MONITORING ECOSYSTEM RESTORATION TREATMENTS AT NORTH STODDART CREEK AND NORTH FONTAINE

MONITORING UPDATE 2004

Submitted to: John Krebs
Senior Wildlife Biologist
Columbia Basin Fish and Wildlife Compensation Program
Suite 103 333 Victoria Street, Nelson, BC V1L 4K3

Submitted by: Hillary Page M.Sc.
Sage Ecological Research

Box 2455
1313 7th Avenue
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 Columbia Basin 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 IDFun 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 are two Units within the North Fontaine treatment area, one open unit that was not subject to slashing and one forested unit that was subject to slashing as well as burning. Post-treatment monitoring occurred at North Fontaine in 2000, 2001 and 2004. Stoddart Creek was harvested in 2001, slashed and sloop burned in 2002. Post-treatment monitoring occurred at Stoddart Creek in 2004. Effects of restoration, were assessed though monitoring of the plant community. Restoration at North Fontaine has not yet had a significantly positive effect on the vegetation community, whereas changes at Stoddart Creek have been generally positive. Structurally, both stands are good examples of open forest and open range ecosystems. Lower stem densities, with a greater distribution of stems in the upper diameter (dbh) classes characterize both restoration sites. Responses in the understory plant community varied according to site. The shrub community at North Fontaine initially declined in cover and then recovered to pre-treatment levels in 2004. Individual species at North Fontaine responded differently to treatments in the forested and open units. Antelope brush cover declined significantly post-treatment and has not yet recovered to pre-treatment levels in the slashed portion of North Fontaine, but has recovered to pre-treatment levels in the open unit. Saskatoon cover declined significantly in the forested unit, not recovering to pre-treatment levels, whereas cover was not affected by treatments in the open unit. Forb cover was not affected by treatments in either unit, although there has been an increase in sulphur cinquefoil cover across both units. The grass layer has declined significantly compared to pre-treatment levels in the slashed unit, but has recovered to pre-treatment levels in the open unit. Understory response at Stoddart Creek North has been positive. Although shrub cover declined significantly, shrubs were not a major component of this plant community. The forb layer was unaffected as was the grass layer, except for a significant increase in cover of bluebunch wheatgrass, a desirable forage and native species. Different treatments and response times have resulted in a varied plant community response, the primary differences appear to be related to the use of mechanical restoration techniques. Both restoration sites are good examples of restoration in practice and provide valuable information about the type and timing of plant community response to restoration activities.

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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). These 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 the BC 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 1% of grassland and open forest is lost annually in NDT4 systems of the Rocky Mountain Trench due to forest ingrowth or encroachment, equivalent to approximately 3 000 ha per year. This rate is similar to estimates made in other areas of British Columbia exhibiting 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 decreased timber and forage production (Powell et al. 1998). As a result of this conversion, domestic livestock and native ungulates are exerting increased pressure on a declining land base as they compete for forage. Remaining grassland habitats are being further degraded by noxious weeds which may out-compete native vegetation and reduce residual forage quantity and quality. Densely stocked stands also pose an increased risk of severe insect outbreaks and catastrophic crown fires (Powell et al. 1998; Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000).

To mitigate these changes, land management agencies (Columbia Basin Fish and Wildlife Compensation Program, Ministry of Forests, Ministry of Water, Land and Air Protection) and agriculture and conservation stakeholders have adopted ecosystem restoration or habitat enhancement programs intended to restore the required ecological processes of fire-maintained systems in the Rocky Mountain Trench (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000). The primary objective of the Trench Ecosystem Restoration Program is to remove excess immature and understory trees from NDT4 communities over the next several decades 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 (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2000). The Trench Restoration Program is the largest, longest running terrestrial initiative underway in the province of BC (Machmer et al. 2002).

Ecosystem restoration is designed to achieve a number of different objectives. One of the primary objectives is the maintenance or enhancement of habitat diversity and associated wildlife species. This is generally accomplished through the reduction of litter layer depths/slash accumulations that restrict forb and grass production, ideally thereby increasing the percentage area or production of target grassland species coverage (e.g. bluebunch wheatgrass and rough fescue). Maintenance and enhancement of wildlife habitat also requires that existing overstory veterans and wildlife trees throughout the site are protected and maintained. These objectives and requirements of ecosystem restoration require different prescriptions for each site, dependent on pre-treatment conditions. The main tools of dry forest ecosystem restoration are tree removal (harvesting, spacing) and or periodic prescribed burning to kill tree seedlings and smaller undesirable trees.

An integral component of a restoration plan is a detailed monitoring plan. Long-term monitoring of vegetation, of a particular species of interest, or a key physical parameter is the only way to determine the success of a restoration effort (Gayton 2001). Monitoring will aid in the development of future plans, plans that contain an understanding of the ecological processes that link overstory management to understory dynamics and diversity (Naumberg and DeWald 1999). The objectives of dry forest restoration monitoring are to assess characteristics related to forest and ecosystem health, forage production, maintenance of open forest habitat and associated plant species (Ritchie and Harksen 1999).

This project is in response to a request from the Columbia Basin Fish and Wildlife Compensation Program (CBFWCP). Specific objectives of the project were to (1) 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 (2) 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 recently 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

Original vegetation data collection methods were adapted from Mowat et al. (1998). Percent cover of grasses and forb data were collected in 1.26m radius plots. These were both labeled the C layer. Shrub cover data were collected in 5.64m radius plots. Shrubs greater than 2m height were classified as the B1 layer and shrubs under 2m in height were classified as the B2 layer. Canopy cover was estimated in 11.26m radius plots, stem density (by species) was also collected in 11.26m radius plots. Tree species' density data for those less than 2m height were recorded in the 5.64m radius shrub plot. In all plots (grass/forb, shrub, tree) cover of individual species was recorded if that species made up greater than or equal to 5% cover within a given plot.

North Fontaine pre-treatment data (1999) and post-treatment (2000 and 2004) data were entered into Excel. 2004 data were entered in a format that can easily be imported into a statistics program or ACCESS© database. 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 post-treatment data were entered into Excel in a format that can easily be imported into a statistics program or ACCESS© database (i.e. every observation is a single record). All data for both projects can be found in Appendix 1.

Vegetation response to restoration activities was summarized by functional/descriptive group. This approach reduces the variability and increases the chance of finding significant differences in the plant community pre- and post-treatment. Response of the plant communities was also considered in the context of three restoration objectives as outlined by Machmer et al. (2002):

Restoration Objective 1:

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:

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

Restoration Objective 3:

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

2.1 Study Area

There were two sites monitored for this project.

