Assessment of Ungulate Resource Values Within the Cline River Subbasin Following the 2009 Upper North Saskatchewan River Prescribed Fire

Alberta Conservation Association

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EXECUTIVE SUMMARY

In response to the effects of wildfire control and the consequences of a lack of natural fire events on the landscape, Alberta Conservation Association partnered with other agencies to help plan a prescribed fire and monitor ungulate resource values within the Cline River subbasin southwest of the town of Rocky Mountain House, Alberta. The Upper North Saskatchewan River prescribed fire, conducted in 2009, was intended to restore ungulate winter range value within a landscape that had aged beyond the natural range of variability. The Cline River Subbasin Ungulate Winter Range Restoration Plan outlined values, objectives, indicators, and targets to evaluate ungulate resource values before and after a series of treatments. This report outlines the monitoring program conducted between 2005 and 2015, as well as an initial evaluation of treatment success on landscape-, ecosystem-, and species-level objectives and indicators for ungulates.

Outcomes at the landscape- and ecosystem-level (presented in the appendices) generally indicated achievement of, or substantial progress towards, winter range targets; however, outcomes at the species-level were more mixed and perhaps less beneficial for winter range than predicted. Stand-age distribution and disturbance rates within ungulate winter range of the Cline River subbasin shifted towards targets, recognizing these long-term values may require multiple treatments to achieve. The Upper North Saskatchewan River prescribed fire mimicked historical large fires in its total burned area and number and size of remnant unburned patches, but had more burned patches than historical wildfires.

At the species-level, forage access for bighorn sheep should improve as the prescribed fire occurred primarily on southern exposures used by sheep in the winter and the increased horizontal visibility should assist in predator detection. Similarly, open forage areas were increased in proximity to security cover, which should increase forage access for mule deer and elk. Forage abundance showed an immediate short-term increase in grass and herbaceous forb biomass but had decreased by six years post-fire, while grass and forb cover reached peak values at six years post-fire. These results were noted primarily in montane study areas and were less consistent in subalpine study areas. Shrub biomass showed a slight decrease but by six years post-fire, shrub cover had increased. Finally, forage quality for elk as measured through a Forage Preference Index showed the most unanticipated result; spring indices increased at most study areas while there was no change in winter forage preference indices. Recent studies have indicated the importance of quality late spring and especially summer nutritional resources for many aspects of elk reproduction. We recommend that future range restoration work for elk should thus focus not on winter range but on other seasons instead.

Key words: ungulates, winter range, restoration, habitat enhancement, prescribed fire, monitoring, treatment, Cline River, North Saskatchewan River.

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1.0 INTRODUCTION

Wildfire control activities began in Alberta's national parks in the 1930s and on provincial forested land in the 1950s. Though initiated with reasonable intentions for protecting national heritage areas, commercial forests, and communities, wildfire control activities have had serious ecological implications for wildlife resource value through impacts on vegetation patterns and stand age (Andison 2000, Smith 2000, White et al. 2003, King and Schlossberg 2014, Rogeau et al. 2016). For most large mammals, these impacts meant a loss of habitat quality (Pengelly and Rogeau 2001). Areas of previously high-quality ungulate habitat that were historically maintained by natural fire events may no longer support former levels of ungulate productivity, which in turn affects ungulate distribution on the landscape. Though the commercial forest industry creates over 80,000 hectares (ha) of young forest each year (Alberta Agriculture and Forestry 2017), there are areas of the province that are not currently managed for timber harvest and receive aggressive wildfire suppression. There are also important meadow habitats within provincial Forest Management Units that are not considered part of the managed forested landbase but that have been altered by forest encroachment as a result of protection from wildfire. Each year a lack of wildfire in these ecosystems results in incremental habitat loss and fragmentation affecting species ranging from butterflies to elk and grizzly bears (Pengelly and Rogeau 2001).

One area of focus for Alberta Conservation Association (ACA) was the restoration of ungulate winter range values within landscape units that have aged beyond the natural range of variability, primarily through encouraging the use of prescribed fire and mechanical clearing as treatments. In 2005, ACA adopted a strategic approach to proposing treatments based on recommendations by The Wildlife Society Technical Committee on Performance Measures for Ecosystem Management (Haufler et al. 2002). ACA developed hierarchical values, objectives, indicators, and targets (VOITs) at three levels/scales: landscape, ecosystem, and species. Watershed subbasins were chosen as the landscape planning unit. Landscape-level objectives for each subbasin supported the goal of restoring broad habitat patterns naturally found within fire-adapted ecosystems, while ecosystem-level objectives supported the goal of mimicking smaller-scale effects of wildfire in terms of burn patterns and the amount of burned area. Species-level objectives sought to ensure that treatments provide high-quality winter range for a set of big game ungulate species, at a scale that is biologically meaningful. An indicator was identified for each objective that could be measured against a target, thereby providing feedback on success and/or the need for future refinement of treatment protocols.

The Cline River subbasin was a priority subbasin identified for habitat treatment due to its relatively high composition of potential ungulate winter range, lack of forest harvesting and wildfire, and complementary forest health and community protection objectives put forward by the Government of Alberta (GOA). The Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009) outlined seven landscape-level VOITs that focused on stand age distribution (i.e., acceptable range of forest cover and age class combinations) and disturbance rates that should occur within ungulate winter range. These measures were established for montane and subalpine natural subregion portions of the subbasin based on the best current knowledge of historical natural disturbance patterns. Five ecosystem-level VOITs described temporal and spatial patterns that should be created by treatments to mimic the effects of wildfire (e.g., frequency, size, shape, residual patches). Finally, 22 species-level VOITs focused on providing the general forage, predator avoidance, and thermal cover characteristics required by elk, bighorn sheep, and mule deer within treatment areas (e.g., distance to cover, percent grass cover).

Much of the Cline River subbasin is zoned as Prime Protection under the Eastern Slopes Integrated Policy (GOA 1984, ASRD 2007) or is located within national parks. Limited timber harvest in the subbasin occurs only for ecological or fire protection purposes. In recognition of habitat loss and forest health issues resulting from the lack of wildfire disturbance, Government of Alberta, Parks Canada, and ACA partnered on a prescribed fire between Whirlpool Point and Banff National Park along the David Thompson Corridor (Highway 11). Ignited in 2009 by the Government of Alberta and Parks Canada, this 4,835 hectare treatment was expected to positively contribute to goals and objectives outlined in the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009) and GOA’s R11 Forest Management Plan (ASRD 2007). These plans operate at different scales but are spatially overlapped and are complementary in their intent to achieve enhanced biological diversity, wildlife habitat, and ecosystem resiliency.

Three key questions about the prescribed fire treatment are informed by the 34 VOITs from the Cline River subbasin plan:

1. Did ungulate winter range improve after the prescribed fire? (species-level)
2. Did the prescribed fire mimic natural wildfire patterns? (ecosystem-level)
3. Did landscape conditions move towards the natural range historically created by wildfire in the Cline River subbasin? (landscape-level)

The body of this report will highlight 14 representative species-level VOITs that address question #1 regarding improvement in ungulate winter range (Table 1). Information related to the two questions addressing landscape- and ecosystem-level VOITs, as well as the remaining 8 species-level VOITs, can be found in the appendices (Appendices A, B, and C, respectively).

Table 1. Representative species-level values, objectives, indicators, and targets from the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009).

Value	Objective	Indicator	Target	Reference (if applicable)
Bighorn sheep - Forage access	Foraging habitat created/ restored in snow-free areas	Aspect within treatment area	Average aspect is between 135 and 225 degrees	Johnson and Swift 2000; Zeigenfuss et al. 2000
Bighorn sheep - Forage abundance	Create a significant increase in forage availability	% cover and biomass of grasses and forbs	20-30% increase in palatable grass and forb species within the study area	ACA objective
Bighorn sheep - Predator avoidance	Foraging habitat located in close proximity to escape terrain	Distance to escape terrain (escape terrain is defined as areas where the slope is between 27° and 85°)	Mean distance from open transects to escape terrain + 2 SD is < 300 m (this should ensure that approximately 95% of foraging habitat is in close proximity to escape terrain)	Johnson and Swift 2000
	Sheep are able to detect approaching predators	Horizontal visibility (proportion of a 1 m^2 target that can be seen at 28 m)	Median horizontal visibility is > 62%	Johnson and Swift 2000

Value	Objective	Indicator	Target	Reference (if applicable)
Elk - Forage access	Create forage in areas that are most likely to be used by elk	Distance from treatment areas to closest cover	Mean distance to cover plus 1 SD is < 200 m in open transects. (This should ensure that approximately 2/3 of foraging areas are within an elk's "comfort zone" for feeding).	Buckmaster et al. 1999; Frair et al. 2005
Elk - Forage abundance	Create minimum forage cover conditions to promote ungulate use	% cover of grasses in treatment areas	> 10% grass cover	Buckmaster et al. 1999
	Create a significant increase in forage availability at study area level	Biomass of grasses and forbs; % cover or biomass of shrubs	Statistically significant increase over pre-treatment conditions.	ACA objective
Elk - Forage value	Create a vegetation community with good winter forage value	Seasonal Elk Forage Index – calculated using the percent cover and preference ranking for each forage species	50% increase	ACA target value, based on results in Sachro 2003
Elk - Optimum cover to forage ratio	Treatments provide a ratio of 60% cover to 40% foraging habitat.	Percent of the study area classified as cover or open habitat from satellite image or air photo	60:40 ratio ± 10% acceptable variance.	Buckmaster et al. 1999

Value	Objective	Indicator	Target	Reference (if applicable)
Elk - Predator avoidance	Cover retained within treatment can serve as hiding cover for predator avoidance	Animal hiding distance, measured in plots classified as cover. Estimated as the distance at which 90% of an animal is hidden from view	Average hiding distance within cover patches plus 1 SD is < 61 m. This should ensure that approximately 2/3 or more cover provides hiding cover.	Buckmaster et al. 1999
Mule deer - Forage access	Create forage in areas that are most likely to be used by mule deer	Distance from treatment areas to closest thermal cover. (distance to thermal cover may be difficult to determine in the field; use distance to closest cover)	Mean distance plus 1 SD is < 180 m. (This should ensure that approximately 2/3 of foraging areas are within a mule deer's "comfort zone" for feeding).	Wood et al. 1999
Mule deer - Forage abundance	Create minimum forage cover conditions to promote mule deer use	% cover of deciduous shrubs in treatment areas	> 50% shrub cover	Wood et al. 1999
	Create a significant increase in forage availability	Biomass of deciduous shrubs in study area	Statistically significant increase in palatable shrub species.	ACA objective
Mule deer - Optimum cover to forage ratio	Treatments provide the optimum ratio of cover to foraging habitat (foraging habitat is defined as either 0 to 20% canopy closure or > 50% deciduous shrub cover).	% of the study area classified as cover or open habitat from satellite image or air photos	60:40 ratio, ± 10% acceptable variance	Wood et al. 1999

2.0 STUDY AREA

The focal watershed subbasin is located along the eastern slopes of the Rocky Mountains in western Alberta, approximately 100 km southwest of the town of Rocky Mountain House, Alberta (Figure 1). Major rivers that flow into the North Saskatchewan River system within this subbasin include the North Saskatchewan, Cline, Siffleur, Alexandra, and Howse rivers. This subbasin measures approximately 80 km west-to-east and 80 km north-to-south and has a total area of 94,392 ha (ACA 2009). Banff National Park overlaps the western portion of the subbasin but was excluded from the study area for logistical reasons.

The Cline River subbasin is made up of four natural subregions (Natural Regions Committee 2006): alpine, subalpine, montane, and upper foothills. Our assessment focused on the lower-elevation montane and mid-slope subalpine areas (a thorough summary of each subregion is provided in Appendix A of ACA 2009). The montane natural subregion ranges from a lower elevational limit of 850 m to an upper limit of 1850 m, while the subalpine natural subregion ranges from around 1750 m to 2200 m in elevation. Montane vegetation typically includes forests of lodgepole pine (*Pinus contorta*), aspen (*Populus tremuloides*), or white spruce (*Picea glauca)*, with understories of hairy wild rye (*Elymus innovatus)*, Canada buffaloberry (*Shepherdia canadensis*), diverse forbs, and feather mosses. Montane grasslands in the area are dominated by northern wheatgrass (*Agropyron cristatum*) and June grass (*Koeleria macrantha*), while open forests include Douglas-fir (*Pseudotsuga menziesii*) and occasionally limber pine (*Pinus flexilis*) at exposed locations. Lodgepole pine forests, particularly in areas previously burned, are also common at lower elevations of the subalpine natural subregion, while Engelman spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*) are common at higher elevations. Typical subalpine understory species include Canada buffaloberry, hairy wild rye, showy aster (*Aster conspicuus)*, bearberry (*Arctostaphylos uva-ursi*), juniper (*Juniperus spp*.), heart-leaved arnica (*Arnica cordifolia*), twinflower (*Linnaea borealis*), one-sided wintergreen (*Orthilia secunda*), and bunchberry (*Cornus canadensis*). False azalea (*Menziesia ferruginea*) and grouseberry (*Vaccinium scoparium*) are important species of higher elevations.

The spatial extent of the study area within the Cline River subbasin varied with the objective being addressed. Landscape-level analyses occurred for an area that encompassed all the ungulate winter range within the subbasin (outside the national park), regardless of whether it was burned or not (Figure 1). Ecosystem-level objectives were assessed for an area bounded by the extent of the Upper North Saskatchewan River prescribed fire (Figure 2). Species-level objectives were monitored at multiple biologically relevant smaller study areas within and adjacent to the prescribed fire (Figure 2).

