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Conservation and Restoration of Northwest BC Grasslands

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Summary

Grasslands of BC are among the most endangered ecosystems in Canada. Although they occupy only 1% of BC's land base they provide critical habitat for a variety of plants, mammals, birds, reptiles and insects. In northwest BC, mild wet summers, fire suppression and changes in grazing and browsing pressure have reduced grassland area and range quality or condition through shrub and tree encroachment. The goal of this report is to outline the condition of some northwest BC grasslands and to report on the impacts and effectiveness of restoration treatments on their vegetation communities.

Six grassland sites in the southern Skeena region between Smithers and Burns Lake were selected to compare and monitor the effects of three restoration procedures. Grassland monitoring was carried out over a six-year time period starting in 2001 and continuing to 2007. One site was broadcast burned, one was manually brushed, and one site received combinations of burning and brushing. Three sites remained untreated in 2007. Woody plant % cover, herbaceous plant % cover, graminoid (grasses & sedges) % cover, non-native plant % cover and Shannon's diversity index were used as indicators to monitor grassland condition. In spring 2008, we also counted cervid (deer, moose, elk) pellet groups at all sites shortly after snowmelt.

Woody cover did not increase significantly region-wide from 2001 to 2007, while herbs, graminoids and species diversity were more abundant on untreated grasslands in 2007 than in 2001. Non-native species were more abundant in 2007 (3% cover) than in 2001 (1% cover; $p = 0.04$). Relative to total herbaceous cover, however, the increase was not statistically significant ($p = 0.38$), and appears to reflect a greater overall lushness of herbaceous vegetation in 2007 than in 2001 rather than deteriorating grassland condition. Timothy, dandelion, Kentucky bluegrass and smooth brome were the dominant non-native species on the monitoring plots – which do not include roads or other severely compacted and disturbed soils prone to weed invasion.

Burning and manual brushing, at two sites each, decreased woody cover by 30-40% but there was no corresponding increase in herb or graminoid cover or in species diversity, beyond that observed on untreated grasslands. There was no evidence, at our single site, that combination treatments increased plant response over burning or manual brushing alone. None of the restoration treatments caused a significant increase in non-native plant cover.

All sites were well-used by deer (160 – 1357 pellet groups per hectare). Three sites were well-used by moose (216 – 332/ha in 2007) and one elk pellet group was found. To date, we were not able to detect any preferential use of treated grasslands.

We recommend that field-based monitoring continue over a longer period and larger number of sites to differentiate local and short-term variability from larger trends. Field monitoring should also be complemented by aerial photo inventory to assess changes in grassland area and habitat fragmentation. Manual cutting and spreading of brush prior to burning should be tested as a means to increase burn severity and allow more frequent burns on the same site. Brushing should be discontinued on some treatment plots to determine whether annual brushing has any lasting effect on grassland condition.

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Acknowledgements

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Contents

List of Figures

List of Tables

Introduction

The Grassland Conservation Council of British Columbia has identified BC's grasslands as some of the most endangered ecosystems in Canada. Although they occupy only 1% of BC's land base, they provide critical habitat for a variety of plants, mammals, birds, reptiles and insects (GCCBC 2004; Gayton 2004). It is documented that grasslands contain 30% of BC's threatened and endangered species (Gayton 2004). For these reasons it is pertinent to take necessary measures to maintain and restore these highly valuable ecosystems.

When one thinks of grasslands, BC's southern interior is the first thought that may come to mind; however, BC grasslands extend north to the Yukon Border with evidence suggesting that dry low elevation grasslands were originally fairly common in west central BC (Pojar 1982; Haeussler 2006). In the southern Skeena Region, most grasslands occur in the dry cool subzone of the Sub-boreal Spruce biogeoclimatic zone (SBSdk), but some also occur in the moist cold subzones of the SBS (SBSmc) and Interior Cedar Hemlock biogeoclimatic zones (ICHmc) (Banner *et al.* 1993). Native grasslands may not cover a large area (Table 1), but they do provide critical habitat for many wildlife species such as mule deer. Many of these grasslands are endangered and red-listed by the BC Conservation Data Centre (CDC 2008).

Table 1. Grassland statistics (GCCBC 2004)

Region	**Grasslands (ha)**
Southern Skeena Region	18 384
Ecosection	**Grasslands (ha)**
Bulkley Basin	15 581
Bulkley Ranges	380
Nechako Uplands	783
Biogeoclimatic Unit	**Grasslands (ha)**
SBSdk	12 692 (1.5 %)
SBSmc2	4 752 (0.3 %)
ICHmc2	59 (0.02 %)

Historically, these grassland ecosystems were primarily maintained by both natural and anthropogenic burning (Haeussler 1998); however, with the suppression of wildfires, land development, disturbance and fragmentation, wetter climates and changes in grazing pressures most of these grasslands are deteriorating in size and condition. The remaining grasslands are experiencing encroachment by shrubs, aspen and other trees, as well as invasions of non-native species. Ecosystems such as the red-listed saskatoon-slender wheatgrass (SBSdk/81) and bluegrass-slender wheatgrass (SBSdk/82) are of particular interest as these dry, south-facing valley-bottom ecosystems have exceptionally high value for wildlife, especially in winter and early spring.

In 2001, five sites (Call Lake, Colleymount, Dieleman, Hubert Hill and Summit Lake) in the SBSdk subzone of the Nadina and Skeena-Stikine Forest Districts were selected for a grassland restoration study (Veenstra and McLennan 2002). In 2007 funding was made available through the Habitat Conservation Trust Fund for remeasurements of the sites established in 2001, while BC Parks funded the addition of a sixth site at Red Hills (de Groot 2008). At each site, a grassland monitoring plot or set of linear transects was established and intensively sampled to describe baseline conditions prior to the restoration process. In 2002, 2005, 2006 and 2007 repeated treatments, including prescribed burning, manual cutting, girdling and a combination of burning and cutting were completed on three of the five sites. After each treatment, all sites were remeasured using woody, herbaceous, graminoid (grasses & sedges) and non-native plant percent cover and plant species diversity as indicators of grassland condition. The goal of this report is to outline the condition of these northwest BC grasslands and to report on the impacts and effectiveness of the restoration treatments on their vegetation communities.

Background Information

Forest Encroachment onto the Grasslands of the Southern Skeena Region

With the absence of fire and changes in climate and land use practices, grasslands within the forested zones of the southern Skeena Region are becoming gradually overgrown with trees and shrubs (Pojar 1982, de Groot and Armitage 2007; Figure 1). On southwest-facing slopes fires occur more frequently and are more variable in size, seasonality and severity than in the surrounding forested landscapes (Haeussler 2000). In the past, burning was used extensively by aboriginals to prevent forest encroachment in order to maintain browse for ungulates and encourage herb growth (Blackstock and McAllister 2004). Herbivores play a key role in preventing tree and shrub encroachment. They also maintain grassland diversity through grazing pressure, redistribution of seeds and exposing mineral soil (Haeussler 2000).

Figure 1. Call Lake aspen growth within monitoring plot

Forest encroachment onto grasslands changes forage species composition, decreases forage production and reduces forage quality (Veenstra and McLennan 2002). In a recent report Grant et al. (2004) found that even nominal increases in woody vegetation compromise the use of grasslands by bird species. Occurrence of woodland-sensitive species declined rapidly as woodland cover increased to only 5-20% and more species were negatively impacted as woody-plant height increased from brush to tall shrubs and trees. The loss of grasslands may bring about a decrease in biodiversity, as grasslands support an array of species, both plant and animal (Veenstra and McLennan 2002). It has been documented that openings, whether they are grasslands or meadows, will generate four to five times the herbaceous production and plant richness of the nearby forest interior (Moore and Huffman 2004).

Along with burning and herbivore grazing pressure, climate also plays an important role in grassland production. Over the last few decades the climate in northwest BC has been warmer in the winter and wetter in the summer (Haeussler 2007). Because moist conditions reduce summer fires and encourage tree and shrub growth, it is believed that this milder and wetter climate has increased the woody species cover creating smaller grasslands with higher shrub cover (Haeussler 2007).

Rationale for Grassland Monitoring and Restoration

Anecdotal reports of deteriorating grassland condition due to tree and shrub encroachment have been common among First Nations, ranchers and wildlife advocates throughout the southeast Skeena Region since at least the 1980s, and probably much earlier (Gottesfeld 1994; Bob Fowler and Don Russell BC Ministry of Forests and Range, Herb Green, Northwest Wildlife for the Future, pers. comm. at various dates). Comparisons of historical and recent aerial photographs for the Summit Lake area (O'Byrne 2000) and Uncha Mountain –Red Hills Park (de Groot and Armitage 2007) showed an estimated 40 - 75% decrease in grassland area since 1949.

The provincial Ecological Reserves and BEC programs began describing and classifying rare grasslands of northwest BC in 1974 and immediately identified a need for their conservation (Krajina and Pojar 1974; Haeussler 1980; Pojar et al. 1984; Banner et al. 1993). Haeussler (1998; Haeussler and Hetherington 2000) conducted the first inventory of red-listed grasslands in the southern Skeena Region, recommending the establishment of a system of large and small reference areas and the initiation of ecosystem restoration trials. The first formal field-based monitoring of grassland condition began in 2001, when Veenstra and McLennan (2002) established six 1 hectare unfenced grassland monitoring plots between Kispiox and Burns Lake, adopting the provincial Range Reference Area monitoring protocol (Gayton 2003). This report summarizes the results of the first comprehensive remeasurement and analysis of the 2001 monitoring plots, and (other than Veenstra and Haeussler's (2002) 1- year report for a single site) represents the first formal documentation of vegetation changes in Skeena Region grasslands based on repeated sampling.

Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability (SER 2004). Grasslands are uniquely sensitive to changes in land use, and have been the focus of ecosystem restoration efforts since the earliest days (Packard and Mutel 2005) Prescribed fire has long been a preferred tool for restoring grasslands subject to tree and shrub encroachment because most grasslands, including those of the southern Skeena Region, are well adapted to wild and anthropogenic fire (Pyne 1995; Gottesfeld 1994). Historically at least, large areas could be burned at little cost. With urban development, land fragmentation and changes in grazing patterns and fuel loads, interagency and stakeholder politics, the risks, difficulties and costs of burning have skyrocketed, particularly in regions where fire suppression has been the norm and regular grassland burning is no longer part of the local culture (see, e.g., Gottesfeld 1994; Hansen 2007). In these situations, brushing techniques such as tree girdling, brushsaw cutting, and manual cutting with hand tools are often employed either as a stand-alone technique for removing woody material or as a fuel preparation technique to increase the efficacy and reduce the risks of subsequent burns (Neal and Anderson 2009). The applicability of these and other grassland ecosystem restoration techniques to red-listed grassland ecosystems of the southern Skeena Region was thoroughly reviewed by Veenstra and McLennan (2002). Their report recommended spring prescribed burning of each of the six study areas and manual techniques for localized applications where burning was either too difficult or two risky. BC Ministry of Forest and Range began to follow-through on these recommendations on range tenures in spring 2002 (Veenstra and Haeussler 2002) with BC Parks following in 2005 (Glover and Haeussler 2005), but implementation has been intermittent due to staff changes and budgetary constraints.

Site Descriptions

Call Lake

The Call Lake study site is located 4.3 km east of Smithers, BC in Call Lake Provincial Park. Call Lake Park is 62 ha in size and supports a mosaic of ecosystems including forested and non-forested wetlands, coniferous and deciduous forest with pockets of grasslands, aspen woodlands (SBSdk/Atss; Williams *et al* 2001) and scrub-steppe ecosystems. Transects were placed in a complex of saskatoon-slender wheatgrass scrub-steppe ecosystems (SBSdk/81) dominated by low growing saskatoon with a variety of grasses and forbs and in grassland/aspen woodland ecotones dominated by trembling aspen and snowberry (Haeussler and Glover 2005, Figure 2).

Figure 2. Call Lake monitoring plot

Colleymount

The Colleymount site is located approximately 44 km from the town of Burns Lake, BC on the north shore of Francois Lake. Its southeast- to southwest-facing slopes are made up of grasslands, bedrock outcrops, colluvial shrub patches, aspen patches and lodgepole pine stands (Veenstra and McLennan 2002). The monitoring plot falls within an intricate mix of saskatoon-slender wheatgrass scrub-steppe (SBSdk/81) ecosystems and bluebunch wheatgrass-slender wheatgrass steppe (SBSdk/82) ecosystems with aspen stands in the draws and on the benches where it encroaches on the scrub-steppe ecosystems (Veenstra and McLennan 2002).

Dieleman (Grouse Mountain)

The Dieleman site is located on Grouse Mountain approximately 41 km east of Smithers, BC near the bottom of Hungry Hill. Grouse Mountain consists of south and southwest-facing slopes that hold a complex of bedrock outcrops, steep colluvial slopes, grasslands and aspen forests (Veenstra and McLennan 2002). Scattered throughout this complex are pockets of hybrid spruce and lodgepole pine stands. The monitoring plot is situated on a southwest facing slope composed of saskatoon-slender wheatgrass scrub and steppe ecosystems (SBSdk/81), aspen stands in draws and gullies with encroachment into the scrub-steppe grasslands, rocky outcrops and steep colluvial slopes (Veenstra and McLennan 2002).

Hubert Hill (Toodienia)

The Hubert Hill (Toodienia) site is located at the junction of Hubert Road and Highway 16, approximately 5 km southeast of Telkwa, BC. The property on which the site is located was purchased by the Habitat Conservation Trust Fund for conservation purposes in 1997. The Hubert Hill slopes are composed of grasslands, juniper savannas and aspen woodlands (Veenstra and McLennan 2002). The monitoring plot consists of a complex of saskatoon-slender wheatgrass steppe (SBSdk/81), saskatoon-slender wheatgrass scrub-steppe (SBSdk/81), encroaching aspen stands from the benches and gullies and juniper savanna (Veenstra and McLennan 2002, Figure 3).

Figure 3. Hubert Hill monitoring plot

Red Hills (Uncha Mountain - Red Hills)

The Red Hills site is located on the southwest side of Francois Lake, approximately 30 km south of Burns Lake, BC on Highway #35. The plot falls in the Uncha Mountain - Red Hills Provincial Park established in 2001. The south-facing slopes of Red Hills are covered with a mosaic of grasslands, scrub-steppe ecosystems and deciduous and coniferous forests. The plot was placed in the saskatoon-slender wheatgrass scrub-steppe (SBSdk/81) ecosystem on steep colluvial veneers (de Groot 2008). Kinnikinnick is more prominent than typically found on the SBSdk/81 but the site and other vegetation features are consistent with the SBSdk/81 classification (de Groot 2008). Saskatoon is co-dominant with kinnikinnick while other shrubs such as common juniper, snowberry, pin cherry and Rocky Mountain juniper are also present (de Groot 2008).

Summit Lake

The Summit Lake site is located approximately 20 km northwest of Houston, BC near Grouse Mountain. Summit Lake consists of scrub-steppe ecosystems, rocky outcrops and steep colluvial slopes, patches of exposed soil, and at the crest of the hill lodgepole pine stands (SBSmc2/02) (Veenstra and McLennan 2002). This monitoring plot is positioned on a small hill composed of saskatoon-slender wheatgrass scrub-steppe (SBSdk/81) and aspen-forested lower slopes.

Tenas Hill

Tenas Hill is a prominent hill in the Kispiox Valley, approximately 13 km north of Hazelton, BC on Highway #62. South- and southwest-facing slopes support a mosaic of ecosystems including scrub-steppe, bedrock outcrops, colluvium and aspen stands (Veenstra and McLennan 2002). The Tenas Hill plot encompasses saskatoon-slender wheatgrass scrub-steppe ecosystems (SBSdk/81), aspen- and tall-shrub communities and patches of colluvium (Veenstra and McLennan 2002). In 2007, Tenas Hill was not included in the study due to access issues, so data from this site were not used for analyses in this report.

Methods

Experimental Layout and Treatments

In May 2001 Colleymount, Dieleman, Hubert Hill, Summit Lake and Tenas Hill sites were selected and established by Oikos Ecological Services Ltd (Veenstra and McLennan 2002). Call Lake was established in July 2005 by Skeena Forestry Consultants (Haeussler and Glover 2005) and in August 2007 Red Hills was established by Skeena Forestry Consultants and Drosera Ecological Consulting (de Groot 2008).

All sites were established and monitored following the guidelines set out by Gayton (2003), with minor variations at Call Lake, Red Hills and Summit Lake. Plots were laid out in a one-hectare area with ten 100 m line transects each spaced ten meters apart (Figure 4). Along each transect, ten 20 cm x 50 cm Daubenmire plots were located randomly at selected distances. Call Lake was set up with five 100 m linear transects placed parallel to the ridge top. Each transect at Call Lake was divided into two 50 m sub-transects (e.g., Transect 1-1, 1-2 to Transect 5-1, 5-2). Red Hills consisted of five 100 m transects within a 0.5 ha area and Summit Lake had ten 100 m transects each placed six meters apart. All transects had ten randomly selected Daubenmire plots (see Appendix I for details).

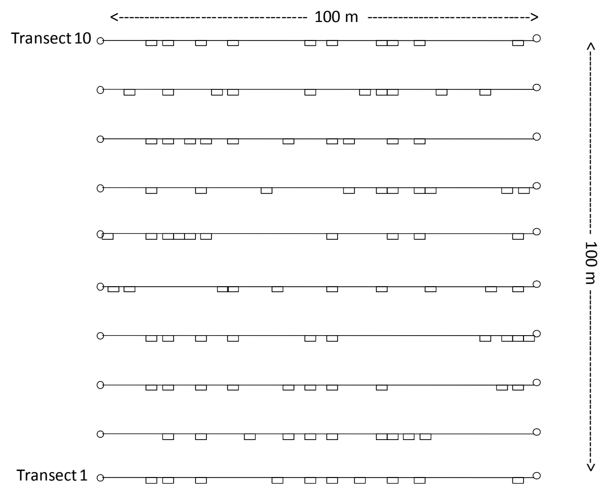


Figure 4. Layout of one-hectare monitoring plot showing 100 m transects and ten randomly-located 20 cm x 50 cm Daubenmire plots per transect (after Gayton 2003).

Each line transect was marked with a metal peg at the beginning and end while Daubenmire plots were marked with two six-inch corner nails and a piece of flagging tape. The U-shaped Daubenmire frames were positioned with the open arms of the frame pointing downslope (Figure 5). Upon returning in 2007 Daubenmire plots were re-located and re-marked, as necessary. If the marking nails could not be located, the Daubenmire frame was placed at the meter mark where the nail should have been. If only one marking nail was located, the frame was placed toward the 100 m end of the transect and a new nail was added and flagged.

Three sites received restoration treatments after their establishment. The Dieleman plot was broadcast burned on May 15, 2002, Hubert Hill was broadcast burned on March 29, 2005, then five 20 m x 25 m subplots were randomly selected and brushed on June 2, 2005, June 19, 2006 and July 31, 2007. Call Lake had one randomly selected 50 m sub-section of each transect brushed in August 2006 and July 31, 2007 (Appendix I).

Data Collection

Vegetation data were collected at all sites following establishment. For sites that were established in 2001 and did not receive restoration treatments, data were not collected again until June and July of 2007. For sites that did receive treatments, data collection varied depending on the treatment dates and the funding available. At Dieleman and Hubert Hill, burn severity was recorded on all Daubenmire plots shortly after the burn (methods in Veenstra and Haeussler 2002). At Dieleman, vegetation data were collected one month after the 2002 burn and again in June, 2007. Hubert Hill vegetation data collection occurred in August 2005, four months after the burn, which was also one month after the manual brushing treatment; however, only Daubenmire plot data were collected.

Data were collected again in June 2007. Call Lake data were collected upon establishment in 2005 and then again in June of 2007, one year after the brushing treatment (see Appendix I for details). In 2007 data from five transects and 50 Daubenmire plots only were collected from each of the six sites. At Red Hills establishment data were collected in 2007 and these are reported in de Groot (2008).

