Monitoring Ecosystem Restoration Treatments in Kootenay National Park.

Year three restoration effects monitoring

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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 restoration plots occurred in 2004, 2005 and 2006. This report summarizes activities associated with year three of a vegetation monitoring program: monitoring restoration effects on the understory and overstory plant community.

Thirty permanently-located plots were sampled, 21 in the burn area, eight in the unburned area and one control plot. Burn plots were subject to a low-intensity prescribed fire over a two-day period in April 2005. 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 3rd, 2006. Overstory sampling (tree density by species, diameter, cover, and decay class) in nested fixed radius plots was completed in October, 2006.

There were several significant changes in observed in the understory plant community from 2004 – 2006. Across the entire restoration area, significant changes in species diversity have been observed, as well as significant increases in bunchgrass, pinegrass, sedge and forb cover. Pinegrass and sedge cover have increased significantly in the burn treatment.

Current overstory structure remains 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 remain a primary management concern at this site.

Acknowledgements

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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). There are approximately 4.5 million ha of NDT4 in the Province, approximately 60% of which occurs on crown land (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 2001a). 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 the mean fire-return interval was normally distributed, with very short and long intervals being uncommon (Gayton 2001a). 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 (IDF 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; IDFun); and 2002/03

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

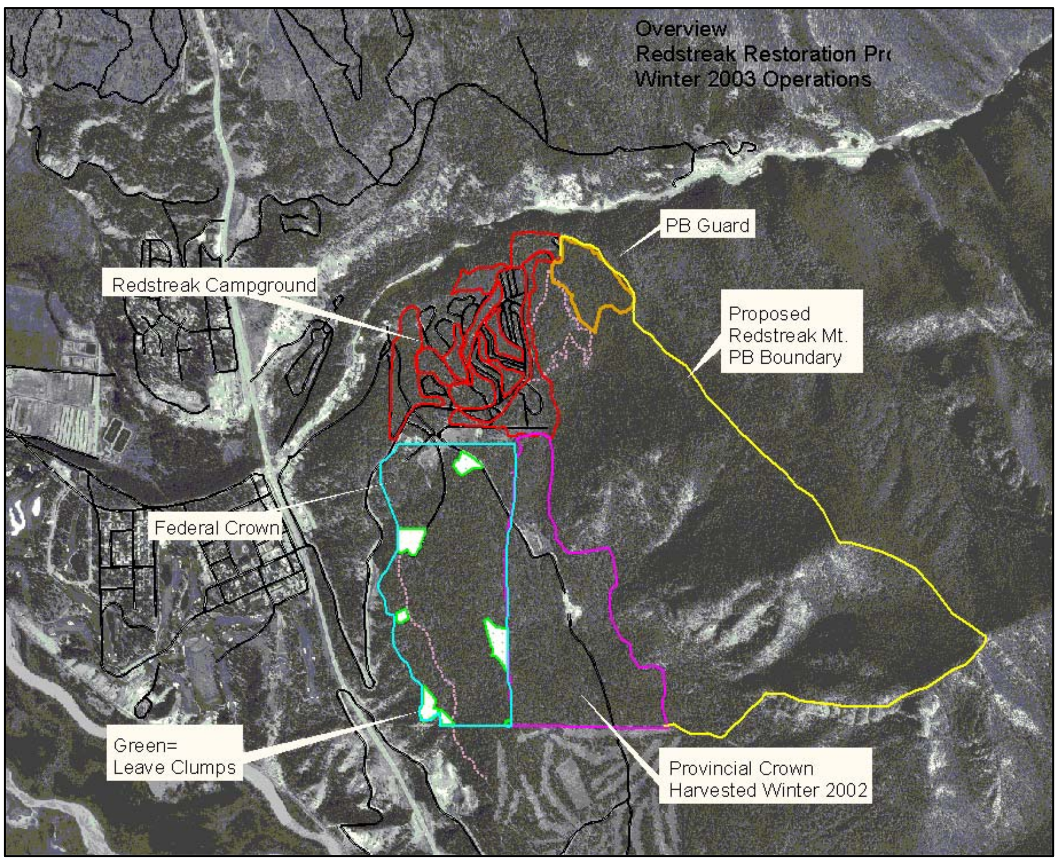

Figure 1. Location of site 1 (federal crown) and site 2 (provincial crown) located at the south end of Kootenay National Park.

In July 2004, fifteen plots were systematically established at site 1, fourteen at site 2 and one control plot. 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 and 2006.

