MONITORING ECOSYSTEM RESTORATION TREATMENTS AT NORTH STODDART CREEK AND BULL RIVER

MONITORING UPDATE 2010

Submitted to: B. Houston and J. Krebs
Fish and Wildlife Compensation Program
Suite 103 333 Victoria Street, Nelson,
BC V1L 4K3

Submitted by: Hillary Page R.P. Bio
Sage Ecological Research

Box 2455
Invermere, BC
V0A 1K0

"The acid test of our understanding is not whether we can take ecosystems to bits and pieces of paper, however scientifically, but whether we can put them together in practice and make them work."

A.D. Bradshaw, 1983

Summary

In 1999, the Fish and Wildlife Compensation Program initiated restoration activities at two sites in the East Kootenay Valley. One site is located in the IDFdm2 biogeoclimatic zone at Bull River (North Fontaine Pasture) and the other in the IDFxk biogeoclimatic zone at Stoddart Creek North. Both sites had pre-treatment plots installed in 1999. Slashing occurred at North Fontaine in 1999 as well as a broadcast burn in 2000. There were two treatment units within the North Fontaine treatment area, one forested unit that was subject to slashing and burning and an open unit subject to slashing only. Stoddart Creek was harvested in 2001, slashed and sloop burned in 2002. Effects of restoration were assessed though monitoring of the understory and overstory plant community. Post-treatment monitoring occurred at North Fontaine in 2000, 2001, 2004 and 2009. Post-treatment monitoring occurred at Stoddart Creek in 2004 and 2009.

The two restoration sites provide examples of differential responses to restoration activities. Vegetation response at North Stoddart Creek has been generally positive. Overstory structure provides the key elements needed for high value Bighorn Sheep habitat. In the understory, bunchgrass and forbs have increased significantly since 1999. Although there has been an overall negative trend detected in shrub cover, there was a significant increase observed from 2004 indicating potential recovery of the shrub layer. There was no observed increase or decrease in the level of non-native species cover on site. Based on monitoring completed to date, it appears that restoration has been successful at North Stoddart Creek. At Bull River the overstory has been successfully restored, but changes in the understory have not been as positive. Despite a significant increase in bunchgrass presence there has also been a significant increase in 3 non-native species (cheatgrass, bluegrass and sulphur cinquefoil) and a decline in the presence of two key shrub species (Saskatoon and chokecherry). Results at Bull River have likely been affected by wildlife and livestock use at the site.

Despite differences in data collection and collectors between years, significant trends have been detected at both sites highlighting the value of long-term monitoring. Future monitoring should focus on confirming trends detected in 2009.

Detection of trends in 2009 indicates there may be value in analyzing plant community response at the Trench level. Broad level analysis will provide valuable information on plant community response to restoration, the timing of plant community response and the effect of management activities on that response.

Acknowledgements

Field work for this project was completed by Andrea Davidson, Dave Lewis, Hillary Page, Richard Klafki, Rebecca Whidden, Barb Houston, Claire Schadeli, and Anneli Schadeli. I would like to thank John Krebs, Barb Houston, Cam Gillies, Doug Adama, Larry Ingham, Denis Petryshen, Anne Skinner, Rae Haddow, Randy Harris, Jeannette Page and Victoria Page for their assistance with this project. Finally I would like to thank John Krebs and Barb Houston for administering the project and the Fish and Wildlife Compensation Program for providing funding to complete the monitoring and data analysis.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

Ecosystems can be characterized by their natural disturbance regime. For the purposes of setting biodiversity objectives in BC, five Natural Disturbance Types (NDTs) are recognized in the province. Disturbance types range from NDT1 systems with rare stand-initiating events, to NDT4 systems with frequent stand-maintaining events. NDT5 systems include alpine tundra and subalpine parkland (Province of British Columbia 1995). NDT4 systems of the southern interior of BC are characterized by grasslands and 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]. NDT4 systems historically experienced frequent (every 7 – 50 years), low intensity fires which limited encroachment by most conifer species and shrubs (Province of British Columbia 1995). Although the NDT classification system is currently under review (it is thought that NDT4 ecosystems can likely be classified into 9 different fire regimes) (Harris, R. 2009. *pers. comm*. Ecosystem Restoration Team Leader. BC Ministry of Forests) it is clear that these plant communities have undergone dramatic changes. It is hypothesized that changes in overstory structure and losses of species diversity are caused by forest ingrowth and encroachment that followed the introduction of fire suppression policies introduced by the Ministry of Forests 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 30, 000 ha of grassland and open forest has been lost in the Rocky Mountain Trench since the early 1950's. This rate of loss is similar to estimates made in other areas of British Columbia 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 the loss of wildlife habitat as well as decreased timber and forage production (Rocky Mountain Trench Ecosystem Restoration Steering Committee (RMTERSC 2006). As a result of this conversion, domestic livestock and native ungulates are exerting increased pressure on the declining land base as they compete for forage. The East Kootenay Trench Agriculture/Wildlife Committee (EKTAWC) found that combined wildlife and livestock forage consumption averaged 60% across monitored sites (RMTERSC 2006). Generally range managers in the Trench consider 50% utilization between livestock and wildlife to be a 'safe' level of use.

Remaining grassland habitats are being further degraded by noxious weeds which may out-compete native vegetation and reduce residual forage quantity and quality. Densely stocked stands also increase the risk of severe insect outbreaks and catastrophic crown fires (Powell et al. 1998, RMTERSC 2000).

To mitigate these changes, government and non-government land management agencies (The Fish and Wildlife Compensation Program, Ministry of Forests, Ministry of Environment, The Nature Trust, The Nature Conservancy of Canada) and other agriculture and conservation stakeholders have adopted ecosystem restoration or habitat enhancement programs. These programs are intended to restore the required ecological processes of fire-maintained systems in the Rocky Mountain Trench. The primary goal of ecosystem restoration in the Trench is to remove excess immature and understory trees from NDT4 communities over the next several decades in order to create an ecologically appropriate mosaic of NDT4 habitats on Crown land. The mosaic is intended to mimic the historical landscape under natural conditions when fire was an integral part of the ecosystem (RMTERSC 2000). The Trench Restoration Program is the largest, longest running terrestrial initiative underway in the province of BC (Machmer et al. 2002). Since 1997, approximately $6,000,000 has been spent on restoration and associated activities in Trench (RMTERSC 2006).

An integral component of a restoration plan is a detailed monitoring 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 will help in the development of future plans through the understanding of the ecological processes that link overstory management to understory dynamics and diversity (Naumberg and DeWald 1999). In addition to monitoring key response variables, monitoring must focus on the recovery of stand structure, species diversity and of 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). In the context of ecosystem restoration, monitoring is conducted to determine whether restoration prescriptions are having the desired effect (Noon 2003). Given the significant investment in restoration, it is the responsibility of agencies to collect information that can inform practitioners and the public about whether prescriptions are having the intended effect and whether forest and rangeland resources are being sustained (Noon 2003). The objectives of dry forest restoration monitoring are to assess characteristics related to forest and ecosystem health, to forage production and to the maintenance of open forest habitat and associated plant species (Ritchie and Harksen 1999).

This project is in response to a request from the Fish and Wildlife Compensation Program (FWCP). Specific objectives of the project were to one; measure existing plots installed at North Fontaine (2 x 25 plots) and Stoddart Creek (25 plots), following protocols used during plot establishment (e.g. Mowat et al. 1998) and two; summarize changes occurring in the forb, grass, shrub and tree layers of both sites. Restoration at these sites was initiated prior to the development of monitoring protocols specifically for ecosystem restoration activities in the Trench (Machmer et al. 2002). These more recent protocols have been developed in order to standardize the assessment of restoration activities in the Rocky Mountain Trench. Interpretation of results in this report has been considered within the context of new monitoring protocols and objectives.

2. Methods

2.1 Data Collection

In 1999, a total of 52 plots were installed at Bull River. (26 monitoring plots were installed in Block B and 26 in Block C) (Fig. 1). Data were collected at these plots in 1999, 2000, 2004 and 2009. In 2000, three plots were not located and 1 plot was permanently discarded from the project due to location. In 2004, surveyors did not re-locate the same three plots as in 2000. In 2009, a subset of 29 of the 52 plots was monitored. Of the 23 plots not monitored, two plots were not located, one plot was lost to road construction,, two plots were permanently lost to active drilling and the remaining 18 plots were not monitored due to time constraints. It should be noted that the 29 plots monitored were systematically chosen to ensure a representative sample was monitored. Detailed notes for the plots that were not monitored in each year of monitoring can be found in the data spreadsheets (Appendix 1; Bull River UTMs).

In 1999, 25 monitoring plots were installed at North Stoddart Creek (Fig. 2). All plots were monitored and located in 1999, 2004 and 2009. One plot centre was moved in 2009 because surveyors were unable to locate it (see spreadsheet North Stoddart UTMs in Appendix 1 for plot notes). This plot was excluded from data analysis in 2010.

At both sites, plots were installed 100m apart on a constant bearing. Plot locations and tie points were recorded using a Trimble Pathfinder Global Positioning System (GPS). Plot centres were marked using an 8” galvanized spike with a spray-painted washer and flagging. UTMs are provided in Appendix 1.