Along the transects, woody plant cover was recorded using the line intercept method (Habitat Monitoring Committee 1996; Gayton 2003). Dwarf woody shrubs (BC MoELP and BC MoF 1998) were not recorded on line transects except at Red Hills where kinnikinnick (Arctostaphylos uva-ursi) was included because it was the dominant woody plant. Any tree or shrub that intersected the tape was recorded, by species, along with the start and stop locations of the interception. In the Daubenmire plots, all species (and substrates) including mosses, herbs, and shrubs or trees less than 100 cm tall, were recorded and the percent cover of each species was visually estimated using foliar cover estimates (Gayton 2003, Figure 5). Species with less than 1% cover were estimated to the tenth of a percent, those with 1-30% cover were estimated to the percent, and species with greater than 30% cover were estimated to the nearest five percent.

In April 2008, immediately after snowmelt, cervid pellet groups were counted in a 5 m wide band centred on five 100 m transects per site (including Red Hills). Pellets were identified as deer (mule deer + whitetail deer), moose or elk, and as old (non-shiny, weathered and/or covered by vegetation and litter) or new (shiny or moist, unweathered, not covered by vegetation or litter). A minimum of 5 pellets was needed to constitute a pellet group. Pellets were collected and removed from the monitoring plot.

Figure 5. Hubert Hill line transect and Daubenmire plot collection

Data Analysis

Although there were six study sites spread across the southeast Skeena Region, not all sampling dates were available for all study sites and not all of the sites received the same, or any, restoration treatments. In fact, two sites were burned (Dieleman and Hubert Hill), two sites received manual brushing (Hubert Hill and Call Lake), and only one site had a combination of burning and manual brushing on the same subplots (Hubert Hill). Thus, although the study sites represent a well-replicated representative sample of the SBSdk dry grasslands, the gaps in the dataset limit the scope of inference of results. We can make reasonable inferences about region-wide changes in grassland condition on untreated sites from 2001-2007, but the scope of inference for the results of restoration treatments is much narrower. We can only report site-specific results, rather than region-wide results for the effectiveness of burning or manual cutting.

Because plots and transects were sampled sequentially over a series of years we used repeated measures ANOVA as a statistical test for plant percent cover (woody species, herbs including graminoids, graminoids (grasses and sedges) only, and non-native plants) and Shannon's diversity index. Each response variable was examined for normality and natural log or square root transformations were carried out as needed prior to ANOVA and T-tests. For region-wide analysis we looked at untreated plots in 2001 and 2007 to see how the vegetation responded when left untreated. We excluded Call Lake (established 2005) and Red Hills (established 2007) from the 2001-2007 region-wide analysis.

All woody vegetation cover results were taken from the line transects and all other indicator variables were taken from the Daubenmire plots. For the region-wide analysis all Daubenmire plots from a study site were pooled to produce an average percent cover for the whole site; this was also done for woody cover on the line transects. Since only five line transect were done at each site in 2007, only data from these same transects (and Daubenmire plots) were used for the analysis. For the analysis of individual study sites, each line transect and each Daubenmire plot was treated as a separate treatment unit. Each study site has an analysis of plant cover when left untreated for five or two years (Call Lake). To test for differences between untreated plots and burned or manually brushed plots at Dieleman, Hubert Hill and Call Lake we used the Student's T-test on 2007 data only.

For most tests of significance, we set an alpha of 0.05. To reduce the likelihood of a Type II error where sample sizes were small, we set the alpha level at 0.10 for the region-wide analysis ($n = 4$), and Hubert Hill analyses that for compared untreated, burned, manually brushed (manual) and burning in combination with manual brushing (burn-manual). There were just three Daubenmire plots in the manual and burn-manual treatments and we randomly selected three Daubenmire plots from untreated and burned portions of the monitoring plot to create a balanced data set.

Cervid pellet group numbers were converted to per hectare density measures for each species and for all cervid species combined. The density of old versus new pellet groups was compared using a region-wide paired t-test with $n = 6$ sites and five subsamples (transects) per site. The density of pellet groups on untreated versus manually treated areas was compared using a paired t-test with $n = 5$ transect pairs per site.

Results

Vegetation

Region-wide

The cover of woody species (trees and shrubs) on grassland sites decreased across the region from 89% in 2001 to 62% in 2007(P = 0.09; Figure 6(a)). This result includes both burned (Dieleman and Hubert Hill) and unburned (Colleymount and Summit Lake) sites, but a sizeable decrease was evident on all but the Summit Lake site. On untreated grasslands only, herbaceous cover averaged 14%in 2001 compared to 29% in 2007, but this difference was not statistically significant (P = 0.11; Figure 6(b)). Graminoids increased significantly across the region from 2% in 2001 to 6% in 2007 (P = 0.04; Figure 6(c)). In absolute terms, the abundance of non-native plant species also increased from 1% in 2001 to 3% in 2007 (P = 0.03; Figure 6(d); but when their cover was expressed as a percentage of the total herbaceous cover, the change was no longer statistically significant (9% vs 11%; p = 0.38) because relative abundance increased on two sites (Dieleman and Summit Lake) and decreased on two sites (Colleymount and Hubert Hill). The diversity index, which averaged 1.3 in 2001 and 1.5 in 2007, also increased region-wide (P = 0.06).

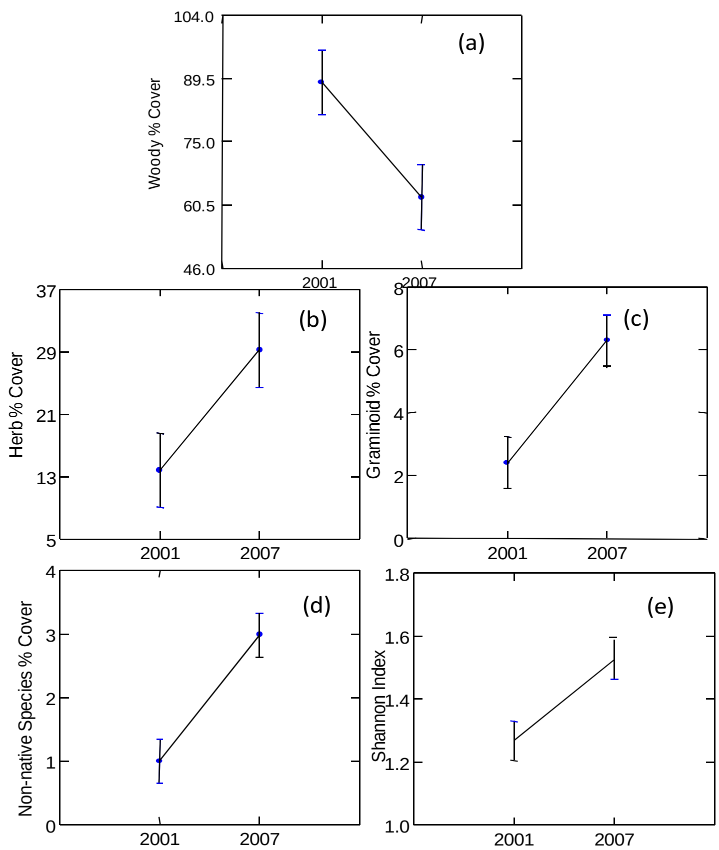


Figure 6. Region-wide percent cover of (a) woody plants, (b) herbs, (c) graminoids, (d) non-native plants and (e) Shannon's diversity index for 2001 and 2007.

Call Lake

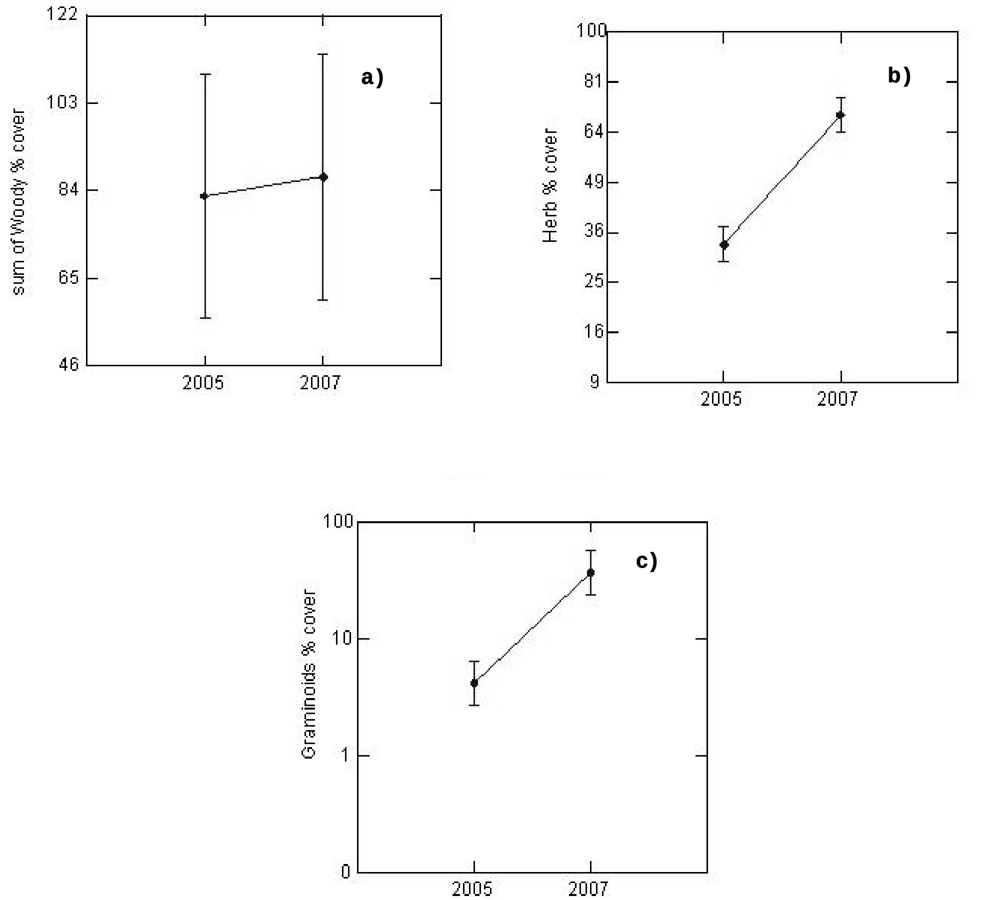


Figure 7. Call Lake plant percent cover for untreated plots in 2005 and 2007; a) woody cover (line transects), b) herb, and c) graminoid cover (Daubenmire plots).

