Monitoring Ecosystem Restoration Treatments in Kootenay National Park.

2009 monitoring

Submitted to: Rick Kubian

Fire and Vegetation Specialist

LLKY Field Unit

Parks Canada

Submitted by: Hillary Page M.Sc.R.P.Bio

Summary

In June, 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, the western half of the restoration area was subject to a prescribed burn. Monitoring of the burned restoration plots occurred 2005 and 2006. The western half of the restoration area was burned a second time in April 2009. This report summarizes activities associated with the vegetation monitoring program in 2009: monitoring restoration effects on the understory and overstory plant community.

Thirty permanently-located plots were sampled, 22 in the burn area, eight in the unburned area and one control plot. One additional permanent sample plot was located in the western half of the restoration area. Plots in the burn treatment were subject to a low-intensity prescribed fire over a two-day period on April 8th, 2009. 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 20th to August 8th, 2009. Overstory sampling (tree density by species, diameter, cover, and decay class) in nested fixed radius plots was completed at the same time.

There were several significant changes in observed in the understory plant community. After observing increases in all vegetation cover groups during past monitoring sessions (2004, 2005, 2006), pinegrass, bunchgrass and non-native species cover all experienced slight declines in the restoration area. Sedge and forb cover increased significantly in the restoration area. Changes were largely due to prescribed fire effects. However, pinegrass cover declined significantly in the unburned plots. Pinegrass declines may have been due to local weather effects or could be an indication of changing plant species composition at this site.

Current overstory structure remains ideal for several species of interest and concern (e.g. bighorn sheep). Due to immediate fire effects it is not possible to determine the trajectory of the understory plant community response. Monitoring in one to two years will more accurately determine the trend of plant community response.

Acknowledgements

This project was conducted by Hillary Page. I would like to thank Emilia Cronin for field assistance. I would also like to thank Rick Kubian and Karen Lassen (Parks Canada) for administering the project and acknowledge the Parks Canada Agency (LLKY Field Unit) for providing funding.

Table of Contents

List of Tables

List of Figures

List of Appendices

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 [*Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco], ponderosa pine (*Pinus ponderosa* Douglas ex Lawson & Lawson var. *ponderosa*) and bunchgrass zones (Gayton 2001a). 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 subjected to a 'mixed fire regime', meaning frequent low-intensity fires with occasional, randomly occurring stand-replacement fires (Gayton 2001). This is more apparent in areas where NDT4 transitions into NDT3 systems. 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 in these areas, the mean fire-return interval was normally distributed, with very short and long intervals being uncommon (Gayton 2001). Regardless of the fire regime, it is clear that dry, interior 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 and dry NDT3 systems of the Rocky Mountain Trench due to forest ingrowth or encroachment. This is equivalent to an annual loss of 3000 ha (the loss of grassland is not equivalent in each year). The rate of loss 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). Forest structure conversions can result in domestic livestock and native ungulates exerting increased pressure on a declining land base as they compete for forage. Increased use of remaining grassland habitats by ungulates may also result in further degradation by noxious weeds. Noxious weeds and non-native species have the capability to out-compete native vegetation and reduce residual forage quantity and quality.

Additionally, 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 of concern due 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 (O*vis 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).

Critical winter range habitat has been significantly reduced throughout the Rocky Mountain Bighorn Sheep's range (≤50%) over the last 70 years. Forest encroachment and fire suppression are reducing suitable habitat by replacing grass, forbs and deciduous shrubs with conifers. Forest succession can interfere with seasonal movement patterns and grazing behaviour by decreasing visibility and increased predation by carnivores relying on stealth (Demarchi 2004). Desirable bighorn sheep forage species, 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. The Identified Wildlife Management Strategy suggests that at least 50% of critical bighorn sheep range should be maintained in late seral/climax condition bunchgrass dominated communities with abundant, tall grass (easily accessible above snow cover) for winter forage (Demarchi 2004).

In response to forest ingrowth and the concomitant loss of high quality bighorn sheep habitat, managers at Kootenay National Park (KNP) have developed objectives for the south end of KNP (Redstreak). The south entrance to KNP is located in the town of Radium Hot Springs, BC. Examination of historic natural fire regime models reveals that the slope toes (IDFxk (Very Dry Cool Interior Douglas fir) into the (Dry Cool Montane Spruce Subzone) (MSdk)) around Radium are subject to a mixed-severity fire regime (R.W.. Gray, R.W. Gray Consulting, *pers. comm*., 2005). Restoration objectives were designed to more effectively manage Redstreak for bighorn sheep habitat, fuel management surrounding recreation facilities 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 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 (see Page 2005 for second phase monitoring results).

Parks Canada developed a series of performance indicators to monitor the success of restoration activities (A. Dibb, senior wildlife biologist, LLYK Field Unit, pers. comm., 2005). Based on selected indicators monitoring programs were developed that include bighorn sheep telemetry, ground squirrel and small mammals transects, ungulate pellet counts and permanently-located vegetation plots.

Monitoring is an integral component of the KNP 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). In addition to monitoring key response variables, 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 2005). Monitoring involves the measurement of environmental characteristics, over an extended period of time, to determine status or trends in some aspect of environmental quality (Suter 1993). Environmental monitoring should address one or more specific objectives (Goldsmith 1991) that are associated with specific targets (e.g., a 5% increase in bunchgrass cover over five years). In the context of ecosystem restoration (ER), monitoring is conducted to determine if restoration prescriptions are having the desired effect (Noon 2003). Given the significant investment in ER, it is the responsibility of agencies to collect information that can inform practitioners and the public about whether ER is having the intended effect and whether forest and rangeland resources are being sustained (Noon 2003). The EM strategy developed by Machmer et al. (2002) was intended to provide data that allows the ER community to evaluate progress towards goals developed at different spatial scales (e.g., site, range unit and landscape level scales; Ringold et al. 2003).

This project is in response to a Request for Proposals from KNP to use the Trench EMP to conduct vegetation monitoring of the Redstreak Restoration Area. Specific objectives of the project were to (1) monitor two permanent monitoring sites within a historically mixed-severity fire regime site in the Park, (2) to collect data on vegetation overstory and understory conditions at two restoration sites (one thinned and burned, one thinned only), and (3) to summarize and analyze the short-term response of the understory and overstory plant community to restoration activities.

