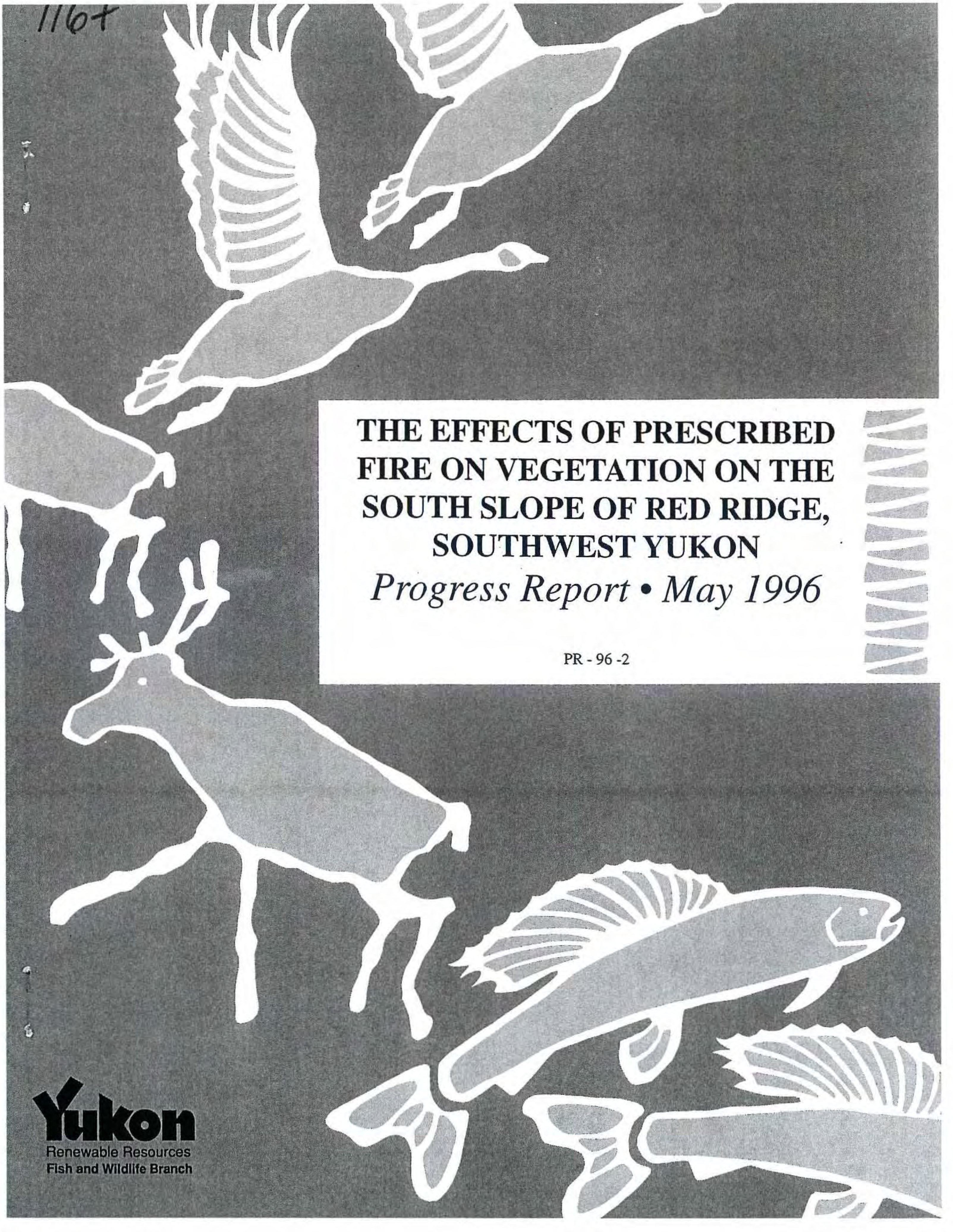

THE EFFECTS OF PRESCRIBED FIRE ON VEGETATION ON THE SOUTH SLOPE OF RED RIDGE, SOUTHWEST YUKON

Progress Report • May 1996

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Yukon
Renewable Resources
Fish and Wildlife Branch

The Effects of Prescribed Fire on Vegetation on the South Slope of Red Ridge, Southwest Yukon

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1992-1995

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1.0 Introduction

1.1 Background

Historically, prescribed fire was used by many North American indigenous cultures to improve the production of natural grasses, berries, and tubers, to prevent unwanted fires, and more commonly to improve hunting within their traditional hunting grounds (Pyne 1992). This practice essentially disappeared when European ideals and cultures spread through the continent. With the coming of European settlers came the emphasis that the forests were a valuable source of timber, and because fire killed trees it was viewed as bad. Not until the early 1960's did this view start to change.

Leopold et al. (1963) recognized that protecting all plant communities from fire could be detrimental. Without fire, impacts include excessive fuel build-up in forested areas, forests evolving into monocultures prone to disease and insect infestation, encroachment of shrubs and trees into grasslands, and significantly less plant and animal diversity. Fire is, in many ecosystems, an important ecological force—like wind, rain, and other natural forces—acting as a catalyst for species diversity and providing stability (Vogl 1971). Fire is a particularly dominant force in the northern boreal forest, which covers much of Yukon.

Today the use of prescribed fire to achieve renewable resource management objectives is once again being practiced, but its use is much more limited than was the case in recent history. Prescribed fire is a controlled means of reintroducing fire into ecosystems (particularly where natural fires are suppressed) and achieving specific objectives. This tool is used to reduce forest fire hazard in developed areas, maintain grasslands, improve forest rejuvenation (silviculture), control the spread of forest disease and insect infestation, and enhance wildlife habitat. Prescribed fire, when conducted in specific situations by trained professionals, can create desired results and meet specific resource objectives.

A prescribed burn project was initiated on Red Ridge in 1992 to look at the effectiveness of prescribed fire in suppressing the encroachment of woody species onto grassy slopes, and in improving thinhorn sheep (*Ovis dalli*) winter range. The intention is not to increase sheep numbers in this area but rather to determine the effectiveness of fire in promoting the growth of vegetation that is palatable for sheep, primarily grasses and to a lesser extent forbs (Hoefs et al. 1975, Hoefs and Cowan 1979). Therefore, the study area is within small, pre-defined plots. If the results of the study are favourable the expertise acquired could be applied in similar but larger areas to improve sheep winter range.

This project was funded by the Government of Yukon through the Economic Development Agreement (EDA), and by the Department of Indian and Northern Development (DIAND). Budget and expenditure details are provided in Appendix 1.

