FINAL REPORT

Restoration of seismic cutlines in southern mountain and boreal caribou range in west-central and north-western Alberta

Maximising success and targeting areas used by alternate prey

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Disclaimer

This is a draft final report. Results and opinions presented are therefore considered preliminary, are to be interpreted with caution, and are subject to revision. Any opinions expressed in this report are those of the authors and do not necessarily reflect those of the organizations for which they work, or fRI Research.

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Executive Summary

Seismic lines are one of the most pervasive anthropogenic disturbances in caribou ranges, with over 85,000km in west-central Alberta and Chinchaga caribou ranges. Building on previous work, we used field-based measurements of seismic line regeneration (tree and understory species abundance and occurrence), and animal use (tracks and signs, and camera traps), in combination with field and GIS-derived variables to identify seismic lines that 1) are following a trajectory towards natural recovery, and 2) have attributes associated with a high probability of use by alternate prey and predators. Our project was focused within the ranges of four west-central caribou herds: Little Smoky (LSM), A La Peche (ALP), Redrock Prairie Creek (RPC), and Narraway (NAR), and one north-west caribou herd: Chinchaga.

Using field data collected on occurrence and abundance of trees and understory species collected on seismic lines and in adjacent forest stands between 2013 and 2015, we found that trees were more likely to occur off seismic lines, and that generally, shrubs, forbs, graminoids were more likely to occur on seismic lines. We also found that large shrubs, and a number of forb and graminoid species were more abundant on seismic lines, although there were regional differences. Our models describing tree and understory species dissimilarity in relation to Geographic Information System (GIS) variables were poor, and we were therefore unable to create maps showing areas that are following a trajectory towards natural recovery (i.e. seismic lines that are highly similar to the adjacent forest stand) versus seismic lines that might need active restoration. Nevertheless, individual species models built using data collected on seismic lines demonstrated that large woody shrubs (alder, willow, gooseberry, and birch), sedges, fireweed, clover, and graminoids were more abundant in wetter areas and on North/South orientated seismic lines. Using the results of vegetation species-specific models, we mapped the probability of occurrence and abundance of species on seismic lines across the five herd ranges. We identified 7,884km (18%) of seismic lines with high birch abundance in Chinchaga, 391km (9%) of seismic lines with high gooseberry abundance in RPC/NAR, 210km (5%) of seismic lines with high graminoid species abundance in RPC/NAR, 1,966km (15%) of seismic lines with high sedge abundance in LSM/ALP, and 199km (1.6%) of seismic lines with high clover abundance in LSM/ALP. Based on occurrence models, we also identified 2,152km (55%) of seismic lines with a high probability of alder occurrence in RPC/NAR, 909km (7%) of seismic lines with a high probability of willow occurrence in LSM/ALP, and 452km (3.5%) of seismic lines with a high probability of fireweed occurrence in LSM/ALP.

Using a combination of tracks and signs data collected on seismic lines during summer (all five herds), and camera traps deployed on seismic lines year-round (west-central herds only), we assessed relationships between seismic line attributes (depth to water, LiDAR measurements of regeneration height, soil type, etc.) and wildlife use of seismic lines. For alternate prey (deer, moose, and elk) we found that use of seismic lines increased in areas with more early seral stage habitat types such as cutblocks, young forest stands, and wellsites. Detection of alternate prey on seismic lines was also partly explained by the abundance and occurrence of vegetation growing on seismic lines (higher detection with less alder and more graminoids). For predators, we found that bears were more likely to use seismic lines with more vegetation cover and more signs of moose, while lynx and wolves used seismic lines with less vegetation cover. Black bears also occurred more on seismic lines with less alder, while lynx and wolves were detected more on seismic lines with low vegetation heights. Using these results, we mapped the probability of

occurrence of alternate prey and predators across west-central Alberta range and identified 10,596km of seismic lines with high probability of use by deer, 584km of seismic lines with high probability of use by elk, and 7,035km of seismic lines with high probability of use by bear species.

Based on our findings, we then overlaid spatially explicit maps of vegetation occurrence and abundance, and wildlife use. The resulting maps identify seismic lines with the highest probability of 'undesirable' species abundance and occurrence, the highest probability of alternate prey use, and seismic lines where high 'undesirable' vegetation species abundance and occurrence, and high probability of alternate prey use overlap. Using this approach, we classified 146km (0.9%) of seismic lines as very high, and 2,570km (17%) as high priority for restoration based on the probability of overlap between alternate prey and undesirable species. In Chinchaga, we identified 13,219km (25%) of seismic lines as very high priority for restoration based on the occurrence and abundance of undesirable species. By identifying seismic lines in west-central caribou ranges and the Chinchaga caribou range that have a high occurrence and abundance of 'undesirable species' the resulting maps can be used to target and prioritize restoration efforts towards seismic lines where natural regeneration is not occurring, and where active tree planting may be required to effectively restore seismic lines to reflect the composition of the adjacent forest. In addition, by linking seismic line attributes (vegetation height and species composition, soil type, and wetness) to the use of seismic lines by alternate prey and predators, the results of this project can also be used to prioritize restoration efforts towards reducing the distribution of alternate prey within caribou ranges, and thus reducing the attractiveness of seismic lines to predators of alternate prey (i.e. wolves and bears) and reduce caribou predation risk. Ultimately the priority lines for restoration identified from this project can be combined with priority lines for restoration identified from our previous work to focus restoration efforts and minimise the overlap between caribou and predators, decrease the use of seismic lines by alternate prey, and focus tree planting to seismic lines that are not naturally regenerating.

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1. General Introduction

1.1. Background

Boreal and southern mountain woodland caribou (*Rangifer tarandus tarandus*), hereafter caribou) are federally listed as threatened (Environment Canada 2012, 2014), and the Committee on the Status of Endangered Wildlife in Canada lists the central mountain designatable unit (DU), part of the southern mountain ecotype) as endangered (COSEWIC 2011; COSEWIC 2014). Anthropogenic disturbance is the ultimate cause of caribou declines (Festa-Bianchet *et al.* 2011; Hervieux *et al.* 2013). Habitat conversion to early seral stages has increased the densities of moose (*Alces alces*), deer (*Odocoileus* spp.), and elk (*Cervus elaphus*) within caribou ranges (Gasway *et al.* 1989; Serrouya *et al.* 2011), resulting in an increase in predators, and a corresponding decrease in caribou populations via apparent competition (Wittmer *et al.* 2005; DeCesare *et al.* 2010; Hervieux *et al.* 2013). Restoration of previously disturbed areas within caribou ranges is believed to be a crucial step towards achieving self-sustaining caribou herds in Alberta (Alberta Woodland Caribou Recovery Team 2005; Environment Canada 2012; Schneider *et al.* 2012).

To reach a 60% chance of self-sustaining caribou herds in Alberta, anthropogenic disturbance within caribou ranges must fall below 35% disturbed area for each herd range (Environment 2008). Current landscape disturbance within Alberta caribou ranges exceeds this threshold, and to meet federal targets, there is pressure to implement habitat restoration within Alberta caribou ranges. Although the cumulative effects of industrial development within caribou ranges are of concern (i.e. Sorensen *et al.* 2008), linear access corridors have been the main focus of scientific inquiry because these features facilitate predator travel and increase predation rates within caribou ranges (Alberta Woodland Caribou Recovery Team 2005; Whittington *et al.* 2011; DeCesare 2012; Dickie *et al.* 2016).

In Alberta, the predominant linear disturbance in caribou range are 'legacy' seismic lines built prior to 1984 (hereafter seismic lines). Seismic lines are slow to recover naturally, in part because of the removal of the organic soil layers during construction (MacFarlane 2003; Lee & Boutin 2006; van Rensen *et al.* 2015). Restoration of seismic lines is considered a priority for caribou conservation in Alberta, but the extensive distribution of their footprint on the landscape means that targeted restoration is essential. Previously, accurate quantification of seismic line regeneration across large geographic areas was difficult due to the large extent of the seismic line footprint in western Canada, and the low resolution of remote sensing data (~30m). However, high resolution light detection and ranging (LiDAR) data now available have sufficiently high resolution (1m) to measure vegetation regeneration within linear access corridors (Bayne *et al.* 2011; van Rensen *et al.* 2015). LiDAR data therefore provide an opportunity to quantify regeneration of seismic

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lines across broad geographic scales, and this information can be used to inform seismic line restoration priorities across Alberta.

In Phases 1 to 3 of this study (HSP 6617, 6699, and 7195), and in a complimentary study focused in north-west Alberta, we used LiDAR to assess the effects of seismic lines at different stages of regeneration on habitat selection of caribou, and caribou predators, and on the use of seismic lines by humans within five caribou ranges: A La Peche, Redrock Prairie Creek, Narraway (all southern mountain ecotype, central mountain DU), and Chinchaga and Little Smoky (boreal ecotype, boreal DU). We previously identified priority seismic lines for restoration based on the relative probability of use of areas near regenerating seismic lines by caribou, wolves, and grizzly bears (GPS location data; Finnegan *et al.* 2014, 2016; MacNearney *et al.* 2015; Pigeon *et al.* 2016), and also used a combination of field and GIS-derived data to identify seismic lines with a high probability of human use (Hornseth *et al.* in prep; Pigeon *et al.* 2016). Based on these analyses, we previously identified 3,100km (20%) of seismic lines as high priority for restoration based on overlap among caribou, wolves, and grizzly bears in the A La Peche, Redrock Prairie Creek, Narraway, and Little Smoky ranges, and 1,539 (2.9%) of seismic lines as high priority for restoration based on overlap between caribou and wolves in the Chinchaga caribou range. We also previously identified 4,147km (35%), 1,886km (49%), and 15,743km (25%) of seismic lines within the Little Smoky/A La Peche, Redrock Prairie Creek/Narraway, and Chinchaga caribou ranges respectively where human impact mitigation may be required in addition to restoration tactics to facilitate regeneration of seismic lines (Hornseth *et al.* in prep).

In the current project, we build on our previous work by using field-based measurements of seismic line regeneration (tree and understory species abundance and occurrence data), and animal use (tracks and signs, and camera trap data), in combination with field and GIS-derived variables to assess vegetation growth on seismic lines and the response of alternate prey and predators to regenerating seismic lines. We use the results of these analyses to identify seismic lines that 1) are following a trajectory towards natural recovery, and 2) have attributes associated with a high probability of use by alternate prey and predators.

1.2. Study Area

The study area was located in west-central and north-west Alberta and encompassed the range of five caribou herds: Little Smoky, A La Peche, Narraway, Redrock Prairie Creek, and Chinchaga (Figure 1.1 and 1.2). We confined our study area to public lands within provincial caribou range boundaries. This area was approximately 33,000km^2 and included three natural regions (boreal, foothills, and rocky mountains), and nine natural sub-regions (dry mixedwood, central mixedwood, lower boreal highlands, upper boreal highlands, lower foothills, upper foothills, subalpine, alpine, and montane; Natural Regions Committee 2006). We did not include mountainous portions of central mountain caribou ranges in our study area

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because those areas are largely protected and therefore have a low human footprint (Figure 1.1). There are over 85,000km of seismic lines within the study area (Figure 1.1 and 1.2).

Forests in west-central Alberta are mainly coniferous and are characterized by lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) with patches of trembling aspen (*Populus tremuloides*) in upland areas, while lowland areas are composed mainly of black spruce (*Picea mariana*), larch (*Larix laricina*), and poorly drained muskeg (Smith *et al.* 2000; Saher & Schmiegelow 2005; Natural Regions Committee 2006). In addition to caribou, ungulates within the study area include whitetail and mule deer (*Odocoileus virginianus* and *O. humionus*), moose (*Alces alces*), and elk (*Cervus elaphus*) at lower elevations. Primary predators of caribou in this area are grizzly bears (*Ursus arctos*), cougars (*Felis concolor*), and wolves (*Canis lupus*), and additional predators include black bears (*Ursus americanus*), lynx (*Lynx canadensis*), wolverines (*Gulo gulo*), and coyotes (*Canis latrans*; Stevenson *et al.* 2001; Wittmer *et al.* 2005; Stotyn *et al.* 2007). The landscape in north-western Alberta differs from west-central because elevation is lower (600-800m above sea level), topography is relatively flat, and forests are more characteristic of the boreal forest and include black spruce, larch, and poorly drained muskeg and fen in lowland areas, and white spruce, trembling aspen, and balsam poplar (*Populus balsamifera*) in upland areas (Natural Regions Committee 2006; Bayne *et al.* 2011; Tigner *et al.* 2014). Moose are the most abundant ungulate in this area, although whitetail and mule deer, elk, and wood bison (*Bison bison athabascae*) are also present (Rowe 2007). The predator guild for this region includes wolves, black bears, grizzly bears, coyotes, wolverine, and lynx.

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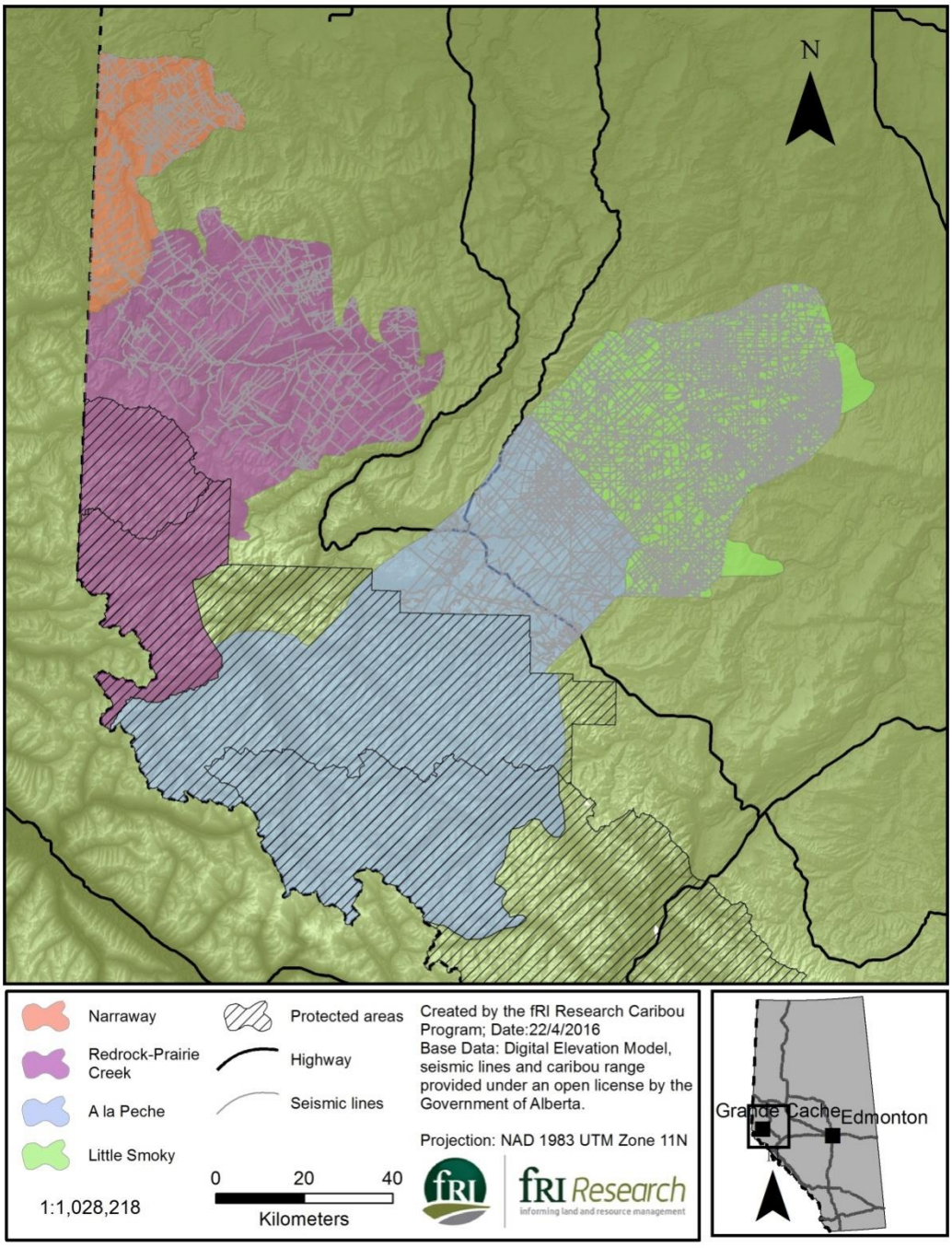

Figure 1.1. Seismic line footprint within west-central Alberta caribou ranges (Narraway, Redrock Prairie Creek, A La Peche, and Little Smoky).

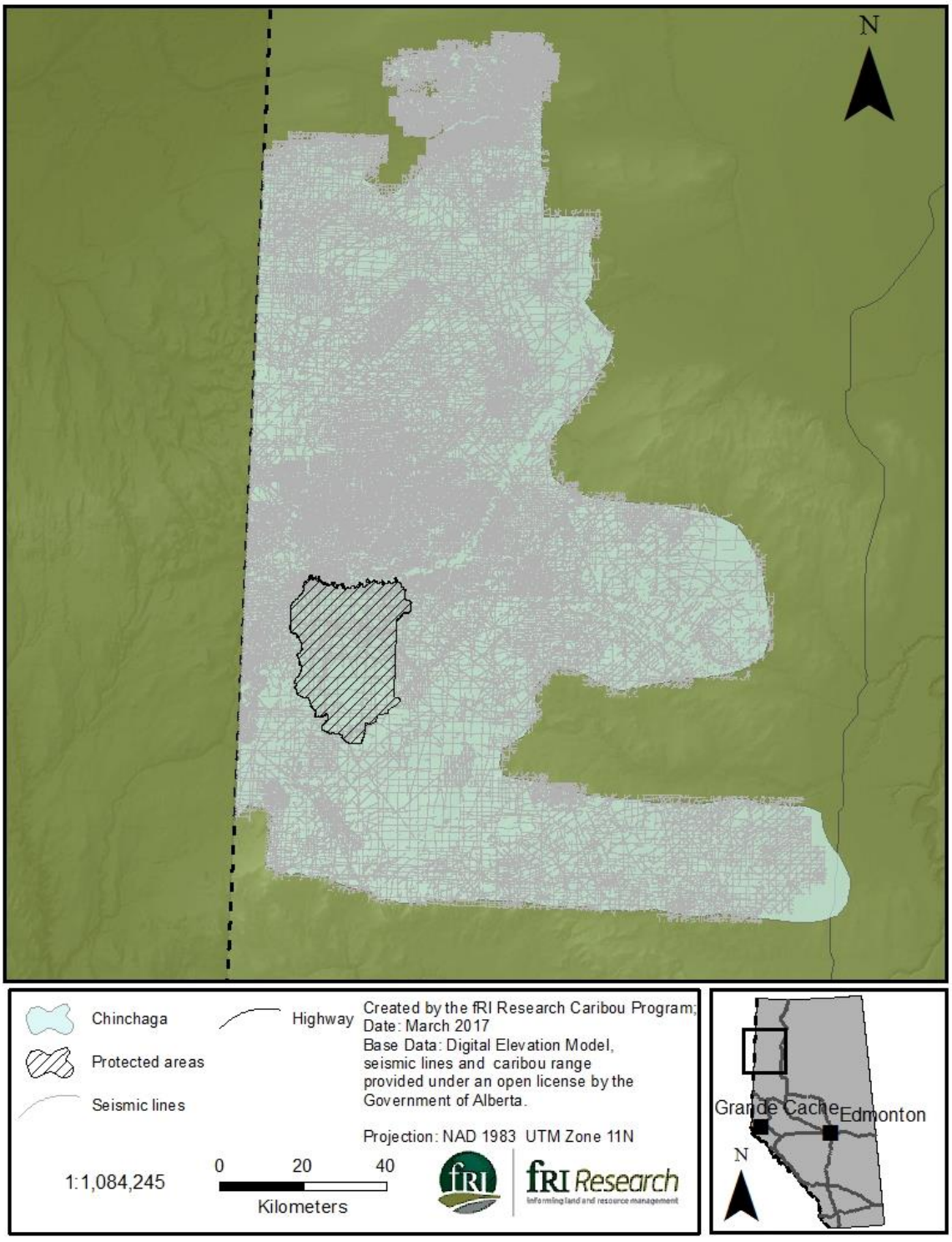

Figure 1.2. Seismic line footprint within the Chinchaga caribou range in north-west Alberta.

1.3. OBJECTIVES

We used additional analyses and new field data to expand upon Phases 1 to 3 of this project and on previous work in north-west Alberta (Finnegan *et al.* 2014, 2016; MacNearney *et al.* 2015; Pigeon *et al.* 2016). Specifically, we used field data on tree occurrence, and understory species abundance and occurrence (vascular plants, lichens, and mosses), collected between 2013 and 2015, and GIS-derived variables (LiDAR, terrain, and habitat), to 1) assess tree and understory species dissimilarities between seismic lines and adjacent forest stands, 2) model understory species occurrence and abundance as a function of GIS-derived variables, and 3) build predictive maps of tree and understory species growth on seismic lines. Although previous research has assessed differences in vegetation growth between seismic lines and adjacent forest stands (Revel *et al.* 1984; MacFarlane 2003; Seccombe-Hett & Walker-Larsen 2004; Kemper & Macdonald 2009), to our knowledge none have assessed these differences as a function of GIS-derived variables. Models built using GIS data will facilitate prediction of the relative probability of understory species growth across the entirety of west-central and north-west Alberta caribou ranges. These predictive maps can then be used to identify seismic lines that are on a growth trajectory reflecting the adjacent forest stand, versus those that may need active restoration.