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 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; IDFxk); and 2002/03

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

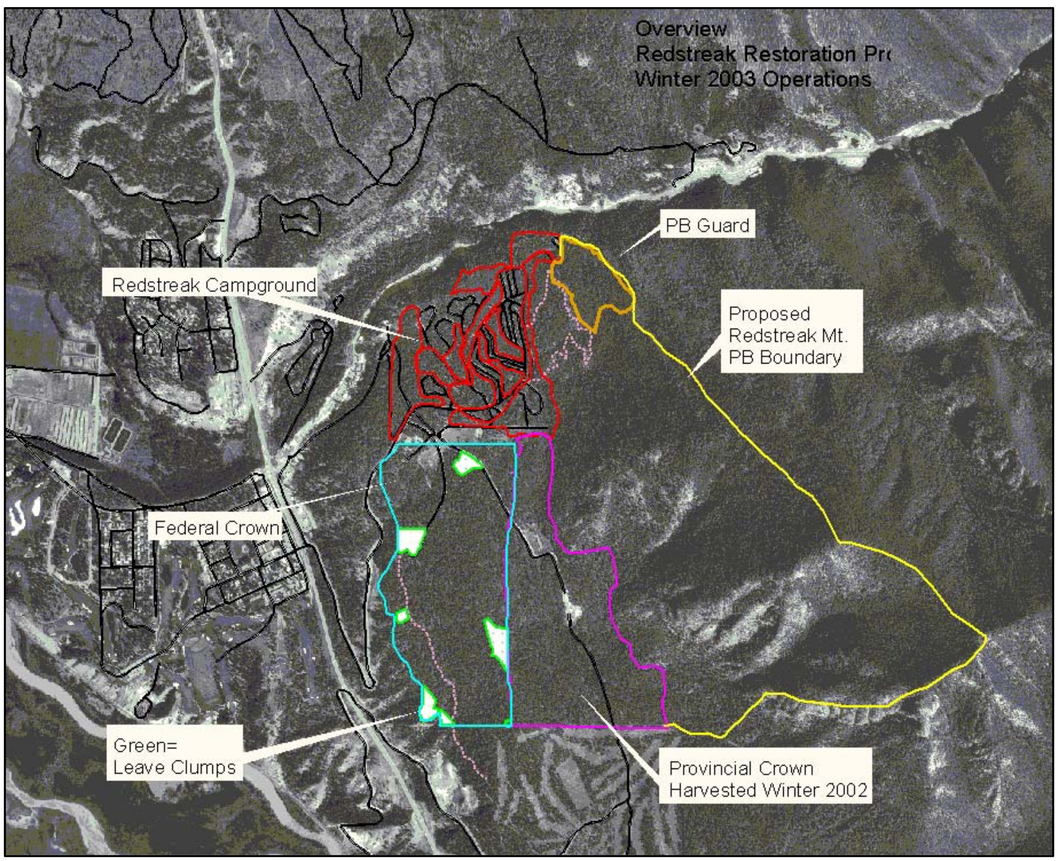

Figure 1. Location of site 1 (federal crown) and site 2 (provincial crown) located at the south end of Kootenay National Park.

In July 2004, fifteen plots were systematically established at site 1, fourteen at site 2 and one control plot. One additional plot was located in July 2009. 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 of the Daubenmire frame was permanently marked with an 8" galvanized spike and 1 spray painted washer. Each spike was marked with orange flagging. Flagging was replaced in 2005, 2006 and 2009.

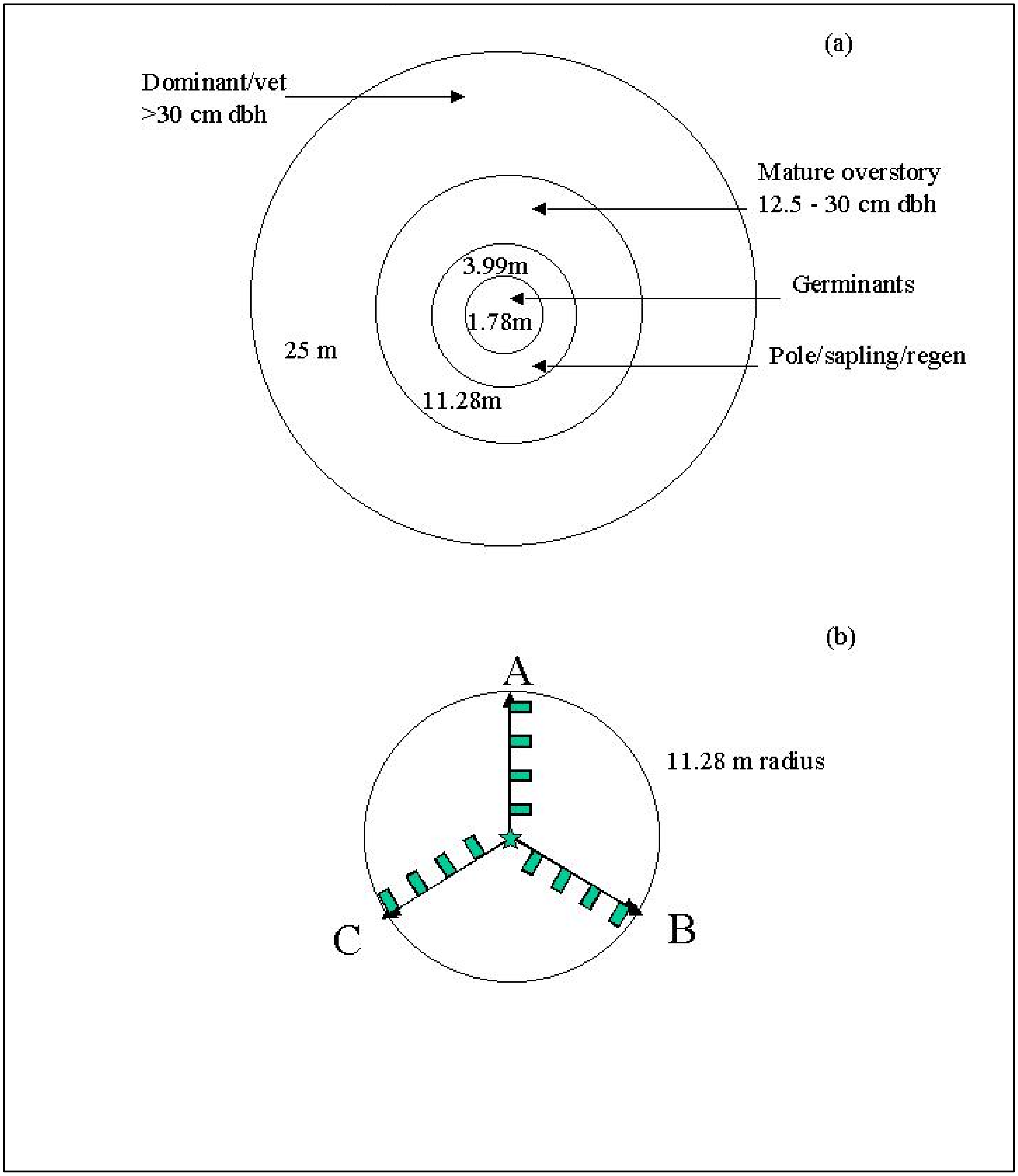

Figure 2 a&b Layout of overstory (a) and understory (b) sampling plots adapted from DeLong et al. (2001).