1.2 Problem Statement

Winter ranges of thinhorn sheep typically occur on south facing, grassy slopes, that have minimal snow accumulation due to wind and solar exposure. The quality of winter range can be reduced through the encroachment of aspen, balsam poplar, and shrub species to the point where the area is no longer suitable as winter range. Woody species reduce the quality of sheep winter range by sheltering the ground from wind allowing excessive snow accumulation during winter. Forage preferred by sheep may be reduced and/or made inaccessible.

1.3 Objectives

The use of fire as a tool to reverse the encroachment of woody species and to improve sheep habitat is being investigated on Red Ridge. The objective of this study is to:

- investigate whether or not the use of prescribed fire will reverse the encroachment of aspen, balsam poplar, and shrub species onto thinhorn sheep winter range, and promote the growth of forage preferred by sheep.

Burn-specific objectives, such as fire intensity and optimal weather conditions, are listed in the spring 1993 and 1994 burn proposals (Kiemele and Legare 1993, Waterreus 1994).

2.0 Study Area

2.1 Location

The prescribed burn area is located on the south slope of Red Ridge, approximately 6 kilometres west of Annie Lake; Thompson Creek is immediately south, and the Watson River is 2 kilometres to the north (Figure 1). This area is accessible by four-wheel-drive along an existing mining road. The road represents the southern boundary of the study blocks, and serves as an effective fire break. Specific geographic features include:

Map Location: UTM (point of origin) = 494000E 6690750N
Latitude/Longitude = 60° 22'/135° 06'
NTS Map/Quad: 105D/06
Elevation: Top = 1,219 metres Bottom = 1,067 metres
Slope: 20%
Aspect: south
Drainage: well drained
Area: 6 plots x 1.75 hectares = 10.5 ha

2.2 Study Plots

The study area comprised two separate blocks, 330x175 metres each (Figure 1). The block to the east is called 'Block A' and the block to the west 'Block B'. Within each block there

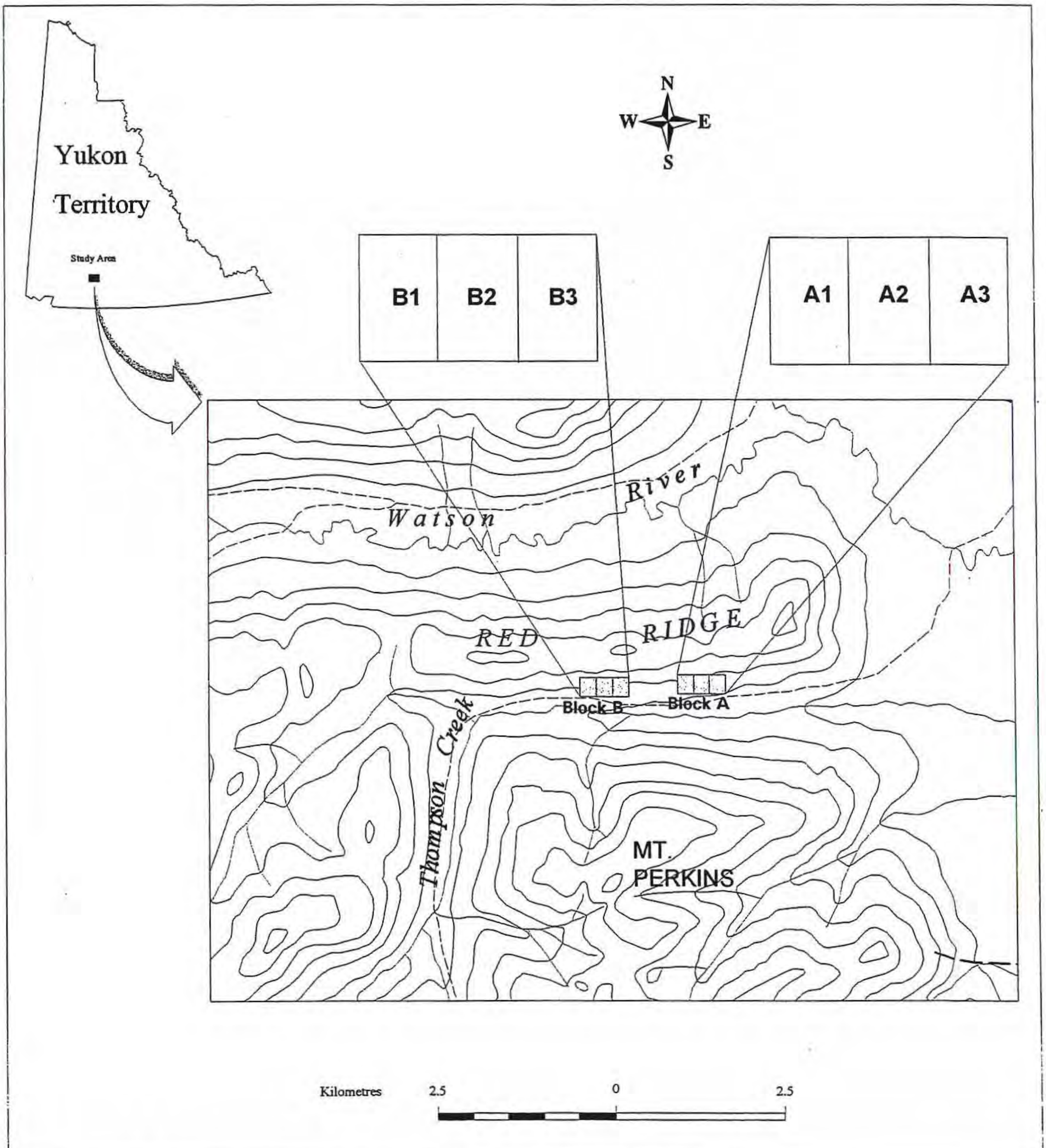


Figure 1. Red Ridge prescribed burn study area and plot locations.

are 2 burn plots (i.e. A1, A2 and B1, B2) and 1 unburned or control plot (i.e. A3 and B3). Each plot is 100 metres running east to west by 175 metres along a north/south axis.

2.3 Soil

The south slopes of Red Ridge at about 1,000 metres is made up of glaciofluvial deposits modified by colluvial processes, which are still active. Near-surface bedrock is present at this elevation.

The soil characteristics of the burn area alternate between relatively deep loamy textures and surface bedrock and stones. Stones cover about 30% of the surface of the mineral soil (evident from burned plots), which is covered by 5 cm of leaf litter and humic material (evident from unburned plots).

