

Monitoring Ecosystem Restoration Treatments in Kootenay National Park

Year one post-fire monitoring

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Summary

In June of 2004, Kootenay National Park initiated year one of a multi-year field study designed to monitor the effects of ecosystem restoration treatments on overstory and understory vegetation characteristics in fire-maintained ecosystems located in the Park. In April 2005, a portion of the restoration area was subject to a prescribed burn. This report summarizes activities associated with year two of the vegetation monitoring program: monitoring the immediate prescribed fire effects on the plant community.

Thirty permanently-located plots were sampled, 21 in the burn area, eight in the unburned area and one control plot. Burned plots were subject to a low-intensity prescribed fire over a two-day period in April. Sampling was conducted according to general methods outlined in Machmer et al. (2002). Understory sampling (% cover by species, species composition and richness) was conducted from July 17 to 31, 2005. Overstory sampling (tree density by species, diameter, cover, and decay class) in nested fixed radius plots was completed in October.

There were no significant changes in the understory plant community observed in the unburned plots from 2004 to 2005. In the burned plots, litter and bare soil increased significantly, whereas dead wood cover decreased ($p < 0.05$). Carex cover was the only vegetation group that responded significantly ($p < 0.05$) to the fire, increasing significantly in the burned plots. Key bunchgrasses and non-native species were observed in several plots had no records of cover in 2004. The author hypothesizes that increases in Carex cover and distribution of key species is due to a consumption of the duff and dead wood layer and a 'release' of plants from the duff layer.

Declines in cover and production were expected in the burn plots, therefore, the lack of a significant response of the plant community in the burn plots was generally seen as positive. Expected declines in production and cover may have been prevented by high spring precipitation values. A potential barrier to successful restoration at this site is non-native species presence.

Current overstory structures is ideal for several species of interest and concern (e.g. bighorn sheep). Understory conditions show signs of developing attributes that will be beneficial for several wildlife species. Non-native species presence and abundance are a primary management concern at this site.

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1. Introduction and background

Ecosystems can be characterized by their natural disturbance regime. For the purposes of setting biodiversity objectives in British Columbia (BC), five Natural Disturbance Types (NDTs) are recognized in the Province. Disturbance types range from NDT1, systems with rare stand-initiating events to NDT5 systems (alpine tundra and subalpine parkland) (Province of BC 1995). NDT4 systems of the southern interior of BC are comprised of the interior Douglas-fir, ponderosa pine and bunchgrass zones of the Cariboo, Kamloops, and Nelson forest regions (Gayton 2001a). There are approximately 4.5 million ha of NDT4 in the Province, roughly 60% occurring on crown land (Gayton 2001a). NDT4 systems are characterized as shrublands mixed with open stands of ponderosa pine (*Pinus ponderosa* Douglas ex Lawson & Lawson var. *ponderosa*) and interior Douglas-fir [*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco]. The conventional assumption is that NDT4 systems historically experienced frequent (every 7 – 50 years), low intensity fires which limited encroachment by most conifer species and shrubs (Province of BC 1995), although there is little empirical data to back this assumption. Although NDT4 systems have been characterized as having a low-frequency fire regime, there is general agreement that BC's NDT4 was probably subjected to a 'mixed fire regime', meaning frequent low-intensity fires with an occasional, randomly occurring stand-replacement fires (Gayton 2001a). This is more apparent in areas where NDT4 transitions into NDT3 systems, such as the case at the south end of Kootenay National Park. NDT3 ecosystems are defined as having an infrequent, stand-replacement fire regime as opposed to the frequent stand-maintaining fire regime that characterizes the NDT4 (Province of British Columbia 1995). However, it can be assumed that the mean fire-return interval was normally distributed, with very short and long intervals being uncommon (Gayton 2001a). Regardless, these dry plant communities have undergone dramatic changes in structure and losses in diversity hypothesized to be due to forest ingrowth and encroachment brought about with fire suppression policies introduced by land management agencies in the 1940's (Daigle 1996).

Conifer encroachment has contributed to the rapid disappearance of grassland ranges and open forests in BC (Strang and Parminter 1980, Gayton 1997, Bai et al. 2001). Gayton (1997) estimated, that over 50 – 60 years, 1% of grassland and open forest is lost annually in NDT4 systems of the Rocky Mountain Trench due to forest ingrowth or encroachment. This is equivalent to a loss of 3000 ha. This rate is similar to estimates made in other areas of BC that exhibit similar ecosystem changes (Bai et al. 2001). Extensive forest ingrowth and encroachment within NDT4 ecosystems of the southern interior of BC has resulted in a loss of wildlife habitat as well as in decreased timber and forage production (Powell et al. 1998). The result of this conversion is that domestic livestock and native ungulates are exerting increased pressure on a declining land base as they compete for forage. Remaining grassland habitats are being further degraded by noxious weeds which out-compete native vegetation and reduce residual forage quantity

and quality. Densely stocked stands are prone to severe insect outbreaks and to catastrophic crown fires (Powell et al. 1998; Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000).

The loss of grassland and open forest habitat is also of concern to the 30% of the species' at risk in BC that occur in grassland and open forest areas (GCC 2005). One such species is the Rocky Mountain bighorn sheep (*Ovis canadensis*), a species that relies on open forest habitats for winter foraging. Bighorn sheep are a blue-listed species in BC and are an identified wildlife species under the BC Forest and Range Practices Act (Demarchi 2004). Desirable forage species for sheep, such as, rough fescue (*Festuca campestris* Rydb.) and bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve), are negatively affected by closed- canopies and thick litter layers caused by conifer ingrowth and encroachment.

In response to forest ingrowth and the concomitant loss of bighorn sheep habitat, managers at Kootenay National Park (KNP) have developed a set of objectives for the south end of KNP (Redstreak) in order to more effectively manage Redstreak for bighorn sheep habitat, for fuel management surrounding a campground and to bring the ecosystem within the historic disturbance regime. The overall objectives are:

- To enhance Rocky Mountain bighorn sheep habitat by restoring grasslands and the open forest structure,
- to reduce dangerous forest fuel levels in and around Redstreak Campground, and
- to create a fire guard on the east side of the Redstreak Campground.

Parks Canada initiated a multi-year ecosystem based management program at Redstreak in order to meet these objectives. The first phase of restoration required significant harvesting and tree removal to reduce overstory cover and the fuel load at the site (2002-2003. See Page 2004 for first phase monitoring results). This was followed by prescribed fire in spring 2005.

Parks Canada developed a series of performance indicators to monitor the success of the prescribed restoration activities (A. Dibb, senior wildlife biologist, LLYK Field Unit, pers. comm., 2005) Monitoring programs include bighorn sheep telemetry, ground squirrel and small mammals transects, ungulate pellet counts and permanently-located vegetation plots. Monitoring is an integral component of a restoration plan. Long-term monitoring of vegetation, of a particular species of interest, or of a key physical parameter is the only way to determine the success of a restoration effort (Gayton 2001). Monitoring must focus on the recovery of stand structure, species diversity and ecosystem processes to ensure the ecosystem will persist in a stable state in the future (Ruiz-Jean and Aide *in press*). Desired end points should be identified to provide a goal by which success will be measured. Monitoring will aid in the development of future plans, plans that contain an understanding of the ecological processes that link overstory management to understory dynamics and diversity (Naumberg and DeWald 1999). Ruiz-Jean and Aide (*in press*) state vegetation structure, species diversity, and ecosystem processes are essential

components for the long-term persistence of the ecosystem, and as such, should be monitored to determine the success of restoration. The objectives outlined in the East Kootenay Trench Effectiveness Monitoring Plan (EMP), a restoration monitoring plan, (Machmer et al. 2002) were developed to assess characteristics related to overstory structure, to forest and ecosystem health, to forage production, species diversity and to the maintenance of open forest habitat and associated plant species.