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 ($H=-P_i\log[P_i]$) (Bonham 1983).

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.

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 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.). Comparisons between years (2004, 2005, 2006, 2009) were made using a Student's t test.

3. Results and observations

3.1 General site and treatment descriptions

The Redstreak site is located at the toe of the Rockies in the IDFxk (Very Dry Cool Interior Douglas fir). The site transitions to the MSdk (Montane Spruce) on the eastern boundary. IDFxk sites are found in the valley bottom of the Rocky Mountain Trench. Zonal stands are dominated by Douglas fir. The poorly developed shrub layer is dominated by Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) and low cover of Saskatoon (*Amelanchier alnifolia* Nutt.), snowberry [*Symphoricarpos albus* (L.) Blake] and rose (*Rosa* sp.). The herb layer contains a diverse mixture of species, but is dominated by bluebunch wheatgrass, rough fescue and low cover of northern goldenrod (*Solidago multiradiata* Ait.) and kinnikinnick (bearberry) [*Arctostaphylos uva-ursi* (L.) Spreng.]. Throughout this subzone, the abundance of bluebunch wheatgrass and rough fescue has been significantly reduced by elk, deer and cattle. Zonal warm aspects in the MSdk are dominated by Saskatoon and bluebunch wheatgrass (Braumandl and Curran 1992). 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 treatment

The 2009 one-day prescribed burn took place on April 8th. The burn covered all of site 1 and the western half of site 2. Site 1 is located on relatively level ground (mean slope = 3%), except for moderate east facing slopes on the eastern boundary of the block. The western half of site 2 is an east-facing slope characterized by mesic plant communities [pinegrass (*Calamagrostis rubescens* Buckl.), aspen (*Populus tremuloides* Michx.), chokecherry (*Prunus virginiana* L.)]. Eighty to 90% of the area was burned with a low-intensity burn (LLYK Fire and Vegetation Management Section 2009). Fuels analysis showed 97% combustion of herbaceous cover and 75% of shrub cover (LLYK Fire and Vegetation Management Section 2009). Fire behaviour is described in detail in the Redstreak Benches Restoration Prescribed Fire Report (LLYK Fire and Vegetation Management Section 2009).

In the burn treatment, there was a significant reduction in litter observed from 2006 to 2009 (75%±6 to 68%±7; p=0.002). Despite a decline in litter cover there was not a significant increase in bare soil, although cover of bare soil in the burned plots is almost 4% higher than in the unburned plots (5±5 vs 1±3; p=0.03)

3.1.2 Unburned treatment

The road dividing site 2 was used as the eastern fire guard (Fig. 1). There were eight restoration monitoring plots located in this area. The unburned portion of site 2 is mostly level (7.6%) with southwest facing slopes on the eastern block boundary (Fig. 1). Site 2 generally has a drier moisture regime than site1, due to topography (southwest facing slopes). Plant communities in the unburned plots are characterized by a high cover of pinegrass and moderate levels of smooth aster (*Aster laevis* L. var. *geyeri*) and kinnikinnick.

3.3 Overstory characteristics

The only discernible change in overstory characteristics from 2005 was an increase in aspen regeneration in the burned plots. There were approximately 2100 aspen regenerating stems per hectare in the burned plots (live aspen regeneration was 648 stems/ha in 2005). Aspen regeneration was only found in a small number of plots, so variability across the site is high. There was also an increased observation of feeding on trees. Approximately 10% of the stems observed in the burned areas displayed signs of wildlife feeding.

3.3 Understory characteristics

In 2009, there were 68 understory species observed. Similar to previous monitoring sessions, across the entire site, pinegrass was the most common species observed. In Block 1, although pinegrass was still the dominant species observed, showy aster (*Aster conspicuus* Lindl.) and Canada thistle (C*irsium arvense* (L.) Scop.) were replaced by sedge species and birch-leaved spirea respectively as dominant species (Table 2).

Table 2. Dominant species as recorded in the Daubenmire quadrats in Block 1 of the Redstreak Restoration Area in 2004 – 2009.

year	species	cover (%)	species	cover (%)	species	cover (%)
2004	pinegrass	10±7	birch-leaved spirea[1]	4±3	heart-leaved arnica[3]	2±2[4]
2005	pinegrass	10±8	perennial sowthistle[2]	3±3	birch-leaved spirea	3±2
2006	pinegrass	15±11	showy aster	4±7	Canada thistle[5]	4±6
2009	pinegrass	15±6	carex species	5±4	birch-leaved spirea	4±3

[1] *Spiraea betulifolia* ssp. *lucida* (Dougl. ex Greene) Taylor & MacBryde Pall
[2] *Sonchus arvensis* L.
[3] *Arnica cordifolia* Hook
[4] heart-leaved arnica was not observed in 2005 and 2006 in Block 1.

Although Canada thistle and showy aster were replaced as dominant species, there were no significant changes detected in cover of either of the species. Change in Block 1 species composition reflect species immediate response to the effects of prescribed burning.

After 7 years, species composition changes were also evident in Block 2. Kinnikinnick replaced pinegrass as the dominant species in block 2 (Table 3).

Table 3. Dominant species as recorded in the Daubenmire quadrats in Block 2 of the Redstreak Restoration Area in 2004 – 2009.

year	species	cover (%)	species	cover (%)	species	cover (%)
2004	pinegrass	13+8	kinnikinnick	3±4	prickly rose[1]	2±2
2005	pinegrass	15±10	kinnikinnick	3±4	leafy aster	2±2
2006	pinegrass	19±9	kinnikinnick	8±8	leafy aster	3±4
2009	kinnikinnick	12±12	pinegrass	12±6	leafy aster	3±2

[1] *Rosa acicularis* Lindl.

Over three growing seasons pinegrass has declined significantly from 19±9 to 12±6 ($p=0.01$). The decline in pinegrass could be due to a slow drying of the site or potentially to local weather conditions.

Across the burn and unburned site, from 2006, there was a slight increase in species diversity (Shannon-Weiner index) across the site, although the change was not significant. Species diversity increased in block 1 and decreased slightly in the block 2.

Treatments superimposed over the blocks (i.e. prescribed burning) confound analyses of results by block. For the purposes of detecting trends at a treatment unit level as well as a restoration unit level, changes are summarized by descriptive group within a treatment rather than by site.