The soil sample site (pit) showed 5 cm of humis rich mineral soil. Soil samples show mean organic matter levels in Block A of 14.8% while those in Block B had a mean of 11%. These organic matter levels are surprisingly high, and with a pH in the slightly acid range (6.0-6.5) the prescribed burn site provides a relatively rich growth medium.

2.4 Vegetation

The south facing slope of Red Ridge is thickly covered with slender *Populus tremuloides*, *P. balsamifera*, and *Salix spp.* The shrub understory consists primarily of *Shepherdia canadensis, Rosa acicularis* and *Betula glandulosa. Epilobium angustifolium* and *Festuca altaica* are herb species commonly found in the study plots. Ground shrubs found include *Arctostaphylos uva-ursi* and *Linnaea borealis*. Appendix 2 lists the plant species found within the sample plots during the 1992, 1994, and 1995 field seasons.

3.0 Methods

3.1 Experimental Design

Following the selection of Blocks A and B (each being relatively homogeneous within), the Red Ridge prescribed burn study was structured into three phases. These are as follows:

Phase 1: *Pre-burn assessment and preparation 1992* - vegetation sampling, fuel inventory, and control lines cut around each proposed burn plot.

Phase 2: *Prescribed burns 1993 and 1994* - burn 2 plots in spring of 1993 and 2 plots in spring of 1994. Initially 2 plots were intended for fall burning, but this was abandoned because weather conditions were inadequate and personnel was limited in the "non-fire" season. Instead a second spring burn was conducted.

Phase 3: *Post-burn assessment in summers of 1994 to an undetermined year* - vegetation sampling of burn plots and control plots, analyzing vegetation composition and biomass and evaluating changes over time.

3.2 Prescribed Fire Treatments

The following description of the prescribed fire treatment methodology is only in general terms. For more specific detail see the spring 1993 and 1994 burn proposals (Kiemele and Legare 1993, Waterreus 1994).

3.2.1 Pre-burn Monitoring

Pre-burn monitoring was needed to ensure that the burn ignition occurred within the calculated acceptable fire conditions (i.e. conditions that would most likely meet the project objectives). This involved monitoring air temperature, relative humidity, precipitation, and wind speed and direction. Initially, regional weather forecasts and data from an on-site, remote weather station (WX) were used to predict the "best" day for burning. Once on site, the WX data was monitored regularly to determine the best time of day to conduct a burn.

3.2.2 Spring Burn 1993 and 1994

The ignition phase of the burn proposals was initiated only when the conditions for burning met the specified criteria, and when appropriate safety measures were in place. Safety measures included establishing control lines, setting up hose line and sprinkler system, black lining the control lines, putting fire crew on site, and alerting back up personnel. Ignition was done with hand-held drip torches, and the interior of the blocks were left to burn themselves out. Fire crews only extinguished spot fires that spread outside of the burn plots. Sprinklers were only used in 1994 as an additional precaution to prevent fire escaping from the plots. The sprinklers would have been used if the fire jumped the control lines.

3.3 Vegetation/Biomass Sampling

Vegetation sampling was conducted prior to the prescribed burns in August, 1992 (all plots), and after the burns in August, 1994 (all plots), and August, 1995 (plots A2, A3, B2, B3). Variables measured from sampling included percent cover of each plant species, dried weights (grams) of select species considered to be forage for herbivores—particularly sheep (Appendix 2), and a twig and stem count of shrub species. Additional variables measured during the post-burn sampling included an assessment of ground and stem suckering, and counting dead and live trees.

Twenty ***vegetation sample sites*** were randomly selected within each burn and control plot. These sample sites were selected and located within a grid overlay for each plot through random drawing of numbers and letters assigned to the grid (Figure 2). Each vegetation sample site included a ***shrub plot*** of 2x5 metres, and a ***herb plot*** of 1x1 metre, which was located in the northeast corner of the shrub plot in 1994 and the northwest corner in 1995 (Figure 2).

Browse stem availability was assessed in the shrub plot. All stems rooted within the 2x5 metre area were tallied by species. One stem of each species in the shrub plot was selected arbitrarily, and all current annual twigs were put into one of 2 categories: ground level (>0

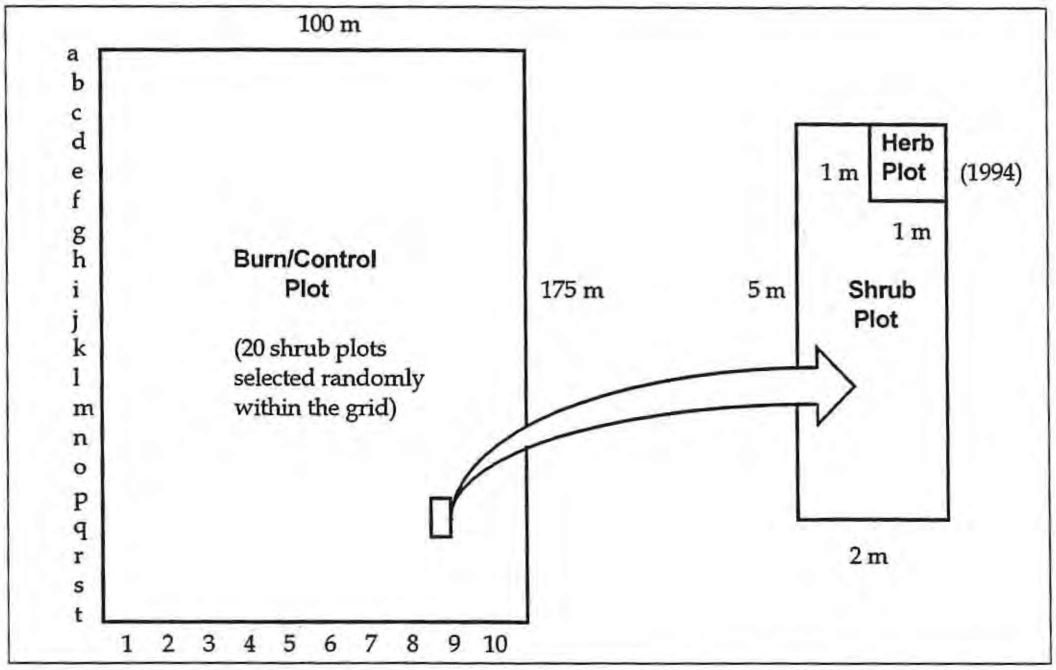


Figure 2. Experimental layout and plot sizes for the Red Ridge prescribed burn study location.

metres) to 1.50 metres and >1.50 to 2.50 metres high. Three additional plot measurements were conducted in the shrub plots during the field seasons following the prescribed burns; these are:

(i) live/dead residual tree count (trees are defined as all coniferous species and any deciduous species > 2.5 metres),

(ii) aspen and poplar sucker count (part of the twig/stem count), and

(iii) recording the representative sucker age (using the modal age of the suckers).