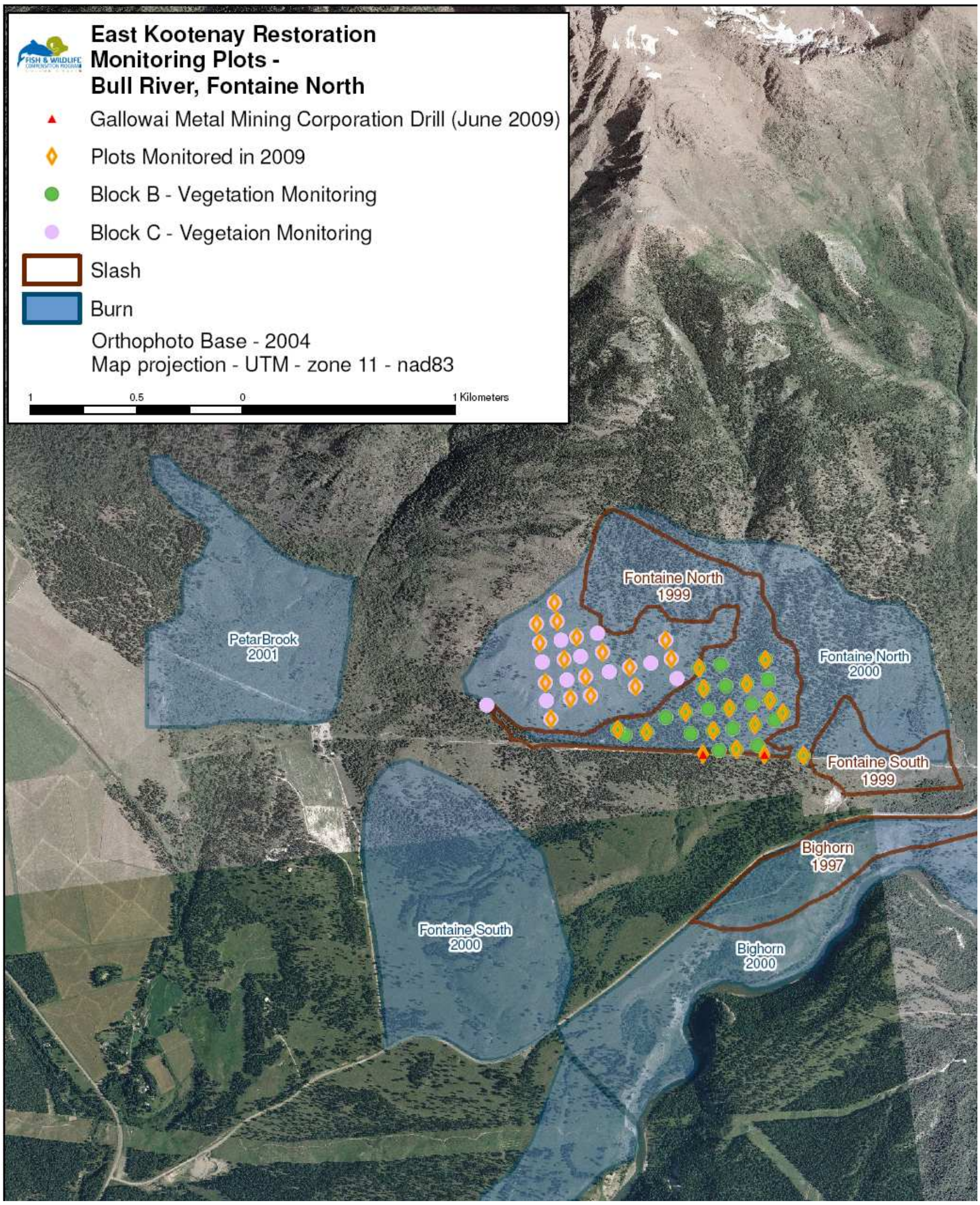


Figure 1. Bull River ecosystem restoration monitoring plots monitored in 2009.

Original vegetation data collection methods were adapted from Mowat et al. (1998). Percent cover of grass and forb data were collected in 1.26m radius plots. Forb and grass cover were both labeled the C layer, although cover was estimated for each functional group separately. Shrub cover data were collected in 5.64m radius plots. Shrubs taller than 2m were classified as being in the B1 layer and shrubs less than 2m in height were classified as the B2 layer. Canopy cover was estimated in 11.26m radius plots, stem density (by species) and stem dbh (diameter at breast height) data were also collected in the 11.26m radius plots. Data for trees less than 2m in height were collected in the 5.64m radius shrub plots. Trees were grouped into 8 classes based on their dbh (class 1: 0 – 5cm, class 2: 6 – 10cm,…class 8: >35cm dbh) Plot photos were taken at each site.

Due to changes in people collecting data, data collection varied by site and by year. It is important to note these changes as data collection affects the choice of analysis methods.

At Bull River in 1999, 2000, 2001 and 2004 percent cover of an individual species was recorded only if a species represented the equivalent to or more than 5% cover within a given plot. Cover estimates were also provided for each layer (D, C_{herb}, C_{grass}, B2, B1, A). In 2009, cover estimates were provided for each individual species, regardless of percent cover. Cover estimates were then summed to provide total cover for each layer. Because methods for determining percent cover of vegetation layers differed in 2009, layer estimates are higher in 2009 than in previous years (in previous years (1999 – 2004) estimating cover of each layer (instead of summing individual species) took into account overlap in species resulting in lower estimates of cover for each layer). In 1999, 2000, 2001 and 2004 general stand plot photos were taken at every second plot facing south. In 2009 general stand plot photos were taken at each plot surveyed facing both south and north.

At North Stoddart Creek, in 1999 and 2004 cover data were collected for each individual species. Cover estimates were also provided for each layer (D, C_{herb}, C_{grass}, B2, B1, A). In 2009, cover estimates were provided for each individual species. Individual cover estimates were then summed to provide total cover for each layer, resulting in higher estimates of cover than in previous years (in previous years, layer estimates took into account vegetation overlap). In 1999 and 2004 two photographs were taken at each plot centre. One photograph of the canopy was taken facing south and one photograph of ground cover was taken facing north. In 2009 general stand plot photos were taken at each plot facing both south and north.

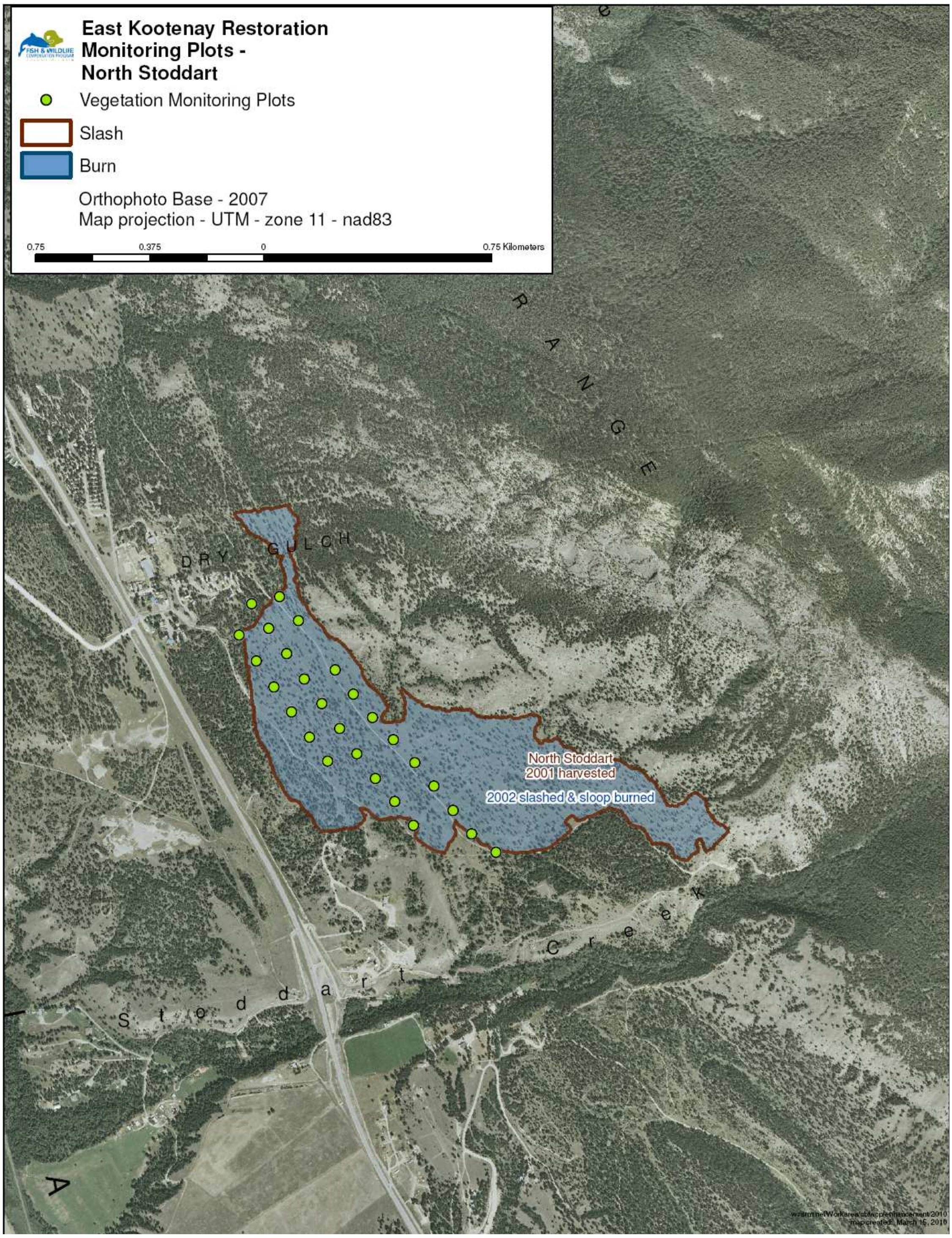


Figure 2. North Stoddart Creek ecosystem restoration monitoring plots monitored in 2009.