At Call Lake the most significant changes on untreated areas from 2005 to 2007 were the increases in herbaceous plants and graminoids (Figures 7b and 7c). Herbs increased from 36% in 2005 to 70% in 2007 ($P < 0.001$) and graminoids increased from 7% in 2005 to 18% in 2007 ($P = 0.001$). The diversity index also increased significantly (Figure 8b) from 1.5 in 2005 to 1.8 in 2007 ($P = 0.04$).

Woody vegetation did not change over the two years (Figure 7a) with 87% cover in 2005 and 87% cover in 2007 ($P = 0.91$). Non-native plant percent cover (Figure 8a) also had no change with 5% cover in 2005 and 5% cover in 2007 ($P = 0.78$).

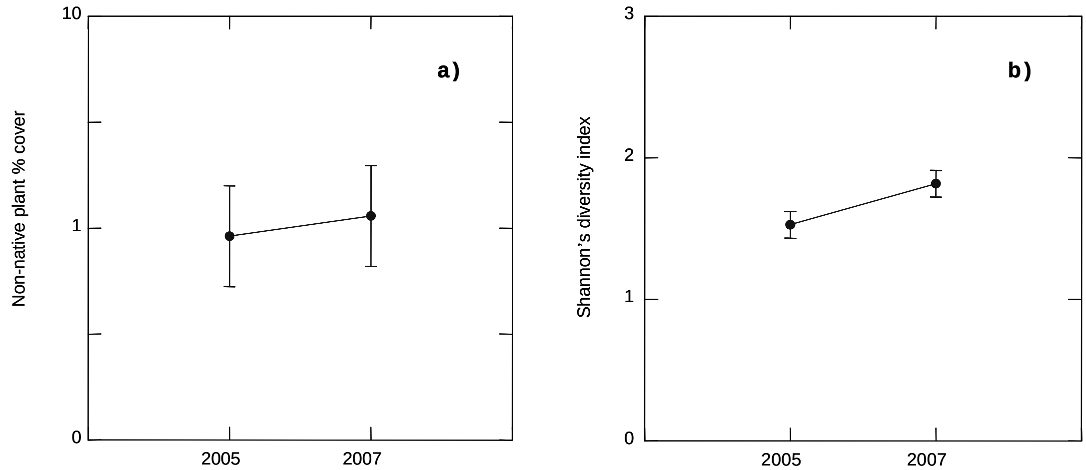
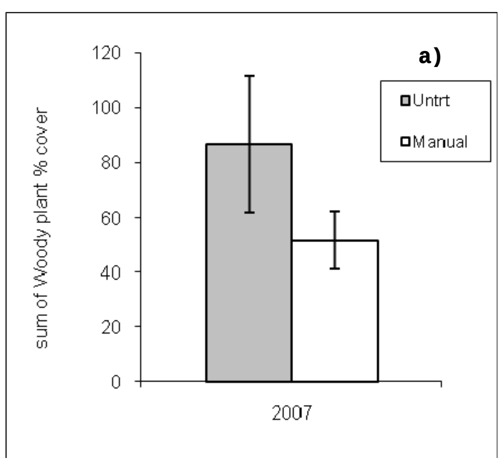


Figure 8 Call Lake a) non-native species percent cover, and b) Shannon's diversity index in 2005 and 2007 on untreated plots only.

Figure 9(a) compares woody plant % cover at the Call Lake site in 2007 in untreated plots and manually brushed plots. Woody plant cover in the manually brushed plots was 52% and in the untreated plots, 87% (P = 0.23). Herb cover (Figure 9(b)) on untreated plots in 2007 also showed no significant difference between manually brushed plots (80%) and untreated plots (70%) (P = 0.66). Graminoids, however, had significantly higher cover in the untreated plots than the manually brushed plots (Figure 9(c)). Percent cover was 18% in the untreated plots and 9% in the brushed plots (P = 0.01). Non-native plant cover (Figure 9(d)) did not differ between brushed plots and untreated plots (P = 0.78) The diversity index (Figure 9(e)) in 2007 was 1.8 in both brushed plots and untreated plots (P = 0.85).



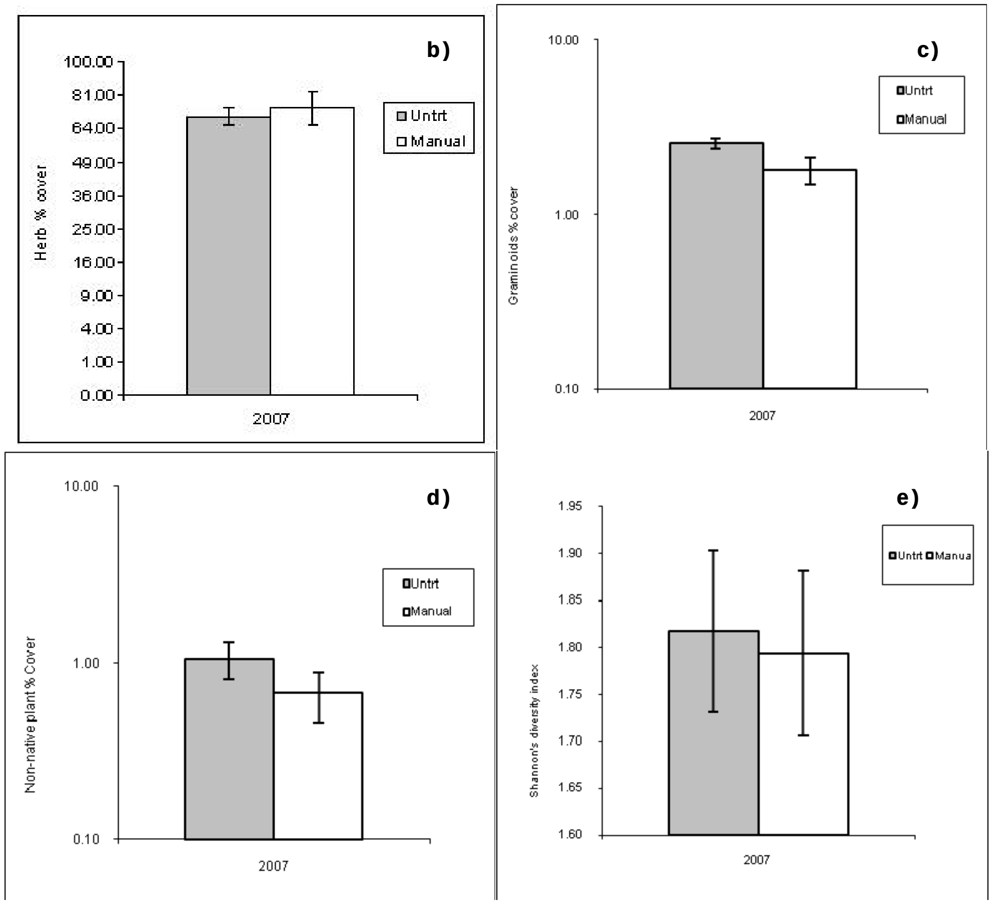
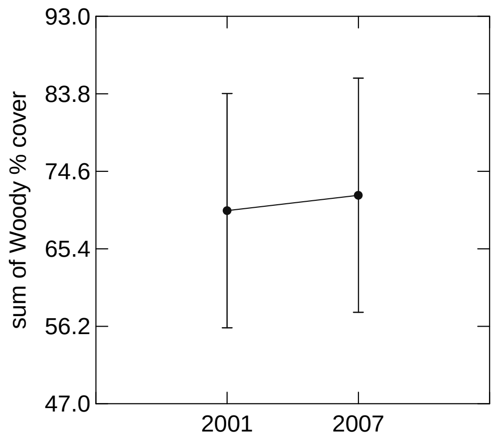


Figure 9. Percent cover of a) woody plants (line transects), b) herbaceous plants, c) Graminoids, d) non-native plants, and e) Shannon's diversity index at the Call Lake site on untreated and manually brushed plots.

Colleymount



At Colleymount, there was no change in woody plant cover (Figure 10) between 2001 (70%) and 2007 (72%) ($P = 0.93$). Herbaceous cover increased from 10 % to 26 % (Figure 11(a), $P < 0.001$) but there was no significant change in graminoid cover (Figure 11(b), $P = 0.17$), non-native cover (Figure 11(c), $P = 0.15$) or species diversity (Figure 11(d), $P = 0.73$).

Figure 10. Woody plant percent cover at the Colleymount site in 2001 and 2007. Averages taken from the line transects only.

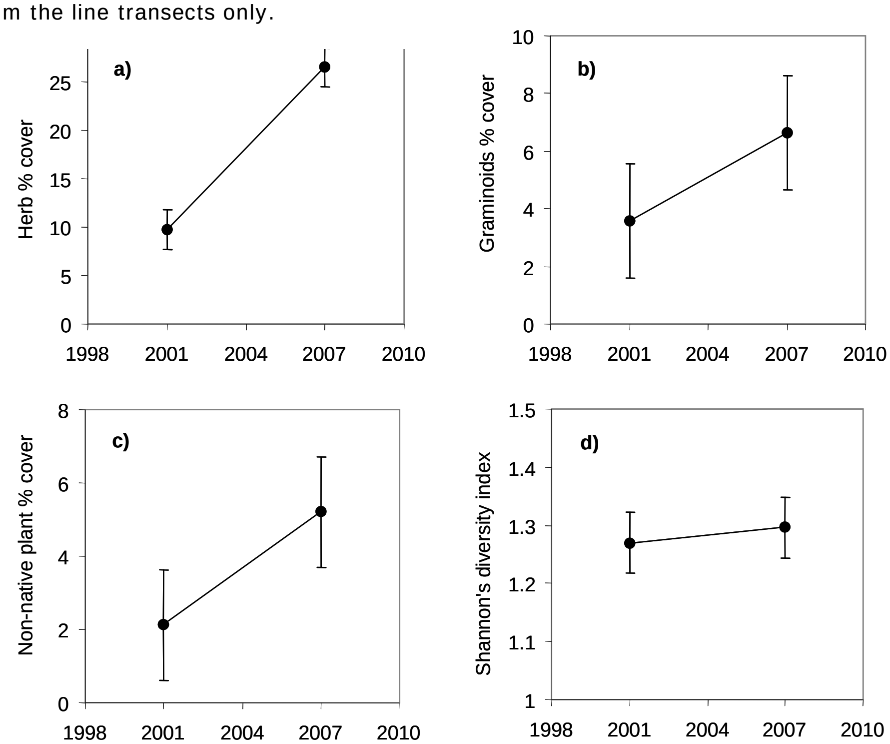


Figure 4. Colleymount percent cover of a) herbs, b) graminoids, c) non-native plants, and d) Shannon's diversity index for untreated Daubenmire plots in 2001 and 2007.