We also use tracks and signs and camera trap data to 1) assess the probability of use of seismic for alternate prey and predators in west-central Alberta and the Chinchaga caribou range, and 2) assess occupancy and detection of alternate prey and predator in west-central Alberta. In Phases 1 to 3 of this project, and in previous work in the Chinchaga caribou range (Finnegan *et al.* 2014, 2016; MacNearney *et al.* 2015; Pigeon *et al.* 2016), we used location data from GPS-collars to model caribou, grizzly bear, and wolf seasonal response to characteristics of seismic lines (regeneration height and seismic line wetness), and a range of landscape attributes (e.g. elevation, habitat type, and slope). Although GPS-collar data revealed patterns of caribou, grizzly bear, and wolf habitat use close to seismic lines, data available were of insufficient resolution (1 to 4 hour fix interval) to assess use of 8m wide seismic lines (*sensu* Dickie *et al.* 2016). In addition, we were unable to assess use of seismic lines by other wildlife species of interest (e.g. alternate prey – deer, moose, and elk; other predators – black bears, lynx, and cougar). In particular, modelling the use of seismic line by alternate prey could be informative for seismic line restoration because as ungulate specialists and omnivores respectively, the response of wolves and bears to seismic lines may be partially mediated by the use of seismic lines of their ungulate prey. Tracks and signs, and camera trap data provide an opportunity to assess the use and occurrence of alternate prey and predators on seismic lines, and will contribute towards a more thorough understanding of the fine scale responses of caribou, grizzly bears, wolves, and other wildlife species to regenerating seismic lines within west-central and north-western caribou ranges.

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The objectives of this project are to:

- Model dissimilarity, occurrence, and abundance of tree and understory species on seismic lines and the adjacent stand as a function of regeneration height, seismic line wetness, and other anthropogenic and natural variables (Chapter 2).
- Model the use of seismic lines by deer, moose, elk, canines, and bears using tracks and signs (Chapter 3).
- Model the occupancy and detection of deer, moose, elk, canines, lynx, and bears on seismic lines using camera traps (Chapter 3).
- Map the probability of occurrence and abundance of understory species on seismic lines in relation GIS-derived variables (Chapter 4).
- Map the use of seismic lines by deer, elk, and bears on seismic lines (Chapter 5)
- Identify seismic lines that could be prioritized for restoration based on the probability of understory species growth, and their use by alternate prey (Chapter 6).

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2. ASSESSING NATURAL REGENERATION OF TREES AND UNDERSTORY SPECIES WITHIN SEISMIC LINES

Laura Finnegan

2.1. INTRODUCTION AND OBJECTIVES

Soil compaction during seismic line construction and the associated altered microsite topography delays regeneration and alters natural succession (Revel *et al.* 1984; Small & McCarthy 2002; MacFarlane 2003; Lee & Boutin 2006; Caners & Lieffers 2014; van Rensen *et al.* 2015). Research in the tundra of the Northwest Territories, and in northern and western Alberta found that even 30 to 50 years after clearing, the tree and understory communities on seismic lines have failed to regenerate to match those of the adjacent undisturbed habitat (Revel *et al.* 1984; MacFarlane 2003; Seccombe-Hett & Walker-Larsen 2004; Kemper & Macdonald 2009; Joroenson *et al.* 2010; Lankau 2014). In north-east Alberta, aerial photography and LiDAR-based research has reported that seismic line regeneration heights and percent cover are slow to meet targets outlined in provincial restoration standards (3m; Alberta Environment and Sustainable Development 2012) and federal recovery strategies (visible on Landsat imagery; Environment Canada 2011), particularly in wetter areas (Lee & Boutin 2006; van Rensen *et al.* 2015).

Because of slow recovery rates and because of their extensive footprint, seismic lines may reduce effective habitat for wildlife species such as caribou (Dyer *et al.* 2001; Polfus *et al.* 2011), marten (Tigner *et al.* 2015), and ovenbirds (Lankau *et al.* 2013). For other wildlife species such as black bears and wolves, seismic lines may serve as travel corridors (Latham *et al.* 2011a; Tigner *et al.* 2014; Dickie *et al.* 2016). For species that prefer early seral stage vegetation like moose and deer, and omnivores like black and grizzly bears, the long-lasting distributional shifts in understory species composition on seismic lines may continue to attract wildlife because seismic lines provide sources of vegetative food or prey even at later stages of regeneration (Roever *et al.* 2008; Lankau 2014).

Although research to date has assessed differences in understory species and tree regeneration on seismic lines (e.g. MacFarlane 2003; Seccombe-Hett & Walker-Larsen 2004; Joroenson *et al.* 2010; Lankau 2014), only van Rensen *et al.* (2015) has linked seismic line regeneration patterns to GIS variables. Determining how GIS-derived attributes of seismic lines are linked to tree and understory species distributions will facilitate mapping of seismic line regeneration patterns across broad geographic space, and may be used to inform restoration efforts required under caribou federal recovery strategies (Environment Canada 2012, 2014). In addition, a broader understanding of patterns in wildlife species distribution and habitat use in relation to seismic line regeneration will provide insight into how anthropogenic impacts on a number of

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wildlife species can be mitigated more effectively. In this chapter, our goal was to assess whether seismic lines are on a trajectory towards natural recovery using tree and understory species occurrence and abundance data collected from seismic lines and adjacent forest stands in west-central and north-west Alberta, across the Little Smoky, A La Peche, Redrock Prairie Creek, Narraway, and Chinchaga caribou ranges. We also aimed to determine what attributes of seismic lines are affecting tree and understory species growth. For understory species, we focused sampling on food resources preferred by moose, deer, elk, caribou, and bears (Thomas *et al.* 1996; Nielsen *et al.* 2004; Tremblay *et al.* 2005; Munro *et al.* 2006; Visscher & Merrill 2009; Denryter *et al.* 2017; see Appendix 1: Table A1.1). Specifically, our objectives were to:

1. Compare tree and understory species occurrence and abundance between seismic lines and the adjacent forest stand, and model dissimilarities using GIS-derived variables.

2. Assess natural regeneration of tree and understory species within seismic lines, and determine whether understory species are related to specific attributes of seismic lines (e.g. regeneration height, soil wetness, and orientation).

Results from this analysis can be used to identify and create maps of seismic lines that are on a trajectory towards recovery versus those that may need active restoration and planting (see Chapter 4), results may also be used to identify seismic lines that have a higher probability of containing vegetative food resources that makes them attractive to alternate prey and their predators (Chapter 3 & 4).

2.2. METHODS

2.2.1. Field data collection

Using a GIS, we selected seismic lines that intersected with active roads within the study area. We used a random number generator to identify a subset of these seismic lines for field data collection. Field crews carried out vegetation surveys between June and September 2014 (LSM/ALP and RPC/NAR), and 2015 (LSM/ALP, RPC/NAR, and Chinchaga; Figure 2.1 and 2.2). At each seismic line, field crews recorded data within plots located 0m, 100m, and 500m from the intersection between the seismic line and the road. At each plot, field crews recorded dominant and subdominant tree species, mean tree height, and mean vegetation height (see Appendix 1 for details) within three separate subplots. Two of the subplots were located on the seismic line (online) and one was located within the adjacent forest stand (offline; Appendix 1: Figure A1.1). Forest stand subplots were located 20m from the seismic line edge to avoid the potential effects of forest edge on vegetation growth (MacFarlane 2003; Harper *et al.* 2005). At the 100m plot, field crews recorded additional detailed vegetation data (presence/absence and percent ground cover of key vegetation species within a $1m^2$ or $10m^2$ species-specific area; see Appendix 1 for details). To identify linear

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features where motorized human use may be affecting natural regeneration and species composition, field crews also recorded and classified levels of human use at all online plots (see Pigeon *et al.* 2016 for a detailed description), and tracks and signs (scat, visual sightings) of ungulates (moose, deer, and elk), bears, and canines (see Chapter 3). Detailed field methodology and field data are described in Appendix 1.

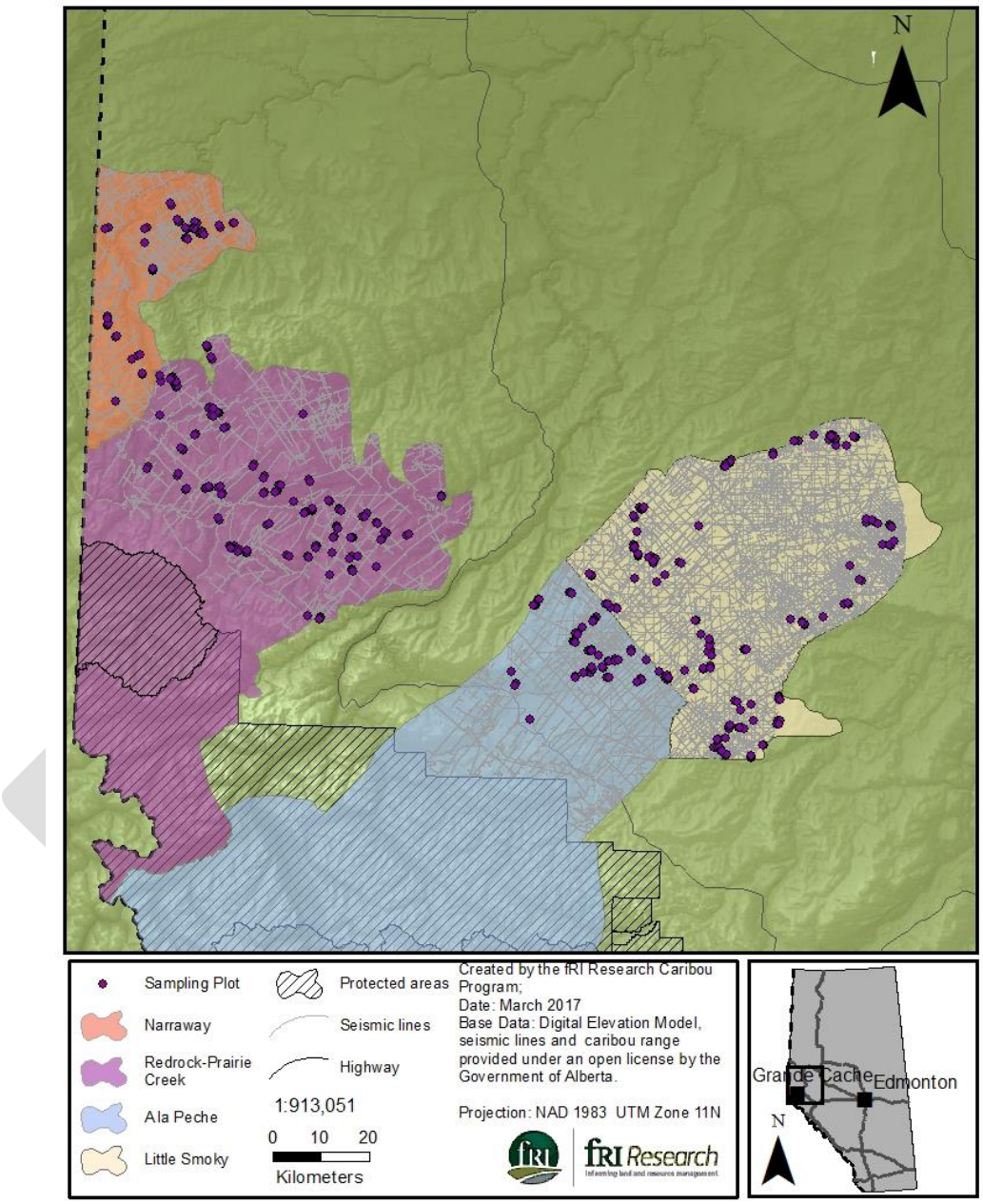

Figure 2.1. Little Smoky, A La Peche, Redrock Prairie Creek and Narraway caribou ranges in west-central Alberta showing the location of seismic line plots sampled between June and September 2013, 2014, and 2015.

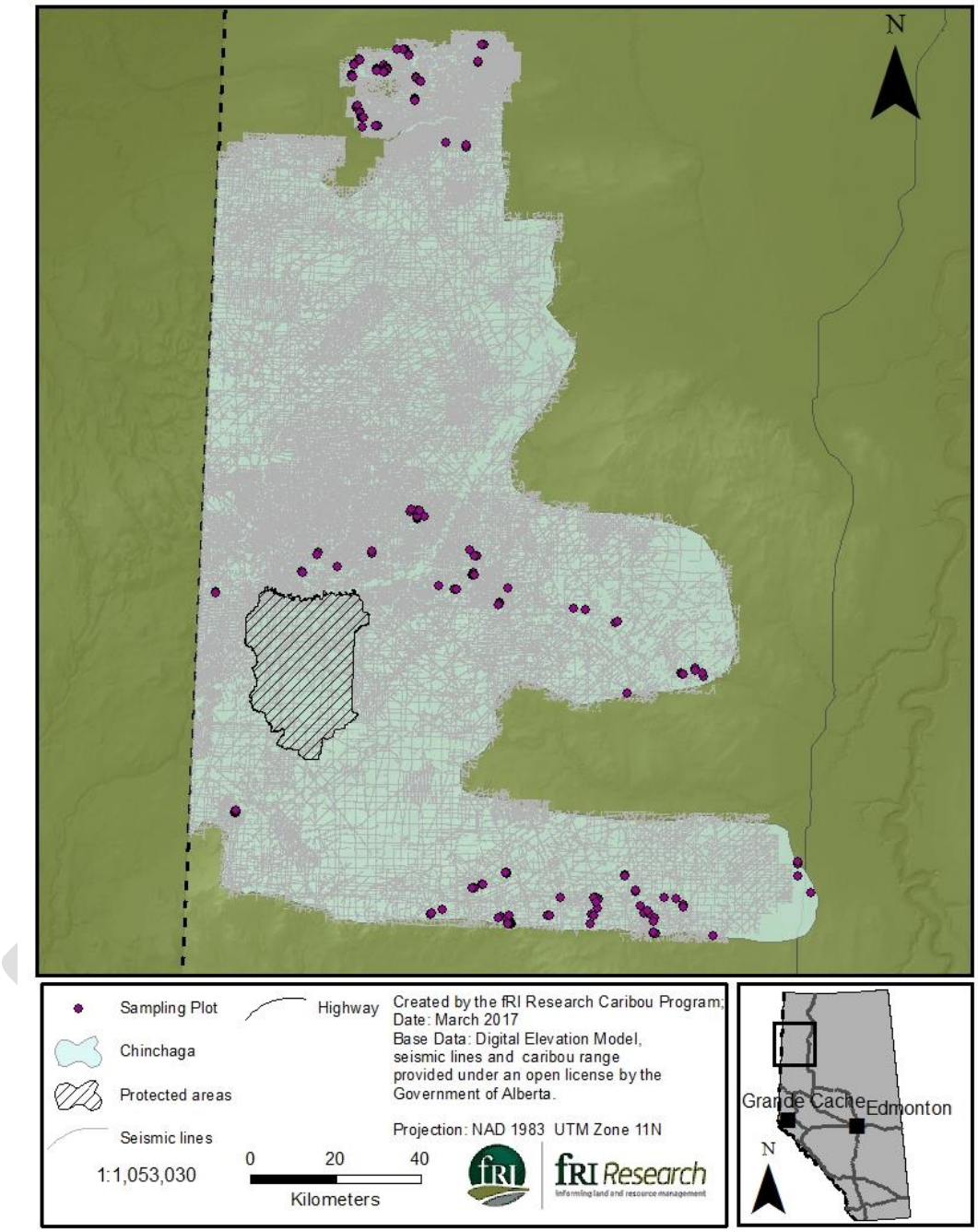

Figure 2.2. Chinchaga caribou range in north-west Alberta showing the location of seismic line plots sampled between June and September 2015.

2.2.1. Data analysis

Because our goal was to assess natural regeneration on seismic lines, and motorized human use and associated soil erosion and vegetation compaction could confound our results (Lee & Boutin 2006; van Rensen *et al.* 2015; Pigeon *et al.* 2016), we only used data from plots where zero human use signs were detected during field surveys. After removing plots with signs of human use, 673 plots remained for analysis of tree occurrence (LSM/ALP: 264; RPC/NAR: 214; Chinchaga: 195) and 212 plots remained for analysis of understory species (LSM/ALP: 94; RPC/NAR: 71; Chinchaga: 47).

2.2.1.1. Differences in tree composition and understory species between seismic lines and the adjacent forest stand

We used a two stage approach to assess differences in understory and tree composition between online and offline subplots. A detailed description of modelling methodology is in Appendix 3. First, for tree occurrence we used generalized linear models to determine if occurrence of tree species differed between paired online and offline plots; building individual models for each species. Then, for understory species occurrence and abundance, we built individual models for each species, and simultaneously modelled differences in occurrence and abundance between paired online (maximum or mean values respectively from the two online subplots combined; Appendix 1), and offline subplots using beta regression.

Second, for species identified as different in occurrence (tree and understory species) and/or abundance (understory species only), between paired online and offline subplots, we grouped species into one of seven groups (trees, large woody shrubs, small woody shrubs, grasses and forbs, terrestrial lichens, mosses, and mushrooms; Appendix 1: Table A1.1). We then calculated seven separate measures of dissimilarity based on these groups of species between online and offline subplots. For tree and understory occurrence, we quantified online/offline differences using the Jaccard index of dissimilarity (Jaccard 1912). For understory abundance, we calculated average percent cover across the two online subplots, and then quantified online/offline differences using the Bray-Curtis index of dissimilarity (Bray & Curtis 1957). Both measures of dissimilarity are scaled between 0 to 1, with 0 being completely similar species occurrence/abundance online and offline, and 1 being completely dissimilar species occurrence/abundance online and offline.

We then used these seven indices of dissimilarity and binomial generalized linear models (GLM; understory species) or binomial generalized linear mixed models (GLMM; tree species) to identify what field-derived and environmental variables (e.g. attributes of seismic lines and adjacent stands, topography, precipitation, etc.; see Section 2.2.2, Appendix 1 and 2) best explained dissimilarity between online and offline subplots. We used a hypothesis testing approach and Akaike's Information Criterion (AIC) to identify the most

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parsimonious combination of environmental data to include as explanatory variables (e.g. soil moisture, terrain, seismic line orientation, etc.; see Table A3.1).

2.2.1.2. Natural regeneration on seismic lines

We described natural regeneration on seismic lines as a function of environmental data using three separate metrics: 1) tree occurrence, 2) understory species occurrence, and 3) understory species abundance (maximum and averaged values from both online subplots respectively; see Appendix 1: Table A1.2). Detailed variable descriptions and modelling approaches are in Appendix 4. As before, for each analysis we used a hypothesis testing approach and Akaike's Information Criterion (AIC) to identify the most parsimonious combination of environmental data to include within each model as explanatory variables.

2.2.2. Environmental data

For explanatory variables, we considered field data and GIS-derived environmental and climate data that we hypothesized would explain vegetation growth, or that were previously found to be important predictors of vegetation cover and growth. Broadly these data were classified into four groups: regeneration (field measurements of tree height, vegetation height, and regeneration height (maximum of tree height and vegetation height)), habitat (stand age, stand height, canopy cover, and ecosite), terrain (elevation, terrain ruggedness (TPI), and slope), and plant growth (orientation of the linear feature, climate data, depth to water, soil wetness, and ecosite). Field-derived environmental data are described in Appendix 1 and GIS-derived environmental and climate data are described in Appendix 2.

2.3. Results

2.3.1. Differences in tree composition and understory vegetation between seismic lines and the adjacent forest stand

A detailed description of results, associated model parameters, and figures are in Appendix 3.

2.3.1.1. Species differences between seismic lines and the adjacent forest stand

Generally the occurrence of tree species was lower on online subplots compared to offline subplots, although there were some regional differences (Figure 2.3). Statistically there was no difference in the occurrence of balsam fir, birch, and poplar between online and offline subplots in LSM/ALP, balsam fir, tamarack, white spruce, and subalpine fir in RPC/NAR, or birch and tamarack in Chinchaga. However, pine was more likely to occur offline in all study areas, white spruce was more likely to occur offline in LSM/ALP and Chinchaga, and black spruce and aspen were more likely to occur offline in LSM/ALP and RPC/NAR (Table A3.2).