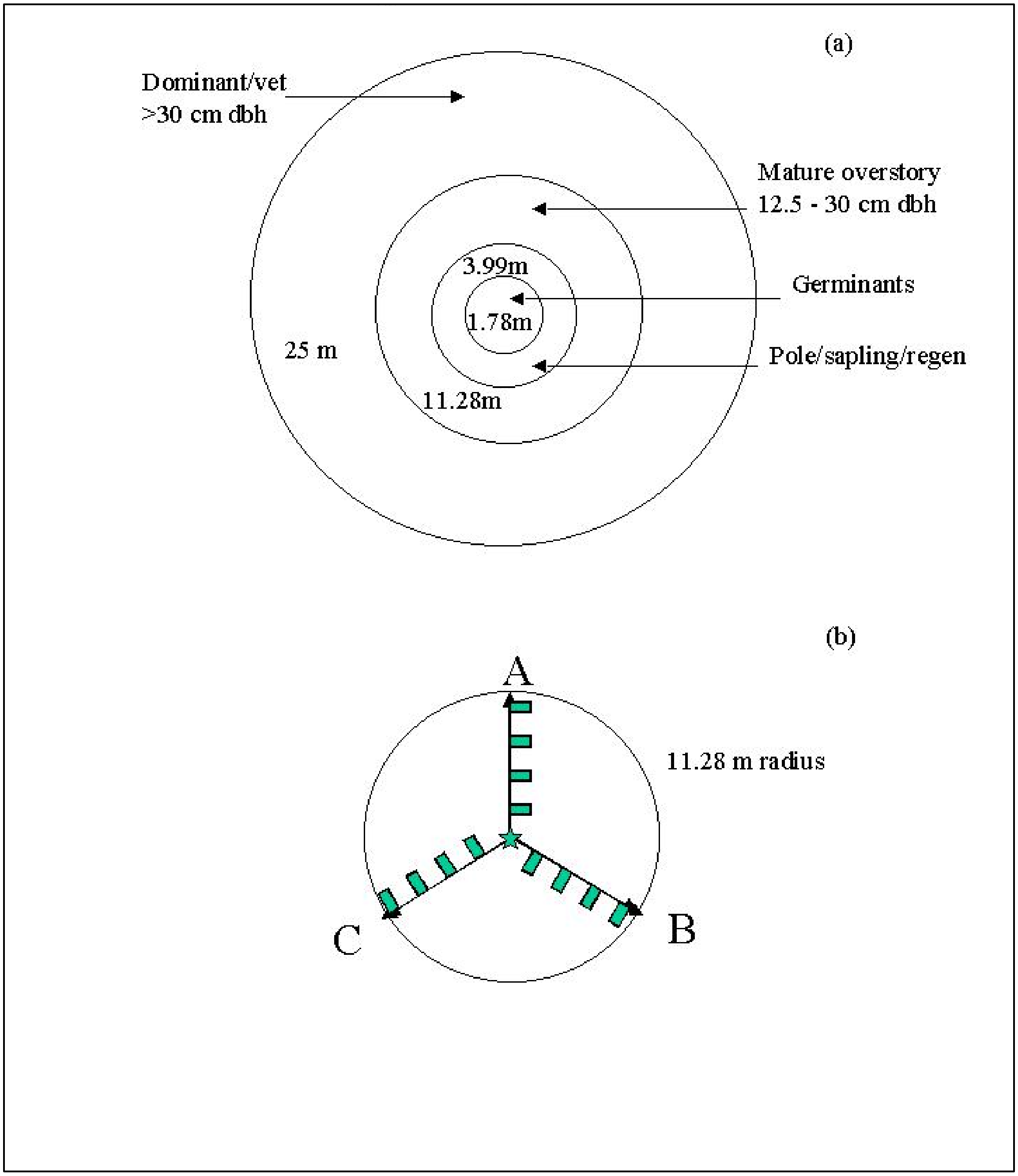

Figure 2 a&b Layout of overstory (a) and understory (b) sampling plots adapted from DeLong et al. (2001).

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.). Functional group data were analyzed for normality and transformations were made if necessary. Comparisons between years (2004, 2005, 2006) 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 located at the toe of the Rockies and is in transition to the MSdk (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 treatment

The 2005 two-day prescribed 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.)]. 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%±3.98% versus Site 2: 7.39%±4.81%). Site 1 had generally lower vegetation cover than Site 2.

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 (bearberry) (*Arctostaphylos uva-ursi* L.).