This project is in response to a Request for Proposals from KNP to use the Trench EMP to conduct vegetation monitoring on the 2005 Redstreak burn. Specific objectives of the project were to (1) monitor two permanent monitoring sites within a historically open NDT3 site in the Park, (2) to collect data on vegetation overstory and understory conditions at two recently burned restoration sites, (3) to summarize and analyze the short-term response of the understory and overstory plant community to prescribed fire, and (4) to investigate and analyze weed treatment options for the Redstreak area. Long term re-assessments are planned for each site.

2. Methods

Methods are based on those described in “An Effectiveness Monitoring Plan (EMP) for NDT4 Ecosystem Restoration in the East Kootenay Trench” (Machmer et al. 2002), with modifications based on discussions with Rick Kubian (Fire and Vegetation Specialist, LLYK Field Unit). Three restoration objectives outlined in the EMP were chosen for monitoring purposes:

Restoration Objective 1:

To reduce tree density, increase tree size, and achieve a tree species composition that falls within the historical range of variability for treated areas (based on aspect, slope, topography, moisture).

Restoration Objective 2:

To maintain or increase fire-adapted native understory vegetation in treated areas.

Restoration Objective 3:

To minimize the establishment and spread of non-native plant species, particularly noxious species, in treated areas.

2.1 Study area

Restoration harvesting took occurred over two years (2002-2003). The treatment area was separated into two sites based on the year of harvesting (Fig. 1), hereafter referred to as sites 1 and 2 respectively:

(1) Site 1 (81 ha in Kootenay National Park; IDFun); and 2002/03

(2) Site 2 (60 ha of Provincial Crown adjacent to Kootenay National Park; IDFun)harvested 2001/02;

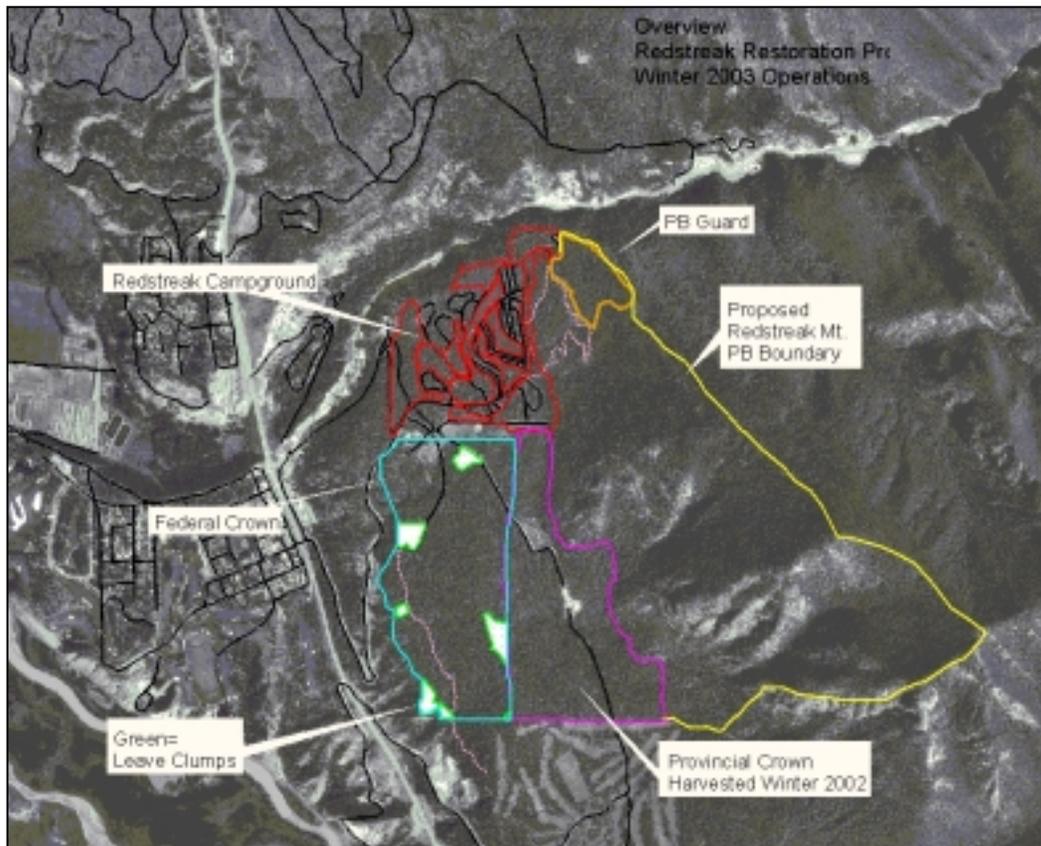


Figure 1. Location of site 1 (federal crown) and site 2 (provincial crown) located at the south end of Kootenay National Park.

In July 2004, fifteen plots were systematically established at site 1, fourteen at site 2 and one control plot in July, 2004. Plots were located to avoid areas that were heavily disturbed or unrepresentative of the rest of the block. Plots were located 200m apart on a North-South grid and 100m apart on an East-West grid. Plot locations were recorded using a Global Positioning System (GPS). Plot locations (UTMs) are provided in Appendix 1.

Plot centers were permanently marked using a 12" galvanized spike and 1" diameter electrical conduit. Three 11.28m transects (Fig. 2b) were established radiating out from each plot centre to form a spoke separated by 120°. The first bearing was randomly selected, with subsequent bearings determined by adding 120° and 240°, respectively. The second and third transects followed in a clockwise position (from plot center, facing north) (Fig. 2b). All bearings were recorded and entered into a database (Appendix 1). Four Daubenmire frame locations were permanently marked on each transect (4 frames/transect = 12 total/plot). Daubenmire frames were located on the left hand side of the transect at meters 3, 5, 7 and 9. The left hand corner located on the transect was permanently marked with an 8" galvanized spike and 1 spray painted washer. Each spike was marked with flagging. Flagging was replaced after the fire.