2.2 Data Entry

North Fontaine pre-treatment data (1999) and post-treatment (2000, 2004, 2009) data were entered into Excel. In 2010, all data were compiled into one Excel spreadsheet.

Stoddart pre-treatment data (1999) were entered into VENUS. VENUS is an ACCESS© database program for data entry, management, and analysis of the provincial ecological (BEC) database. 2004 and 2009 post-treatment data were entered into Excel. In 2010, all data were compiled into one Excel spreadsheet.

Data for both projects can be found in Appendix 1.

2.3 Data Analysis

In past reports for Bull River and North Stoddart Creek, the approach has been to assess changes in vegetation layers year to year. In order to determine trends in plant community response, the analysis was designed to determine change year to year. Despite efforts to maintain consistent data collection year to year, layer cover data were collected differently between years, therefore, analysis of change in vegetation layers was not possible. The general approach to in 2009 was to assess the long-term change in functional vegetation group presence or cover (e.g. bunchgrass, weeds) since 1999. This approach was used with, where possible, individual species as well. Layers and vegetation functional groups are similar enough that data analysis in 2009 will build on previous analyses. Understory data analysis differed by site because of different methods of data collection between sites.

At Stoddart Creek North, because cover data of individual species were collected in all years, the approach was to summarize long-term response to restoration activities by functional/descriptive group (e.g. bunchgrasses, weeds etc.). This approach reduces the variability and increases the chance of finding significant differences in the plant community pre- and post-treatment. Although response was summarized by functional group, response of individual species was determined as well. The percent cover of each species and of the functional groups at the Stoddart Creek site were analyzed to determine whether the cover of these species or groups had changed over time. Because much of the data included zeros, it was not possible to normalize the data using transformation with standard least squares regression. Instead, the data were analyzed using gamma regression using the gllamm procedure in Stata 10.1 (StataCorp 2007). Gamma regression assumes a gamma distribution in the dependent variable, which is flexible enough to accommodate data with a non-normal distribution of the dependent variable. A random intercept was included in the analyses to account for the correlation inherent in measuring cover at the same plot over time (repeated measures). Unfortunately, the gamma regression was able to converge in only a small number of cases, likely due to the large number of zeros in the data. As an alternative, a negative binomial regression was used with a random intercept using the xtnbreg procedure in Stata (StataCorp 2007). While negative binomial regression assumes that the data being analyzed are count data (e.g. number of individuals), the percentages analyzed here appeared to have a similar distribution, so the analysis offered a reasonable alternative where there were few other options. Even with this method, the models were still unable to converge for some of the individual species analyzed.

At Bull River, because individual species data (species with less than 5% cover were not recorded in 1999 and 2000) and layer data were collected differently among years, changes in cover data could not be assessed. Because of these differences, percentages for all years are classified as less than 5% or greater than or equal to 5% for twelve species of interest at Bull River. Species of interest were selected in 2004 based on their role in the plant community (e.g. high value forage species, invasive species etc.) (Table 2). The data classification created a binomial dependent variable (0 or 1), analogous to presence/absence data. These data were then analyzed for each species using logistic regression with the xtlogit procedure in Stata 10.1 (StataCorp 2007). A random intercept was included in the model to account for repeated measurement at the same plots over time.

Response of the plant communities was considered in the context of the stand prescription goals (Appendix 2) and of three restoration objectives as outlined by Machmer et al. (2002):

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.

3. Study Area

3.1 Bull River

The area known as Bull River is one of a series of ungulate winter ranges in the southern Rocky Mountain Trench. It contains high quality winter ranges for Bighorn Sheep (*Ovis canadensis*), Mule Deer (*Odocoileus hemionus*), White-tailed deer (*Odocoileus virginianus*) and Elk (*Cervus elaphus*) (Halko 1996). The exclusion of wildfire from the ecosystem has resulted in an increase in forest cover and canopy closure, which has significantly decreased the amount of forage produced on this key winter range (Halko 1996).

Based on forest cover, the Bull River treatment block consists of two units. The lower or more southern unit is labeled Block B and is approximately 108 ha (Fig. 1). Block B had a moderately low-density overstory of mature and veteran stems and a significant amount of conifer regeneration. Block C is an open, south facing-slope dominated by antelope bitterbrush [*Purshia tridentata* (Pursh) DC.] and Saskatoon (*Amelanchier alnifolia* Nutt.). Block C is approximately 109 ha (Fig. 1). Both units are located in the IDFdm2 biogeoclimatic zone. Soils at Bull River are classified as an Orthic Eutric Brunisol. Eutric Brunisols are calcareous and are characterized by their low organic matter (National Research Council of Canada 1998).

It was intended that both units be managed as a contiguous block containing both open range and open forest habitats. Prior to treatment, stocking was clumped, with areas of high-density stocking (e.g. 4000 stems ha^{-1}), although across both sites pre-treatment stem density was relatively low (~200 stems ha^{-1}).

The goal of the Bull River enhancement/restoration plan was to reduce the ingrowth of coniferous and deciduous tree species in key areas and to maintain existing forage producing areas in their current successional state without compromising cover and movement corridor values (Halko 1996). Of high priority, at the Bull River site, was to return this unit to a high forage production area.

According to the stand prescription, the target stand conditions for Block C were to maintain this site as open range, with a maximum stand density of 75 stems ha^{-1}. The target for Block B was 250 stems ha^{-1} with a maximum of 400 stems over the long term. In 1999 Block B was treated with slashing, followed by a prescribed broadcast burn in 2000, over both units. The burn was designed to be 'cool' in order not to damage the shallow duff area.

Up to 2005, the North Fontaine pasture at Bull River (Fig. 1) was used for late-season livestock grazing (2000- 2004) by two range agreement holders. The agreement holders grazed 113 cow/calf pairs for approximately 27 days. Based on inventory work, at that time, there were approximately 104 AUMS (animal unit months (the amount of forage a 455 kg cow requires in one month)) of available forage at the North Fontaine in the Bull River area (Skinner, Anne. Range Agrologist, BC Ministry of Forests, pers. comm., 2005). In 2009, according to Ministry of Forests staff, there are anywhere from 80 – 100 animal units on North Fontaine pasture in any given year (Haddow, Rae. Range Agrologist, BC Ministry of Forests, pers. comm., 2009).

According to recent Ministry of Environment surveys (2009), the Bull River area has a relatively high level of non-native species cover (Ministry of Environment 2009). The area has an average non-native species cover of 5% and 71% of sites surveyed had some level of soil disturbance. Grass production, as measured in 2009, was approximately 250 kg ha^{-1}(Ministry of Environment 2009).

Post-treatment ecosystem restoration monitoring occurred at this site in 2000, 2001, 2004 and 2009.

3.2 Stoddart Creek North

Stoddart Creek North is located is the IDFxk biogeoclimatic zone. Prior to treatment stem density was approximately 250 stems ha^{-1} with a significant amount of conifer regeneration (~4000 stems ha^{-1}) (Fig 3). Soils at Stoddart Creek North are classified as Orthic Eutric Brunisols (Lacelle 1990).

This area was harvested over the winter of 2001. All understory stems less than 15cm dbh were spaced to a minimum intertree distance of 6.5m to create open range/open forest conditions (Ministry of Forests Silviculture Prescription Amendment 2000). The prescription stated that approximately 275 stems ha^{-1} of trees, less than 15cm dbh, would be retained post-spacing. All harvesting occurred during winter months on frozen ground in order to minimize spread of leafy spurge (*Euphorbia esula* L.). Understory slash was piled and burned in a sloop or trough burner, where burning by sloop was not possible, slash was hand piled.

Removal of understory was intended to improve site lines for Bighorn Sheep.

Figure 3. Example of conifer regeneration at Stoddart Creek. Photograph taken in 1999.

Livestock grazing has been excluded from North Stoddart Creek since 1970, grazing pressure is primarily from Bighorn Sheep, Elk, and White-tailed Deer.

4. Results and Observations

4.1 Bull River

4.1.1 Overstory

Block B

The pre-treatment overstory at Bull River was characterized by an open stand of mature and veteran ponderosa pine and Douglas fir with a well developed conifer regeneration layer. Pre-treatment stem density was low (197 stems ha^{-1}; Stdev=308). In the first year post-treatment stem density was reduced to 91 stems ha^{-1} (Stdev=99) but increased to 111 $stemsha^{-1}$ (Stdev=198) in 2004. In 2009, stem density was 123 $stemsha^{-1}$ (stdev=121) in 2009.

All stems surveyed in 2009 were class 5 dbh or higher (>21cm dbh) (Fig. 4). The highest numbers of stems were found in dbh class 8 (Fig. 4). Stem diameter distributions were similar to 2004.