Within the herb plot the percent cover was estimated for each herb and shrub species. The current annual growth (CAG) of selected herb and shrub species (Appendix 2) were then clipped and put in separate, labeled paper bags for later biomass assessment.

Plant samples were stored until moved to a drying oven. If samples were damp because of rain or heavy dew, they were taken in to be dried within 3 days of collection. All samples were oven dried at 30°C for a minimum of 48 hours prior to weighing. Samples not dried by then were further dried until no additional weight change was observed. All samples were weighed to within 0.1 g on an electronic balance, soon after removal from the oven.

3.4 Data Analysis

For each vegetation type (grass, shrub, forb), treatment-minus-control difference values were calculated as the mean biomass from the 20 subsamples in a treatment plot minus the mean biomass in its corresponding control plot (i.e., A1-A3, A2-A3, B1-B3, B2-B3). All pre-burn difference values were calculated using 1992 data, whereas 1-year-post-burn difference values were calculated using 1994 data for plots A1 and B1, and 1995 data for plots A2 and B2. The treatment-control difference values from the pre-burn and 1-year-post-burn samples were then analyzed using a 2-tailed paired *t*-test (H_0: mean difference between pre- and post-burn difference values equals zero), under the assumption that the 4 burn plots were effectively independent experimental units (i.e., there was no apparent bias associated with plots within blocks). The paired *t*-tests in effect tested for interaction between the two factors in this experiment, burn and control versus before and after treatment. The treatment and control effects were assessed and interpreted only by examining plots of the data.

The data could not be tested for normality because of the low sample sizes. A 2-tailed Wilcoxon signed-ranks test, the non-parametric equivalent, could not be used because it is virtually powerless when the sample size is 4, regardless of how great the differences between two samples are. Given the low sample sizes, the paired *t*-tests are expected to have low power, which means that failure to reject H_0 at a low α is inconclusive. Additional problems with the experimental design and their effects on the analysis of the data are presented in Section 5.2.

Statistical analysis of % cover by species and stem/twig count was not completed for this progress report but will be included in the final report.

4.0 Preliminary Results

4.1 Direct Impacts of Burning

Assessment of many fire behaviour variables were not completed. Two of the most important parameters are fire **intensity** (expressed as kw/m) and **severity** (ratio or percent of organic layer removed). Intensity is the product of the available heat of combustion of the fuel, the amount of fuel consumed, and the rate of spread; I=HWR where H is the low heat of combustion in J/kg, W is the fuel loading in kg/m², and R is the rate of spread in m/sec (Byram 1959). Intensity can also be estimated using the formula $I=3(10h)^2$, where "h" is the estimated height of flame. In this study the intensity was only rated subjectively by Fire Management personnel.

Severity is a measure of (1) the depth of burn into the organic layer of the soil, expressed as a ratio or percent of the weight or depth of the layer removed, and (2) the % or size of area burned at varying degrees of "severity." The latter takes into account the mosaic pattern or variability common within large, boreal forest burns. Wells et al. (1979) suggested a standardised classification scheme for fire severity that considers the % of area that is burned heavily, moderately or lightly, as modified from the severity classes developed by Viereck et al. (1979). It would be sufficient in the Red Ridge study area to only consider the depth of burn as a measure of severity, since the area is relatively small.

Assessment of some fire variables may be achieved after the fact from analysis of photographs, video, and subjective opinion.

4.1.1 Spring 1993

The 1993 spring burn in plot A1 was patchy and incomplete in the lower half of the plot because the burn was of low intensity. The upper half was more complete and of higher intensity. It is likely that the humidity was too high and that green-up was too far advanced to attain the desired burn results.

The 1993 spring burn in plot B1 was a moderate to high intensity burn. Figure 3a and 3b shows that the surface fuels were largely consumed in plot B1.

4.1.2 Spring 1994

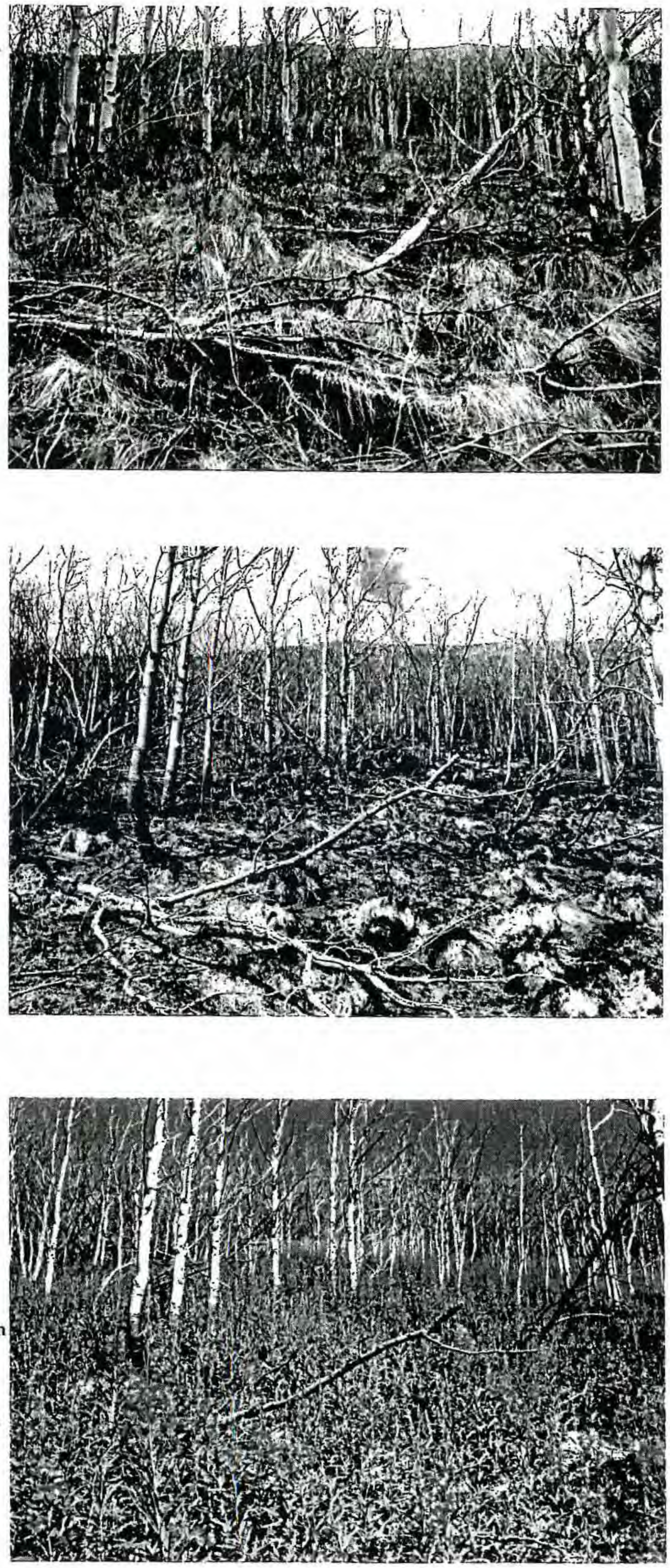
The 1994 spring burn of plot A2 was also of moderate intensity. At the start of the burn temperature was 10.1°C, relative humidity (RH) 23%, wind speed (WS) 5.9 km/h, and wind direction (WD) 225/180/90. Figure 4a and 4b depicts the immediate effects of the fire in plot A2, revealing that surface fuel was significantly consumed.