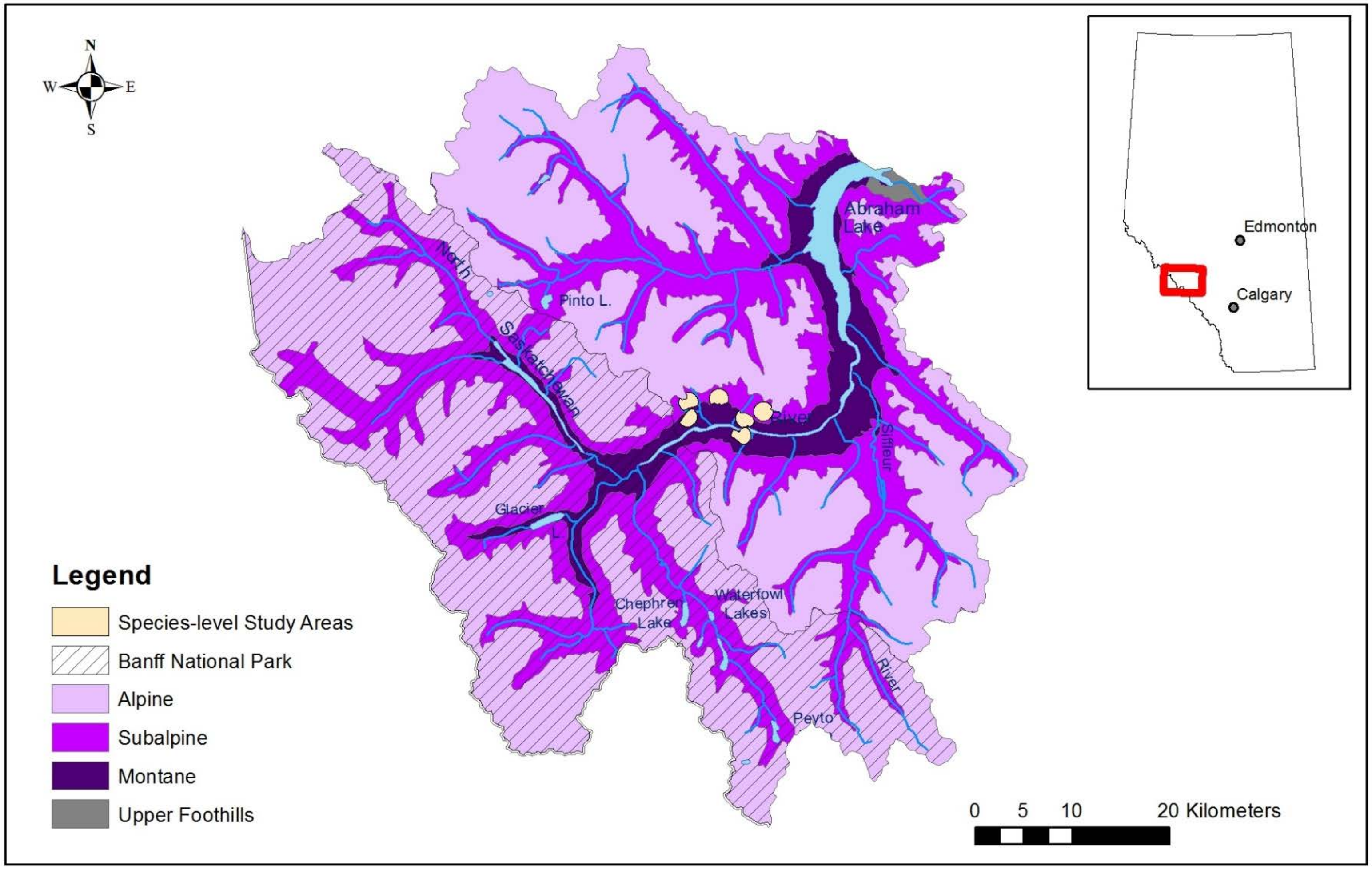


Figure 1. Cline River subbasin and species-level study areas in which ungulate winter range restoration objectives were assessed. Inset map shows the location within Alberta.

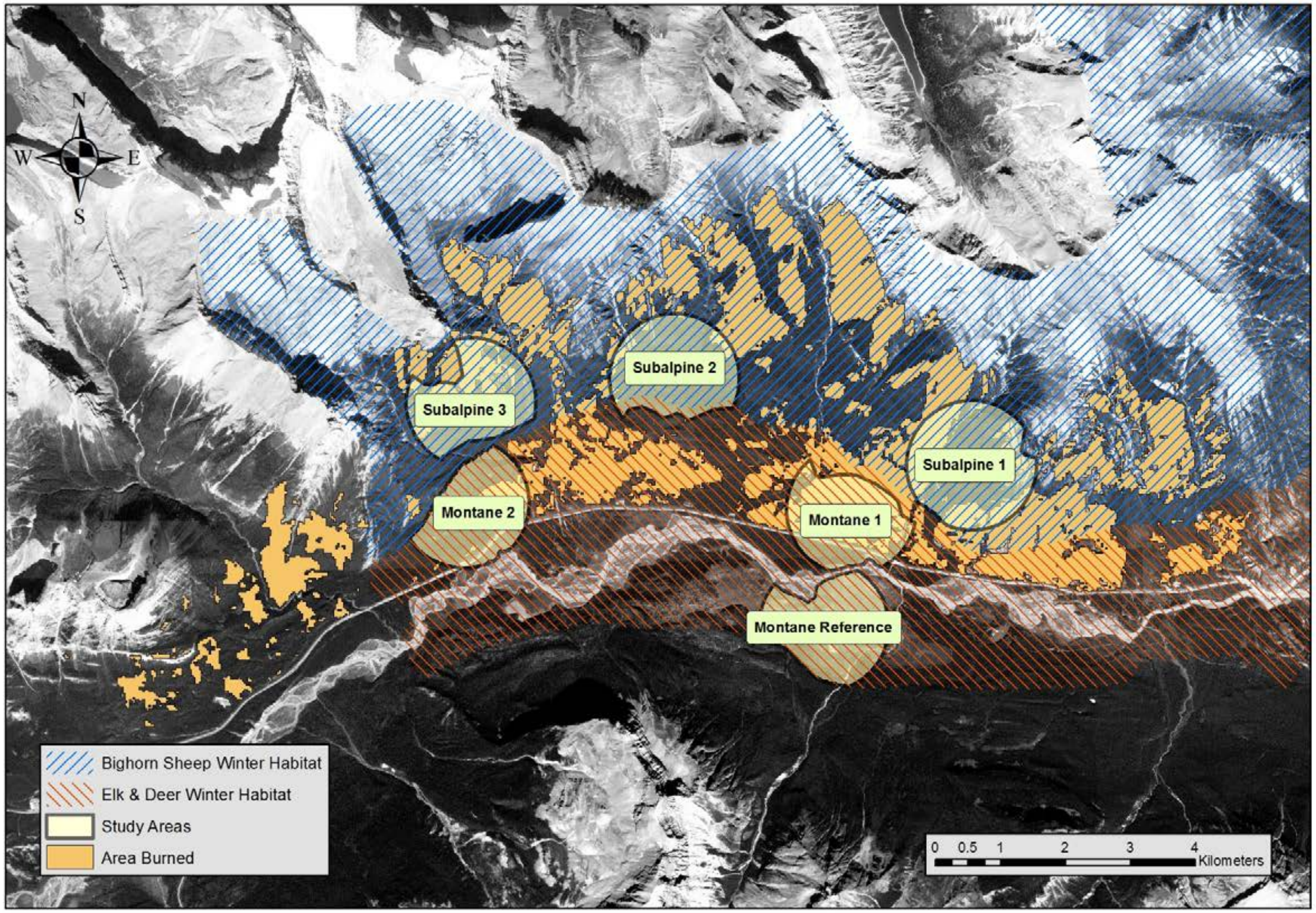


Figure 2. Location of the 2009 Upper North Saskatchewan River prescribed fire and species-level study areas within the Cline River subbasin.

3.0 MATERIALS AND METHODS

3.1 Prescribed fire planning and implementation

Logistics of the Upper North Saskatchewan River prescribed fire were planned jointly by the Government of Alberta and Parks Canada, and evolved over the course of the pretreatment data collection period. Recognizing the logistical and temporal constraints associated with implementing large-scale disturbance treatments (e.g., weather windows for prescribed fires), the initial planning approach was to treat a number of small adjacent prescribed fire units completed over a 20 year period as a single disturbance event from an ecological perspective. Ultimately, multiple identified prescribed fire units were amalgamated into a single proposed 7,900 ha prescribed fire located north of the North Saskatchewan River from Mount Wilson in Banff National Park extending 20 km east to Whirlpool Point. Approximately 2,550 ha of the proposed prescribed fire were within the national park and 5,350 ha were on provincial lands. Prescribed burning was initiated when conditions were deemed favorable on May 21, 2009 (initial burn) and September 28, 2009 (fall burn). These two events were treated as a single prescribed fire disturbance that encompassed an area of 5,727 ha, including remnants of unburned habitat within the outer event boundary. The total burned area was 4,835 ha.

3.2 Species-level study design

Species-level VOITs for ungulate winter range were assessed using field data collected both before and after the prescribed fire at localized study areas. In general, species-level assessment followed a nested design: study areas were selected within natural subregions; multiple sampling transects were nested within each study area; and multiple sampling plots were nested within each transect. By repeat sampling of these study areas over time, we further attempted to follow a Before-After-Control-Impact (BACI) study design (Green 1979). Field data collection focused on resource characteristics important for evaluating ungulate habitat suitability including terrain parameters, canopy characteristics, security cover, and vegetation composition, cover, and biomass. In combination with Geographic Information System (GIS) digital mapping tools, these measurements were used to assess forage access, forage abundance, forage value, cover-to-open forage ratio, security cover and/or proximity to escape terrain for predator avoidance, thermal cover, and human disturbance potential. The collection of field data and subsequent analyses are discussed below.

3.3 Selection of study areas and sampling transects

We selected local study areas within the montane and subalpine natural subregions based on the following criteria: (1) areas with high ungulate winter range potential, (2) areas identified for future prescribed fires, and (3) areas that encompassed a single natural subregion. To create a biologically meaningful study area for assessing impacts on ungulates, we chose a spatial extent relevant to elk foraging movements. Frair et al. (2005) found the scale separating localized foraging movement and relocating behaviour ranged from 550 m to 1650 m across individuals. We applied the approximate mid point of this range (1000 m) as the radius of each local study area for measuring elk habitat values and assumed this radius would also capture typical mule deer and bighorn sheep foraging movements. Local study area boundaries were further refined to follow natural subregion boundaries and significant geographic features.

Four consecutive years of pre-fire sampling were conducted between 2005 and 2008, followed by three years of post-fire sampling in 2010, 2011, and 2015 as manpower permitted. These sampling times captured the immediate post-fire period when the greatest forage quality impacts might be noted as well as a subsequent year (2015) within the range of when elk use of burned areas is known to be highest (< 17 years post-fire [Innes 2011]). With the evolution of the prescribed fire planning process described above and the refinement of sampling protocols, the ultimate suite of study areas was not finalized until 2008 and thus not all sites have data in all years (e.g., only one of the three areas sampled in 2005, subalpine 1, remained within the final prescribed fire plan). Five of the sites represented treatment sites as they were disturbed in the 2009 prescribed fire. The one montane site south of the North Saskatchewan River remained as a reference site for comparison to natural fire effects (it had burned previously in 1998), until a portion subsequently burned again in a 2014 wildfire[1].

Prior to each survey season, random transect locations were generated in GIS for each study area. We attempted to survey 20 transects from the previously identified random start locations, with a given transect established perpendicular to the slope. If topography or safety concerns precluded sampling at a given start location, another start location was substituted where possible. We surveyed 467 different transects across the six study areas during the pre-

[1] In July 2014, lightning ignited the Spreading Creek wildfire within the Banff National Park boundary. This fire spread east paralleling the 2009 Upper North Saskatchewan River prescribed fire on the opposite side of the river. The wildfire ultimately jumped the river and re-burned small areas burned by the 2009 prescribed fire. The only affected study area was the montane reference site, which had not burned in 2009. This natural event fell outside the ten-year assessment period for disturbance targets evaluated within this document.

treatment (2005-2008) and post-treatment (2010-2015) periods (Table 2). No sampling took place in the treatment year (2009).

Table 2. Number of transects surveyed within each study area per given year.

Study Area	2005	2006	2007	2008	2009	2010	2011	2015
Montane 1		15	20	20	Treatment Year	20		18
Montane 2		15	20	19		19		16
Montane Reference		15	20	19		20		
Subalpine 1	20		20	19			19	20
Subalpine 2				19			19	17
Subalpine 3				20			19	19
Total	20	45	80	116		59	57	90

3.4 Field data collection

3.4.1 General site and terrain characteristics

General site data were recorded at the start of each transect including a UTM location (NAD 83, Zone 11), elevation, transect bearing, terrain aspect, slope, and a digital photo to capture transect and study area character.

3.4.2 Canopy characteristics

In the field, transects were classified as open or closed canopy. Open transects were defined as those with less than 20% canopy closure; closed transects were those that were equal to or greater than 20% canopy closure. Open habitat, including deciduous habitat, typically has high availability of grasses and shrubs and valuable winter forage for ungulates (Buckmaster et al. 1999). We visually estimated percent canopy closure for each transect. If the transect did not entirely fall within a single classification, it was relocated a maximum distance of 30 m. We also visually estimated the percent conifer in the canopy, and canopy height was estimated with a clinometer using a representative tree of average height whose base and top were clearly visible from 20 m or more.

3.4.3 *Security cover*

Horizontal visibility was measured as the proportion of a 1 m^2 checkered target that could be seen at a 28 m distance along the transect. This measure of visibility is relevant for bighorn sheep and their ability to detect approaching predators. For transects classified as closed canopy, animal hiding distance was defined as the distance at which 90% of an animal was hidden from view and was measured as the distance along the transect at which 90% of a 1 m^2 checkered target was obscured from view. This metric was relevant for assessing elk security habitat for predator avoidance (Buckmaster et al. 1999).

3.4.4 *Vegetation cover and composition*

The dominant tree, shrub, dwarf shrub, forb, and grass species were identified and recorded for each transect. Ground cover of moss/lichen, forb, grass/sedge, dwarf shrub, deciduous shrub, coniferous shrub, and bare/rock/litter was estimated within two 1 m^2 square subplots along each transect. The bottom left corner of a subplot was placed on the uphill side of the transect at 5 m and 25 m (Figure 3). Species composition of herbaceous and woody plants (≤ 2.0 m in height) was also recorded for all plants that provided at least 1% cover within the square subplot. Unknown species were recorded to the nearest genera if possible. Additionally, a 10 m^2 circular subplot (1.78 m radius) was established at 5 m and 25 m (Figure 3), and shrub cover was visually estimated for all shrub species ≥ 0.25 m and ≤ 2.0 m that covered a minimum of 1% of the circular subplot (Figure 3).

Measures of dominant vegetation, ground cover, shrub cover, and species composition were important to characterize changes in the vegetative community as a result of the prescribed fire. The fire was expected to create open habitat and enhance forage availability for grazers that focus primarily on grass with up to 25% browse (i.e., bighorn sheep) and for mixed feeders that select both grass and browse (i.e., elk, mule deer; Shipley 1999).

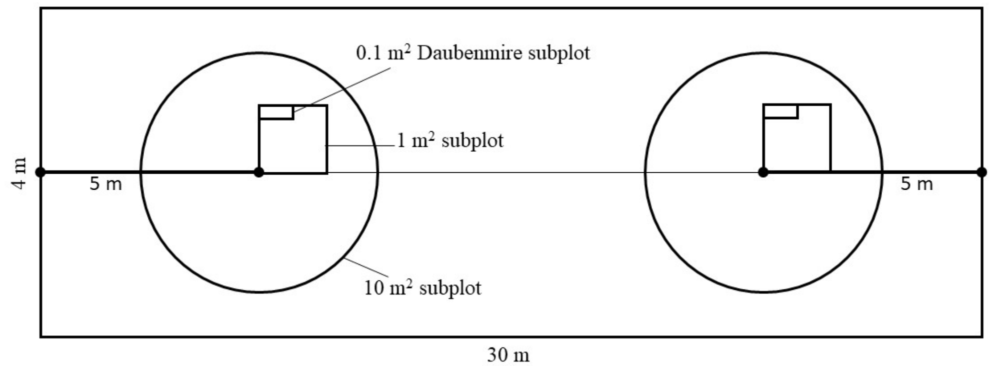
3.4.5 *Herbaceous biomass*

Forage abundance was anticipated to increase with the creation of more open habitat through the prescribed fire treatment. As a measure of forage available to wildlife, herbaceous biomass was estimated by clipping old and green standing biomass greater than 2 cm in height within a 20 cm x 50 cm (0.1 m^2) Daubenmire sampling frame nested in the top left corner of the 1 m^2 square subplot (Figure 3). All clipped biomass was separated into forb and grass, placed in labelled paper bags, and weighed to determine wet weight. No clip was taken if the sample was estimated to be less than 1 g dry weight, though this was noted. Dry weight was determined by drying samples for a minimum of 36 hours in a forced-air drying oven until a constant weight was achieved.