3.3.1 Bunchgrass

Bunchgrass cover has continued to increase on-site since 2004 (Fig.3). However, the increase in bunchgrass cover in 2009 can largely be attributed to an increase in spreading needlegrass and Idaho fescue cover in two of the burned plots. If these plots are removed from analysis as outliers, bunchgrass cover actually drops slightly in 2009 (Fig. 4).

In the burn plots, all species of bunchgrass declined, except spreading needlegrass. The biggest decline in cover was rough fescue with about a 50% drop in cover. Despite cover declines, bunchgrass cover in the burn treatments is still higher than in 2004 (1%±1 vs 2%±2) (Fig. 4). Changes in bunchgrass cover on-site are being driven by changes in the burn treatment. Bunchgrass cover in the unburned plots remained roughly at the same level (~3%) as previous years.

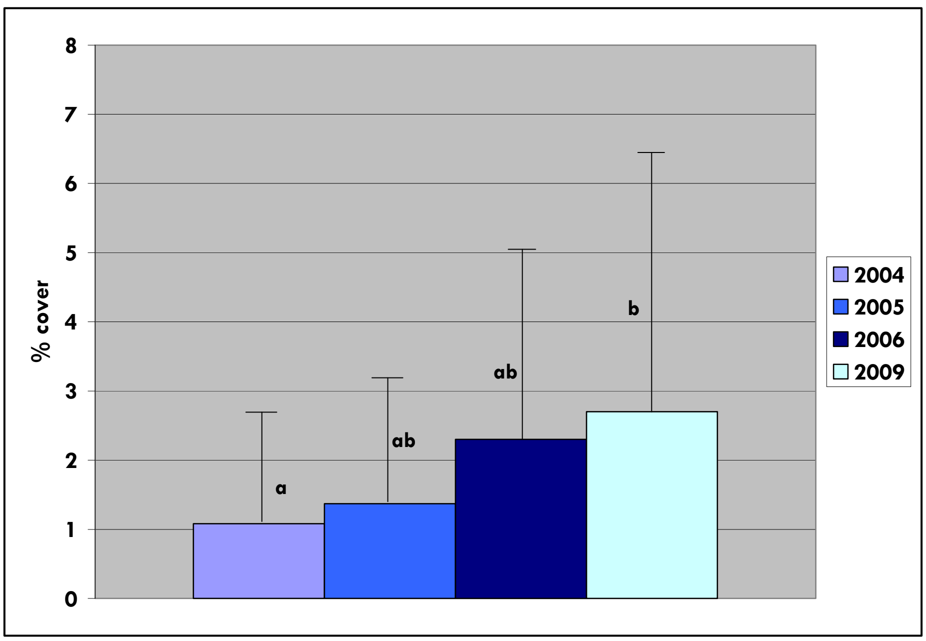

Figure 3. Bunchgrass cover in 2004 – 2009 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference (p<0.1)

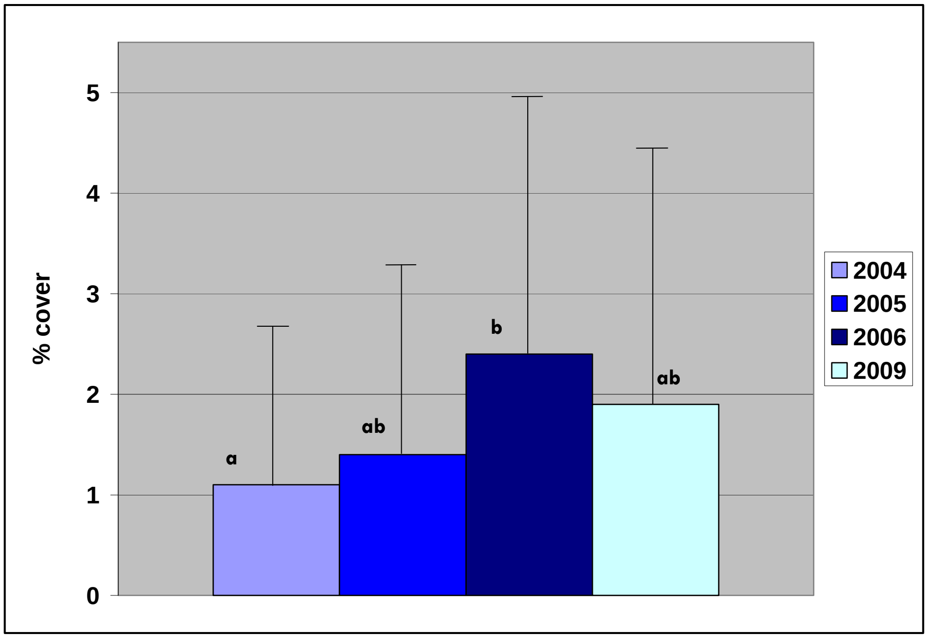

Figure 4. Bunchgrass cover in 2004 – 2009 at the Redstreak Restoration Area (both blocks combined) excluding outliers. Means with a different letter indicate a significant difference (p<0.1).

3.3.2 Grass and Grasslikes

Across the site, pinegrass cover declined to pre-2006 levels (Fig. 5). Changes across the site are reflected in the both the burned and unburned treatments.

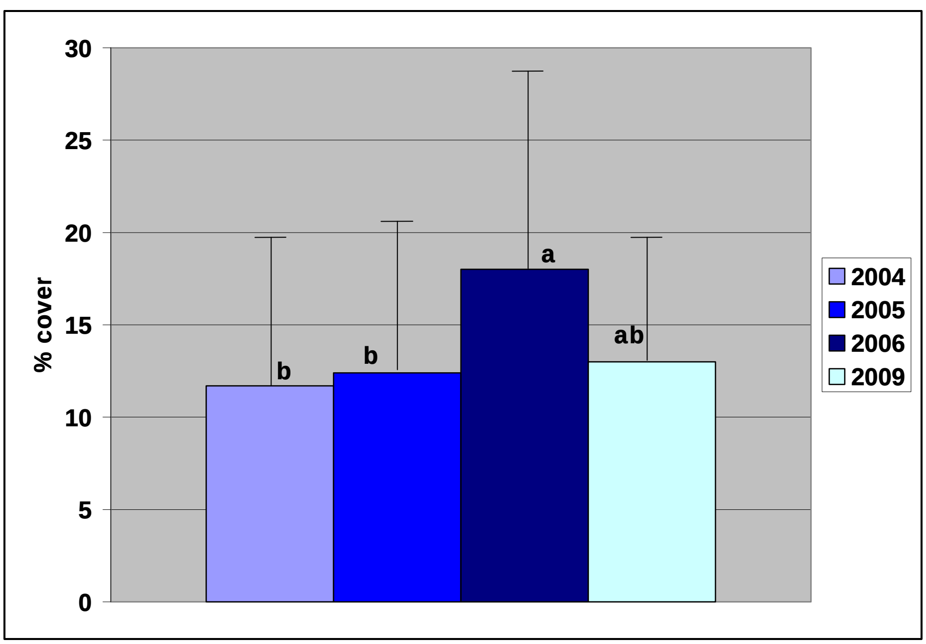

Figure 5. Pinegrass cover in 2004 – 2009 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference (p<0.1)

In the burn plots, pinegrass declined to pre-2006 levels, although the change was not significant (Fig. 6). Decline in pinegrass cover was likely due to top-kill fire effects. There was, however, a significant decline in pinegrass cover in the unburned plots from 2006(19$\pm$10 to 10$\pm$6; $p<0.1$) (Fig. 6). Declines could potentially be attributed to a gradual drying of the site combined with weather effects. Further monitoring will determine whether or not the change reflects actual species composition changes rather than environmental factors.