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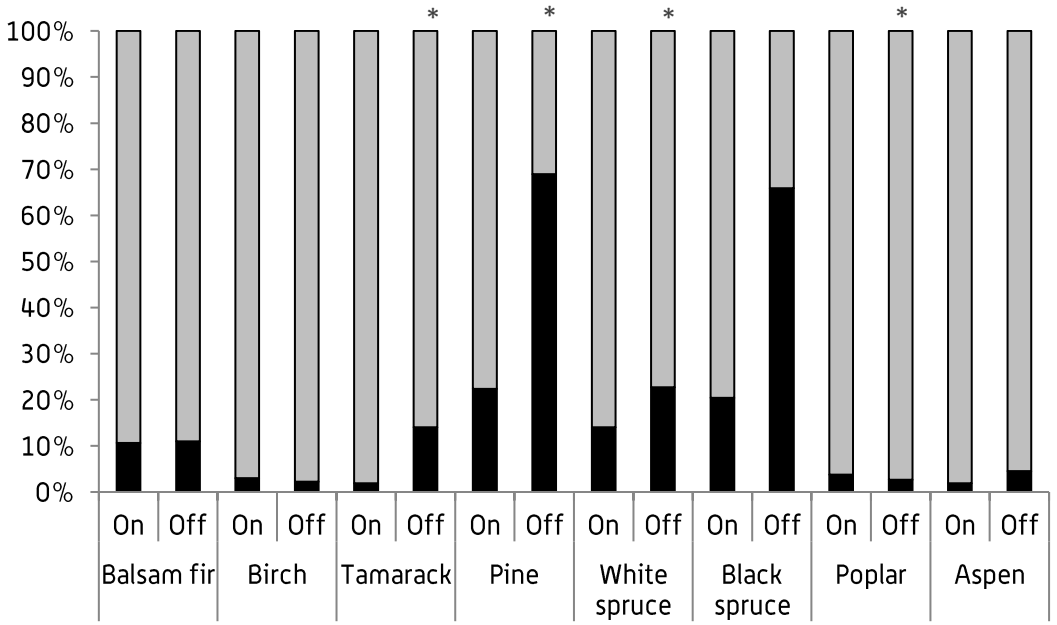
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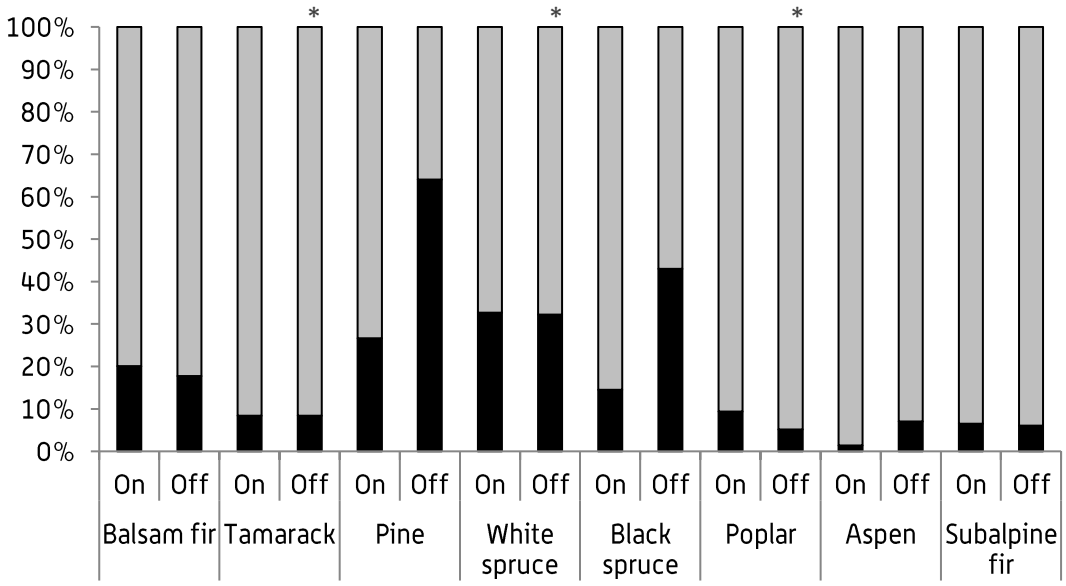
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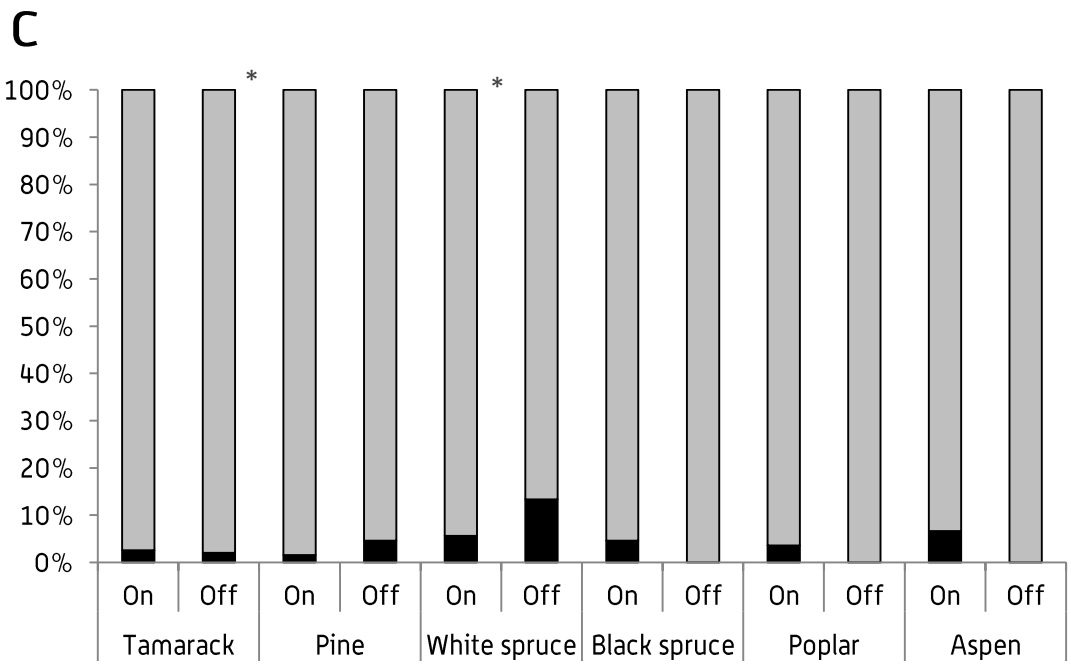

*Figure 2.3 Presence (black) and absence (grey) of tree species on seismic lines and adjacent forest stand subplots sampled in the Little Smoky and A La Peche (A), Redrock Prairie Creek and Narraway (B), and Chinchaga (C) caribou ranges in 2014 and 2015. Statistical differences between seismic lines and adjacent forest stand subplots are indicated with *.*

In all cases, large woody shrubs were either more likely to occur online, or there were no differences in occurrence between online and offline subplots (Table A3.3). However, the abundance of large woody shrubs was consistently higher on offline subplots, aside from four exceptions (Table A3.3; Figure 2.4). The first exception was *Alnus* spp., where abundance was significantly higher online in LSM/ALP and RPC/NAR, while higher offline in Chinchaga. Second, *Betula* spp. (BEGL) abundance was significantly higher on online subplots in Chinchaga, while significantly higher on offline subplots in LSM/ALP. Third, *Ribes* gooseberry spp. were more abundant online in RPC/NAR, and finally, *Salix* spp. was more abundant online in LSM/ALP. Although *S. Canadensis* (SHCA) was generally more abundant online in LSM/ALP and RPC/NAR, and *V. edule* (VIED) was more abundant online in LSM/ALP and Chinchaga, when we statistically compared paired online and offline subplots, these patterns were not significant (Table A3.3).

Similar to large woody shrubs, small woody shrubs were also more likely to occur online than offline, with the exception of *V. vitis-idaea* (VAVI) which was more likely to occur offline in LSM/ALP and RPC/NAR (Table A3.3). *E. nigrum* (EMNI) was less abundant online in LSM/ALP and Chinchaga, but there was no difference between online and offline subplots in RPC/NAR. Although *A.uva-ursi* (ARUV) was generally more abundant

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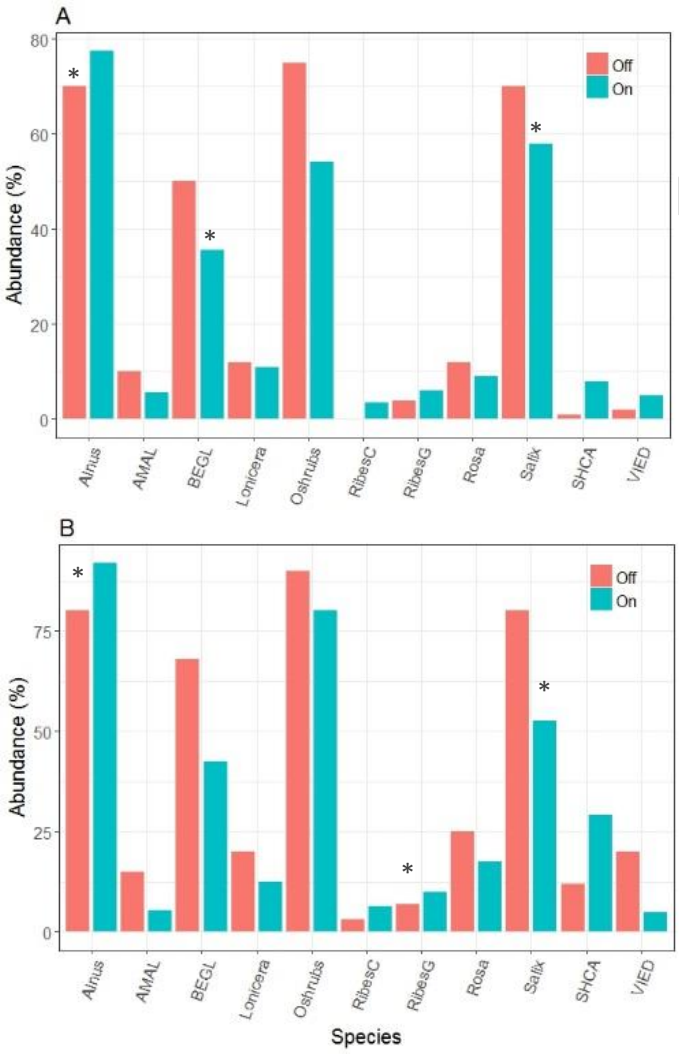
online in LSM/ALP and RPC/NAR (Figure 2.5A and 2.5B), statistically the species was more abundant offline (Table A3.3). *Rhododendron* spp. was generally more abundant offline in LSM/ALP and RPC/NAR, and online in Chinchaga, but comparing paired online and offline subplots revealed no differences in abundance in any study area (Table A3.3). *C. Canadensis* (COCA) was more abundant offline in RPC/NAR but there was no difference in the other study areas (Table A3.3; Figure 2.5).

With the exception of *Chamerion* spp., in RPC/NAR, all forbs and graminoids were more likely to occur on online subplots (Table A3.3), and generally forb and graminoid abundance was higher on online subplots in all areas (Figure 2.6). Specifically, *Carex* spp., *Chamerion* spp., and *Trifolium* spp. were more abundant online in LSM/ALP, and other graminoids were higher in abundance on online subplots in all areas. However, *Equisiteum* spp. was more abundant offline in LSM/ALP and Chinchaga, but there was no difference in RPC/NAR. Statistically there was no difference in other forb abundance between online and offline subplots in any study area (Table A3.3; Figure 2.6).



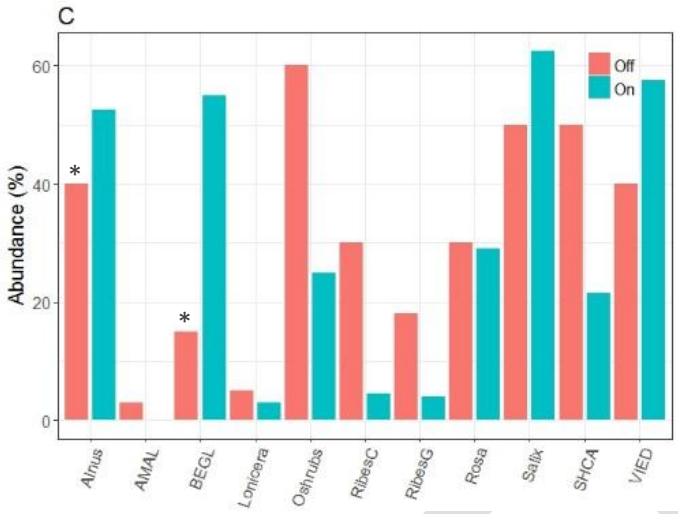
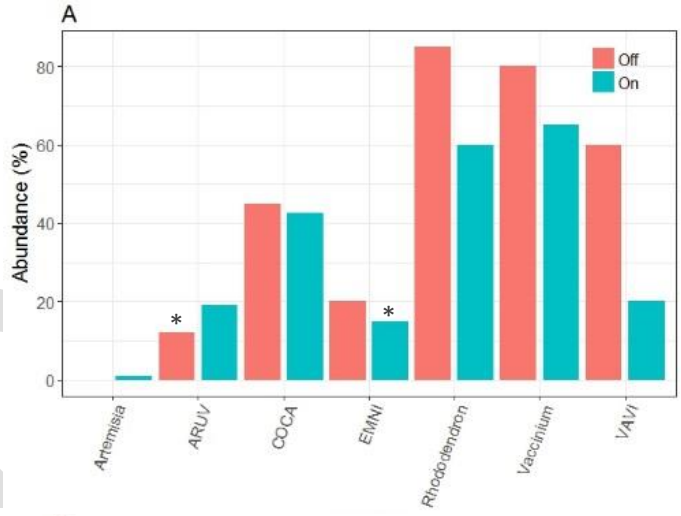
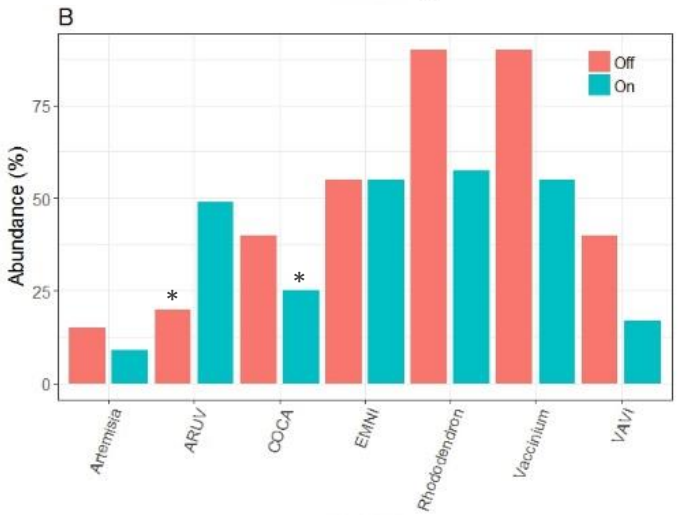


*Figure 2.4 Abundance (% cover) of large woody shrub species on seismic lines (on) and adjacent forest stand (off) subplots sampled in the Little Smoky and A La Peche (A), Redrock Prairie Creek and Narraway (B), and Chinchaga (C) caribou ranges in 2014 and 2015. Species abbreviations are in Table A1.1. Statistical differences between seismic lines and adjacent forest stand subplots are indicated with *.*





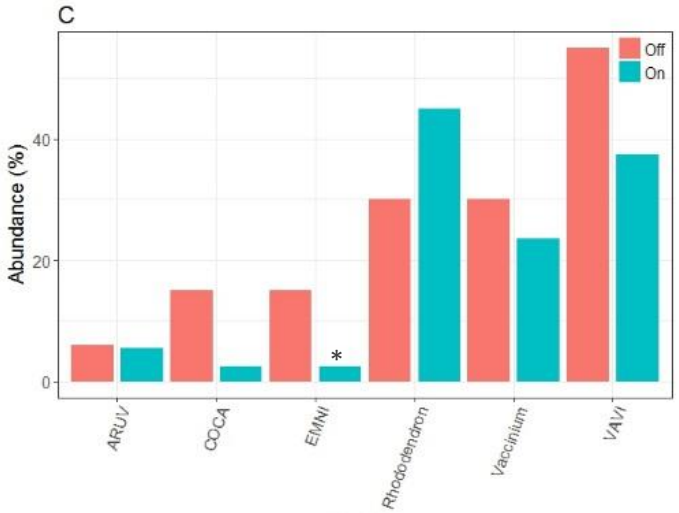
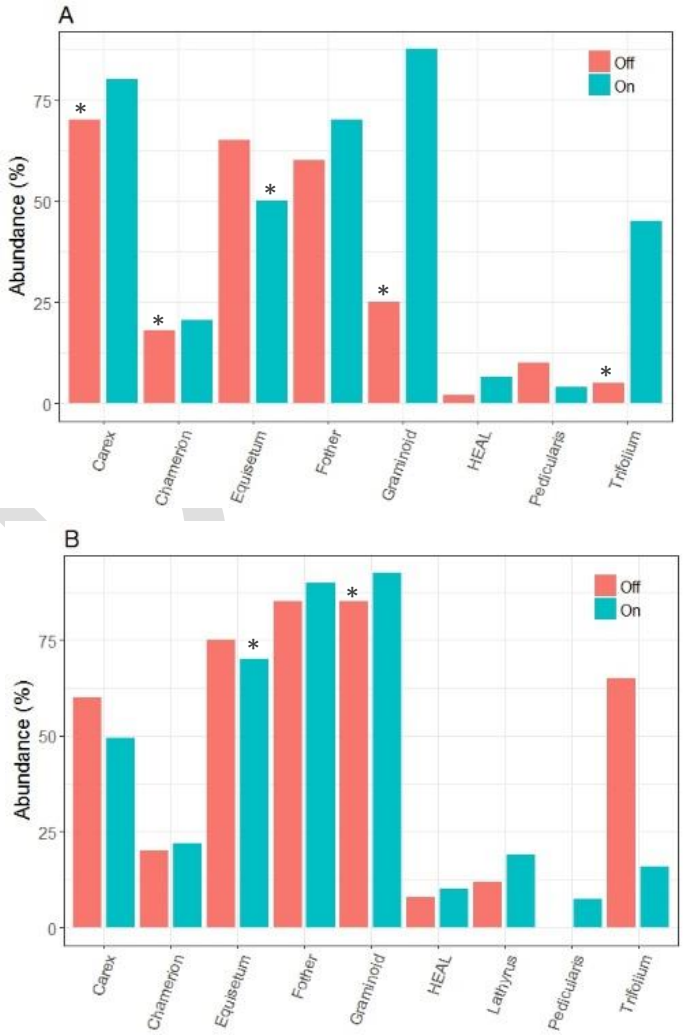


*Figure 2.5. Abundance (% cover) of small woody shrub species on seismic lines (on) and adjacent forest stand (off) subplots sampled in the Little Smoky and A La Peche (A), Redrock Prairie Creek and Narraway (B), and Chinchaga (C) caribou ranges in 2014 and 2015. Species abbreviations are in Table A1.1. Statistical differences between seismic lines and adjacent forest stand subplots are indicated with *.*



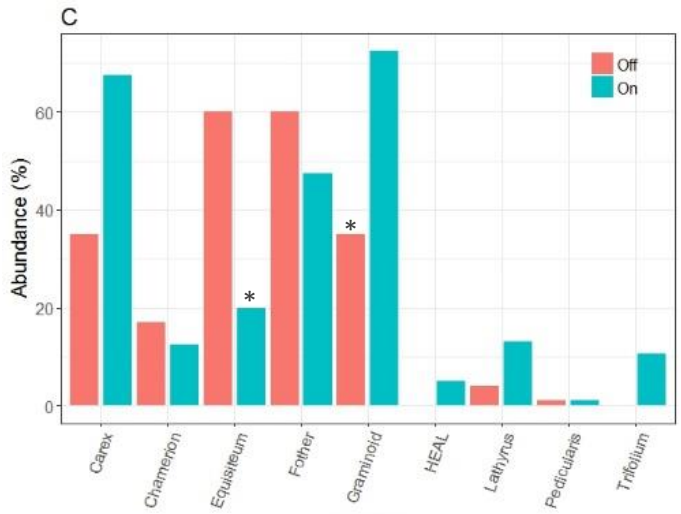


*Figure 2.6 Abundance (% cover) of forb and graminoid species on seismic lines (on) and adjacent forest stand (off) subplots sampled in the Little Smoky and A La Peche (A), Redrock Prairie Creek and Narraway (B), and Chinchaga (C) caribou ranges in 2014 and 2015. Species abbreviations are in Table A1.1. Statistical differences between seismic lines and adjacent forest stand subplots are indicated with *.*

Cladina spp. was more likely to occur online in LSM/ALP, and *Cladina* spp. and *Cladonia* spp. were more likely to occur online in RPC/NAR. Generally, terrestrial lichens were more abundant offline in all areas, with the exception of *Peltigera* spp. which were more abundant online in LSM/ALP (Table A3.3). Considering mosses, bryophytes were more likely to occur online in LSM/ALP, but were more abundant offline in all areas. In LSM/ALP mushrooms were more likely to occur online but were more abundant offline (Table A3.3).

2.3.1.2. Dissimilarity indices describing differences between seismic lines and the adjacent forest stand

Dissimilarly models generally failed to explain differences in tree occurrence between offline and online subplots. Although in LSM/ALP, trees species between online and offline subplots were more similar as regeneration on seismic lines increased in height, the predictive power of the model was poor (r = 0.4), and models failed to explain differences in tree occurrence in the other two study areas.