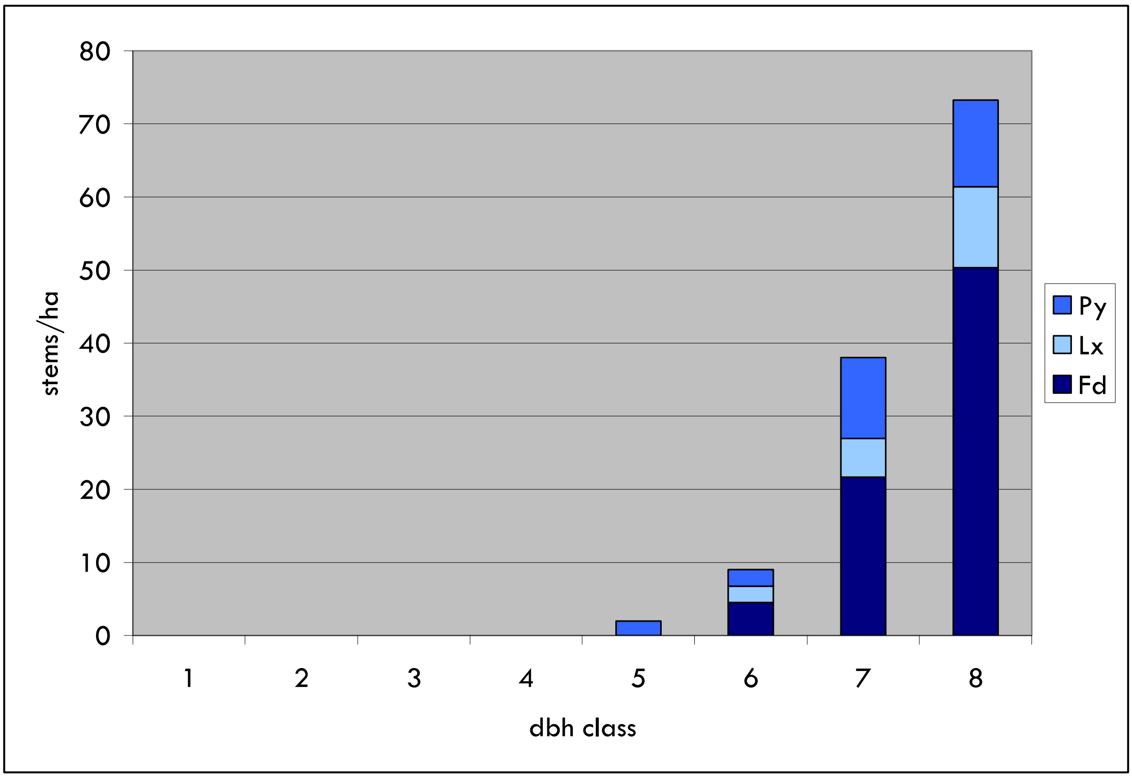


Figure 4. Stems per hectare and species distribution at Bull River (Block B) in 2009.

Douglas fir made up the largest proportion of stems in all dbh classes except dbh class 5 (Table 1). Only Douglas fir, western larch (*Larix occidentalis* Nutt.) and ponderosa pine were detected in 2009.

Table 1. Species composition by diameter at breast height (DBH) class in 2009 at Bull River.

	DBH class							
Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Douglas fir	0	0	0	0	0	50	57	68
western larch	0	0	0	0	0	25	14	15
ponderosa pine	0	0	0	0	100	25	29	16

Block C

Due to the open nature of Unit C (9 stems ha^{-1}) there was no need for mechanical treatment in this area. All trees were in class 8 (>35cm dbh). In 2009, there were 144 regenerating aspen stems

(122 class 1 and 22 class 2) located at one plot in Block C. Otherwise there were 8 ponderosa pine stems surveyed in 2009, all were class 8 (>35cm dbh).

4.1.2 Understory

Because vegetation layers and individual species cover cannot be analyzed, 12 species of interest (non-natives, desirable forage species) were selected for analysis (Table 2). And because species with less than 5% cover were not recorded prior to 2009, cover percentages for all years were classified as less than 5% or greater than or equal to 5%. This created a binomial dependent variable (0 or 1), analogous to presence/absence data. Results were pooled across Block B and Block C to indicate trends at the site level. A significant result indicates that a given species occurs in more or less plots over time.

Table 2. Presence/absence data for 12 species of interest at Bull River from 1999 - 2009. Data are pooled across sites and years (p<0.05). A negative coefficient indicates species occur in fewer plots over time and a positive coefficient indicates a species occurs in more plots over time.

Species	Functional Group	Coefficient	increasing (+) /decreasing (-)	pvalue
Saskatoon (*Amelanchier alnifolia* (Nutt.) Ex M. Roem)	shrubs	-0.153	-	0.001*
showy aster (*Eurybia conspicua* (Lindl.) G.L. Nesom)	forbs	-0.259	-	0.133
cheatgrass (*Bromus tectorum* L.)	non-native	0.430	+	0.006*
pinegrass (*Calamagrostis rubescens* Buckley)	pinegrass	0.180	+	0.004*
Canada thistle (*Cirsium arvense* (L.) Scop)	non-native	-5.706	-	0[1]
timber oatgrass (*Danthonia intermedia* Vasey)	grass	-0.226	-	0.002*
common St. John's-wort (*Hypericum perforatum* L.)	non-native	0.067	+	0.679
bluegrass sp. (*Poa* sp.)	non-native	-0.150	-	0.052*
sulphur cinquefoil (*Potentilla recta* L.)	non-native	0.425	+	0.000*
chokecherry (*Prunus virginiana* L.)	shrubs	-0.225	-	0.012*
bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love)	bunchgrass	0.144	+	0.049*
antelope bitterbrush (*Purshia tridentata* (Pursh) DC)	shrubs	-0.001	-	0.979

* indicates a significant result
[1]Due to high variability in the data, the xlogit model could not solve for this species

Three shrub species were selected for analysis; Saskatoon, chokecherry and antelope bitterbrush. Shrub presence was only considered in the B2 layer as the B1 layer was not well-developed at this site.. Two of the three species showed a significant decline in presence from 1999 - 2009 (Table 2; Fig. 5)). Antelope bitterbrush was the only species selected that did not decline significantly (Table 2; Fig. 5). Although the data cannot be compared, previous analyses also indicated declining shrub cover across the site (Table 3 and Table 4).

Table 3. Average cover (%) for vegetation layers in Block B at Bull River in 1999, 2000 and 2004[1]

	1999		2000		2004	
Layer	**average**	**stdev**	**average**	**stdev**	**average**	**stdev**
A	10.3	10.6	6.3	6.1	4.7	5.3
B1	6	5	2	4	1	2
B2	33	13	28	19	28	13
C forb	11.8	5.9	12.4	8.67	9.5	5.9
C grass	25.4	16	16.2	9	15.4	6.6

[1] Layer cover data from 1999 – 2004 are provided to show comparisons to 2009 presence/absence data

Table 4. Average cover (%) for vegetation layers in Block C at Bull River in 1999, 2000 and 2004. Cover was only recorded if the species had >5% cover in a given plot[1].

	1999		2000		2004	
Layer	**average**	**stdev**	**average**	**stdev**	**average**	**stdev**
A	0	0	0	0	0	0
B1	2.12	2.98	0.12	0.6	0.52	2.4
B2	25.44	10.29	27.48	9.59	23.96	8.67
C forb	12.85	6.85	14.34	9.957	10.96	5.61
C grass	16.38	10.8	11.19	7.98	20.6	8.87

[1] Layer cover data from 1999 – 2004 are provided to show comparisons to 2009 presence/absence data

A significant increase in presence was detected for 4 other species that were selected for analysis; bluebunch wheatgrass, pinegrass, cheatgrass and sulphur cinquefoil (Table 2; Fig. 6). Two of these species are native (bluebunch wheatgrass and pinegrass) and two are non-native (cheatgrass and sulphur cinquefoil) (see Appendix 3 for a list of non-native species found at Bull River). A significant increase in sulphur cinquefoil cover had been detected in 2004 in Block C and there was an observed increase in presence of this species in Block B.

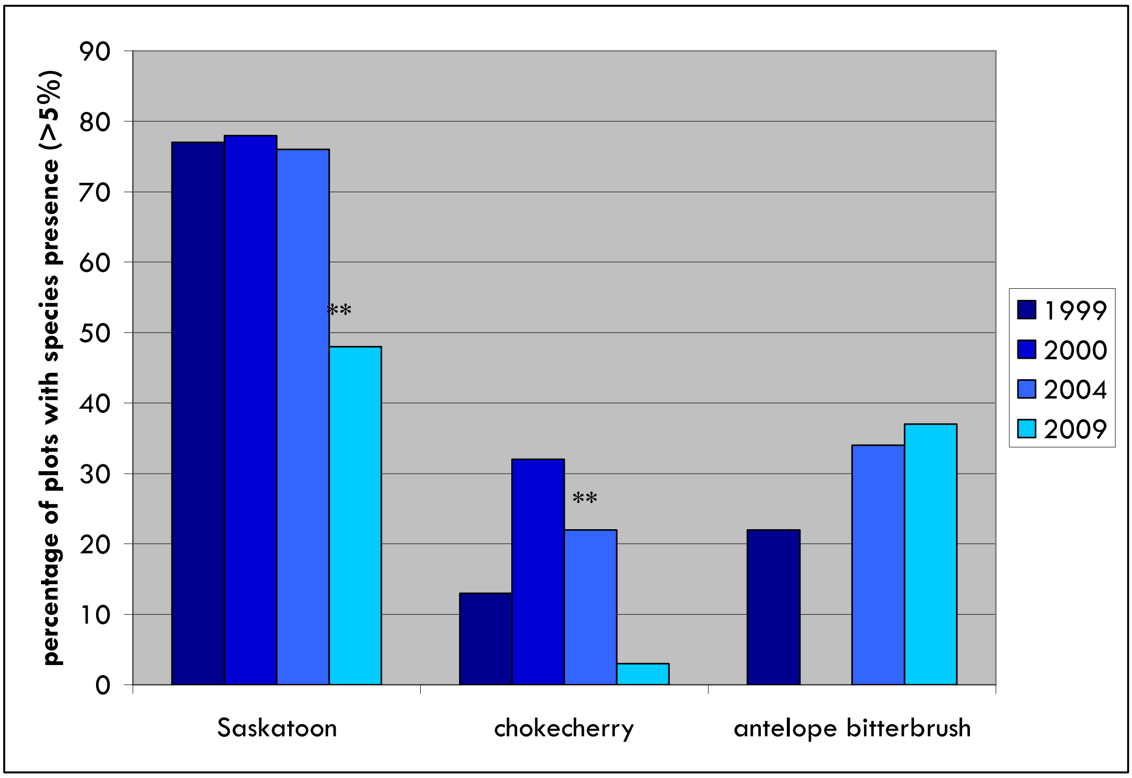


Figure 5. Percentage of plots with Saskatoon, chokecherry and antelope bitterbrush presence (>5%) cover at Bull River (blocks B and C combined) from 1999 – 2009 (indicates a significant change in presence (P<0.05)).**

In 2004, a significant decline was detected in the dominant grass species (timber oatgrass) and in the grass layer overall. There was a concomitant increase in pinegrass from 1.1%; Stdev=2.8 in 1999 to 3.6%; Stdev=4.5 in 2004. This trend was mirrored in the species presence data in 2009 as well. Pinegrass was observed more frequently (Table 2; Fig 6; p=0.004) and timber oatgrass was observed less frequently (Table 2; Fig. 6; p=0.002). Besides pinegrass, bluebunch wheatgrass (p=0.05) and cheatgrass (p=0.06) have both been observed more frequently since 1999 (Table 2; Fig. 6).