3.4.6 Woody shrub biomass

In addition to herbaceous biomass, open habitat created through the prescribed fire treatment was expected to increase woody shrub cover and biomass available for mixed feeders, particularly for winter forage. During the winter, mixed feeders browse more heavily on woody forage (aspen and shrub tips; Visscher et.al. 2006) that is higher in protein, phosphorus, and carotene than grasses (Stelfox and Stelfox 1993). Aspen and shrub stem tips provide mule deer with much of their winter food during high snowfall years (Wood et.al. 1999).

Woody shrub biomass calculations required two unique field measurements for each shrub species. Basal diameter was measured for the closest stem to the subplot center for each species in each quadrant in the 10 m^2 circular subplot as well as for a second stem identified to be the nearest neighbor at a right angle from the first stem. The distance from the subplot centre and from the nearest neighbor were also measured. Shrubs were required to be $\geq$ 0.25 m and $\leq$ 2.0 m in height with cover $\geq$ 1% to be considered for measurement. These basal diameter (mm) and distance measurements (m) were subsequently used to estimate biomass using established predictive equations (Visscher et al. 2006) and shrub density based on the T-Squared Density Estimation method (Krebs 1999).



Metrics measured at each plot type were as follows:

- 30 m X 4 m transect
  - Terrain Characteristics (slope, aspect)
  - Canopy Characteristics (canopy closure, canopy height, % conifer)
  - Security Cover (horizontal visibility, animal hiding distance)
  - Dominant Vegetation
- 10-m^2 circular subplot
  - Shrub Cover
  - Woody Shrub Biomass
- 1-m^2 square subplot
  - Species Composition

Figure 3. Nested subplots within transects used to sample resource characteristics important for evaluating ungulate habitat suitability at species-level study areas. Metrics collected within each transect or subplot are identified. Not to scale.

3.5 Data analysis

Species-level data summary statistics were generated using R Open source statistical software within the RStudio platform (R Core Team 2015; R Studio Team 2015). Additionally, R packages RODBC (Ripley and Lapsley 2015), ggplot2 (Wickham 2009), dplyr (Wickham and Francois 2015), and ReporteRs (Gohel 2016) as well as Stata 11.2 (StataCorp 2009) were used to access and analyze data.

The 14 species-level objectives identified in Table 1 are assessed in this report based on pre- and post-prescribed fire field data and associated GIS analyses. These VOITs look primarily at fire treatment impacts on forage (access, abundance, quality) and predator avoidance (proximity of security cover/escape terrain, visibility for predators/prey) in relation to improvement in winter range. Eight additional species-level objectives from the subbasin plan are discussed in Appendix C.

3.5.1 Forage access

Average aspect and distance to cover - To determine forage access for bighorn sheep, the mean aspect of burned areas within bighorn sheep winter range in each species-level study area was calculated using ArcGIS. Typically, greater solar radiation on south-facing slopes favours winter use by sheep due to higher available grass and lower energetic requirements to access the forage (Stelfox and Stelfox 1993, Safford 2004).

To evaluate forage access for elk and mule deer, we evaluated the mean distance to cover (i.e., distance to forest canopy closure ≥ 20%) based on sampling at open canopy transects at each species-level study area each year. Wood et al. (1999) and Buckmaster et al. (1999) identified comfortable foraging to be within 140 m and 180 m of cover for mule deer and elk, respectively in their winter habitat suitability models.

Optimum cover-to-forage ratio - Crown closure was used to assess the cover-to-forage area ratio before and after the prescribed fire. The Foothills Research Institute crown closure layer covers much of western Alberta and was used in ArcGIS to differentiate open cover types that represent foraging areas (crown closure < 20%) versus closed cover types that represent more secure habitat (crown closure ≥ 20%). Assuming recently burned areas were detectedable by satellite imagery and were stand-replacing fires that no longer had a closed canopy, the canopy closure layer was first updated to reclassify areas burned since 2004 as open canopy. This assumption is supported by post-fire field data and observations of crown closure in other recently burned areas. Using the updated crown closure layer, the total area of closed cover types compared to open cover types within a given species-level study area was calculated before and after the prescribed fire and compared to the desired 60% cover to 40% open/foraging habitat ratio (Buckmaster et al. 1999). This measure is relevant to both elk and mule deer.

3.5.2 Forage abundance

Vegetation percent cover - The mean percent cover of forbs, grasses, and deciduous shrubs assessed at the two 1 m^2 square subplots within each transect was calculated for each species-level study area in each year. The pre- to post-fire change in percent cover was compared to relevant species-specific targets (e.g., % grass and % forb for sheep, % grass for elk, % shrub for mule deer).

Forb/grass and shrub biomass - For each species-level study area in each year, the mean forb and grass dry weights (g/m^2) were calculated from samples collected at the two 1 m^2 square subplots within each transect. Subplots in which no sample was collected were treated as zeros. These measures were used to assess forage abundance for sheep and elk.

For a given forage shrub species, the basal measurement was averaged for the two measured specimens within a 10 m^2 circular subplot. This value was subsequently used to calculate average twig biomass (g/stem) for the species following established species-specific biomass regressions (Visscher et al. 2006). The average twig biomass for each species was multiplied by the shrub stem density ($stems/m^2$) for that species as calculated based on the T-Square Density Estimation method (Krebs 1999) to give the total biomass for that species in the circular subplot. The various species-specific biomass estimates were summed across a subplot and then averaged across the two subplots within a transect to produce a total shrub biomass estimate (g/m^2) for the transect. This forage abundance measure was relevant for elk and deer.

3.5.3 Forage value

Seasonal Elk Forage Index - Using R statistical software and following Sachro (2003), a seasonal Elk Forage Preference Index was calculated for each study area each year. This index assesses the percent cover and preference ranking for each forage species relative to total plant cover and can be assessed for each season based on dietary shifts. Forage Preference Index values range from 0 to 3 with values < 1 considered low, > 1 considered moderate, and > 2 considered high forage quality (Sachro 2003).

3.5.4 Predator avoidance

Distance to escape terrain, horizontal visibility, animal hiding distance - Bighorn sheep, elk, and mule deer use slightly different strategies for predator avoidance (ACA 2009). Sheep need open area and steep terrain for predator detection and avoidance (Stelfox and Stelfox 1993, Zeigenfuss et al. 2000). Elk use tree cover (Stelfox and Stelfox 1993, Jones et al. 2002, Eisenberg et al. 2015), while mule deer tend to use tree cover and topography (Stelfox and Stelfox 1993, Wood et al. 1999). Predator avoidance values were assessed using field-based transect data to calculate the mean animal hiding distance on closed transects (for elk and mule deer) and mean horizontal visibility distance on all transects (for bighorn sheep), while mean distance to escape terrain (i.e., areas where the slope is between 27° and 85°, relevant for bighorn sheep) was calculated in GIS for open transects for each study area each year.

4.0 RESULTS

Field data in combination with GIS analyses were used to assess species-level objectives identified in Table 1 and those addressed in Appendix C. The results presented below look primarily at prescribed fire impacts on forage (access, abundance, quality) and predator avoidance (proximity of security cover/escape terrain, visibility for predators/prey). For results related to thermal cover and human disturbance potential, please refer to the appendix.

Use of BACI analyses was ultimately limited by a lack of reference study areas and intermittent sampling (Smokoroski et al. 2015). The montane reference site was sampled only once following the 2009 prescribed fire before it burned in a subsequent wildfire. No subalpine reference sites were monitored throughout the study period. Recognizing studies may face logistical constraints, Smokoroski et al. (2015) recommend a minimum three consecutive pre-fire sampling years (met in the montane but not subalpine study areas), three immediate and consecutive post-fire sampling years (two consecutive years met in one study area only), a further three consecutive post-fire years (only a single year in this study), and a final revisit at ten years post-fire. Thus, statistical tests were limited to before/after treatment analyses that do not have the same power to detect impacts as a full BACI design. Smokoroski and Randall (2017) tested before/after comparisons on a full dataset that met BACI standards and found that some significant impacts evident in the full dataset were no longer apparent in a reduced dataset and that different conclusions were reached depending on what sampling interval was used.

4.1 Forage access

The average aspect across all burned areas that overlapped sheep winter range was 186.5^0 (SD = 37.9^0), and the average aspect within the burned portions of the species-level study areas was 182.2^0 (SD = 34.9^0). Thus, the forage access target for bighorn sheep of an average aspect between 135^0 and 225^0 was met. This also suggests that the study area aspects were fairly representative of the entire prescribed fire area.

Forage access for elk and mule deer was evaluated through a field measure of distance from burn area to closest cover. Data were not collected on distance to cover for 2010 and 2011; only 2015 data are available for assessment of post-fire distance to cover, though this measure is not expected to have changed appreciably in the time lapsed since treatment. The pre-fire mean distance to cover plus one standard deviation on all open canopy transects was 16.8 m for montane study areas and 25.3 m for subalpine study areas, but increased post-fire to 95.6 m and 77.9 m respectively (Table 3). These increases were significant ($z=-3.75$, $p<0.001$ and $z=-4.47$, $p<0.001$ for montane and subalpine respectively) and were below the established maximum targets of 200 m for elk and 180 m for mule deer (Table 1). Furthermore, the maximum distance to cover was less than 100 m for all treatment study areas, suggesting the prescribed fire was successful at creating foraging areas close to cover. Interestingly, the montane reference site showed higher distance to cover values from 2006 to 2008 than both pre-fire montane study areas, indicating that the 1998 Steepbank wildfire was also effective at creating open feeding areas in close proximity to cover.

Similar in intent to distance-to-cover objectives but evaluated using GIS analyses across an entire species-level study area, cover-to-forage ratio objectives for elk and mule deer provide an adequate mix of foraging and security habitat in post-fire areas (Table 4). Open cover increased significantly across montane burn areas, from an average of 7.8% open cover pre-fire to 59.2% post-fire, while open cover in the subalpine study areas increased from 8% pre-fire to 31.8% post-fire. There was variation among study areas, likely attributable to variation in burn patterns and intensity. Although not all study areas met the targeted ratio of 60% closed cover to 40% open cover, the range of study area ratios below, within, and above the targeted ratio suggests that overall the treatments were effective in creating an adequate mix of open foraging habitat near cover habitat at a large scale for both elk and mule deer.

Table 3. Distance from forage areas to cover for open canopy transects in montane and subalpine species-level study areas.

Natural Subregion	Year	n	Mean (m) (± SD)	Min	Max
Montane	2006	2	9.0 (± 1.4)	8	10
	2008	5	11.6 (± 7.1)	0	18
	2009		*Treatment Year*		
	2015	15	62.0 (± 33.6)	20	100
Montane Reference	2006	13	33.8 (± 29.6)	0	100
	2007	17	45.0 (± 43.9)	0	150
	2008	16	63.8 (± 57.8)	0	200
	2009		*Treatment Year*		
Subalpine	2005	4	20.0 (± 16.3)	0	40
	2008	13	8.7 (± 12.6)	0	40
	2009		*Treatment Year*		
	2015	25	48.0 (± 29.9)	10	100

Table 4. Percentage of species-level study area classified as open or closed canopy.

Study area	Pre-treatment closed canopy (% of area)	Pre-treatment open canopy (% of area)	Post-treatment closed canopy (% of area)	Post-treatment open canopy (% of area)
Montane 1	88.9	11.1	3.2	96.8
Montane 2	95.5	4.5	78.3	21.7
Montane Reference	22.4	77.6	22.4	77.6
Subalpine 1	92.9	7.1	55.9	44.1
Subalpine 2	98.2	1.8	89.9	10.1
Subalpine 3	85.0	15.0	58.9	41.1

4.1 Forage abundance

Forage abundance measures were examined graphically for individual study areas within each natural subregion. As study areas were generally similar (as indicated by large overlap in 95% confidence intervals around means), they were pooled for the following analyses and graphical presentations, unless otherwise noted.

Grass abundance - Mean grass cover was consistently below 10% for all pre-fire time periods as well as at one year post-fire (Figure 4). By six years post-fire, the mean grass cover increased significantly, reaching above 15% for montane transects ($H=15.01$, $p=0.0032$). Grass biomass showed a significant increase immediately post-fire across montane study areas (Figure 5, $H=15.86$, $p=0.0032$) but decreased by six years post-fire and was not significantly different from pre-fire (all post-hoc comparisons with Bonferroni correction were $p>0.05$). The montane reference study area (previously burned in 1998) consistently had higher mean grass cover and biomass than the other montane study areas (Figure 4, Figure 5). Fairly consistent mean grass cover values from year to year within the montane reference area suggests that grass cover had stabilized since the 1998 fire, though mean grass biomass was more variable between the years and supports the alternate explanation that montane grass biomass may have only increased one year post-fire as a result of a year effect. Overall, these results suggest grass forage abundance targets within the montane study areas were met for elk (i.e., minimum 10% grass cover; statistically significant increase in grass biomass) and appear to be trending positively towards targets for bighorn sheep (i.e., 20-30% increase in cover and biomass of palatable grass species).

Within the subalpine natural subregion, a significant change in grass cover was noted by six years post-fire (Figure 4, H=50.61, p=0.0001), but only the subalpine 1 study area exceeded the 10% grass cover target for elk. No significant change in mean grass biomass was noted across the subalpine study areas (Figure 5, H=2.34, p=0.6728). These results suggest further treatment in the subalpine natural subregion would be required to meet grass forage abundance targets for elk and bighorn sheep.

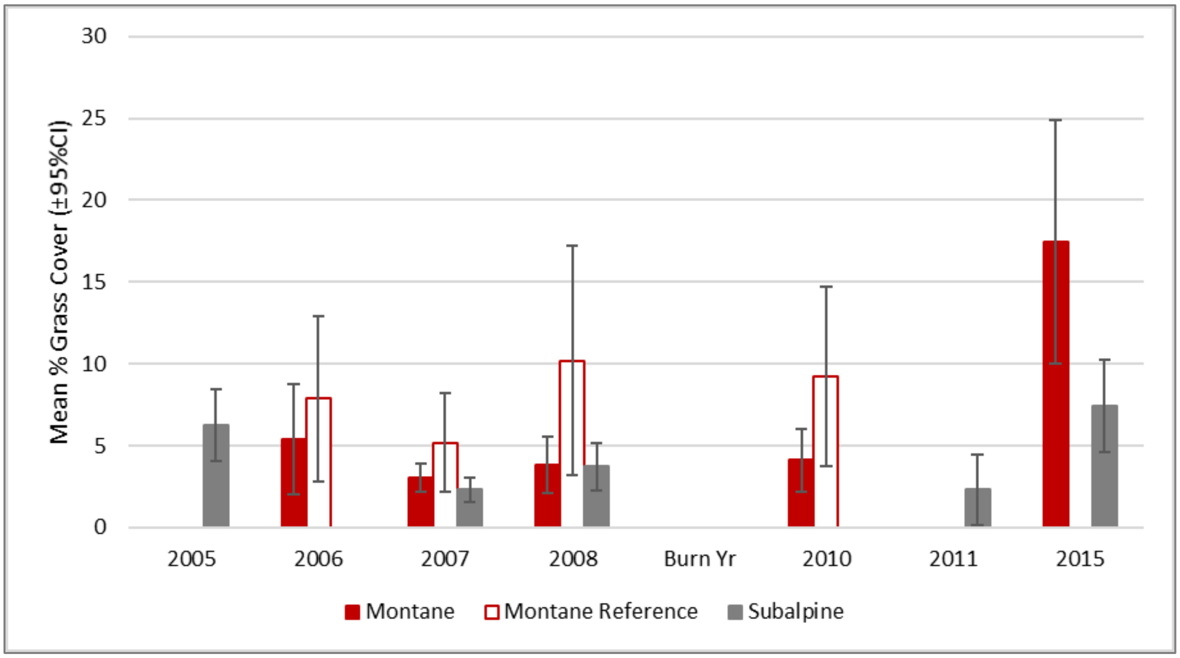


Figure 4. Mean grass cover (%) with 95% confidence intervals measured at 1 m^2 square subplots in montane and subalpine species-level study areas.