2.1.2 North Fontaine

The North Fontaine treatment area is located in the Bull Mountain area. 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*), whitetail 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).

The North Fontaine treatment block consists of two units. The lower or more southern unit was labeled Unit A, the unit is approximately 108 ha. Unit A had a moderately low-density overstory of mature and veteran stems and a significant amount of conifer regeneration. Unit B is an open, south facing block dominated by antelope brush [*Purshia tridentata* (Pursh) DC.] and Saskatoon (*Amelanchier alnifolia* Nutt.). Unit B is approximately 109 ha. Both units are located in the IDFdm2 biogeoclimatic zone, Unit A is in the 03 site series and Unit A is in the 02 site series. 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 overall pre- treatment stem density was relatively low (~200 stems ha^{-1}).

The goal of the overall Bull River enhancement/restoration plan is 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). High priority at North Fontaine pasture was to return this unit to a high forage production area.

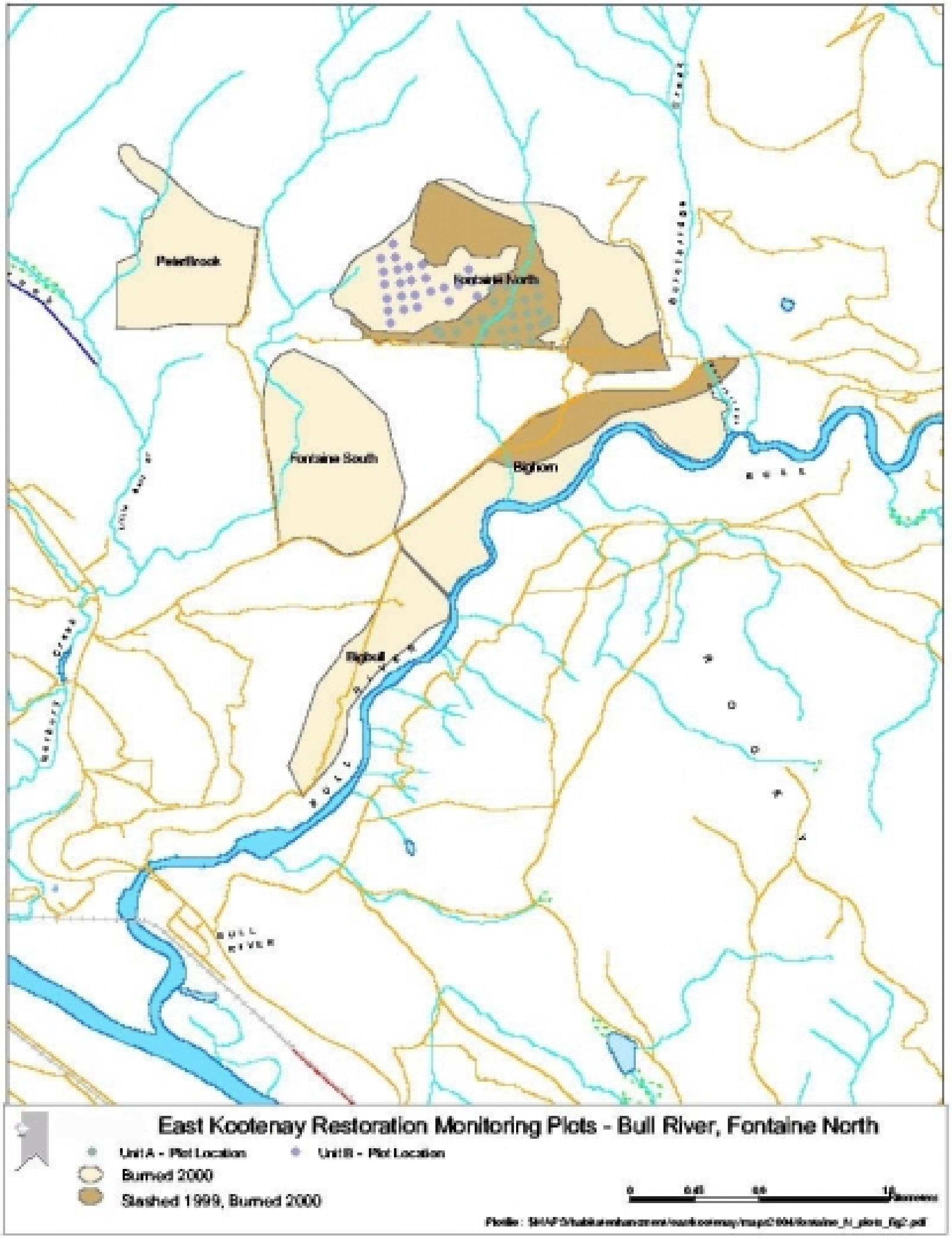

Figure 1. North Fontaine Treatment Site.

26 monitoring plots were installed at Bull River in both Unit A and B. Plots were installed 100m apart on a north-south bearing in each block. 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.

The target stand conditions for Unit B were to maintain this site as open range, with a maximum stand density of 75 $stemsha^{-1}$. The target for Unit A was 250 $stemsha^{-1}$ with maximum of 400 stems over the long term. In 1999 Unit A 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.

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

North Fontaine has been used for late-season livestock grazing (2000- 2004) by two range agreement holders. The agreement holders graze 113 cow/calf pairs for approximately 27 days. Based on inventory work there is approximately 104 AUMS of available forage at North Fontaine (Skinner, Range Agrologist, BC Ministry of Forests, pers. comm., 2005).

2.1.3 Stoddart Creek North

Stoddart Creek North is located is the IDFun biogeoclimatic zone (Fig 2). Prior to treatment stem density was approximately 250 $stemsha^{-1}$ with a significant amount of conifer regeneration (~4000 $stemsha^{-1}$) (Fig 3). Soils at Stoddart Creek North are classified as Orthic Eutric Brunisols (Lacelle 1990).

25 plots were established at Stoddart Creek North in 1999. 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.

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). Prescriptions stated that approximately 275 $stemsha^{-1}$ 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 (*Ovis canadensis*). Slashing occurred at Stoddart in 2002 followed by a sloop burn in 2002. Post-treatment monitoring occurred at this site in 2004.