Dieleman (Grouse Mountain)

Severity of the Dieleman burn varied over the one hectare sample area with 87 of the 100 Daubenmire plots receiving some degree of burning (Figure 12). In total, 25 plots were unburned or very lightly burned, 60 were lightly burned and 15 were severely burned.

Woody plant cover over the entire Dieleman study area (Figure 13) decreased significantly from 2002 to 2007 (P = 0.02). Woody vegetation cover pre-treatment was 102% and in 2002, one month after the burn was 91% and in 2007 five-years after the burn was 64%.

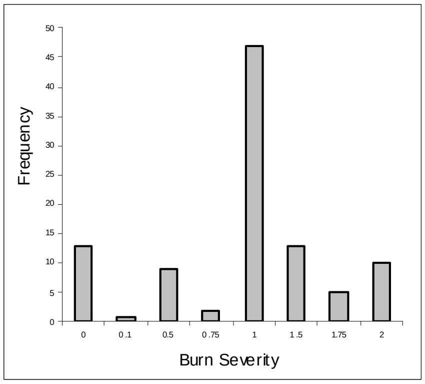


Figure 5. Frequency of burned plots based on burning severity for the Dieleman site. For this graph the zero represents unburned plots and two represents severely burned plots. Data collected in 2002 after the burn (Veenstra and Haeussler 2002).

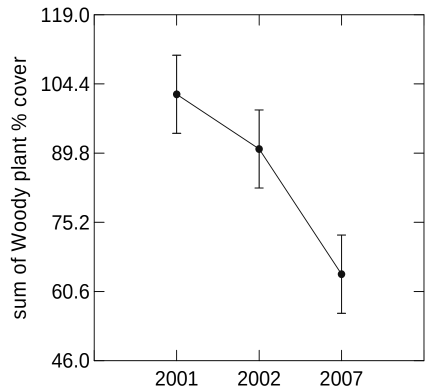
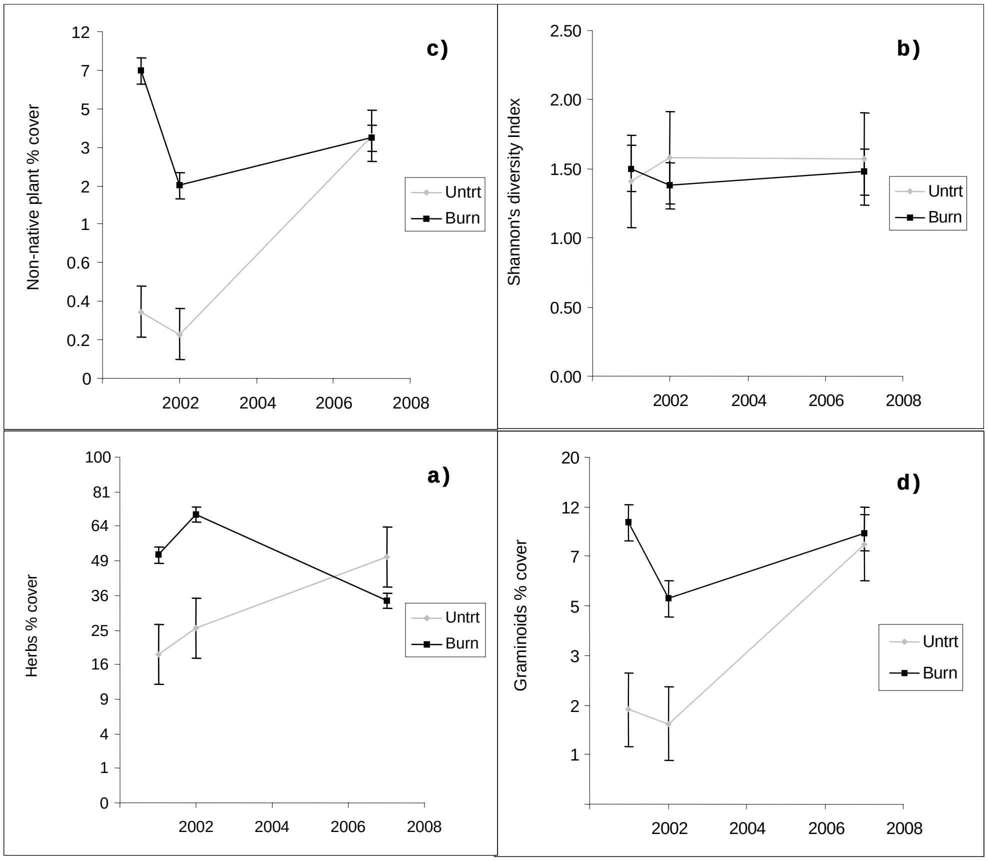


Figure 6. Woody plant percent cover at the Dieleman site in 2001, 2002 and 2007. Averages taken from the line transects only.

Figure 14 shows how herbaceous, graminoid and non-native cover and plant diversity differed between unburned and burned Daubenmire plots in 2001 (before the burn), 2002 (immediately after the burn), and 2007. The Daubenmire plots that burned had significantly more herbs, graminoids and non-native plants prior to the burn than the Daubenmire plots that did not burn, because the fire carried well through open herbaceous areas with abundant dry fuels and burned poorly in shaded aspen groves with little herbaceous cover. These pre-treatment biases complicate the interpretation of the post-treatment results.



PLEASE RE-ORGANIZE THE ORDER OF GRAPHS (a – d).

Figure 14 Dieleman percent cover of a) herbs, b) graminoids, c) non-native plants, and d) Shannon's diversity index in untreated and burned plots in 2001 (pre-treatment), 2002 (one month after burn), and 2007 (five years after burn).

Herb cover (Figure 14(a)) increased from 20% in 2001-2002 to 50% in 2007 on unburned Daubenmire plots, but decreased significantly on burned Daubenmire plots (from 50-70% in 2001-2002 to 36% in 2007). As a result, there were significantly more herbs on burned plots before the burn, but significantly fewer herbs on unburned plots after the burn (($P = 0.004$ for burn effect, $P = 0.002$ for the time x burn interaction). Graminoids (Figure 14(b)) decreased slightly after the burn on both the unburned and burned plots. By 2007 they had increased by 4 times on unburned plots, whereas on burned plots they had barely recovered to their pre-burn level. The result was that in 2007 there was no longer any significant difference in graminoid cover between the unburned and burned plots (7-8% cover for both, $P = 0.01$ for burn and time effects, $P = 0.83$ for time x burn interaction). Non-native plant cover (Figure 14(c)) had the same response as the graminoids ($P = 0.07$ burn effect, $P = 0.04$ for time effect; $P = 0.52$ for time x burn interaction).

Species diversity was approximately 1.5 on both unburned and burned Daubenmire plots at the Dieleman site and did not change significantly between 2001 and 2007 ($P = 0.61$ for burn effect; Figure 14(d)).

Hubert Hill (Toodienia) PLEASE FIX Y AXIS LABEL (Frequency)

Comment [SH1]: Y axis on Fig 14 should read: "Frequency"

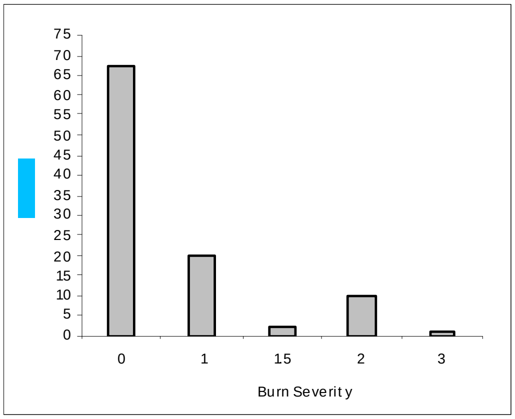


Figure 15. Hubert Hill frequency of burned plots based on burn severity in 2005. For this graph the zero represents unburned plots and two represents severely burned plots.

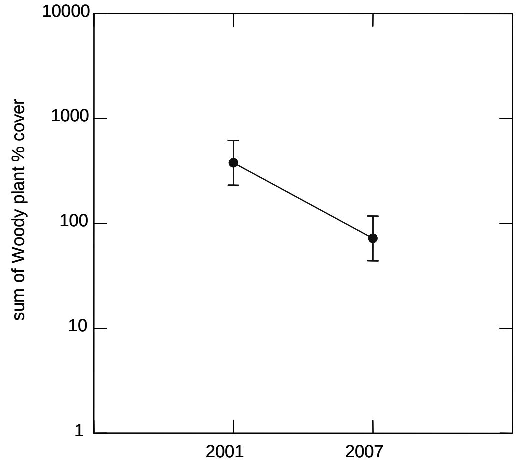


Figure 16. Hubert Hill woody plant percent cover in 2001 and 2007. Averages taken from the uncut portions of Line Transects.

As at the Dieleman site, burn severity was recorded for all Daubenmire plots in the one-hectare Hubert Hill area (Figure 15). Unlike Dieleman, a much larger portion of the plot did not burn, resulting in a much lower intensity burn. Out of 100 Daubenmire plots, 67 had no burn, 22 plots were lightly burned, and 11 plots were moderately to severely burned.