3.2 Burn behaviour

See Page 2005a for a characterization of the prescribed burn.

3.3 Overstory characteristics

Overstory characteristics remained relatively unchanged in both the burn and unburned treatments. Overstory structure should be reassessed in 5 years to monitor overstory structure and recruitment. Wildlife use of the overstory layer should be assessed to ensure there is sufficient structure to support species that use trees for feeding and nesting.

3.3 Understory characteristics

In 2006, there were 69 species recorded in the Redstreak restoration area. There have been significant species composition shifts in both blocks since 2004. Despite significant composition shifts in both blocks, pinegrass has remained the dominant species in both blocks over two years (Table 2).

Table 2. Dominant species as recorded in the Daubenmire quadrats in Block 1 of the Redstreak Restoration Area in 2004 – 2006.

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

[1] *Spiraea betulifolia* ssp. *lucida* (Dougl. ex Greene) Taylor & MacBryde Pall
[2] *Sonchus arvensis* L.
[3] *Aster conspicuus* Lindl.
[4] *Arnica cordifolia* Hook
[5] *Cirsium arvense* (L.) Scop.
[6]heart-leaved arnica was not observed in 2005 and 2006 in Block 1.
[7] showy aster cover increased significantly from 2004 (0.3±1 to 4±7; $p<0.05$)
[8]Canada thistle cover had significantly increased from 2004 (0 to 4±6;$p<0.05$)

The shift in the species composition shift illustrates individual species' tolerance for prescribed burning. Notably, there was a significant increase in showy aster and Canada thistle cover and the disappearance of heart-leaved arnica from the monitoring plots in Block 1 (Table 2).

Species composition changes were not as evident in Block 2, most likely because most of this block was not subjected to a prescribed burn.

Table 3. Dominant species as recorded in the Daubenmire quadrats in Block 2 of the Redstreak Restoration Area in 2004 – 2006.

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

[1] *Spiraea betulifolia* ssp. *lucida* (Dougl. ex Greene) Taylor & MacBryde Pall

Although there were shifts in the block 2 sub-dominant species, there were no significant changes in species' cover detected between years.

Species diversity (Shannon-Weiner index) increased significantly in 2005 ($p=0.1$), but then declined slightly in 2006, although diversity was still higher than in 2004. This trend was mirrored when the burn treatment was analyzed separately although the changes were not statistically significant.

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 rather than by site.

3.3.1 Bunchgrass

Bunchgrass cover has increased significantly at the Redstreak Restoration Area from 2004 (Fig. 3). Changes appear to be driven by a significant increase in bluebunch wheatgrass cover from 2004 – 2006 (0.2%±0.7 in 2004 to 1%±2 in 2006; p=0.06) as well as a sizeable increase in rough fescue cover, although this change was not statistically significant. Interestingly, there has been a small decline in junegrass cover. This was the only bunchgrass species that experienced a decline in cover.

Changes in bunchgrass cover are not significant when the burn and unburned treatments are analyzed independently although bunchgrass cover in the burn treatments has nearly tripled in 2 years (1%±2 in 2004 to 3%±3 in 2006) and doubled (1%±1 – 2%±2) in the unburned treatments.

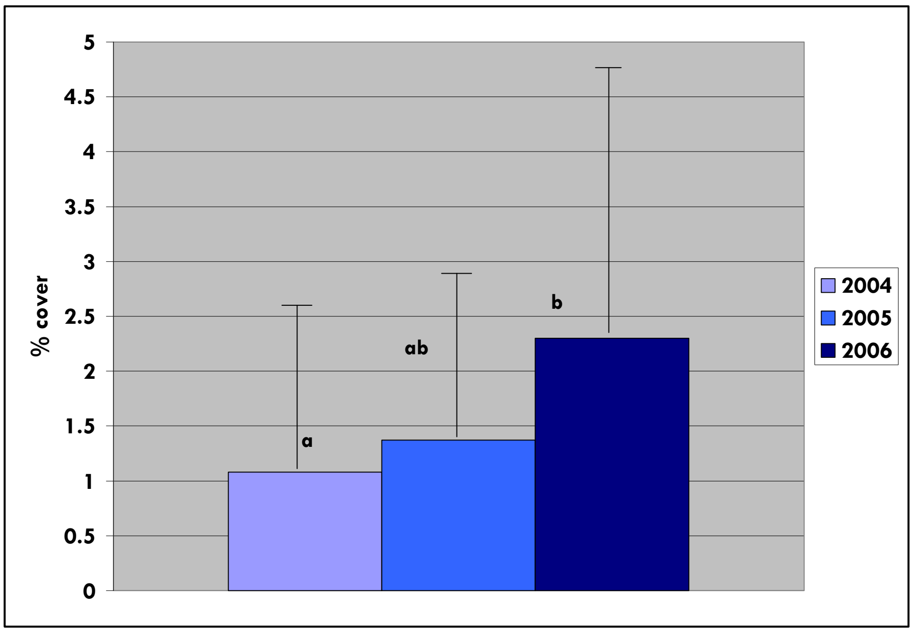

Figure 3. Bunchgrass cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference (p<0.1)