Considering understory species, models also failed to explain differences in the occurrence or abundance of large shrubs like *Alnus* spp., *Salix* spp., and *Rosa* spp. For small woody shrubs like *Vaccinium* spp. and *E. nigrum*, in Chinchaga, seismic lines were more similar to the adjacent forest at lower elevations, but models failed to explain differences in small woody shrubs in the LSM/ALP and RPC/NAR ranges. Models also failed to explain differences in forbs and graminoids in all areas. For terrestrial lichens, in LSM/ALP, lichens were

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more similar online and offline in areas with lower TPI values (representing valleys), and in Chinchaga, lichens were more similar online and offline at lower elevations.

2.3.2. Natural regeneration on seismic lines

A detailed description of results, associated model parameters, and figures are in Appendix 4.

2.3.2.1. Tree occurrence

Tree occurrence on seismic lines showed strong regional patterns, with environmental covariates predicting occurrence of a species in one area, but failing to predict occurrence in other areas (see Appendix 4). However, tree occurrence was generally related to regeneration height, and the odds of tree occurrence on seismic lines in LSM/ALP and RPC/NAR was 100% once regeneration height (maximum of tree and woody shrub growth) on seismic lines reached 3m. In LSM/ALP the odds of black spruce occurrence increased with increasing seismic line regeneration height, while in Chinchaga, black and white spruce occurrence was higher on seismic lines with higher regeneration heights, and black spruce occurrence was also higher on seismic lines that occurred in areas with lower TPI values (e.g. valleys). Models failed to predict the occurrence of pine in LSM/ALP and Chinchaga, but in RPC/NAR, pine was more likely to occur at higher elevations. Considering broadleaf species, models failed to predict the occurrence of aspen in LSM/ALP, but in Chinchaga, aspen was more likely to occur at lower elevations and lower TPI values (i.e. valleys), and on drier seismic lines (low soil wetness and less growing season precipitation). Aspen was also more likely to occur on E/W orientated seismic lines, and on seismic lines with quite high regeneration heights, at least 4m. Finally, in Chinchaga, the odds of poplar occurrence was higher on seismic lines at higher elevations.

2.3.2.3. Understory species occurrence and abundance

Considering large woody shrub species that were different in abundance between online and offline plots (see Section 2.3.1.1), in LSM/ALP and RPC/NAR, *Alnus* spp. were more abundant on seismic lines at lower elevations, in drier areas, in areas with lower TPI values (i.e. valleys), and on mesic-poor ecosites. In Chinchaga, *Betula* spp. abundance was higher on seismic lines in wetter areas; specifically wetter N/S orientated seismic lines, and *Betula* spp. were also more abundant on seismic lines with lower vegetation heights. In LSM/ALP, *Salix* spp. were more abundant on wetter N/S orientated seismic lines. In RPC/NAR, *Ribes* gooseberry spp. abundance was also higher on more N/S orientated seismic lines.

Small woody shrubs were more likely to occur online on N/S orientated seismic lines, at higher elevations, and on drier seismic lines. Abundance of small woody shrubs was variable across species with *Rhododendron* spp. being more abundant in wetter areas at higher elevations, and *E. nigrum* and *C. canadensis* being more abundant on drier seismic lines at lower elevations. *A. uva-ursi* was more abundant on seismic lines with lower canopy cover, while for other small shrub species, abundance was higher on

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seismic lines with higher canopy cover. *Vaccinium* spp. and *V. vitis-idaea* abundance were high on mesic ecosites, on wetter E/W orientated seismic lines, and on N/S seismic lines.

In LSM/ALP and RPC/NAR, forbs and graminoids were more likely to occur online on wetter low elevation seismic lines, and with the exception of *Equisiteum* spp., forbs and graminoids were more abundant on wetter N/S orientated seismic lines. In contrast, in Chinchaga, *Carex* spp. were more abundant on drier E/W orientated seismic lines, and at higher elevations. The abundance of forb and graminoids was also related to regeneration height on seismic lines, with *Carex* spp. and *Trifolium* spp. being more abundant on seismic lines with lower regeneration heights, and *Chamerion* spp. and *Equisiteum* spp. being more abundant on seismic lines with higher regeneration heights.

Mosses were generally more likely to occur on seismic lines with low canopy cover, and on seismic lines that occurred in areas with low TPI values (i.e. valleys). In all areas, mosses were also more abundant in wetter areas, on E/W orientated seismic lines, and on seismic lines with higher canopy cover. In LSM/ALP, mushrooms were more abundant on seismic lines with lower vegetation heights, at lower elevations, and on seismic lines that were N/S orientated. There were insufficient data to model mushrooms outside of LSM/ALP.

Finally, considering terrestrial lichens, *Cladina* spp., *Cladonia* spp., and *Sterocaulon* spp. were more likely to occur, and were also more abundant on seismic lines with lower growing season precipitation, adjacent to older stands, with lower canopy cover, and on seismic lines with low or intermediate regeneration heights. These lichen species were also more abundant on N/S orientated seismic lines and drier E/W orientated seismic lines. In contrast, *Peltigera* spp. were more abundant on E/W orientated seismic lines and on wetter seismic lines.

2.4. Discussion

We found differences between tree and understory species composition on seismic lines and in adjacent forest stands, but also detected regional patterns in regeneration composition on seismic lines. Generally, tree species were less likely to occur on seismic lines, but tree occurrence was lowest on seismic lines sampled in the Chinchaga caribou range in north-west Alberta. We found that the abundance of large woody shrubs (*Alnus* spp., *Betula* spp., *Ribes* spp., *and Salix* spp.) and forbs (*Carex* spp., *Chamerion* spp., *and Trifolium* spp.) was higher on seismic lines, while the abundance of small woody shrubs (*Vaccinium* spp., *E. nigrum*, *Rhodendron* spp., *and C. Canadensis*), terrestrial lichens, and bryophytes was higher off seismic lines. GIS variables failed to predict dissimilarity in tree and understory species between seismic lines and the adjacent forest stand but did predict understory species composition on seismic lines. Although regeneration height was related to tree occurrence and abundance of some large shrubs and terrestrial

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lichens, other variables like seismic line orientation, seismic line wetness, and growing season precipitation were important predictors of abundance and occurrence of understory species.

Our tree results are largely in accordance with previous research that described low regeneration heights on seismic lines even decades after construction (Revel *et al.* 1984; Bella 1986; Seccombe-Hett & Walker-Larsen 2004; Lee & Boutin 2006; van Rensen *et al.* 2015). Although we found no associations between the occurrence of tree species and seismic line wetness, the increased abundance of forbs, graminoids, and small woody shrubs on wetter seismic lines supports the lower regeneration heights on wetter seismic lines that were reported by van Rensen *et al.* 2015. It is possible that tree abundance data, rather than tree occurrence, may have revealed closer associations between trees and seismic line wetness.

Previous research has described significant differences in plant communities on seismic lines when compared to undisturbed habitat, irrespective of the age of the seismic line (MacFarlane 2003; Kemper & Macdonald 2009; Lankau 2014). The higher abundance on seismic lines of large woody shrubs like *Betula* spp. and *Salix* spp. are in accordance with results from the boreal forest and tundra (Revel *et al.* 1984; Seccombe-Hett & Walker-Larsen 2004; Joroenson *et al.* 2010; Lankau 2014), although unlike our results, MacFarlane (2003) found no difference in the abundance of *Ribes* spp. or *Salix* spp. in an aspen-dominated system in north-east Alberta, and Seccombe-Hett & Walker-Larsen (2004) also found no difference in the abundance of *Ribes* spp.

For small woody shrubs, we detected lower abundance of *V. vitis idaea, E. nigrum, C. Canadensis,* and *Rhododendron* spp. on online plots. MacFarlane (2003) also reported lower abundance of *C. Canadensis* on online plots, and Seccombe-Hett & Walker-Larsen (2004) found lower abundance of *V. vitis-idaea* and *Rhododendron* spp. online. However, in contrast to our results, Seccombe-Hett & Walker-Larsen (2004) detected no difference in *E. nigrum* between online and offline plots, and MacFarlane (2003) found lower abundance of *V. edule* on seismic lines. Considering forbs and graminiods, the generally higher abundance that we detected on seismic lines also agrees with previous research (Revel *et al.* 1984; Seccombe-Hett & Walker-Larsen 2004; Kemper & Macdonald 2009; Joroenson *et al.* 2010), and the lower abundance of bryophytes and lichens that we found also agrees with previous work (Revel *et al.* 1984; Kemper & Macdonald 2009; Joroenson *et al.* 2010). Considering that strong ecosite and upland/lowland differences affecting seismic line regeneration were reported for other studies (Revel *et al.* 1984; Seccombe-Hett & Walker-Larsen 2004; Lee & Boutin 2006; Lankau 2014; van Rensen *et al.* 2015), contrasting results amongst species groups, studies, and even among our three study areas are not surprising. Natural succession and growth is a complex interplay between soil, light, and moisture, and thus is likely to be quite different among different species, and in different areas (Joroenson *et al.* 2010). This variation also likely explains the poor performance of the dissimilarity and GIS variable models.

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However, for individual understory species models, we found that GIS variables could accurately predict occurrence and abundance of a number of species on seismic lines. Specifically, indices of soil wetness (TPI, soil wetness, and depth to water) and seismic line orientation emerged as significant predictors of understory species occurrence and abundance. Soil wetness is intrinsically linked to plant growth and is an important determinant of species distribution and tree species germination, thus, links between plant growth and indices of soil wetness were expected. Seismic lines orientated on an E/W axis will experience direct sunlight, larger temperature fluctuations, and may be drier than seismic lines oriented in different directions. In contrast, seismic lines orientated on a north/south axis will be shadier, more moist, and have smaller temperature fluctuations (Revel *et al.* 1984; van Rensen *et al.* 2015). Our results revealed that the woody shrubs *Betula* spp., *Ribes* spp., and *C. Canadensis* were more abundant on north/south orientated seismic lines, that *Salix* spp. were more abundant on wetter N/S lines, and that *Vaccinium* spp. were more abundant on N/S lines and wetter E/W lines. Forb and graminoids were also generally more abundant on wetter N/S orientated seismic lines while terrestrial lichens were more abundant on drier and E/W orientated seismic lines.

Current restoration standards for forest cutblocks in Alberta set a threshold of 3m regeneration height to define successful restoration. Although our tree occurrence models are in accordance with this, and we found that abundance of *Alnus* spp. decreased once vegetation height reached 2m, we also found that abundance of *Ribes* spp. did not decrease until vegetation height reached 7m. Also, for other species like *Salix* spp. and *Betula* spp., abundance decreased linearly with increasing vegetation height, and for many understory species, abundance was not predicted by regeneration heights on seismic lines at all. Although we found evidence that tree occurrence was associated with vegetation height, our results suggest that regeneration height alone likely fails to quantify seismic line restoration, and that even at later stages of regeneration, seismic lines may contain understory species patterns that diverge from the adjacent forest stand. This divergence in understory species between seismic lines and adjacent stands may attract alternate prey and predators to these lines, therefore increasing competition with, and predation risk for caribou. The relationship between wildlife occurrence and understory species composition is addressed in the next chapter (Chapter 3).

2.5 Conclusions

Although we detected differences in tree and understory species occurrence and abundance between seismic lines and the adjacent forest stand, GIS covariates failed to predict broad similarities in the occurrence and abundance of species. However, individual species models revealed that wetter N/S orientated seismic lines had higher abundance of large woody shrubs, and forbs and graminoids. Targeting restoration efforts to wetter N/S orientated seismic lines (see Chapter 4) may help to expedite seismic line recovery. Collecting tree abundance data from E/W and N/S orientated seismic lines could also help

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determine whether E/W orientated seismic lines are on a different trajectory than N/S oriented seismic lines, and therefore more in line with the adjacent stands conditions.

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3. WILDLIFE USE OF SEISMIC LINES

Karine Pigeon

3.1. INTRODUCTION AND OBJECTIVES

In this chapter, we assessed the use of seismic lines, and the occupancy and detection of alternate prey (deer, moose, and elk), and predators (bears, canines, cougar, and lynx) on seismic lines. The goal of this analysis was to refine maps of seismic lines identified as high priority for restoration in west-central Alberta and in the Chinchaga herd range (HSP 6617, 6699, and 7195), based on the probability of overlap among caribou, wolves, and grizzly bears. More specifically, our objectives were to 1) identify seismic line characteristics that were attractive to alternate prey and their predators by modeling wildlife tracks and signs on seismic lines as a function of field-based variables (i.e. % cover of ungulate food, tree species composition, and regeneration heights) and GIS-based variables (i.e. ecosites, wet areas mapping (WAM), and topographic variables) in west-central Alberta and the Chinchaga caribou range, and 2) identify GIS-based attributes of seismic lines and adjacent areas, including models of probability of vegetation occurrence and abundance generated in Chapter 2, associated with high occupancy and detection of alternate prey and predators on seismic lines in west-central Alberta.

3.2. METHODS

3.2.1. Field data collection – Tracks and signs

Field crews recorded tracks and signs (i.e. tracks, scats, or pellets) of canines, bears, cougar, caribou, elk, deer, and moose at 766 plots (303 seismic lines) in west-central Alberta caribou herd ranges between 2013 and 2015, and at 290 plots (154 seismic lines) in the Chinchaga caribou herd range in 2015 (Figure 2.1 and 2.2). Detailed field data collection protocols are in Appendix 1 and 2. As tracks and signs were often difficult to identify due to substrate and degradation over time, field crews also recorded a measure of their confidence level when identifying tracks and signs (low, moderate, or high). For data analysis, we used only records identified with moderate (n = 4) and high (n =1052) confidence levels. We treated tracks and signs data as a measure of 'presence' but not as an adequate measure of 'absence' because the surface conditions where tracks are observed (i.e. hardpack trail vs. muddy trail, bare ground vs. heavily vegetated ground) influence the probability of tracks and signs being detected at particular sites. Weather can also influence the probability of detecting tracks and signs, and the timeframe during which the animal was present at a site cannot be adequately known because site conditions and weather influence the persistence of tracks and signs at sites (Reid *et al.* 2013).

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3.2.2. Field data collection – Occupancy and detection

Between November 2014 and November 2015, we deployed Bushnell Trophy Cam® cameras at 47 sites (25 sites in the LSM/ALP herd ranges, and 22 sites in the RPC/NAR herd ranges, Figure 3.1). We did not install cameras in the Chinchaga herd range. As we were primarily interested in the influence of regeneration (tree or vegetation height) on seismic lines as a predictor of animal occupancy, we stratified camera sites by categories of vegetation heights (0-1m, 1-3m, and >3m) to obtain adequate representation of seismic lines with the gradient of vegetation height available in each landscape. Between November 2015 and September 2016, we deployed cameras at 60 sites (23 sites in the LSM/ALP, and 37 sites in RPC/NAR landscape, Table 3.1; Figure 3.1). All variables collected at sites are described in Appendix 1 and 2.

Table 3.1. Number of camera trap sites per category of vegetation height on seismic lines in LSM/ALP and RPC/NAR caribou herd ranges of west-central Alberta during 2015 and 2016. LSM/ALP includes the Little Smoky (LSM) and A La Peche (ALP) herd ranges while RPC/NAR includes the Redrock Prairie Creek (RPC) and Narraway (NAR) herd ranges.

		Vegetation height strata		
		0-1m	1-3m	>3m
LSM/ALP	Nov 2014 – Nov 2015	11	9	5
	Nov 2015 – Sept 2016	10	9	4
RPC/NAR	Nov 2014 – Nov 2015	9	8	5
	Nov 2015 – Sept 2016	13	15	9

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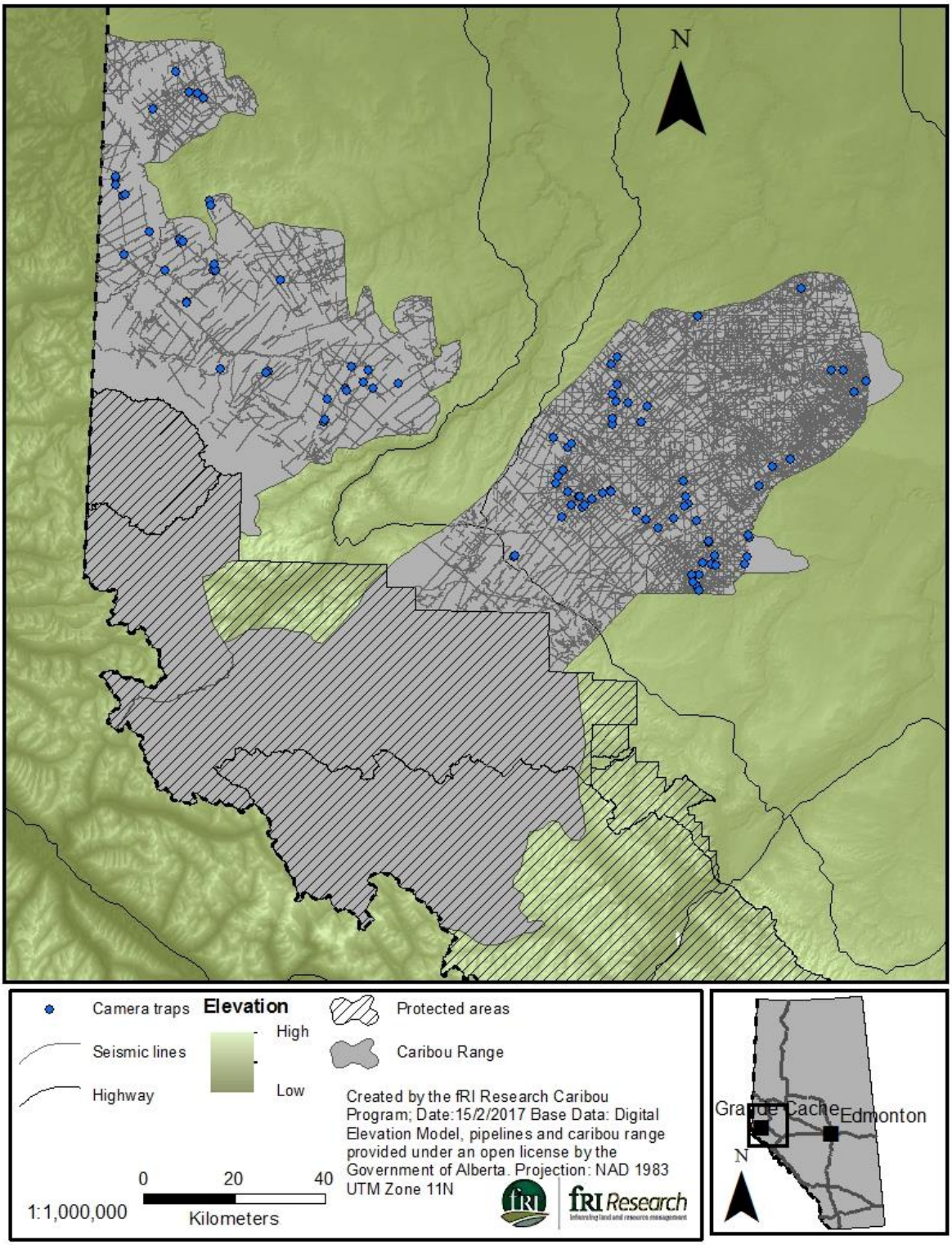

Figure 3.1. Camera trap sites in west-central Alberta (LSM, ALP, RPC, and NAR) during 2015 and 2016.

3.2.3. Data analysis – Tracks and signs

We built generalized linear mixed models (GLMMs) of animal use of seismic lines in west-central Alberta (LSM/ALP) and (RPC/NAR), and the Chinchaga herd range, using evidence of tracks and signs, field data collected at plots, and GIS variables (Appendix 1 and 2). We used a multi-step approach to build models assessing the use of seismic lines by alternate prey and predators, and details of our methods can be found in Appendix 5.

3.2.3. Data analysis – Occupancy and detection

We used occupancy models following methods outlined by Mackenzie et al. (2002; 2006) in an attempt to estimate the relationship between seismic line characteristics and characteristics of the surrounding landscape to the probability of a seismic line being occupied by alternate prey and predators. We therefore built seasonal occupancy models for moose, deer, elk, black bears, lynx, and wolves. We used a multi-step approach to first build models explaining detection probability, and then built models assessing variables for occupancy (Arnold 2010; Kéry *et al*. 2010; Steenweg *et al*. 2015). Details of our analysis methods can be found in Appendix 6.

3.3. Results

3.3.1. Tracks and signs

In west-central Alberta, missing explanatory variables for 78 plots reduced the sample size to 621 plots (265 seismic lines). We observed deer on 325 out of 621 plots (52%), elk on 182 plots (29%), bear species on 119 (19%), and canines on 53 (9%) of plots. We observed moose at 471 plots (76%) in west-central Alberta, and models did not converge for this species because of the lack of 'absences' at plots.

In the Chinchaga herd range, missing explanatory variables for 57 plots reduced our sample size to 290 plots (154 seismic lines). We observed deer on 32 out of 290 plots (11%), moose on 156 plots (54%), elk on only 3 out of 290 plots (1%), caribou on 16 plots (5.5%), bears on 72 plots (25%), and canines on 25 plots (9%). Because of low sample size, we did not build models for species with <15% use, and therefore did not build models for caribou and canines in all study areas, and for deer and elk in the Chinchaga herd range.

