULTS

Bighorn sheep pellet groups are fives times more frequent in the burned area than in the control area, and pellet groups within the burned area now total 400 per hectare (Figure II.2). Moose pellets have increased from 13 to 20 groups per hectare between postburn surveys. Deer and elk pellet groups were found only on the control site.

The following plant species were chosen for observation in the grazed and ungrazed plots on the burned area because they constitute 92% of the relative subordinate plant cover on this site: *Arctostaphylos uva-ursi*, *Aster alpinus*, *Astragalus alpinus*, *Carex aurea*, *C. scirpoidea*, *Dryas integrifolia*, *Elymus innovatus*, *Epilobium angustifolium*, *Fragaria virginiana*, *Galium boreale*, *Hedysarum alpinum*, *Linnaea borealis*, *Potentilla fruticosa*, *Solidago spathulata*, and *Zigadenus elegans*. Burning did not significantly

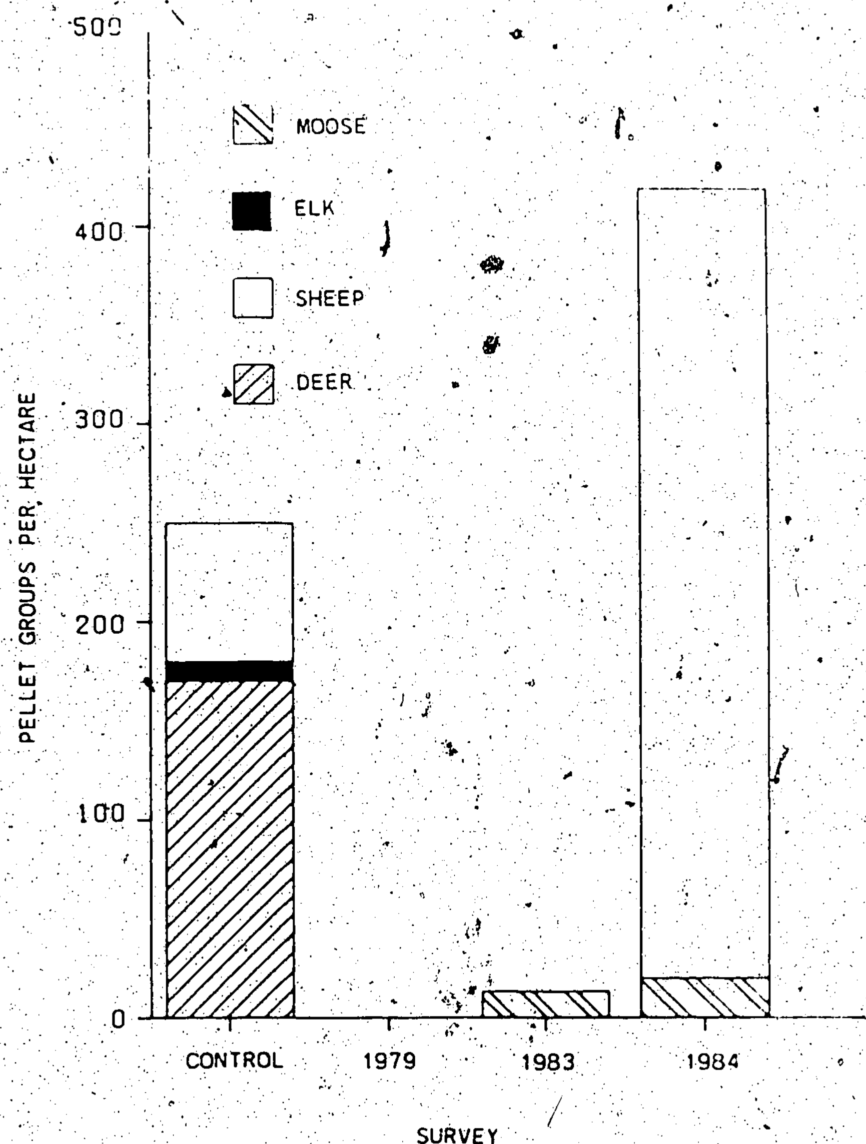

Figure II.2. Number of pellet groups per hectare for each animal species on the burned site (1983, 1984) and the control site (1984).

increase plant use by ungulates. Seven percent of all plants (and tillers) observed on the burned area were grazed compared to four percent on the control area (see Appendix I for raw data).