3.3.2 Grass and Grasslikes

It is important to analyze pinegrass cover as it is the most abundant species at this site. Pinegrass cover has increased by 6% (p<0.05) across the entire Redstreak Restoration area (Fig. 4). Pinegrass cover increased significantly in the burn treatment, although the increase occurred in 2006 only (i.e. cover remained relatively stable from 2004-2005) (Fig. 5). The significant change in pinegrass cover across the entire site appears to be driven by a significant cover increase in the burn treatment in 2006.

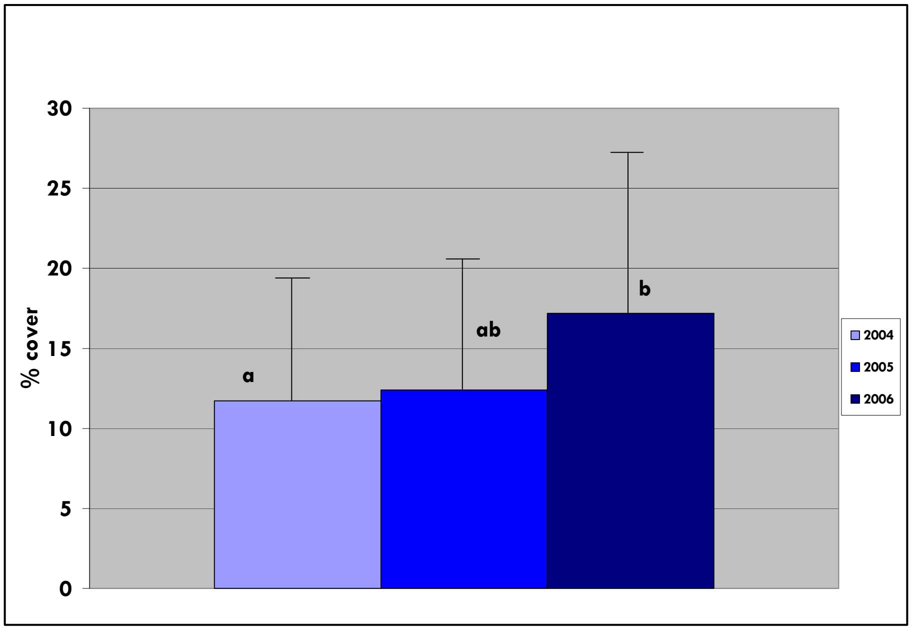

Figure 4. Pinegrass cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference (p<0.1)

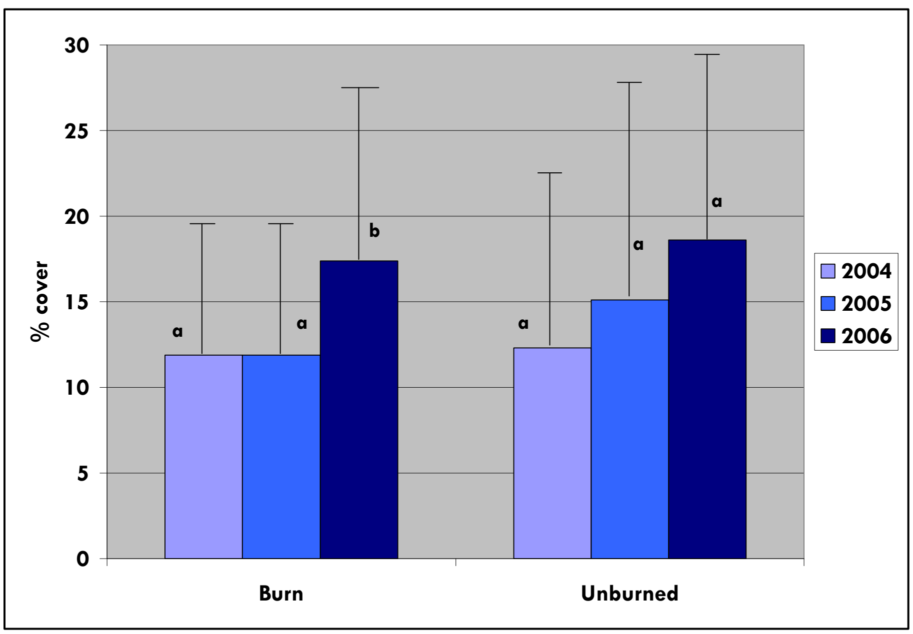

Figure 5. Pinegrass cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means, within a treatment, with a different letter indicate a significant difference (p<0.1).

