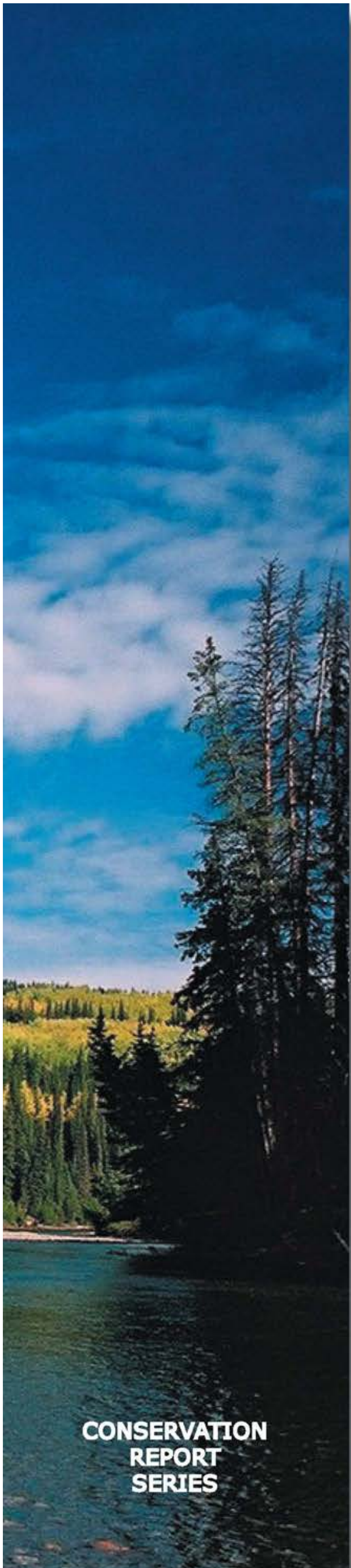


Notikewin River Watershed Subbasin (07HC) Ungulate Winter Range Restoration Program, 2008-2010

Alberta Conservation Association

wildlife | fish | habitat

Notikewin River Watershed Subbasin (07HC) Ungulate Winter Range Restoration Program, 2008-2010

C. Rasmussen and E. Anderson
Alberta Conservation Association
#101, 9 Chippewa Road
Sherwood Park, Alberta, Canada
T8A 6J7

Alberta Conservation Association

Report Editors

DOUG MANZER
Alberta Conservation Association
Box 1139, Provincial Building
Blairmore, AB T0K 0E0

GLENDA SAMUELSON
R.R. #2
Craven, SK S0G 0W0

Conservation Report Series Type
Data

ISBN: 978-1-989448-07-6

Suggested Citation:
C. Rasmussen, E. Anderson, and R. Anderson. 2019. Notikewin River watershed subbasine (07HC) ungulate winter range restoration program, 2008-2010. Data Report produced by the Alberta Conservation Association, Sherwood Park, Alberta, Canada. 31 pp + App.

Cover photo credit: David Fairless

Digital copies of conservation reports can be obtained from:
Alberta Conservation Association
101 – 9 Chippewa Rd.
Sherwood Park, AB T8A 6J7
Toll Free: 1-877-969-9091
Tel: (780) 410-1998
Fax: (780) 464-0990
Email: info@ab-conservation.com
Website: www.ab-conservation.com

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 (ACA) initiated an ungulate winter range restoration program within the ACA Restoring Natural Habitat for Wildlife project. Prescribed fire and mechanical clearing treatments have been used as part of the program to restore ungulate winter range habitats on landscapes that have aged beyond the natural range of variability, and a monitoring program was developed to evaluate the success of the treatments. The Notikewin River Subbasin (07HC) Ungulate Winter Range Ecosystem Management Plan outlined values, objectives, indicators, and targets to evaluate resource values before and after a series of treatments. This report outlines the monitoring program immediately before and after the Hutton Creek 2 prescribed fire within the Notikewin River subbasin, as well as an initial evaluation of treatment success on landscape-, ecosystem-, and species-level objectives and indicators for ungulate winter range.

The study was conducted along the Peace River corridor in northwestern Alberta, approximately 60 km north of the town of Peace River. Monitoring focused on two spatial scales: the watershed subbasin scale was used to assess landscape-level objectives and the treatment area scale was used to analyze ecosystem- and species-level objectives. Specifically, species-level objectives were evaluated within the dry mixedwood natural subregion at three study sites in the Hutton Creek 2 prescribed fire area: Hutton Creek 2A (HC2A), Hutton Creek 2B (HC2B), and Hutton Creek 2C (HC2C). Monitoring occurred for one year pre-fire (2008) and one year post-fire (2010), thus this report represents an initial assessment of vegetation response and achievement of targets. Future sampling would be required to more adequately evaluate the success of the restoration of ungulate winter range in the Notikewin River watershed subbasin.

Key words: ungulates, Notikewin River, Hutton Creek, winter range, restoration, habitat enhancement, prescribed fire, monitoring, elk, mule deer, moose.

ACKNOWLEDGEMENTS

The authors acknowledge the following individuals, agencies, and corporations for their contributions and assistance in delivering the project:

Government of Alberta,

and Foothills Research Institute.

We thank the following Alberta Conservation Association staff for their assistance during fieldwork: Shevenell Webb, John Hallett, Chad Croft, Robert Anderson, and Mike Ranger. Karl Zimmer produced data summaries and GIS analysis that were critical to the production of this report. Additionally, we would like to thank Dr. David Andison from the Foothills Research Institute and Mr. Brian Maier from the Forestry Corporation for conducting the NEPTUNE analysis for this project. Furthermore, we would like to thank Joseph Litke, Shari Clare, and Sheila McKeage of Fiera Biological Consulting for their assistance on the initial project design.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1.0 INTRODUCTION

Wildfire control activities began in Alberta's national parks in the 1930s and on provincial forested land in the 1950s. Although initiated with reasonable intentions for protecting national heritage areas, commercial forests, and communities, wildfire control activities have had serious ecological implications for wildlife habitat 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. Although the commercial forest industry creates over 80,000 hectares 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) is 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 Notikewin River subbasin was a priority subbasin identified for habitat treatment under ACA's winter range restoration program due to its relatively high composition of potential ungulate winter range, a high level of interest in the area from potential partner organizations, and a history of habitat treatments that could be built upon to meet program objectives. The Notikewin River Subbasin (07HC) Ungulate Winter Range Ecosystem Management Plan (Hermanutz 2009) outlined nine landscape-level VOITs that focussed 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 the dry mixedwood, lower boreal highlands, and upper boreal highlands 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, 18 species-level VOITs focused on providing the general forage, predator avoidance, and thermal cover characteristics required by elk, moose, and mule deer within treatment areas (e.g., distance to cover, percent grass cover).

Three key questions about the prescribed fire treatment are informed by the 32 VOITs from the Notikewin River watershed 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 Notikewin River subbasin? (landscape-level)

The body of this report will highlight the 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 can be found in Appendices A and B, respectively.

Table 1. Species-level values, objectives, indicators, and targets from the Notikewin River Subbasin Ungulate Winter Range Ecosystem Management Plan (Hermanutz 2009).

Species	Value	Objective	Indicator	Target	Reference
Elk	Forage access	Create forage in areas that are most likely to be used by ungulates	Distance from treatment areas to closest cover	Mean distance to cover plus 1 SD < 200 m[a].	Buckmaster et al. 1999
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 treatment area level	Biomass of grasses and forbs % cover or biomass of shrubs	Statistically significant increase over control 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 over control conditions	ACA target value, based on 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 photos	60:40 ratio, ± 10% acceptable variance	Buckmaster et al. 1999
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	Mean hiding distance within cover patches plus 1 SD < 61 m[b].	Buckmaster et al. 1999

Species	Value	Objective	Indicator	Target	Reference
Elk	Thermal cover	Half of the remnant cover within the treatment 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 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 minus 2 SD > 100 m[c]. Assumes cover objective is met. If not, the mean distance must be > 500 m.	Buckmaster et al. 1999, ACA objective
Moose	Forage abundance	Create minimum forage cover conditions to promote moose use	% cover of deciduous shrubs in treatment areas	> 25% shrub cover	Romito 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
Moose	Thermal cover	Half of the remnant cover within the treatment 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.	Romito et al. 1999
Moose	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 minus 2 SD > 100 m[c].	Romito et al. 1999

Species	Value	Objective	Indicator	Target	Reference
Mule deer	Forage access	Create forage in areas that are most likely to be used by mule deer	Distance from treatment areas to closest cover	Mean distance to cover plus 1 SD is < 180 m[a].	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 (0 to 20% canopy closure or > 50% deciduous shrub cover).	Percent 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
Mule deer	Thermal cover	Half of the remnant cover within the treatment 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.	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 minus 2 SD > 100 m[c]	Wood et al. 1999

[a] This should result in approximately ⅔ of foraging areas are within an animal's "comfort zone" for feeding.
[b] This should result in approximately ⅔ or more cover provides hiding cover.
[c] This should result in approximately ⅔ of the treatment is outside the zone of influence of these features.

2.0 STUDY AREA

The study was conducted within the Notikewin River watershed subbasin of northwest Alberta (Figure 1). The town of Manning lies near the center of the subbasin and Notikewin Provincial Park is located within the subbasin along the northeastern boundary. The subbasin is bordered to the west by a portion of the Clear Hills and its eastern border extends roughly 30 km east of the Peace River. The community of Keg River is approximately 20 km north of the northern boundary, while the south border is roughly seven kilometers north of Dixonville. Major rivers that flow into the Peace River system within this subbasin include the Notikewin, Hotchkiss, and Meikle rivers. The Notikewin River subbasin measures approximately 175 km west-to-east and 115 km north-to-south. It is a relatively large subbasin (the seventh largest in the province) totaling 1,233,738 ha in area, 80 percent of which is part of the Green Area (provincial Crown land). The subbasin is made up of three natural subregions (Natural Regions Committee 2006): dry mixedwood, lower boreal highlands, and upper boreal highlands.

Much of the dry mixedwood natural subregion has been cultivated for agriculture, as it has the warmest summers and highest growing-degree day accumulations of any of the boreal natural subregions. In the Peace River region, aspen (*Populus tremuloides*) forests with shrubby understories of rose (*Rosa* spp.), low-bush cranberry (*Viburnum edule*), beaked hazelnut (*Corylus cornuta*), saskatoon (*Amelanchier alnifolia*), Canada buffaloberry (*Shepherdia canadensis*), bunchberry (*Cornus canadensis*), and hairy wild rye (*Elymus innovatus)* dominate the forest cover with intermittent white spruce (*Picea glauca*). Treed, shrubby or sedge-dominated fens often occur in low areas. Porcupine grass (*Stipa spartea*), June grass (*Koeleria macrantha*), sedges (*Carex* spp.), and pasture sagewort (*Artemisia frigida*) are commonly observed on steep, dry south-facing river slopes while northern wheat grass (*Agropyron cristatum*) and slender wheat grass (*Agropyron trachycaulum*) may be found on shallower slopes. Elevations range from 200 m along the Peace River to about 700 m in the surrounding uplands (Natural Regions Committee 2006).