The five principal species utilized by animals were *Elymus innovatus*, *Bromus inermis* ssp *pumpellianus*, *Hedysarum alpinum*, *Astragalus alpinus* and *Zigadenus elegans*. These plant species showed evidence of animal use in both the burned and control areas. Percent utilization for *Elymus innovatus* and *Bromus inermis* ssp *pumpellianus* was 8 and 7 for the burned and control sites, respectively for *Hedysarum alpinum* and *Astragalus alpinus*, and for *Zigadenus elegans*, the percent utilization on burned versus control areas were 11 and 8, and 0 and 41, respectively. The difference in utilization values between the burn and control sites was significant only for *Zigadenus elegans*. However, this species did not occur in the plots sampled on the burn site but was evident on the site and was used by sheep in the burned area (pers. comm. J. Jorgensen, Alta. Fish and Wildlife Div.). All but *Zigadenus elegans* increased in cover subsequent to burning (Figure II.3).

Analysis of variance results on exclosure data indicated some interesting responses by *Elymus innovatus* (Appendix II holds raw data). Fewer tillers were found per square metre on control sites than on burned sites. Burning also appeared to affect tiller density per plant (R^2=.56) as does grazing (R^2=.40). Slope position had little influence

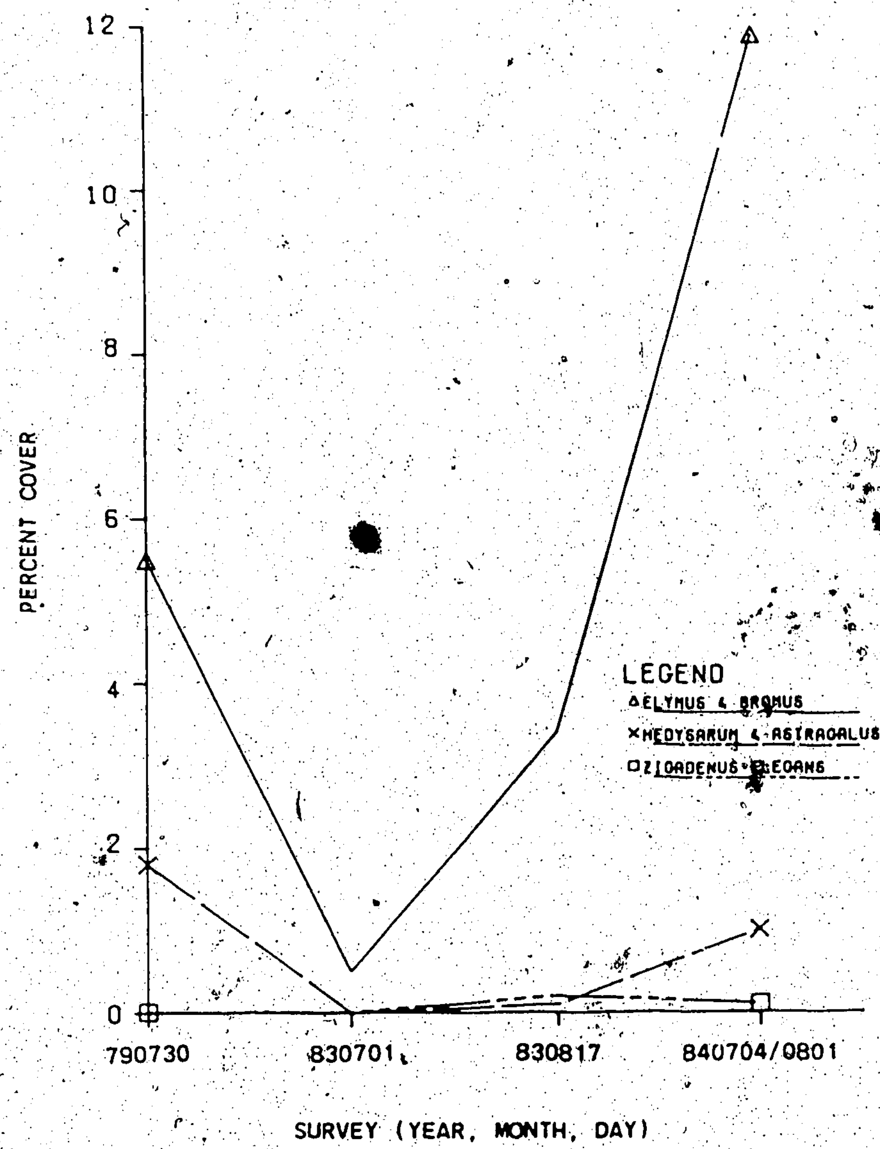

Figure II.3. Changes in percent cover over time for utilized plant species on the burned study site (data extracted from Table I.1).

on tiller density (R^2=.21). Tiller density increased with increased grazing (Figure II.4). In addition, tiller density was greater for plants growing in the upper portion of the burned site. However, the effects of slope position may be masked by the effects of grazing, as grazing was also found to be greater in the upper slope positions. Tiller density per plant is highly correlated with all three variables (R^2=.80), although it is difficult to determine the relative contribution of each.

Seedheads of *Elymus innovatus* were not abundant on the burned site. But the fact that seedheads were not observed on the control site would indicate that burning had some effect on seed development. Grazing decreased the number of seedheads on this grass, but slope position could not be used to predict seedhead occurrence.

No significant differences in biomass levels were detected. The high variability in biomass across the site precluded accurate determination of relationships in biomass versus grazing, burning or slope position (see Appendix II for raw data).

E. DISCUSSION

The presence of animals on the treatment area, particularly bighorn sheep and to a lesser extent moose, increased significantly as a result of burning when the number of pellet groups on the burned area is compared to those on the control area. In fact, the magnitude of