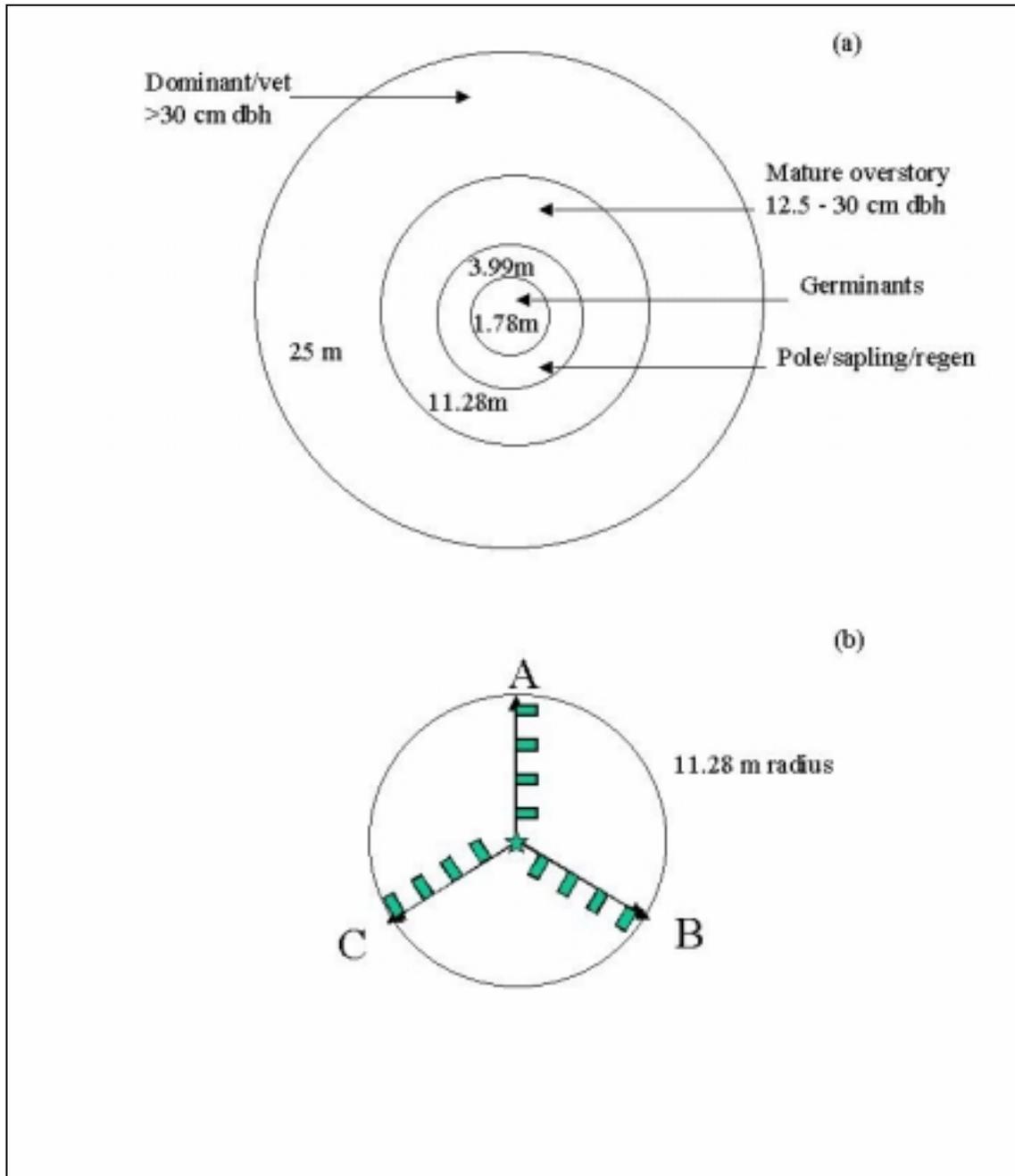


Figure 2 a&b Layout of overstory (a) and understory (b) sampling plots adapted from DeLong et al. (2001).

2.2 Restoration objective monitoring

2.2.1 Restoration objective 1

Objective: To reduce tree density, increase tree size, and achieve a tree species composition that falls within the historical range of variability for treated areas (based on aspect, slope, topography, moisture, etc.) (Machmer et al. 2002).

Response variables: Tree density, diameter and species composition.

Overstory plot layout conformed to methods developed by the BC Forest Service Permanent Sample Plot procedures (BCMOF 2000) and DeLong et al. (2001), with modifications, to ensure that large trees and snags were adequately sampled. Fifteen nested, fixed-radius plots (Fig. 2a) were established to sample each layer as follows: layer 1 (1.78 m radius), layer 2, 3 and 4 (3.99 m radius), layer 1 mature (11.28 m radius), and layer 1 dominant/veteran (25 m radius) (Table 1). Tree species, diameter (diameter at breast height in cm), decay class, and evidence of insects or diseases were recorded for each tree in layers 1, 2 and 3. A tally was made by species (live/dead) for layer 4. Canopy cover estimates were made using a spherical densiometer.

Table 1 Tree descriptions by layer used for overstory measurements (see figure2a).

layer number	layer name	layer description
1	dominant/veteran	>30 cm dbh
1	mature	12.5 – 30 cm dbh
2	pole	7.5 – 12.49 cm dbh
3	sapling	1.3 m height and < 7.5 cm dbh
4	regeneration	< 1.3 m height
4	germinant	seedlings < 2 years old

2.2.2 Restoration objective 2

Objective: To maintain or increase fire-adapted native vegetation (grass, herb, shrub) in treated areas.

Response variables: Grass, herb and shrub cover by species, species richness and composition.

Understory plot layout conformed to methods developed by DeLong et al. (2001) and Powell et al. (1998). Three 11.28m transects (Fig. 2b) were established radiating out from each plot centre to form a spoke separated by 120°. Understory vegetation cover and composition data were collected in Daubenmire frames (Daubenmire 1959). In each frame, percentage of herb and grass cover by species was recorded. Species richness was recorded by plot, and species diversity (by plot and overall) was determined using the Shannon-Weiner diversity index ($H = -\sum P_i \log[P_i]$) (Bonham 1983).

To assess plant vigor, flowering culm counts were conducted for bunchgrasses (see Page 2002). Bunchgrasses chosen for monitoring are species considered historically common in NDT4 stands and include: rough fescue, Idaho fescue (*Festuca idahoensis* Elmer), bluebunch wheatgrass, Junegrass (*Koeleria macrantha* (Ledeb. J.A. Schultes f.), Richardson's needlegrass (*Stipa richardsonii* Link.), needle-and-thread grass (*Stipa comata* Trin.&Rupr.) and stiff needlegrass (*Stipa occidentalis* Thurb. ex S. Wats. var. *pubescens* Maze, Taylor and MacBryde). Percentage cover by domestic and native ungulate feces was recorded to provide an indication of animal use, although change in this variable is not expected in the short-term.

The line-intercept method (Bonham 1983) was used to estimate shrub cover along each 11.28 m spoke. All shrub species intersecting the three transects were recorded to the nearest centimeter. Canopy cover rather than foliar cover was used to determine plant 'interception' (i.e., the outside perimeter of the plant).

2.2.3 Restoration objective 3

Objective: To minimize the establishment and spread of non-native plant species, particularly of noxious species, in treated areas.

Response variables: Number of species, cover, and noxious weed density (if cover <5%).

Non-native vegetation cover by species was estimated in Daubenmire frames in each of the 15 plots per site (Fig. 2b). If weed cover (noxious and nuisance weeds) was less than 5%, individual plants in the Daubenmire frames were counted to provide a density measure. Additionally, flowering culm counts were recorded for non-native, invasive grasses (e.g., cheatgrass [*Bromus tectorum* L.], quackgrass [*Elymus repens* (L.) Gould] to assess their vigor and health.

2.3 Fire behaviour monitoring

Daubenmire corner markers were used as duff consumption pins. Eight inch duff pins were placed flush to the ground (n=12/plot). Pins were not used to record consumption if they could not be placed flush with the ground. Duff consumption was calculated by measuring from the top of the pin to the ground immediately after the fire. Percentage of scorch was estimated in the Daubenmire quadrats immediately after the fire. Additionally, scorch height was noted on trees found in the plot.

Fire behaviour observations from LLKY Field Unit staff were incorporated to develop an assessment of the fire behaviour.

2.4 Data entry

Raw data were entered into EXCEL spreadsheets (Appendix 1) in a format that permits easy import into an ACCESS relational database or into the JMP SAS programme (Sall et al. 2005). Species codes and life-form identifications used were provided by the British Columbia Ministry of Forests Research Branch.

2.5 Data summary and analysis

Data were summarized in EXCEL spreadsheets (Appendix 3) and summary statistics were calculated using JMP (Sall et al. 2005). Data were summarized by species and by functional/descriptive group (e.g., shrubs, forbs, grasses, etc.). Functional group data were analyzed for normality and transformations were made if necessary. Comparisons between years (2004 and 2005) were made using a repeated measures design (Sall et al. 2005).

3. Results and observations

3.1 General site and treatment descriptions

Both sites are located in the IDFun biogeoclimatic subzone (Undifferentiated Interior Douglas fir). The Redstreak site is in transition to MSdk (Dry Cool Montane Spruce Subzone) (Braumandl and Curran 1992). Zonal IDFun sites have open stands of Douglas-fir with bluebunch wheatgrass and junegrass being the dominant understory species. Zonal warm aspects in the MSdk are dominated by Saskatoon (*Amelanchier alnifolia* Nutt.) and bluebunch wheatgrass. Soils at both sites are classified as Orthic Eutric Brunisols (Lacelle 1990). Eutric Brunisols are strongly calcareous and low in organic matter (National Research Council of Canada 1998).

3.1.1 Burn

The two day prescribed burn encompassed all of site 1 and the western half of site 2. Site 1 is located on relatively level ground (mean slope = 3%) with few slopes and gullies, except for moderate slopes on the eastern boundary of the block, that lead into site 2. The western half of site 2 is east facing with mesic plant communities (pinegrass, aspen, chokecherry) occupying the site. Site 1 was more recently harvested (2003) than site 2 (2002). Year of harvesting significantly affected understory structure, site 1 had significantly more ($p < 0.0001$) fuel (dead wood) on the ground as measured in 2004 (Site 1: 14.67% stdev=3.98% versus Site 2: 7.39% stdev=4.81%). Site 1 was also characterized as having greater vegetation cover (Table 2).