On the Hubert Hill study plot, woody vegetation (Figure 16) decreased significantly from 2001 (before the burn) to 2007 (2 years after the burn). Total woody cover averaged 105% in 2001 and in 2007 had dropped to 56% ($P = 0.04$)

Figure 17 illustrates trends in herbaceous, graminoid and non-native plant cover and species diversity from 2001 to 2007 on unburned and burned Daubenmire plots that were not manually brushed. It is clear that burning had little or no effect on the abundance of herbaceous vegetation (Figure 17(a)), which increased from 16% cover in 2001 to approximately 50% cover in 2007 regardless of whether or not plots were burned ($P = 0.43$ for 2007 comparison; $P < 0.001$ for time effect, $P > 0.30$ for burn effect and time x burn interaction).

For graminoids (Figure 17(b)) and non-native plants (Figure 17(c)), the time trends were more complex. Open, grassy patches at Hubert Hill, just as at the Dieleman site, burned most readily. As a result, graminoids and non-native plants were more than twice as abundant prior to the burn within Daubenmire plots that later burned than within plots that did not burn. However, by 2007, the difference in graminoid cover was no longer statistically significant ($P = 0.10$) because graminoids increased much more slowly in burned patches than in unburned patches ($P = 0.026$ time x burn interaction). Non-native plants, on the other hand, continued to be more abundant on burned plots than unburned plots right through to 2007 ($P = 0.001$ burn effect, $P = 0.47$ time x burn interaction).

Species diversity (Figure 17(d)) increased steadily at Hubert Hill from 1.2 in 2001 to 1.4 in 2005 to 1.5-1.6 in 2007 ($P < 0.001$ for time effect). There was no significant difference in species diversity between the unburned and burned Daubenmire plots ($P = 0.13$ for burn effect, $P = 0.93$).

Our results for manual brushing (manual) and burning followed by manual brushing (burn-manual) are less reliable than the results for burning alone because they are based on just 3 Daubenmire plots for each treatment. On this subset of plots, all three restoration treatments appear to have caused a significant increase in herb cover (Figure 18(a)) which was not significantly different from untreated plots in 2001, but 40% higher than untreated in 2007; $P < 0.05$). Effects of manual cutting and combination treatments on graminoids (Figure 18(b)) and non-native plants (Figure 17(c)) were either short-lived or not statistically significant. Manual cutting did not significantly increase species diversity compared to untreated plots (Figure 17(d)), but had less of dampening effect on the general increase in species diversity than burning alone ($P = 0.04$ for time effect, $P = 0.80$ for burn effect, $P = 0.02$ for manual effect, $P > 0.20$ for all interaction effects).

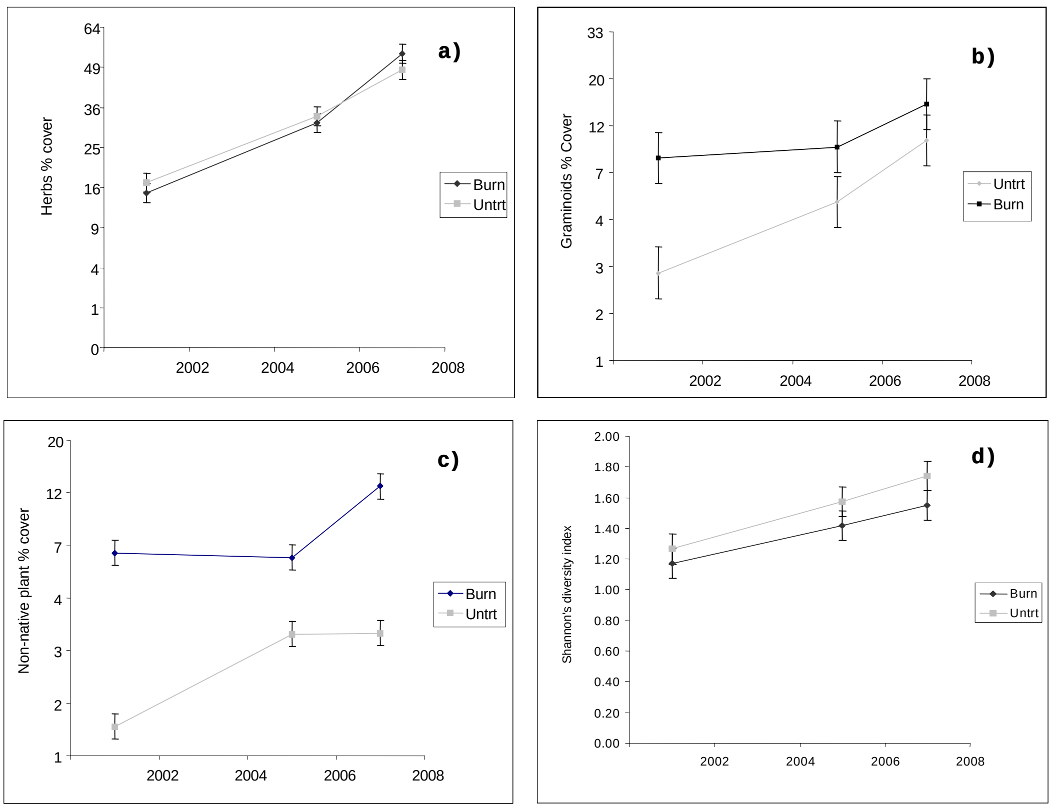


Figure 17. Percent cover at Hubert Hill for a) herbs, b) graminoids, c) non-native plants, and d) Shannon's diversity index in untreated and burned plots for 2001 (pre-treatment), 2005 (four months after treatment) and 2007 (five years after treatment).

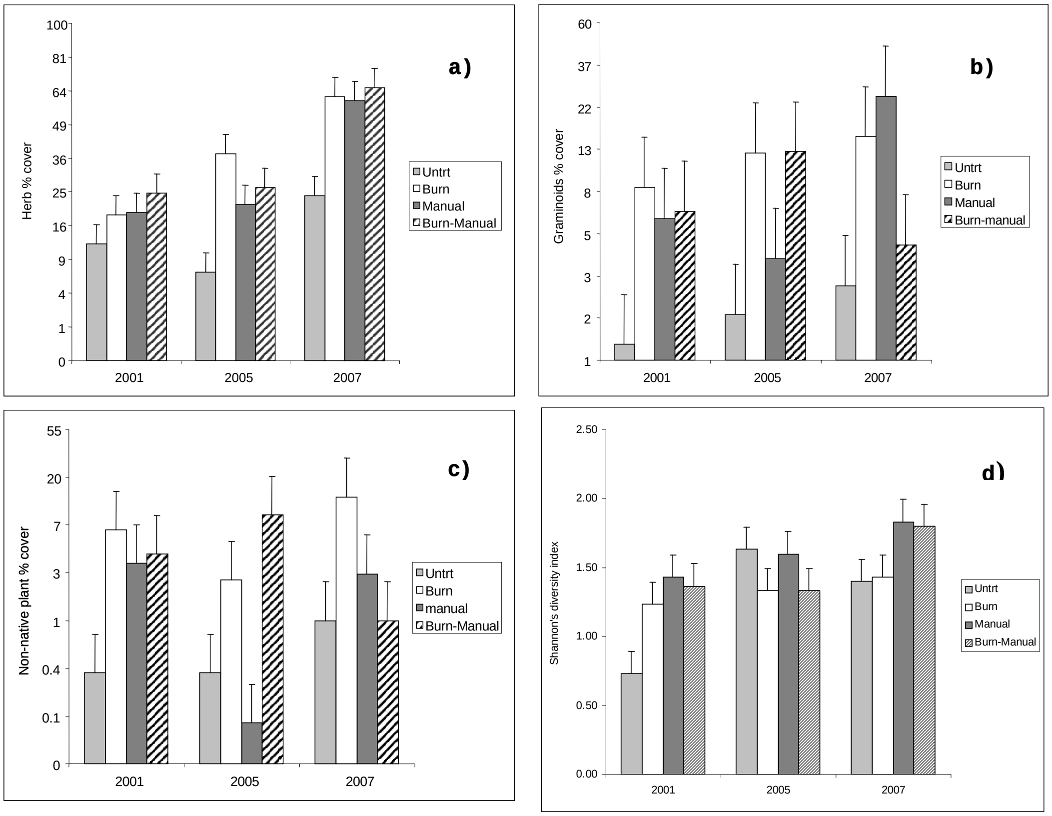


Figure 18. Hubert Hill percent cover of a) herbs, b) graminoids, c) non-native plants, and d) Shannon's diversity index on all four treatments (untreated, burned, manually brushed and burned-manually brushed) in 2001 (pre-treatment), 2005 (four months after burn and one month after manual brushing) and 2007 (two years after burning and manual brushing).

Summit Lake

Summit Lake woody vegetation (Figure 19) averaged 90% in 2001 and 57 % in 2007, but the difference was not statistically significant (P = 0.17). Herb cover (Figure 20(a)) increased from 13% in 2001 to 23% in 2007 and graminoid cover (Figure 20(b)) increased from 2.3% to 5.5% (P < 0.001 for both tests). Along with the increase in herbaceous plants, there was a significant increase in Shannon's diversity (Figure 20(d)) from 1.3 in 2001 to 1.5 in 2007 (P = 0.03). However, non-native cover (Figure 20(c)) also increased significantly from 0.5 % cover to 2.2 % cover (P = 0.001), mainly due to an increase in timothy (*Phleum pratense).* Summit lies within an active grazing lease. The changes may have reflected lower intensity of cattle grazing in 2007 than in 2001, allowing for the recovery of timothy and other forage species.

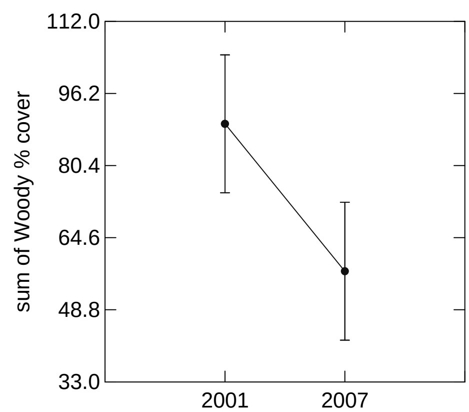


Figure 19. Woody plant percent cover at the Summit Lake site in 2001 and 2007.