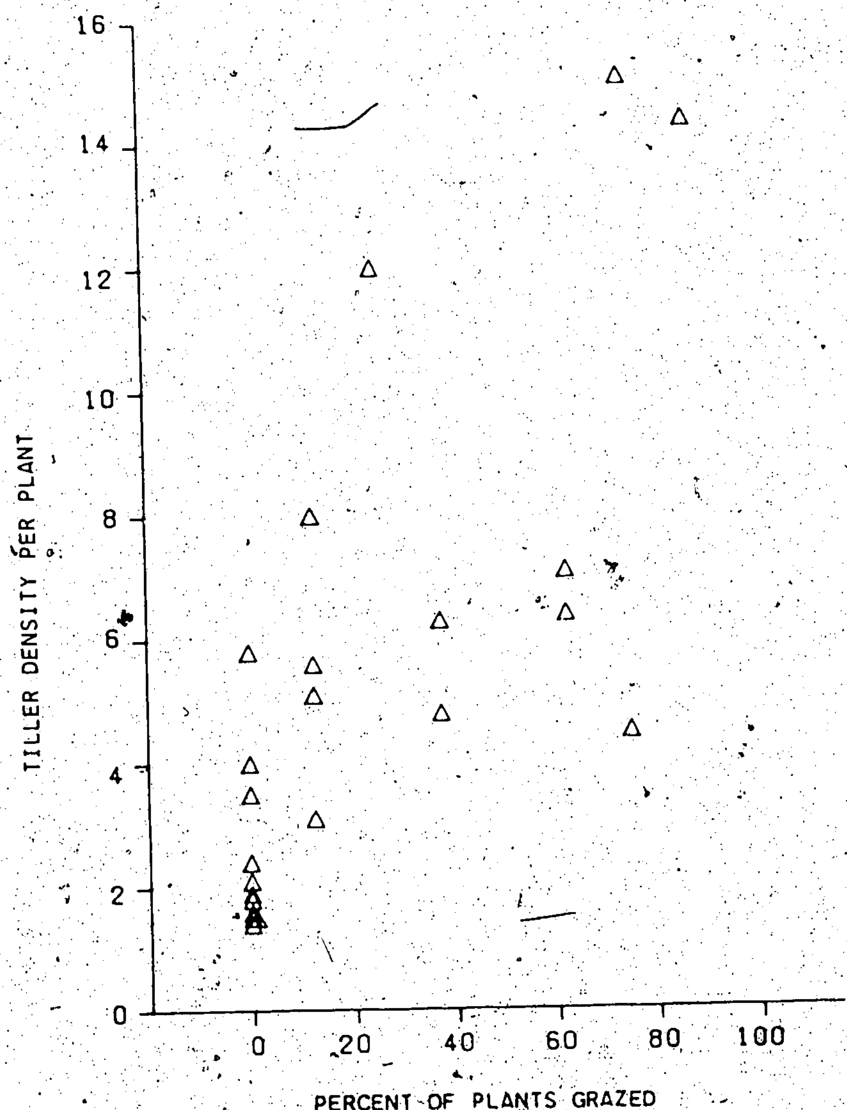

Figure II.4. Tiller density of *Elymus innovatus* plants in relation to grazing (% of plants grazed).

increase is even more significant if one accepts the hypothesis that pellet groups remain intact for more than one year. Further, the presence of bighorn sheep pellet groups on the control site in 1984 may be a result of the increased use in the adjacent burned area. The lack of preburn use data, as determined by pellet groups, prevents this study from actually documenting increases. Without historical records, the value of this data could be questioned because sheep use of an area is determined by more variables than burning.

Evidence of grazing within the burned area does not substantiate the level of sheep use, as determined by the deposition of feces. Only 7% of all plants and tillers were utilized. However, this data may be confounded by limitations in sample size, and timing of sampling. Currently, plant cover is extremely limited within the burned area, and the most prominent plant within the burned area, *Elymus innovatus*, is not normally utilized by sheep. In fact, only 5 of the 15 species studied in the exclosure areas were utilized. It is possible that the increased use is a result of increased visibility, and that the site is used primarily as a resting area (pers. comm. W. Wishart, Alta. Fish and Wildlife Div.).

Fish and Wildlife researchers in Alberta feel that *Elymus innovatus* is eaten because of its availability, especially during spring green up, whereas *Hedysarum alpinum*, *Astragalus alpinus*, and *Zigadenus elegans* are selected due to their palatability (pers. comm. J. Jorgensen and W. Wishart, Alta. Fish and Wildlife Div.). *Bromus inermis* ssp *pumpellianus* was found in only one exclosure when the presence of seedheads enabled it to be positively identified. This species of grass is somewhat more palatable than *Elymus innovatus* (W. Wishart, Alta. Fish and Wildlife Div.), but the sheep did not appear to be selecting for it.