Sedge cover increased significantly in the restoration area (0.3%±0.5 in 2004 to 1%±2 in 2006; p=0.003), this change remained significant when the burn treatment was analyzed (p=0.006).

3.3.3 Forbs

Forb cover increased significantly in the Redstreak Restoration Area from 2004 – 2006 (Fig 6).

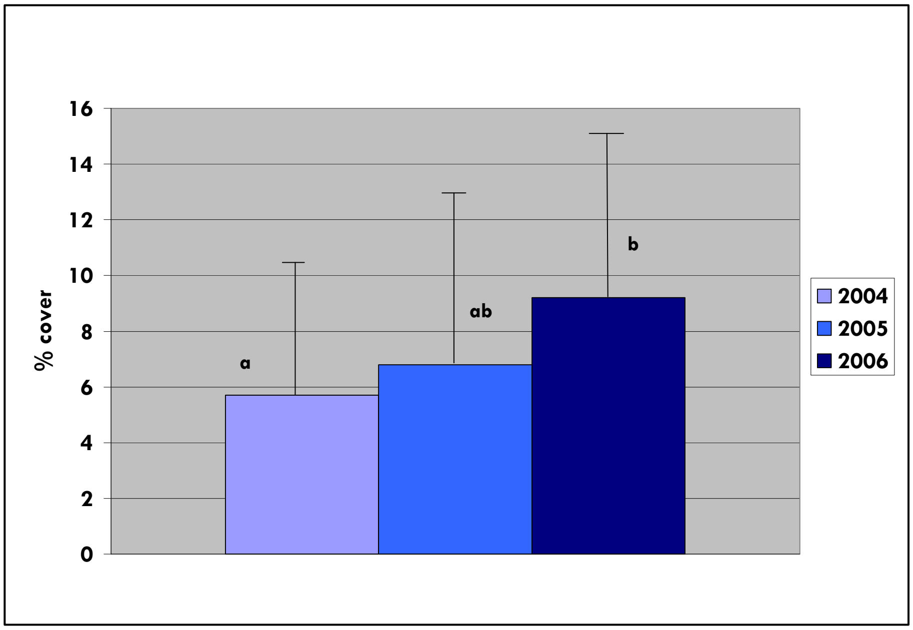

Figure 6. Forb cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference ($p<0.1$)

Large increases in cover are most apparent in the burn treatment. Significant changes were detected in three individual species; showy aster, wild strawberry (*Fragaria virginiana* Duchesne) and northern bedstraw (*Galium boreale* L.) (Fig. 7).

Forb cover is significantly higher in the unburned treatment than it is in the burn treatment (Table 4); this difference was only detected in 2006, although forb cover has been consistently higher in the unburned treatment over the three years of monitoring (2004 – 2006).

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

descriptive group	**burn**	**unburned**	**p-value**[1]
bunchgrass	2±2	3±3	0.34
forbs	8±7	13±4	**0.09**
non-native	7±12	2±4	0.21
sedge species	2±2	1±2	0.57
bluegrass	1±2	0.5±0.5	0.17
shrubs	5±3	3±3	0.21