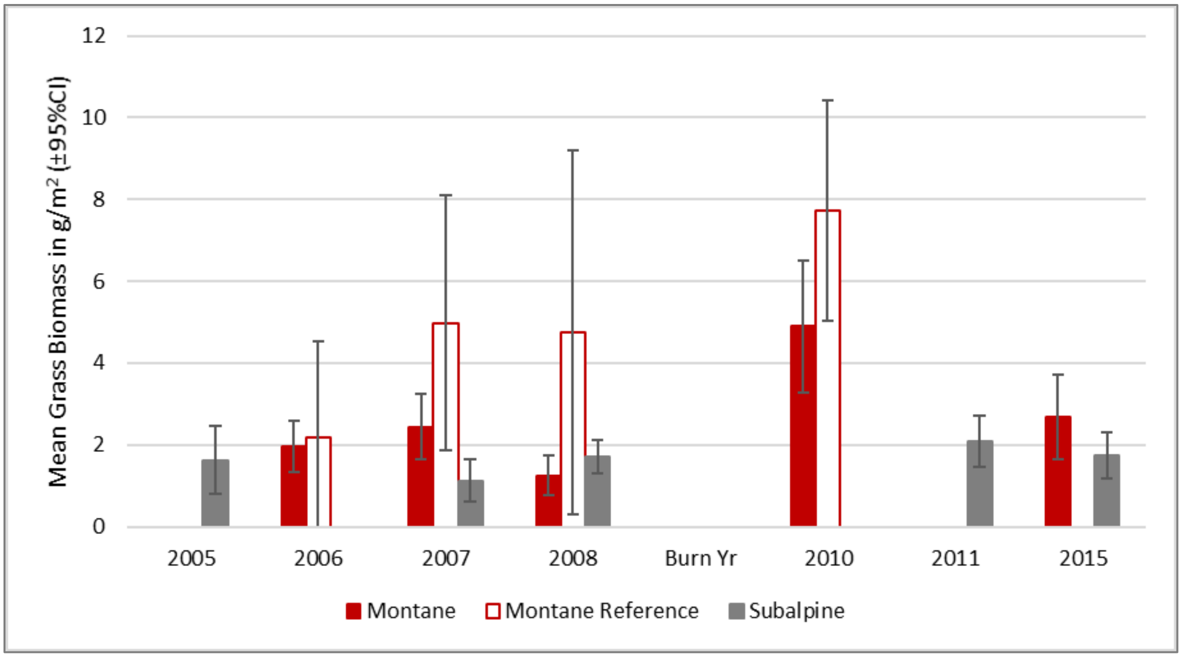


Figure 5. Mean grass biomass (g/m^2) with 95% confidence intervals measured from dry weights taken at 0.1 m^2 Daubenmire subplots at montane and subalpine species-level study areas.

Forb abundance - Mean forb cover was consistently below 10% for both pre- and immediate post-fire time periods in montane study areas; however, forb cover reached its highest level in 2015 which suggests forb presence may be increasing as burned areas continue to revegetate (Figure 6; H=12.48, p=0.0141). Conversely, forb biomass by dry weight in montane study areas showed a significant pulse in the first-year post-fire but then declined by six years post-fire (Figure 7; H=21.61, p=0.002); whether this is due to the prescribed fire or particularly good growing conditions in that year is unclear. Within the subalpine species-level study areas, mean forb cover was consistently higher than montane study areas and showed a similar pattern of forb cover increasing with time over the post-fire period (Figure 6), though the changes were only marginally significant (H=9.19, p=0.0563) and driven by a large change in the subalpine 2 study area. Evaluation of forb biomass showed no significant difference in mean forb dry weights among years (Figure 7, H=7.54, p=0.1011). These results suggest that forb abundance is variable within the subalpine study areas, with a possible increase in cover but not biomass as a result of the prescribed fire. Additional consecutive years of sampling would help discern post-fire impacts from a growing year effect. Additional treatment would be required in both natural subregions to meet the forb forage abundance targets for elk (i.e., statistically significant increase in forb biomass) and bighorn sheep (i.e., 20%-30% increase in cover and biomass of palatable forb species).

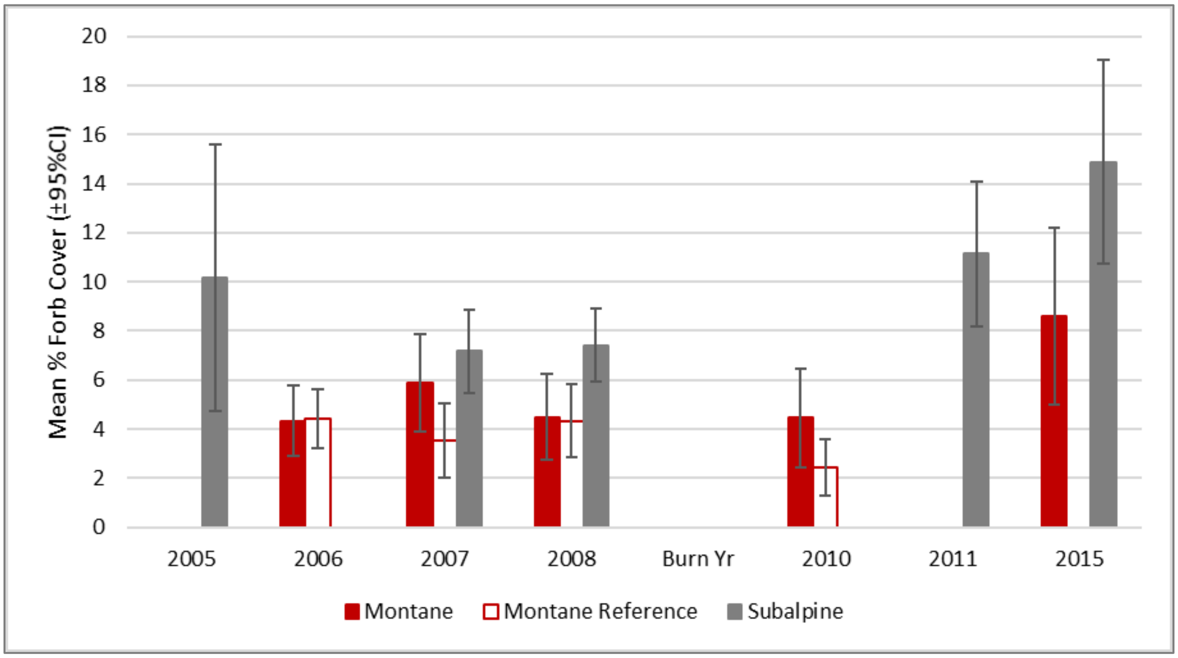


Figure 6. Mean forb cover (%) with 95% confidence intervals measured at 1 m^2 square subplots in montane and subalpine species-level study areas.

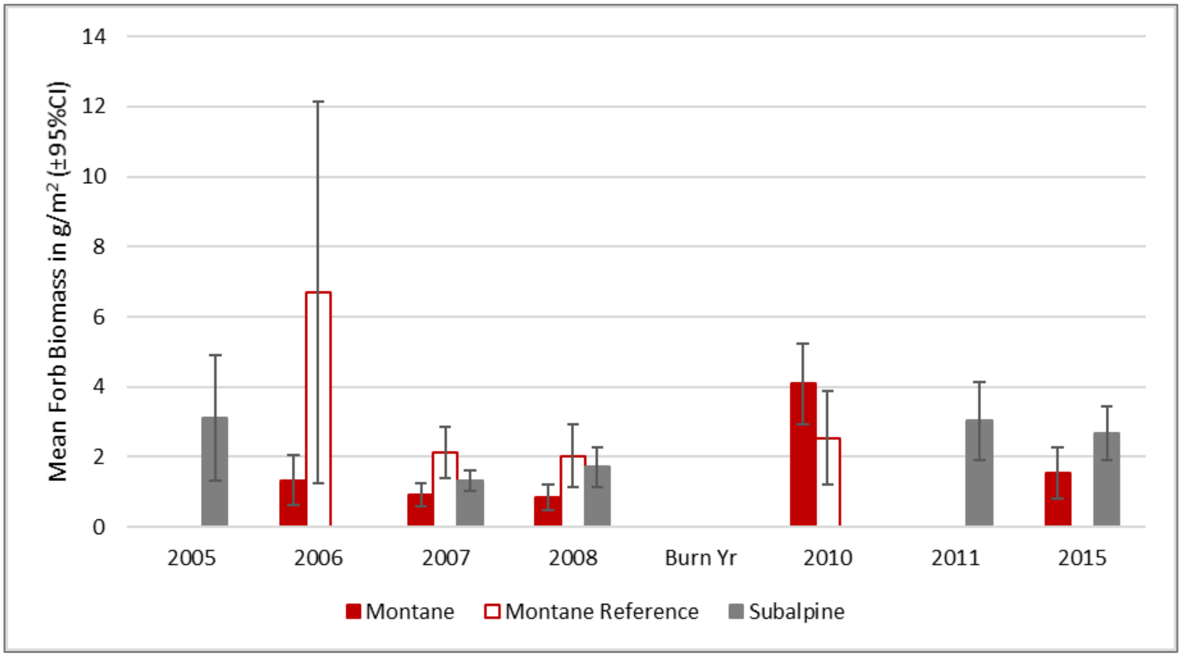


Figure 7. Mean forb biomass (g/m^2) with 95% confidence intervals measured from dry weights taken at 0.1 m^2 Daubenmire subplots at montane and subalpine species-level study areas.

Shrub abundance - Mean shrub biomass for forage species was significantly higher in both montane and subalpine study areas pre-fire and very low post-fire (Figure 8, H=49.49, p=0.0001; H=59.13, p=0.001, respectively), though deciduous shrub cover may be rebounding six years post-fire as vegetation regenerates within the study areas (Figure 9). High within-year and between-year variability in shrub biomass was noted. Targets for shrub forage abundance for elk (i.e., statistically significant increase in biomass of shrubs) and mule deer (i.e., greater than 50% cover of deciduous shrubs) do not appear to have been met and further monitoring would be required to determine whether shrub forage abundance will increase over time as a result of the treatment.

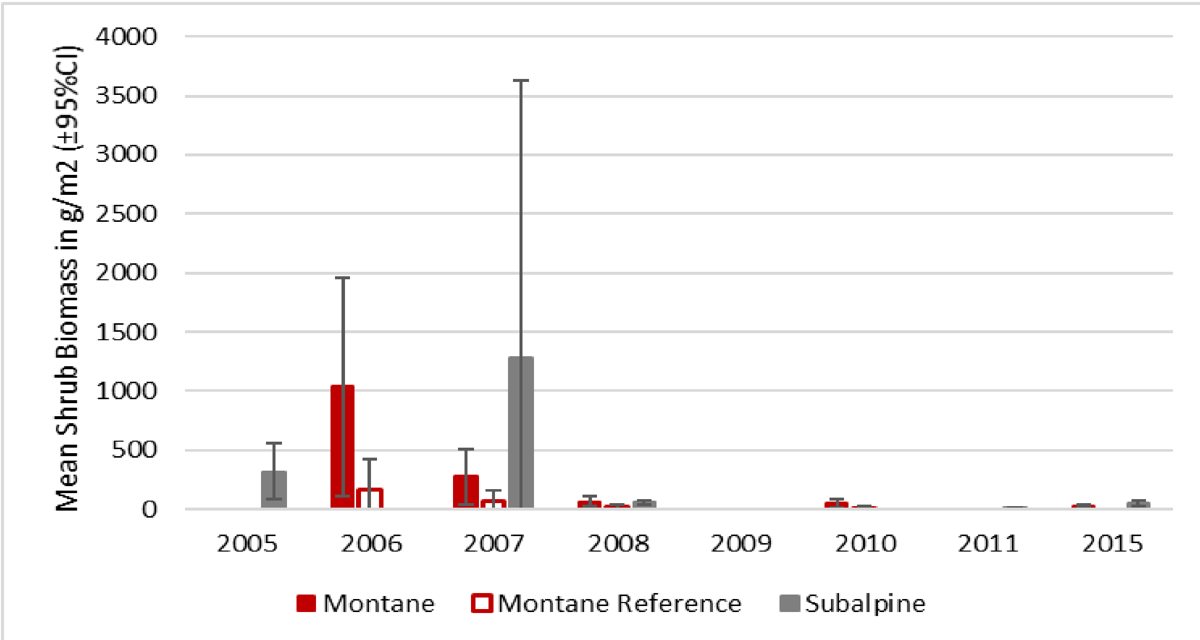


Figure 8. Mean shrub biomass (g/m^2) with 95% confidence intervals for montane and subalpine species-level study areas estimated using basal diameter and shrub density measured in 10 m^2 circular subplots.

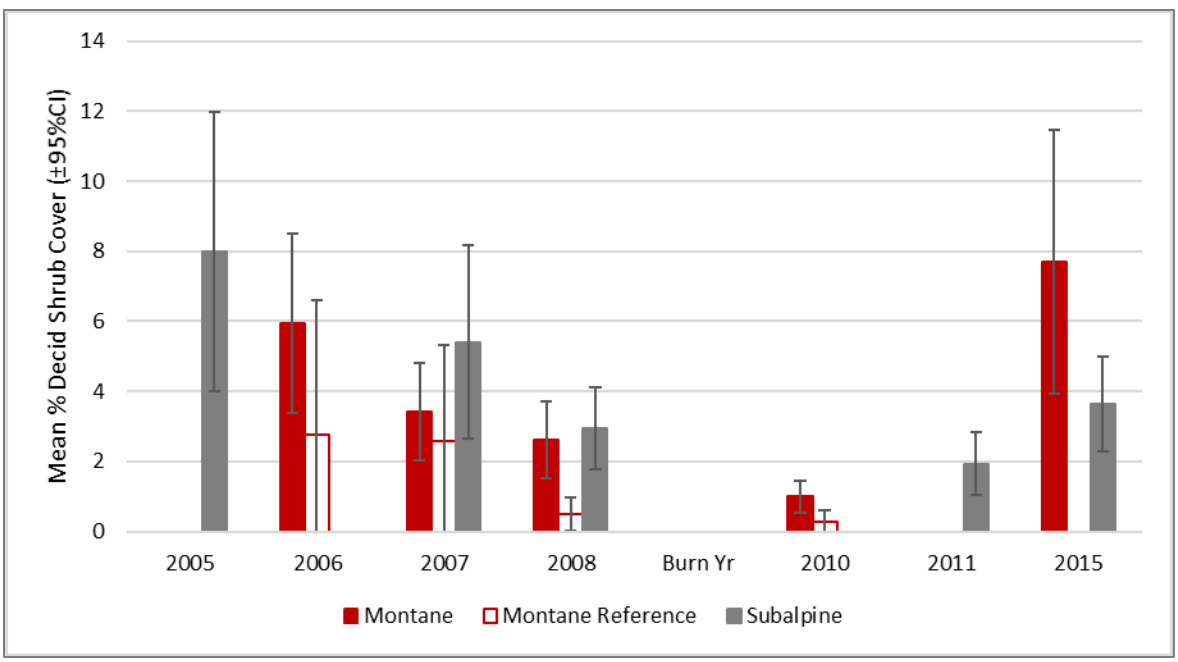


Figure 9. Mean deciduous shrub cover (%) with 95% confidence intervals measured in 1 m^2 square subplots for montane and subalpine species-level study areas.