The relationship between tiller density and grazing, where density increased with increased grazing, could be expected as the removal of top growth would release dormant underground buds. However, the possibility exists that grazers selected plants with more tillers in an attempt to be more energy efficient. A similar effect to grazing would be produced by burning. When live above ground biomass is consumed by fire, roots and rhizomes could be stimulated into vegetative reproduction. Sinton and Bailey (1980) found similar results with rough fescue, in which tiller numbers increased by 6 to 34% following spring burning.

The removal of the overstory canopy and the increase in nutrients and net radiation received, as a result of burning, may account for the positive response in seedhead production by *Elymus innovatus*. This type of response was noted in rough fescue (Sinton and Bailey 1980), and in western porcupine grass (Bailey and Anderson 1978). The reduction, by grazing, of seedheads on the burned site on Ram Mountain is an obvious result of the culms being eaten and therefore not being allowed to reach maturity.

F. CONCLUSIONS

Presence of bighorn sheep, as indicated by pellet groups, has increased as a result of burning. Of the 15 plant species studied on the burned site in 1984 only 5 were utilized. These include; *Elymus innovatus*, *Bromus inermis* ssp. *pumpellianus*, *Hedysarum alpinum*, *Astragalus alpinus*, and *Zigadenus elegans*. There was no significant difference in percent grazing between the burned and control sites. Therefore, changes in forage status may not be the main reason for the increased use of the site by ungulates. However, the increase in the number of animals on the burned site does indicate an improvement of part of the range, which is evidently providing niche space of importance to sheep. The site may be used as a sheltered resting area due to the increased visibility.