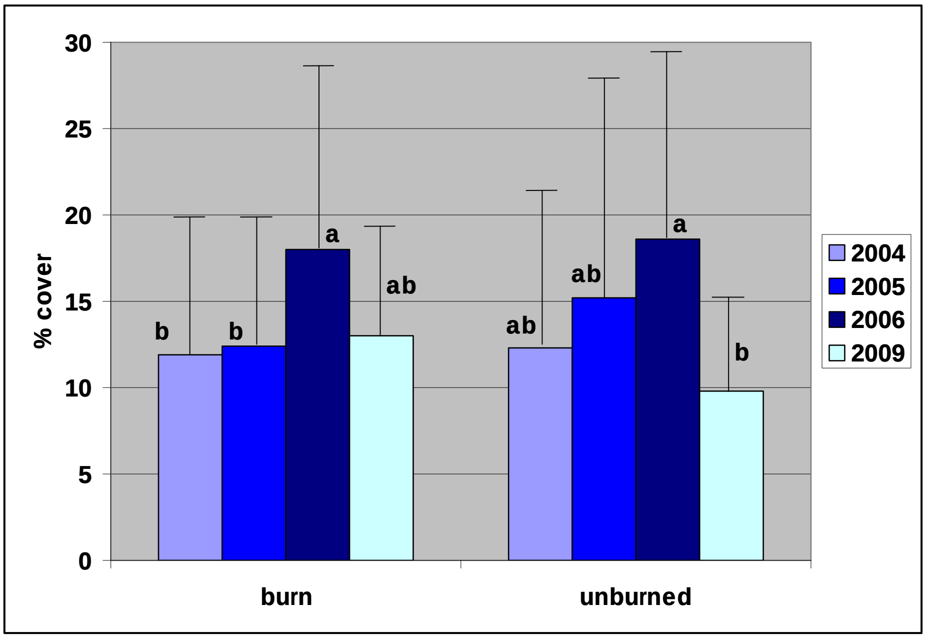

Figure 6. Pinegrass cover in 2004 – 2009 at the Redstreak Restoration Area in the burned and unburned treatments. Means, within a treatment, with a different letter indicate a significant difference ($p<0.1$).

There was a significant increase in sedge cover observed within the Redstreak Restoration Area ($p<0.1$) (Fig. 7). Changes in sedge cover were driven by significant increases within the burn plots (1$\pm$2 to 4$\pm$2; $p<0.1$) as there was no significant change in sedge cover observed in the unburned plots. Sedge cover increases were likely due to consumption of herbaceous fuels allowing for emergence of suppressed sedge plants within the understory.

There was also a significant increase in bluegrass species (*Poa* sp.) observed across the site. This can also be largely attributed to an increase in cover within the burned plots. Despite the increase, cover was negligible across the site (<1%).

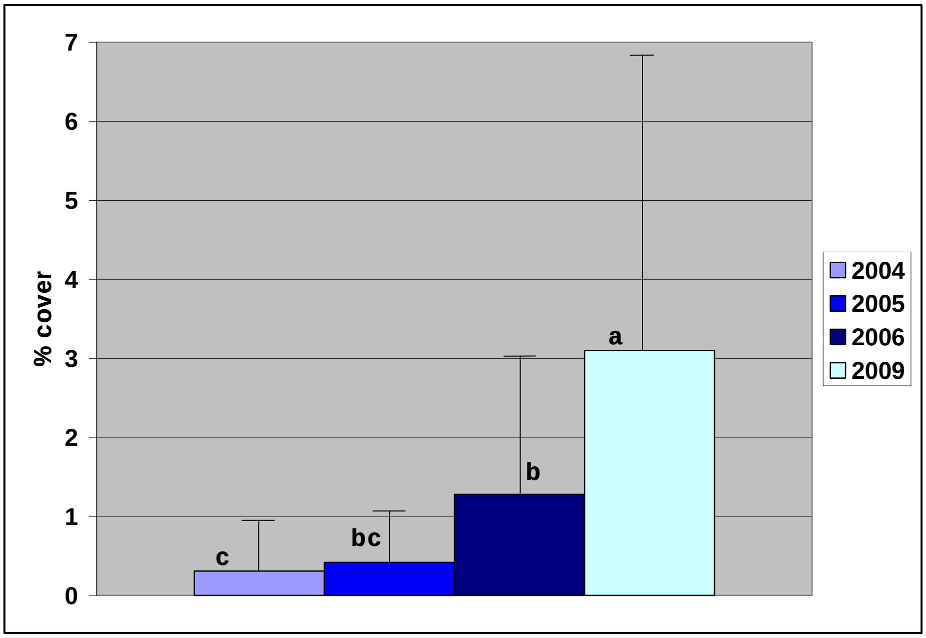

Figure 7. Sedge cover in 2004 – 2009 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference ($p<0.1$)

3.3.3 Forbs

Forb cover increased significantly in the Redstreak Restoration Area from 2006 (Fig. 8). This was the second significant increase in forb cover observed during the course of monitoring.