Desired indices for the prescribed burn were between the range of 87-91 for the fine fuel moisture code (FFMC), 20-50 for the duff moisture code (DMC), buildup index (BUI) of <60 and the initial spread index (ISI) between 3 and 15. The preferred weather included a wind speed of 5-10 km/hr from the south-southwest.

The goal of the prescribed fire was to attain a low to moderate intensity surface fire with relatively slow spread. The DMC was considered critical to the objective of burning slash, surface litter and duff while not compromising the early spring growth of the rough fescue and the bluebunch wheatgrass.

Table 2. Summary of understory cover characteristics by functional/descriptive group in site 1 and site 2 at the Redstreak restoration sites as sampled in 2004.

Understory component	Site 1		Site 2	
	mean	stdev	mean	stdev
Bunchgrass Cover ¹ (%)	0.84	1.41	1.36	1.79
Grass Cover ² (%)	7.07	10.51	19.14	27.85
Forb Cover (%)	4.64	4.28	8.24	5.08
Carex Cover (%)	4.13	6.40	4.64	7.64
Shrub Cover (%)	10.24	7.55	12.06	7.42
Exotics species cover	3.5	4.32	2.47	6.47
Conifer cover (%)	0	0	0	0

¹ Includes native bunchgrasses considered historically common in the Rocky Mountain Trench.

² Includes any native grass that is not classified as a bunchgrass.

During the first day of the prescribed burn (April 21) the average temperature was 19° (ranging from 16.6° to 21.4°) and the rH was 30% (ranging from 22 – 41). Average wind speed was 1.5km/hour, blowing out the north during most of the day. Cloud cover was high, ranging from 50% to 80%. The second day of burning was hotter, the average temperature was 22.7° and the rH was 14%. Average wind speed was 5.1km/hr blowing out of the south and west. Cloud cover was lower on April 22nd ranging from 10% - 20%.

On April 21st, the FFMC was 87, DMC 40, the DC 360. April 22 codes were the same except the FFMC which increased to 91 due to a drop in the rH. Rate of spread on the 21st was approximately 1.3m/min. Flame heights were 0.5m – 3m. Rate of spread was approximately 5.5m/min on the 22nd; flame heights were 1 – 5m.

Average bole scorch height on the 21st was 3.1m and 9.5m on the 22nd. Although bole scorch height is significantly related to mortality caused by prescribed fire it may not be the best predictor of mortality. Wyant et al. (1986) found that crown scorch variables are superior predictors of mortality.

Average coverage of the entire burn was 39.4% (stdev=43.9%), as determined from the air. Percent burn coverage (on the ground) differed significantly between days ($p < 0.0001$). Scorch in plots burned on April 21 was 19% (stdev= 34) and scorch in plots burned on April 22 was 52% (stdev=45%). Duff consumption also varied significantly ($p < 0.001$) between days, 0.14cm (stdev=0.51) on April 21 and 0.7cm (stdev=1.3) on April 22. Scorch and duff consumption did not vary between site 1 and site 2, i.e. year of harvesting did not have a significant impact on scorch. Therefore, analysis of the understory and overstory response was stratified by burned and unburned sites.

Bare soil cover in the burn plots was 5% (stdev=5%) (Fig 3). This was a significant increase from 2004 (3%; stdev=5) ($p=0.01$). Litter increased unexpectedly from 70% (stdev=11) to 80% (stdev=8) ($p<0.001$) in the burn plots (Fig 3). Increased litter cover is likely due to the significant consumption of dead wood by the prescribed fire ($>1\text{cm dbh}$) ($p=0.0002$) (Fig. 3) (12%; stdev=5 to 7%; stdev=5).

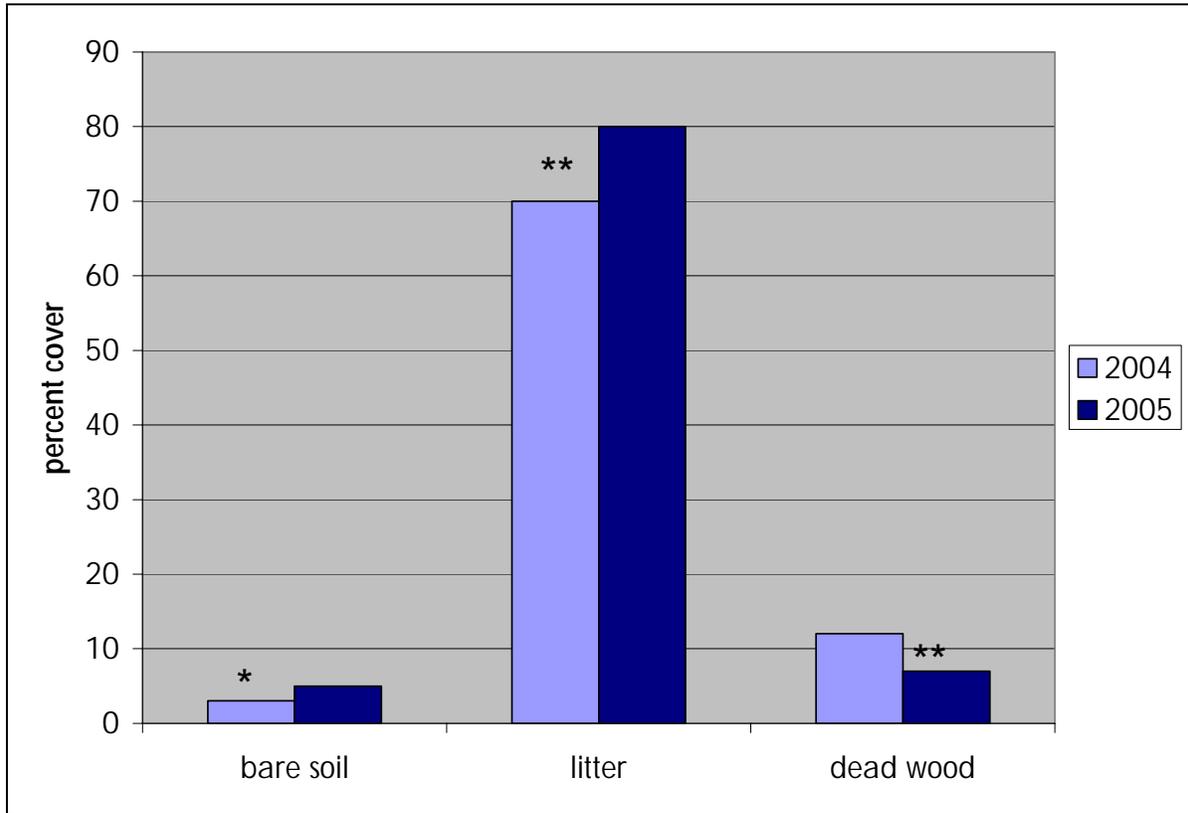


Figure 3. Bare soil, litter and dead wood cover in Redstreak burn plots in 2004 and 2005. * indicates a significant difference ($p<0.05$), ** indicates a significant difference ($p<0.001$).

3.1.2 Unburned site

The road dissecting site 2 was used as the eastern fire guard (Fig. 1). There were eight plots located in this area. The unburned portion of site 2 is mostly level (7.6%) with southwest facing slopes bordering the east half of the block. Variation in topography contributes to varied moisture regimes at this site. This site generally has a drier moisture regime than site1, due to topography (southwest facing slopes). Plant communities in the unburned portion of the block are characterized by a high cover of pinegrass (*Calamagrostis rubescens* Buckl.) and moderate levels of smooth aster (*Aster laevis* L. var. *geyeri*) and kinnikinnick (bearberry) [*Arctostaphylos uva-ursi* (L.)].