Grazing and burning increased the tiller density of *Elymus innovatus* perhaps by releasing underground dormant buds. Seedheads of this grass were found only on the burned site. Exclosure data showed that grazing reduced the total biomass of *Elymus innovatus*, although the reductions were not significant. *Elymus innovatus*, although not preferred, may be a potentially important forage for bighorn sheep on this site. This may be particularly true during the early spring when this species has not produced hairy blades and culms.

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III. MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH NEEDS

This study was designed to provide important ecological information on the response of subalpine sites in Alberta to fire in an attempt to establish a management technique for improving or increasing Rocky Mountain bighorn sheep range. Very little information exists on the effects of fire on subalpine plants and large ungulates native to this zone. Therefore, most responses noted in this manuscript are new and useful. Land managers may be able to justify or provide guidelines for prescribed burning programs from the information on initial response and availability of forage species and the degree and pattern of utilization by ungulates, particularily bighorn sheep, provided by this, and similar, research.

Judging from the marked reaction of bighorn sheep to the burned site on Ram Mountain, one could assume that prescribed burns would indeed increase the carrying capacity of bighorn sheep range if a greater number of areas, similar to the study site, were burned. However, habitat requirements such as proximity to escape terrain also need to be met (Bentz 1981). Also, in light of the amount of plant cover immediately following burning, large areas within the range of a sheep population should not be burned. Areas suitable for this type of management scheme need to be designated by land managers in areas where management of bighorn sheep populations is deemed necessary. It should be remembered that this type of area receives little precipitation and, therefore, is very dry and little erosion results. An analysis of the preburn plant community and knowledge of the morphological, phenological and reproductive strategies will enable managers to better predict the likely response of plants preferred by sheep. This information must be evaluated if burning is to be used in a responsible habitat enhancement program.

The ignition techniques and prescription used for this fire contributed immeasurably to the ecological response of the site. For the first time, it can be shown that a prescribed crown fire can be sustained without significant involvement of surface fuels. Also, because surface fuel loadings were not required for crowning, the shallow duff layers were not completely oxidized and many perennial plant species survived.

Important future research objectives would be;

1) to analyze nutrient, protein and fibre content of the forage species on site prior to, and after, burning,

2) to replicate parameters measured in the exclosures, perhaps over a longer period of time,

3) to determine long-term impacts of fire on all the parameters studied in this research, and

4) to define, and test the fire parameters and prescriptions most appropriate for creating or maintaining high elevation subalpine bighorn sheep range.

A. LITERATURE CITED

Bentz, J.A. 1981. Effects of fire on the subalpine range of Rocky Mountain bighorn sheep in Alberta. M.Sc. Thesis, University of Alberta, Edmonton, Alberta. 192 p.

Appendix I

Raw data from observations of numbers of plants and numbers of plants grazed for 15 plant species in open and exclosed plots.

Carex aurea and C. scirpoidea

	Ungrazed		Grazed	
#	Number	Util	Number	Util*
B1	27		10	
B2				
B3				
B4				
B5				
B6				
C7				
C8				
C9	357		317	
C10			45	
C11				
C12	232		107	

Hedysarum alpinum and Astragalus alpinus

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	10		4	2
B2	18		10	
B3				
B4	38		7	
B5	11		1	
B6	3			
C7	2		3	3
C8				
C9	6		6	
C10	8		17	
C11	25		8	
C12	15		3	

Solidago spathulata

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	23		3	
B2				
B3				
B4				
B5				
B6			6	
C7				
C8				
C9				
C10	16		15	
C11				
C12				

Aster sibiricus

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1				
B2	68		54	
B3				
B4				
B5	62		21	
B6				
C7				