A suite of four prescribed fires were conceptualized for ungulate winter range restoration along the Peace River within the dry mixedwood natural subregion[1]. The approximately 380 ha Hutton Creek 1 prescribed fire was planned and ultimately implemented in spring 2008 by the Government of Alberta and Alberta Conservation Association. The initial Hutton Creek

[1] Although our focus for this project is the dry mixedwood natural subregion, a thorough summary of each natural subregion occurring in the Notikewin River watershed is provided in Appendix A of Hermanutz (2009).

prescribed fire was intended to improve ungulate foraging opportunities by reducing aspen encroachment along the steep slopes and small terraces, removing downed woody debris, and rejuvenating early successional shrub and grass understory. To further improve ungulate winter range and build on the Hutton Creek 1 prescribed fire, a second prescribed fire, Hutton Creek 2, was implemented in 2009. Hutton Creek 2 is 602 ha located adjacent to the Hutton Creek 1 prescribed fire and runs for approximately 4 km downstream. Additional prescribed fires planned in this project area include a 260 ha Deadwood prescribed fire to the south along the Peace River and a 450 ha Cadotte River prescribed fire to the southeast. This report focuses solely on the Hutton Creek 2 prescribed fire.

For the purposes of this report, the spatial extent of the study area varied with the particular objective from the Notikewin River Subbasin (07HC) Ungulate Winter Range Ecosystem Management Plan (Hermanutz 2009) that was being addressed. Landscape-level analyses occurred for an area encompassing all the ungulate winter range within the Notikewin River subbasin, regardless of whether it was burned or not (Figure 1). Ecosystem-level objectives were assessed for an area bounded by the extent of the Hutton Creek 2 prescribed fire (Figure 2). Species-level objectives were monitored at smaller, biologically-relevant study sites within and near the prescribed fire (Figure 2).

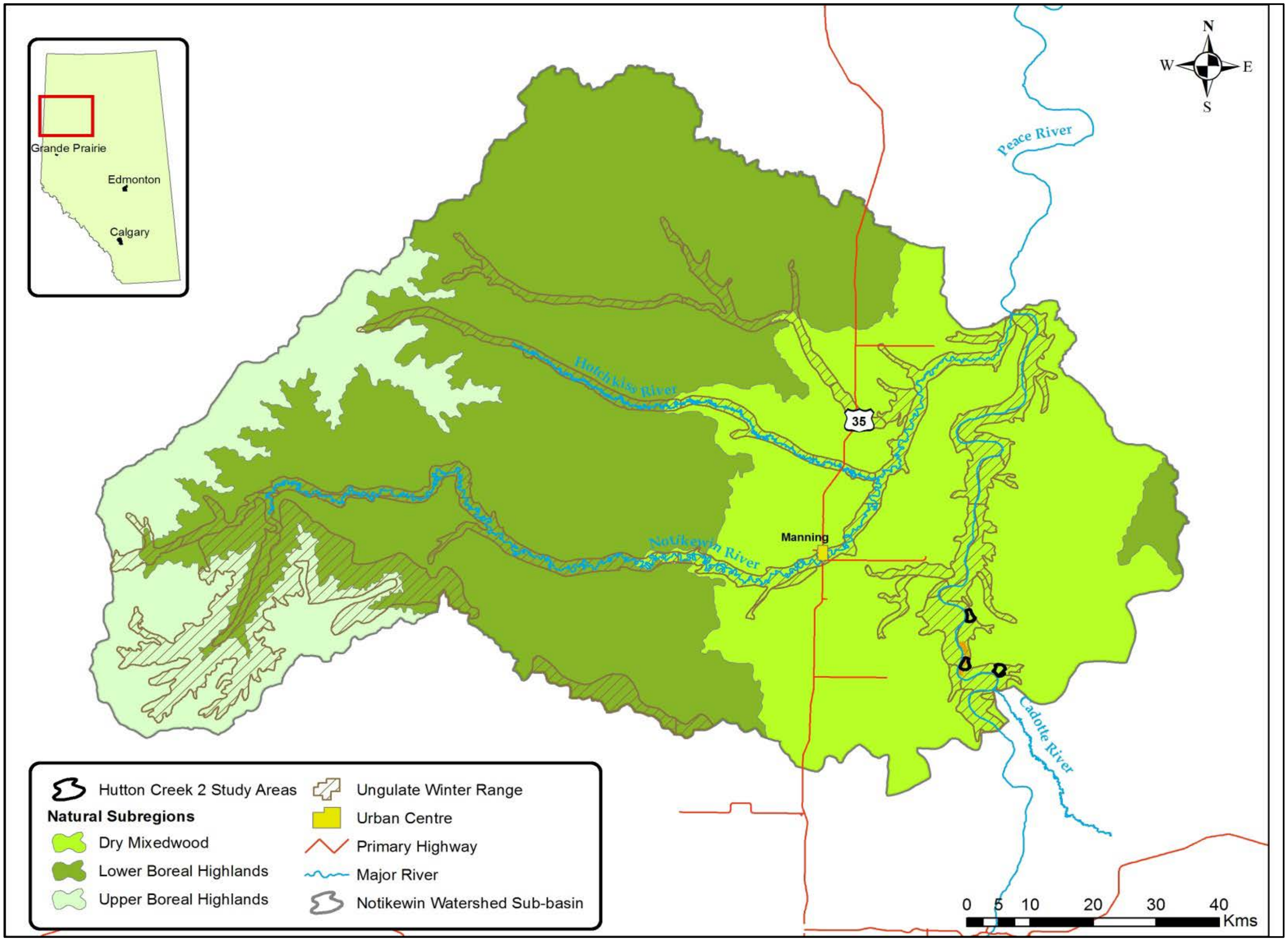


Figure 1. Study area location for the Notikewin River ungulate winter range restoration project in northwest Alberta. Inset map shows the location with Alberta.

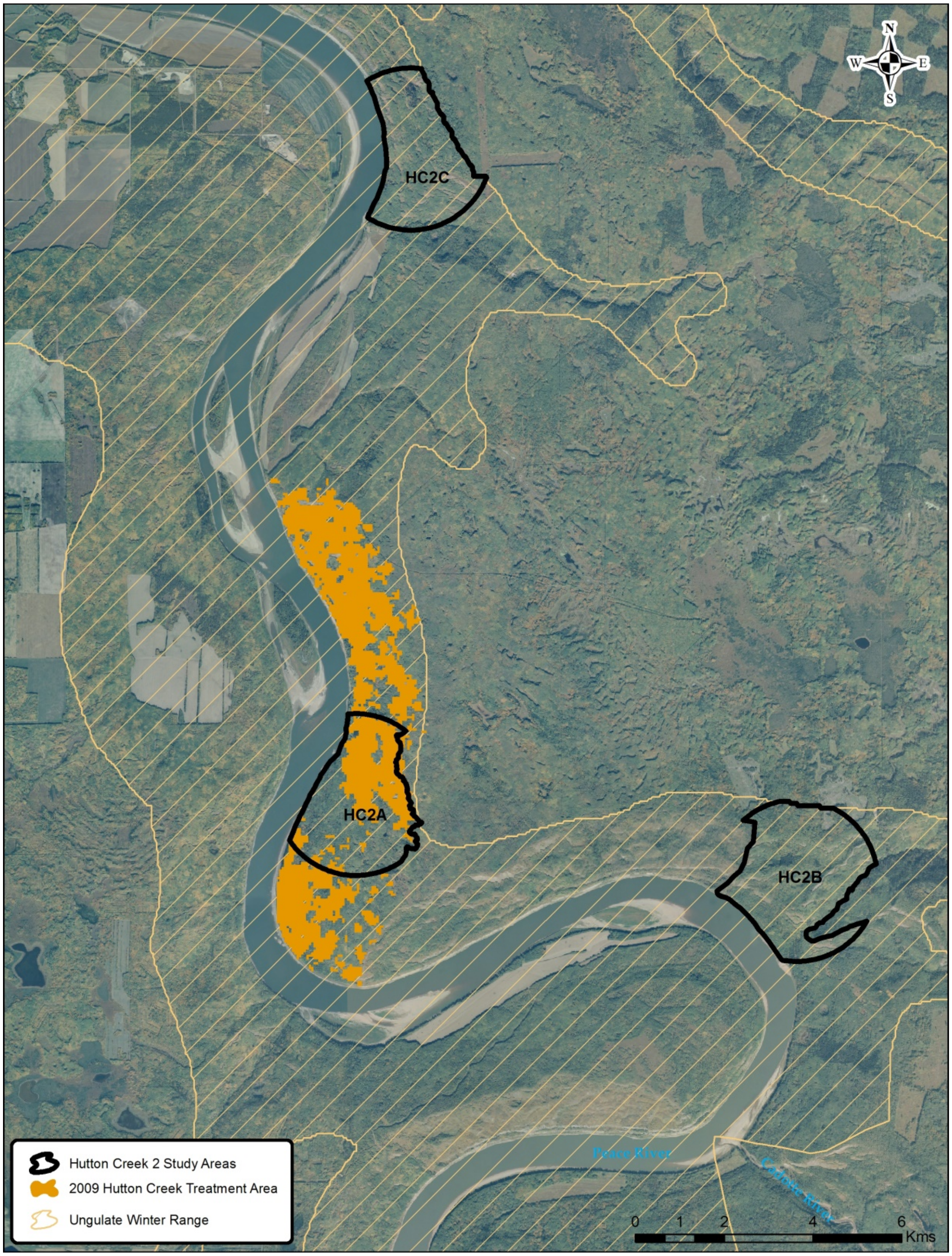


Figure 2. Overview showing the location of the Hutton Creek 2 study sites and the 2009 treatment area within the Notikewin River watershed subbasin.

3.0 MATERIALS AND METHODS

Species-level objectives for ungulate winter range were assessed using field data collected both before and after the 2009 Hutton Creek 2 prescribed fire at localized study sites. In general, species-level assessment followed a nested design with multiple sampling transects nested within a study site and multiple sampling plots nested within each transect. 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 for predator avoidance, thermal cover, and human disturbance potential. The collection of field data and subsequent analyses are discussed below.

3.1 Selection of species-level study sites and sampling transects

To create a biologically meaningful study site 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 a local study site for measuring elk habitat values and assumed this radius would also capture typical mule deer and moose foraging movements. Potential study sites were assessed based on the following criteria: (1) areas with high ungulate winter range potential; (2) areas associated with a proposed prescribed fire plan; and (3) areas that fell within the dry mixedwood natural subregion. The three study sites were selected within and adjacent to the Hutton Creek 2 prescribed fire, with study site boundaries further refined to follow significant geographic features. These sites were identified as Hutton Creek 2A (HC2A – treatment), Hutton Creek 2B (HC2B - control), and Hutton Creek 2C (HC2C – control; Figure 2).

Prior to each survey season, random transect locations were generated in GIS for each study site. We attempted to survey 20 transects from the previously identified random start locations, with a given 30 m 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.

In 2008, pre-fire field data were collected from August 12th to 14th. A total of 61 transects were sampled: 20 in Hutton Creek 2A, 21 in Hutton Creek 2B, and 20 in the Hutton Creek 2C. No field sampling was conducted in 2009, the year of the Hutton Creek 2 prescribed fire. In 2010, post-fire field data were collected from August 10th to 12th. A total of 58 transects were sampled: 20 in Hutton Creek 2A, 19 in Hutton Creek 2B, and 19 in the Hutton Creek 2C. Thus, study sites were monitored for one year pre-fire (2008) and one year post-fire (2010).

3.2 Field data collection

3.2.1 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 site character.

3.2.2 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 % 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.

3.2.3 Security cover

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) and was measured for closed canopy transects only.