Since 1999, there has been a significant decrease in the number of plots bluegrass species have been observed in (Table 2; Fig. 6; p=0.05)

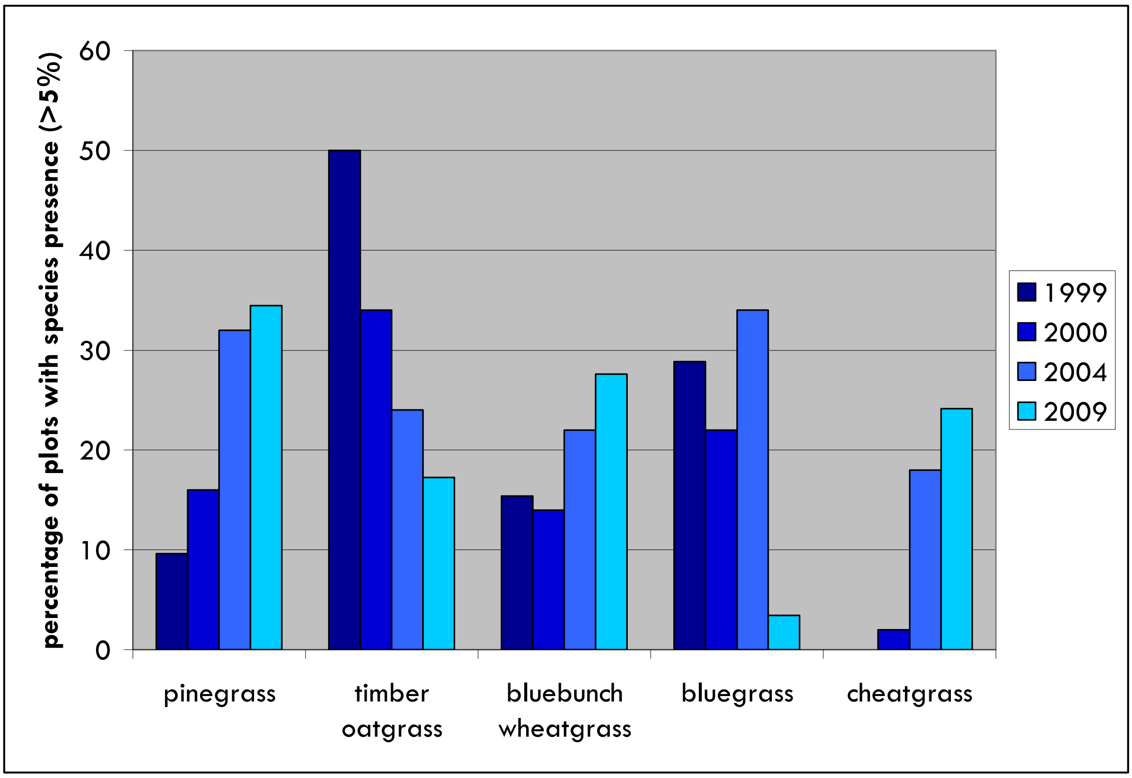


Figure 6. Percentage of plots with bluebunch wheatgrass, sulphur cinquefoil, cheatgrass and pinegrass presence (>5%) cover at Bull River from 1999 – 2009.

4.1.3 Bull River Vegetation Response Summary

Overstory Layer

There was little change in the overstory observed (Fig. 7) or detected since 2004. Stem density (123 stems ha^{-1}) falls within the low end of the open forest classification (76 – 400 stems ha^{-1}), but this was also true prior to treatment (197 stems ha^{-1}). More importantly the distribution of size classes has shifted to a larger number of stems in the upper diameter classes (>35cm dbh) (Fig 4).

Overstory structure at Bull River meets the objectives laid out in the stand prescription. Stem density is well below the goal of 75 stems ha^{-1} in Block C and 275 stems ha^{-1} in Block B. Current structure change at Bull River is beneficial to several red and blue listed wildlife species (Cooper et al. 2004), particularly cavity nesters.

Figure 7. Plot photos taken at plot 16, Bull River in 1999, 2000 and 2009 (left to right).

Shrub Layers

The shrub species selected for analysis in 2009 (Saskatoon, antelope bitterbrush and choke cherry) were selected for their browse value and because they are all physiologically adapted to fire. In 2004, it appeared that the shrub layer might have been recovering from mechanical and burning treatments. Despite showing signs of recovery from an initial significant decline in cover, the presence of Saskatoon and chokecherry appear to have declined by approximately 40% from pre-treatment levels (Fig. 5). Despite significant decreases in chokecherry and Saskatoon, antelope bitterbrush has shown a slight increase in presence on-site (Fig. 5), although this change is not significant (p=0.9).

Saskatoon and antelope bitterbrush require the open habitats (light) (Page et al. 2005) created by restoration activities such as slashing and burning for continued vigor and growth. However, by maintaining aboveground perennial biomass, shrubs are particularly susceptible to mechanical thinning, which may account for several studies that have found shrub production does not respond significantly to thinning within xeric ecosystems (McConnell and Smith 1965; Riegel et al. 1992; Thomas et al. 1999). Page et al. (2005) found a significant inverse relationship between thinning intensity and Saskatoon density at both a PPdh 2 and IDFdm2 site in the Trench.

In 2005, it was hypothesized that recovery of this layer would be function of time and that a recovery was expected in the mid to long term. Lack of recovery of this layer may have been compounded by ungulate and livestock use in the area. Ministry of Environment (2009) found that 81% of plots in the Bull River area had some level (slight – moderate) of browse use. In 2008, 162 elk were found to be using the area.

Assuming a safe use forage level of 25% for livestock and 25% of wildlife, there is approximately 216 kg of forage available per year for livestock (assuming a 400kg cow eating 2% of its body weight a day). This means that a safe stocking rate would be 37 cows for approximately one month in the summer. These calculations do not take into account the slope of North Fontaine pasture which can reduce the amount of available forage anywhere from 30% (11%-30% slope) to 60% (over 60% slope) (Holechek et al. 1998). Additionally, some range management guidelines suggest a safe use level of 35 – 40% in semi-arid ecosystems (Holechek et al. 1998). Given the number of elk and livestock using this area, it is possible the Bull River area may be overstocked. Overstocking may be the reason that chokecherry and Saskatoon presence is not increasing on-site. Despite a decline in species presence there is no way to detect change in species cover, so results should be interpreted cautiously. It should also be noted that antelope bitterbrush presence has increased over time (Table 2; Fig. 5).

Forb Layer

Four forb species were selected for analysis in 2009 (showy aster, sulphur cinquefoil, common St. John's wort and Canada thistle) (Table 2).

The one native species selected, showy aster, declined in presence over time (Table 2). Although this change was not significant, the p-value (0.1) is low enough to merit observation. The rhizomatous habit of showy aster enables this species to be adapted to light to moderate severity fires (Fischer and Bradley 1987). Growth is stimulated after fire, resulting in mass flowering in the first few post-fire years (Stickney 1989). This species likely experienced a flush in growth after the fire and then declined in the plant community as other species gained dominance.

In 2005, there was no difference detected in forb cover in either of the Bull River blocks. However, it was noted that sulphur cinquefoil cover was increasing. In 2009, there was a significant increase in the number of plots sulphur cinquefoil was observed in (Table 2; Fig. 6). Although it is not possible to detect changes in cover, it was observed in nearly 50% of the plots (Fig. 6). In 2005, it was hypothesized that the increase in cinquefoil cover was an indication of early successional habitat post-fire as sulphur cinquefoil is a pioneer species and is often found in early seral habitats (Powell 1996). However, widespread presence indicates the plant is a now a dominant species in this area. Once established in areas with limited competitive vegetation, the spreading root system and seed producing capability of sulphur cinquefoil enables it to become the dominant plant species (BC Ministry of Agriculture and Lands 2009). Due to the widespread distribution of this plant, management options are limited, besides the encouragement of native species growth and minimizing disturbance (e.g. reduction of livestock stocking rates).

Although not found in any of the plots, three discrete patches of Dalmatian toadflax [*Linaria genistifolia* ssp. *dalmatica* (L.) Maire & Petitmengen] were observed at this site in 2004. This appears to be an increase from 2000, where only one patch was observed. In 2009, the species was found in one plot (118). Due to the patch size (small) and clearly defined borders several management options are available and should be implemented. Hand-pulling before seed-set is an effective, low risk method of controlling the spread of this species. Although labour- intensive, the small size of the infestations makes this a viable option. Chemical treatment is also an available option.