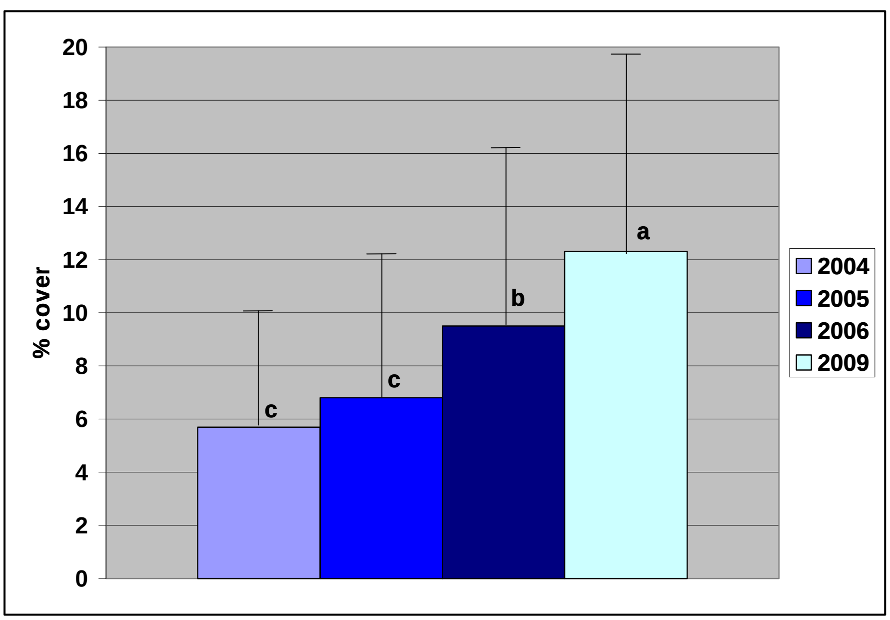

Figure 8. Forb cover in 2004 – 2009 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference ($p<0.1$)

Large increases in cover were most apparent in the burn treatment, although forb cover continued to increase in the unburned treatment (Fig. 9). Across the entire site significant increases from 2006 were detected in three individual species; northern bedstraw (*Galium boreale* L.), yellow penstemon (*Penstemon confertus* Dougl. ex Lindl.) and early blue violet (*Viola adunca* J.E. Smith).

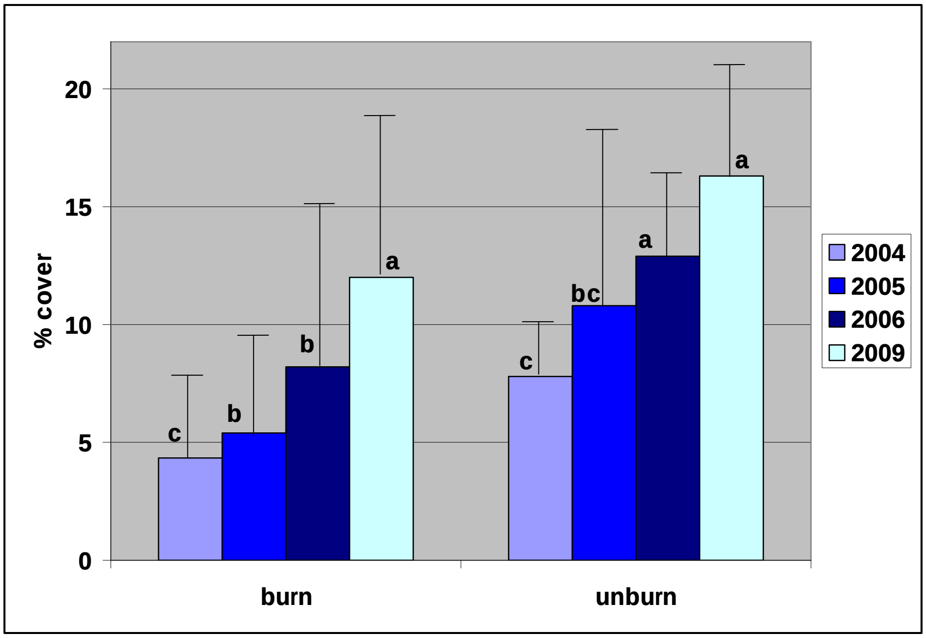

Figure 9. Forb cover in the burned and unburned plots from 2004 to 2009. Means, within a treatment, with a different letter indicate a significant difference ($p<0.1$).

In 2006, forb cover was significantly higher in the unburned plots than in the burned plots (Page 2006). In 2009, this difference is no longer evident (Table 4). Significant differences are likely diminished because of increases in species favored by the prescribed burn such as northern bedstraw and early blue violet within the burn treatment.

Table 4. Descriptive group cover in the burn and unburned treatments in 2009. Means are compared across rows.

descriptive group	burn	unburned	p-value[1]
bunchgrass	2±2	3±4	0.26
forbs	12±7	14±7	0.34
non-native	4±3	1±1	**0.01**
sedge species	4±4	1±2	**0.03**
bluegrass	1±1	1±1	0.93
shrubs	5±3	7±4	0.21

[1]p-values compare means between treatments across rows

3.3.4 Non-Native Species

Despite a small decline in non-native species cover, from 2006, there were no significant changes detected in non-native species cover across the site. Despite this, there was a significant difference in cover between the burned and unburned plots ($p=0.01$) (Table 4).

Non-native species cover declined in the burn plots, but experienced a minor increase in the unburned plots (Fig. 10), neither change was significant.

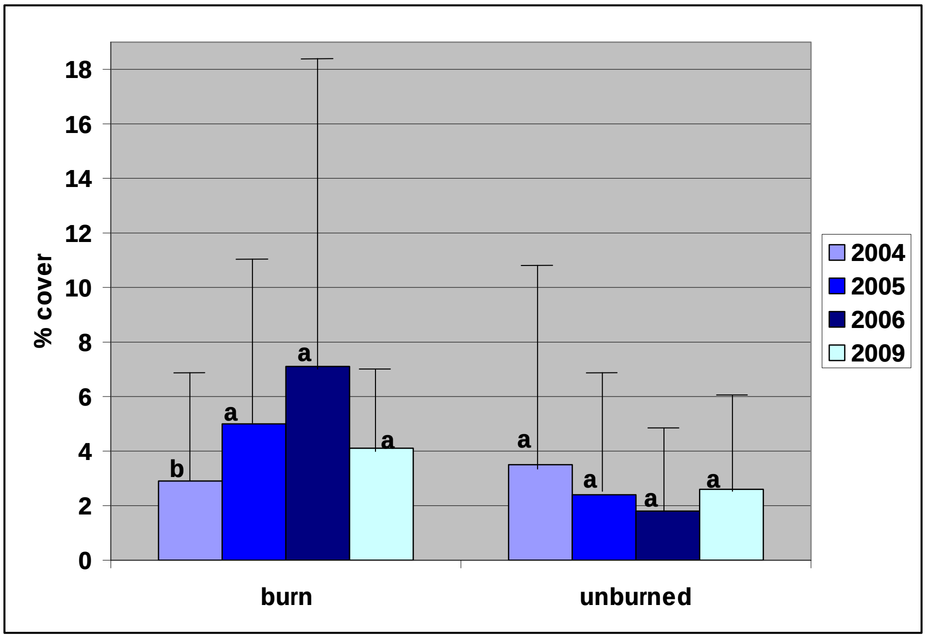

Figure 10. Non-native species cover in 2004 – 2009 at the Redstreak Restoration Area in burned and unburned plots Means with a different letter within a treatment (burn and unburned) indicate a significant difference ($p<0.1$)

In the burn plots, cover of the three dominant non-native species (bull thistle, Canada thistle, perennial sowthistle) has declined (Table 5).