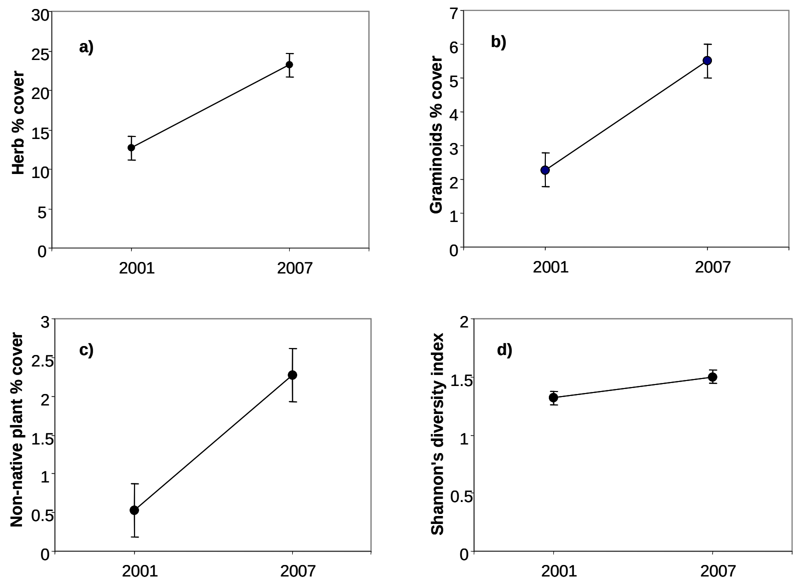


Figure 20. Summit Lake percent cover of a) herbs, b) graminoids, c) non-native plants and d) a measure of diversity for untreated Daubenmire plots in 2001 and 2007.

Cervid Pellet Groups

Deer pellet groups averaged 610 (± 450) per hectare across the region in the spring of 2008 and ranged from 160/ha at Red Hills to 1357/ha at Hubert Hill (Table 2). Moose pellet groups averaged 134 (± 146) per hectare and were abundant at Call Lake, Dieleman and Summit Lake (216-332/ha) but absent to uncommon at Colleymount, Red Hills and Hubert Hill (0 – 11/ha). One old elk pellet group (4/ha) was found at Dieleman. Although we observed deer feeding on spring grasses and forbs, all of the pellets were firm and woody and it was difficult to distinguish between shiny new pellets, supposedly from spring 2008, and dull older pellets, supposedly from winter 2007 or earlier. The numbers of old versus new pellet groups were not significantly different for either species ($p > 0.26$).

The density of pellet groups was not significantly different between untreated and manually treated portions of the transects at Call Lake ($p = 0.59$ for deer, $p = 0.32$ for moose) or Hubert Hill ($p = 0.24$ for deer). At Hubert Hill there was an exceptionally high density of deer pellet groups (2800/ha) in two manually cut and girdled sub-plots surrounded by uncut aspen. Deer were observed to preferentially congregate in this area in the spring. By contrast, manually cut sub-plots in open savanna-steppe vegetation with few girdled aspen averaged 933/ha and untreated areas averaged 1035/ha. At Call Lake there was no evidence that either deer or moose had a preference for manually cut subplots surrounded by aspen.

Table 2. Cervid pellet group densities (number of groups per hectare) at the six grassland study sites. Old pellets were dull and weathered and assumed to date from fall-winter 2007. New pellets were shiny and unweathered and assumed to date from spring 2008. However, it was difficult to distinguish between shiny and dull pellets and since we do not know how quickly the pellets weather on these sites, the categories should be considered arbitrary at this stage.

		Deer									Moose									All Ungulates*								
		Untreated			Manual			Old	New	Total	Untreated			Manual			Old	New	Total	Untreated			Manual			Old	New	Total
Site		*Old*	*New*	*Total*	*Old*	*New*	*Total*				*Old*	*New*	*Total*	*Old*	*New*	*Total*				*New*	*Old*	*Total*	*Old*	*New*	*Total*			
Call Lake	*Mean*	280	368	648	184	280	464	232	324	556	256	152	408	232	24	256	244	88	332	536	520	1056	416	304	720	476	412	888
	Stdev	390	294	656	92	210	271	227	170	363	246	87	322	137	22	134	158	46	195	579	312	854	218	217	346	363	153	474
Colleymount	*Mean*	--	--	--	--	--	--	390	485	874	--	--	--	--	--	--	0	0	0	--	--	--	--	--	--	390	485	874
	Stdev	--	--	--	--	--	--	259	70	273	--	--	--	--	--	--	0	0	0	--	--	--	--	--	--	259	70	273
Dieleman	*Mean*	--	--	--	--	--	--	224	288	512	--	--	--	--	--	--	108	132	240	--	--	--	--	--	--	336*	420	756*
	Stdev	--	--	--	--	--	--	204	83	272	--	--	--	--	--	--	33	48	62	--	--	--	--	--	--	223	124	336
Hubert Hill	*Mean*	624	411	1035	928	752	1680	776	581	1357	0	21	21	0	0	0	0	11	11	624	432	1056	928	752	1680	776	592	1368
	Stdev	207	149	337	651	520	1024	782	452	1112	0	48	48	0	0	0	0	48	48	207	180	363	651	520	1024	782	475	1148
Red Hills	*Mean*	--	--	--	--	--	--	84	76	160	--	--	--	--	--	--	0	8	8	--	--	--	--	--	--	84	84	168
	Stdev	--	--	--	--	--	--	61	46	68	--	--	--	--	--	--	0	11	11	--	--	--	--	--	--	61	38	63
Summit Lake	*Mean*	--	--	--	--	--	--	148	52	200	--	--	--	--	--	--	180	36	216	--	--	--	--	--	--	328	88	416
	Stdev	--	--	--	--	--	--	81	45	95	--	--	--	--	--	--	185	33	210	--	--	--	--	--	--	250	56	289
All Sites	*Mean*	452	389	841	556	516	1072	309	301	610	128	87	215	116	12	128	89	46	134	580	476	1056	672	528	1200	411	347	743
	Stdev	243	30	273	526	334	860	251	212	450	181	92	273	164	17	181	106	53	146	62	62	0	362	317	679	251	212	465

*Dieleman site had 4 old elk pellet groups per hectare

Discussion

Grassland Vegetation Trends

Grasslands are very dynamic ecosystems that generally exhibit much greater variability in species composition and productivity in response to short-term changes in weather and disturbance than forest ecosystems because of the predominance of herbaceous and other short-lived vegetation. This instability makes them more sensitive or vulnerable to invasive species and to changes in land use practices, and makes them valuable bellwethers of ecological change such as global warming. However, their inherent seasonal and interannual variability can also make it more difficult to differentiate short- and long-term trends and to document the positive or negative effects of restoration practices and other disturbances.

The fact that many northwest BC grasslands became considerably smaller during the 20th Century is well known from anecdotal evidence of long time residents (Bob Fowler, District Agrology Officer, Burns Lake, BC pers. comm., May 2007) and from comparing aerial photographs from the 1940s and 50s to those of the present day (O'Byrne 2000, de Groot and Armitage 2007). It is also acknowledged that aspen, shrub and coniferous tree cover has generally increased on the remaining grasslands, resulting in reduced forage quality and diversity (Jim Pojar, former Regional Ecologist, Don Russell former Regional Range Officer, Smithers, BC, pers. comm. various dates); however, these increases in woody plants and decreases in grasses and other herbaceous plants had not previously been documented experimentally in the Skeena Region. The replicated grassland habitat monitoring projects established in the Bulkley Valley and Lakes District in 2001 provided us with an opportunity to document the pace of these widely recognized changes as well as to determine whether our experimental restoration practices (burning and manual brushing) were having the desired effect before being expanded to an operational scale.

Five years after the initiation of the grassland monitoring and restoration program, our results are either quite different from what we expected or inconclusive.

The results from untreated vegetation transects did not show the steady increase in woody vegetation that we expected to see. On three unburned study sites, Colleymount, Summit Lake and Call Lake, woody vegetation cover either remained the same or decreased over the time frame of the study. At the two burned study sites, Dieleman and Hubert Hill, woody vegetation decreased by 30%, despite 25 to 67 percent of the surface area being essentially unburned. Region-wide, we also recorded a significant increase in graminoids and species diversity, a slight but non-significant increase in herbaceous cover, and no significant change in the relative cover of non-native species on untreated sites between 2001 and 2007. These indicators suggest stable to improving grassland conditions, rather than a general deterioration.

We do not know whether what we have recorded represents a long- or medium-term improvement in grassland condition - contrary to expert and popular opinion - or a short-term phenomenon that could soon be reversed. There are many potential sources of variability. The winter of 2006/07 had some of the deepest snow packs ever recorded in the Skeena Region (BC Ministry of Environment 2007) and it is possible that exceptionally moist grassland soils caused a flush of herbaceous growth in the spring and summer of 2007. Woody species could take a year or longer to respond to the increased moisture. Short term changes in cattle grazing intensity at Colleymount and Summit Lake probably account for some of the observed patterns. It is also likely that some of the differences between 2001 and 2007 were due to sampling error. Data were collected by different crews who could have measured somewhat differently. Moreover, the 2001 data were collected mostly in August and early September when many herbs had already senesced, whereas the 2007 data were collected mostly in July, when herbs were lush but shrubs may not yet have attained full size. The fact that 2002 and 2005 results for untreated plots at Dieleman and Hubert Hill tend to lie on the

2001-2007 trendlines, suggests, however, that these were at least partly real trends and not a seasonal blip or the result of inconsistent sampling.