The 1994 spring burn of plot B2 was of moderate intensity. At the start of the burn temperature was 8.9°C, RH 35%, WS 11.9 km/h, and WD 270. Figure 5a and 5b reveals the immediate effects of the fire in plot B2, showing that here too surface fuels were largely consumed by fire.

4.2 Effects of Burning on Vegetation

Figures 3c, 4c, and 5c show the regrowth of vegetation 2 months to 1 year following the prescribed burns. In all cases fireweed (*Epilobium angustifolium*) appears to be the dominant successional species, with some visual evidence of shrub suckering. It appears that aspen trees were fire-killed, because of the absence of leaves in the growing season.

Within all burn plots, grasses decreased in biomass while forbs and shrubs increased from the pre-burn to the 1-year-post-burn samples (Figure 6, Appendix 3). Within control plots, changes in biomass were either less marked or opposite to what was observed in burn plots (Figure 6, Appendix 3). The treatment-control biomass difference values differed significantly between pre- and post-burn sampling in shrubs and forbs at $\alpha = 0.05$ and in grasses at $\alpha = 0.10$ (Table 1). Given the expected low power of the test used, weight should be given to the fact that the changes in biomass in the 3 vegetation types were consistent among treatment plots. Therefore, the evidence suggests that burning enhanced forb and shrub biomass and depressed grass biomass relative to unburned areas in the year following the burn. The mean differences were +30.0 g/m^2 for forbs, +20.5 g/m^2 for shrubs, and -12.9 g/m^2 for grasses (Table 1). Much of the increase in forb biomass was attributable to fireweed.



a.

b.

c.

Figure 5. Burn plot B2, photo pin B2-2, looking north.
(a) May 26, 1994; 1 day prior to burn.
(b) May 31, 1994; 4 days after burn.
(c) August 2, 1994; 2 months post-burn.

a.

b.

c.

Figure 3. Burn plot B1, photo pin B1-2 looking west.
(a) May 28, 1993; the morning prior to burn.
(b) June 13, 1993; 16 days post-burn.
(c) August 2, 1994; 1 year post-burn.

a.

b.

c.

Figure 4. Burn plot A2, photo pin A2-2, looking south.
(a) May 26, 1994; 2 days prior to burn.
(b) May 31, 1994; 3 days after burn.
(c) August 2, 1994; 2 months post-burn.