3.2.4 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 mixed feeders such as elk and mule deer that select both grass and browse (Shipley 1999) as well as for moose that select primarily browse.

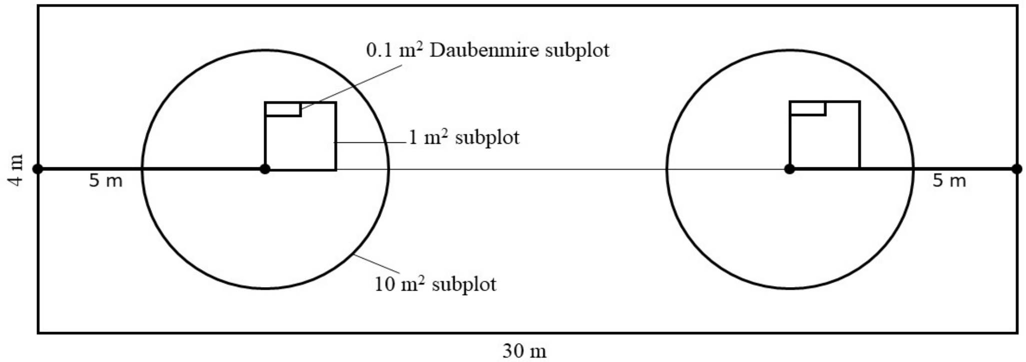
3.2.5 Herbaceous biomass

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 and this was noted. Dry weight was determined by drying samples for a minimum of 24 hours in a 60°C forced-air drying oven until a constant weight was achieved.

3.2.6 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 both browsers and 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 (m) measurements were subsequently used to estimate stem biomass following established predictive equations (Brown 1976, Visscher et al. 2006, Halpern and Lutz 2013) 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
  - Ground Cover Estimates (grass, forb, dwarf shrub, litter, woody debris, rock, bare ground)
- 0.1 m^2 Daubenmire subplot
  - Herbaceous Biomass

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.

3.3 Data analyses

Species-level objectives identified in Table 1 are assessed below based on pre- and post-fire field data and associated GIS analyses. These VOITs look primarily at prescribed fire treatment impacts on forage (access, abundance, quality), predator avoidance (proximity of security cover, animal hiding distance), thermal cover, and human disturbance potential. 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.

3.3.1 Forage access

Distance to cover – To evaluate forage access, we evaluated the mean distance to cover (i.e., distance to forest canopy closure ≥ 20%) based on sampling at both open and closed canopy transects at each species-level study site each year. Habitat suitability models for mule deer and elk identified comfortable foraging to be within 140 m and 180 m of cover, respectively (Wood et al. 1999; Buckmaster et al. 1999); distance-to-cover targets in Hermanutz (2009) incorporated these distances as the mean plus one standard deviation to ensure that approximately two thirds of foraging areas are within an animal's "comfort zone" for feeding.

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 (FRI) crown closure layer covering much of western Alberta 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 stand-replacing fires that no longer had a closed canopy, the canopy closure layer was first updated to reclassify areas burned since 2009 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 site was calculated before and after the prescribed fire and compared to the desired 60% cover to 40% foraging habitat ratio (Buckmaster et al. 1999). This measure is relevant to both elk and mule deer. Unfortunately, the FRI crown closure layer did not cover the Hutton Creek 2C study site, so this study site was not assessed using this method.

3.3.2 Forage abundance

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

Forb/grass and shrub biomass – For each species-level study site 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 due to lack of vegetation were treated as zeros. These measures were used to assess forage abundance for 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, Brown 1976, Halpern and Lutz 2013). If the biomass regression estimated a negative biomass, a zero value was assigned. 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 estimated 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, moose, and mule deer.

3.3.3 Forage value

Seasonal Elk Forage Index – Using the method outlined in Sachro (2003), a seasonal Elk Forage Preference Index was calculated for each study site in each year. This index assesses the percent cover and preference ranking for each forage species relative to total plant cover and is assessed for each season to incorporate dietary shifts. Forage ratings for various plant species were based on Kufeld (1973); species not included in this reference were assigned a value based on similar genus/species and expert opinion where possible or were omitted from the analysis. Forage Preference Index values range from 0 to 3 with values < 1 considered low, > 1 considered moderate, and > 2 considered high forage quality (Sachro et al. 2005).

3.3.4 *Predator avoidance*

Animal hiding distance – Elk, moose, and deer use slightly different strategies for predator avoidance (Hermanutz 2009). Elk and moose use tree cover for hiding and escape (Stelfox and Stelfox 1993, Jones et al. 2002, Eisenberg et al. 2015), while mule deer require open country and steep slopes for predator avoidance on the prairies, but will use tree cover in combination with topography in the foothills and mountains (Stelfox and Stelfox 1993, Wood et al. 1999). Predator avoidance values for elk were assessed using field-based transect data to calculate the mean animal hiding distance on closed cover transects.

3.3.5 *Thermal cover*

Data on cover class, canopy closure, % conifer, and canopy height from each 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 access 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 site in each year.

3.3.6 *Human disturbance*

Using ArcGIS, a human disturbance layer was created by merging together roads, cutlines, and trails, as well as major rivers, from the base features Single Line Hydrography Network (SLNET) shapefiles. The distance from each transect to the nearest human disturbance feature was calculated and averaged across a given species-level study site 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 elk, moose, and mule deer.

4.0 RESULTS

4.1 Forage access

As expected, the mean distance to cover remained similar between the 2008 pre-fire and 2010 post-fire time periods for the control sites (HC2B, HC2C; Table 2) and increased slightly on open canopy transects of the treatment site (HC2A), although there was no significant statistical differences (HC2A: $z=1.415$, $p=0.157$; HC2B: $z=-0.313$, $p=0.754$; HC2C: $z=1.239$, $p=0.215$). For all study sites, the mean distance to cover plus one standard deviation was far less than 180 m across both open and closed canopy transects, and the maximum distance to cover never exceeded 90 m. Therefore, forage access targets for elk and mule deer were met within the Hutton Creek 2 prescribed fire.

Table 2. Mean distance (m) from forage area to cover measured on open and closed canopy transects as estimated during field sampling at three species-level study sites.

Study area	Canopy closure	Year	N	Mean (± SD)	Mean + SD	Min	Max
HC2A (Treatment)	Closed	2008	15	3.3 (±8.2)	11.5	0	30
		2010	13	0.0 (±0.0)	0.0	0	0
	Open	2008	5	7.0 (±4.5)	11.5	0	10
		2010	7	36.0 (±49.3)	85.3	0	90
	Combined	2008	20	4.2 (±7.5)	11.7	0	30
		2010	20	10.0 (±29.1)	39.1	0	90
HC2B (Control)	Closed	2008	14	0.0 (±0.0)	0.0	0	0
		2010	14	0.0 (±0.0)	0.0	0	0
	Open	2008	5	11.0 (±8.2)	19.2	0	20
		2010	5	12.6 (±7.8)	20.4	5	25
	Combined	2008	19	2.9 (±6.3)	9.2	0	20
		2010	19	3.3 (±6.8)	10.1	0	25
HC2C (Control)	Closed	2008	13	0.0 (±0.0)	0.0	0	0
		2010	16	0.0 (±0.0)	0.0	0	0
	Open	2008	7	12.1 (±11.5)	23.6	0	30
		2010	3	7.7 (±10.8)	18.5	0	20
	Combined	2008	20	4.2 (±8.8)	13.0	0	30
		2010	19	1.2 (±4.6)	5.8	0	20

Similar in intent to distance-to-cover objectives but evaluated using GIS across an entire species-level study site, cover-to-forage ratio objectives for elk and mule deer assess the mix of foraging and security habitat in post-treatment areas. Ratios were calculated for HC2A and HC2B, but crown closure data was not available for HC2C (Table 3). The HC2A treatment site was close to the target of a 60:40 ratio of closed cover to open habitat following the prescribed fire, while the HC2B control site remained at approximately a 50:50 ratio.

Table 3. Percentage of the species-level study sites classified as closed or open cover from a GIS analysis of canopy closure.

Study site	Pre-treatment closed cover (% of area)	Pre-treatment open cover (% of area)	Post-treatment closed cover (% of area)	Post-treatment open cover (% of area)
HC2A (Treatment)	99	1	57	43
HC2B (Control)	48	52	49	51
HC2C (Control)	n/a	n/a	n/a	n/a

4.2 Forage abundance

Grass and forb abundance - Mean grass cover increased significantly between pre-fire and post-fire time periods at the HC2A treatment site (z=-4.154, p<0.0001) and the HC2B control site (z=-2.806, p=0.005) (Figure 4), but did not change significantly between years at the HC2C control site (z=-1.613, p=0.107). Overall, however, grass cover was well below the 10% grass cover target for elk forage. Grass biomass increased significantly between years at the HC2A treatment site (z=-2.612, p=0.009) (Figure 5), and did not differ significantly at the two control sites (HC2B: z=-0.094, p=0.925; HC2C: z=-1.281, p=0.200). Mean forb cover did not change significantly at any study site between years (HC2A: z=-0.947, p=0.3435; HC2B: z=-0.657, p=0.511; HC2C: z=-1.265, p=0.206) (Figure 6), nor did mean forb biomass change significantly at any study site between years (HC2A: z=-1.193, p=0.233; HC2B: z=-0.380, p=0.704; HC2C: z=-1.506, p=0.132) (Figure 7). Only the elk forage target related to a significant increase in grass biomass was achieved while the forb biomass target was not achieved.

Shrub abundance - Mean deciduous shrub cover was highest at the HC2A treatment site and above the 25% cover target for moose, but below the 50% cover target for mule deer forage abundance (Figure 8). Neither HC2B nor HC2C exceeded deciduous shrub cover targets for either species, and there were no significant changes at any of the study sites between the pre- and post-fire years (HC2A: z =-0.879, p=0.379; HC2B: z=0.643, p=0.520; HC2C: z=-1.167, p=0.243). Mean shrub biomass was significantly lower at the HC2A treatment site (z=2.272, p=0.023) and marginally lower at the HC2C control site (z=1.770, p=0.077) in 2010 compared to 2008, but not significantly different at the HC2B control site (z=0.598, p=0.550) (Figure 9). The moose and elk targets of a significant increase in shrub biomass were not met, but this is not surprising as shrubs may require more than one year after a prescribed fire to achieve increases in biomass.