3.2 Overstory characteristics

3.2.1 Burn plots

There were 20 stems per hectare (sph) in the burned plots (stdev=21) (Fig 4). Crown cover was 8% (stdev=11). Variability in overstory response variables indicates a clumped distribution of trees across the landscape.

Stem density was largely composed of veteran trees (>30cm dbh) stems (11psh; stdev=9). There was 25% mortality in the veteran layer; 2 dead veterans/ha (stdev=6) and 8 live veterans/ha (stdev=9). Pre-burn mortality was high on the burned site in 2004, approximately 35% in the mature and veteran overstory layer. Post-burn mortality in 2005 was actually lower in these layers due to total consumption of several veterans during the prescribed fire.

Densities in the mature layer were low and highly variable (8 sph; stdev=16). There was no mortality in this layer. Mature trees (12.5cm dbh – 30cm dbh) were only found in 4 plots in the burned area.

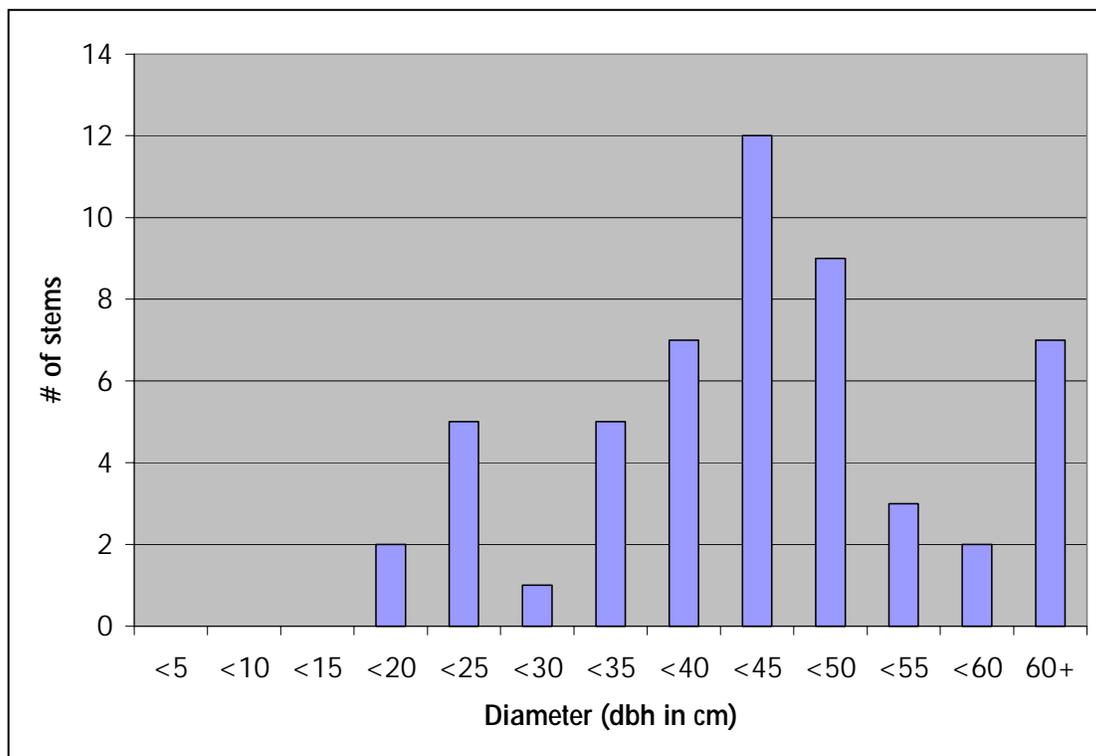


Figure 4. Stem diameter distributions for overstory layers 1a, 1, 2 and 3 in the burned portion of the Redstreak restoration area

Habitat attribute targets for bighorn sheep suggest target stocking rates of 5 – 25 sph and a canopy closure of less than 25% (Cooper et al. 2004). Cooper et. al. (2004) also suggests a composition of 100% Douglas fir in the overstory layer with the stems occurring in scattered patches. Overstory

conditions in the burned plots are highly suitable for bighorn sheep habitat. Overstory conditions also suit the COSEWIC (Committee on the Status of Endangered Wildlife in Canada) listed badger (10-20 sph with 0 – 10% canopy closure) (Cooper et al. 2004). Badgers could potentially inhabit this site and should be considered a priority in management plans. High mortality in the veteran layer makes this suitable habitat for cavity nesting species, although the lack of a pole or sapling layer (Fig 4) warrants monitoring overstory structure to ensure there is recruitment structure to provide suitable habitat in the long-term.

Regeneration did not vary significantly between years. Live aspen regeneration in 2004 was 452sph (stdev=1254). Aspen regeneration increased to 648 sph (stdev=1352) in 2005, though this change was not significant. There was minor mortality in the aspen regeneration layer, from 0 to 76 sph (stdev=272). There was a slight increase in Douglas fir regeneration in the burned site, from 0 to 22 sph (stdev=67). Consumption of the duff and fuel layers has likely 'released' a small number of Douglas fir germinants.

3.2.2 Unburned plots

There were no significant changes in the overstory layer in the unburned portion of the block. Stem density was 23sph (stdev=21), composed entirely of Douglas fir. Sampled stems were largely concentrated in the veteran layer (Fig 5). Crown closure was 10% (stdev=7).

Stem density in the veteran layer was 12 sph (stdev=11). Stems were relatively evenly distributed across the site. There was no mortality in this layer.

Density in the mature layer was slightly higher, 13 sph (stdev=20), although stems were not as evenly distributed across the site (i.e. there was clumped distribution across the site). There was no mortality in the mature layer.

The sapling layer had the highest stem density (75 sph; stdev=200), composed entirely of trembling aspen (*Populus tremuloides* Michx) (Fig 5). High variation about the mean was due to the aspen stems being found in a localized depression at one plot.

There was no significant difference in overstory regeneration between 2004 and 2005 in the unburned portion of the restoration site. Both aspen and Douglas fir had 25 sph (stdev=71) in the regeneration layer.

Overstory structure in the unburned plots is compatible with bighorn sheep habitat requirements as well as with badger habitat requirements (Cooper et al. 2004). If cavity nesting habitat is a management priority, creation of wildlife trees through inoculation may encourage use of the unburned portion of this area by cavity nesters. This objective may also be achieved by future prescribed burns.