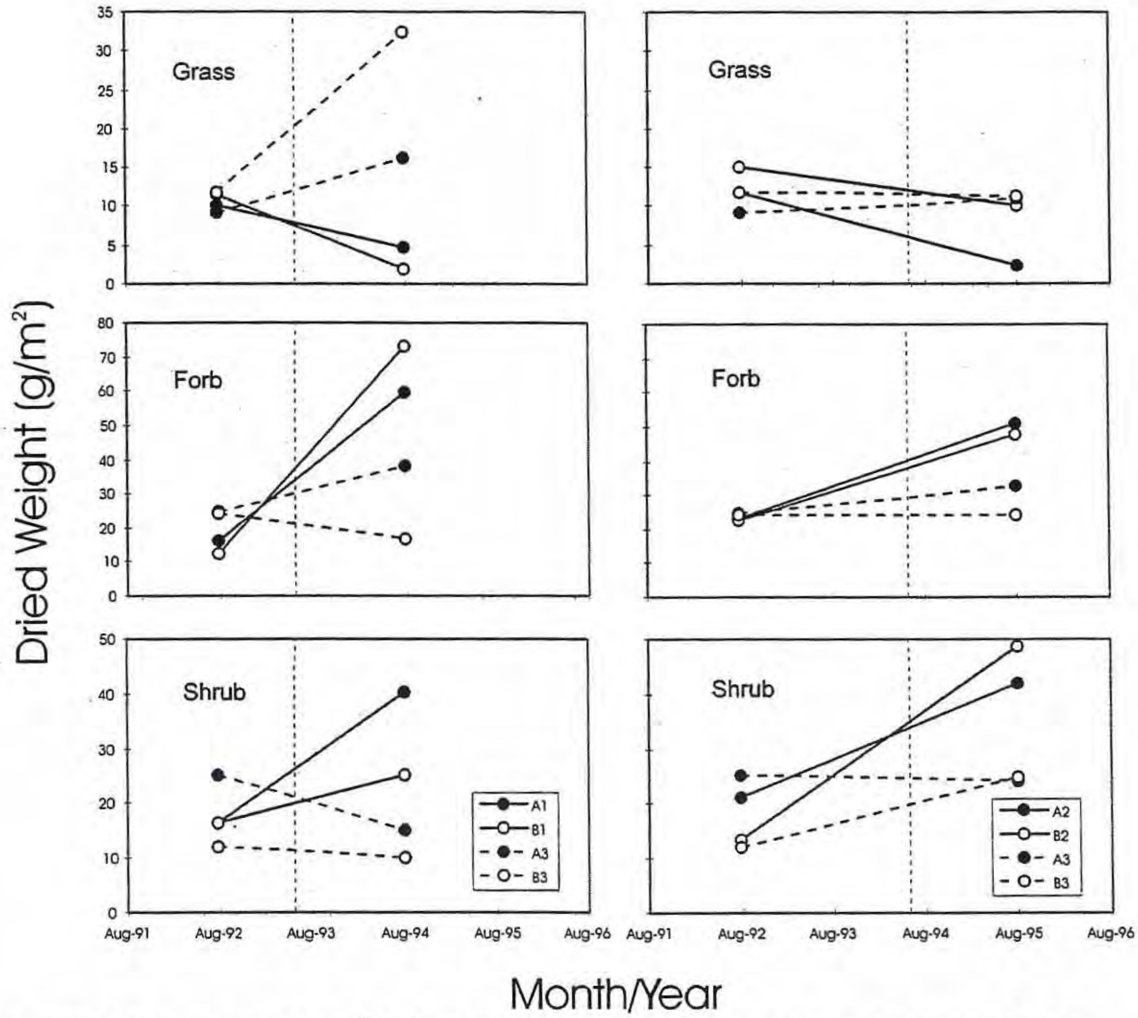


Figure 6. Mean biomass (g/m²) of grasses, forbs, and shrubs in burn plots and control plots sampled at Red Ridge, southwest Yukon (date of prescribed fire is indicated by vertical, dashed line).

Table 1. Mean differences in biomass (g/m²) between burn and control plots in the pre-burn and 1-year-post-burn samples at Red Ridge, Yukon, in August 1992, 1994, and 1995.

Vegetation Type	Pre-burn Mean	Pre-burn SE	1-year post-burn Mean	1-year post-burn SE	Paired *t*-test *t*	Paired *t*-test *P*
Grasses	1.6	0.8	-12.9	6.2	2.67	0.076
Shrubs	-1.8	3.0	20.5	2.4	4.63	0.019
Forbs	-5.8	2.5	30.0	8.8	3.32	0.045

Note: Sample size for all cells is 4.

5.0 Discussion

5.1 Fire Effects

In the Southwest Yukon a prescribed fire was conducted in April 1983, in an attempt to improve the quality and quantity of winter range for a population of Dall's sheep (*O. d. dalli*) on the mountain slopes adjacent to Talbot Arm, Kluane Lake (Government of Yukon, Habitat/Land Use Section 1985). It was expected that woody species would be killed and suppressed from further successional growth, but this did not occur. Instead suckering of these species occurred as well as invasion of new woody species. This response was attributed to a light, low intensity fire. It was concluded that a hotter, more intense fire may be needed to successfully suppress woody species, by killing the rhizomatous roots beneath the soil surface. However, the study also warned that a hot burn may also inhibit the growth of desirable, herbaceous species. It may also have a detrimental impact on the soil viability (Clark 1994).

The prescribed burns at Red Ridge were applied later in the season to achieve a hotter burn (i.e. moderate-high intensity) than was applied at Talbot Arm. However, this appears to have had no effect in suppressing shrub growth at one-year post-burn. Grasses decreased whereas forbs and shrubs increased relative to control plots one year after burning. Many shrub species are early colonizers of disturbed sites, and fire is a mechanism of disturbance. It is likely that shrubs cannot be eradicated from a given area with the use of fire, and if this is achieved then other, desirable species will also be effectively removed. It is perhaps unrealistic to hope for lush, grassy slopes with no presence of shrubs. A more intensive literature review of fire effects on vegetation will be completed for the final report, with particular reference to similar, northern regions.

The use of prescribed fire to improve wildlife habitat has focused primarily on increasing the health and numbers of deer (*Odocoileus spp.*), elk (*Cervus elaphus*), moose (*Alces alces*), and bighorn sheep (*Ovis canadensis*) (Lehnhausen 1978, Basile 1979, Peek et al. 1979, Wood 1988, Peck and Peek 1991, Loranger et al. 1991). Studies of this type related to thinhorn sheep (*Ovis dalli*) have been limited.

In northern British Columbia Stone's sheep (*O. d. stonei*) appeared to use subalpine grasslands that were created by natural or human-caused fires (Seip and Bunnell 1984). This led to a widespread burning program to improve habitat conditions for sheep. Seip and Bunnell (1984) questioned the value of such a program, arguing that just because sheep use a burned, subalpine, grass slope does not mean that they need that habitat type. Other limiting factors may be at work. Two criteria can be used to determine whether a range is limiting a population: (i) when competition for the resource has a negative effect on the population; and (ii) when animals with access to the "enhanced" range are in better condition than those that do not have access to that habitat (Seip and Bunnell 1984).

Seip and Bunnell (1985) found that sheep of a population wintering on alpine range were in poorer condition than those of a population wintering on burned, subalpine range; sheep wintering in the alpine had higher lungworm counts, lower lamb crops, and less horn growth in young rams. They attributed this to the fact that sheep using burned, subalpine slopes in winter benefited from higher forage quantity; winter forage quality did not improve, and was not a contributing factor. It was also found that in winter most burned, subalpine ranges were covered with deep snow forcing Stone's sheep to use windswept, alpine ranges, thus severely limiting the effectiveness of prescribed burning to enhance winter range (Seip and Bunnell 1985). They conclude that future range burning should only include subalpine areas that will be windswept in winter, and thus available to sheep.

5.2 Problems with Experimental Design

Three problems complicated the analysis of data from the burn experiments. The first problem was low sample size. For treatment effects, the sample size was at most 4 if all plots were considered to be essentially independent, or 2 in 2 experiments if A1 and B1 were treated as one experimental set and A2 and B2 as another. The 20 subsamples per plot were not replicate samples at the treatment level. Low sample size reduces the power of parametric and non-parametric statistical tests (i.e., conclusions of "no difference" are unreliable) and hampers testing the assumptions of parametric statistical tests, such as normality. Violation of normality also reduces the power of parametric tests such as *t*-tests. Therefore, lack of statistically detectable differences can be more a product of study design than absence of treatment effects. A higher α-value would be appropriate in such cases (e.g., $\alpha = 0.10$). Although low sample size is a serious problem, there is often little that can be done to increase sample size because of budget constraints, as was the case in this experiment.

The second problem was the allocation and sampling of control plots relative to burn plots. Each block had 2 burn plots but only 1 control plot. Furthermore, the pre-burn sampling of control and burn plots took place 2 years before the post-burn sampling of plots A1 and B1, but 3 years before the post-burn sampling of plots A2 and B2. This occurred partly by chance, as the original plan was to have one spring burn, one fall burn, and one control per block, a design which would have suffered even more from low sample sizes (i.e., n=2). These problems made it impossible to construct even an unbalanced 2-factor ANOVA, Factor-1 being burned versus control, and Factor-2 being pre-burn versus 1-year-post-burn, because there were no appropriate data for the control-by-post-burn cell of the ANOVA.