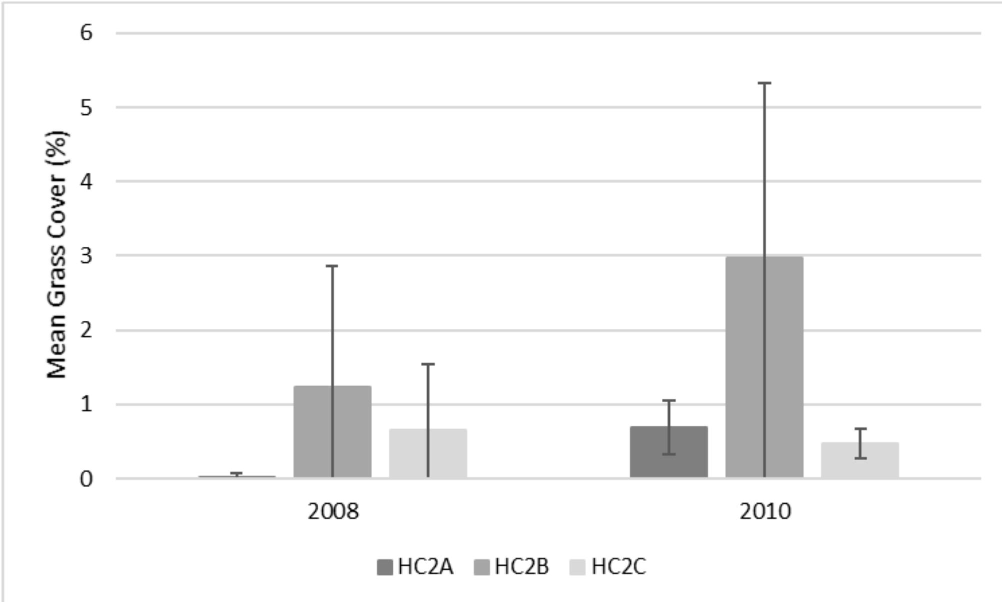


Figure 4. Mean grass cover (%) with 95% confidence intervals measured at 1 m² square subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

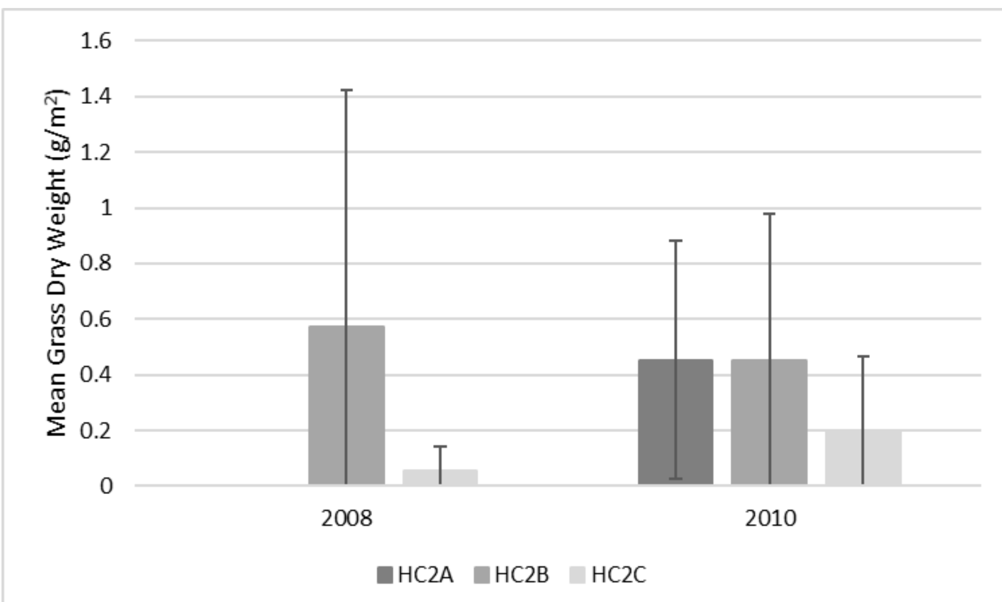


Figure 5. Mean grass biomass (g/m²) with 95% confidence intervals measured from dry weights taken at 0.1 m² Daubenmire subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

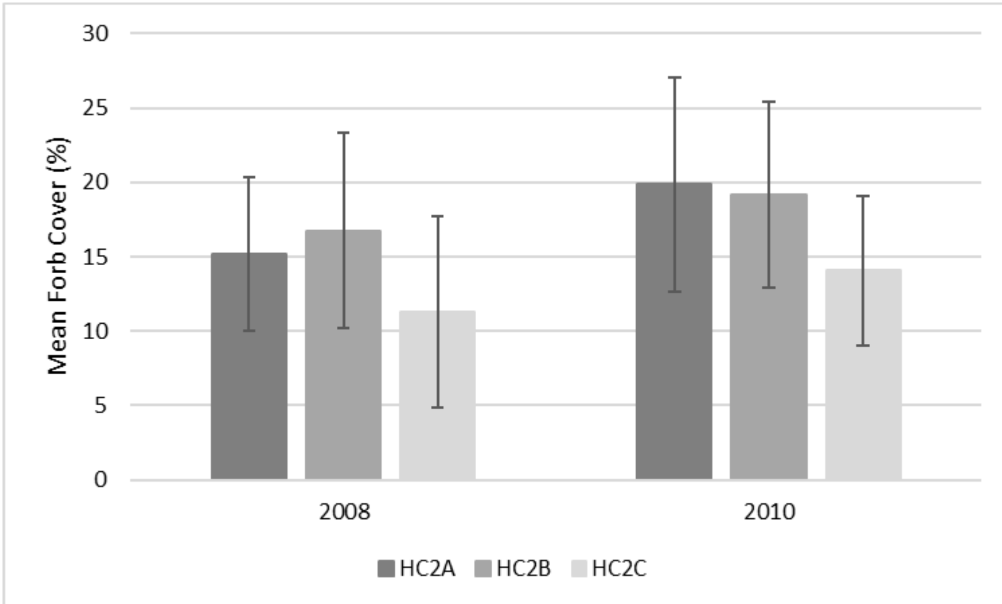


Figure 6. Mean forb cover (%) with 95% confidence intervals measured at 1 m^2 square subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

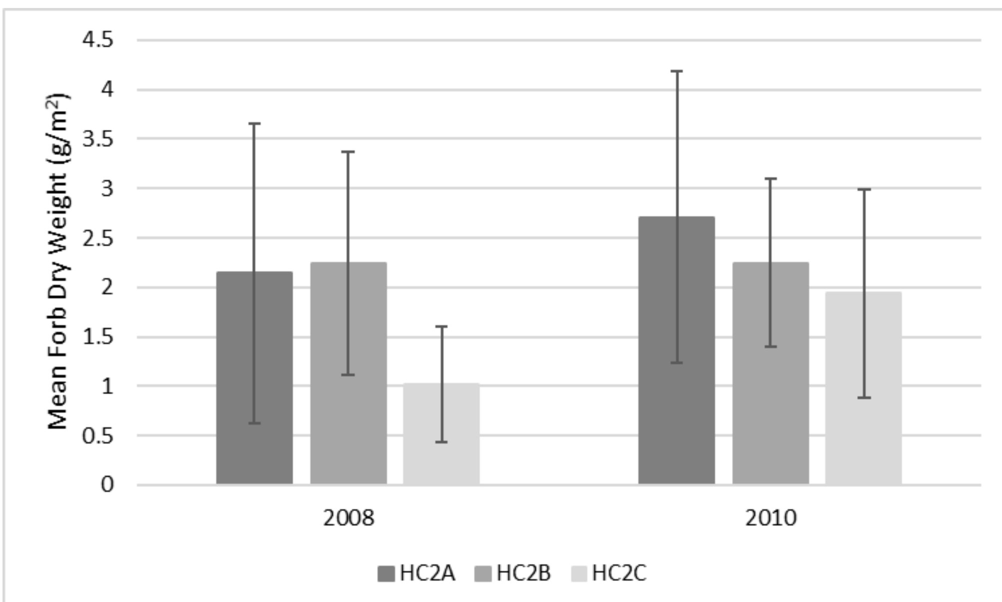


Figure 7. Mean forb biomass (g/m^2) with 95% confidence intervals measured from dry weights taken at 0.1 m^2 Daubenmire subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

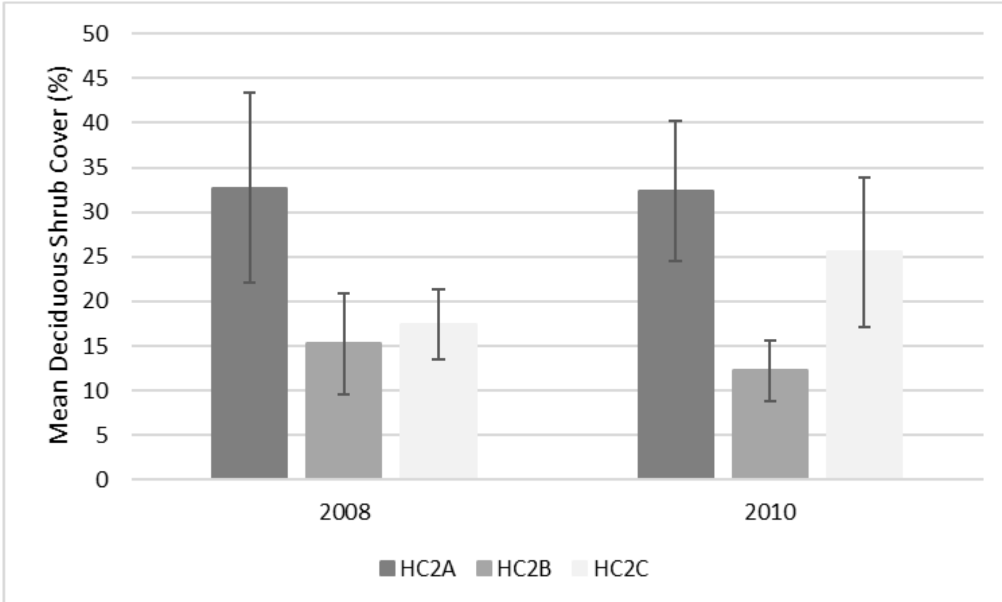


Figure 8. Mean deciduous shrub cover (%) with 95% confidence intervals measured in 10 m^2 circular subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

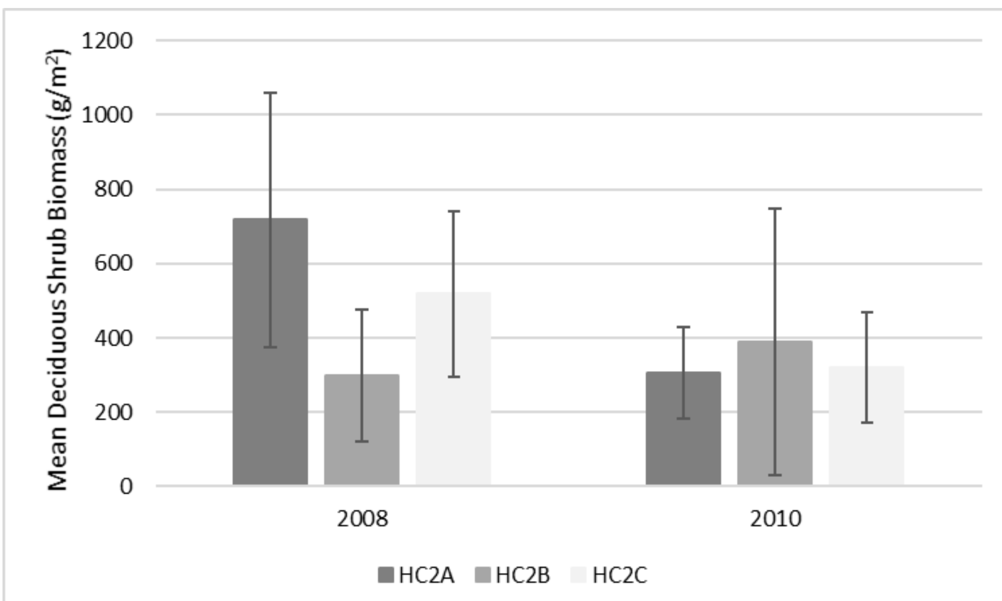


Figure 9. Mean deciduous shrub biomass (g/m^2) with 95% confidence intervals measured from dry weights taken at 10 m^2 circular subplots at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

4.3 Forage value

Forage value indicators and targets were evaluated for elk for each season at each study site, with the exception of HC2C in 2010 as vegetation percent cover values were not available (Table 4). Within the HC2A treatment site, a marginally significant increase was noted in the elk forage preference value for the spring ($z=-1.697$, $p=0.090$), while a slight increase noted for the winter value and slight decreases observed for the summer and fall values were non-significant ($z=-1.028$ to 1.515, $p>0.130$). A significant decrease in the fall Elk Forage Preference Index ($z=2.232$, $p=0.026$) and a significant increase in the winter index ($z=-2.596$, $p=.009$) were noted at the HC2B control site: any differences in spring and summer were non-significant ($z=-0.989$, $p=0.323$; $z=1.315$, $p= 0.189$, respectively). Elk forage index targets were not met as observed changes were generally non-significant and similar to control study sites, and did not represent an increase of 50% beyond control conditions. Additional years of sampling would be necessary to identify changes beyond annual environmental variability.