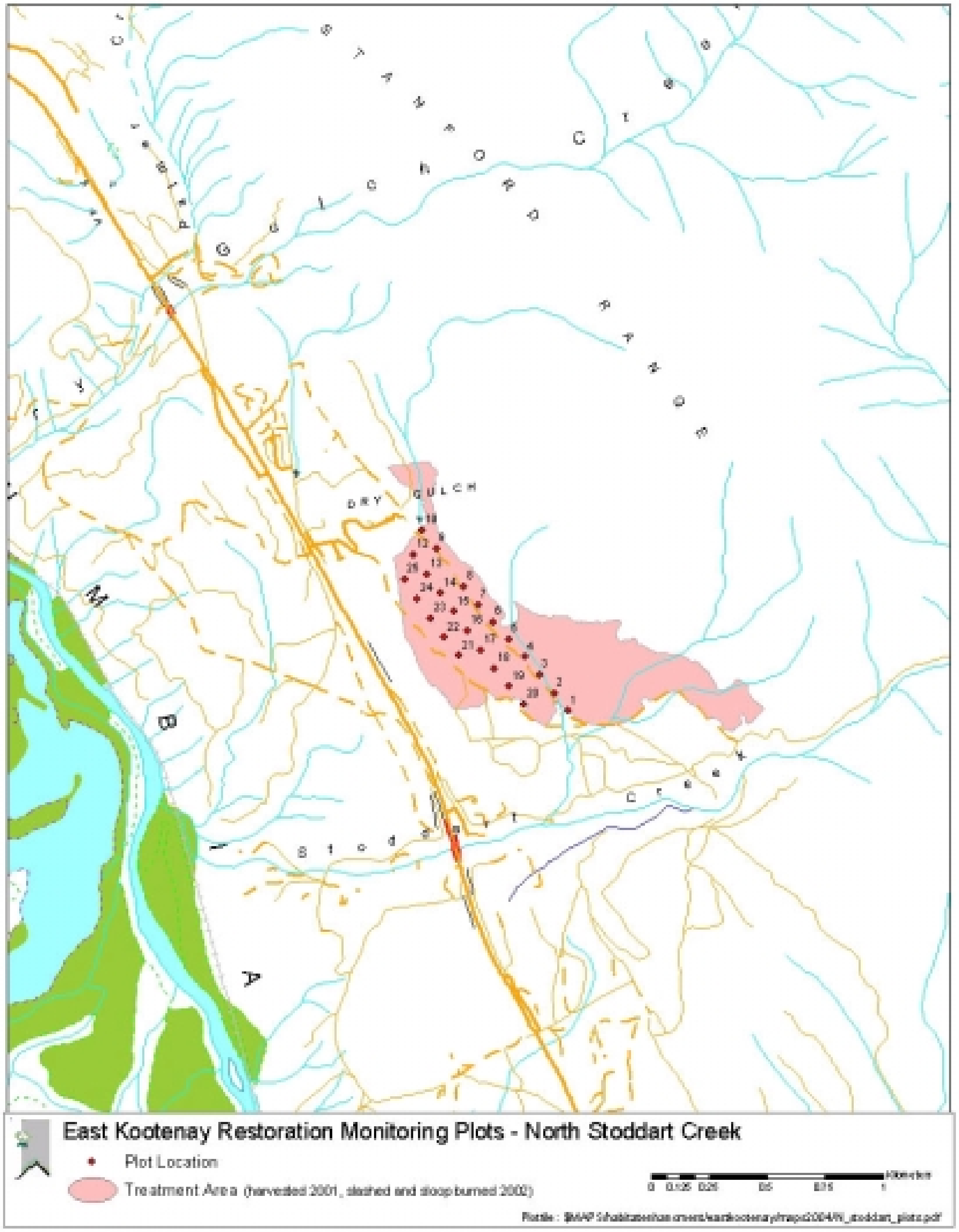

Figure 2. Stoddart Creek Treatment Site

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

Livestock grazing has been excluded from Stoddart North since 1970, grazing pressure is primarily from bighorn sheep, elk, and white-tailed deer.

3. Results and Observations

3.1 North Fontaine

Due to data collection methods, it was not possible to detect responses in each species observed at this site (i.e. data was only recorded when a species had greater than 5% cover). Comparisons were made for species of 'interest' (non-natives, desirable forage species) to more accurately characterize trends in plant community responses. Plots with less than 5% cover of a certain species were not included in these comparisons.

3.1.1 Overstory

Unit A

The pre-treatment overstory at North Fontaine 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 $stemsha^{-1}$; Stdev=308). In the first year post-treatment stem density was reduced to 91 $stemsha^{-1}$ (Stdev=99) but increased to 111 $stemsha^{-1}$ (Stdev=198) in 2004. The increase in stem density was largely due to an increase in aspen stems in one plot (3-10). There was no significant difference found in stem density found among years. There did appear to be some growth release at this site i.e. lack of competition from young conifers allowed for greater growth in the mature and veteran layer (Table 1). There is a lack of residual slash in the understory, indicating a high intensity burn.

Table 1. Average dbh (cm) of three overstory species in 1999 and 2004. DBH was determined in 5cm increments. Anything greater than 35cm was counted as 37.5cm.

	1999				2004			
Species	**live**	**n**	**dead**	**n**	**live**	**n**	**dead**	**n**
Douglas fir	25	118	n/a	0	35	50	32.5	2
Western larch	25.6	27	17.5	1	36	11	30	2
Ponderosa pine	31	11	27.5	2	35	11	37.5	4

A growth response is also evident in the distribution of diameter classes (Fig 4). Trees were grouped into eight 5cm dbh increments. Anything greater than 36cm was considered to be in class 8 (Class 1:0 – 5cm, Class 2:6 – 10cm, Class 3:11 – 15cm…Class 8:>36cm). There was a large increase in the number of stems in class 8 and class 3, otherwise the number of stems in a given diameter class declined (Fig 4). The increase in stems in class 3 is due to an increase in the number of aspen stems, which made up 100% of the stems in classes 1 through 4 (Fig 5). The post-treatment stand structure has no Douglas fir, larch or ponderosa pine stems in diameter classes 1 – 4 (Fig 5). These three species comprise 73 stems ha^{-1} in classes 5 – 8 (there is one aspen stem ha^{-1} in layer 5), with the greatest stems ha^{-1} being found in class 8 (46 stems ha^{-1}). There is approximately 7% mortality in layer 8, an increase from 0% in 1999.