To deal with this, Factor-1 was removed from the analysis by calculating the treatment-minus-control difference values, which were then analyzed using paired *t*-tests. A risk in this approach was that each 1992 control plot influenced the analysis twice, which could have introduced bias. A more appropriate design would have been to sample 4 independent control plots within the study area and conduct the pre-burn sampling at the same time relative to burning the plots. This would have required only marginally more work during the first field season (i.e., a total of 40 more subsamples, 20 per additional control plot).

The last problem was that plots within blocks were not independent because they were side-by-side (i.e., A1 beside A2, B1 beside B2), although they acquired some independence because adjacent plots were burned in different years (A1 and B1 in 1993, A2 and B2 in 1994). This would not have been a problem if the fall burns had been done, as the design would then have been a Randomized Block Design (Krebs 1989: 282). Lack of independence can introduce bias, which could either enhance or depress apparent treatment effects. It can be a serious problem and is statistically intractable (Sokal and Rohlf 1981:401).

Based on inspection of the data from the 4 burn plots, there did not appear to be bias associated with plots within blocks. Bias would have been suggested if within a given plant type the slopes of A1 and B1 differed markedly, and the slopes of A2 and B2 differed in the same way as for A1 and B1 (Fig. 6). As this was not the case, we assumed that the plots were effectively independent. A more appropriate design would have been to spread the plots randomly but with effective dispersion (Hurlbert 1984) across the study area. This design would have required only minimal additional work during the first field season (i.e., an additional 350 m of fire-break would had to have been cut).

6.0 Recommendations

To complete this study the following must be finished:

(i) Conduct **vegetation/biomass sampling** periodically. The next vegetation sampling period will be at 3 years post-burn. This means sampling plots A1, A3, B1, B3 in August, 1996 and plots A2, A3, B2, B3 in August, 1997. The next sampling period will be at 6 year post burn (1999 and 2000) if necessary. The need to continue sampling will be evaluated after the 3-year and 6-year post-burn samplings.

(ii) Continue the **photograph time-series** annually in the first week of August at all permanent pin locations, to show the advances of successional growth.

(iii) Complete a statistical analysis and interpretation of % cover by species and twig/stem counts, and update biomass statistics.

(iv) For each burn plot determine subjectively the fire intensity and severity from video tape, photographs, and knowledgeable opinion. This will be part of a more detailed description of the treatments.

(v) Assess the costs and benefits of implementing a prescribed burn (i.e. cost/benefit analysis).

To improve future prescribed burn studies the following recommendations are made:

(i) Try other burn prescriptions that may achieve suppression of woody species and promote the growth of grasses favourable as thinhorn sheep forage.

- Investigate further the use of fall burning as a possible treatment; what measures need to be taken to implement a fall burn?

- Induce a secondary burn a few years following initial burn, depending on fuel availability.

- Conduct a burn later in the spring or into the early summer to generate a fire with higher intensity and severity.

(ii) Treatment assessments must be improved through meticulously recording and documenting fire behaviour parameters. This can be achieved by devising and using a detailed standard field form, which has all the fire behaviour and environmental variables included, and by ensuring that methods to measure all these parameters are in place prior to burning.

(iii) Future burn studies should have a minimum of 4-6 burn plots and an equal number of control plots. If the study area has large blocks of different habitat types (i.e., heterogeneity is coarse relative to plot size), then a Randomized Block Design would be appropriate (Krebs 1989: 282). The burn and control plots could then be placed side-by-side or in close proximity to each other. If habitat heterogeneity is fine-grained, then burn and control plots could be located randomly within the study area.

(iv) If cost is a factor treatments could be applied in the same year so that post-burn vegetation sampling would fall on the same year for all plots. Ideally, if budgets permit, treatments could be applied in different years so that year to year effects could be examined (e.g. weather).

(v) Treatments should also be applied to an adequate buffer zone to minimize the edge-effect in the treatment plots (i.e. burn a larger area than will be sampled).

(vi) To better assess damage and mortality of tree species, determine % crown scorch and consumption, and damage to tree stems. Also, mark live trees before the burn with fire resistant markers and monitor these same trees for several years after to determine if they have been killed (Millar and Findley 1994).

(vii) Assess changes in forage (preferred by targeted wildlife species) nutrient content induced by prescribed fire.

(viii) Assess pre and post-burn snow depth to further determine if changing vegetation patterns improve wildlife winter range.

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Appendix 1

Budget/Expenditures

This project is a cooperative effort between the Government of Yukon, Fish and Wildlife Branch and the Department of Indian Affairs and Northern Development (DIAND), Fire Management. Funding for this project to date was provided by DIAND and Government of Yukon through the Economic Development Agreement (EDA). EDA provided $33,000.00 over 3 years (1992-1994) most of which went toward the shared cost of helicopter time and fuel, and contracts for vegetation sampling. DIAND covered their own personnel costs and the shared cost of helicopter time and fuel. Details of the expenses to date are provided in the table below.

Red Ridge prescribed burn project expenses ($) to date.

Expense Category	DIAND	Gov. of Yukon	Total
1992 Vegetation Sampling			
Vegetation Sampling	0.00	5,150.00	5,150.00
Materials	0.00	185.16	185.16
Subtotal	*0.00*	*5,335.16*	*5,335.16*
1992 Control Line Cutting			
Control Line Cutting	0.00	1,295.00	1,295.00
Subtotal	*0.00*	*1,295.00*	*1,295.00*
1993 Spring Burn			
Personnel	6,002.37	0.00	6,002.37
Helicopter/Fuel	4,410.39	2,500.00	6,910.39
Subtotal	*10,412.76*	*2,500.00*	*12,912.76*
1994 Spring Burn			
Materials	0.00	36.44	36.44
Personnel	9,245.70	0.00	9,245.70
Helicopter/Fuel	1,295.66	3,233.54	4,529.20
Advertising	0.00	384.00	384.00
Subtotal	*10,541.36*	*3,653.98*	*14,195.34*
1994 Vegetation Sampling			
Vegetation Sampling	0.00	5,000.00	5,000.00
Subtotal	*0.00*	*5,000.00*	*5,000.00*
1995 Vegetation Sampling			
Vegetation Sampling	0.00	4,524.08	4,524.08
Materials		73.87	73.87
Subtotal	*0.00*	*4,597.95*	*4,597.95*
Total	**20,954.12**	**22,382.09**	**43,336.21**

Appendix 2

Methods applied (✓) to the vascular plants found at the Red Ridge Prescribed Burn Study Area, and the relative importance of each species in the winter diet of Dall's sheep as found at Sheep Mountain, Kluane National Park (Hoefs and Cowan 1979).