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

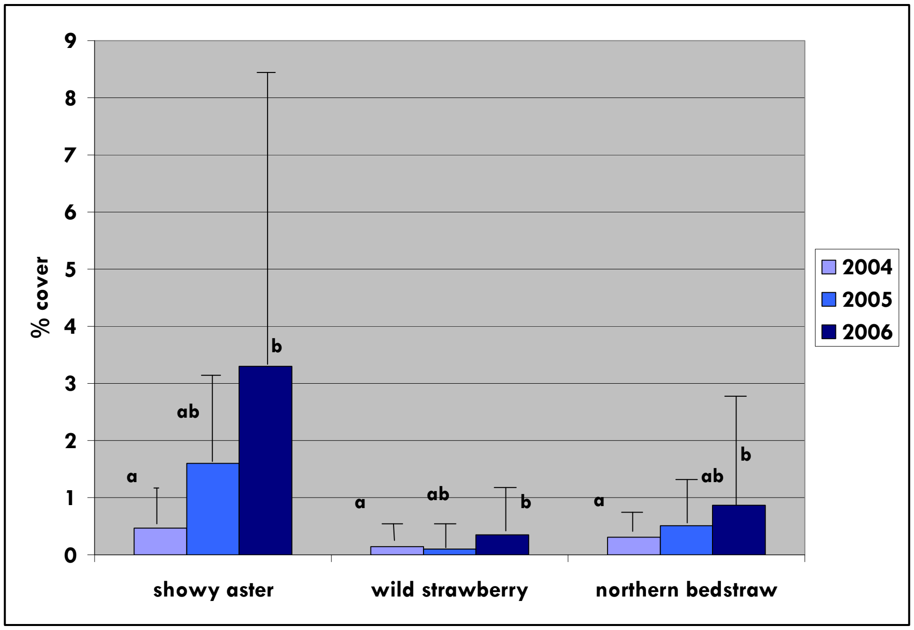

Figure 7. Showy aster, wild strawberry and northern bedstraw cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means, within a species, with a different letter indicate a significant difference ($p<0.1$)

3.3.4 Non-Native Species

Non-native species was the only descriptive group in which a significant cover increase was not observed. Despite not detecting a difference there has been a continual increase in non-native species cover since 2004 (Fig. 8) with a concomitant increase in response variability.

Bluegrass species (Poa sp.) were not included in the analyses of non-native species response, as they are considered 'naturalized' species. Despite the classification, they are considered to be indicators of poor ecosystem integrity (Adams et al. 2005). Bluegrass species cover increased significantly across the restoration area (0.1%±0.4 in 2004 to 0.8%±1 in 2006; $p=0.002$), when the burn treatment was analyzed a significant increase was still detected ($p=0.003$). There was an increase observed in the unburned treatment as well, although this change was not statistically significant ($p<0.1$).

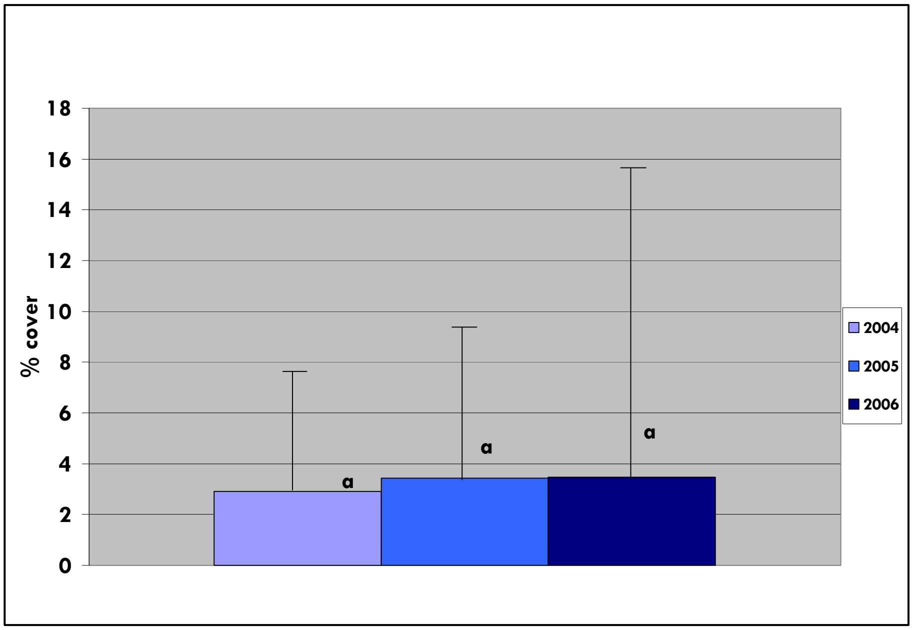

Figure 8. Non-native species cover in 2004 – 2006 at the Redstreak Restoration Area (both blocks combined). Means with a different letter indicate a significant difference (p<0.1)

Increases in non-native species cover appear to be driven by increases occurring in the burn treatment (Fig. 9) as cover has increased from 2004 – 2006 wheras non-native species cover has declined in the unburned treatment. Non-native species cover is greater in the burn treatment than in the unburned treatment; it is the only descriptive group that has greater cover in the burn treatment than in the unburned treatment. It should be noted that differences observed were not deemed to be significant.