#	Number	Util	Number	Util
C8				
C9				
C10				
C11				
C12				

Dryas hookeriana

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	4			
B2				
B3				
B4				
B5				
B6				
C7				
C8				
C9	25%		30%	
C10				
C11				
C12	50%		40%	

Arctostaphylos uva-ursi

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	1			
B2				
B3				
B4	18		6	
B5				
B6				
C7	23		2	
C8	38			
C9	7			
C10				
C11	20		8	
C12				

Potentilla fruticosa

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	1			
B2				
B3				
B4				
B5				
B6				
C7				
C8				
C9	12		8	
C10				
C11	3		2	
C12	6		3	

Galium boreale

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1	8		3	

B2	285		93	
B3	30		23	
B4	57		35	
B5	262		110	
B6				
C7	21		8	
C8				
C9				
C10				
C11	50		29	
C12				

Epilobium angustifolium

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1				
B2				
B3	52		76	
B4	48		60	
B5				
B6				
C7				
C8				
C9				
C10				
C11				
C12				

Linnaea borealis

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1				
B2				
B3	78		18	
B4				
B5				
B6				
C7	15		15	
C8				
C9				
C10				
C11				
C12				

Fragaria virginiana

	Ungrazed		Grazed	
#	Number	Util	Number	Util
B1				
B2				
B3				
B4	25		29	
B5				
B6				
C7	4		2	
C8	27		1	
C9				
C10				

C11
C12

Zigadenus elegans

#	Ungrazed Number	Ungrazed Util	Grazed Number	Grazed Util
B1				
B2				
B3				
B4	9			
B5				
B6				
C7				
C8				
C9	16		9	9
C10	1		4	
C11	11		12	4
C12	27		7	

Elymus innovatus

#	Ungrazed Number	Ungrazed Seedheads	Ungrazed Util	Grazed Number	Grazed Seedheads	Grazed Util
B1	101			77		13
B2	879	135	8	1114	137	83
B3	941			1249	1	33
B4	921	3	13	1183	2	57
B5	657	59	19	1002	19	152
B6	388	35	8	305	62	62
C7	268			275		5
C8	73			82		12
C9	10			3		
C10	18			29		
C11	97			62		14
C12	14			15		

---

* # = Plot number (1 - 12); B = burned area, C = control.
Number = number of plants observed.
Util = number of plants grazed.

Appendix II

Raw data from density and biomass studies of *Elymus innovatus*.

A	B	C	D	E	F	G	H	I
EB1	1	1	0	5	.3811	.2251		1
	2	1	0	6	.7111	.5333		1
	3	1	0	3	.3917	.3859		1
	4	1	0	3	.2657	.2267		1
	5	1	0	5	.4603	.1437		1
	6	1	0	3	.1516	.2031		1
	7	1	0	2	.5064	.1708		1
	8	1	0	5	.9073	.2650		1
OB1	1	2	0	7	.1357	.3219		1
	2	1	0	6	.2539	.4948		1
	3	2	0	8	.6423	.4223		1
	4	2	0	2	.1307	.1478		1
	5	2	0	14	1.4878	1.0625		1
	6	2	0	8	.5526	.3861		1
	7	1	0	3	.4099	.1170		1
	8	1	0	3	.2330	.2911		1
EB2	1	1	1	6	.2980	.3677	.3898	2
	2	1	0	7	.2713	.5913		2
	3	1	3	8	.2717	.4408	.8836	2
	4	1	0	4	.6306	.5903		2
	5	2	2	17	.4214	.6311	.5585	2
	6	1	0	3	.1483	.3215		2
	7	1	4	11	.7030	.7546	2.4974	2
	8	1	2	8	.3260	.4449	.6531	2
OB2	1	2	2	19	1.2614	.7631	.6065	2
	2	2	1	12	.4537	1.1439	.2242	2
	3	2	3	23	1.3074	1.0098	.7560	2
	4	1	0	6	.1962	.3465		2
	5	1	1	14	.7345	.8624	.2964	2
	6	2	2	18	.4292	.7663	.2644	2
	7	2	0	18	.5204	.7683		2
	8	2	1	11	.2273	.4675	.3433	2
EB3	1	1	0	4	.4571	.1467		3
	2	1	0	3	.2782	.3156		3
	3	1	0	8	.0758	.3265		3
	4	1	0	4	.2548	.3548		3
	5	1	0	3	.1136	.4419		3
	6	1	0	6	.2821	.4336		3
	7	1	0	7	.3252	.8662		3