4.3 Forage value

When the seasonal Elk Forage Preference Indices were calculated (i.e., spring, summer, fall, winter examined separately), both montane and subalpine study areas showed significant increases in spring indices post-fire (Figure 10a; H=50.38, p=0.0001 and H=31.01, p=0.0001, respectively). Summer forage preference indices also significantly increased between pre-fire and six years post-fire at montane and subalpine study areas (Figure 10b, H=27.30, p=0.0001 and H=25.43, p=0.0001), though the montane 2 and subalpine 1 study areas were actually lower six years post-fire than immediately post-fire. Fall forage preference indices for montane study areas also increased significantly by six years post-fire relative to pre-fire years (Figure 10c, H=32.41, p=0.0001), while fall forage preference indices for subalpine study areas were only significantly different between 2005 and 2015 (H=33.84, p=0.001). Given that 2015 was only different from one of three pre-fire years, subsequent sampling may be necessary to determine if this is explained by a treatment effect or simply annual variation. Likewise, winter forage preference indices in montane and subalpine study areas only displayed significant differences between select pre-fire years (Figure 10d, H=17.39, p=0.0016 and H=17.13, p=0.0018, respectively) and not between pre- and post-fire years. The target of a 50% increase in quality winter elk forage was not met; however, increases in preferred spring and summer forage were noted.

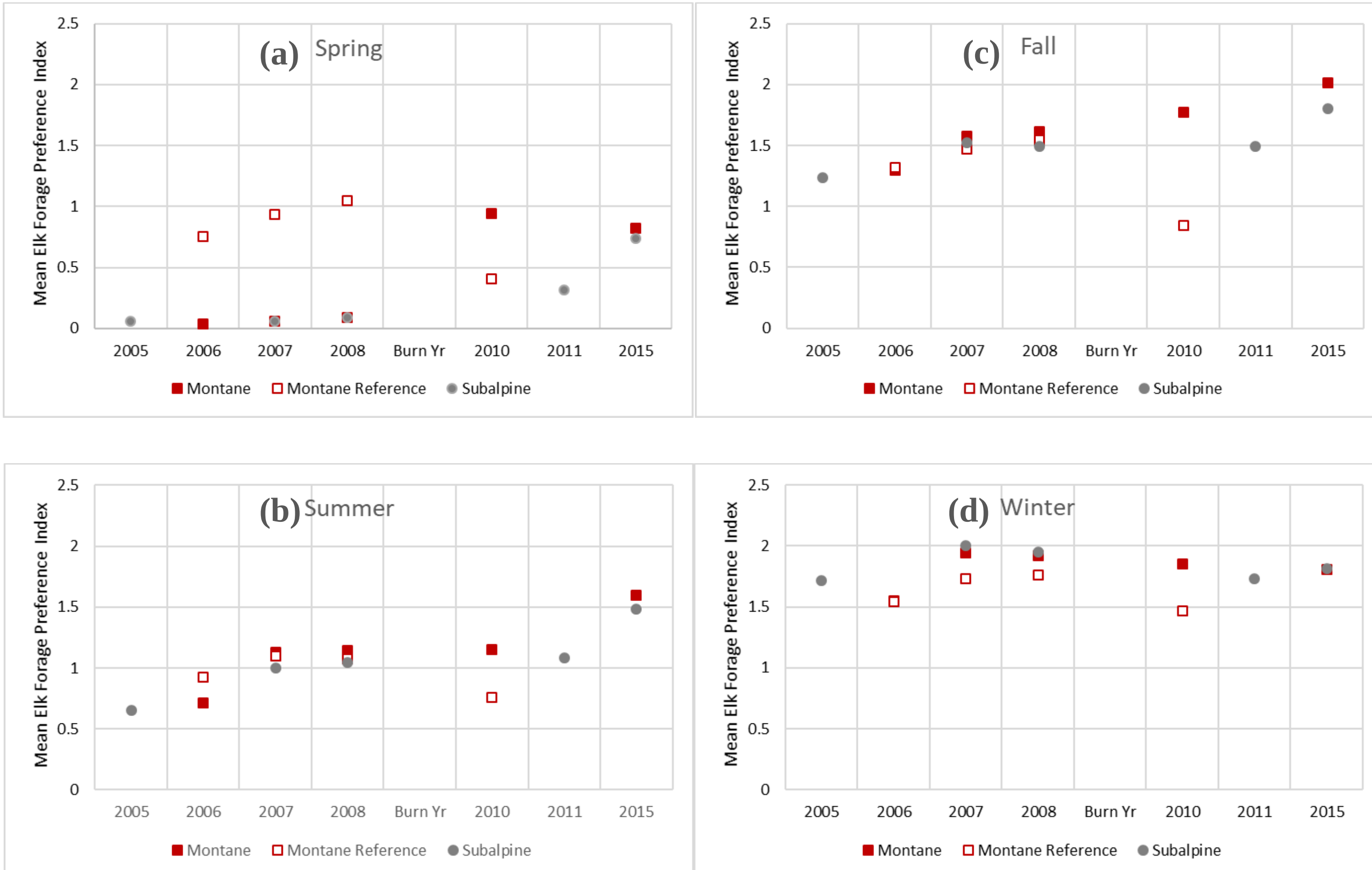


Figure 10. Seasonal Elk Forage Preference Index for (a) spring, (b) summer, (c) fall, and (d) winter averaged across species-level study area transects for a given year.

4.4 Predator avoidance

Predator avoidance indicators and targets were evaluated for bighorn sheep and elk. Distance to escape terrain for open canopy transects exceeded the mean distance target (mean +2SD <300 m) in both montane and subalpine study areas both pre- and post-fire, with the exception of a single year pre-fire in subalpine areas (Table 5). Differences between years were not significant for the montane treatment (H=4.60, p=0.2035) or montane reference study areas (H=5.19, p=0.1581) though they were for subalpine study areas (H=8.62, p=0.0348) owing to a significant difference between 2008 and 2015. Horizontal visibility was also measured as an indicator for evaluating bighorn sheep predator avoidance. For the montane study areas, horizontal visibility increased significantly by six years post-fire (Table 5; H=61.74, p=0.0001). As expected, no significant change was noted at the montane reference site (H=6.18, p=0.103), but its values were already higher due to the previous fire in that area. Subalpine study areas also show significant increases in horizontal visibility post-fire (H=64.11, p=0.0001), though the post-fire years were not different from the 2005 values. The median values for montane transects in 2015 and subalpine transects in 2011 approached or met targets of greater than 62%, and the 25^{th} to 75^{th} interquartile ranges (i.e., middle 50% of the data) encompassed the target in all post-fire years. Accordingly, there are likely areas of habitat at most montane and subalpine study sites that exceed the target.

Mean animal hiding distance of study areas (> 20% canopy closure) was measured to evaluate predator avoidance potential for elk. Mean animal hiding distance generally showed little change between pre- and post-fire values for the montane reference site as expected (Table 5; H=3.17, p=0.3669), but did show a significant increase by six years post-fire across the other montane study areas (H=28.40, p=0.0001). Likewise, the subalpine study areas displayed increasing animal hiding distance with time post-fire and this was significant (H=39.62, p=0.001). Again 2005 appears to be a bit of an anomaly with high animal hiding distance measurements relative to other pre- and post-fire years. Maximum hiding distances exceeded 61 m on some transects, but generally the mean and one standard deviation were below the 61 m threshold for both pre- and immediate post-fire time periods. By six years post-fire, the maximum target appears to be exceeded in both montane and subalpine areas. Increasing animal hiding distances as the time since fire increases could be related to the toppling of burned timber, causing some cover study areas to provide less cover.

Table 5. Predator avoidance indicators for bighorn sheep (i.e., distance to escape terrain, horizontal visibility) and elk (i.e., animal hiding distance) within montane and subalpine species-level study areas.

Study area	Year	Distance to escape terrain (m)		Horizontal visibility (%)		Animal hiding distance (m)	
		n	Mean (± SD)	n	Median (25^{th}-75^{th}) Interquartile range	n	Mean (± SD)
Montane	2006	2	1146.0 (± 271.5)	30	0 (0)	28	29.3 (± 10.6)
	2007			20	0 (0)	40	24.4 (± 12.1)
	2008	5	482.4 (± 326.7)	19	0 (0)	34	31.0 (± 15.4)
	2009				*Treatment Year*		
	2010	20	642.4 (± 390.6)	39	0 (0-85)	19	34.2 (± 9.8)
	2015	23	538.7 (± 346.7)	34	60.0 (30.0-85.0)	11	54.4 (± 33.8)
Montane Reference	2006	13	547.0 (± 159.5)	15	40.0 (0-85.0)	2	7.5 (± 10.6)
	2007	17	695.7 (± 289.5)	20	92.5 (10.5-100.0)	3	21.0 (± 5.3)
	2008	16	638.0 (± 260.1)	19	12.0 (0-70.0)	3	20.0 (± 10.0)
	2009				*Treatment Year*		
	2010	13	471.0 (± 268.0)	20	67.5 (0-98.5)	7	22.1 (± 9.1)
Subalpine	2005	4	34.8 (± 52.5)	20	52.5 (12.5-75.0)	16	54.9 (± 74.0)
	2007			20	0 (0-8.5)	20	26.0 (± 8.3)
	2008	13	78.3 (± 126.7)	39	0 (0)	45	28.0 (± 15.3)
	2009				*Treatment Year*		
	2011	35	162.2 (± 176.2)	31	75.0 (22.0-95.0)	21	39.2 (± 11.9)
	2015	33	221.8 (± 250.2)	56	47.5 (12.5-72.5)	23	49.1 (± 13.5)

5.0 SUMMARY

Late winter has traditionally been regarded as a limiting season for ungulates in northern environments that face bioenergetic challenges from reduced forage availability, loss of body condition, increased energetic demands when moving through the snow pack, and for females, increased nutritional demands for gestation (reviewed in Parker et al. 2009). Further adding to these challenges, ungulate populations have experienced incremental loss of traditional habitat ranges through wildfire suppression, forest succession, and shrub encroachment (Didkowsky et al. 2010). ACA partnered with other agencies on the Upper North Saskatchewan River prescribed fire with the intent of improving winter range value for bighorn sheep, mule deer, and elk. Outcomes at the landscape- and ecosystem-level study areas (see Appendices A and B) generally indicated achievement of or substantial progress towards targets established in the Cline River Watershed Subbasin Ungulate Winter Range Restoration Plan (ACA 2009); however, outcomes at the species-level study areas were more mixed and perhaps less beneficial for winter range than predicted.

Ungulate prey species must be able to access seasonal forage resources while balancing predation risk. For wintering bighorn sheep, this requirement is met using south-facing slopes and ridges where vegetation is exposed due to slope, solar radiation, and wind exposure in combination with nearby escape terrain provided by rocky outcrops or talus slopes. The southerly aspect of burn areas within the prescribed fire boundary is congruent with bighorn sheep requirements, but field measurements of distance to escape terrain proved unreliable. GIS-based analyses would be required to determine if the distance from open canopy cover to escape terrain increased post-fire. Previously burned areas in sheep habitat receive highest use and selection in winter (Green et al. 2012, Sittler et al. 2018, Ruckstuhl et al. 2000) and forage quality in burned grasslands is highest immediate post-fire (Ruckstuhl et al. 2000). Horizontal visibility increased from pre-fire conditions and approached the target though it was not met across study areas. An increase in this metric post-fire likely corresponds to a decrease in predation risk as sheep are better able to detect stalking predators (Green et al. 2012, Blake 2014), with the importance of horizontal visibility likely being higher at subalpine elevations where they would spend more time than in montane areas where they forage less frequently.

The prescribed fire was successful at creating open foraging areas for mule deer and elk within a comfortable proximity to security cover. Relative to historical wildfires (Andison 2003), the final burn mosaic resulted in a high number of disturbed patches for the burn area, with a similar frequency and area of unburned island remnants. These disturbed patches should revegetate with desirable forage for elk and deer while the nearby island remnants provide hiding cover from predators. The target of an optimal ratio of 60% cover habitat to 40% forage habitat within this mosaic was achieved for only two of five study areas. Within the cover patches, the average hiding distance for elk may be increasing as the time-since-fire increases. This increase in animal hiding distance could occur if trees at the edge of remnant patches suffered wildfire damage or a low-intensity fire within the patch weakened trees and they subsequently fell down.

Recognizing this trade-off between foraging and predation risk, ACA partnered with the University of Alberta to create an elk habitat planning tool to help land managers evaluate the influence of proposed landscape treatment scenarios on elk habitat occupancy and survival (Webb and Anderson 2009). This tool identified source and sink habitat as a function of habitat value and predation risk. In advance of the Upper North Saskatchewan River prescribed fire, the elk tool was applied to the Cline River subbasin under various burn scenarios but all constrained to occur within a ten-year period. The elk tool predicted an increase in winter secure source habitat (i.e., medium to high habitat value-low predation risk) ranging from 15% to 22% as a result of prescribed fire treatments. Following the prescribed fire, we ran the tool again for the Cline River subbasin and found a 54% increase in winter secure source habitat (ACA, unpublished data).

Elk avoidance of burned areas is likely until vegetation growth begins, and then greater use is anticipated as forage becomes more abundant, with greatest use generally occurring between 2 to 17 years post-fire (reviewed in Innes 2011). Elk use of burned areas seems to vary widely, likely related to variation in post-fire vegetation growth rates, rates of succession, adjacent habitat, and pre-fire elk density and movements (Innes 2011). Furthermore, predation risk from wolves can affect how elk use the landscape, but their response can be variable and may be mediated by habitat characteristics (e.g., amount of downed woody debris; Eisenberg et al. 2015).

Although we were unable to assess elk use in the study areas, we did capture single year snapshots of post-fire forage abundance that correspond with the early stages of this high use time period (i.e., years 1, 2, and 6 post-fire). Forage abundance impacts were generally more pronounced and consistent in montane study areas than in subalpine areas, where results were absent or mixed at best. Both grass and forb biomass increased immediately post-fire but had dropped close to pre-fire levels at six years post-fire. Grass and forb cover, on the other hand, appeared slower to respond and higher levels were noted at six years post-fire. Following the 1988 Yellowstone fires, most herbaceous and shrub species in pre-fire conifer forests had re-established by one to four years post-fire and continued to increase in cover after that (Romme et al. 2011), suggesting that perhaps grass and forb cover may continue to rise in the study areas. Shrub biomass was much lower in both montane and subalpine areas post-fire, while deciduous shrub cover was distinctly higher at six years post-fire in montane areas. Sachro et al. (2005) found increases in herbaceous biomass and deciduous shrub biomass on subalpine sites burned within the previous 12 years in Banff. As various abiotic (e.g., temperature, moisture, solar radiation, soil) and biotic parameters (e.g., herbivory, plant phenology, reproductive effort) can influence vegetation growth along elevational gradients (Milla et al. 2008, De Long et al. 2015), higher elevation subalpine sites might require longer to respond post-fire than lower elevation sites. Overall, additional sampling years would be required to determine if any observed changes are due to natural inter-annual variation or treatment effects as well as to determine any longer-term impacts of the prescribed fire treatment on forage abundance, as sporadic single years of sampling may render different conclusions than consecutive sampling years repeated at intervals (Smokorowski et al. 2015, Smokorowski and Randall 2017).