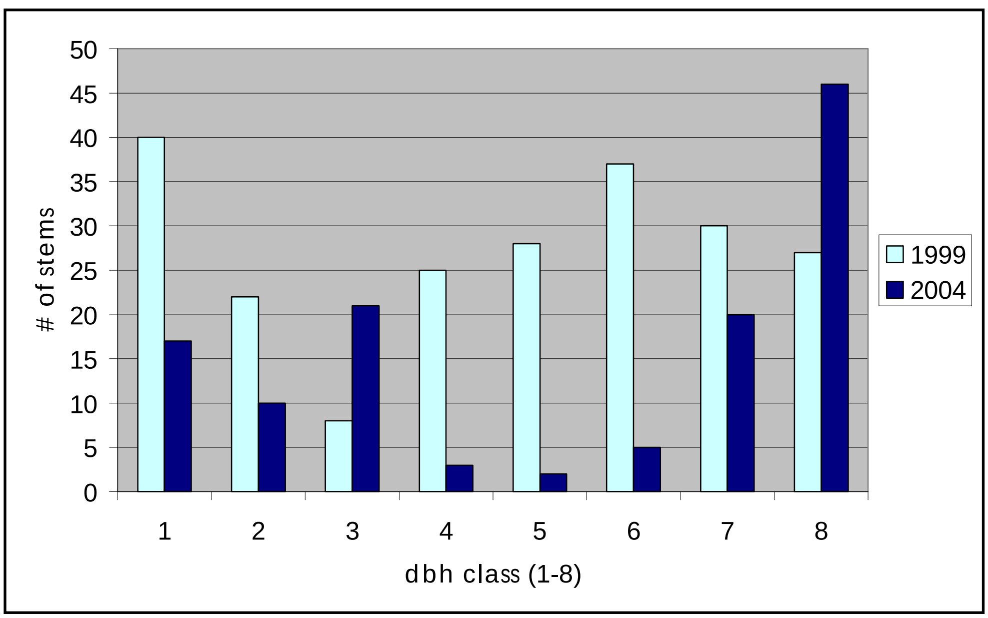

Figure 4. Stem diameter distributions for all stems at Bull River (Unit A) in 1999 and 2004.

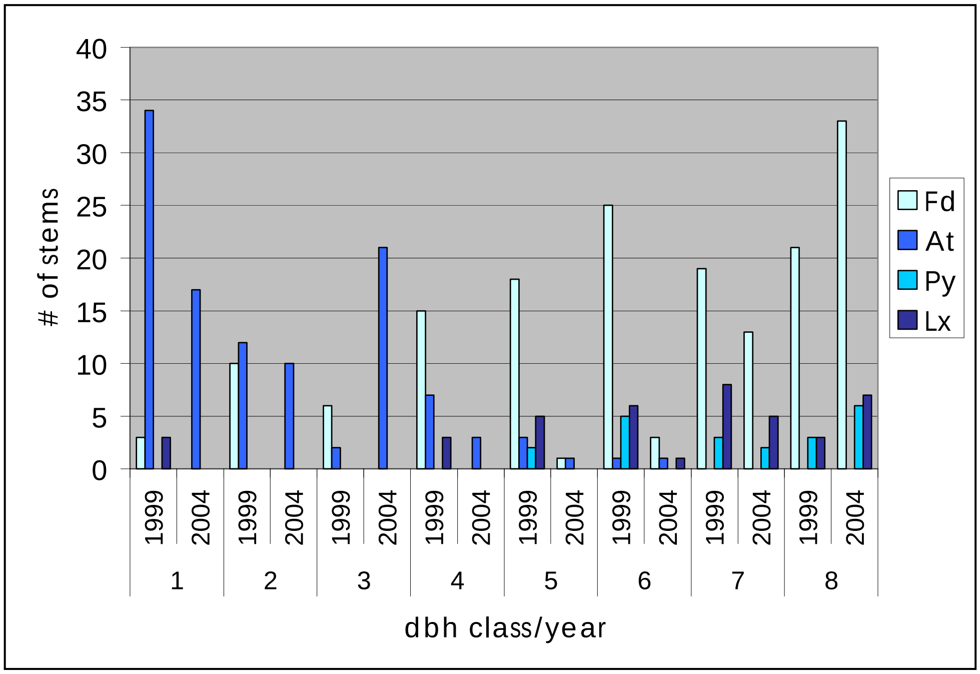

Figure 5. Number of stems grouped by species in the eight class dbh distribution.

There was a significant decline in the A layer cover (i.e. canopy cover) from 10.3%; Stdev=10.6 in 1999 to 4.7%; Stdev=5.3 in 2004 (p=0.02) (Table 2).

Unit B

Due to the open nature of Unit B (9 stems ha^{-1}) there was no need for mechanical treatment. All trees were in class 8 (>35cm dbh). There was no overstory mortality in 1999, whereas there were two dead ponderosa pine in 2004. Mortality was likely caused by prescribed fire.

3.1.2 Shrubs

Unit A

There was a significant difference found in cover (%) of the B1 layer between 1999 and 2000 (p=0.002) and 1999 and 2004 (p<0.0001) (Table 2). There was no significant difference found between years in the B2 layer although there was a general decline in shrub cover from 1999 to 2004.

Table 2. Average cover (%) for vegetation layers in Unit A at North Fontaine in 1999, 2000 and 2004

	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

In both the B1 and B2 layers, Saskatoon (*Amelanchier alnifolia* Nutt.) cover declined significantly from 1999 – 2000 ($p<0.0001$) and 2004 ($p=0.002$), although cover had increased slightly from 2000 to 2004 (Table 3). It is notable that in 1999 antelope brush made up >5% cover in 11 of 26 plots in 1999 and that it did not occur in any plots in 2000. Cover had recovered slightly in 2004, but was still significantly lower than in 1999 ($p=0.03$). It is the decline of these two dominant shrub species that has led to the lower cover of the B2 layer post-treatment.

Table 3. Average cover (%) of selected shrub species in Unit A at North Fontaine in 1999, 2000 and 2004. Cover was only recorded if the species had >5% cover in a given plot.

	1999		2000		2004	
Species	average	stdev	average	stdev	average	stdev
Saskatoon	18.9	10.3	7.8	7.4	10.3	8.2
Antelope brush	4.16	5.5	0	0	0.6	1.8

Unit B

Tall shrubs declined significantly in Unit B from 1999 to 2000 (Table 4; $p=0.02$). There was no significant difference found in B2 cover between years. The decline in tall shrubs was likely due to the loss of tall antelope brush and Saskatoon plants. When both B1 and B2 layers are combined Saskatoon cover did not appear to be affected by treatment (i.e. fire), whereas antelope brush declined significantly in 2000 (Table 6; $p<0.0001$) and then increased significantly in 2004 (from 1999) (Table 5; $p=0.001$).

Table 4. Average cover (%) for vegetation layers in Unit B at North Fontaine in 1999, 2000 and 2004. Cover was only recorded if the species had >5% cover in a given plot.