Table 4. Seasonal Elk Forage Preference Index estimated at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

Study area	Year	n	Spring	Summer	Fall	Winter
HC2A (Treatment)	2008	20	0.34	2.08	1.95	1.85
	2010	20	0.59	1.77	1.76	1.96
HC2B (Control)	2008	18	0.44	2.50	2.50	1.46
	2010	18	0.57	2.24	2.08	1.93
HC2C (Control)	2008	20	0.77	2.55	2.39	1.80

4.4 Predator avoidance

As expected, the mean animal hiding distance remained similar with no significant differences between the pre- and post-fire periods for the control sites (HC2B: $z=-0.561$, $p=0.575$; HC2C: $z=-0.088$, $p=0.930$), and increased slightly for the treatment site, although the increase was only marginally significant (HC2A: $z=-1.767$, $p=0.077$) (Table 5). For all study sites in all time periods, the mean distance to cover plus one standard deviation was considerably less than 61 m. The maximum distance to cover never reached above 60 m for any study site. Therefore, predator avoidance targets for elk were met within all study sites.

Table 5. Mean animal hiding distance (m) as measured on closed canopy transects at study sites in 2008 (pre-treatment) and 2010 (post-treatment).

Study area	Year	n	Mean (± SD)	Mean + SD	Min	Max
HC2A (Treatment)	2008	15	19.8 (±10.8)	30.6	5	45
	2010	13	30.0 (±15.3)	45.3	10	60
HC2B (Control)	2008	14	23.6 (±11.4)	35.0	5	45
	2010	13	27.3 (±13.2)	40.5	10	55
HC2C (Control)	2008	13	24.5 (±11.9)	36.4	10	45
	2010	16	25.8 (±12.8)	38.6	10	60

4.5 Thermal cover

Although thermal cover indicators and targets were evaluated for elk, mule deer, and moose for closed canopy transects, no study sites in either year met the criteria for thermal cover due to canopy closure not exceeding 70% at any transect. Consequently, thermal cover targets were not met.

4.6 Human disturbance

Human disturbance indicators and targets were evaluated for elk, mule deer, and moose by measuring the average distance from random transects to the nearest human access (road, cutline, trail, major river) in GIS. On average, transects in 2008 were a greater distance from human access than transects in 2010 for the HC2A treatment site; both years were at or above the target of 100 m for mean distance minus two standard deviations (Table 6). At the two control sites, mean distances between the years remained fairly similar but were well below the target distance for proximity to human disturbance.

Table 6. Mean distance (m) to nearest active road or trail used by motorized vehicles at study sites in 2008 (pre-treatment) and 2010 (post-treatment) as calculated in a GIS. The Peace River was also considered an active access trail as it provides human access by boat.

Study area	Year	n	Mean (± SD)	Mean - 2SD	Min	Max
HC2A (Treatment)	2008	20	643.5 (±271.7)	100.1	148.5	1199.7
	2010	20	570.7 (±232.5)	105.7	116.6	1038.0
HC2B (Control)	2008	19	452.8 (±254.6)	-56.4	64.5	827.9
	2010	19	428.2 (±227.5)	-26.8	33.7	835.1
HC2C (Control)	2008	20	157.5 (±118.9)	-80.3	5.5	416.3
	2010	19	193.2 (±119.9)	-46.6	13.7	409.6

5.0 SUMMARY

The Hutton Creek 2 prescribed fire in 2009 was intended to increase winter forage potential for elk, moose, and mule deer along the Peace River under the larger Notikewin River Watershed Subbasin (07HC) Ungulate Winter Range Restoration Plan. Recognizing this plan would require multiple treatments over many years or decades to achieve, the current study represents an initial evaluation of progress towards targets outlined therein at the first year following the prescribed fire treatment.

Forage abundance improvements were mixed at one year following the prescribed fire treatment. Grass cover and biomass increased at the treatment study site but were generally still below the targets for elk forage, while there was no change in forb cover or biomass. Shrub cover was at the target level for moose prior to the fire at the treatment study site (though below the target for mule deer) and did not change post-fire. Shrub biomass, on the other hand, was negatively impacted by the prescribed fire treatment, at least for the short term. Future sampling would be required to determine whether the shrub biomass rebounds and achieves the established targets for ungulate browse.

Ungulate range treatments must balance forage improvements with providing adequate cover in which animals can find thermal cover, avoid predators, and spatially separate themselves from human disturbance. The location and extent of the Hutton Creek 2 prescribed fire appeared to provide such a balance. Following the prescribed fire treatment, the closed cover to open foraging habitat ratio approximated the desired 60% to 40% ratio and all sites met the associated distance-to-cover targets for mule deer and elk, thus a mix of forage and secure habitat was created. Although the treatment site was more open following the fire and there was a slight increase in the distance at which an animal would be hidden from view, the animal hiding distance target was still met. Similarly, the distance from the nearest human access feature to the prescribed fire area exceeded the minimum targeted distance for the treatment study site, while control study sites did not.

The thermal cover targets could not be assessed as no transects met the established criteria; these objectives and targets should be re-examined to determine if a lower percent cover threshold will still provide adequate thermal cover within the local study sites or should consider the use of alternative canopy closure estimation techniques. Field data collection methods relied on the observers to conduct an ocular estimation, which is 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.

Monitoring of the 2009 Hutton Creek 2 prescribed fire occurred for one year pre-fire (2008) and one year post-fire (2010), thus this report represents an initial assessment of vegetation response and achievement of targets. Future sampling would be required to more adequately evaluate the success of the restoration of ungulate winter range in the Notikewin River watershed subbasin.

6.0 LITERATURE CITED

Alberta Agriculture and Forestry. 2017. Sustainable Forest Management 2015 Facts & Statistics. Spring 2017. Available online at https://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/formain15744/$FILE/2015-Area-Harvested.pdf. [Accessed 21 November 2018].

Andison, D.W. 2000. Landscape-level fire activity on foothills and mountain landscape of Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 2., Foothills Model Forest, Hinton, Alberta, Canada. 38 pp.

Andison, D.W. 2003. Patch and event sizes on foothills and mountain landscapes of Alberta. Alberta Foothills Disturbance Ecology Research Series, Report No. 4., Foothills Model Forest, Hinton, Alberta, Canada. 48 pp.

Andison, D.W. 2006. Finding common ground: Some definitions. Natural Disturbance Program Integration Note Series, Issue #1, Foothills Model Forest, Hinton, Alberta, Canada. 6 pp.

Brown, J.K. 1976. Estimating shrub biomass from basal stem diameters. Canadian Journal of Forest Research 6: 153-158.

Buckmaster, G., M. Todd, K. Smith, K. Bonar, B. Beck, J. Beck, and R. Quinlan. 1999. Elk winter foraging: habitat suitability index model, Version 5. Unpublished report prepared for Foothills Model Forest, Hinton, Alberta, Canada. 8 pp.

Eisenberg, C., D.E. Hibbs, and W.J. Ripple. 2015. Effects of predation risk on elk (Cervus elaphus) landscape use in a wolf (Canis lupus) dominated system. Canadian Journal of Zoology 93: 99-111.

Fahrig, L. 2017. Ecological responses to habitat fragmentation per se. Annual Review of Ecology, Evolution, and Systematics 48: 1-23.

Fletcher, R.J.Jr., R.K. Didham, C. Banks-Leite, J. Barlow, R.M. Ewers, J. Rosindell, R.D. Holt, A. Gonzalez, R. Pardini, E.I. Damschen, F.P.L. Melo, L. Ries, J.A. Prevedello, T. Tscharntke, W.F. Laurance, T. Lovejoy, and N.M. Haddad. 2018. Is habitat fragmentation good for biodiversity? Biological Conservation 226: 9-15.

Frair, J.L., E.H. Merrill, D.R. Visscher, D. Fortin, H.L. Beyer, and J.M. Morales. 2005. Scales of movement by elk (Cervus elaphus) in response to heterogeneity in forage resources and predation risk. Landscape Ecology 20: 273–287.

Gohel, D. 2016. ReporteRs: Microsoft Word, Microsoft PowerPoint, and HTML Documents Generation. R package version 0.8.6. Available online at https://cran.r-project.org/src/contrib/Archive/ReporteRs/ [Accessed 24 January 2019].

Government of Alberta. 2015. Historical Wildfire Perimeter Data: 1931-2014. Provincial Forest Fire Center. Available online at http://wildfire.alberta.ca/wildfire-maps/historical-wildfire-information/spatial-wildfire-data.aspx

Halpern, C.B., and J.A. Lutz. 2013. Canopy closure exerts weak controls on understory dynamics: a 30-year study of overstory–understory interactions. Ecological Monographs 83: 221-237.

Haufler, J.B., R.K. Baydack, H. Campa III, B.J. Kernohan, C. Miller, J. O'Neil, and L. Waits. 2002. Performance measures for ecosystem management and ecological sustainability. Wildlife Society Technical Review 02-1 produced by The Wildlife Society, Bethesda, Maryland, USA. 33 pp.

Hermanutz, R. 2009. Notikewin River watershed subbasin (07HC) ungulate winter range restoration plan. Data report produced by the Alberta Conservation Association, Rocky Mountain House, Alberta, Canada. 60 pp.

Jones, P.F., R.J. Hudson, and D.R. Farr. 2002. Evaluation of a winter habitat suitability index model for elk in west-central Alberta. Forest Science 48: 417-425.

Key, C.H., and N.C. Benson. 2006. Landscape assessment (LA) sampling and analysis methods. General Technical Report RMRS-GTR-165-CD produced by USDA Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado, USA. 55 pp. Available online at https://www.fs.fed.us/postfirevegcondition/documents/publications/FIREMON_LandscapeAssessment.pdf [Accessed 24 January 2019].

King, D.I., and S. Schlossberg. 2014. Synthesis of the conservation value of the early-successional stage in forests of eastern North America. Forest Ecology and Management 324: 186-195.

Korhonen, L., K.T. Korhonen, M. Rautiainen, and P. Stenberg. 2006. Estimation of forest canopy cover: A comparison of field measurement techniques. Silva Fennica 40: 577-578.

Krebs, C.J. 1999. Ecological Methodology, 2nd ed. Addison-Wesley Educational Publishers, Inc., Menlo Park, California, USA. 620 pp.

Kufeld, R.C. 1973. Foods eaten by the Rocky Mountain elk. Journal of Range Management 26: 106-113.