Grass Layer

There were four grass species selected for analysis in 2009; bluebunch wheatgrass, timber oatgrass, cheatgrass and bluegrass (Table 2). There were significant changes in presence observed for all four species (Table 2; Fig. 6).

In 1999, timber oatgrass was the dominant grass species. Since 1999, timber oatgrass presence at Bull River has declined over 50% (Fig. 6).The decline in the presence of timber oatgrass on-site was observed in 2004 as well. Although most studies indicate that timber oatgrass increases post-fire, a few studies have observed a decline in this species after fire (Covington 2000). Compared to graminoid associates, nutritional value of oatgrass is low (Covington 2000), therefore the decline in the presence of this species is not a concern.

The presence of pinegrass has continually increased in the Bull River restoration blocks (Fig. 6). Although pinegrass is shade-tolerant, there is no indication that it is light-intolerant. Due to its rhizomatous habit, it can more easily access soil moisture in the upper soil layers in recently opened stands. Eventually, due to greater evapotranspiration caused by the opening of the canopy, it is hypothesized that this site will become ‘drier’ and unsuitable for pinegrass growth, allowing for growth of more desirable drought tolerant bunchgrasses. A significant reduction of pinegrass cover was observed in a Kootenay National Park restoration site near Radium Hot Springs 8 years after thinning (Page 2010). Pinegrass cover had been increasing in the plots since the site was harvested in 2001. As the decrease was only observed in one year, it was not possible to determine the cause of the decline.

Bluebunch wheatgrass and cheatgrass have also continually increased in presence in the Bull River restoration blocks (Fig. 6). The increase in bluebunch wheatgrass can be viewed as a positive ecological change given the forage value of this species and the level of livestock and wildlife use in the Bull River area. Additionally, this species is a key indicator species of functioning open forest and open range systems in the Trench.

The increase in observations of cheatgrass is not a positive ecological change. In 1999, there were no observations of cheatgrass, ten years later, it has been observed in over 20% of the plots (Fig. 6). Cheatgrass alters successional trajectories of postfire plant communities by interfering with native seedling establishment, by competing with established perennials for resources, and by shortening the interval between fires (Zouhar 2003). Because cheatgrass is persistent once it becomes established, eradication of large infestations is not usually a reasonable goal (Zouhar 2003). Zouhar (2003) also notes that protection from grazing has not been successful in reducing cheatgrass populations and in some cases leads to an increased risk of fire and increased presence/cover of cheatgrass.

There was nearly a 30% decline in the number of plots bluegrass species was observed in from 2004 to 2009. This decline was detected after observed increases in 2000 and 2004 (Fig. 6). The decline may be a case of species misidentification as bluegrass species are relatively difficult to identify. Further monitoring may be needed to determine if this is an actual trend.

4.2 Stoddart Creek North

4.2.1 Overstory

Excluding dbh class 1 (0-5cm dbh), stem density in 2009 was 124 stems ha^{-1} (stdev=110) (Fig. 8). In 2004 stem density for trees greater than 5cm dbh was 64 stems ha^{-1}. The increase in stem density in the upper dbh classes is likely due to the growth of small diameter recruitment trees. In 2009, stem density in dbh class 1 was 4696 stems ha^{-1} (stdev=4305). Stem density has increased significantly since 2004 (from 1120 stems ha^{-1}) ($p<0.0001$).

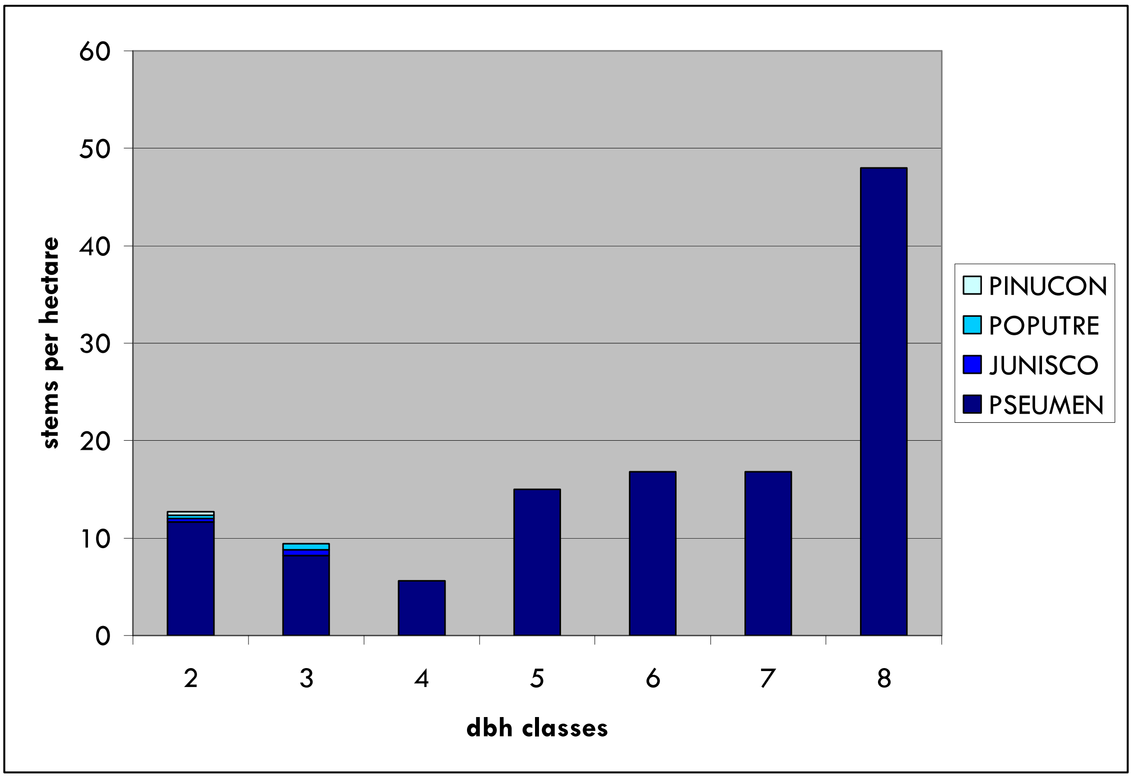


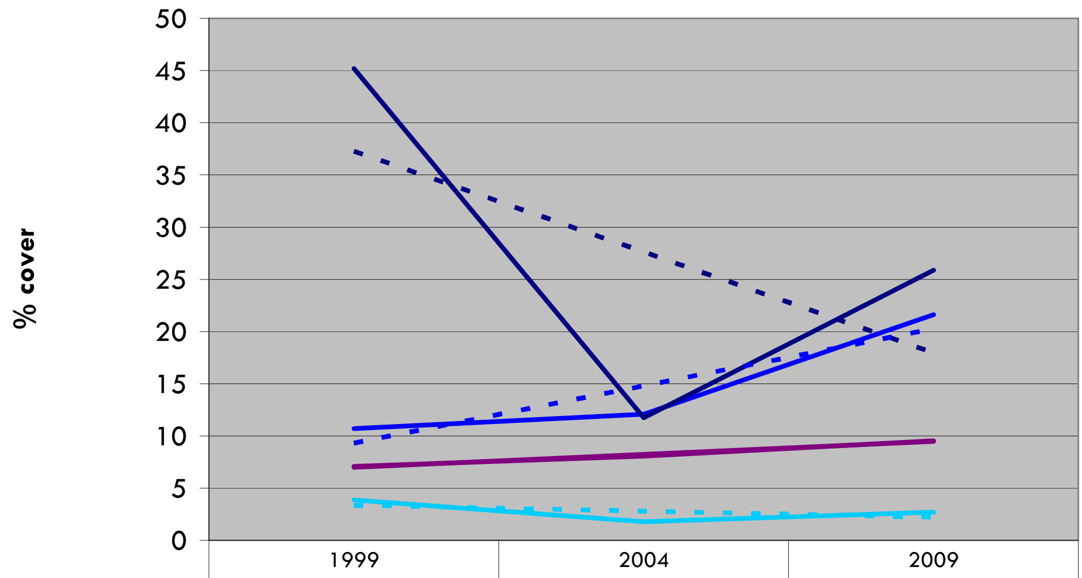
Figure 8. Stems per hectare and species distribution for stems greater than 5cm dbh (dbh class 1) at North Stoddart Creek in 2009.

In 2009, stem composition varied somewhat from 2004, although the overstory is still almost entirely comprised of Douglas fir (Fig. 8). After a significant decline in canopy cover from 1999 to 2004 from 9% to 5%, canopy cover increased significantly from 5% in 2004 to 18% in 2009 ($p<0.001$).

4.2.2 Understory

Several significant changes were detected in the understory. Cover data for all species were collected in all years, so it is possible to analyze change in species and in functional/descriptive groups (bunchgrass, forbs, non-native species, and shrubs). A significant change ($p<0.05$) indicates that a species or functional group has increased in abundance over time (i.e. since 1999).

All vegetation functional groups demonstrated significant trends over time except for non-native species (Fig. 9). Bunchgrass and forb cover has shown a significant increase since 1999, whereas shrub cover has declined significantly over time.



	1999	2004	2009
bunchgrass	7	8	10
forbs	11	12	22
weeds	4	2	3
shrubs	45	12	26

Figure 9. Change in percent cover of vegetation functional groups (bunchgrass, forbs, weeds, shrubs) over ten years (1999 – 2009) at North Stoddart Creek. Solid line indicates actual data points and dashed line indicates linear trend based on data collected between 1999 and 2009.