	8	1	0	11	.6117	.9323		3
OB3	1	2	0	9	.1546	.3487		3
	2	1	0	5	.2465	.5048		3
	3	2	0	2	.1397	.1485		3
	4	1	0	3	.1571	.0721		3
	5	1	0	3	.0995	.1847		3
	6	1	0	2	.2887	.0660		3
	7	1	0	5	.1013	.2291		3
	8	2	0	21	.8261	1.3148		3
EB4	1	2	0	3	.1780	.1911		3
	2	1	0	5	.0876	.3476		3
	3	2	0	7	.0940	.5910		3
	4	1	0	2	.1380	.2443		3
	5	1	0	3	.1458	.3513		3
	6	2	0	12	.2373	.8189		3
	7	1	0	2	.2421	.4035		3
	8	1	0	4	.1161	.3365		3
OB4	1	2	0	2	.1095	.3098		3
	2	1	0	6	.0953	.3618		3
	3	1	0	4	.1247	.1751		3
	4	2	0	6	.1100	.3515		3
	5	2	0	3	.1807	.2923		3
	6	2	0	3	.1273	.2758		3
	7	2	0	5	.0991	.5960		3
	8	2	0	7	.4826	1.0669		3
EB5	1	1	0	3	.0705	.1426		2
	2	1	0	2	.0310	.0901		2
	3	1	1	10	.1995	.5695	.3257	2
	4	1	0	11	.2271	.6180		2
	5	1	0	3	.1032	.1948		2
	6	2	2	36	2.9640	3.0033	.7454	2
	7	1	4	10	.2243	.1257	.4023	2
	8	2	4	21	.3984	.6749	1.4375	2
OB5	1	2	0	6	.0863	.2023		2
	2	2	0	21	.5119	.5214		2
	3	2	0	28	.2932	.7514		2
	4	2	1	16	.2025	.8589	.1802	2
	5	2	0	16	.4217	.7160		2
	6	2	0	9	.0709	.1253		2
	7	2	0	5	.0818	.2067		2

	8	1	2	14	.2656	.6195	.2788	2
EB6	1	1	1	6	.1627	.4141	.297[illegible]	1
	2	1	0	2	.1573	.2752		1
	3	1	0	11	.2824	.6881		1
	4	1	0	4	.2165	.2838		1
	5	1	0	2	.1471	.2494		1
	6	1	0	2	.2446	.1587		1
	7	1	0	3	.0902	.1497		1
	8	2	1	11	.3278	.5816	.1986	1
OB6	1	1	0	9	.2480	.3717		1
	2	2	1	12	.2335	.5151	.0985	1
	3	2	0	9	.3813	.5585		1
	4	1	0	2	.0378	.0950		1
	5	2	0	4	.0777	.2402		1
	6	2	0	10	.0693	.2773		1
	7	1	0	1	.0626	.0704		1
	8	2	1	10	.3064	.4354	.3098	1
EC4	1	1	0	2	.1572	.2815		3
	2	1	0	1	.1463	.2317		3
	3	1	0	5	.2534	.1834		3
	4	1	0	3	.3056	1.0156		3
	5	1	0	4	.3399	.8594		3
	6	1	0	1	.1690	.2239		3
	7	1	0	2	.0526	.4373		3
	8	1	0	1	.1582	.2372		3
OC7	1	1	0	3	.1374	.6762		3
	2	1	0	2	.5685	.6581		3
	3	1	0	1	.1507	.1210		3
	4	1	0	5	.5815	.6870		3
	5	1	0	3	.2915	.4709		3
	6	1	0	3	.1428	.5251		3
	7	1	0	6	.4685	1.4885		3
	8	2	0	2	.2276	.4586		3
EC8	1	1	0	3	.1888	.3474		2
	2	1	0	1	.1340	.2879		2
	3	1	0	4	.2220	.5790		2
	4	1	0	5	.7083	1.2961		2
	5	1	0	2	.4547	.2121		2
	6	1	0	5	.4887	.6850		2
	7	1	0	3	.2495	.4249		2