	1999		2000		2004	
Layer	average	stdev	average	stdev	average	stdev
A	n/a	n/a	n/a	n/a	n/a	n/a
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

Table 5. Average cover (%) of selected shrub species in Unit B at North Fontaine in 1999, 2000 and 2004. Cover was only recorded if the species had >5% cover in a given plot.

	1999		2000		2004	
Species	**average**	**stdev**	**average**	**stdev**	**average**	**stdev**
Saskatoon	8.2	9.6	7.8	8.0	8.2	8.2
Antelope brush	9.9	6.6	0	0	4.3	4.4
choke cherry	3.5	6.3	4.0	6.1	3.2	4.4

3.1.3 Forbs

Unit A

There was no significant difference found in forb cover between years (Table 2). One of the forbs contributing to cover in this layer is sulphur cinquefoil (*Potentilla recta* L.). Sulphur cinquefoil did not contribute greater than 5% of cover in any plots in 1999, but did so in one plot in 2000 and it was found in five plots in 2004 (at >5% cover). Sulphur cinquefoil was also found in 10 additional plots (contributing <5% cover).

Unit B

There was no significant difference found in forb cover between years (Table 4). There is concern about the presence of sulphur cinquefoil in Unit B. Sulphur cinquefoil increased from 0.8%; Stdev=2.3 to 1.8%; Stdev=4.3 in 2000 to 2.9%; Stdev=4.3 in 2004. The change from 2000 to 2004 was significant (p=0.04). There were no other forbs that showed a marked decline or increase in this Unit B.

3.1.4 Grass Layer

Unit A

There was a significant decline in grass cover from 1999 to 2000 (p=0.02) and 1999 to 2004 (p=0.01) (Table 2). Poverty oatgrass (*Danthonia spicata* L.) was the dominant pre-treatment grass in this vegetation layer. Oatgrass cover declined significantly from 12.8%; Stdev=15.1 in 1999 to 2.5%; Stdev=3.8 in 2004 (Fig 6, p=0.001). Despite a decline in the dominant grass species and in the grass layer, there was an observed increase in pinegrass (*Calamagrostis rubescens* Buckl.) from 1.1%; Stdev=2.8 in 1999 to 3.6%; Stdev=4.5 (cover was <1% in 2000) (Fig 6).

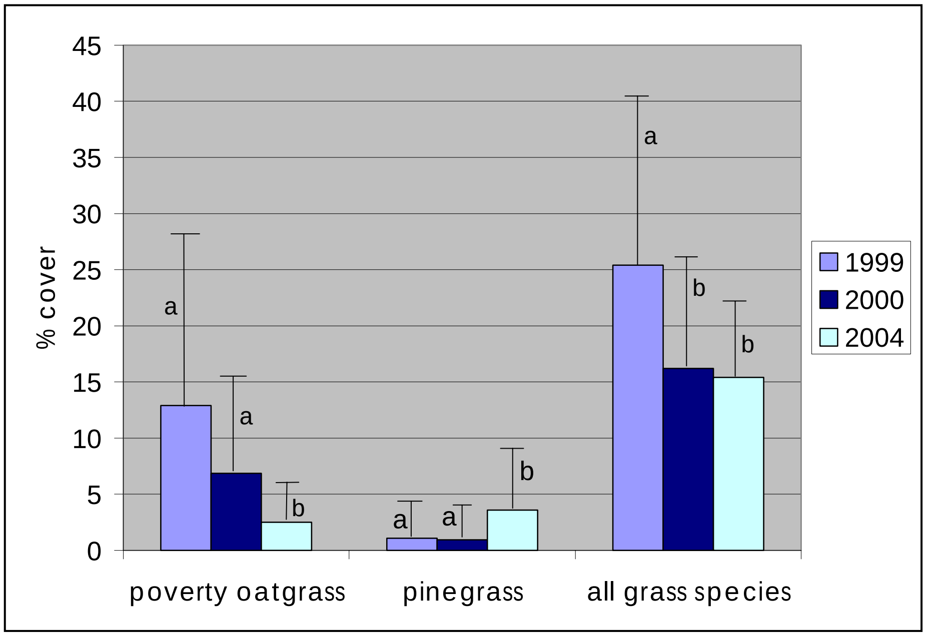

Figure 6. Average cover (%) of grass species pre- and post-treatment at Unit A, Bull River. Within a species means with different letters differ significantly (p<0.05).

Unit B

After prescribed fire, grass cover declined significantly in 2000 (Table 5; p=0.05). In 2004 however, grass cover was significantly higher than it was in 2000 (Table 5; p>0.0001), but not significantly higher than it was in 1999. This trend is reflected in the dominant grass, bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Löve). Bluebunch wheatgrass cover declined from 2.7%; Stdev=4.4 in 1999 to 1.8%; Stdev=3.2 in 2000 and then increased to 6.0%; Stdev=8.5 in 2004. The increase from 2000 to 2004 was considered significant (p=0.03).

3.1.5 North Fontaine Vegetation Response Summary

Overstory Layer

Overstory response to slashing and burning treatments in Unit A has been positive. Units A and B are good structural examples of a restored NDT4 stand. Stem density (111 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). There are also a small number of stems present in layers 5-7 available for recruitment of veteran trees at lower stem densities.

It appears that there has been a growth 'release' in this stand (i.e. the shift in dbh classes to the upper classes). Historic increases in density have resulted in decreased tree growth rates and increased mortality of veteran trees (Feeney et al. 1998). A possible mechanism behind the decline in growth rates could be the excessive competition between pre-settlement and post-settlement origin trees for limited resources, likely resulting in greater physiological stress (Arno et al. 2000, Feeney et al. 1998). In some cases, favourable physiological responses to thinning have resulted in increased radial growth (Della-Bianca and Dils 1960, Helvey 1975, Feeney et al. 1998).

The change in the stand structure at North Fontaine is beneficial to several red and blue listed wildlife species (Cooper et al. 2004), particularly cavity nesters.

Shrub Layers

Treatment (slashing and burning) has resulted in a significant decline in tall shrub species in both units. Recovery of this layer is a function of time and is expected to recover in the mid to long term. The B2 layer does not seem to have been adversely affected by restoration treatments, although certain shrub species are not as resilient as others. Differential responses of Saskatoon and antelope brush between treatment units highlights the effects of different treatments (i.e. fire versus mechanical treatment) and the physiological adaptations of these species to fire and disturbance.