Table 5. Canada thistle, bull thistle and perennial sowthistle cover (%) in the burn treatments in the Redstreak Restoration Area from 2004 – 2009.

year	Canada thistle	bull thistle	perennial sowthistle
2004	0±0	1±2	2±3
2005	1±2	1±2	2±3
2006	3±6	3±6	1±1
2009	0.5±2	0±0	0±0

4.0 Discussion

The 2009 burn was operationally successful and has had a significant impact on the Redstreak Restoration Area plant community. Declines in bunchgrass, pinegrass and non-native species cover have been observed in the burn year while there were significant increases in forb and sedge cover observed across the entire site.

Although there were no significant changes noted in the overstory in 2009, the fire seems to have resulted in an increase in aspen regeneration (648 stems/ha to 2100 stems/ha) in the burned areas, although these changes are highly variable across the site. Trembling aspen is very competitive in burned areas (DeByle et al. 1987), although small diameter aspen are usually top-killed by a low-intensity surface fire (Jones and DeByle 1985). Stems on-site have likely been increasing since the 2005 burn and were large enough to withstand the 2009 low-intensity burn.

Changes in the understory at the Redstreak Restoration site were largely driven by changes caused by the prescribed burn. Bunchgrass cover returned to pre-2006 levels immediately post-fire. Changes in cover on the site are due to changes within the burn plots. Cover levels remained stable in the unburned plots but declined in the burn plots (although cover is still higher than 2004 levels). The moderate decline is not surprising as although bunchgrass species are resistant to fire (buds are protected by soil or plant material) plants can be top-killed by fire. Recovery of prefire coverages and herbage production is usually attained in 2 – 3 years (Tirmenstein 2000).

Pinegrass declined on site for the first time since monitoring was initiated in 2004. Pinegrass was reduced to pre-2006 levels in the burn plots. Pinegrass is usually top-killed by fire (Mc Clure 1958), so the decline is expected and likely temporary in the burn plots. However, a significant reduction of pinegrass cover was also observed in the unburned plots. The decline in cover is somewhat surprising as pinegrass cover has been increasing in the unburned plots since the site was harvested in 2001. The explanation for the reduction in cover will not be clear until further monitoring occurs. Although pinegrass can dominate the understory when the overstory is opened up (Coates and Haeussler 1986), it is hypothesized that the open overstory will eventually lead to a drying of the site which will enable bunchgrasses and other species to be more competitive and result in pinegrass being less competitive in the more xeric environment. Further monitoring will determine whether or not the reduction of pinegrass in the unburned plots is due to local weather or actual changing site conditions.

Despite a lack of pinegrass increase there was a significant increase in sedge cover across the site, due to a significant increase in sedge cover in the burn plots. Increases in cover are likely due to a consumption of herbaceous fuel that exposed the plants and allowed them to flourish.

Forb cover continued to increase across the site. There was a significant increase in forb cover in the burn plots. Cover increases were observed in the unburned plots as well, although the changes were not significant. Cover increases are likely due to the response of fire-resistant species to the spring burn. Northern bedstraw, yellow penstemon and early blue violet all increased significantly in the burn plots. All three species are adapted to fire. Northern bedstraw and early blue violet are both rhizomatous and can easily reproduce after a light-intensity fire. Although yellow penstemon is not rhizomatous, it is an earlier seral species and able to adapt to disturbance. Heidel and Shelly found in 5 years of monitoring lemhi penstemon (*Penstemon lemhiensis*) that fire resulted in increased propagation of this species. It is interesting to note that up to this monitoring year, forb cover has been significantly higher in the unburned plots, however in 2009, there was no longer a significant difference between treatment blocks observed.

There were no significant changes in non-native species cover observed across the site. Although there were no significant changes detected, cover decreased slightly in the burn plots. Lack of non-native species response is likely due to top-kill of the three most common non-native species; Canada thistle, bull thistle and perennial sowthistle. It is worth noting that despite the lack of response, non-native species cover is significantly higher in the burn plots than it is in the unburned plots. Higher cover levels are due to the non-native species positive response after the 2005 fire. It will be important to monitor non-native species cover in the coming years to determine the trajectory of the response.

4.1 Weeds to Watch

Despite the lack of non-native species response, it is still essential to monitor non-native species cover to determine the mid to long – term response of these species to repeated prescribed burning.

- Canada thistle – found at site 2 scattered throughout the block in 2004. Canada thistle cover has increased significantly in the burn plots. Control of this species should be the management priority at this site.

- Bull thistle decreased in cover in the unburned plots in 2005 and experienced a slight increase in 2006. Bull thistle cover has increased in the burn plots in both 2005 and 2006. This species widely scattered throughout the burn and unburned areas.

- Perennial sowthistle formed the highest non-native species cover at both sites in 2005. In 2006, sowthistle has the lowest cover of all non-native species. Information in the literature concerning perennial sowthistle's response to fire is both sparse and conflicting (McWilliams 2004).

4.2 General recommendations

Plant community changes at the Redstreak Restoration area have been varied due the effects of repeated prescribed burning combined with long term recovery from harvesting operations.

Most vegetation groups experienced a decline in cover (pinegrass, bunchgrass, non-native species) likely due to immediate fire effects. It will take one to two years to determine the response trend in the burn plots. There was a significant increase in both sedge and forb cover. Again, changes are likely due to immediate post-fire effects.

The most interesting change was the significant decline in pinegrass cover in the unburned plots. It is possible that this a positive indication that site conditions have become xeric enough that pinegrass is slowly declining within the understory plant community.

With the 2009 burn, Parks Managers were hoping to increase bunchgrass cover over 5% and maintain non-native species cover below 7% (LLYK Fire and Vegetation Management Section 2009), however success of the 2009 prescribed burn can only be assessed with additional monitoring. Plant community monitoring is proposed two growing seasons (2011) post-fire to determine trends in plant community response after two prescribed burns. It will also be interesting to observe whether pinegrass cover levels continue to decline in the unburned plots

Future monitoring should focus on bunchgrass, Canada thistle, bull thistle and bluegrass cover. Monitoring should examine seral stages, species composition and structure of plant communities to determine if plant communities are on a desirable successional pathway.

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.

5. Literature Cited

Bai, Y, N. Walsworth, B. Roddan, D.A. Hill and D. Thompson. 2001. Quantifying tree encroachment in rangelands using image classification and pattern detection. Poster presentation. Society for Range Management 54th Annual Meeting, Kona-Kailua, Hawaii. February 17 – 23, 2001.