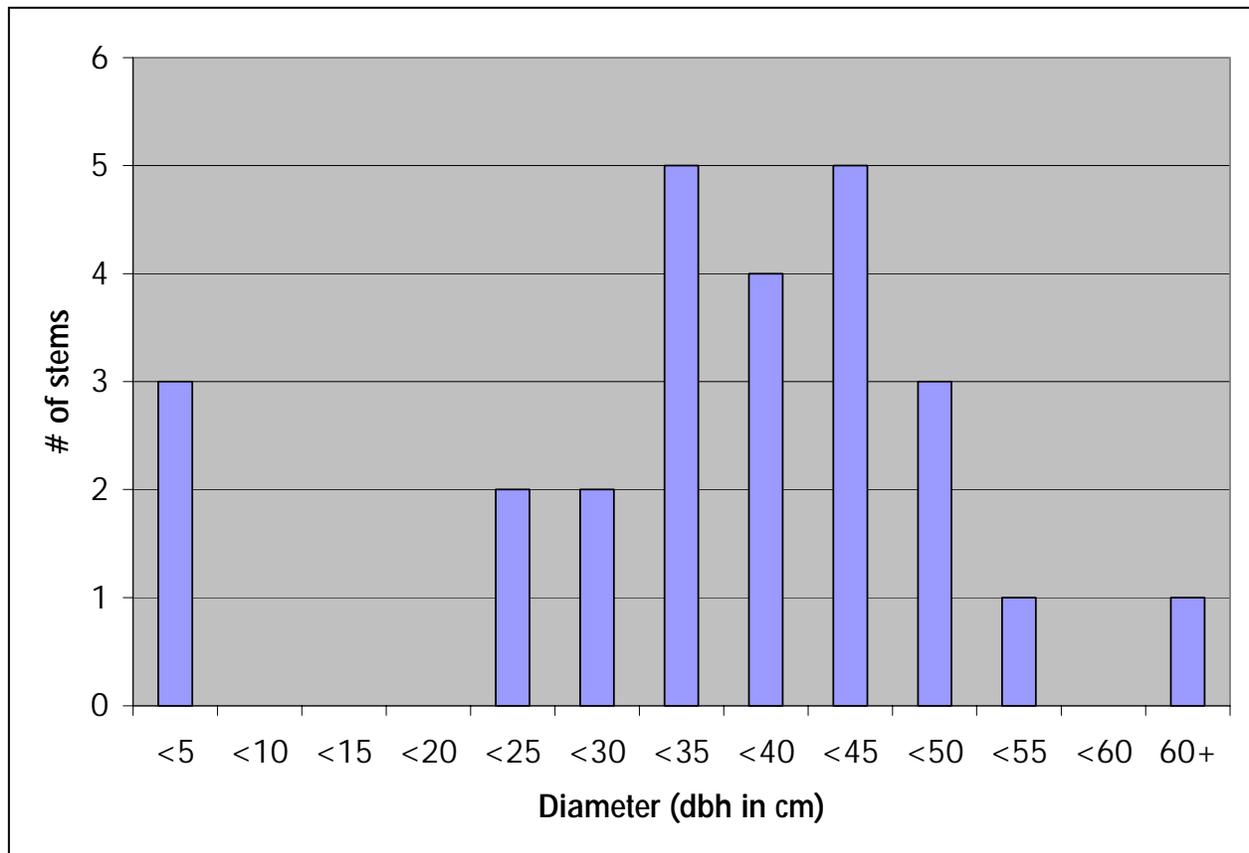


Figure 5. Stem diameter distributions for overstory layers 1a, 1, 2 and 3 in the unburned portion of the Redstreak restoration area

3.3 Understory characteristics

There were 76 species recorded in the monitoring plots at both sites combined. The most common species recorded, across both sites, were pinegrass, birch-leaved spirea (*Spiraea betulifolia* Pall. ssp. *lucida*), and showy aster (*Aster conspicuus* Lindl.). Summary of results at both sites should be considered in the context of high precipitation levels in the spring of 2005.

3.3.1 Burn plots

There were 72 species recorded in the burned plots. Average vegetation cover was 28% (stdev=7). Pinegrass exhibited the highest level of cover (Table 3) followed by birch-leaved spirea (2%; stdev=2) and perennial sowthistle (*Sonchus arvensis* L.) (2%; stdev=2).

Forb cover at the burned site formed the most frequent cover for a descriptive group (Table 3; Fig 8). Showy aster was the most abundant forb (2%; stdev=6). Timber milk vetch (*Astragalus miser* Dougl. ex. Hook.) (0.5%; stdev=2) and creamy peavine (*Lathyrus ochroleucus* Hook.) (0.4%; stdev=2) formed the next highest cover levels. Percentage forb cover did not vary significantly between years.

The three dominant forb species in the burn plots are adapted to fire. The rhizomatous habit of showy aster indicated this species is resistant to light and moderate severity fires (Fischer and Bradley 1987). Growth of showy aster is stimulated after fire, resulting in mass flowerings in the initial post-fire years (Stickney 1989). Showy aster regenerates from wind-dispersed seed and the existing seed bank (Stickney 1989), easily establishing itself in ideal post-fire conditions. Examples of showy aster mass flowering were observed in the burned plots. In general, legumes, such as timber milk vetch and creamy peavine show positive growth after fire from belowground buds that re-sprout easily after a light to moderate intensity surface disturbance.



Figure 6. Rough fescue plant killed by prescribed fire at the Redstreak restoration site in 2005

Bunchgrass cover was low (Fig 8; Table 3) relative to other grassland sites in the trench (Page and Machmer 2003; Page 2005). Rough fescue made up nearly half of the bunchgrass cover (0.5%; stdev=3) with bluebunch wheatgrass and Richardson's needlegrass each making up 0.3% of the cover (stdev=2). Bunchgrass cover increased in 2005, but the change was not statistically significant ($p=0.06$). Although a p -value of 0.05 was used in analyses, a p -value of 0.06 is viewed to be a biologically significant in this system. Concurrent with the bunchgrass cover increase was an increase in the variability of the response. Rough fescue was found in six plots in 2004 and in eight plots in 2004. Bluebunch wheatgrass was surveyed in one plot in 2004 and found in four plots in 2005. Increases in bunchgrass presence are not likely due to new plants but rather to a reduction in the duff layer thus facilitating the emergence of plants in a high moisture year. Maintenance of bunchgrass cover and increases in density achieved the primary burn objective: fire conditions should allow for the consumption of duff layers without compromising early spring growth of bunchgrasses like rough fescue and bluebunch wheatgrass (J. Morin, Fire Management,

Parks Canada, pers. comm., 2005). Historic bunchgrass communities are generally resilient to wildfire due to phenology and growth cycles. Bogen et al. (2002) found in a laboratory study, that foothills rough fescue was less tolerant to heat stress than other cool season grasses. A temperature of 60°C within growing points was the threshold at which fescue growth was reduced. The probability of rough fescue mortality obviously increases with litter build-up. At Redstreak, there was mortality of rough fescue observed (Fig 6), likely occurring in deeper litter layers, although most rough fescue plants survived the fire, indicating an overall low-intensity burn.

Burning should lead to increased seed production by the local bunchgrass species. In Alberta, burning increased rough fescue seed head densities to nearly twice that of the unburned area ($p < 0.10$). The authors concluded that this was likely due to loss of litter, or perhaps to the addition of soil nutrient from fire effects (Bork et al. 2002).

Grass cover [*Poa* and *Danthonia* sp.(oatgrass)] made up a small portion of cover at this site (Table 3). Cover did not change significantly after the burn (Fig 8).

Non-native species cover (Table 3) increased in 2005, but the change was not significant (Fig 8). In 2004, there were seven of 21 burn plots that had no non-native species presence, in 2005 there was only one plot without non-native species cover. Perennial sowthistle cover increased slightly from 1.8% (stdev=4) to 2% (stdev=3). Bull thistle was found in eight new plots in 2005 and increased slightly in cover (0.6%; stdev=2 to 0.9%; stdev=2). Increases in presence (and cover) was likely offset by mortality of plants (Fig 7).



Figure 7. Bull thistle plant killed by prescribed fire at the Redstreak restoration site in 2005.

Perennial sowthistle is a geophyte, meaning its growing points are deep in the soil, making it well-adapted to fire. Although perennial sowthistle is adapted to fire it may be susceptible to top-kill. There are conflicting reports about this species' general response to fire (FEIS 2003). Bull thistle reproduces from abundant seed (FEIS 2003), if growing conditions are favourable and there is little competition. Fire may enhance the cover of this species, although response will vary depending on site-specific conditions.

The one statistically detected change in the understory plant community was a significant increase ($p < 0.05$) in *Carex* (sedge) cover in the burned plots (Fig 8). The increase in cover is likely due to suppressed plants being released by a reduction in duff and coarse woody debris.