Antelope brush is highly susceptible to fire kill. Plants will sprout from dormant buds above the root crown or from tissue beneath the bark. Very young (<5 years) and very old plants (40 – 60 years) do not sprout well (USDA 2003). Response to fire explains the significant decline in both units one year post-fire. Mechanical treatment (slashing of overstory and understory conifers) disturbance in Unit A has likely compounded the negative effects of fire and has slowed the response of this shrub species.

Saskatoon sprouts from the root crown and/or rhizomes after fire. Saskatoon is also able to sprout from rhizomes growing relatively deep in the soil, allowing this species to withstand higher intensity burns (USDA 2003). Although this species is adapted to fire, it is susceptible to mechanical treatments, as evidenced by the decline in cover at Unit A (Table 5). Page et al. (in press) found a significant inverse relationship between thinning intensity and Saskatoon density at both a PPdh 2 and IDFdm2 site in the East Kootenay Valley. 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).

Although there were no significant increases in cover, the shrub layer has largely recovered from treatments, especially in areas where mechanical treatment has not been applied (Unit B). Although treatments may not initially result in significant increases in cover and production (in fact, likely the opposite), Saskatoon and antelope brush require the open habitats (light) (Page et al. in press) created by restoration activities such as slashing and burning for continued vigor and growth. Maintenance of the shrub layer, particularly Saskatoon and antelope brush is essential for the continued support of wild ungulate populations that use North Fontaine pasture and Bull River.

Forb Layer

Forb cover in both units was not affected by restoration treatments. Although there are no detectable differences in the forb layer, sulphur cinquefoil cover is increasing. Increases in cover could be due to a number of reasons, including increased light, the plants' response to fire or overgrazing. There is little information available on this species' response to fire (USDA 2003). Sulphur cinquefoil is a pioneer species and is often found in early seral habitats (Powell 1996). Cover increases by sulphur cinquefoil could potentially be an indicator of early-successional habitat due to overgrazing or an indicator of excessive disturbance as a result of restoration activities. 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). This plant should be monitored closely to ensure spread does not continue.

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. This appears to be an increase from 2000, where only one patch was observed. Due to the patch size (small) and clearly defined borders several management options are available. 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

Unit A and Unit B have different pre-treatment dominant grasses in the understory and thus had varied responses to restoration activities.

The dominant grass species in Unit A in 1999 was poverty oatgrass. Poverty oatgrass is an indication of poor soil conditions. Its presence may indicate overgrazing or the prolonged absence of fire (USDA 2003). This species has not responded well to fire and slashing at Unit A. This may allow for greater spread of more desirable bunchgrasses (e.g. bluebunch wheatgrass). However, the one grass species observed to increase was pinegrass. Although pinegrass is shade-tolerant, there is no indication that 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.

Bluebunch wheatgrass in Unit B has responded well to prescribed fire. Bunchgrass communities are generally characterized as resilient to wildfire. In southwestern Alberta, with the exception of Parry’s oatgrass, foothills rough fescue and all other dominant grasses appeared to recover by the second year after wildfire (Bork et al. 2002). Although in the cited study forage production declined by 40% in the first year, it had recovered fully by the third year after fire. The authors concluded that this was likely due to loss of litter, or perhaps to the addition of soil nutrients from fire effects (Bork et al., 2002).

Due to more complex overstory-understory relationships and greater disturbance, Unit A may be slower to positively respond to restoration activities. Additionally, pre-treatment species composition differences i.e. greater presence of undesirable species necessitates a longer response time. However, in Unit B, bluebunch wheatgrass cover appears to have recovered to pre-treatment levels. Increasing cover also indicates enhancement of this species at this site.

3.2 Stoddart Creek North

Data collection was slightly varied at Stoddart Creek North (as opposed to North Fontaine) as each species’ cover was recorded regardless of whether it had greater than 5% cover. This enables comparisons among all species observed in the monitoring plots. Such comparisons were made as well as among vegetation layers (overstory, shrubs, forbs and grasses).

3.2.1 Overstory

Tree stem density data were originally collected in 10 dbh classes (5cm increments up to 50cmdbh). The ten dbh classes were consolidated into four classes to more closely match the current dbh class system being used in ecosystem restoration monitoring (Machmer et al. 2002) (Class 1= 0 – 5cm, Class 2= 5 – 15cm, Class 3= 15 – 30cm and Class 4= 30 – 50cm dbh).

Table 6. Stem densities (stems ha^{-1}) both pre-treatment (1999) and post-treatment (2004) at North Stoddart Creek.

	pre-treatment		post-treatment		
DBH class	**stems ha^{-1}**	**stdev**	**stems ha^{-1}**	**stdev**	**p<F**
1	3864	3659	1120	1152	0.001
2	60	41	3	11	<0.0001
3	136	151	25	33	<0.0001
4	50	35	35	32	0.14

Stem density has significantly declined in every layer except for layer 4 (Table 6). Canopy cover has also declined significantly from 9% to 5% (p=0.02; Table 7). The overstory was comprised of Douglas fir only.

3.2.2 Shrubs

Shrub cover declined significantly two years post-treatment (Table 7). There was not a developed B1 layer present, therefore, the B1 and B2 shrub layers were combined in analysis. The decline in shrub species does not appear to be due to any one species. The three most common shrubs in 1999 were Rocky Mountain Juniper (*Juniperus scopulorum* Sarg.) (3.22% cover), common snowberry [*Symphoricarpos albus* (L.) Blake] (3.42% cover) and baldhip rose (Rosa gymnocarpa Nutt.) (1.86%). In 2004 (two years post-treatment), the three most common shrub species were baldhip rose (1.56%), common snowberry (1.44%) and both Saskatoon and soopolallie [*Sheperdia canadensis* (l.) Nutt.] with 0.88% cover in the post-treatment stand (Rocky Mountain Juniper had 0.8% cover). There was no significant difference between Saskatoon or Rocky Mountain juniper cover in 1999 and 2004.

The decline in the shrub layer seems to be a generalized response of this plant community to the disturbance caused by the mechanical restoration treatment applied to this site.

Table 7. Average cover (%) of vegetation layers pre- and post-treatment at Stoddart Creek North

	1999		2004		
Layer	**average**	**Stdev**	**average**	**Stdev**	**p<F**
A	9	20	5	11	0.02
B	13.5	10.3	7.2	3.9	0.01
C forb	11.1	7.6	9.2	7.8	0.4
C grass	12.3	19	14.2	14	0.6

3.2.3 Forb Layer

The forb layer at Stoddart Creek North was not significantly affected by harvesting and slashing. Species composition did not vary either. Spikelike goldenrod (*Solidago spathulata* DC.) was the dominant forb both pre- and post-treatment. Goldenrod cover increased slightly in 2004 (1.6% - 2.5%), but this change was not considered significant (p>0.05).