Forage quality may or may not increase during the immediate post-fire years (1-2 years; reviewed in Innes 2011). Generally, forage quality is highest in young plants but decreases both within and between years as they mature, and is frequently assessed based on crude protein or digestible energy measurements (Green et al. 2012, Cook et al. 2016). Following Sachro et al. (2005), we chose to use a seasonal Forage Preference Index as a biologically meaningful indicator of general forage quality for elk and anticipated an increase in the winter index following the prescribed fire. Contrary to our prediction, no differences were noted pre- and post-fire in the winter index. Instead, slight increases were noted in the fall indices (26% and 18% increases for montane and subalpine study areas, respectively); obvious increases were noted in the summer indices (38% and 42%); and very large increases were noted in the spring forage preference indices (1370% and 657% across montane and subalpine study areas, respectively. Innes (2011) suggests that deeper winter snow pack, than in closed canopy unburned areas, may limit elk use of open burned habitat in some areas, but the rapid melt can facilitate use in spring. Our results indicate desirable forage may be available at that time in the recently burned area, though overall spring values were still considered low quality forage (<1), compared to moderate quality forage (1.3-2.0) in other seasons (Sachro 2003). Increasing evidence indicates that the adequacy of late spring and summer nutrition may have a greater influence on body condition and reproductive success than winter nutrition (Monteith et al. 2013, Cook et al. 2004, 2013, 2016, Lukacs et al. 2018). Furthermore, Lukacs et al. (2018) noted that the influence of habitat productivity on elk reproduction varies spatially across a north-south gradient in the western United States. The productivity of winter range was more important in southern regions while annual variation in productivity of summer habitat had more influence on recruitment in northern areas (e.g., Montana).

Female elk must acquire sufficient summer nutritional resources to compensate for lower forage quantity and quality during the winter months, recover the energetic costs of lactation, and accrue adequate fat reserves to survive and maintain pregnancy during the winter (Cook et al. 2004, 2013, 2016). The implications of inadequate summer forage are far reaching: pregnancy rates decline (Proffitt et al. 2016), juvenile growth and recruitment suffers, particularly in areas with multiple predators (Cook et al. 2013, Lukacs et al. 2018), and even future antler size in males is impacted by maternal condition (Freeman et al. 2013). These recent findings, coupled with our improvements in spring and summer forage preference indices, suggest that future habitat improvement work for elk should reconsider a focus on winter range.

In conclusion, the Upper North Saskatchewan River prescribed fire began the process of reintroducing disturbance to a relatively homogenous landscape that has moved outside its natural range of variability created by historical disturbance patterns and within which ungulate habitats have declined. The large size of the prescribed fire and the associated burn patterns were successful in full or partial achievement of landscape- and ecosystem-level targets identified in the Cline River Watershed Subbasin Ungulate Winter Range Restoration Plan (ACA 2009). Forage access improved for bighorn sheep winter range and for elk and mule deer with the creation of open foraging areas near adequate cover for security from predators. Forage abundance as measured through biomass and percent cover appeared to vary temporally and spatially, while forage quality for elk improved most during the spring and summer seasons. Continued monitoring would be necessary to determine additional forage changes over the longer-term period in which elk might be expected to use burned areas (up to 17 years post-fire). Future prescribed fire treatments should broaden the habitat restoration scope to reflect the importance of quality spring/summer nutritional resources.

6.0 LITERATURE CITED

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7.0 APPENDICES

Appendix A. Landscape-level assessment methods and results.

A.1. Landscape-level assessment methods

Landscape-level analyses occurred for a study area that encompassed all the ungulate winter range within the Cline River subbasin (outside the national park), regardless of whether it was burned or not. Associated objectives focused on the stand age distribution and disturbance rates in the montane, subalpine, and alpine natural subregions (Table A-1). Assessment of these metrics was a Geographic Information System (GIS)-based computer exercise.

A.1.1. Stand age distribution

Stand age is defined as the time since the last stand replacing fire, and we followed Andison (2000) in defining the following stand age class categories: young (0-20 years post-fire), pole (21-100 years), mature (101-180 years), and old (>180 years). Stand age distribution refers to the distribution of forested stands of different age classes throughout an area. We used the Alberta Vegetation Inventory (AVI) layer in ArcGIS to assess stand age distribution over our landscape-level study area. The AVI layer available for the Cline River subbasin was incomplete and thus was updated to assign stand origin dates for recently disturbed areas (both wildfires and prescribed fires). This layer was then clipped by the ungulate winter range and stand age distribution assessed therein.

For the Cline River subbasin, this stand age distribution was calculated for two different stand age criteria in two natural subregions:

- Young forest (1994-2014 stand origin date) in the montane and subalpine natural subregions
- Mature forest (1834-1913 stand origin date) in the montane and subalpine natural subregions.

The resulting stand age distributions within the ungulate winter range were compared to established targets and the natural range of variability (NRV) (Table A-1, Figure A-1). NRV describes the range in amount of each ecosystem type (forest cover and age class combination) that should be present within these natural subregions in historical wildfire-disturbed landscapes.

Table A-1. Landscape-level values, objectives, indicators, and targets (VOITs) identified in the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009).

Value	Objective	Indicator	Target
Stand age distribution in the montane	The amount of young forest (0 – 20 years old) in ungulate winter range falls within the NRV*	Area of young forest in the ungulate winter range as determined from AVI and GIS	Between 6% to 39% of the ungulate winter range contains forest cover that is 20 years old or younger (Figure 2, ACA 2009)
	The amount of mature forest (101-180 years old) in ungulate winter range falls within the NRV	Area of mature forest in the ungulate winter range as determined from AVI and GIS	% of mature age class within the montane portion of the winter range is continuing towards the NRV
Disturbance rate in the montane	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at ¾ the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the montane, this value is 960 ha of forested winter range and 270 ha of vegetated non-forest winter range disturbed over ten years.
Stand age distribution in the subalpine	The amount of young forest (0 – 20 years old) in ungulate winter range falls within the NRV	Area of young forest in the ungulate winter range as determined from AVI and GIS	Between 6% and 20% of the ungulate winter range in the subalpine contains forest cover that is 20 years old or younger (Figure 3, ACA 2009)
	The amount of mature forest (101– 180 years old) in ungulate winter range falls within the NRV	Area of mature forest in the ungulate winter range as determined from AVI and GIS	% of mature age class within the subalpine portion of the winter range is continuing towards the NRV

Value	Objective	Indicator	Target
Disturbance rate in the subalpine	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at ¾ the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the subalpine, this value is 1,450 ha of forested winter range over ten years and 210 ha of vegetated non-forested winter range over ten years.
Disturbance rate in the alpine	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at ¾ the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the alpine, this value is 120 ha of forested winter range and 97 ha of vegetated non-forested winter range disturbed over ten years.

*NRV=natural range of variation

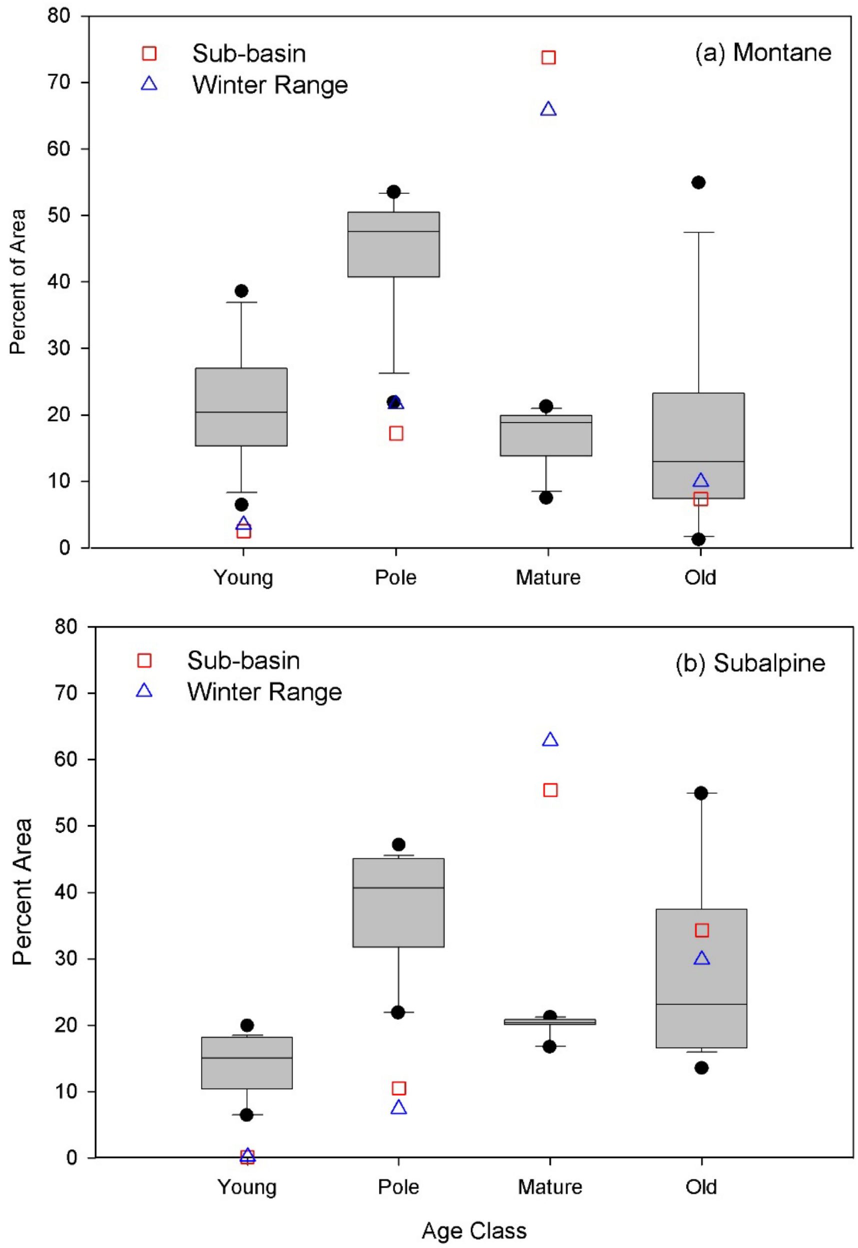

Figure A-1. Theoretical NRV in age distribution of forests in the (a) montane, and (b) subalpine natural subregions of the Cline River subbasin derived from reported fire cycle estimates (pre-fire suppression). Boxes show the median and 25th to 75th interquartile range in area for each age class. End points indicate the minimum and maximum forest area. Pre-fire subbasin and winter range stand age distributions are overlaid for comparison (adapted from ACA 2009).

A.1.2. Disturbance rate

Fire cycle length is the time, in years, to burn a defined area (this may mean some parts of an area are burned twice, and other parts not at all). An estimate of the natural fire cycle can be used to calculate the amount of area expected to burn per decade under natural conditions, which can then be used to identify appropriate treatment rates and to establish targets for the amount of forest in each age class. For this portion of the landscape-level assessment, a GIS model was created using ArcGIS ModelBuilder to analyze disturbance rates within the ungulate winter range of the Cline River subbasin. This disturbance rate model was run based on a 10-year rolling window for both forested and non-forested areas of three natural subregions:

- 10-year disturbance rate (2004-2014) in forested and vegetated non-forested areas of the montane natural subregion
- 10-year disturbance rate (2004-2014) in forested and vegetated non-forested areas of the subalpine natural subregion
- 10-year disturbance rate (2004-2014) in the alpine natural subregion

As detailed fire cycle data was not available for the Cline River subbasin, ACA (2009) used information generalized from detailed studies conducted within the same natural subregions in other parts of Alberta to set disturbance rate targets. The results of the disturbance rate model described above were then compared to these targets.

A.2. Landscape-level assessment results

A.2.1. Stand age distribution

Stand age distribution indicators and targets were evaluated for the Cline River subbasin (Table A-1). AVI data was used to determine stand ages; however, we did not have access to data for Banff and Jasper National Parks, so the results only represent a portion of the subbasin. Mature forests still dominate ungulate winter range of both the montane (40%) and subalpine (55%) natural subregions (Table A-2); nonetheless, this age class has moved considerably lower and closer to the target as a result of the Upper North Saskatchewan River prescribed fire. Young forest is less prevalent and is still below the targeted range for the subalpine natural subregion (4%), while it is at the lower end of the target range of the montane natural subregion (13%). This suggests further treatments would be required to continue progressing towards stand age distribution targets in the subalpine and to remain within the target range as the young montane forest transitions to the pole age class category.

A.2.2. Disturbance rate

Disturbance rate indicators and targets (Table A-1) were evaluated for the Cline River subbasin. Within the forested ungulate winter range, the ten-year rolling disturbance rate from 2004 to 2014 exceeded area targets for the montane and alpine natural subregions, but only reached about 60% of the targeted disturbance rate in the subalpine (Table A-3). Some disturbance overlapped the non-forested vegetated ungulate winter range; however, the area was well below targets for all three natural subregions. This suggests additional treatments would be required in these non-forested areas to ensure open vegetated habitats are maintained or enhanced.

Table A-2. Post-treatment stand age distribution within ungulate winter range within the Cline River subbasin as assessed by natural subregions.

Natural subregion	Total ungulate winter range in subbasin[1]	Ungulate winter range in subbasin with stand age (AVI) Data[2]	Young (0 – 20 Years)			Mature (101 – 180 Years)		
	Area (ha)	Area (ha)	Target (%)	Area (ha)	%	Target (%)	Area (ha)	%
Montane	17,034	17,027	6 to 39	2,178	13	14 to 20[3]	6,839	40
Subalpine	26,350	26,344	6 to 20	968	4	20 to 22[3]	14,451	55

[1] Excludes area of subbasin within Banff and Jasper National Parks

[2] Includes portion of ungulate winter range covered by AVI data or recent wildfire/prescribed fire data

[3] Represents approximate targets taken from Figure A-1. Target wording states "percentage of age class within the natural subregion portion of the ungulate winter range is continuing towards the Natural Range of Variation"

Table A-3. Disturbance rate between 2004 and 2014 within forested and non-forested ungulate winter range of the Cline River subbasin for each natural subregion.

Natural subregion	Forested ungulate winter range			Non-forested ungulate winter range		
	Total area (ha)	Target (ha)	Disturbance rate (2004-2014) (ha)	Total area (ha)	Target (ha)	Disturbance rate (2004-2014) (ha)
Montane	11,156	960	3,574	1,204	270	60
Subalpine	22,258	1,450	910	1,613	210	27
Alpine	3,282	118	392	648	97	22

A.3. Landscape-level summary

The Upper North Saskatchewan River prescribed fire resulted in a treatment area of 4,835 ha within the 94,392 ha of the Cline River subbasin. This shifted the stand age distribution towards targets for young forest, but additional treatments are required to achieve targets at the subbasin level and to maintain the montane young forest within the target range as this young forest ages. This prescribed fire did, however, exceed the ten-year rolling disturbance rates within forested ungulate winter range in the montane and alpine natural subregions and achieved 60% of the targeted disturbance rate in the subalpine natural subregion. Targets were not, however, achieved for non-forested, open habitat. These habitats should receive greater focus in future treatments to reduce forest encroachment and maintain these valuable foraging areas. Future work should also investigate the use of local fire history information to refine targets. Overall, this single disturbance event enabled significant progress towards landscape-level targets identified in the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009).