Deer in west-central Alberta were more likely to use seismic lines in the RPC/NAR caribou ranges compared to LSM/ALP caribou ranges, and were more likely to use seismic lines in forest stands with short trees in areas with low densities of roads and seismic lines (Appendix 5: Table A5.2.1). Deer use in west-central Alberta was also explained, in part, by high use of seismic lines by elk (Table A5.1). Moose in the Chinchaga herd range used seismic lines more when these lines were in stands with shorter trees (Appendix 5). Finally, elk in west-central Alberta used seismic lines more in wet and rich ecosite types, and at low elevation

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where moose were also present. Elk were also more likely to use seismic lines in 2014 compared to 2015 (Table A5.1)

Bears in west-central Alberta were more likely to use seismic lines with more vegetation cover, and in areas with low densities of seismic lines (Table A5.2). For bears, we found no evidence of yearly differences or landscape differences in their use of seismic lines. In Chinchaga, bear use of seismic lines increased with presence of moose, and with depth to the water table (a proxy of wetness; Table A5.2).

In general all tracks and signs models for prey and predators in the study areas performed well, with Area under the curve (AUC) Receiver Operating Characteristic (ROC) values ranging between 0.65 and 0.87 (see Appendix 5).

3.3.2. Occupancy and detection

In 2015, 41 out of 47 camera sites captured alternate prey (i.e. moose, deer, or elk) at least once during the year (27 out of 47 sites during winter), while during the 2016 camera trapping effort, 42 out of 60 camera sites captured alternate prey at least once (32 sites during winter). For predators (black bears, grizzly bears, cougar, lynx, wolves, and coyotes), 33 out of 47 camera sites captured a predator at least once during 2015 (25 sites during winter), while in 2016, 35 out of 60 camera sites captured predators at least once (29 sites during winter). Table 3.2 summarizes the number of camera trap sites and the trapping effort.

Table 3.2. Number of camera trap sites (Sites), number of independent sampling occasions (# days), and trapping period (Period) by caribou herd ranges (Range) during the 2015 and 2016 camera trap surveys conducted on regenerating seismic lines in west-central Alberta, Canada within the Little Smoky (LSM), A La Peche (ALP), Redrock Prairie Creek (RPC), and Narraway (NAR) caribou ranges.

Year	Range	Sites	# days	Period
2015	LSM	15	4,140	02 Dec 2014 – 14 Oct 2015
	ALP	10	2,741	26 Nov 2014 – 18 Oct 2015
	RPC	15	5,695	18 Nov 2014 – 5 Nov 2015
	NAR	7	2,192	20 Nov 2014 – 24 Oct 2015
	LSM/ALP	25	6,881	-
	RPC/NAR	22	7,887	-
2016	LSM	20	4,682	19 Nov 2015 – 19 Sept 2016
	ALP	3	360	3 Mar 2016 – 18 Jul 2016
	RPC	26	7,965	7 Nov 2015 – 11 Aug 2016
	NAR	11	3,426	9 Nov 2015 – 19 Aug 2016
	LSM/ALP	23	5,042	-
	RPC/NAR	37	11,391	-
	Total (both years)	107	31,201	18 Nov 2014 – 19 Sept 2016

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Overall naïve occupancy on seismic lines was especially high for moose (0.86 – 0.95, Table 3.2), followed by deer (0.68 – 0.76), and elk (0.22 – 0.24). For predators, lynx had the highest naïve occupancy (0.66 – 0.73), followed by coyote (0.43 – 0.55), black bear (0.34 – 0.42), grizzly bear (0.34 – 0.39), and wolf (0.2 – 0.33). Naïve occupancy for cougar, on seismic lines, was very low (0.03 – 0.06; Table 3.2). Detection rates followed similar patterns with high relative abundance for moose and deer, and less so, for lynx and coyote (Table 3.2).

Table 3.2. Relative abundance index (i.e. detection rate; RAI) and naïve occupancy (¥; [# detections / # sites]) by ranges for moose, deer, elk, black bear, grizzly bear, cougar, lynx, wolf, and coyote from the 2015 and 2016 camera trap surveys conducted on regenerating seismic lines in west-central Alberta, Canada. LSM/ALP includes the Little Smoky (LSM) and A La Peche (ALP) herd ranges while RPC/NAR includes the Redrock Prairie Creek (RPC) and Narraway (NAR) herd ranges.

	LSM/ALP		RPC/NAR		**Total**
	RAI	¥	RAI	¥	**¥**
2015					
Moose	1.03	0.96	0.81	0.81	**0.95**
Deer	2.81	0.69	0.74	0.54	**0.68**
Elk	0.19	0.27	0.05	0.11	**0.22**
Black bear	0.36	0.56	0.06	0.29	**0.42**
Grizzly bear	0.16	0.31	0.28	0.47	**0.39**
Cougar	0.01	0.06	0.00	0.00	**0.03**
Lynx	0.26	0.56	0.82	0.88	**0.73**
Wolf	0.17	0.25	0.62	0.41	**0.33**
Coyote	0.41	0.63	0.58	0.47	**0.55**
2016					
Moose	2.02	1.00	0.69	0.76	**0.86**
Deer	1.82	0.90	0.55	0.68	**0.76**
Elk	0.33	0.24	0.06	0.24	**0.24**
Black bear	0.30	0.53	0.05	0.20	**0.34**
Grizzly bear	0.20	0.40	0.15	0.30	**0.34**
Cougar	0.04	0.07	0.009	0.05	**0.06**
Lynx	0.14	0.50	0.54	0.80	**0.66**
Wolf	0.12	0.27	0.07	0.15	**0.20**
Coyote	0.30	0.47	0.18	0.40	**0.43**

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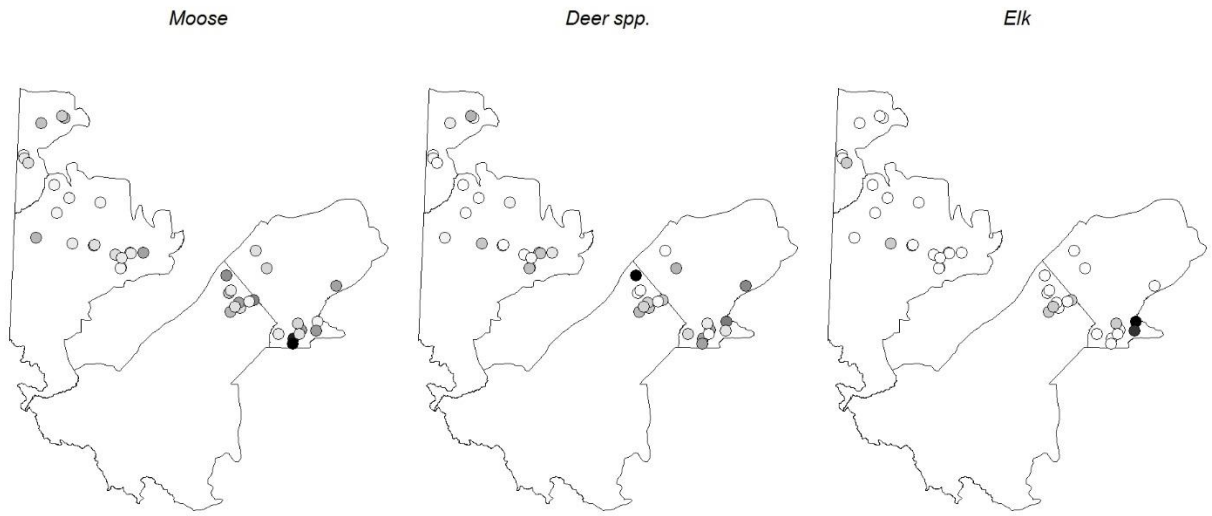

Figure 3.2. Camera trapping events for moose, deer, and elk across caribou ranges in west-central Alberta during 2015. Grey scale represents cumulative daily events standardized by the maximum number of events per species, with light grey indicating fewer detection events and dark grey indicating more detection events.

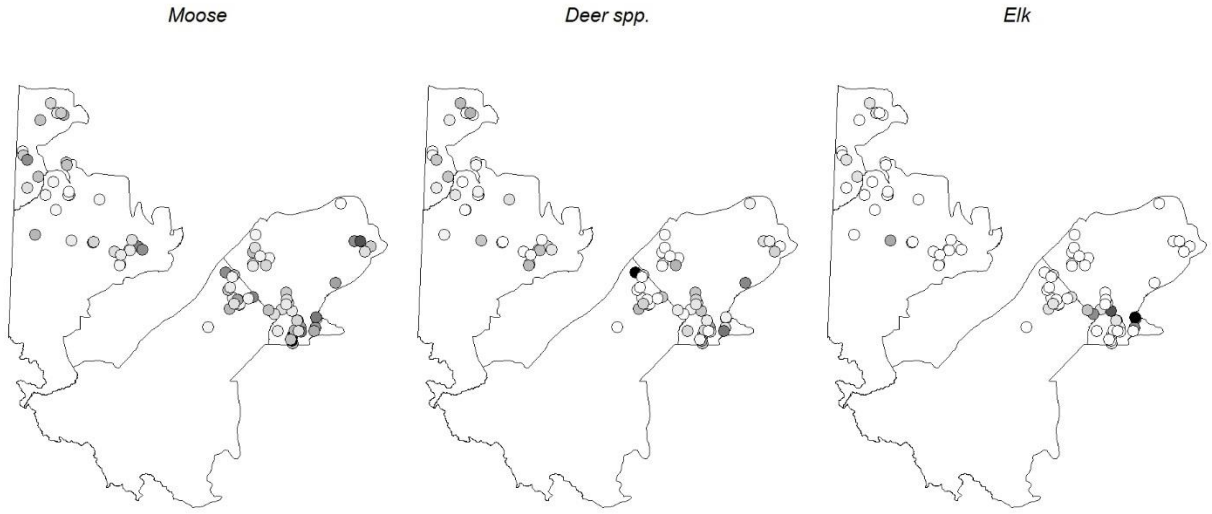

Figure 3.3. Camera trapping events for moose, deer, and elk across caribou ranges in west-central Alberta during 2016. Grey scale represents cumulative daily events standardized by the maximum number of events per species, with light grey indicating fewer detection events and dark grey indicating more detection events.

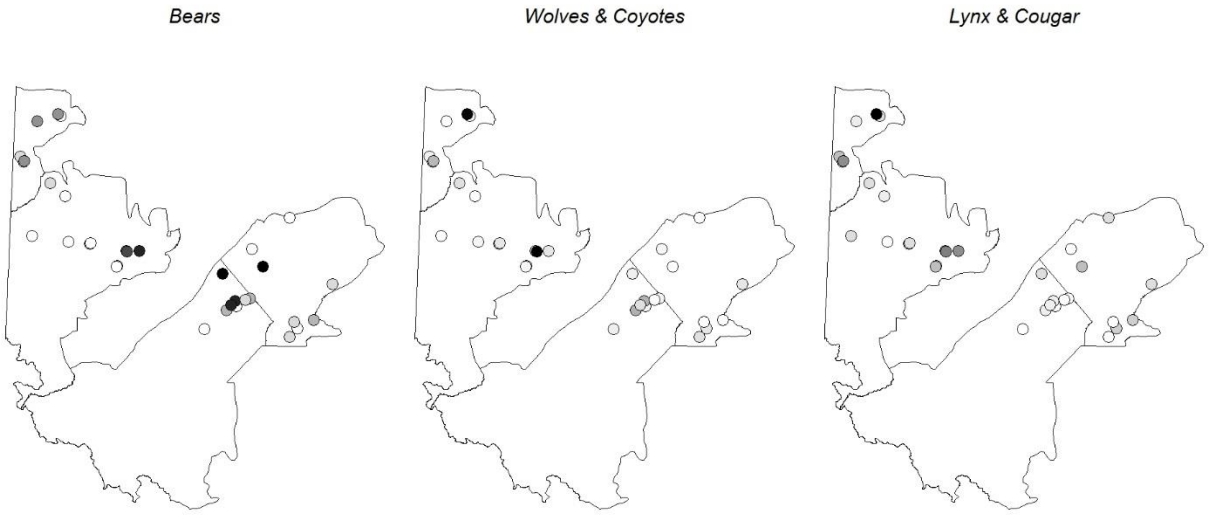

Figure 3.4. Camera trapping events for bears, canines, and lynx and cougar across all caribou ranges in west-central Alberta during 2015. Grey scale represents cumulative daily events standardized by the maximum number of events per species, with light grey indicating fewer detection events and dark grey indicating more detection events.

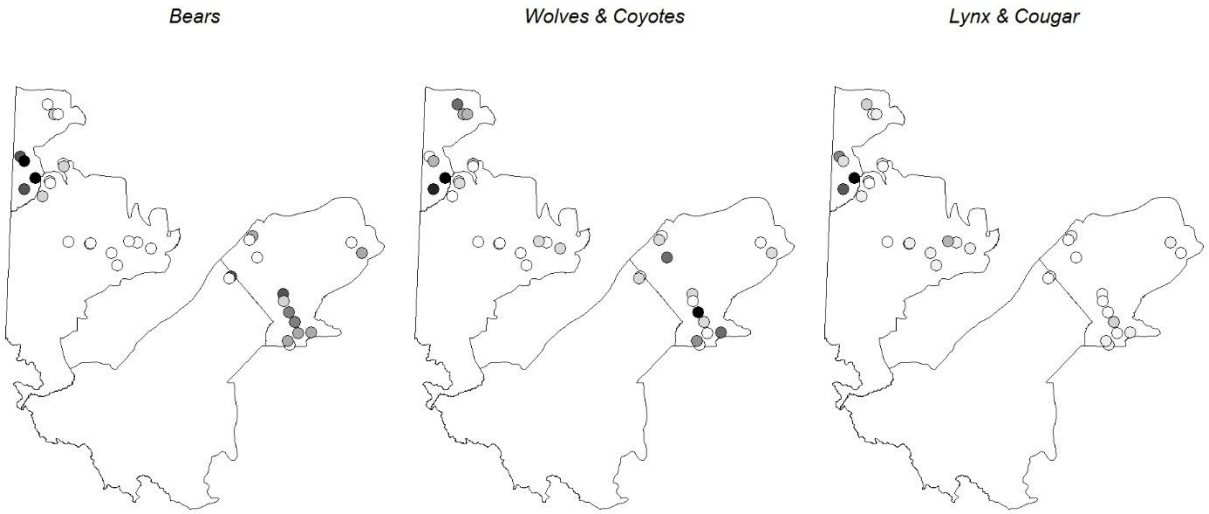

Figure 3.5. Camera trapping events for bears, canines, and lynx and cougar across all caribou ranges in west-central Alberta (LSM, ALP, RPC, and NAR) during 2016. Grey scale represents cumulative daily events standardized by the maximum number of events per species, with light grey indicating fewer detection events and dark grey indicating more detection events.

3.3.2.1. Occupancy and detection – Alternate Prey

For alternate prey during the summer of 2015, no variable adequately explained occupancy, except for elevation in moose and elk models (Appendix 6: Table A6.2 and Table A6.3). Moose and elk occupancy decreased with elevation (Table A6.2, Table A6.3, and Figure A6.1). Detection for alternate prey was influenced by the presence of alder and vegetation height on seismic lines, the depth to the water table (a proxy of wetness), the density of seismic lines, 0 – 30 year old cutblocks, and well sites at the landscape scale (1km-radius), the abundance of graminoid species, and the density of seismic lines at the local scale (70m-radius; Appendix 6: Tables A6.1 – A6.3). Deer detection decreased with the presence of alder, but increased with vegetation height on seismic lines, on dry sites, and with the density of cutblocks and well sites (Table A6.1). Moose detection increased with the abundance of graminoids and with the density of seismic lines, cutblocks, and well sites (Table A6.2), and elk detection decreased with the density of seismic lines (Table A6.3).

Our sample size for sites with at least one detection of alternate prey during winters were small and models for deer generally failed to detect any influential variable (Appendix 6). For moose, occupancy during winter increased at low vegetation height on seismic lines, and detection increased with slope angle, and with densities of roads, 0 – 30 year old cutblocks, and well sites (Appendix 6: Table A6.4).

3.3.2.2. Occupancy and detection – Predators

For predators, we focused modelling efforts on black bears, lynx, and wolves because (1) cougar occupancy was too low to build models, (2) grizzly bear selection of areas near seismic lines was assessed previously using GPS-collar data (Finnegan *et al.* 2016), (3) we were specifically interested in black bear and lynx occupancy as likely predators of caribou for which we had no previous information, and (4) although we had previously assessed wolf selection of areas near seismic lines using GPS-collar data (Finnegan *et al*. 2016), we were specifically interested in assessing direct occupancy of seismic lines by wolves because wolves are believed to be the main predator of caribou in the study area, and have been shown to use linear features to facilitate travel (Dickie *et al.* 2016), and because cameras installed on seismic lines provided a new opportunity to specifically assess relationships between seismic lines characteristics and wolf behaviour.

For black bears, lynx, and wolves during the summer of 2015, the only variable with confidence intervals that did not overlap zeros for occupancy was the presence of alder (Table A6.5). Occupancy for black bears decreased with the presence of alder on seismic lines (Table A6.5, Figure A6.2). Still, models showed that occupancy of lynx and wolves increased with the density of roads on the landscape, and with the abundance of graminoids on seismic lines respectively, however the confidence intervals for those variables overlapped zero (Table A6.6 and Table A6.7). Detection for black bears decreased on north-east facing slopes compared to south-west facing slopes and flat areas, detection for lynx and wolves decreased with

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vegetation height on seismic lines, and detection for lynx also decreased with high densities of seismic lines on the landscape (Table A6.6 and Table A6.7).

Our sample size for sites with at least one detection of predators during winters were small and models generally failed to detect any influential variable. However, for lynx during winter 2016, detection increased at low elevation (Appendix 6).

3.4. Discussion

Results from our tracks and signs, and occupancy analyses of alternate prey are consistent with previous findings that linked greater use and presence of deer and moose with productive early seral stands (Bjørneraas *et al.* 2011; Fisher *et al.* 2016). We found greater evidence of alternate prey use of seismic lines associated with shorter forest stand heights, in wet and rich ecosites, and at low elevation. We also found that summer occupancy was higher for moose and elk at low elevation, and that summer detections of moose and deer were higher in areas of high densities of regenerating cutblocks and well sites.

For predators, our tracks and signs analysis showed that black bears were more likely to use seismic lines with high vegetation cover, in dry areas with low densities of seismic lines, and with higher presence of moose signs. Use of seismic lines with high vegetation cover by bears is consistent with previous research that found bears use seismic lines and other linear features for a combination of travel and forage (Roever *et al.* 2008; Tigner *et al.* 2014). In addition, our occupancy analysis showed that black bear occupancy decreased with presence of alder, and we observed the same relationship with deer detection (increased detection with decreased presence of alder). Occupancy of lynx, and detection of lynx and wolves was associated with high road densities, and with low vegetation height on seismic lines respectively. Although lynx are not known to follow seismic lines to facilitate their movement, these results are consistent with research on wolves that reported wolves use linear feature as movement corridors (McKenzie *et al.* 2012; Dickie *et al.* 2016). In addition, Revel *et al.* (1984) found extensive browsing activity by snowshoe hares on woody shrubs and saplings on seismic lines. It is plausible that lynx are attracted to low vegetation height seismic lines as a movement corridor, or because they attract their primary prey (Murray *et al.* 1994) but further data are needed to confirm this hypothesis. Wolf occupancy was also associated with high abundance of graminoids, where we also found high detection for moose. Therefore, like lynx, wolves may be attracted to seismic lines to facilitate travel, and because they attract prey.

Overall, low sample sizes of camera traps prevented us from observing clear occupancy patterns, especially during winter. Cameras are currently collecting data and we therefore hope to have sufficient sample sizes in the near future. Still, we found that moose occupancy during winter decreased with vegetation height on seismic lines, and that detection increased with the density of anthropogenic features consistent with early seral habitat (Bjørneraas *et al.* 2011). We also found that detection probability for lynx was higher at low

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elevation. Regardless of low sample size for occupancy analyses, the observed pattern in use of seismic lines and in occupancy and detection probability were generally in accordance with alternate prey using seismic lines in early stages of regeneration, and near productive early seral stands. Our results also suggest that linear features are attractive to predators, and these results are therefore in accordance with the use of linear features to facilitate movement for predators.

Finally, the presence and abundance of vegetation on seismic lines were also important predictors of detection for these species, and further work investigating the link between presence and abundance of key food species and alternate prey could help target seismic line reclamation so as to reduce alternate prey numbers in caribou ranges. Moreover, in accordance with previous knowledge of increased deer densities in north-eastern Alberta (Latham *et al.* 2011b), our occupancy analysis shows that in west-central Alberta, moose in particular (and deer to a lesser degree) are also overabundant. Research focused on identifying ways to effectively reduce moose numbers within caribou ranges would therefore likely be beneficial to caribou persistence (i.e. Latham et al. 2011b; Serrouya *et al.* 2011, 2015).

3.5. Conclusion

Although tracks and signs data are biased towards detecting 'presence' rather than 'absence', and although occupancy analyses are limited by expenses associated with camera trap installations, maintenance, and the ability to move camera sites often (i.e. fund limitation associated with field work), results from this report generally show that alternate prey are associated with productive early seral stands, and that alternate prey and predator use, occupancy, and detection can be modelled at a landscape scale using non-invasive methods given sufficient resources. The results outlined in this chapter can be used to guide ongoing restoration treatments for seismic lines according to a prioritization plan based on the novel use of a combination of non-invasive methods to obtain empirical data of animal use, and field-based and GIS-based vegetation, habitat, and anthropogenic data. The results of this chapter can be combined with vegetation models from Chapter 2 to help refine priority of seismic lines for restoration (defined in HSP 6617, 6699, and 7195).