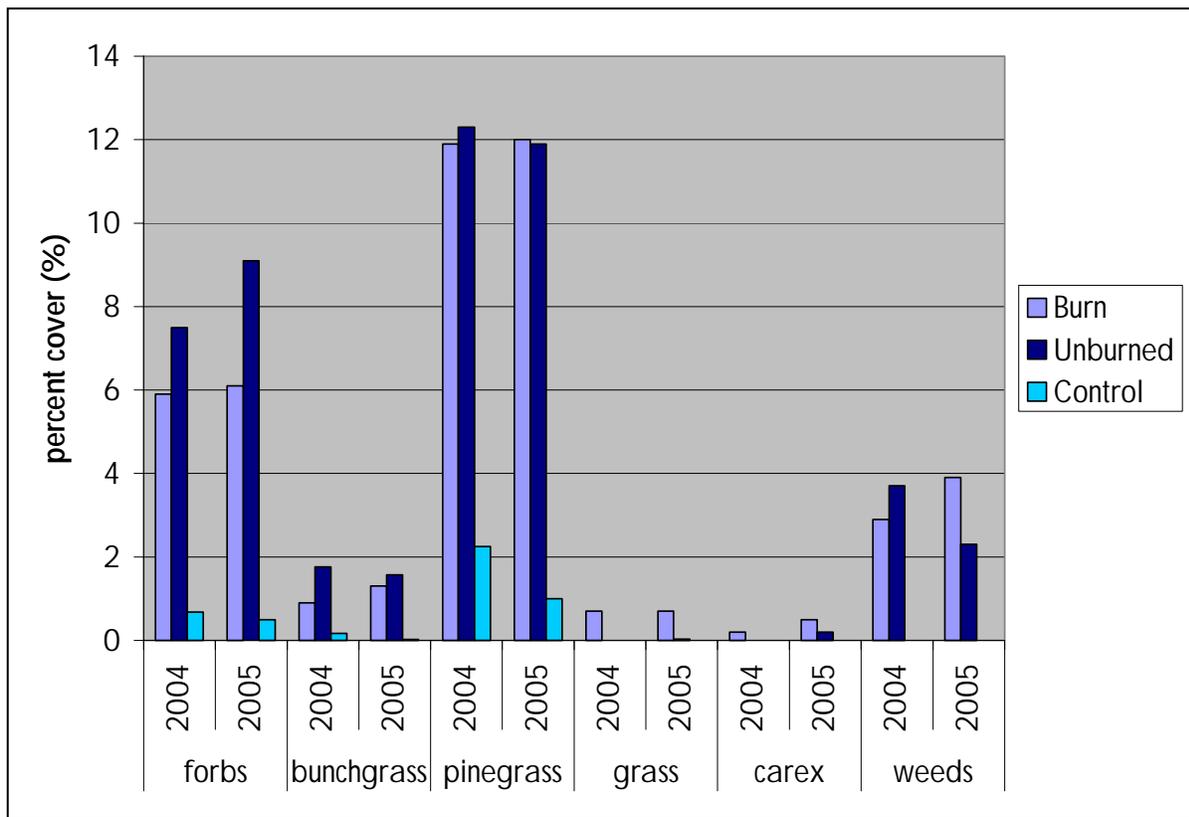


Figure 8. Summary of understory characteristics at the Redstreak burn, unburned and control plots in 2004 and 2005.

3.3.2 Unburned plots

Average vegetation cover was 41% (stdev=13). Cover was slightly higher than the burned site, but site 2 cover was higher in 2004 as well. Pinegrass cover formed the largest component of cover (15%; stdev=12) followed by kinnikinnick, (6%; stdev=6) and smooth aster (2%; stdev=2). Changes in the unburned plots were more difficult to detect due to the smaller number of sampling units.

Average forb cover was higher than in the burned site (Table 3) and slightly higher than site 2 levels in 2004 (Table 2). Forb cover increased slightly in 2005 (Fig. 8). Increases in cover are likely due to high precipitation levels. Smooth aster, showy aster (2%; stdev=2) and northern bedstraw (*Galium trifidum* L. ssp. *subbiflorum*) (1%; stdev=1) formed the highest components of cover. Dominant forbs in the unburned site are not common forbs of late-seral open forests in the Trench. Common forb species in the unburned plots dominate later-seral mesic plant communities. The presence of these species indicate several years of closed canopy conditions.

Table 3. Summary of understory cover characteristics by functional/descriptive group in the Redstreak burn, unburned and control plots as sampled in 2005.

understory component	burn		unburned		control	
	mean	stdev	mean	stdev	mean	stdev
bunchgrass cover ¹ (%)	1	4	2	2	0.17	n/a
pinegrass cover	12	2	15	11	1	n/a
grass cover ² (%)	0.7	2	0.03	0.1	0	n/a
forb cover (%)	6	10	9	6	0.5	n/a
Carex cover (%)	0.5	0.8	0.2	0.2	0	n/a
shrub cover (%)	0	0	0	0	0	n/a
non-native species cover	4	4	2	5	0	n/a
litter (%)	80	8	76	11	87	n/a
bare soil (%)	5	5	0	2	6	n/a

¹ Includes native bunchgrasses considered historically common in the Rocky Mountain Trench.

² Includes any native grass that is not classified as a bunchgrass.

Bunchgrass cover was slightly higher in the unburned plots versus the burned plots (Table 3). Cover of bunchgrasses declined slightly in 2005, but this change was not significant (Fig 8). Bunchgrass cover at this site is dominated by bluebunch wheatgrass (0.4%; stdev=1), Richardson's needlegrass (0.4%; stdev=1) and stiff needlegrass (0.4%; stdev=1). With overstory manipulation and resultant drier conditions on site, the author expects to see a significant increase in bunchgrass cover in the next five years.

There is potential in the unburned plots for the establishment of the CDC (Conservation Data Centre) red listed (endangered) Douglas fir/Snowberry/Balsamroot and Bluebunch Wheatgrass/Junegrass plant communities at this site (Cooper et al. 2004). Primary restoration techniques to promote these plant communities includes restoring low-intensity burn cycles, minimizing soil disturbance and the prevention of non-native species establishment (Cooper et al. 2004).

Unburned plots exhibited negligible grass cover (Table 3) as did the unburned plots in 2004.

Eight non-native species were recorded in the unburned plots forming approximately 2% of the ground cover (Table 3). Quackgrass [*Elymus repens* (L.) Gould] and perennial sowthistle represented the most frequent cover in this functional group (1%; stdev=2 and 0.4%; stdev=1 respectively). Non-native species cover declined in 2005 (Fig 8), most likely due to a decline in bull thistle cover from 2004 to 2005 (2%; stdev=6 to 0.29%; stdev=0.29), although the changes were not significant. There was also a small decline in perennial sowthistle (from 0.99%; stdev=2 to 0.4%; stdev=1). The only non-native species to increase was quackgrass (0.2%; stdev=0.44 to 1.1%; stdev=2.1). Native species growth must be enhanced in order to establish effective competition with non-native species. Continued monitoring is critical to identify trends in the abundance of both native and non-native species.

4. Conclusions and recommendations

4.1 Burn

Burn conditions varied significantly between days. Differences in behavior are largely related to weather but may also be related to varying fuel loads across site 1 and site 2. The second day of burning occurred under warmer, drier conditions in an area with greater vegetation cover (Table 2) and fuel loads. Although there was no significant difference detected in overstory mortality, there were veteran trees killed by the fire on the second day of burning. Under burning conditions on day two and fuel conditions on-site, tight control of the flame length is essential to control scorch and mortality (R.W. Gray, R.W. Gray Consulting, pers. comm., 2005).

Description of the treatment (fire behaviour) would be improved by including larger suite of monitoring variables. Variables measured to describe fire behaviour and intensity can include:

- On-site fuel moisture levels of the duff and litter layer,
- consumption of fuel by size class,
- crown scorch.

(R.W. Gray, R.W. Gray Consulting, pers. comm., 2005)

Monitoring of these variables would require some work prior to burning, but information collected can be used to tie the plant community response to the prescription. Relating response to the prescription will allow for the development of regressions that can tie treatment intensity to a specific response. This information will improve prescriptions through the ability to develop specific treatments in order to obtain a desired response (e.g. a 10% increase in bunchgrass cover).

Fire intensity on the second day of burning may have been a little higher than desired, but overall the burn met the goal of a low to moderate intensity surface fire with relatively slow spread and the consumption

surface litter and duff while not compromising the early spring growth of the rough fescue and the bluebunch wheatgrass.

4.2 Burn plots

There was no immediate significant response of the overstory or understory community to the 2005 prescribed fire. The lack of response is significant in and of itself. Short-term post-restoration response often witnesses significant declines in production and cover (Bork et al. 2002; Page et al. 2005). Small increases in cover and density of key native bunchgrasses (Fig 8) indicates a positive response of these species to burning. The author expects this trend to continue.