Appendix B. Ecosystem-level assessment methods and results.

B.1 Ecosystem-level assessment methods

Ecosystem-level objectives (Table B-1) were assessed for a study area bounded by the extent of the Upper North Saskatchewan River prescribed fire using several metrics outlined below. As with the landscape-scale objectives, this assessment was based on GIS analyses rather than based on field data collection.

B.1.1 Fire mapping

Satellite imagery data (Landsat 5 TM, United States Geological Survey [USGS]) was used to calculate the Normalized Burn Ratio (NBR) for 2008 pre-fire imagery and 2009 post-fire imagery. The differenced NBR (i.e., resulting change in the pre/post-fire NBR; Key and Benson 2006) was assessed using the USGS Fire Effects Monitoring and Inventory Systems (FIREMON) program to determine the severity of the burn. For example, little to no change in NBR of -0.1 to +0.1 indicated unburned habitat, while a change in NBR of >0.66 indicated a high-severity burn. From this analysis, detailed fire polygons were created for use in assessing ecosystem-level objectives.

B.1.2 Event characteristics

A fire event is defined as a single episode of disturbance occurring over a generally contiguous area where at least 20% of the trees have been killed (Andison 2006) and may be composed of multiple disturbed patches that are less than 500 m apart. Within most fire events, particularly larger ones, patches of forest/grassland remain unburned and contribute to the mosaic of habitat types, enhance biodiversity, and provide cover for wildlife. These patches may exist as matrix remnants (i.e., undisturbed residual habitat within an event that are physically attached to the surrounding matrix and usually take the form of corridors or bays [Andison 2003]) or as island remnants (i.e., undisturbed residual habitat completely surrounded by disturbed habitat). The detailed fire polygons delineated through the NBR process were analyzed using the Foothills Research Institute (FRI) Novel Emulation Pattern Tool for Understanding Natural Events (NEPTUNE) decision support analysis tool to determine:

- total fire event size (ha),
- number of fire events
- number of disturbed (burned) patches per event,
- sizes of disturbed patches and island remnants (ha), and
- percent of fire event area in matrix and island remnants.

Details of NEPTUNE methods for calculating these parameters are described in Andison (2006) and Maier (2009). Results from the NEPTUNE analyses were then compared to targets (Table B-1).

Table B-1. Ecosystem-level values, objectives, indicators, and targets (VOITs) identified in the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009).

Value	Objective	Indicator	Target
Event size	A series of concurrently planned treatments that emulate the natural size range of fire events (may include multiple patches)	Total event size, as calculated in GIS (Andison 2006)	Emulated events range in size from 2 ha to 10,000 ha with 60% of events being 600-2,000 ha in the montane and ≥ 2,000 ha in the subalpine
Number of events	Event distribution follows the NRV for each NSR	Number of events across landscape as calculated in GIS	Number of events follows distribution for winter range in Tables 4 & 5, ACA 2009
Number of individual treatment patches	Patch distribution follows the NRV for each NSR	Patch distribution calculated in GIS	Patch distribution per event follows Table 6, ACA 2009, with larger events having more patches
Size of individual treatment patches	Patch size of individual treatments falls within the 95th percentile of natural disturbance patch sizes	Treatment area calculated in GIS	Largest patch in event is 63% to 83% of total event area
Unburned remnants within treatment	% is within historical pattern	% of event area not burned, as calculated in GIS	Between 15% and 62% of treatment event is unburned with majority of remnant area located in corridors

B.2 Ecosystem-level assessment results

B.2.1 Event size and number

The Upper North Saskatchewan River prescribed fire was classified as three events having a total event area of 4,835 ha. The largest event (#1) size was 4,223 ha while the second largest event (#2) was 612 ha. The third event (#3) was only 0.31 ha in size, which is likely a result of the NBR analysis used to define the burn perimeter rather than a separate on-the-ground event. The total event size target in ACA (2009) was delineated by montane and subalpine natural subregions, but since this analysis did not take the natural subregions into account, a direct comparison between the indicator and target is not possible. Nevertheless, this prescribed fire likely achieved the targeted treatment area in the 600 to 2,000 ha event class category for the montane natural subregion and greater than 2000 ha event class category for the subalpine natural region.

B.2.2 Number and sizes of individual treatment patches

NEPTUNE results indicated that when compared to historical natural disturbance patterns, the Upper North Saskatchewan River prescribed fire events #1 and #2 had a very high number of disturbed patches relative to event area (Figure B-1). NEPTUNE indicated the largest patch size of the disturbed area in events #1 and #2 accounted for 20-30% and 30-40% of the total disturbed event area of each event (Figure B-2). In other words, 20-40% of the burned area in events #1 and #2 occurred in one large patch, though the target was to have the largest patch account for 63% to 83% of the total event area. Thus, the Upper North Saskatchewan River prescribed fire appears to have created a higher number of smaller disturbed patches than historical natural disturbance patterns.

B.2.3 Unburned remnants within treatment

Within event #1 in the Upper North Saskatchewan River prescribed fire, 2,208 ha were classified as fully disturbed, 1,928 ha (46%) were classified as matrix remnants, and 87 ha (2%) were classified as island remnants. Within event #2, 229 ha were classified as fully disturbed, 379 ha (62%) were classified as matrix remnants, and 4 ha (0.7%) were classified as island remnants. Overall, approximately 48% of event area #1 and 63% of event area #2 were unburned residual patches. These results met the targets of 15% to 62% of a treatment event remaining unburned with the majority in matrix remnants. These results also fell within the historical range for matrix remnants and total residual, but were slightly lower than historical patterns for area of island remnants (Figure B-3 to Figure B-5). The size of island remnants, however, followed historical natural disturbance patterns (Figure B-6).

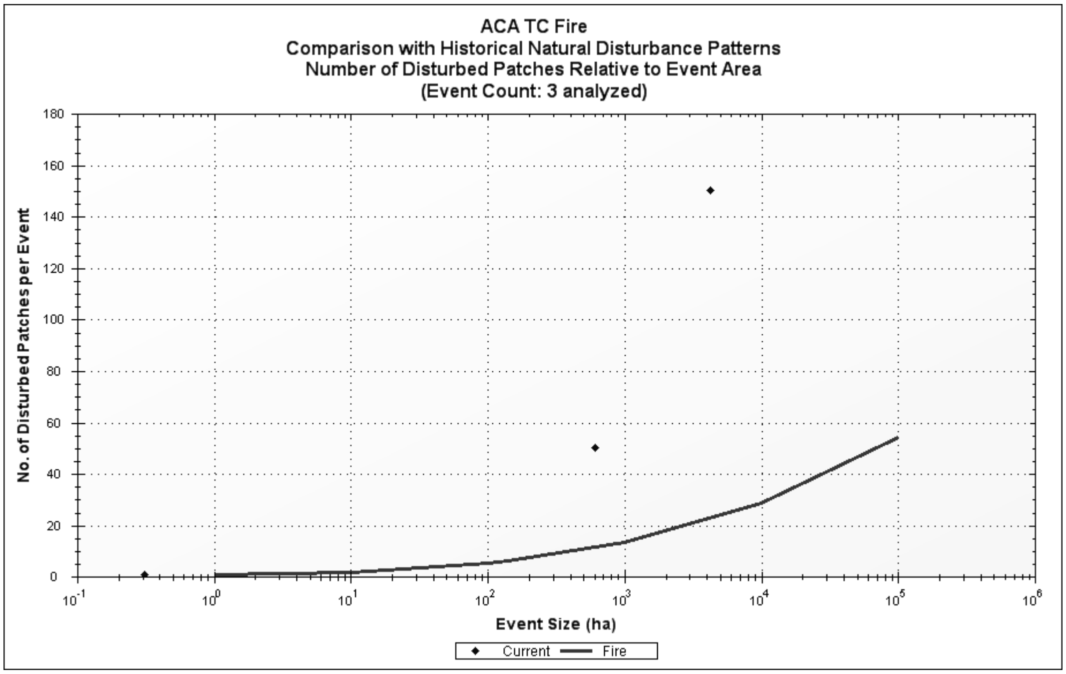

Figure B-1. Number of disturbed patches relative to event area for the Upper North Saskatchewan River prescribed fire (♦ Current) and historical (— Fire) natural disturbance patterns.

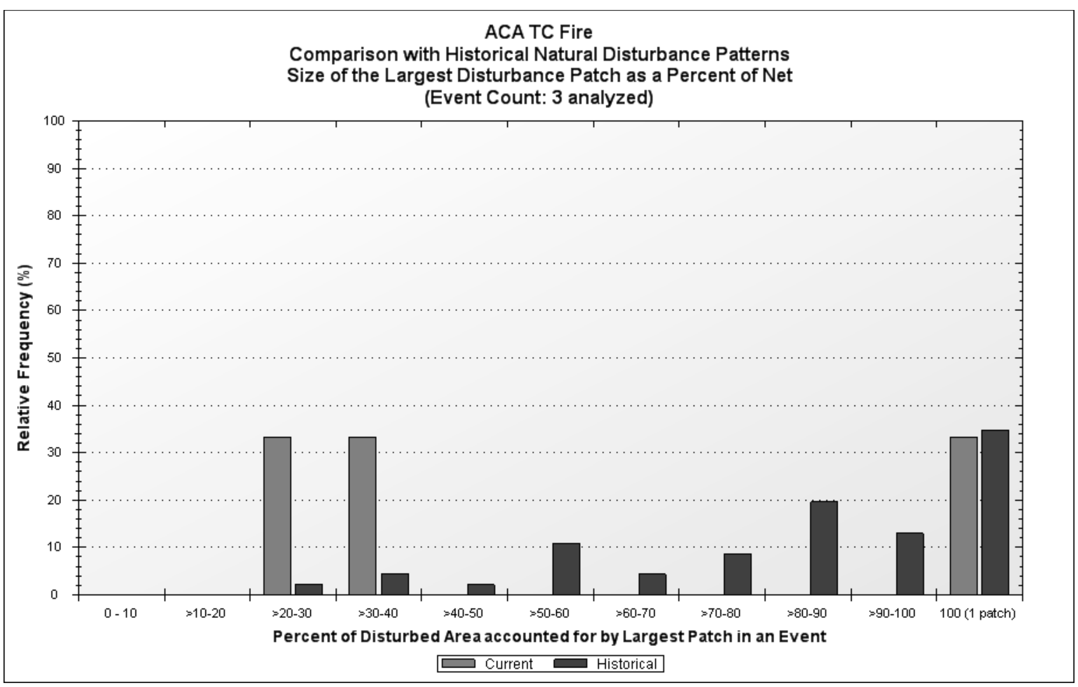

Figure B-2. Size of the largest disturbance patch as a percent of net event size in comparison with historical natural disturbance patterns.

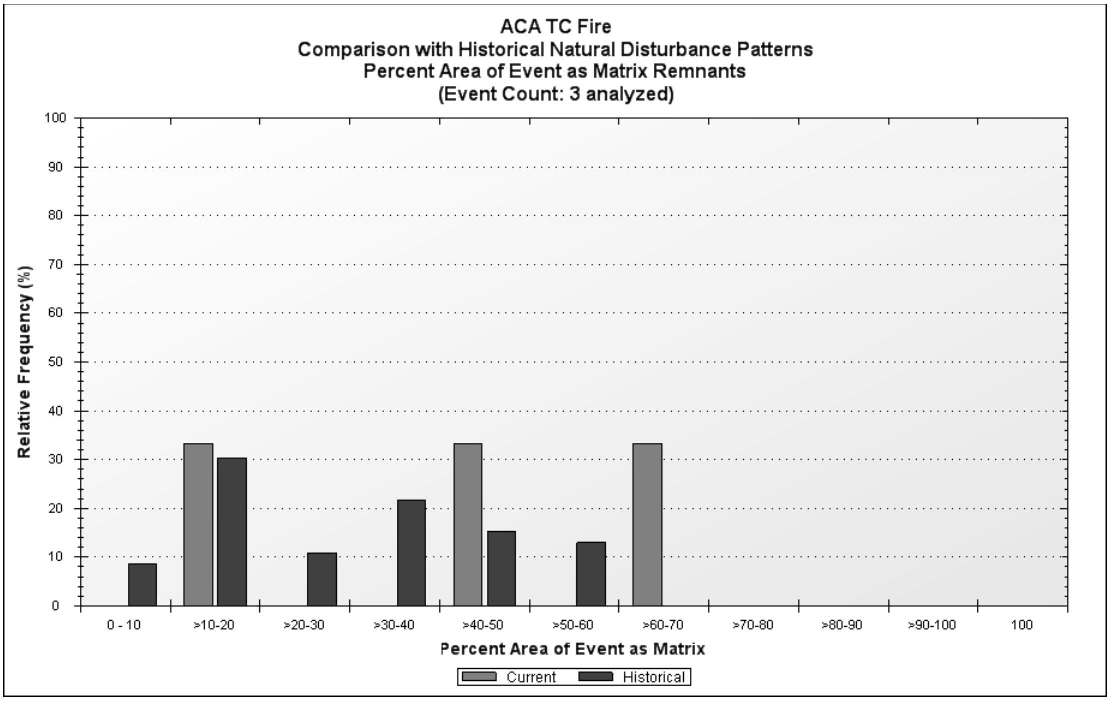

Figure B-3. Percent area of event as matrix remnants compared to historical natural disturbance patterns.

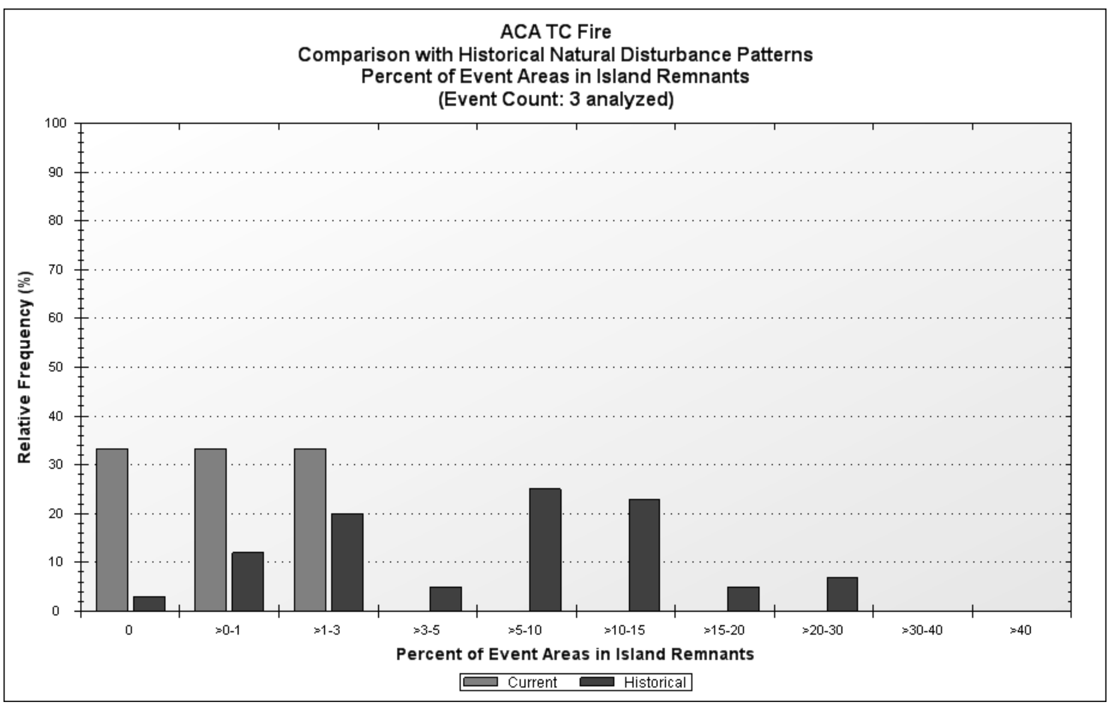

Figure B-4. Percent area of event as island remnants compared to historical natural disturbance patterns.