Grasslands in northern BC are believed to be experiencing tree encroachment mainly from trembling aspen (Veenstra and McLennan 2002). Trembling aspen has been documented to encroach by increasing tree densities and filling in spaces around existing trees (Franklin *et al.* 1971; Rochefort and Peterson 1996). Our study was not specifically designed to examine growth patterns of trembling aspen (e.g., encroachment at edges or growth in height), which could explain the small change in woody vegetation cover we saw.

Meadow-forest boundaries have been explained as inherently dynamic (Moore and Huffman 2004) and may exhibit changes over relatively short time periods, without there necessarily being a long term trend. This study was only conducted over a six year time frame with some sites added only within the last two years. Given that tree invasion of woody vegetation onto grasslands has been documented over the last few centuries, six years may not be long enough to document any significant changes (Heisler *et al.* 2003; Briggs *et al.* 2002; Laliberte *et al.* 2004).

The small size of our treatment plots, the lack of replicated and randomized burn treatments, and the unbalanced nature of the datasets (not all sites had the same treatments or years of observation) are other factors that limit our ability to extrapolate the results of the study to the larger regional context. There are new mixed effects modeling techniques that can be used to overcome some of these statistical constraints (Pinheiro and Bates 2000) and we intend to use them after the next round of measurements when we have more than two observations at each site.

Effects of Restoration Treatments

To date, our two restoration treatments, prescribed fire and manual brushing (cutting and girdling) have had mixed effects on grassland condition. Broadcast burning significantly reduced woody species abundance at both the Dieleman and Hubert Hill sites. Although there was abundant resprouting of woody plants almost immediately after these low to moderate severity burns, the fires seemed to cause gradual mortality of larger aspen over a period of several years. We did not observe the expected increase in herbaceous plants, including graminoids, in response to these burns and the reduction in overtopping aspen. While our data showed higher graminoid and other herb cover on burned than unburned plots, this result was due to the fact that grassy plots were more likely to burn, rather than that burning increased the amount of graminoids. In fact, unburned areas experienced greater increases in herbaceous cover between 2001 and 2007 than burned areas. We do not know why this is so. It is possible that resprouting shrubs and aspen suckers in burned areas competed more directly with the herbaceous vegetation than the overtopping trees on unburned areas. It is also possible that the grasses were more sensitive to spring burns than expected.

Although three years of manual cutting decreased the percentage of woody vegetation and there was limited opportunity for resprouting, there was no corresponding increase in graminoids and other herbaceous plants at either Call Lake or Hubert Hill. Bozzo *et al.* (1992) found similar results and attributed it to the amount of rainfall soon after the brushing treatment. Scrifes and Polk (1974) suggested that an increase in herbaceous vegetation following a brushing treatment may occur only in “wet” years. Weather data for Smithers show total annual rainfall as 449 mm, 425 mm, 272mm and 421 mm, and total annual precipitation as 587 mm, 499 mm, 436 mm and 591 mm for the years 2004 to 2007 (Environment Canada 2008). It is possible that drier weather in 2005-2006 may have inhibited graminoid and other herb response to manual brushing.

Annual manual cutting and girdling treatments are labour intensive and cannot be continued indefinitely or extended over large areas. They will be most useful if initial treatments reduce woody plant abundance to the point where it can be maintained by less costly treatments, such as prescribed burning or light grazing. Aside from conifers, all woody species in Skeena region grasslands have the capacity to resprout or sucker vigorously following manual cutting.

Although girdling results in permanent death, it can only be carried out on single-stemmed trees. Mechanical uprooting of shrub thickets is not an option on these sites because of their steep terrain and thin, sensitive soils. We will need to discontinue manual brushing on a random sub-sample of the manually treated plots to determine whether these treatments have a lasting impact.

We have very limited data for the combination of burning and manual brushing. Our data to date do not suggest that the two treatments together result in any significant synergistic enhancement of grassland condition. However, there is widespread opinion among grassland restoration specialists that once woody species have become dominant in grassland ecosystems, frequent fire alone will not be sufficient to remove them and that manual or mechanical treatments will also be needed (e.g. Briggs et al. 2005). Our concern that these multiple treatments might result in an undesirable enhancement of non-native species abundance so far appears to be unfounded.

Cervid Use of Grasslands

The 2008 cervid pellet group inventory confirmed that these grassland sites are heavily used by deer. These are mostly mule deer, but white-tailed deer are common at Francois Lake (Red Hills, Colleymount) and also occur at low numbers in the Bulkley Valley. The pellet group densities support our observations that Hubert Hill and Colleymount are very heavily used by deer whereas Summit and Red Hills receive less use. The Red Hills site, in particular, has a high cover of kinnikinnick that reduces its value as deer habitat.

We expected to observe higher deer pellet densities in manually treated subplots as these areas have lush green growth with many new suckers and sprouts and we have observed the deer feeding in these open patches in early spring at Hubert Hill when the untreated areas are not yet green. The pellet group density data do not support these observations. This may be because the plots are small and the deer do not necessarily defecate at higher densities where they feed (as opposed to where they gather for shelter). There was no evidence from the proportion of old vs. new pellets that the deer prefer manually brushed plots in spring and untreated plots before snowmelt. Differential pellet decomposition rates between shaded uncut and sunny brushed plots could also influence pellet group densities.

Moose use at Call Lake, Dieleman and Summit was higher than expected, and appears to be similar or slightly lower than deer use at these sites, assuming comparable defecation rates (Neff 1968, Rogers 1987, Joyal and Ricard 1986) and pellet decomposition rates. As our grassland restoration treatments are intended to reduce woody browse and cover over the long term, we expect to see a gradual shift towards fewer moose at these sites with continued treatments and pellet group monitoring.

In 2008, we were unable to compare cervid pellet densities on burned and unburned transects within study areas. Pre- and post-burn monitoring and delineation of burned and unburned portions of transects should allow us to do this in future years. At the Red Hills site which was burned in May 2008, two weeks after the pre-burn cervid pellet group inventory was conducted, we hope to see a reduction in kinnikinnick cover after the burn which should translate into increased deer use. At this site, one half of the transects were burned while the other half were unburned.

Conclusions

The condition of untreated grassland vegetation sampled between Smithers and Burns Lake was stable or improved between 2001 and 2007. We do not know if this is a long-term trend or a short-term effect driven by recent weather conditions.

Prescribed burning and three consectutive years of manual brushing, at two sites each, reduced woody species cover but there was abundant resprouting and no corresponding increase in herbaceous and graminoid cover or species diversity. Burning followed by manual brushing, at one site, did not appear to have a significant additive effect over burning or manual brushing alone. These results are limited to a few, small test areas and should not be extrapolated to predict the response of all SBSdk grasslands in the study area.

There was no evidence that burning or manual brushing, either alone or in combination, increased non-native species abundance. This result suggests that it would be acceptable to experiment with more severe treatments (e.g. hotter burns) and to extend the treatments to larger areas.

Recommendations

- Continue vegetation and cervid pellet monitoring so as to distinguish between long-term and short-term time trends. Vegetation and cervid data should be linked to climatic data. Cervid pellet groups should be counted and cleared annually, whereas 3-5 year intervals are recommended for vegetation inventories.
- Execute more extensive and more severe burns. Carry out repeat burns on areas already burned. Include unburned control areas in the design of prescribed burns.
- Manually cut and spread brushing before burning treatments to improve fuel continuity and achieve higher severity burns. This may allow repeat burns to be carried out sooner (e.g., at Hubert Hill).
- Immediately after burning, monitor burn severity along line transects as was done for Daubenmire plots. This will allow differences in woody vegetation cover between burned and unburned areas to be determined.
- Discontinue annual cutting on a random sub-sample of manually brushed plots to monitor the ability of herbaceous and woody plants to recover.
- Conduct a literature search on the use of herbicides to reduce shrubs and non-native plants on grasslands and begin discussions with partners and stakeholders to determine acceptability of herbicide use on native grasslands.
- Begin monitoring use by non-cervid wildlife.
- Reanalyse the data to assess region-wide trends using mixed-effects modeling techniques following additional restoration treatments and a third round of measurements at all sites.
- Supplement field monitoring with an aerial photo inventory of changes in grassland area and the degree of habitat fragmentation.

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	Plot size	Established	# Of Transects	# Of Daubenmires	Treatment(s) *Brushed*	Treatment(s) *Burned*	Data Collection
Call Lake	N/A	Jul-05	5* (100 m each)	50	Aug-06 31-Jul-07		Jul-05 Jun-07
Colleymount	1 ha	May-01	10 (100 m each)	100			Aug-01 Jul-07[1]
Dieleman	1 ha	May-01	10 (100 m each)**	100		15-May-02	Aug-01 Apr-02 Jun-07[1]
Hubert Hill	1 ha	Aug-01	10 (100 m each)	100	2-Jun-05 19-Jun-06 31-Jul-07	29-Mar-05	Aug-01 Jul-05*** Jun-07[1]
Red Hills	0.5 ha	13-Aug-07	5 (100 m each)	50			13-Aug-07
Summit Lake	0.6 ha	May-01	10 (100 m each)	100			Aug-01 Jun-07[1]
Tenas Hill	1 ha	May-01	10 (100 m each)	100			Aug-01

[1] data from five transects and 50 Daubenmires was collected and recorded
* transects divided into two 50 m sections; one control and one treatment
** some of the transects were shortened by 10-20 m due to rock bluffs

***only the Daubenmires were measured in this year

Appendix I. Summary of treatments received on grassland monitoring sites in the southern Skeena region.

Appendix II. Wildlife notes.

Location	Animal sightings/sign
Call Lake	▪ Moose browse on woody vegetations ▪ Moose rubbing/chewing on aspen trees ▪ Animal den (possibly fox) on transect 3-2
Colleymount	▪ On an active grazing lease – cattle use ▪ Active wildlife trail on transect 6-7
Dieleman	▪ Bear sighting within the plot ▪ Bear sign throughout the plot ▪ Variety of bird species including Bohemian waxwings, flycatchers, chickadees
Hubert Hill	▪ Wildlife trails throughout the plot ▪ Deer browse ▪ Fox den located at the southeast corner ▪ Fox sighting
Red Hills	▪ Garter snake sightings ▪ Wildlife trail runs through the plot
Summit Lake	▪ Active grazing lease