Shrubs

Although shrub cover has increased since 2004, cover was still lower than 1999 resulting in a detection of a significant downward trend since 1999 (Fig. 9). In 2004, there was nearly a 50% decline in shrub cover observed. There were no significant long-term trends detected in individual species. Common shrub species have remained relatively constant over time with common snowberry (*Symphoricarpos occidentalis* Hook.), Rocky Mountain juniper (*Juniperus scopulorum* Sarg.) and baldhip rose (*Rosa gymnocarpa* Nutt.) being the dominant species across all years.

Forbs

Forbs have continued to increase in cover over time (Fig. 9). Cover has increased from 11% (stdev=9) to 22 (stdev=15). Significant trends were detected for 5 forb species (Table 5). All species increased significantly over time, except for littleleaf pussytoes (Table 5). The decline in littleleaf pussytoes may be due to different observers between years resulting in misidentification of pussytoes species (*Antennaria* species can be difficult to identify to the species level).

Spikelike goldenrod (*Solidago spathulata* DC.) was the dominant forb both pre- and post-treatment. Goldenrod cover increased slightly in 2004 (1.6% - 2.5%) and dramatically in 2009 (5%), but this change was not considered significant ($p<0.05$).

Table 5. Forb species at North Stoddart Creek with significant changes in percent cover since 1999 ($p<0.05$) Data are pooled across sites and years ($p<0.05$). A negative coefficient indicates cover increased over time and a positive coefficient indicates cover declined in cover over time.

Species	Coefficient	increasing (+) /decreasing (-)	pvalue
cut-leaved anemone (*Anemone multifida* Poir. var. *multifida*)	0.098	+	0.017*
littleleaf pussytoes (*Antennaria microphylla* Rydb.)	-0.555	-	0.004*
umber pussytoes (*Antennaria umbrinella* auct. Non Rydb)	0.410	+	>0.001*
smooth aster (*Symphyotrichum laeve* (L.) A. Love & D. Love)	0.754	+	>0.001*
northern bedstraw (*Galium boreale* L.)	0.207	+	0.013*

Bunchgrass

Bunchgrass cover has increased significantly over the last 10 years (Fig. 9). Bunchgrass cover is roughly 10% (stdev=7) across the site. The only significant trend detected in an individual species was bluebunch wheatgrass. Bluebunch wheatgrass cover actually declined slightly from 2004 levels from 4% cover to 3%, although the increase from 1999 was still large enough to detect a significant trend upward. Most notably, rough fescue increased from less than 1% cover to over 2% (the change was not significant).

Non-native species

As a functional group, there has been no change in weed cover detected over time (Fig. 9). There was however a significant positive trend detected in the cover of alfalfa. Despite the cover increase in alfalfa, levels are relatively low. Alfalfa cover increased from 0% in 1999 to 1% in 2004. See Appendix 3 for a list of all non-native species found at North Stoddart.

4.2.3 Stoddart Creek North Vegetation Response Summary

Overstory Layer

Including trees greater than 5cm dbh, stem density at North Stoddart Creek is considered to be an open forest ecosystem. Although stem density, it is still within the prescription guidelines of anywhere from 0 – 190 stems ha^{-1}. There was however, a significant increase in stems less than 5cm dbh from 1120 stems ha^{-1} to approximately 4700 stems ha^{-1}. The increase in small diameter stems (regen) indicates the site will need to be treated to ensure the site does not become a closed canopy site again.

Although stem density has increased, the overstory still provides good structure for Rocky Mountain Bighorn Sheep.

Figure 10. Plot photos taken at plot 23, North Stoddart Creek in 1999, 2000 and 2009 (left to right).

Shrub Layer

The decline in the shrub layer observed in 2004 was likely a function of the mechanical treatment imposed at this site. As mentioned previously, several studies have observed the adverse impact of mechanical forest treatments on shrubs (McConnell and Smith 1965, Riegel et al. 1992, Thomas et al. 1999, Page et al. 2005). Although the trend shows a significant decline in cover, there was a significant increase in cover between 2004 and 2009 (12% - 26%; $p<0.05$) implying that the shrub layer may be recovering. It is not possible to determine the level of grazing/browsing because the stocking rate at this site is unknown.

Figure 11. Plot photos taken at plot 16, North Stoddart Creek in 1999, 2000 and 2009 (left to right).

Forb Layer

There has been a continual increase in forbs observed at Stoddart Creek (Fig. 9). There were four forb species that demonstrated a significant increase over time, including northern bedstraw (Table 5). A significant increase in forb cover was also observed eight years post-restoration at a nearby Kootenay National Park (Page 2010). Page (2010) also observed a significant increase in northern bedstraw at the same site.

Grass Layer

Bunchgrasses, as a functional group, have shown a positive linear trend at Stoddart Creek (Fig. 9). Although there was a slight decline in the dominant bunchgrass species, bluebunch wheatgrass, other bunchgrass species' cover increased.

Long-term increases in bunchgrass cover post-restoration have also been observed at Bull River (this report) and at the Redstreak Restoration Area in Kootenay National Park located just north of the North Stoddart site (Page 2010). Bunchgrass levels at North Stoddart (~10%) are relatively high for the Trench (in comparison, bunchgrass cover averaged 2% across the Redstreak site in 2009)

Non-native species

The only functional group that a trend has not been observed in is non-native species. This is a positive result given that non-native species increase is a common result post-restoration (Sutherland and Nelson 2010). Despite the lack of increase in non-native species, there was a significant percentage cover increase in alfalfa (Table 5). The species was likely introduced to and spread through the site by horses as the area is popular area for horseback riding.

5. Summary and Further Monitoring

Long-term monitoring at both Bull River and North Stoddart Creek has detected trends in plant community response to restoration. Monitoring at both sites was initiated prior to standardized ecosystem restoration monitoring resulting in some trial and error monitoring sessions in and since 1999. Despite differences in data collection and data collectors between years, trends were still detected, highlighting the value of long-term monitoring, even at basic levels.

Both sites are in the 'maintenance' mode of restoration and monitoring. To protect the initial investment of financial resources and time to conduct restoration and restoration monitoring periodic monitoring should be conducted to establish if trends are still continuing.

There are some recommendations for future monitoring sessions that apply to both sites and specific recommendations for individual sites.

5.1 Bull River

Trends should be interpreted cautiously at Bull River due to differences in statistical analysis between years. Trends observed in 2009 looked at the presence/absence of species rather than cover. Despite the difference, the data reveals potentially important trends within the plant community.

The overstory structure continues to provide the structure needed to provide key attributes for target wildlife species.

Although the overstory has been successfully restored, changes in the understory have not all been positive. The decline in observations of Saskatoon and chokecherry (Fig. 5) at Bull River is of concern. Maintenance of the shrub layer, particularly Saskatoon and antelope bitterbrush is essential for the continued support of wild ungulate populations that use the Bull River area. The initial decline in shrub cover/presence has been observed elsewhere in the Trench (Page 2010, Page et al. 2005), but levels seem to recover in the mid to long term. A Ministry of Environment study (2009) revealed a high level of shrub use in the general area. Despite the observed decline in Saskatoon and chokecherry, antelope bitterbrush observations appear to be increasing (Fig. 5). Further monitoring should focus on changes in percent cover and shrub use by ungulates and livestock to confirm .trends in the shrub layer Due to the possibility that the area is being over utilized by livestock and wildlife, it would be prudent to examine stocking levels in the short-term to ensure the shrub layer is not being adversely affected in the long-term.

The increase in non-native species observed is also of concern. In a review of 42 studies that addressed the effect of silvicultural treatments on non-native plants, Sutherland and Nelson (2010) found 90% of studies observed a post-treatment increase in at least one non-native species. It is possible that the widespread establishment of cheatgrass and sulphur cinquefoil at Bull River (Fig. 6) has resulted in the transition of this plant community from native to 'modified'. Because of the increase in non-natives, there should be a monitoring session planned in the future (3 – 5 years) to look at percent cover of these species (as well as other non-natives) to see if the trend detected in 2009 will continue.

Despite long-term decreases in the observations of shrubs and the increase in observations of non-native species, there have been positive ecological changes observed (the increase in the presence of bluebunch wheatgrass).

Due to the limitations of data analysis in 2009, it is recommended that the site be monitored in 3 – 5 years to confirm trends and ensure stocking levels are not having an adverse impact on the plant community.

Specific recommendations include:

- Review and treat known Dalmatian toadflax patches. (UTMS: 615405/5484837; 0614553/5485114; 614475/5485273). An additional observation was made at plot 118 in 2009.
- Review and adjust stocking rates to relieve grazing pressure, if needed.
- Monitoring in 2012 – 2014 to confirm trends.

5.2 Stoddart Creek North

It was possible to assess percent cover changes in all functional groups and species at Stoddart Creek. Long-term monitoring at Stoddart Creek North shows that the site remains on a positive trajectory post-restoration. Forbs and bunchgrass have continued to increase since treatment in 2001. Bunchgrass cover is approximately 10% across the site, one of the highest levels observed in the Trench. Although shrubs have declined since 2001, they have significantly increased since the last monitoring session in 2004 (Fig. 9).

The only functional group that did not exhibit a significant change was non-native species. Despite the lack of change there was an observed long-term increase in alfalfa. The increase is likely due to the use of North Stoddart Creek as a popular horseback riding destination.

Although the understory appears to be on an ecologically positive trajectory, the significant increase in conifer regeneration should be addressed. The site should be examined to determine the appropriate treatment for the small trees currently occupying the site. Any treatment considered should be as low-disturbance as possible to discourage any further non-native species establishment.

Recommendations include:

- Site visit to determine restoration maintenance requirements
- Monitoring all plots in year 13-15 post-treatment (2012 - 2014) to confirm understory response and conifer regeneration levels if no maintenance treatment has been applied in the interim.