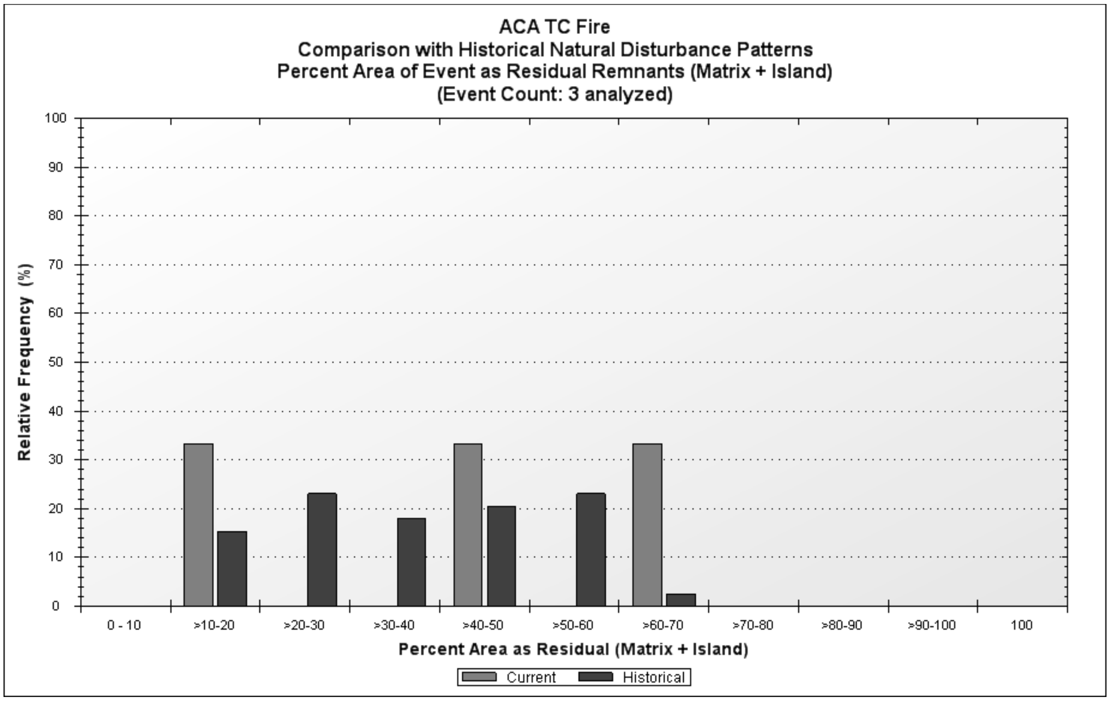

Figure B-5. Percent area of event as total residual compared to historical natural disturbance patterns.

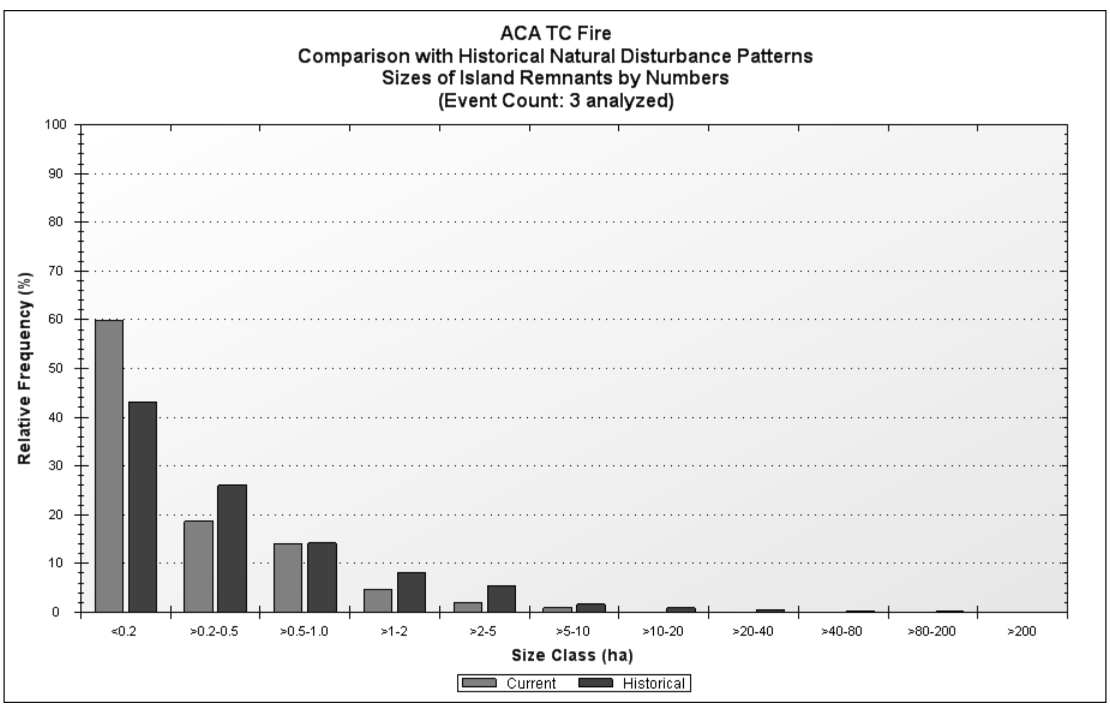

Figure B-6. Sizes of island remnants compared with historical natural disturbance patterns.

B.3 Ecosystem-level summary

At the ecosystem level, the event size and number were demonstrated to be similar to historical fire patterns. Andison (2003) suggests that historically a small number of large fires accounted for most of the disturbed area on a given landscape, and this large prescribed fire attempted to mimic those patterns. The two definable events, 4,223 ha and 612 ha, had a high number of disturbed patches for the burn area relative to historical wildfires, but they were comparable in shape to similar-sized historic natural events. In addition, the frequency and area of unburned island remnants appeared similar to historical natural disturbance patterns. Achievement of such targets creates a naturalized and irregular burn pattern that is beneficial to wildlife as it provides accessible security habitat, foraging habitat, and forest edge favored by foraging wildlife (Fahrig 2017, Fletcher et al. 2018).

Appendix C. Additional species-level assessment methods and results.

C.1 Species-level assessment methods

Species-level objectives were monitored at multiple biologically relevant smaller study areas within and adjacent to the Upper North Saskatchewan River prescribed fire. Methods of field data collection are described in the body of the report (Section 3.4), while assessment of that data is described here for the additional indicators and targets not covered elsewhere (Table C-1).

C.1.1 Thermal cover

Data on cover class, canopy closure, % conifer, and canopy height from each sampling transect were used to create a thermal cover attribute shape file in ArcGIS. All transects containing > 70% canopy closure, > 10 m canopy height, > 50% conifer cover, and > 100 m from the nearest human disturbance were considered suitable for thermal cover for elk and mule deer. The proportion of closed-cover transects meeting these criteria was calculated for each study area in each year.

C.1.2 Human disturbance

Using ArcGIS, a human disturbance layer was created encompassing roads, cutlines, trails, and major rivers. The distance from each sampling transect to the nearest human disturbance feature was calculated and averaged across a given species-level study area each year. This measure essentially determined if the majority of the prescribed fire area, and its associated benefits, fell outside the potential zone of human influence for ungulate species. The mean distance-to-disturbance measure was used to assess the relevant human disturbance indicators for sheep, elk, and deer, although the target thresholds varied with species.

C.1.3 Population condition

Alberta Biodiversity Monitoring Institute conducted an assessment of the sampling effort required to collect rigourous pellet count data from which local population levels could been determined. We determined that we did not have the resources to be able to meet such requirements, thus objectives and indicators associated with population condition were dropped from this study.

Table C-1. Additional species-level values, objectives, indicators, and targets (VOITs) identified in the Cline River Subbasin Ungulate Winter Range Restoration Plan (ACA 2009).

Value	Objective	Indicator	Target	Reference (if applicable)
Bighorn sheep-Human disturbance	Majority of treatment area is beyond the direct influence of roads and human use trails	Distance from random plots to closest active road or OHV trail, as measured in a GIS	Mean distance – 2SD > 150 m (this should ensure that over 95% of the habitat is located outside the zone of influence from roads and trails).	Zeigenfuss et al. 2000
Bighorn sheep - Population condition	Improved population condition	Fecal pellet density (indicates # animals using the area, but not necessarily improved population condition)	Significantly more pellet groups in treatment vs. control areas.	ACA objective
Elk – Thermal cover	Half of the remnant cover within the treatment area provides potential thermal cover	Combination of canopy closure, canopy height, and % conifer	50% of cover plots have a canopy closure > 70%, canopy height > 10 m, > 50% conifer, and are > 100 m from the closest active road or human use trail	Buckmaster et al. 1999
Elk - Human disturbance	Majority of treatment area is beyond the direct influence of roads and human use trails	Distance from random plots to closest active road or OHV trail, as measured in a GIS	Mean distance – 2SD > 100 m. (This should ensure that over 95% of the treatment is outside the zone of influence of these features.) Assumes cover objective is met. If not, mean distance must be > 500 m	Buckmaster et al. 1999; ACA objective

Value	Objective	Indicator	Target	Reference (if applicable)
Mule deer - Thermal cover	Half of the remnant cover within the treatment area provides potential thermal cover	Combination of canopy closure, canopy height, and % conifer	Thermal cover is defined as canopy closure > 70%, canopy height > 10 m, > 50% conifer, and > 100 m from the closest road or human use trail	Wood et al. 1999
Mule deer - Human disturbance	Majority of treatment area is beyond the direct influence of roads and human use trails	Distance from random plots to closest active road or OHV trail, as measured in a GIS	Mean distance – 2SD > 100 m. (This should ensure that over 95% of the treatment is outside the zone of influence of these features.)	Wood et al. 1999
Mule deer – Population condition	Improved population condition	Fecal pellet density (indicates # animals using the area, but not necessarily improved population condition)	Significantly more pellet groups in treatment vs. control areas	

C.2 Species-level results

C.2.1 Thermal cover

Thermal cover indicators and targets were evaluated for elk and mule deer across montane and subalpine species-level study areas. Very few sampling transects within study areas met the full qualifications for thermal cover (i.e., > 70% canopy closure, > 10 m canopy height, > 50% conifer, > 100 m from human disturbance) as they were primarily limited by the canopy closure criterium (Table C-2). Consequently, we did not meet the thermal cover targets requiring at least half of the remnant cover in treatment areas to provide potential thermal cover.

Table C-2. Proportion of transects within montane and subalpine species-level study areas that qualified as thermal cover sites.

Study area	Year	Total transects	Number of transects meeting thermal cover criteria	Proportion of transects meeting thermal cover criteria (%)
Montane	2006	30	3	10.0
	2007	40	13	32.5
	2008	39	0	0.0
	2009		*Treatment Year*	
	2010	38	0	0.0
	2015	33	0	0.0
Montane Reference	2006	15	0	0.0
	2007	20	0	0.0
	2008	19	0	0.0
	2009		*Treatment Year*	
	2010	20	0	0.0
Subalpine	2005	16	0	0.0
	2007	20	11	55.0
	2008	56	0	0.0
	2009		*Treatment Year*	
	2011	57	0	0.0
	2015	54	1	1.9

C.2.2 Human disturbance

Mean distances from sampling transects to the nearest potential human access within montane species-level study areas were much lower than mean distances within subalpine study areas (Table C-3), which is to be expected as the montane habitats are in the valley bottom adjacent to a major travel corridor and recreational infrastructure. In general, montane study areas did not meet the targets for distance to nearest human disturbance for mule deer (i.e., mean distance – 2SD > 100 m), bighorn sheep (i.e., mean distance – 2SD > 150 m), or elk (i.e., mean distance – 2SD > 100 m or mean distance > 500 m). However, standard deviations are quite variable, suggesting at least some portions of montane study areas did meet the human disturbance targets. Subalpine species-level study areas, for the most part, achieved the human disturbance distance targets in all years with the exception of 2005 (Table C-3). An alternative method of measuring this indicator would have been to calculate the percent of each study area meeting the objectives using GIS. This method may have been more informative.

C.3 Species-level summary

Targets for thermal cover and distance to nearest human disturbance were generally not met in montane areas, and only distance to nearest human disturbance targets were met in subalpine areas. For both of these measures, protocol refinements may be necessary for future studies. The 70% canopy closure threshold for thermal cover may need to be re-evaluated to determine if a lower percent cover threshold will still provide adequate thermal cover within the local study areas. Alternatively, canopy closure could be re-assessed using GIS and the Foothills Model Forest canopy closure layer to determine if field measurements were underestimating canopy closure. Field data collection methods relied on the observers to conduct an ocular estimation, which are relatively subjective (Korhonen et al. 2006). Use of a densiometer (canopy closure estimation tool) for field evaluation or conducting a GIS exercise to provide more accurate estimates would be recommended for future estimation. Road/trail/cutline/river features do not change frequently and thus GIS layers are not updated annually. The study areas, similarly, did not change in location though the random transect locations therein were new each sampling year. Significant correlation between pre- and post-treatment distance-to-human-disturbance measures are thus expected, and the measure does not necessarily change with prescribed fire treatment unless the fire results in closure of some human disturbance feature. The purpose of pre-fire planning is to ensure burns occur in habitat areas that will not be disturbed by humans in the future. Accordingly, an assessment of the percent of burned area falling greater than 100 m from a road/trail may be a better indicator of this objective in the future.

Table C-3. Mean distance (m) to the nearest human disturbance (road/cutline/trail/major river) within montane and subalpine species-level study areas.

Study area	Year	n	Mean (m) (± SD)
Montane	2006	30	325.2 (± 260.5)
	2007	40	426.4 (± 281.9)
	2008	39	390.3 (± 271.4)
	2009		*Treatment Year*
	2010	38	316.3 (± 245.1)
	2015	33	438.9 (± 261.9)
Montane Reference	2006	15	112.7 (± 60.8)
	2007	20	145.1 (± 108.4)
	2008	19	160.5 (± 95.8)
	2009		Treatment Year
	2010	20	121.3 (± 86.4)
Subalpine	2005	16	992.5 (± 543.8)
	2007	20	1166.5 (± 407.9)
	2008	56	1278.5 (± 403.1)
	2009		*Treatment Year*
	2011	57	1317.0 (± 443.5)
	2015	54	1371.8 (± 387.9)

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