Bonham, C. 1983. Measurements for Terrestrial Vegetation. John Wiley & Sons. New York, NY. 338p.

Braumandl, T.F. and M.P. Curran. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. B.C. Ministry of Forests, Research Branch, Land Management Handbook Number 20, Victoria, B.C. 311p.

British Columbia Ministry of Forests. 2000. Resources Inventory Committee – Growth and Yield – Standards and Procedures. B.C. Ministry of Forests, Victoria, B.C.

Coates, D. and S. Haeussler. 1986. A preliminary guide to the response of major species of competing vegetation to silvicultural treatments. Victoria, BC: Ministry of Forests, Information Services Branch; Land Management Handbook Number 9. 88 p.

Daigle, P. 1996. Fire in the Dry Interior Forests of British Columbia. British Columbia Ministry of Forests Research Program Extension Note 08:5pp

Daubenmire, R.. 1959. A Canopy-Coverage Method of Vegetational Analysis. Northwest Science 33: 43-64.

Delong, D. 2001. Old growth restoration monitoring in the Interior Douglas-fir zone. Terrestrial Ecosystem Restoration Program Application for Funding, Fiscal Year 2001-2002.

DeByle, N.V., C.D. Bevins, W.C. Fischer. 1987. Wildfire occurrence in aspen in the interior western United States. Western Journal of Applied Forestry. 2: 73-76.

De Marchi, R.A. 2004. Bighorn Sheep (Ovis canadensis) pp 399 – 409. in: Identified Wildlife Management Strategy Accounts and Measures for Managing Identified Wildlife. Southern Interior Forest Region. Version 2004 Ministry of Water, Land and Air Protection. Victoria, BC. 578p.

Gayton, D (ed and compiler). 2001a. Summaries and Observations from Three-Partnership sponsored NDT4 Events. Southern Interior Forest Extension Research Partnership. Kamloops, BC. 32p.

Gayton, D. 1997. Preliminary calculation of excess forest ingrowth and resulting forage impact in the Rocky Mountain Trench. B.C. Ministry of Forests, Nelson Region.

Goldsmith, F.B.. 1991. Monitoring for conservation and ecology. New York: Chapman and Hall.

Grasslands Conservation Council. 2005. Introduction to Grasslands. http://www.bcgrasslands.org/grasslands/introductiontograsslands.htm accessed: November, 2005.

Heidel, B. and J.S. Shelly. 2001. The effect of fire on Lemhi penstemon (Penstemon lemhiensis) – Final Monitoring Report 1995 – 2000. Prepared for: Beaverhead-Deerlodge National Forest and Dillon Field Office – Bureau of Land Management.

Jones, J.R. and N.V. DeByle. 1985. Fire. In: DeByle, N.V. and R.P. Winokur eds. Aspen: ecology and management in the western United States. Gen. Tech. Rep. RM-119. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 77-81.

Lacelle, L.E.H. 1990. Biophysical resources of the East Kootenay area : soils. Victoria, B.C. Wildlife Branch, Habitat Inventory Section.

LLYK Fire and Vegetation Management Section 2009. Redstreak Benches Restoration Prescribed Fire Report. 10p.

Machmer, M., H.N. Page and C. Steeger. 2002. East Kootenay Trench Restoration Effectiveness Monitoring Plan. Submitted to: Habitat Branch, Ministry of Water, Land and Air Protection. Forest Renewal British Columbia Terrestrial Ecosystem Restoration Program. Pandion Ecological Research. Nelson, BC. 50p.

McClure, Norman R. 1958. Grass seedlings on lodgepole pine burns in the northwest. Journal of Range Management. 11: 183-186

National Research Council of Canada. 1998. The Canadian System of Soil Classification. Agricultural and Agri-Food Canada Publication 1646. (Revised). 187p.

Noon, B.R.. 2003. Chapter #2. Conceptual Issues in Monitoring Ecological Resources. In: Monitoring Ecosystems. Interdisciplinary Ecoregional Initiatives. Eds: D.E. Busch and J.C. Trexler. Island Press. WA, USA. Pp.167-188 pp 27 - 51.

Page, H.N.. 2005. Monitoring Ecosystem Restoration Treatments in Kootenay National Park. Year one post-fire monitoring. Submitted to: Kootenay National Park, Lake Louise Kootenay Yoho Field Unit. Radium Hot Springs, BC.. November, 2005. 28P.

Page, H.N. 2004. Monitoring Ecosystem Restoration Treatments in Kootenay National Park. Site Establishment Report. October, 2004. Submitted to: Parks Canada, LLYK Field Unit.

Page, H.N. 2009. Monitoring Ecosystem Restoration Treatments in Kootenay National Park. Year two post-fire Monitoring Report. November, 2009. Submitted to: Parks Canada, LLYK Field Unit.

Powell, G.W., D. White, D. Smith, B. Nyberg. 1998. Monitoring Restoration of Fire-Maintained Ecosystems in the Invermere Forest District. Interim Working Plan. B.C. Ministry of Forests, Research Branch.

Ringhold, P.L., B. Mulder, J. Alegria, R.L. Czaplewski, T. Tolle and K. Burnett. 2003. Chapter 3. Design of an Ecological Monitoring Strategy for the Forest Plan in the Pacific Northwest. In: Monitoring Ecosystems. Interdisciplinary Ecoregional Initiatives. Eds: D.E. Busch and J.C. Trexler. Island Press. WA, USA. Pp. 73 – 99.

Rocky Mountain Trench Ecosystem Restoration Steering Committee. 2000. Fire-Maintained Ecosystem Restoration in the Rocky Mountain Trench. "A Blueprint For Action" 16p.

Ruiz-Jean, M.C. and T.M. Aide. 2005. Vegetation structure, species diversity, and ecosystem processes as measures of restoration success. Forest Ecology and Management 154:409-430.

Sall, J., L. Creighton and A. Lehman. 2005. JMP Start Statistics. Third Ed. A Guide to Statistics and Data Analysis Using JMP® and JMP IN® Software. SAS Institute Inc. Belmont, CA. USA.

Strang, R.M. and J.V. Parminter. 1980. Conifer encroachment on the Chilcotin grasslands of British Columbia. Forestry Chronicle 56: 13 – 18.

Suter, G.W.. 1993. Ecological Risk Assessment. Chelsea, Mich.: Lewis Publishers.

Tirmenstein, D. 2000. Festuca altaica. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Available: http://www.fs.fed.us/database/feis/ 2006, December 18].

Appendix 1 List of EXCEL raw data files and their descriptions (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).
KNPER_overstory	Includes all overstory data (tree species, diameter at breast height, height, decay class, presence of insects and disease)

Appendix 2 Scanned photos (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)