Unfortunately similar responses were observed in the non-native plant community as well. The response of non-native species on-site to prescribed fire are not well-known. Non-native species' cover and density should be monitored closely to ensure park managers can identify pro-active measures to manage growth and density.

Despite current cover levels of non-native species, there is potential to restore habitat for several species and plant communities at risk (Table 4). The biggest threat to achieving successful restoration of these habitats is non-native species invasion.

Table 4. Restoration potential of habitat for species and plant communities at risk in the IDF in burn plots at Redstreak.

species/plant community	status	restoration potential	habitat attributes ²	comments
bighorn sheep	CDC ¹ blue listed	HIGH	5-25sph; <25% crown closure. >74% herb cover.	Overstory conditions have been achieved at this site. Understory conditions have not yet been met, requires late-seral grasslands
badger	CDC ¹ red-listed; listed endangered by COSEWIC	HIGH	0-20sph; 0-10% crown closure. >75% herb cover	Overstory conditions have been achieved at this site. Understory conditions have not yet been met, requires late-seral grasslands.
bluebunch wheatgrass-junegrass	CDC ¹ red-listed	MEDIUM	0-5sph; <10% canopy closure. 30 – 50% canopy cover.	Stems per hectare are slightly higher than desired, but otherwise overstory conditions have been met. Understory conditions have not yet been met, requires late-seral grasslands.

¹ Conservation Data Centre. <http://srmapps.gov.bc.ca/apps/eswp/>

²Habitat attributes are defined by Cooper et al. (2004).

Although understory conditions do not meet habitat attribute recommendations, the current plant communities are in a transitory early-seral state and will, over time, succeed to a late-seral open forest community dominated by desirable native species and forbs.

4.2 Unburned plots

Cover in the unburned plots was generally higher, although this is compounded by higher vegetation cover in 2004 at site 2.

Although cover of all functional groups was higher, plant communities at this site exhibited characteristics of a closed forest sites (high cover of pinegrass and smooth aster). Despite this, low non-native species cover relative to native plant cover (Table 3), indicates this community will respond positively in the long-term to overstory reduction.

Habitat restoration potential for species and plant communities at risk is similar to the burned site (Table 4) although restoration potential for the bluebunch wheatgrass-junegrass plant community is high and there is medium potential for the Douglas fir/snowberry/balsamroot plant community to occur at this site (Table 5). Restoration potential for these plant communities is higher due to a higher cover of bunchgrasses and more xeric nature of the site.

Table 5. Restoration potential of habitat for species and plant communities at risk in the IDF in unburned plots at Redstreak.

species/plant community	status	restoration potential	habitat attributes ²	comments
bighorn sheep	CDC ¹ blue listed	HIGH	5-25sph; <25% crown closure. >74% herb cover.	Overstory conditions have been achieved at this site. Understory conditions have not yet been met, requires late-seral grasslands
badger	CDC ¹ red-listed; listed endangered by COSEWIC	HIGH	0-20sph; 0-10% crown closure. >75% herb cover	Overstory conditions have been achieved at this site. Understory conditions have not yet been met, requires late-seral grasslands
bluebunch wheatgrass-junegrass	CDC ¹ red-listed	HIGH	0-5sph; <10% canopy closure. 30 – 50% canopy cover.	Stems per hectare are slightly higher than desired, but otherwise overstory conditions have been met. Understory conditions have not yet been met, requires late-seral grasslands
Douglas fir/snowberry/balsamroot	CDC ¹ red-listed	MEDIUM	20 – 200sph; 15-30% crown closure (retain a few young conifers). >50% herb cover	Overstory conditions have been achieved at this site, although there are no conifer recruits. Understory conditions have not yet been met, requires late-seral grasslands

¹ Conservation Data Centre. <http://srmapps.gov.bc.ca/apps/eswp/>

²Habitat attributes are defined by Cooper et al. (2004).

Similar to the burn plots, the biggest barrier to successful restoration of these habitats is non-native species invasion. Continued monitoring and management of these species will improve the chance of successful restoration.

4.3 Weeds to Watch

Weeds to watch in 2005 have changed slightly from 2004.

- Canada thistle [*Cirsium arvense* (L.) Scop. Var. *horridum* Wimm. & Grab.] – found at site 2 scattered throughout the block in 2004. Has not shown any signs of increase in 2005 in either the burned or unburned plots.
- Spotted knapweed (*Centaurea biebersteinii* DC.) – found one plant at Site 1 in the vicinity of plot 1-5 in 2004, plant was pulled at that time. There were no records of spotted knapweed in 2005.
- Sticky ragwort (*Senecio viscosus* L.) – found at Site 1 scattered throughout the block in 2004, but was not recorded 2005.
- Bull thistle decreased in cover in the unburned plots in 2005, but increased slightly in the burn plots. This species widely scattered throughout the burn and unburned areas.
- Perennial sowthistle forms the highest non-native species cover at both sites. Sowthistle cover decreased slightly in the unburned plots and increased cover in the burn plots. This species is widespread at the Redstreak site.

Management and monitoring of perennial sowthistle and bull thistle should be the weed management priority at this site.

4.4 General recommendations

Monitoring in 2005 provided valuable information about the immediate response of the plant community to fire as well as valuable information about the fire behaviour. Monitoring highlighted the current successional state of the plant communities on-site and indicated the potential of the Redstreak plant communities.

Overstory monitoring shows successful restoration of overstory structure for species of interest at this site. Bighorn sheep monitoring indicates that sheep made increasing use of the area from 2002 - 2004 (A. Dibb, senior wildlife biologist, LLKY Field Unit, pers. comm. 2005), likely due to more open habitat conditions. The only wildlife habitat concern related to the overstory is a lack of veteran recruitment for cavity nesters, particularly in the unburned plots. Proposed avifauna monitoring should determine the effect of current habitat structure on cavity nesters and be able to propose appropriate solutions if any are needed.

Plant community monitoring should occur one growing season (2006) after the burn to determine if trends in response can be established. After year one post-fire, Machmer et al. (2002) suggest 3, 5 and 10 years post-burn. Monitoring should focus on key non-native and native (bluebunch wheatgrass, rough fescue) species cover and density. Monitoring should also examine the seral stages, species composition and structure of plant communities and determine if the plant communities are tending towards a desirable state.

The author suggests locating more control plots (e.g. immediately south or north of both sites) to more accurately determine the effects of restoration activities. This will be even more important if the eastern half of the site is subject to a burn. The presence of a control site will also increase Park manager's ability to evaluate the trade-off between the potentially negative effects of restoration (e.g. increase in non-natives) and the positive effects of restoration (e.g. decreased wildfire risk, increased forage production, increased use of habitat by bighorn sheep, creation of rare plant communities).

Monitoring of wildlife and plant communities at Redstreak is a valuable component of Kootenay National Park's fire-maintained ecosystem restoration program. Time and financial resources invested are offset by the development of a knowledge base that allows for the development of detailed prescriptions that will achieve goals established by land managers.

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Appendix 1 List of EXCEL raw data files and their descriptions (RW-CD format)

File/Folder Name	Description
KNPER_understory	Includes plot location and ID information, as well as understory species composition raw data (species richness, species canopy cover, flowering culm and weed density).
KNPER_overstory	Includes all overstory data (tree species, diameter at breast height, height, decay class, presence of insects and disease)

Appendix 2 Scanned photos (RW-CD format)

Photos were taken from the plot centre in the direction of each transect. Photos were numbered and ordered to match the number of the transect (1 – 3)

Appendix 3 Names and descriptions of EXCEL spreadsheets in the “Summary Data” file (RW-CD format)

Spreadsheet Name	Description
Overstory	Includes summary tabulations for all overstory characteristics by plot and site. Including species richness and diversity calculations.
Understory	Includes summary tabulations of understory cover by species, plot and site.