Maier, B. 2009. NEPTUNE. Natural Pattern Emulation DSS Planning Tool. Natural Disturbance Program 2009 Workshop Presentation. Foothills Model Forest, Hinton, Alberta, Canada. Available online at https://friresearch.ca/resource/neptune-natural-pattern-emulation-dss-planning-tool [Accessed 24 January 2019].

Natural Regions Committee. 2006. Natural Regions and Subregions of Alberta. Compiled by D.J. Downing and W.W. Pettapiece. Pub No. T/852 produced by the Government of Albert, Edmonton, Alberta, Canada.

Pengelly, I., and M-P. Rogeau. 2001. Banff Field Unit Fire Management Plan. Banff National Park, Banff, Alberta, Canada. 132 pp.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available online at http://www.R-project.org/ [Accessed 24 January 2019].

Ripley, B., and M. Lapsley. 2015. RODBC: ODBC Database Access. R package version 1.3-12. Available online at https://CRAN.R-project.org/package=RODBC [Accessed 24 January 2019].

Rogeau, M.P., M.D. Flannigan, B.C. Hawkes, M.A. Parisien, and R. Arthur. 2016. Spatial and temporal variations of fire regimes in the Canadian Rocky Mountains and Foothills of southern Alberta. International Journal of Wildland Fire 25: 1117-1130.

Romito, T., K. Smith, B. Beck, J. Beck, M. Todd, R. Bonar, and R. Quinlan. 1999. Moose winter habitat: habitat suitability index model, Version 5. Unpublished report prepared for the Foothills Model Forest, Hinton, Alberta, Canada. 6 pp.

R Studio Team. 2015. RStudio: Integrated Development for R. RStudio, Inc. Available online at http://www.rstudio.com/ [Accessed 24 January 2019].

Sachro, L. 2003. The effects of prescribed burning on elk forage habitat suitability in the central eastern slopes of Alberta. Master of Environmental Design Thesis. University of Calgary, Calgary, Alberta, Canada. 142 pp.

Sachro, L.L., W.L. Stronga, and C.C. Gates. 2005. Prescribed burning effects on summer elk forage availability in the subalpine zone, Banff National Park, Canada. Journal of Environmental Management 77: 183-193.

Shipley, L.A. 1999. Grazers and browsers: How digestive morphology affects diet selection. Pages 20-27. *In*: K.L. Launchbaugh, K.D. Sanders, and J.C. Mosley. Grazing behavior of livestock and wildlife. Idaho Forestry, Wildlife & Range Experimental Station Bulletin #70, University of Idaho, Moscow, Idaho, United Stations. Available online at https://nature.berkeley.edu/classes/espm-186/Unit_II_(cont)_files/grazer%20v.%20browser.pdf [Accessed 24 January 2019].

Smith, J.K. 2000. Wildland fire in ecosystems: Effects of fire on fauna. General Technical Report RMRS-GTR-42-Vol. 1 produced by USDA Forest Service, Rocky Mountain Research Station, Ogden, Utah, United States. 83 pp.

StataCorp. 2009. Stata Statistical Software: Release 11.2 College Station, Texas, United States.

Stelfox, J.B., and J.G. Stelfox. 1993. Distribution. Pages 45-62. *In*: J.B. Stelfox. Hoofed Mammals of Alberta. Lone Pine Press, Edmonton, Alberta, Canada.

Tymstra, C., D. Wang, and M-P. Rogeau. 2005. Alberta wildfire regime analysis. Report produced by Alberta Department of Sustainable Resource Development, Forest Protection Division, Edmonton, Alberta, Canada. 171 pp.

Visscher, D.R., E.H. Merrill, D. Fortin, and J.L. Frair. 2006. Estimating woody browse availability for ungulates at increasing snow depths. Forest Ecology and Management 222: 348-354.

White, C.A, I.R. Pengelly, and D. Zell. 2003. Landscape fire regimes and vegetation restoration in Banff National Park, Alberta. Occasional Paper BNP-2003-01. Parks Canada, Banff, Alberta, Canada.

Wickham, H. 2009. ggplot2: Elegant graphics for data analysis. Springer-Verlag New York, USA. Available online at https://cran.r-project.org/web/packages/ggplot2/ [Accessed 24 January 2019].

Wickham, H. and R. Francois. 2015. dplyr: A grammar of data manipulation. R package version 0.4.3. Available online at https://CRAN.R-project.org/package=dplyr [Accessed 24 January 2019].

Wood, L., K. Smith, B. Beck, J. Beck, M. Todd, R. Quinlan, and R. Bonar. 1999. Mule deer winter habitat: habitat suitability index model, Version 5. Unpublished report prepared for Foothills Model Forest, Hinton, Alberta, Canada. 8 pp.

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 Notikewin River subbasin, regardless of whether it was burned or not. Associated objectives focused on the stand age distribution and disturbance rates in the dry mixedwood, lower boreal highlands, and upper boreal highlands natural subregions (Table A-1). Assessment of these metrics was primarily a 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 available AVI layer for this study area had not been updated since 2000; as such, the AVI layer was updated to reclassify stand origin dates for recently burned areas (both wildfires and prescribed fires; assuming all mapped burns were stand-replacing events). Additionally, because AVI data was not available for the entire Notikewin River subbasin, the area of ungulate winter range that intersects the total extent of AVI was also calculated to allow for better comparison of stand age targets. This layer was then clipped by the ungulate winter range and stand age distribution assessed therein.

For the Notikewin River subbasin, we ran this stand age distribution model based on three different stand age criteria for three natural subregions:

1. Young forest (1990-2010 stand origin date) in each of the dry mixedwood, lower boreal highlands, and upper boreal highlands natural subregions
2. Pole forest (1910-1989 stand origin date) in each of the dry mixedwood, lower boreal highlands, and upper boreal highlands natural subregions
3. Mature forest (1830-1909 stand origin date) in each of the dry mixedwood, lower boreal highlands, and upper boreal highlands 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 Notikewin River watershed subbasin (Hermanutz 2009).

Level	Value	Objective	Indicator	Target
Landscape	Stand age distribution in the dry mixedwood	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 8% to 39% of the ungulate winter range contains young forest
		The amount of pole forest (21 - 80 years old) in ungulate winter range falls within the NRV	Area of pole forest in the ungulate winter range as determined from AVI and GIS	The % of pole forest within the dry mixedwood portion of the winter range is continuing towards the NRV
	Disturbance rate in the dry mixedwood	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the dry mixedwood, this value equates to 10,547 ha of ungulate winter range winter range over a ten-year period.
	Stand age distribution in the lower boreal highlands	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 8% and 39% of the ungulate winter range in the lower boreal highlands contains young forest
		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	The % of mature forest within the lower boreal highlands portion of the winter range is continuing towards the NRV

Level	Value	Objective	Indicator	Target
	Disturbance rate in the lower boreal highlands	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the lower boreal highlands, this value is 16,827 ha of ungulate winter range over a ten-year period.
	Stand age distribution in the upper boreal highlands	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 8% to 39% of the ungulate winter range contains young forest
		The amount of pole forest (21 - 100 years old) in ungulate winter range falls within the NRV	Area of pole forest in the ungulate winter range as determined from AVI and GIS	The % of pole forest within the upper boreal highlands portion of the winter range is continuing towards the NRV
	Disturbance rate in the upper boreal highlands	Habitat treatments are conducted at a rate appropriate to the natural disturbance regime	Ten-year rolling average for treatment area	Treatments occur at the rate calculated for the median fire cycle reported in Appendix III of Tymstra et al. (2005). For the upper boreal highlands, this value is 7,760 ha of ungulate winter range over a ten-year period.

*NRV=natural range of variation

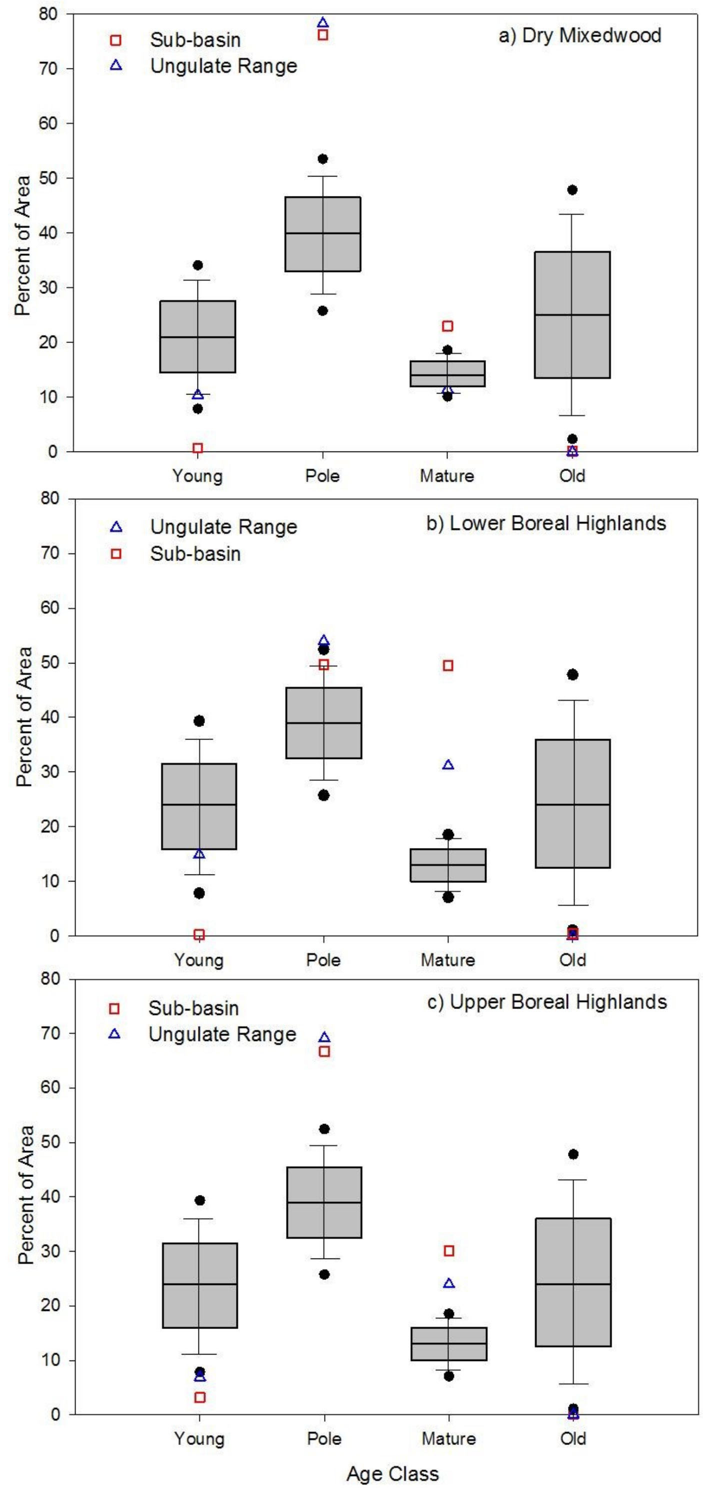


Figure A-1. Theoretical NRV in age distribution of forests in the (a) dry mixedwood, (b) lower boreal highlands, and (c) upper boreal highlands natural subregions of the Notikewin River subbasin derived from reported fire cycle estimates (pre-fire suppression). Boxes show the median and 25th to 75th 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 Hermanutz 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 portion of the Notikewin River subbasin using Alberta Historical Wildfire Perimeter Data (1931-2014; Government of Alberta 2015) and prescribed fire shapefiles. This disturbance rate model was run based on a ten-year rolling window for each of the three natural subregions:

1. 10-year treatments (2000-2010) in dry mixedwood natural subregion
2. 10-year treatments (2000-2010) in lower boreal highlands natural subregion
3. 10-year treatments (2000-2010) in upper boreal highlands natural subregion

The results of the disturbance rate model were compared to targets based on fire cycle lengths and the corresponding disturbance rates that would produce that fire cycle as per Tymstra et al. (2005) (Table A-1).