	8	1	0	8	.7255	1.2857	2
OC8	1	2	0	5	.7230	1.1939	2
	2	1	0	2	.5741	.1966	2
	3	1	0	2	.5285	.6084	2
	4	1	0	5	.4160	.5585	2
	5	1	0	11	.7152	1.2327	2
	6	1	0	7	.2986	.5905	2
	7	1	0	2	.2553	.1095	2
	8	1	0	11	1.3949	1.2863	2
EC9	1	1	0	1	.4606	.4309	1
	2	1	0	2	.3632	.3670	1
	3	1	0	3	.3637	.6613	1
	4	1	0	1	.4108	.2025	1
	5	1	0	1	.1716	.2456	1
	6	1	0	1	.2891	.0867	1
	7	1	0	1	.1728	.2609	1
	8						1
OC9	1	1	0	1	.0551	.0466	1
	2	1	0	2	.0603	.1760	1
	3						1
	4						1
	5						1
	6						1
	7						1
	8						1
EC10	1	1	0	1	.2913	.0770	3
	2	1	0	1	.2164	.4714	3
	3	1	0	1	.1371	.1660	3
	4	1	0	1	.1029	.1995	3
	5	1	0	2	.1606	.1507	3
	6	1	0	1	.0917	.0809	3
	7	1	0	3	.2432	.2579	3
	8	1	0	5	.3546	1.0961	3
OC10	1	1	0	3	.2401	.1747	3
	2	1	0	3	.3014	.0974	3
	3	1	0	2	.1541	.0482	3
	4	1	0	1	.0714	.0743	3
	5	1	0	2	.0576	.0465	3
	6	1	0	1	.0677	.1285	3
	7	1	0	3	.1225	.0776	3

	8	1	0	2	.2949	.0792		3
EC11	1	1	0	1	.0940	.2426		2
	2	1	0	2	.1096	.2305		2
	3	1	0	1	.2001	.3431		2
	4	1	0	1	.0433	.1355		2
	5	1	0	1	.0282	.0503		2
	6	1	0	3	.1846	.2601		2
	7	1	0	2	.1493	.3829		2
	8	1	0	2	.1845	.3041		2
OC11	[illegible]	1	0	2	.2209	.2149		2
	2	1	0	2	.3319	.2512		2
	3	2	0	1	.0793	.1300		2
	4	1	0	2	.1510	.3024		2
	5	1	0	2	.1815	.2524		2
	6	1	0	1	.0834	.0868		2
	7	1	0	1	.0833	.0935		2
	8	1	0	1	.1837	.3715		2
EC12	1	1	0	2	.1048	.1124		1
	2	1	0	1	.1493	.0495		1
	3	1	0	1	.2877	.0834		1
	4	1	0	2	.1268	.0793		1
	5	1	0	2	.0537	.2024		1
	6	1	0	1	.0283	.0573		1
	7	1	0	2	.0783	.0828		1
	8	1	0	3	.3404	.1790		1
OC12	1	1	0	1	.0191	.0785		1
	2	1	0	1	.0301	.0309		1
	3	1	0	1	.0380	.0346		1
	4	1	0	1	.1148	.1075		1
	5	1	0	1	.2771	.1226		1
	6	1	0	4	.2510	.3481		1
	7	1	0	1	.0504	.0700		1
	8	1	0	2	.0902	.0245		1

A = Grazed (O) or ungrazed (E), burn (B) or control (C), exclosure number (1 - 12).
B = Plant number (1 - 8).
C = Utilized (2) or unutilized (1).
D = Number of seedheads.
E = Number of tillers.
F = Above ground biomass (grams).
G = Below ground diomass (grams).
H = Seedhead and culm biomass (grams).
I = Slope position: 1 = top of slope, 2 = mid slope, 3 = base of slope.