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4. MAPPING UNDERSTORY SPECIES ON SEISMIC LINES

Tracy McKay

4.1. METHODS

For understory species that were higher in abundance on seismic lines, we used models developed in Chapter 2 to map their distribution. We generated occurrence and abundance probabilities using the intercepts and coefficients from the best models for each plant species, as determined by AIC model selection (see Appendix 4: Table A4.7 to A4.39). For plant species and ranges where candidate models failed to predict occurrence or abundance, we did not calculate probabilities.

For each occurrence or abundance model, we applied coefficients and intercepts in a GIS to calculate rasters of the probability of occurrence or abundance for each species and range. For species where models were available for both occurrence and abundance, we multiplied probability values to obtain an accurate abundance estimate, i.e. the probability of abundance given occurrence. We defined probabilities of occurrence or abundance ≥ 0.6 as "high" occurrence or abundance, and we calculated the length and percentage of seismic lines with high occurrence or abundance for each plant species in each range.

4.2. RESULTS

We had predictive models of occurrence and abundance for nine plant species that were also higher in abundance on seismic lines (see Appendix 3); for these species, we predicted the probability of occurrence and/or abundance for one or more caribou ranges depending on model results (Table 4.1; Appendix 4). In Chinchaga, 7,884km of seismic lines had a high predicted abundance of *Betula* spp. In LSM/ALP, models predicted a high abundance of *Carex* spp. for 1,966km of seismic lines, high *Peltigera* spp. abundance for 45km of lines, and high *Trifolium* spp. abundance for 199km of seismic lines. Graminoid species had a high predicted abundance on 210km of seismic lines in the RPC/NAR range, and *Ribes* spp. had a high predicted abundance on 391km of seismic lines (Table 4.2). The spatial distributions of abundance for these plant species and ranges are shown in Figures 4.1 to 4.6.

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Table 4.1. Plant species and probability results predicted for seismic lines in the ALP/LSM, RPC/NAR, and Chinchaga caribou ranges, Alberta, Canada.

	Results predicted		
Species	**ALP/LSM**	**RPC/NAR**	**Chinchaga**
Alnus spp.	Occurrence, Abundance	Occurrence	None
Betula spp.	None	None	Occurrence, Abundance
Ribes spp.	None	Occurrence, Abundance	None
Salix spp.	Occurrence	None	None
Carex spp.	Occurrence, Abundance	None	None
Chamerion spp.	Occurrence	None	None
Trifolium spp.	Occurrence, Abundance	None	None
Graminoid spp.	Abundance	Occurrence, Abundance	Occurrence
Peltigera spp.	Occurrence, Abundance	None	None

Table 4.2. Length of seismic lines with high (≥0.6) predicted abundance of understory species in the ALP/LSM, RPC/NAR, and Chinchaga caribou ranges.

		Seismic lines with predicted high abundance		Seismic lines used to predict probabilities
Plant Species	**Herd**	**Length (km)**	**Percent**	**Length (km)**
Betula spp.	Chinchaga	7884	18.72	42,111
Carex spp.	LSM/ALP	1966	15.58	12,615
Graminoid spp.	RPC/NAR	210	5.26	3,993
Peltigera spp.	LSM/ALP	45	0.34	13,174
Ribes spp.	RPC/NAR	391	9.55	4,097
Trifolium spp.	LSM/ALP	199	1.57	12,687

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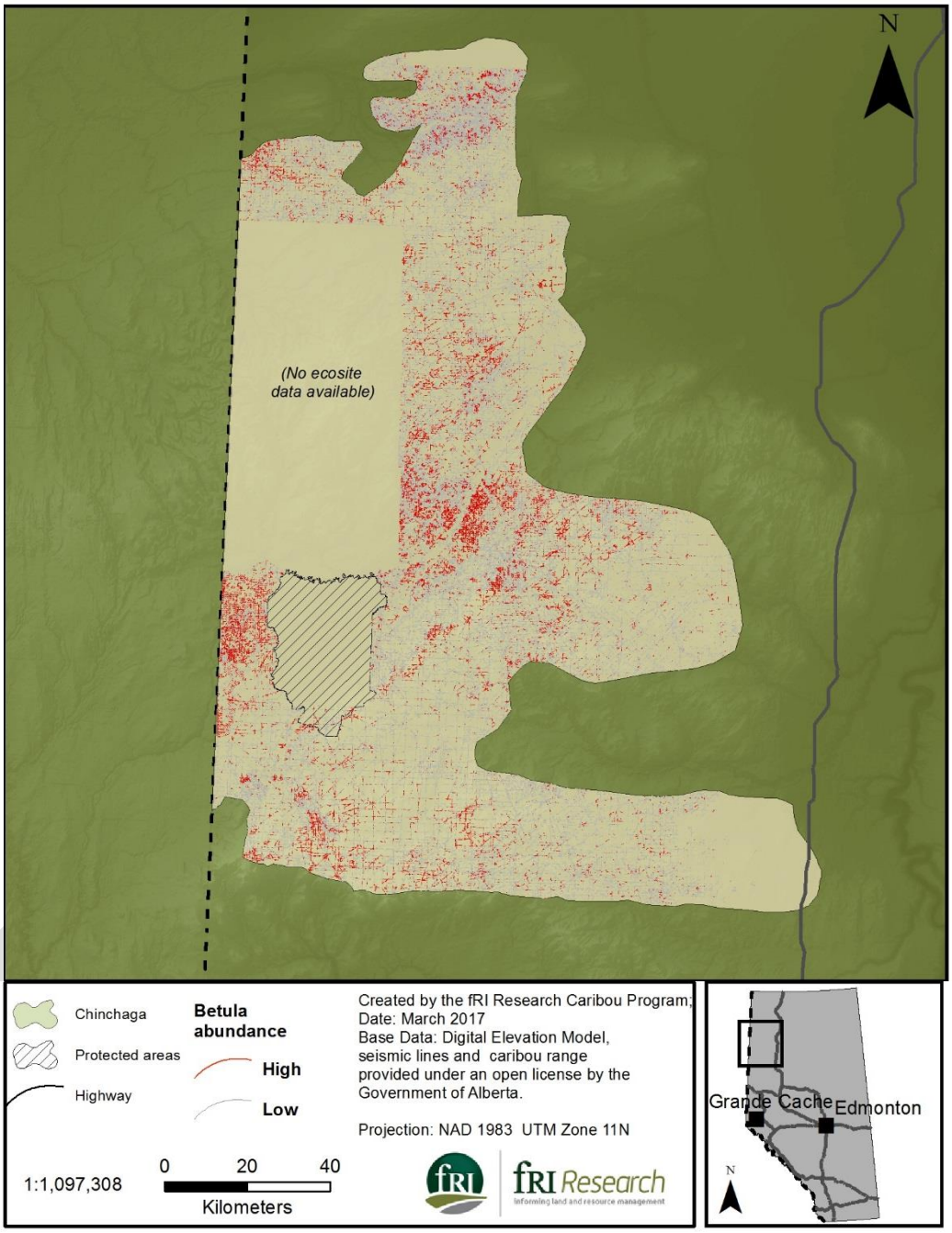

Figure 4.1. Seismic lines with a high and low predicted abundance of Betula spp. in the Chinchaga caribou range from field data collected during 2015. Areas without results, as indicated, are due to lack of ecosite data.

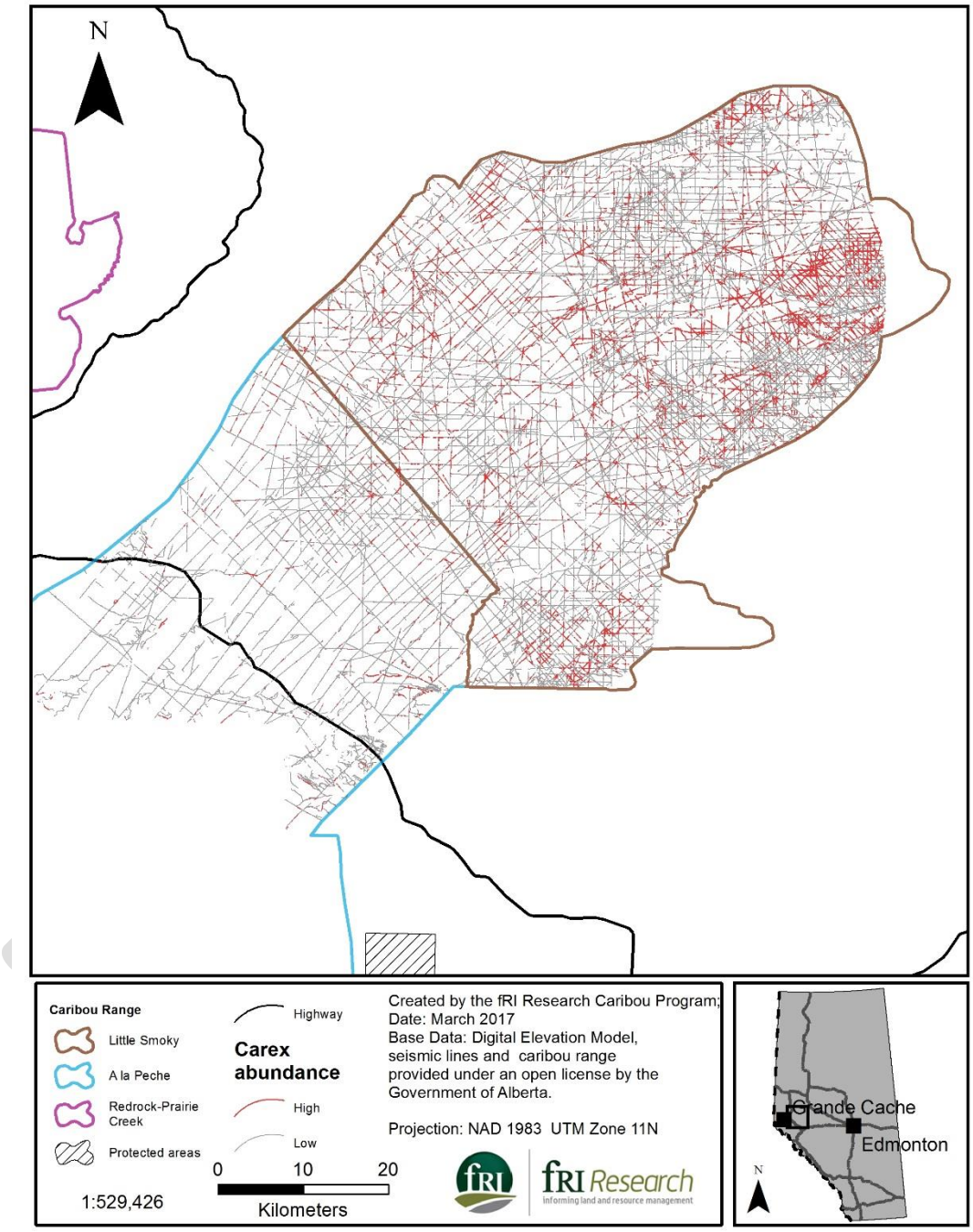

Figure 4.2. Seismic lines with a high and low predicted abundance of Carex spp. in the LSM/ALP caribou range from field data collected between 2014 and 2015.

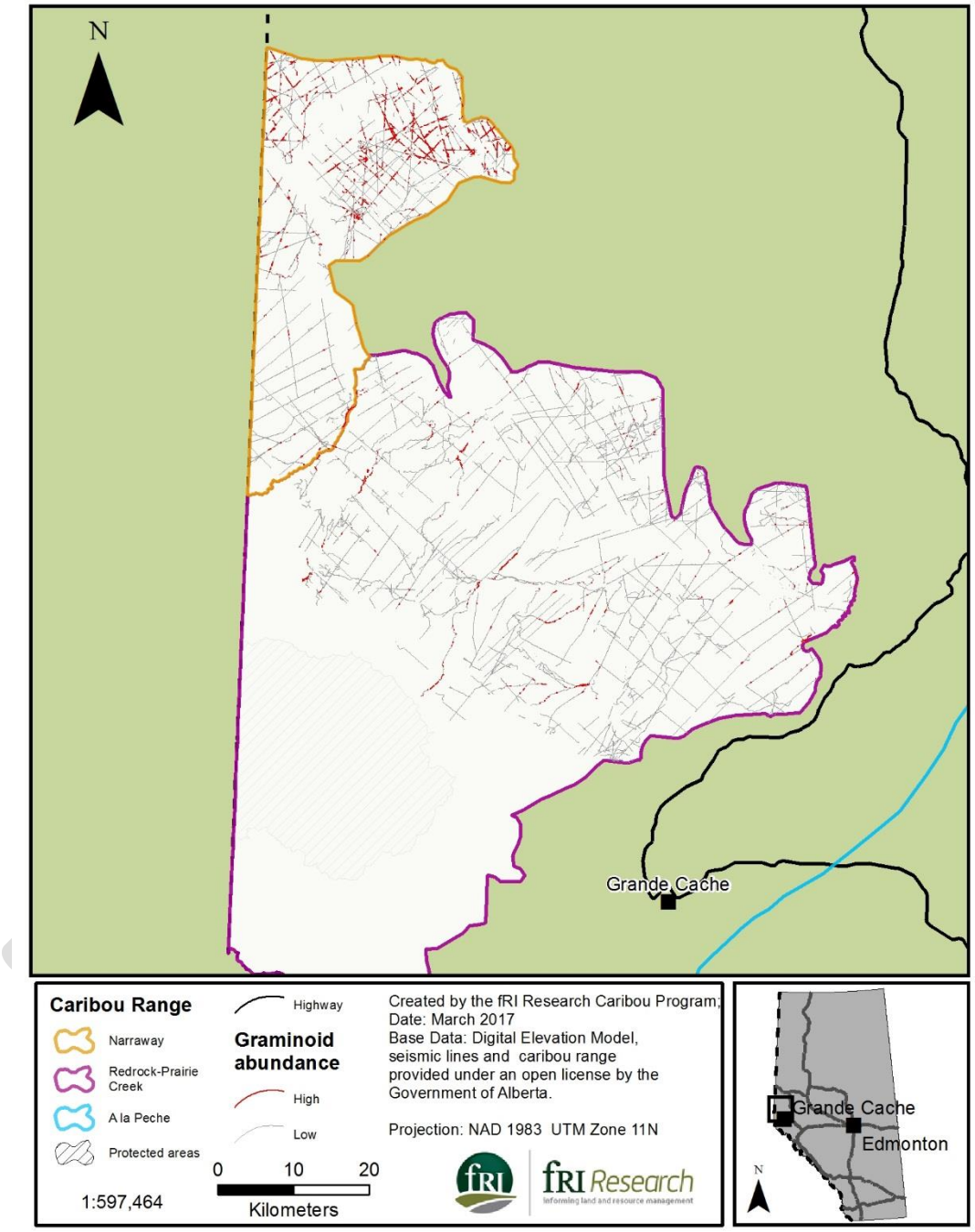

Figure 4.3. Seismic lines with a high and low predicted abundance of Graminoid species in the RPC/NAR caribou range from field data collected between 2014 and 2015.

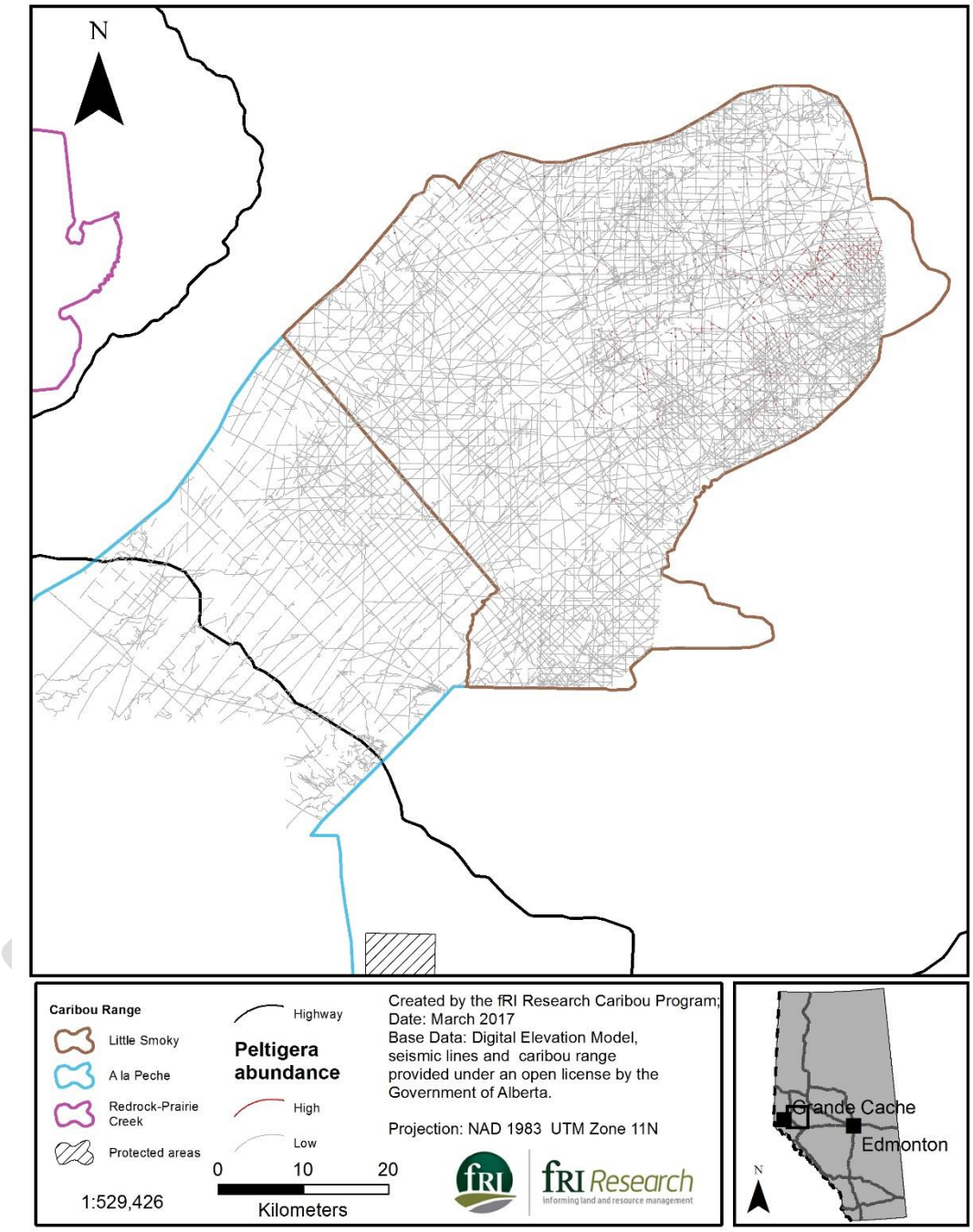

Figure 4.4. Seismic lines with a high and low predicted abundance of Peltigera spp. in the LSM/ALP caribou range from field data collected between 2014 and 2015.

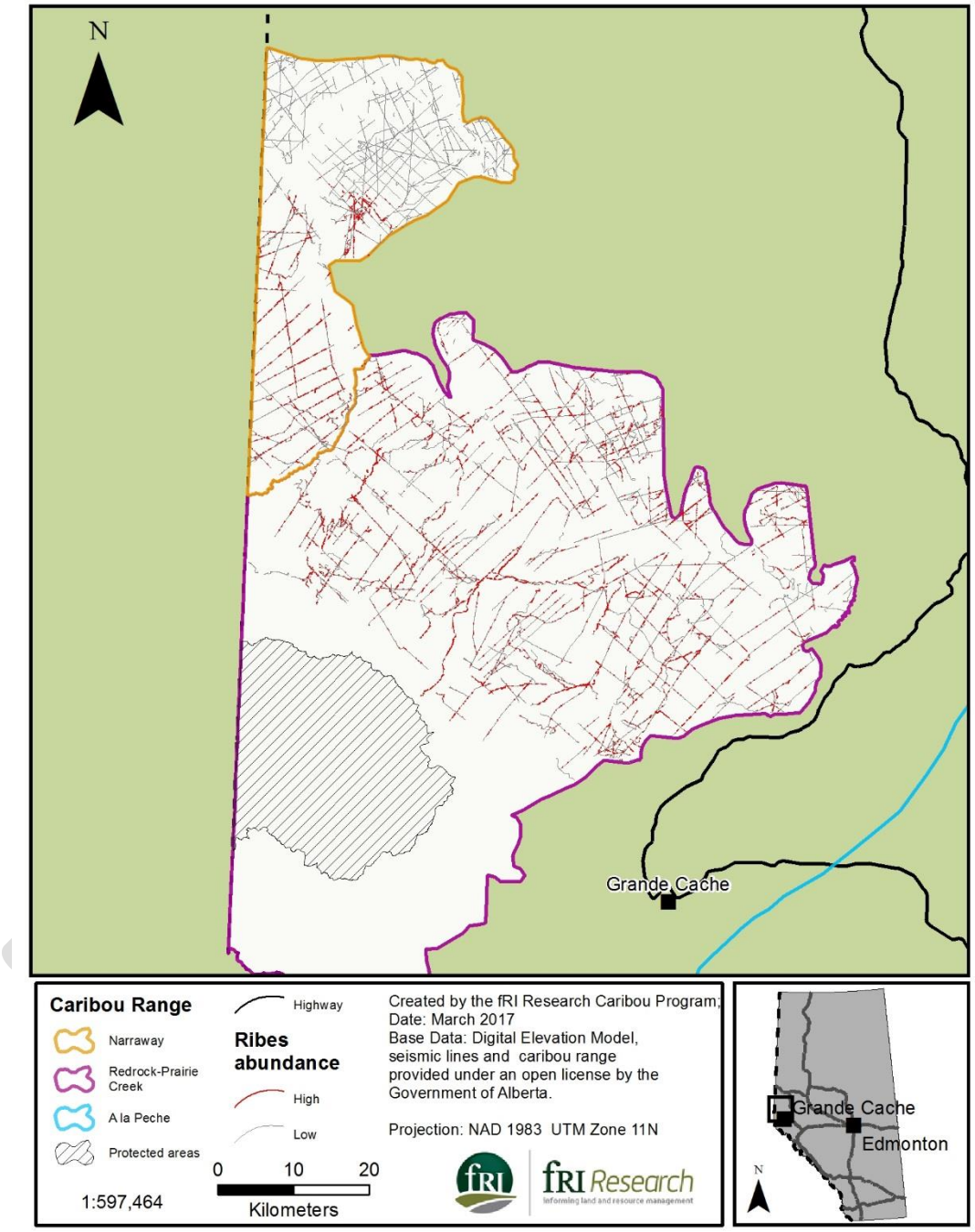

Figure 4.5. Seismic lines with a high and low predicted abundance of Ribes spp. in the RPC/NAR caribou range from field data collected between 2014 and 2015.