Non-native species presence is not a current concern in this treatment block, although leafy spurge is well established in areas adjacent to this site. In 1999 (pre-treatment) there were two non-natives observed, white sweet-clover (*Melilotus alba* Desr.) and yellow sweet-clover [*Melilotus officinalis* (L.) Lam.]. Together they formed approximately 0.4% of the understory. In 2004 these species were not observed in the understory, although two non-natives, alfalfa (*Medicago sativa* L.) and perennial sow-thistle (*Sonchus arvensis* L.) were observed in 2004. These two species comprised approximately 0.2% of the cover at Stoddart Creek North.

3.2.4 Grass Layer

There was no significant difference found in grass cover between 1999 and 2004 (Table 7). However there was a change in species composition. In 1999, the three most abundant grass species (% cover) were quackgrass [*Elymus repens* (L.) Gould] (3.5%), Richardson's needlegrass (*Stipa richardsonii* Link.) (2.0%) and Junegrass (*Koeleria macrantha* (Ledeb. J.A. Schultes f.) (1.8%). In 2004, the three species with the greatest cover were bluebunch wheatgrass (3.8%), pinegrass (2.8%) and junegrass (1.5%).

It was noted that all bunchgrass species observed {(rough fescue (Festuca campestris Rydb.), junegrass, stiff needlegrass [*Achnatherum occidentale* (Thurber) Barkw. ssp. pubescens (Vasey) Barkw.. ex S. Wats. var. pubescens Maze, Tayor and MacBryde], short-awned porcupinegrass [*Hesperostipa curtiseta* (A.S. Hitchc.) Barkw.] and spreading needlegrass [*Achnatherum richardsonii* (Link) Barkw.]} declined slightly in 2004 except for bluebunch wheatgrass. Bluebunch wheatgrass cover increased significantly in 2004 (Fig 7).

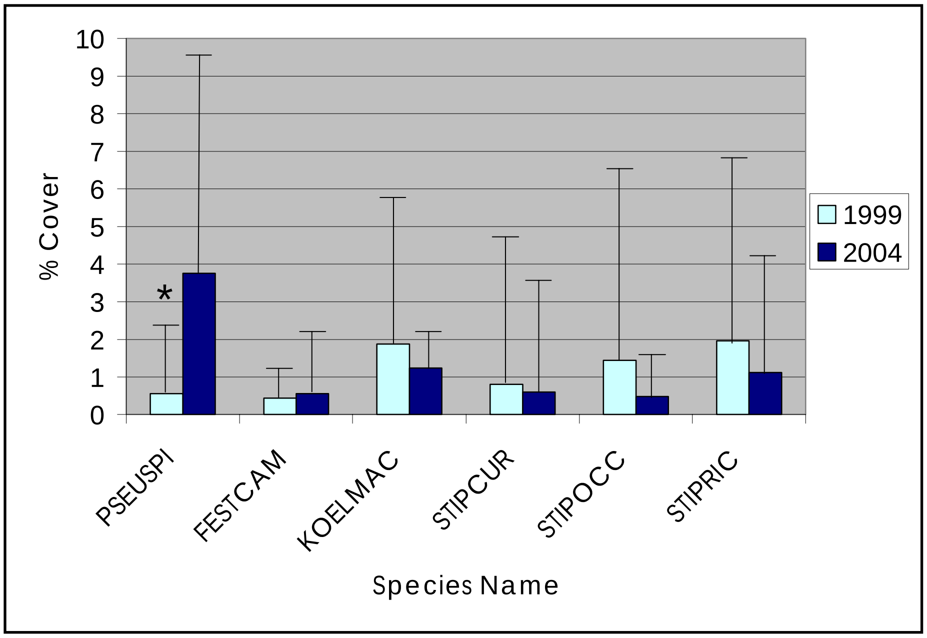

Figure 7. Average cover (%) of bunchgrass species pre- and post-treatment at Stoddart Creek North. Species codes are: PSEUSPI (bluebunch wheatgrass), FESTCAM (rough fescue), KOELMAC (junegrass), STICUR (porcupine grass), STIPOCC (stiff needlegrass) and STIPRIC (Richardson's needlegrass).

Pinegrass also had a large increase in percent cover from 1999 (0.2%; Stdev=0.6) to 2004 (3%; stdev=9). Pinegrass increase was significant in some plots (i.e. from 0 – 40%) but this response was localized. Due to the high variability in this response, the overall response was not significant.

3.2.5 Stoddart Creek North Vegetation Response Summary

Overstory Layer

The structural changes in the overstory have changed this site from an open forest site to an open range site, although it is on the upper limit of this classification (76 stems ha^{-1}). This assessment excludes the conifer regeneration layer. Although treatments have significantly reduced stems in the 0 – 10cm dbh class (Table 6), there is still well-developed conifer regeneration layer present (Table 6). Conifer regeneration is likely a function of the restoration prescription at this site. Harvesting in 2001 and slashing in 2002, although reducing young conifers, also likely 'released' a younger/shorter layer. Due to the lack of a broadcast burn, this layer is still present in the post-treatment stand. This layer should be managed prior to the stems becoming too large to easily burn or slash. Adjacent private properties will constrain management options at this site.

Shrub Layer

A well-developed shrub layer is not historically a defining characteristic of IDFun stand. The dominant pre-treatment shrub species are species typically found in more forested areas, thus the decline in shrub cover is not necessarily a negative result. It is likely species such as snowberry and rose will continue to decline and there will be slight increases in more light-dependent species, such as Saskatoon.

Decline in the shrub layer is likely a function of the mechanical treatment imposed at this site. Similar results were observed at an IDFdm2 in the East Kootenay Valley site two years post-treatment (Page et al. in press).

Forb Layer

The forb layer was not affected by harvesting and slashing at this site. There were no large changes in species composition either. The lack of significant negative change two years post-treatment implies disturbance was limited at this site. This is in contrast to an observed a 29% decline in the herb layer at PPdh2 site two years post-mechanical restoration (Page et al. in press), this response was largely attributed to disturbance caused by harvesting activities and drought conditions at the time.

Additionally there has been no significant increase in non-native species cover, also an indication of minimal disturbance. Disturbance caused by opening of the overstory generally favours early-successional species and possibly, exotics (Thomas et al. 1999, Thysell and Carey 2001).