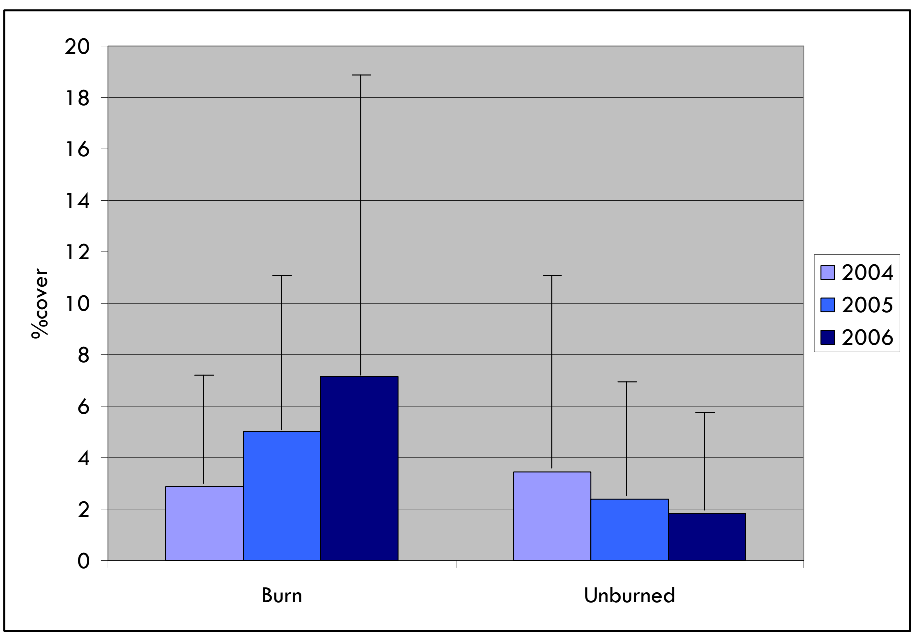

Figure 9. Non-native species cover in 2004 – 2006 at the Redstreak Restoration Area in the burn and unburned treatments.

There appears to be differential increases by species as well (Table 5). Perennial sowthistle has declined in both the burn and unburned treatments. Bull thistle has declined in the unburned treatments, but cover has nearly tripled in the burn treatments. Canada thistle has increased in both the burned and unburned treatments, the increase was statistically significant in the burn plots ($p<0.05$).

Table 5. Canada thistle, bull thistle and perennial sowthistle cover (%) in the burn and unburned treatments in the Redstreak Restoration Area from 2004 – 2006.

year	Canada thistle		bull thistle		perennial sowthistle	
	burn	**unburned**	**burn**	**unburned**	**burn**	**unburned**
2004	0±0	0.0±0.1	1±2	2±6	2±3	1±2
2005	1±2	0.3±1	1±2	0.3±1	2±3	0.4±1
2006	3±6	1±2	3±6	1±2	1±1	0.2±0.5

4.0 Discussion

Restoration activities have had a significant impact on the plant community at the Redstreak Restoration Area. Notably, there has been a dramatic change in overstory structure (Page 2004; Page 2005), significant shifts in species diversity, species' composition changes in the burn plots and a significant increase in cover of nearly all vegetative descriptive groups across the entire restoration area.

Besides the complete restoration of historic overstory structure, the most dramatic changes have been the species composition shifts in the burn plots. Showy aster and Canada thistle have replaced birch-leaved spirea and heart-leaved arnica as sub-dominant species in the burn plots (Table 2) (pinegrass has remained the dominant species). Both species are considered to be highly adapted to fire (Stickney 1989, Zouhar 2001).

The significant increase in bunchgrass cover indicates a positive trend in plant community response. Both bluebunch wheatgrass and rough fescue are valuable forage species and indicator species of open forest and grassland ecosystems. Rough fescue appears to be well-adapted to periodic burning (Aiken and Darbyshire 1990). The dense, tufted habit of rough fescue makes it resistant to 'light' fire. Although plants are initially top-killed, recovery of prefire coverages and herbage production is usually attained in 2 – 3 years (Tirmenstein 2000). It is not possible to know what the pre-treatment cover of rough fescue was, but cover has surpassed 2004 levels. Bluebunch wheatgrass has experienced an even greater increase in cover, resulting in a statistically significant increase over 2004 levels ($p<0.1$). Cover of bluebunch wheatgrass has nearly tripled since 2004. Bluebunch wheatgrass usually survives fire because its buds are protected by soil and/or plant material (Tirmenstein 2000). Bluebunch wheatgrass establishes on newly disturbed sites by tillering (Shiftlet 1994). A mass flowering response after fire (Agee 1996) suggests that on burns, bluebunch may also establish from seed, but seedling establishment after fire or other disturbance is not documented in the literature. The only bunchgrass that experienced a decline in cover was junegrass, this is somewhat surprising as the literature indicates that junegrass herbage production generally increases after fire (Simonen 2000). Decline in cover may be due to competition from more abundant species.