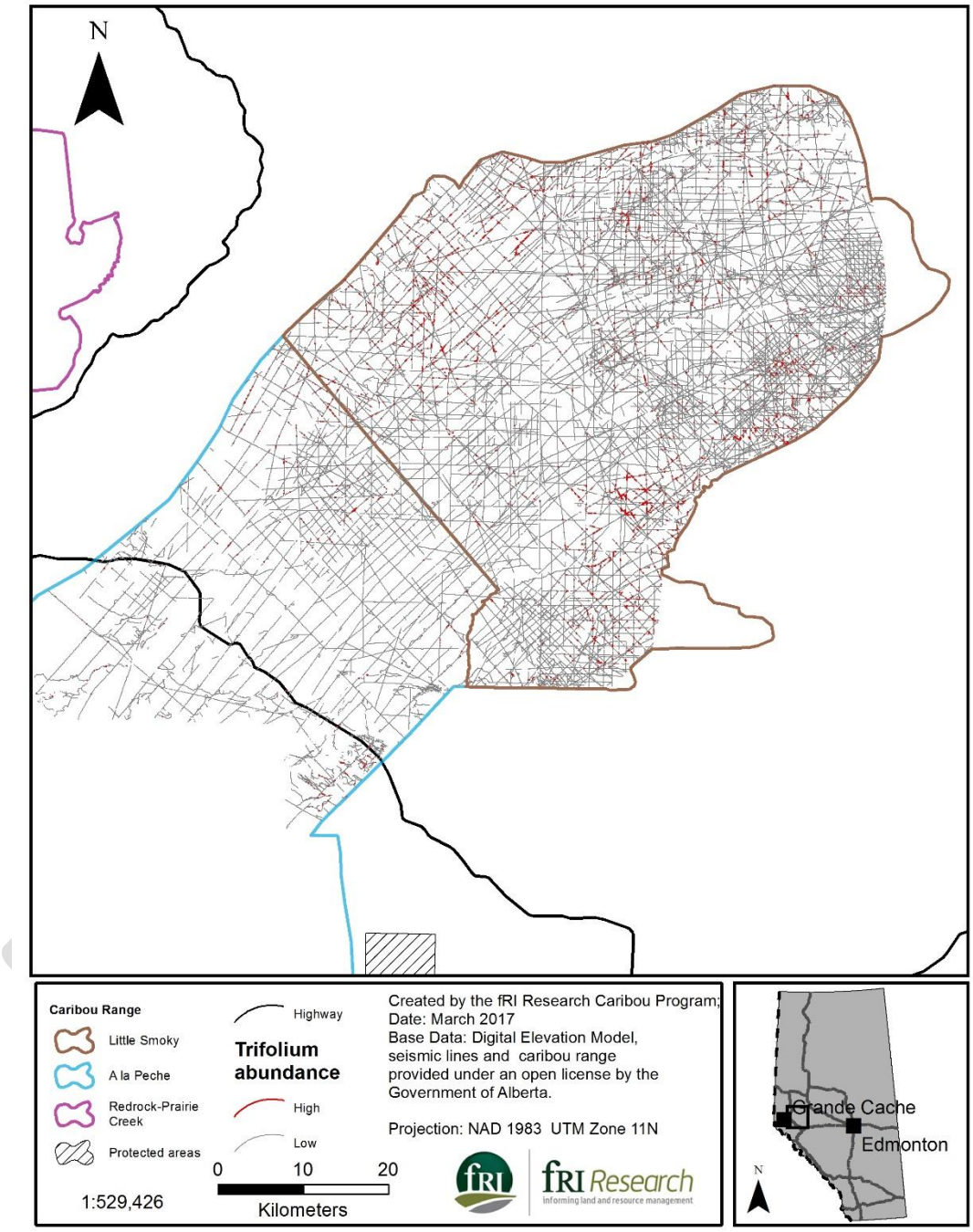

Figure 4.6. Seismic lines with a high and low predicted abundance of Trifolium spp. in the LSM/ALP caribou range from field data collected between 2014 and 2015.

For understory species where we had occurrence models only (i.e. abundance was not explained by environmental variables), our models identified 2,152km of seismic lines with a high probability of *Alnus* spp. occurrence in RPC/NAR, 909km of seismic lines with a high probability of *Salix* spp. occurrence in LSM/ALP, and 452km of seismic lines with a high probability of *Chamerion* spp. occurrence in LSM/ALP (Table 4.3). The spatial distributions of occurrence for these plant species and caribou ranges are shown in Figures 4.7 to 4.9.

Table 4.3. Length of seismic lines with a high (≥0.6) predicted probability of occurrence of understory species in the ALP/LSM and RPC/NAR caribou ranges from field data collected between 2014 and 2015.

Plant Species	Herd	Length of seismic lines with high probability of occurrence (km)	Length of seismic lines with predicted probabilities (km)	Percent of seismic lines with predicted high occurrence
Alnus spp.	RPC/NAR	2,152	3,940	54.63
Salix spp.	LSM/ALP	909	12,666	7.18
Chamerion spp.	LSM/ALP	452	12,959	3.49

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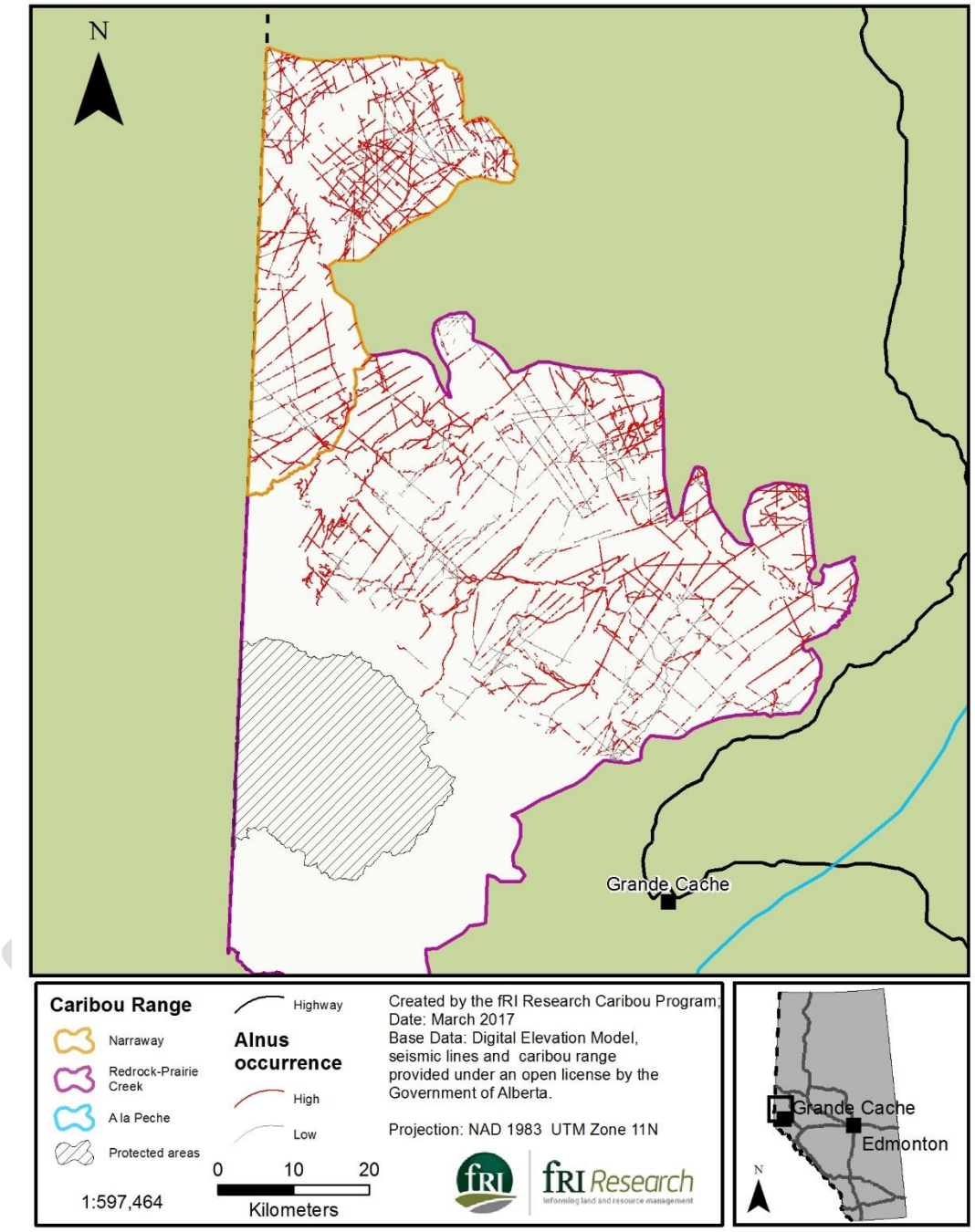

Figure 4.7. Seismic lines with a predicted high and low probability of occurrence of Alnus spp. in the RPC/NAR caribou range from field data collected between 2014 and 2015.

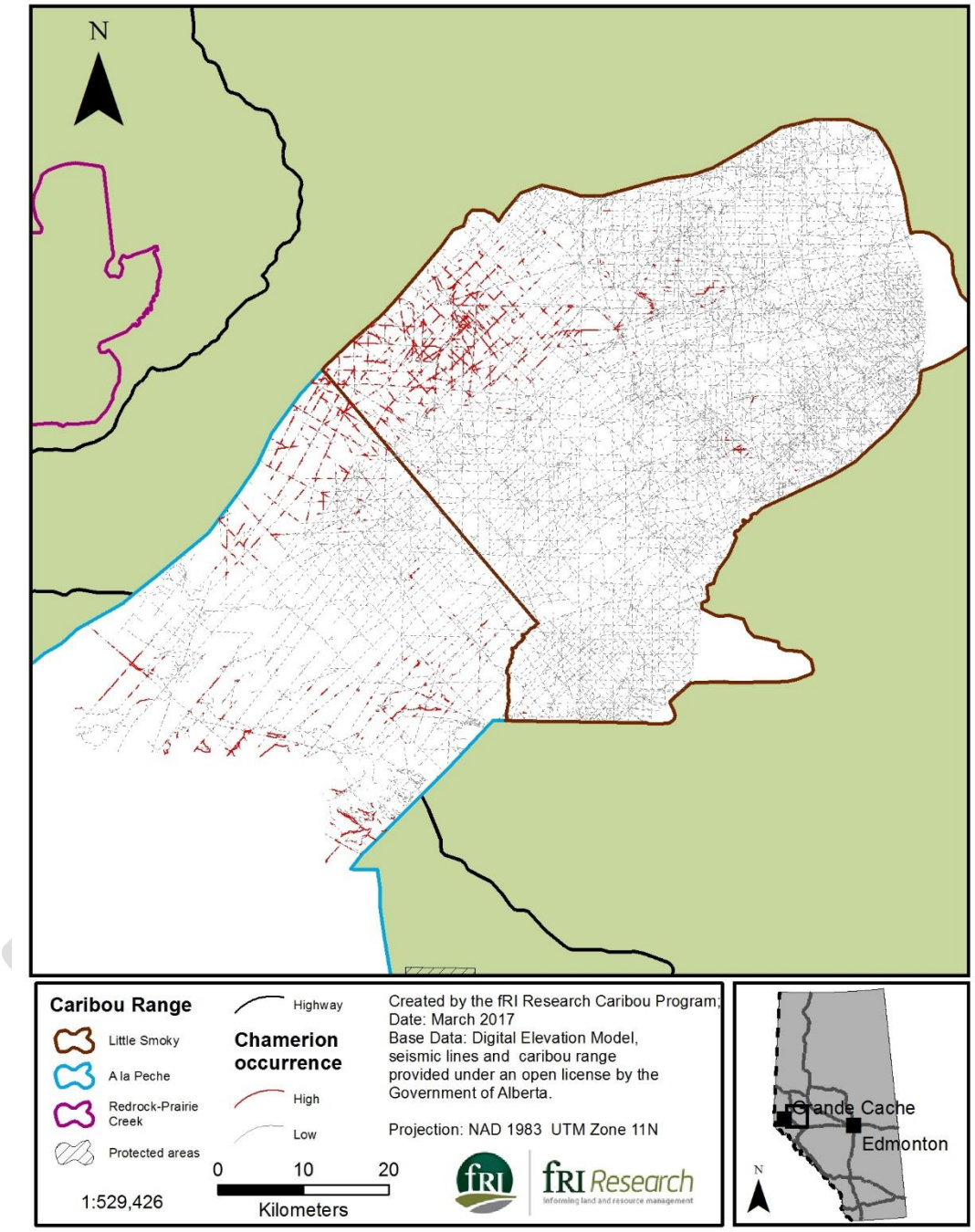

Figure 4.8. Seismic lines with a predicted high and low probability of occurrence of Chamerion spp. in the LSM/ALP caribou range from field data collected between 2014 and 2015.

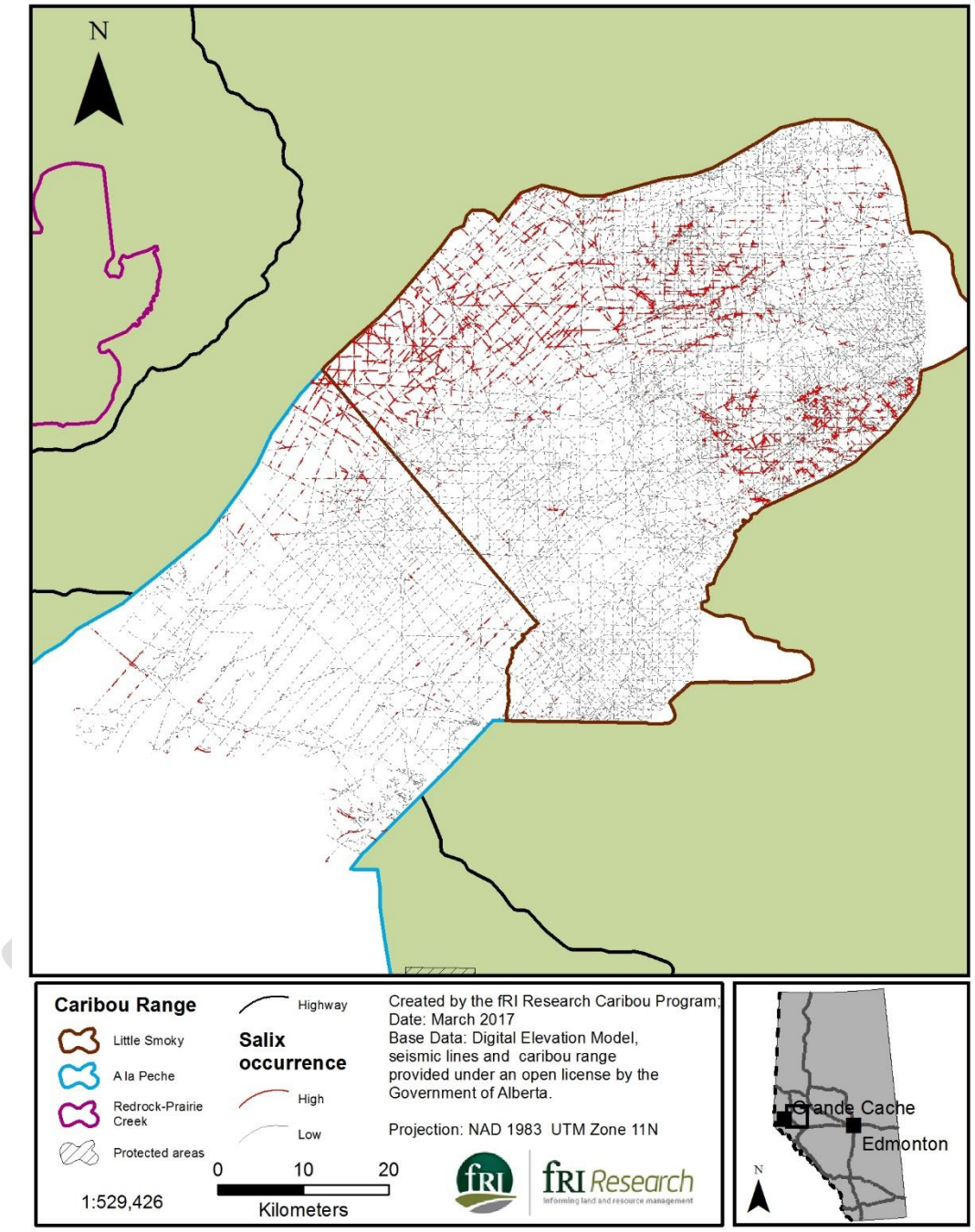

Figure 4.9. Seismic lines with a predicted high and low probability of occurrence of Salix spp. in the LSM/ALP caribou range from field data collected between 2014 and 2015.

5. MAPPING WILDLIFE USE OF SEISMIC LINES

Karine Pigeon

5.1 METHODS

We used tracks and signs models developed in Chapter 3 to map the probability of seismic line use by deer, elk, and bear in west-central Alberta. We generated probabilities using the intercepts and coefficients from the best models for each species, as determined by AIC model selection (see Appendix 5: Table A5.1 and Table A5.2).

We applied coefficients and intercepts in a GIS to calculate rasters of the probability of use for each species within the four caribou herds of west-central Alberta. We defined probabilities ≥ 0.6 as "high" use, and we calculated the length and percentage of seismic lines with high use for species within the four herd ranges combined. We did not generate herd-specific models of tracks and signs because of low sample sizes (Chapter 3, Appendix 5).

5.2. RESULTS

In west-central Alberta, 10,596km of seismic lines were associated with high probability of use by deer, while 584km and 7,035km of seismic lines were associated with high probability of use by elk and bear species respectively (Table 5.1). Figure 5.1 to 5.3 show the probability of seismic line use in west-central Alberta for deer, elk, and bear respectively.

Table 5.1. Length of seismic lines with predicted high probability of use on seismic lines for deer, elk, and bear species in the ALP/LSM and RPC/NAR caribou ranges of west-central Alberta using tracks and signs models developed from data collected on seismic lines between 2013 and 2015.