5.3 General Recommendations for Future Monitoring

- Prior to sampling, review spreadsheets Bull River UTMs and North Stoddart UTMs (Appendix 1) to determine status of monitoring plots at each site (e.g. some plots have been lost to industrial activities or not re-located).
- Estimate cover for each vegetation layer (A, B1, B2, Cherb, Cgrass, D) separate from estimating individual species' cover.
- Select 5 representative plots at each site for photo-monitoring. Ensure photos are taken in the same direction and height.
- Collect Layer D (Bryophyte) to assess the effects of restoration on the bryophyte community.
- Ensure data are entered in the same format as the 2010 spreadsheet, this will enable easy data comparisons between years. Enter all vegetation data into Excel with plot numbers as rows and with species as columns.

6. Conclusion

Bull River and Stoddart Creek North provide good examples of restoration in practice. Information gathered at these sites provides valuable information to land managers about expected results and allows managers to gauge success of restoration activities. As well as characterizing the type of response, monitoring also provides information about the timing of the response, also essential to gauging success.

North Stoddart continues on a positive successional trajectory. Low levels of non-native species cover, high levels of bunchgrass cover, an increasing shrub layer and open forest structure indicate restoration has been a success at this site. Positive results are likely due to low disturbance restoration techniques and low levels at forage/browse use. Despite positive changes in the understory, increases in conifer regeneration necessitate a site visit to determine restoration maintenance needs. If a maintenance treatment is not applied, further monitoring in 2013-2015 would be useful to monitor individual species and vegetation layers to ensure the full recovery of the shrub layer and continued positive response of the plant community.

Responses at Bull River are not as positive. Decreases in the observations of key shrub species and increases in the observations of non-native species indicate the plant community is not on a positive successional trajectory. Restoration results are likely compounded by initial species composition and by high levels of forage/browse use at the site. Results should also be interpreted cautiously due to the difference in analysis in 2009. Further monitoring should focus on monitoring individual vegetation species and vegetation layers to confirm trends in the plant community.

The detection of trends at both these sites ten years post-restoration is an encouraging sign for other monitoring installations in the Trench. The potential exists to expand the examination of ecosystem restoration efforts in the Rocky Mountain Trench to other sites where monitoring has taken place. Percent cover estimates from other sites could be combined into a single analysis to determine if there are consistent responses across all sites for each species or for functional groups. The analysis at the Trench level would increase the power needed to detect significant results. Controlling for grazing/browsing effects and time since treatment would be important to accurately characterize trends and the impact of management decisions.

7. 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.

Bork, E.W., B.W. Adams, and W.D. Willms. 2002. Resilience of foothills rough fescue, Festuca campestris, rangeland to wildfire. Canadian Field Naturalist 116: 51 – 59.

British Columbia Ministry of Agriculture and Lands. 2009. Sulphur cinquefoil – Pastures and Rangeand. [Online]. Available: http://www.al.gov.bc.ca/cropprot/cinquefoil.pdf

Cooper, J.M., C. Steeger, S.M. Beauchesne, M. Machmer, L. Atwood, E.T. Manning. 2004. Habitat Attribute Targets for Red and Blue Listed Wildlife Species and Plant Community Conservation. Report prepared for the Columbia Basin Fish and Wildlife Compensation Program. Nelson, BC.

Covington, D. 2000. Danthonia spicata. 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/ [2010, July 26].

Daigle, P. 1996. Fire in the dry interior of British Columbia. Extension Note 8, BC Ministry of Forests Research Program, Victoria, BC. 5p.

Fischer, W.C.; Bradley, A.F. 1987. Fire ecology of western Montana forest habitat types. Gen. Tech. Rep. INT-223. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Gayton, D.V. 2001. Ground Work: Basic Concepts of Ecological Restoration in British Columbia. Southern Interior Forest Extension and Research Partnership, Kamloops, BC SIFERP Series 3.

Gayton, D. 1997. Preliminary calculation of excess ingrowth and resulting forage impact in the Rocky Mountain Trench. BC Ministry of Forests, Nelson Region, Mimeo. 5p.

Halko, R. 1996. 20 Year Enhancement Plant. Bull Mountain, Mount Broadwood, Sheep Mountain. A report submitted to: Ministry of Environment, Lands and Parks. Submitted By: Robert Halko, A.I.T. Interior Reforestation Co. Ltd. May 30, 1996. Cranbrook, BC.

Harris, R. 2009. pers. comm. Ecosystem Restoration Team Leader. BC Ministry of Forests.

Holechek, J.L., R.D. Pieper, C.H. Herbel. 1998. Range Management Principles and Practices. Third Edition. Prentice-Hall Inc. New Jersey.

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

McConnell, B.R. and J.G. Smith 1965. Understory responses three years after thinning pine. Journal of Range Management 18: 129 – 132.

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.

Ministry of Environment. 2009. Rocky Mountain Trench Rangeland Assessment Project. November 2009 Progress Report. Prepared by: Becky Phillis and Tara Szkorupa. Environmental Stewardship Division. Ministry of Environment. Cranbrook, BC. 17p.

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

Naumberg, E. and L.A. DeWald. 1999. Relationships between Pinus ponderosa forest structure, light characteristics, and understory graminoid species abundance. Forest Ecology and Management 124: 205 – 215.

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., E.W. Bork and R.F. Newman. 2005. Understory response to mechanical restoration and drought within montane forests of British Columbia. British Columbia Journal of Ecosystems and Management. 6: 8 – 21.

Page, H.N. 2010. Monitoring Ecosystem Restoration Treatments in Kootenay National Park. 2009 monitoring. Report submitted to: Kootenay National Park, LLKY Field Unit. 25p.

Powell, G.W.. 1996. Analysis of sulphur cinquefoil in British Columbia. Research Branch. BC Ministry of Forests. Victoria, BC. Working Paper 16.

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

Province of British Columbia. 1995. Biodiversity Guidebook. Forest Practices Code of BC Act. Strategic Planning Regulations. Operational Planning Regulation. BC Ministry of Forests. Victoria, BC.

Riegel, G.M., R.F. Miller, and W.C. Krueger. 1992. Competition for resources between understory vegetation and overstory Pinus ponderosa in northeastern Oregon. Ecological Applications. 2: 71 – 85.

Ritchie, M.W. and K.A. Harksen. 1999. Long-term interdisciplinary research on the Goosenest Adaptive Management Area, Klamath National Forest, California. The Forestry Chronicle 75: 453 – 456.

Rocky Mountain Trench Ecosystem Restoration Steering Committee (RMTERSC). 2006. A Progress Report on the Fire-Maintained Ecosystem Restoration Program in British Columbia's Rocky Mountain Trench – "Blueprint for Action 2005." Draft, Jan 30, 2006. http://www.trenchsociety.com

Rocky Mountain Trench Ecosystem Restoration Steering Committee (RMTERSC). 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.

StataCorp. 2007. Stata Statistical Software: Release 10. College Station, TX.

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

Stickney, P.F. 1989. Seral origin of species originating in northern Rocky Mountain forests. Unpublished draft on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Fire Sciences Laboratory, Missoula, MT.

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

Sutherland, S. and C.R. Nelson. Nonnative plant response to silvicultural treatments: A model based on disturbance, propagule pressure, and competitive abilities. Western Journal of Applied of Forestry 25: 27-33.

Thomas, S.C., C.B. Halpern, D.A. Falk, D.A. Liguori and K.A. Austin. 1999. Plant diversity in managed forests: Understory responses to thinning and fertilization. Ecological Applications 9: 864 – 879.

Zouhar, Kris. 2003. Bromus tectorum. 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/ [2010, July 26].

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

Folder/File Name	Description
North Stoddart 2010 Source Files	Includes all files used to create the North Stoddart Data Summary – 1999 - 2010
Bull River 2010 Source Files	Includes all files used to create the Bull River Data Summary – 1999 - 2010
North Stoddart Data Summary – 1999 – 2010	Summarizes all data collected from 1999 - 2009
Bull River Data Summary – 1999 - 2010	Summarizes all data collected from 1999 - 2009
Bull River UTMs	Provides plot UTMs and data collection notes for each year data were collected
North Stoddart UTMs	Provides plot UTMs and data collection notes for each year data were collected
North Stoddart Plot Photos	Includes scanned 1999 photos, 2004 photos and 2009 photos
Bull River Plot Photos	Includes scanned 1999 photos, 2004 photos and 2009 photos

Appendix 2. Stand prescriptions for Stoddart North and North Fontaine Range Units

Appendix 3. Non-native species found at Bull River and North Stoddart

Table: Non-native species found at Bull River in 2009.

ScientificName	English Name	WeedStatus
Elymus repens	quackgrass	Restricted
Berteroa incana	hoary alyssum	Invasive
Bromus tectorum	cheatgrass	
Hypericum perforatum	common St. John's-wort	Invasive
Linaria genistifolia ssp. *dalmatica*	Dalmatian toadflax	Provincial noxious weed
Melilotus officinalis	yellow sweet-clover	
Phleum pratense	common timothy	
Poa compressa	Canada bluegrass	
Potentilla recta	sulphur cinquefoil	Restricted
Taraxacum officinale	common dandelion	
Tragopogon dubius	yellow salsify	Invasive
Trifolium pratense	red clover	
Verbascum thapsus	great mullein	Invasive

Table: Non-native species found at North Stoddart in 2009.

ScientificName	English Name	WeedStatus
Elymus repens	quackgrass	Restricted
Bromus tectorum	cheatgrass	
Taraxacum officinale	common dandelion	
Medicago sativa	alfalfa	