Species	Code	% Cover	Biomass	Stem/Twig Count	Tree Count Dead/Alive	Mean % Winter* Forage Comp. of Dall's Sheep
Forbs						
Achillea borealis	ACHI BORE	✓	✓			n/a
Aconitum delphinifolium	ACON DELP	✓	✓			n/a
Arnica cordifolia	ARNI CORD	✓	✓			n/a
Cornus canadensis	CORN CANA	✓	✓			n/a
Corydalis aurea	CORY AURE	✓	✓			n/a
Delphinium glaucum	DELP GLAU	✓	✓			n/a
Epilobium angustifolium	EPIL ANGU	✓	✓			0.2
Galium boreale	GALI BORE	✓	✓			<0.1
Gentiana propinqua	GENT PROP	✓	✓			<0.1
Linnaea borealis	LINN BORE	✓				<0.1
Mertensia paniculata	MERT PANI	✓	✓			<0.1
Penstemon gormanii	PENS GORM	✓	✓			0.1
Potentilla furcata	POTE FURC	✓	✓			n/a
Pyrola asarifolia	PYRO ASAR	✓	✓			n/a
Pyrola secunda	PYRO SECU	✓	✓			n/a
Solidago decumbens	SOLI DECU	✓	✓			n/a
Solidago multiradiata	SOLI MULT	✓	✓			<0.1
Stellaria longipes	STEL LONG	✓	✓			n/a
Viola spp	VIOL SPP	✓	✓			n/a
Zygadenus elegans	ZYGA ELEG	✓	✓			n/a
Grasses						
Agropyron trachycaulum	AGRO TRAC	✓	✓			n/a
Bromus ciliatus	BROM CILI	✓	✓			n/a
Calamagrostis canadensis	CALA CANA	✓	✓			n/a
Calamagrostis purpurascens	CALA PURP	✓	✓			19.7
Festuca altaica	FEST ALTA	✓	✓			0.3
Poa glauca	POA GLAU	✓	✓			0.6
Poa pratensis	POA PRAT	✓	✓			n/a
Woody Species						
Arctostaphylos uva-ursi	ARCT UVA-	✓				4.0
Betula glandulosa	BETU GLAN	✓	✓	✓		<0.1
Empetrum nigrum	EMPE NIGR	✓				n/a
Juniperus communis	JUNI COMM	✓		✓		0.4
Picea glauca	PICE GLAU	✓		✓	✓	0.2
Populus balsamifera	POPU BALS	✓	✓	✓	✓	n/a
Populus tremuloides	POPU TREM	✓	✓	✓	✓	0.2

Species	Code	% Cover	Biomass	Stem/Twig Count	Tree Count Dead/Alive	Mean % Winter* Forage Comp. of Dall's Sheep
Woody Species cont'd						
Potentilla fruticosa	POTE FRUT	✓	✓	✓		<0.1
Ribes oxyacanthoides	RIBE OXYA	✓	✓	✓		n/a
Rosa acicularis	ROSA ACICU	✓	✓	✓		0.9
Salix spp	SALI SPP	✓	✓	✓		3.9
Sheperdia canadensis	SHEP CANA	✓	✓	✓		<0.1
Vaccinium uliginosum	VACC ULIG	✓	✓	✓		<0.1
Vaccinium vitis-idaea	VACC VITI	✓				n/a
Viburnum edule	VIBU EDUL	✓	✓	✓		n/a

* Winter months included: November-April.

Appendix 3

Mean biomass (g/m^2) of grasses, shrubs, and forbs in burn and control plots sampled at Red Ridge, Yukon, in 1992 (pre-burn), 1994, and 1995.

Treatment	Plot	mean (SE) biomass g/m^2			*t*-test or ANOVA		
		1992	1994	1995	*t* or *F*	df	*P*
Grasses							
Burned in 1993	A1	10.0* (2.3)	4.6* (1.2)	-	2.07	28	0.05
Burned in 1993	B1	11.4* (2.2)	1.8* (1.1)	-	3.94	28	0.0005
Burned in 1994	A2	11.8* (4.2)	1.2 (0.8)	2.3* (0.8)	2.24	21	0.04
Burned in 1994	B2	15.0* (2.1)	2.7 (1.3)	10.1* (4.4)	1.00	27	0.33
Control	A3	9.1* (1.2)	16.2* (1.9)	11.0* (1.5)	5.44	2, 57	0.007
Control	B3	11.7* (1.9)	32.3* (5.8)	11.2* (1.8)	10.84	2, 57	0.0001
Shrubs							
Burned in 1993	A1	16.3* (2.3)	40.2* (8.1)	-	2.82	22	0.01
Burned in 1993	B1	16.5* (4.2)	25.1* (6.1)	-	1.17	34	0.25
Burned in 1994	A2	21.3* (3.4)	13.5 (2.5)	42.1* (9.0)	2.16	24	0.04
Burned in 1994	B2	13.3* (3.1)	6.9 (1.4)	48.8* (15.2)	2.28	21	0.03
Control	A3	25.3* (4.9)	15.0* (3.0)	24.3* (5.6)	1.52	2, 57	0.23
Control	B3	12.0* (3.6)	10.0* (1.9)	24.7* (7.2)	2.81	2, 57	0.07
Forbs							
Burned in 1993	A1	16.0* (2.2)	59.7* (9.8)	-	4.35	21	0.0003
Burned in 1993	B1	12.6* (3.4)	73.0* (7.9)	-	7.03	26	<0.0001
Burned in 1994	A2	23.0* (4.7)	44.9 (9.4)	50.8* (7.2)	3.26	33	0.003
Burned in 1994	B2	22.3* (5.3)	38.1 (8.2)	47.9* (8.0)	2.65	33	0.01
Control	A3	24.6* (4.5)	37.9* (6.1)	32.7* (6.5)	1.37	2, 57	0.26
Control	B3	23.9* (6.1)	16.9* (3.0)	24.0* (7.4)	0.50	2, 57	0.61

Note: Means and standard errors are based on 20 subsamples of vegetation biomass within each plot.

* Means tested for differences among years: two-tailed *t*-tests for unequal variances for burn plots; single-factor ANOVAs for control plots.