A.2 Landscape level assessment results

A.2.1 Stand age distribution

Stand age distribution indicators and targets (Table A-1) were evaluated for the Notikewin River subbasin. As AVI coverage was not complete, the results only represent a portion of the entire subbasin. Overall, the pole age class dominates within each of the dry mixedwood, lower boreal highlands, and upper boreal highlands natural subregions (Table A-2). Furthermore, the percentage of mature forests is very low in the dry mixedwood natural subregion, but higher in the lower and upper boreal highlands. All three natural subregions are below the stand age targets for young forests, and within the dry mixedwood natural subregion (where the Hutton Creek 2 prescribed fire occurred), the stand age distribution for young forest was further from the targets following the fire. Cutblock boundaries were not included in the analysis as the data was unavailable: inclusion of cutblocks would likely increase the percentage of young stands, but possibly decrease the area of mature stands within the Notikewin River subbasin.

Table A-2. Post-treatment stand age distribution within ungulate winter range in each natural subregion occurring in the Notikewin River watershed subbasin.

Natural subregion	Total ungulate winter range in subbasin	Ungulate winter range in subbasin with stand age (AVI) data	Young (0 - 20 years)			Pole (21 - 100 years)			Mature (101 - 180 years)		
	Area (ha)	Area (ha)	Target	Area (ha)	%	Target[1]	Area (ha)	%	Target[1]	Area (ha)	%
Dry mixedwood	76,996	37,528	8% to 34%	1,651	4	34% to 47%	32,754	87	12% to 17%	1,908	5
Lower boreal highlands	80,439	59,988	8% to 39%	993	1	33% to 45%	36,443	45	10% to 16%	18,152	23
Upper boreal highlands	37,285	37,258	8% to 39%	129	0	33% to 45%	25,833	69	11% to 17%	9,307	25

[1] 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"

A.2.2 Disturbance rate

When disturbance rate VOITs (Table A-1) were evaluated for the Notikewin River subbasin, we found disturbance rates from wildfire or prescribed fire were well below targets (Table A-3). It should be noted that cutblocks were not included in the analysis as the data was not available. Although the inclusion of cutblocks would increase the disturbance rates significantly within the Notikewin River subbasin, further prescribed fire treatments will likely be required to reach disturbance rate targets.

Table A-3. Disturbance rate within ungulate winter range in each natural subregion occurring in the Notikewin River watershed subbasin.

Natural subregion	Ungulate winter range		
	Total area (ha)	Target (ha)	Disturbance rate (ha) from 2000 - 2010
Dry mixedwood	76,996	10,547	1,027
Lower boreal highlands	80,439	16,827	130
Upper boreal highlands	37,285	7,760	72

A.3 Landscape-level assessment summary

By itself, the 2009 Hutton Creek 2 prescribed fire was not sufficient to move the larger landscape towards stand age distribution and disturbance rate targets established in the Notikewin River Subbasin (07HC) Ungulate Winter Range Ecosystem Management Plan (Hermanutz 2009). The plan recognized that a timeframe of up to 50 years may be required to meet targets, and thus multiple treatments over many years would be required to fully implement the plan (e.g., Deadwood and Cadotte River prescribed fires). Future analysis should also incorporate forest harvesting as a complementary disturbance that creates young forest within the landscape.

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 Hutton Creek 2 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. Detailed fire polygons were created manually from the resulting burn severity values 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. Ecosystem-level values, objectives, indicators, and targets (VOITs) identified in the Notikewin River watershed subbasin (Hermanutz 2009).

Level	Value	Objective	Indicator	Target
Ecosystem	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 in dry mixedwood being intermediate to large in size (600-2000 ha) and 60% in upper and lower boreal highlands being large (> 2,000 ha)
	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 in Hermanutz (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 in Hermanutz (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 73% of total event area. Patch size can range from 2 ha to 2,000 ha to balance ecological with social and economic constraints.
	Unburned remnants within treatment	Percent is within historic pattern.	Percent 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.

*NRV=natural range of variation

B.2 Ecosystem-level assessment results

B.2.1 Event size and number

The Hutton Creek 2 prescribed fire was classified as one event having a total event area of 602 ha. NEPTUNE analysis shows that the Hutton Creek 2 fire event shape index was very similar to historical natural disturbance patterns for fires of similar size (Figure B-1). This met the lower end of the event size target range for intermediate size fires (i.e., 600 ha to 2,000 ha).

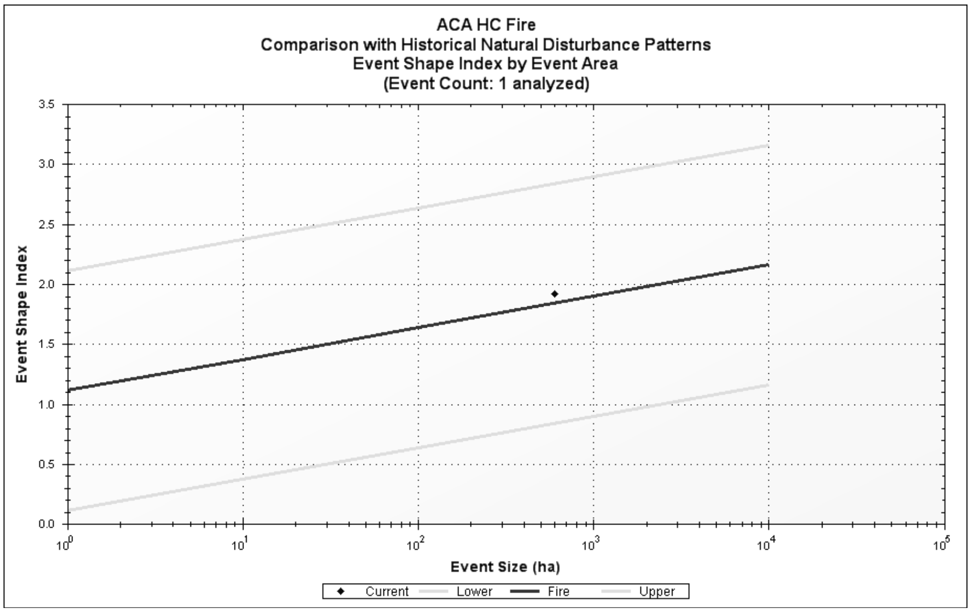


Figure B-1. Event shape index by event area for the Hutton Creek 2 prescribed fire area in comparison with historical natural disturbance patterns.

B.2.2 Number and sizes of individual treatment patches

NEPTUNE results indicated that when compared to historical natural disturbance patterns, the Hutton Creek 2 fire event had a very high number of disturbed patches relative to event area (Figure B-2) and exceeded the target; however, the shape index of most patches was within the typical upper and lower limits of historical natural disturbance patterns (Figure B-3). Furthermore, NEPTUNE indicated the largest patch size of the disturbed area accounted for approximately 70% of the total disturbed event area (Figure B-4). In other words, 70% of the burned area occurred in one large patch and essentially met the target of the largest patch in the event covering 73% of total event area.

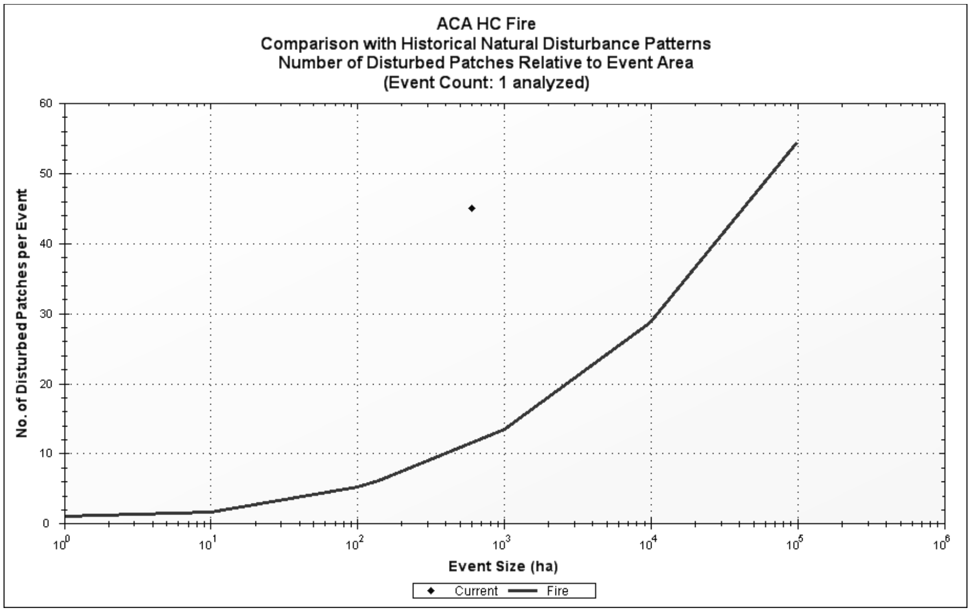


Figure B-2. Number of disturbed patches for the Hutton Creek 2 prescribed fire area (♦ Current) and historical (—Fire) natural disturbance patterns.

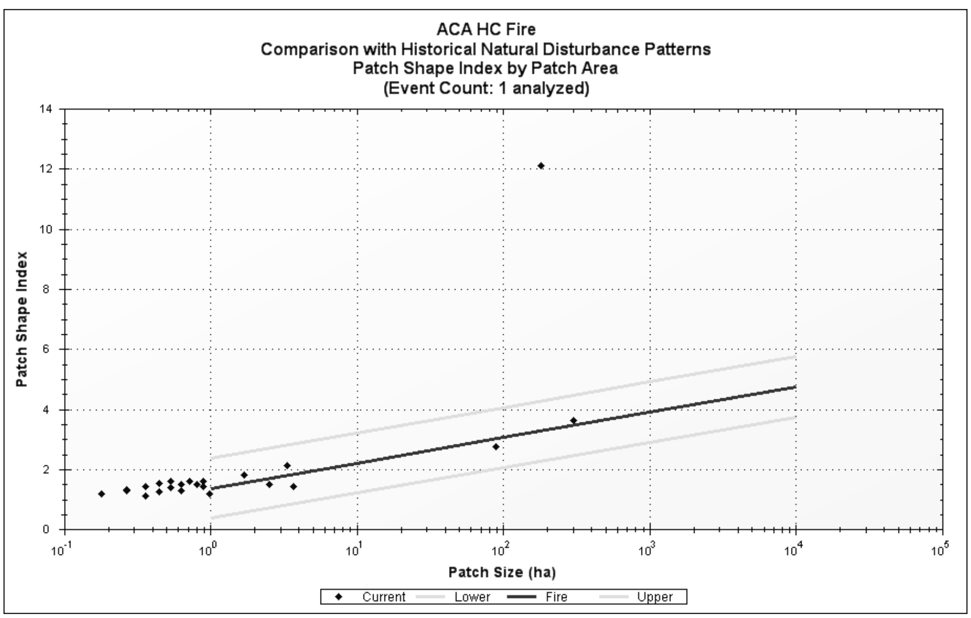


Figure B-3. Patch shape index for the Hutton Creek 2 prescribed fire area (♦ Current) and historical (— Fire) natural disturbance patterns.