Pinegrass has increased significantly across the entire restoration area (Fig. 4) and in the burn plots (Fig. 5). Pinegrass abundance and productivity is highest on open sites (Coates and Haeussler 1986). In many situations, pinegrass can maintain moderate cover under moderate shade conditions, but with increased light, pinegrass will acquire new vigor and dominate the herb layer (Coates and Haeussler 1986). Pinegrass sprouts from rhizomes following fire. Rhizomes are buried in the top 2 inches (5 cm) of mineral soil (Mc Clure 1958), allowing pinegrass to survive fires that do not completely consume the duff layer. Pinegrass is usually top-killed by fire (Mc Clure 1958). Top-kill would explain the lack of increase in the burn plots in 2005. The significant increase in 2006 is likely a result of abundant sprouting from rhizomes. As the site becomes more xeric, pinegrass abundance should decline as bunchgrass cover increases.

Forb cover also increased significantly, with three individual species experiencing significant increases in the Restoration Area; showy aster, wild strawberry and northern bedstraw (Fig. 7). All three species are rhizomatous and can easily reproduce after a light intensity-fire. Showy aster is extremely well-adpated to fire. 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). These changes were observed in 2005 but were not significant until 2006.

The changes in non-native species cover were highly dependent on the burn treatment. Although there were no significant changes detected, there has been a continual increase in cover in the burn treatment and a continual decline in the unburned treatment. Variability among responses is high and likely masks detection of significant results. Variability is caused by the inherently patchy nature of the burn treatment. Canada thistle cover increased significantly in the burn treatment (Table 5). Canada thistle can survive fire and sprout vegetatively from its extensive perennial root system, or colonize bare ground via seedling establishment after fire. For example, in Yellowstone National Park, Canada thistle is rare in unburned forests but locally abundant in burned areas (Zouhar 2001).

Although there was no change detected in the cover of non-natives species there was significant increase in the cover of bluegrass species (Canada and Kentucky bluegrass) across the restoration area and in the burn plots ($p<0.1$). Even after late spring burning, unless burned a second time, Kentucky bluegrass cover will often return to preburn levels within 1 to 3 years. For example, burning in May or June in Wind Cave

National Park, South Dakota, consistently reduced Kentucky bluegrass canopy coverage, height, shoot density, flower stalk density, and biomass during the first postfire growing season but not during postfire years 2 and 3 (Olson 1957).

4.1 Weeds to Watch

- 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

Despite lack of changes in the overstory, the understory plant community has experienced several significant changes. Nearly all vegetative descriptive groups have increased significantly in the Redstreak Restoration Area. Changes are likely largely due to prescribed restoration activities.

Most understory plant community changes indicate a positive response trend. Overstory conditions largely meet the restoration objectives established by Parks management. If the response trajectory continues, meeting the objective of restoring historical understory plant communities should be achieved in the long-term. However, the increase in non-native species, particularly Canada thistle and bull thistle in the burn treatment is of moderate concern. Apparently prescribed burning has enhanced the vigor of these species in the short term. An integrated weed management strategy should be adopted with the goal of reducing the abundance of these two species at this site, particularly in the burn treatment. All other species of concern appear to be declining in abundance (e.g. perennial sowthistle). Future prescribed burns plans in the area should take into account the presence of Canada thistle and manage accordingly (i.e. avoid burning areas where Canada thistle exists).

Plant community monitoring is proposed two growing seasons (2008) post-fire to determine if trends in plant community response. Of particular interest is the trajectory of the plant community response in the burn treatment versus the unburned treatment, it is apparent in 2006 that there has been a differential response based on the burn treatment.

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. If weed treatments are applied, a separate monitoring plan should be established.

The author suggests locating more control plots (e.g. immediately south or north of the restoration area) to more accurately determine the effects of restoration activities. Control plots will become more important when the eastern half of the Redstreak restoration area is subject to a burn. The presence of a control plots will 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)