Grass Layer

Given the relatively short response time since treatment the response of the grass layer has been positive, especially the increase in bluebunch wheatgrass (Fig 7 and Fig 8). In addition, the shift in species composition from quackgrass to bluebunch wheatgrass is an important indicator of restoration success in the short-term. Bluebunch is likely responding to the increased light and availability of resources freed by the reduction in the conifer regeneration layer. The lack of a uniform pinegrass cover prior to treatment likely prevented this species from increasing significantly. The positive response of bluebunch wheatgrass and lack of response in the grass community is another indication of minimal disturbance at this site. Page et al. (in press) observed a significant decline in bunchgrass production at a PPdh2 site two years post-mechanical restoration (summer harvesting). Declines in production were attributed to disturbance as a result of restoration activities.

It is possible that harvesting during the winter months is partially responsible for the favourable responses in the understory. Winter-harvesting results in decreased soil compaction levels thus leading to better plant responses.

Figure 8. An example of bluebunch wheatgrass response at Stoddart Creek North. Photograph taken in 2004.

4. Management and Further Monitoring

4.1 North Fontaine

Treatment of Unit A at North Fontaine has created a desirable stand structure for an open forest site in the NDT4, this is in contrast to the response in the understory. More time is needed to assess the effects of restoration on the shrub, forb and grass layer at Unit A, as there have been undesirable changes in the plant community. Of primary concern is the decline of antelope brush and the increase in sulphur cinquefoil and Dalmatian toadflax. Additionally, the grass layer has not recovered to pre-treatment levels or one year post-treatment levels. As equally important to the treatment prescription is post-restoration management. This includes managing livestock grazing and the spread and presence of noxious/nuisance weeds management. Grazing has occurred at this site every year since restoration. Due to limited forage availability after the fire, grazing may have slowed the vegetation response as well contributed to the spread of sulphur cinquefoil. Intensive livestock management (i.e. limiting stocking rate and duration) is needed at this site to ensure further changes in the plant community move the site closer to the desired state (i.e. greater presence of native bunchgrasses and decreased sulphur cinquefoil). Intensive livestock management may include re-calculating available forage to ensure grazing pressure is appropriate for the site given the topography and location of water sources. Additionally, a integrated noxious weed management plan should be developed for this site including intensive (hand-pulling) and extensive (limiting grazing) management prescriptions.

Response of desirable forage and browse species in Unit B such as bluebunch wheatgrass and antelope brush has been generally positive. Initial declines in cover are expected initially post-treatment, but the understory is exhibiting signs of significant recovery. The significant increase in Saskatoon and bluebunch wheatgrass from 2000 to 2004 is an indicator that the objectives of restoration (to maintain or increase fire-adapted native understory vegetation in treated areas) will eventually be achieved. Due to the topography of this site (steep slopes), livestock grazing is not as large a management factor.

Minimizing spread of non-native species should be a priority at this site. Of concern in this block is the continued expansion of sulphur cinquefoil and Dalmatian toadflax. The proximity of this block to adjacent weed infestations makes this a difficult task.

In general, restoration has had a positive effect on stand structure at both sites. The understory in the open range unit has also responded well (Saskatoon and bluebunch wheatgrass cover). Understory changes in the forested unit should continue to be monitored to ensure current trends do not continue.

Recommendations include:

- Immediate treatment of the three known Dalmatian toadflax patches (UTMS: 0615405/5484837; 0614553/5485114; 0614475/5485273).
- Adjust stocking rates to relieve grazing pressure.
- Monitoring sulphur cinquefoil cover and Dalmatian toadflax patches in the short term (1-2 years). Plots could be re-marked at this time.
- Monitoring all plots in year 10 (2010) as recommended by Machmer et al. (2001).

4.2 Stoddart Creek North

Initial observations (2 years post-treatment) indicate that Stoddart Creek North has responded well to restoration treatments. The response of bluebunch wheatgrass at this site, the lack of non-native species cover and the significant declines in stem density all contribute to achieving the three restoration objectives outlined in Section 2.

Recommendations include:

- Monitoring all plots in year 5 post-treatment (2007) as recommended by Machmer et al. (2001) to assess further trends in the plant community;
- Prior to, or in year 5 post-treatment, conifer regeneration should be managed for, either by burning or slashing.

6. Conclusion

North Fontaine 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.

Interpretation of results observed in this project must be tempered by the presence of drought. During the growing season of 2001 to 2003 summer rainfall was 25% - 45% of the long-term average. Unfortunately, due to the lack of spatial controls, the effects of drought cannot be isolated. However, environmental conditions need to be considered in the context of restoration, particularly post-restoration management (e.g. livestock grazing).

Table 8. Vegetation cover changes at all restoration sites (North Fontaine, Unit A and Unit B and Stoddart Creek North). Arrows indicate significant increases (↑), significant declines (↓) and no significant change (→)

	Bull Mountain		
Layer	**Unit A**	**Unit B**	**Stoddart Creek North**
A	↓	→	↓
B1	↓	↓	↓*
B2	→	→	↓*
C_{grass}	↓	→	→
$C_{bunchgrass}$	→	↑	↑
C_{forbs}	→	→	→
$C_{non\text{-}natives}$	→	↑	→

*B1 and B2 layers were combined for assessment at Stoddart Creek North, thus the significant decline in cover is for all shrubs.

Restoration (mechanical and prescribed fire) has had a generally positive effect on the overstory and understory plant community at both these sites (Table 8).. Non-significant changes can also be considered positive, given the disturbance caused by restoration activities. The exception is the understory response in the forested unit of Bull River, otherwise, the overstory, forb and grass layers have benefited or been unaffected by restoration treatments. Where cover has declined and is not showing signs of recovery, a longer-term assessment is needed, especially in areas where mechanical treatments have been applied. Management issues, such as the presence of non-native species at Bull River and prescribed fire risk at Stoddart Creek, highlight the issues land managers face when undertaking restoration of dry forest ecosystems. It also highlights the need for adaptive management. It is intended that monitoring guide adaptive management efforts in ecosystem restoration efforts to ensure the objectives of ecosystem restoration are being met.

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

Folder/File Name	Description
FMER/Bull River/vegetation data base'04 (99-04).xls	Includes all vegetation layer measurements (understory and overstory). Includes 1999, 2000 and 2004 data
FMER/Stoddart/vegetation data base'04 (99-04).xls	Includes all vegetation layer measurements (understory and overstory). Includes 1999, and 2004 data

Appendix 2. Scanned photos (RW-CD format)

Appendix 3. Stand prescriptions for Stoddart North and North Fontaine Range Units