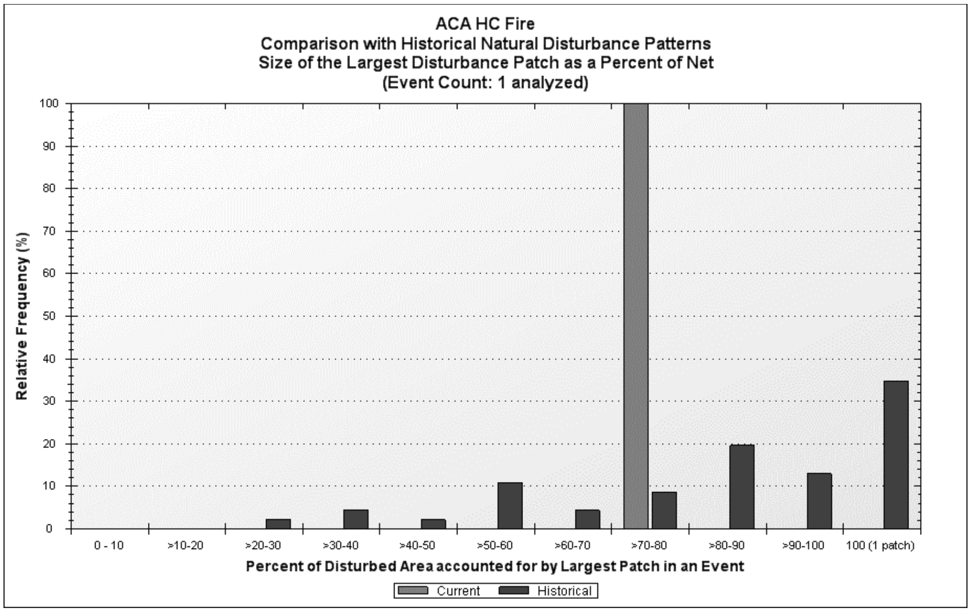


Figure B-4. Size of the largest disturbance patch as a percent of net size for the Hutton Creek 2 prescribed fire area in comparison with historical natural disturbance patterns.

B.2.3 Unburned remnants within treatment

Within the Hutton Creek 2 fire event area, 380 ha were classified as fully disturbed, 41 ha were classified as island remnants, and 181 ha were classified as matrix remnants. This equates to approximately 30% of the event area as matrix remnants (Figure B-5) and 7% as island remnants (Figure B-6), for a total of approximately 37% of the event area in unburned residual (Figure B-7). More specifically, it appears the frequency of island remnants by size was fairly consistent with historical natural disturbance patterns (Figure B-8). These findings met the target of 15% to 64% of the fire event remaining unburned with the majority of remnant area located in matrix remnants or corridors.

B.3 Ecosystem-level assessment summary

At the ecosystem level, the event size and number were demonstrated to be similar to historical natural disturbance patterns. There was a high number of disturbed patches for the burn area relative to historical wildfires, but the patches 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 ensures the creation of 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).

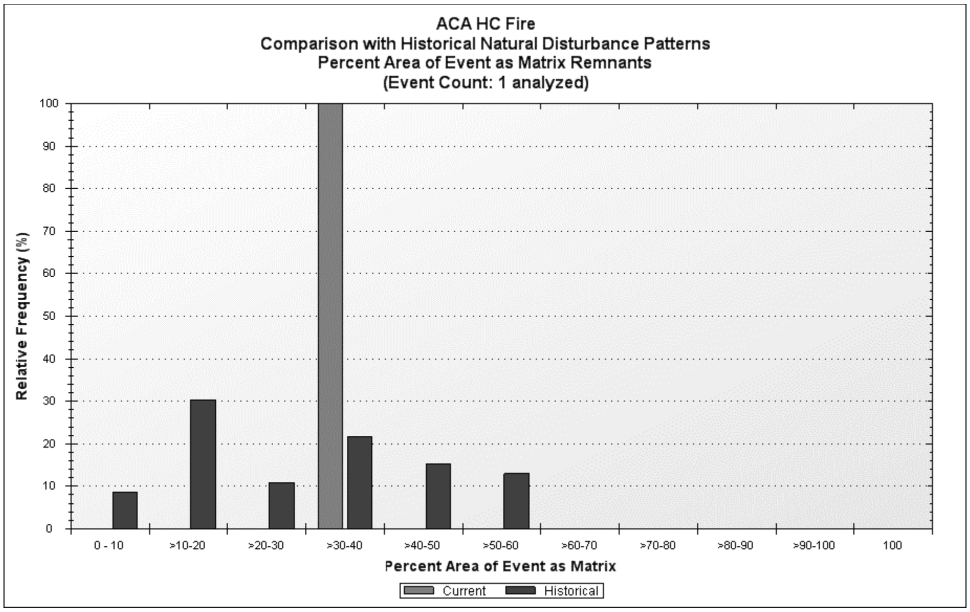


Figure B-5. Percent area of event as matrix remnants in the Hutton Creek 2 prescribed fire area in comparison with historical natural disturbance patterns.

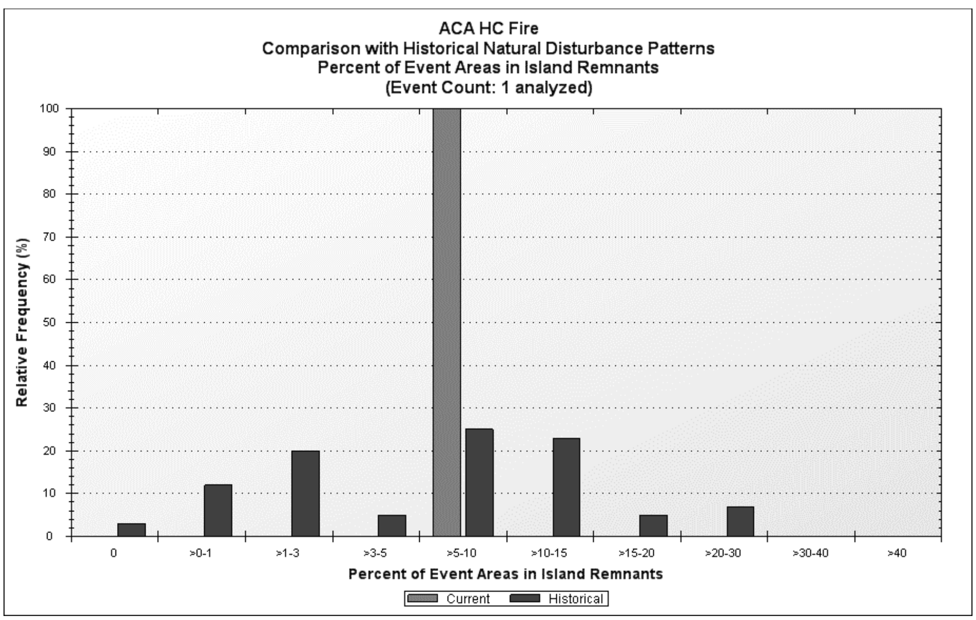


Figure B-6. Percent area of event as island remnants in the Hutton Creek 2 prescribed fire area in comparison with historical natural disturbance patterns.

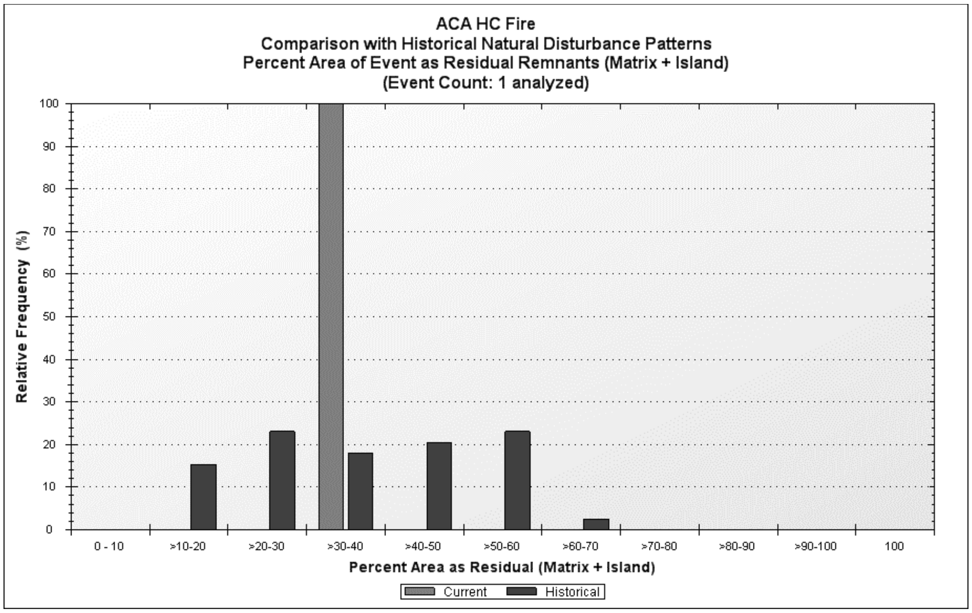


Figure B-7. Percent area of event as residual remnants in the Hutton Creek 2 prescribed fire area in comparison with historic natural disturbance patterns

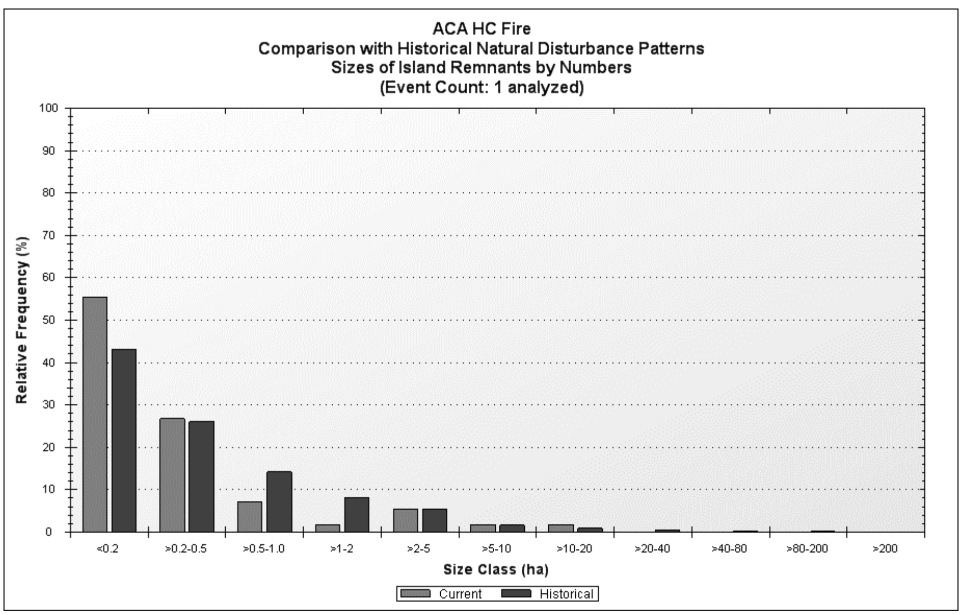


Figure B-8. Frequency of islands of various sizes in the Hutton Creek 2 prescribed fire area in comparison with historical natural disturbance patterns.

Alberta Conservation Association

wildlife | fish | habitat