	Seismic lines with high probability of use	
Species	Length (km)	Percent
Deer	10,596	84
Elk	584	3
Bear	7,035	40

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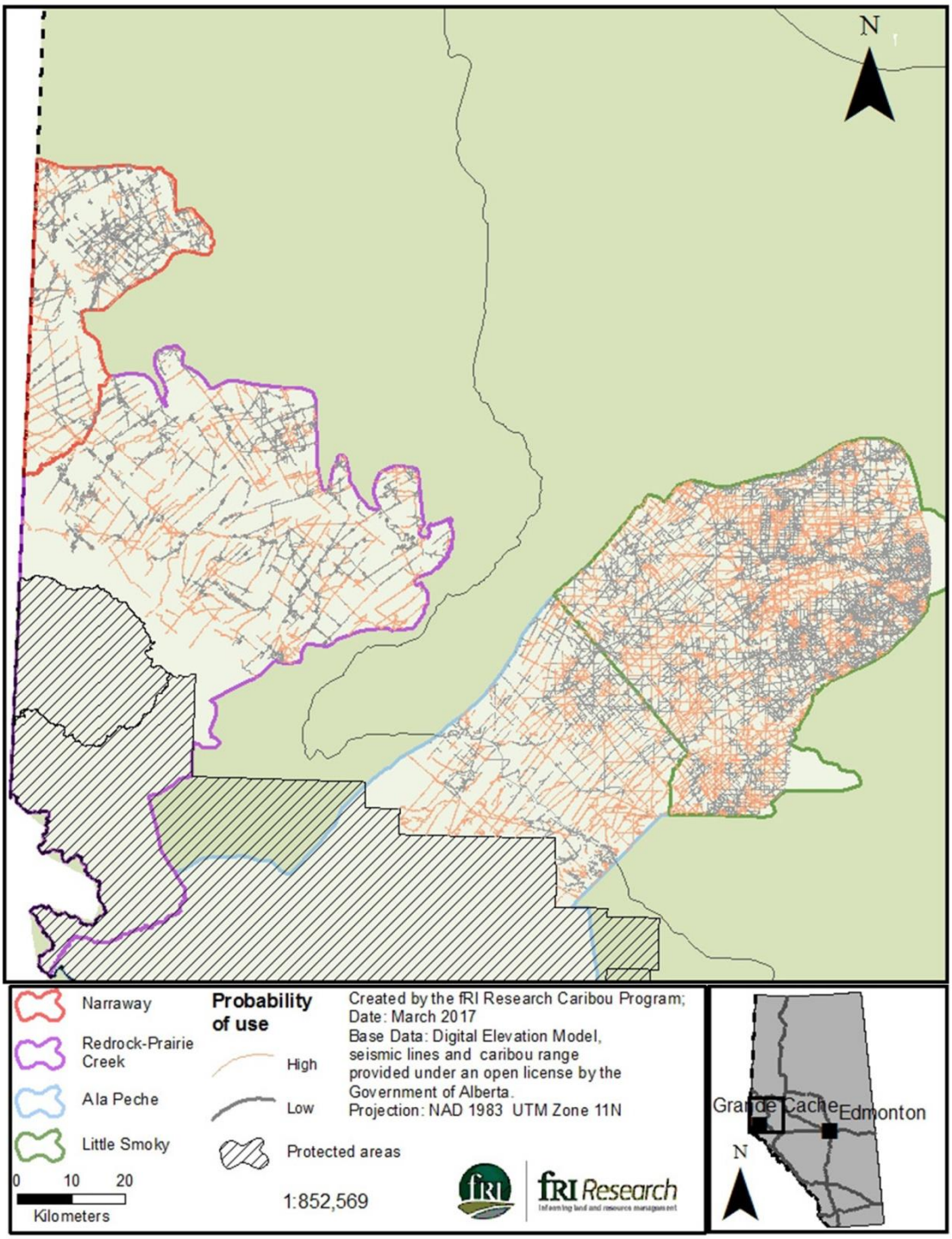

Figure 5.1. Seismic lines with a predicted high and low probability of deer use in LSM/ALP and RPC/NAR herd ranges of west-central Alberta using tracks and signs models developed from data collected on seismic lines between 2013 and 2015.

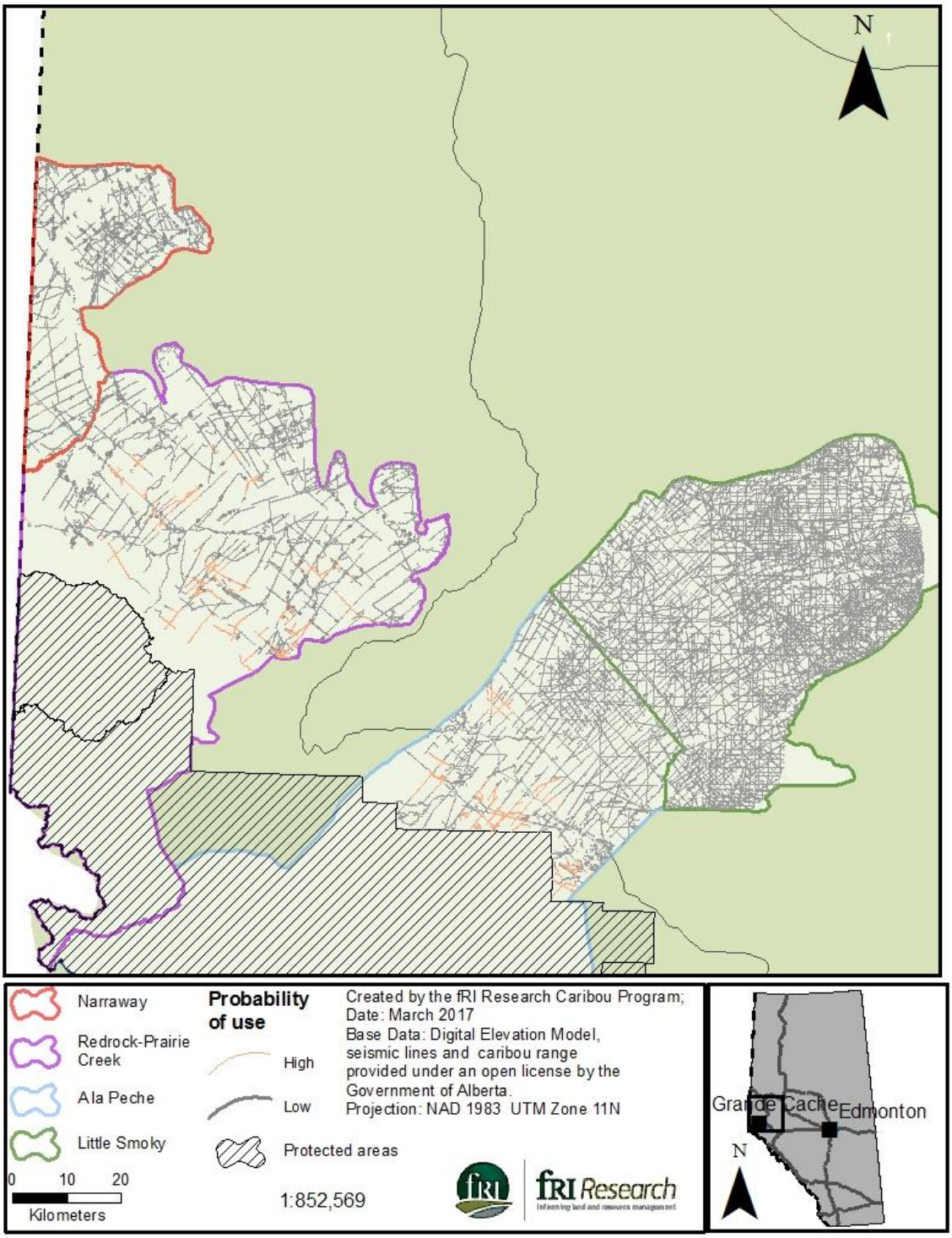

Figure 5.2. Seismic lines with a predicted high and low probability of elk use in LSM/ALP and RPC/NAR herd ranges of west-central Alberta using tracks and signs models developed from data collected on seismic lines between 2013 and 2015.

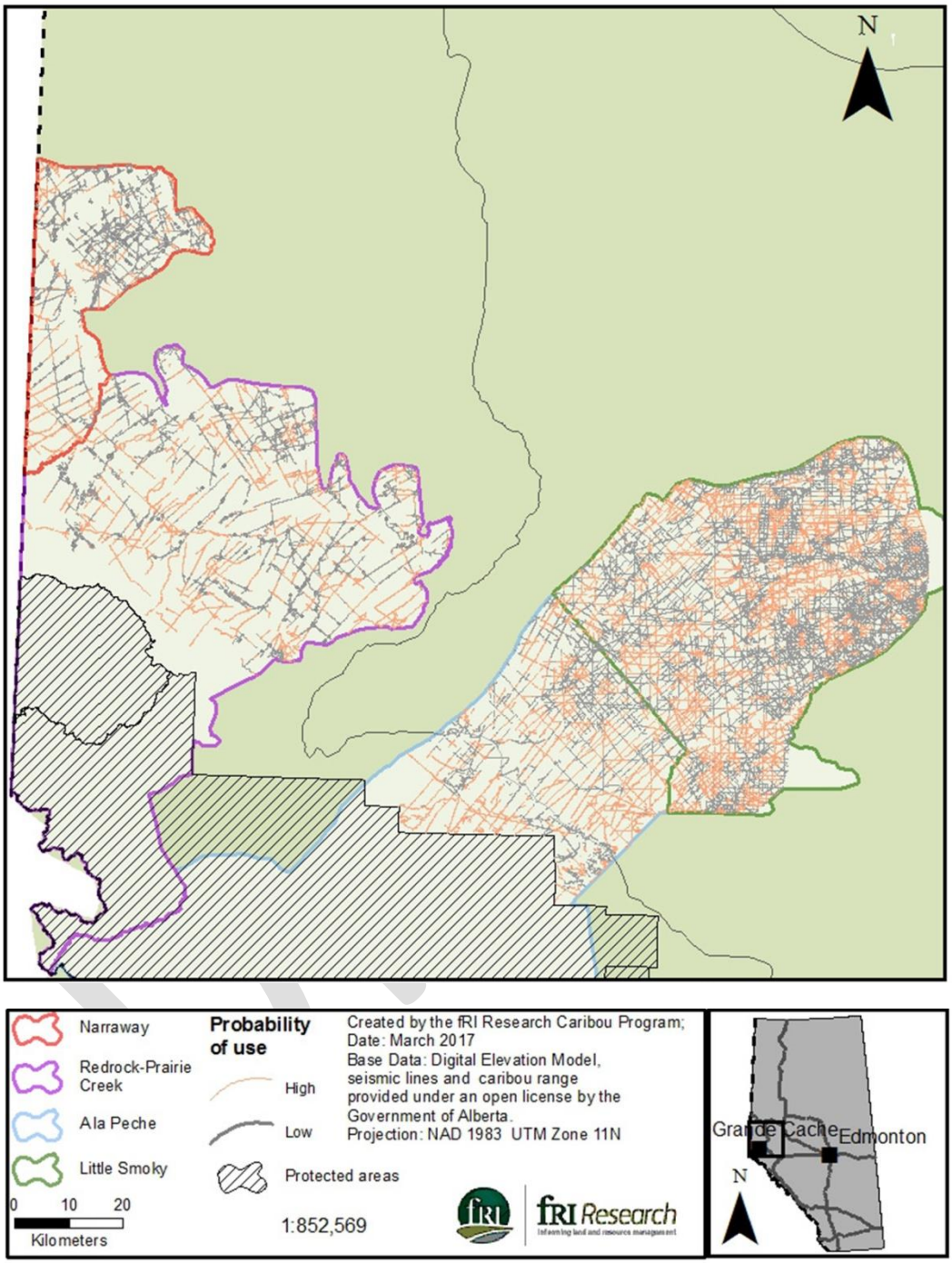

Figure 5.3. Seismic lines with a predicted high and low probability of bear use in LSM/ALP and RPC/NAR herd ranges of west-central Alberta using tracks and signs models developed from data collected on seismic lines between 2013 and 2015.

6. PRIORITY SEISMIC LINES FOR RESTORATION – UNDERSTORY SPECIES AND ALTERNATE PREY

Doug MacNearney

6.1. INTRODUCTION

Because of limited conservation resources available for caribou recovery, prioritizing which seismic lines and other disturbance features will receive treatment first could increase the efficacy of restoration efforts, and the probability that caribou will persist on the landscape. In Chapters 2 to 5, we explored the influence of environmental variables on the occurrence and abundance of understory species on seismic lines, and on the use of seismic lines by alternate prey species and predators. In this chapter, we combined results from Chapters 2 to 5 to produce spatial GIS maps identifying the priority restoration status of each seismic line in our study area based on the use of seismic lines by alternate prey, and based on the occurrence and abundance of understory species that are forage species for alternate prey, and/or that may prevent natural regeneration of trees on seismic lines.

The resulting maps of alternate prey use and understory species growth can be combined with additional GIS layers (i.e. caribou probability of selection, regeneration trajectories, predator occurrence, and caribou zones identified in range plans) to further inform prioritization schedules for seismic line restoration, and to focus efforts to increase benefit for caribou (i.e. reduce overlap with alternate prey).

6.2. METHODS: ASSESSING THE PROBABILITY OF OVERLAP AMONG ALTERNATE PREY, FORAGE VEGETATION, AND CARIBOU.

We assigned priority levels for restoration to seismic line segments based on the probability of overlap between alternate prey on seismic lines, and the occurrence and abundance of understory species on seismic lines. Details of variables used to build spatial models, and model building processes are in Appendices 2 to 4.

We first attributed the probability of understory species occurrence and abundance (from vegetation field data; Chapter 2) and the probability of alternate prey use (from tracks and signs data; Chapter 3), to individual 100m seismic line segments across each caribou range. For understory species, because of variations in species models (different species, occurrence only models, and occurrence and abundance models) between herd ranges (see Chapter 4 for individual understory species maps), first we calculated 1) probability of occurrence values using the maximum predicted probability of occurrence of any understory species in a given herd, and 2) abundance values using maximum values of relative abundance (abundance

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given occupancy) of any understory species (Table 6.1). Then, we used the sum of these two variables as an index of understory species occurrence and abundance on each 100m seismic line segment.

For alternate prey, we calculated the maximum probability of use among alternate prey species (deer and elk) to identify 100m seismic line segments with a high probability of use for alternate prey (Table 6.1). After extracting all probabilities to seismic line segments, each seismic line segment was attributed with the 'probability of alternate prey use', and an 'index of understory species occurrence and abundance'.

As a final step, we binned the probability of alternate prey use and the understory species index into four quantiles (low, medium, high, and very high; range 1 to 4), and developed a ranking matrix based on combinations of these quantiles (Table 6.2). We used this ranking matrix to create a categorical classification scheme that we used to attribute each 100m seismic line segment with a restoration priority (low to very high) based on overlap between alternate prey and understory species on seismic lines (Table 6.3).

Table 6.1. Variables extracted to seismic line segments for seismic line restoration prioritization in Little Smoky (LSM), A La Peche (ALP), Redrock Prairie Creek (RPC), Narraway (NAR), and Chinchaga caribou herd ranges.

		LSM/ALP	RPC/NAR	Chinchaga
Animal use	Deer	X	X	
	Elk	X	X	
Understory species (Occurrence)	*Alnus*	X	X	
	Betula			X
	Carex	X		
	Chamerion	X		
	Graminoid		X	X
	Ribes		X	
	Salix	X		
	Trifolium	X		
Understory species (Occurrence*Abundance)	*Betula*			X
	Carex	X		
	Graminoid		X	
	Ribes		X	
	Trifolium	X		

Table 6.2. Ranking scheme used to identify the relative probability of overlap between alternate prey use and understory species occurrence and abundance (index) for 100m seismic line segments within the Little Smoky, A La Peche, Redrock Prairie Creek, Narraway, and Chinchaga caribou ranges.

		Alternate Prey Use			
		Low	Medium	High	Very High
Understory species index	Low	2	3	4	5
	Medium	3	4	5	6
	High	4	5	6	7
	Very High	5	6	7	8

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Table 6.3. Classification scheme for assigning priority levels to seismic lines based on overlap between alternate prey use and understory species occurrence and abundance (index) for seismic line segments within the Little Smoky, A La Peche, Redrock Prairie Creek, Narraway, and Chinchaga caribou ranges.

		Alternate Prey Use			
		Low	Medium	High	Very High
Understory species index	Low	1	1	2	3
	Medium	1	2	3	4
	High	2	3	4	5
	Very High	3	4	5	6

6.3. Results

Across west-central Alberta caribou herds ,we identified 145.5 km (0.9%) of seismic lines as very high, and 2,670 km (17.1%) as high priority for restoration based on the potential probability of overlap between alternate prey and understory species occurrence (Table 6.4; Figure 6.1). In the Chinchaga caribou range, GIS variables were unsuccessful in predicting alternate prey use, we therefore produced priority maps for Chinchaga using understory species occurrence and abundance only (Figure 6.2). Because of the lack of ecosite data available for a portion of the Chinchaga range, we did not consider 17,176 km (32%) of the seismic lines in Chinchaga for priority rankings. Of the remaining seismic lines in Chinchaga, we identified 13,219 km (25%) as high priority for restoration based on the occurrence and abundance of understory species.

Table 6.4. Length (km) and percent of total seismic footprint attributed with each restoration priority category based on the potential overlap between alternate prey use and the understory species index overlap within the A La Peche (ALP), Little Smoky (LSM), Redrock Prairie Creek (RPC), and Narraway (NAR) caribou ranges in west-central Alberta between 2013 and 2015. Categories of restoration priorities are defined in Table 6.2.

	Priority for Restoration					
	Low	Medium-Low	Medium	Medium-High	High	Very High
ALP	283 km (12.2%)	554 km (23.8%)	544 km (23.4%)	402 km (17.2%)	443 km (19.0%)	22 km (0.9%)
LSM	1,340 km (14.2%)	2,064 km (21.9%)	2,179 km (23.1%)	1,789 km (19.0%)	1,512 km (16.0%)	108 km (1.2%)
RPC	352 km (13.5%)	592 km (22.8%)	628 km (24.2%)	494 km (19.0%)	494 km (19.0%)	11 km (0.4%)
NAR	195 km (15.8%)	296 km (23.9%)	275 km (22.2%)	234 km (18.9%)	221 km (17.8%)	4.5 km (0.3%)

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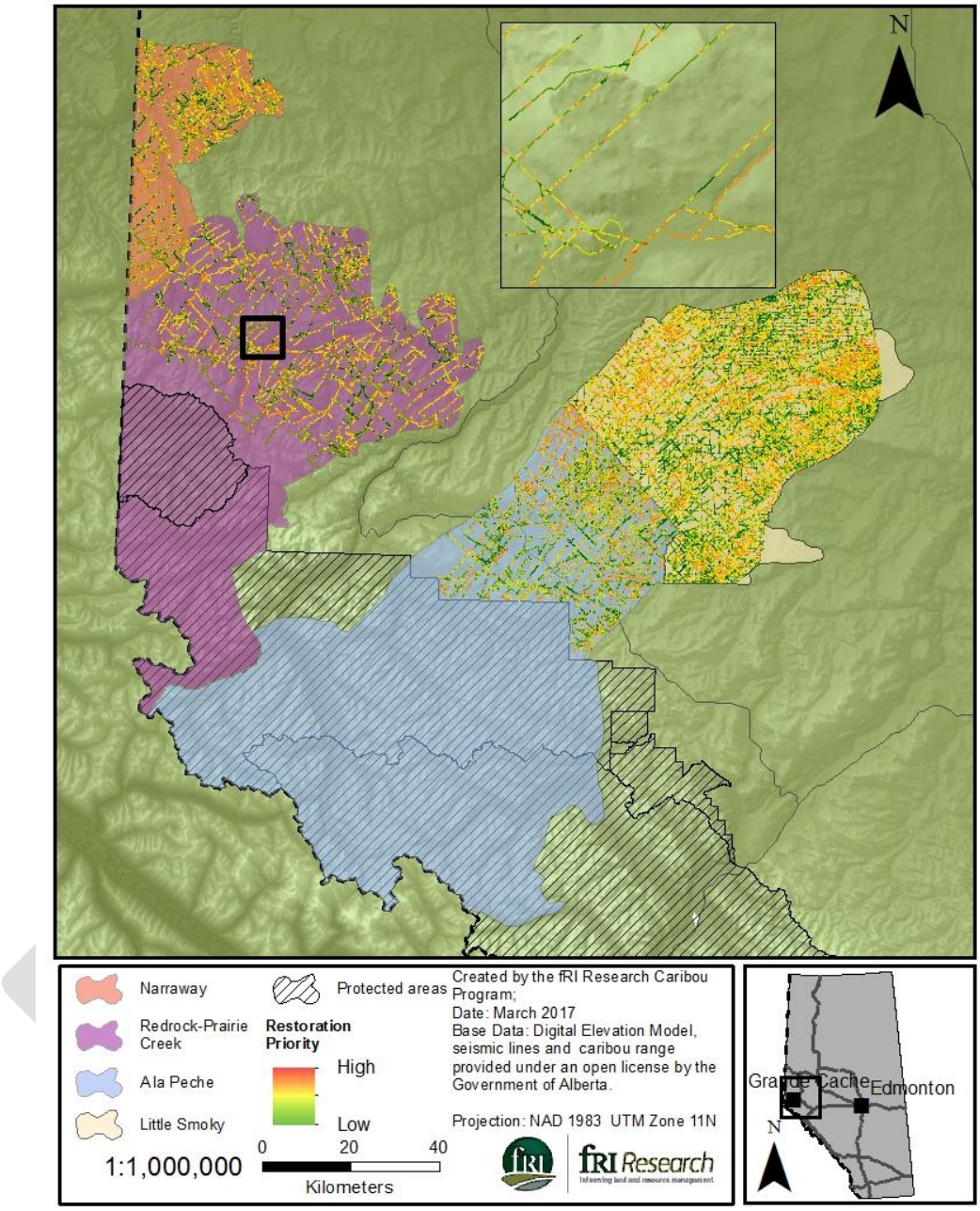

Figure 6.1. Seismic line priority ranking for restoration based on overlap between alternate prey use and the occurrence and abundance of understory species on seismic lines in the Little Smoky, A La Peche, Redrock Prairie Creek, and Narraway caribou ranges in west-central Alberta, Canada. Maps were created based on landscape characteristics in 2015.

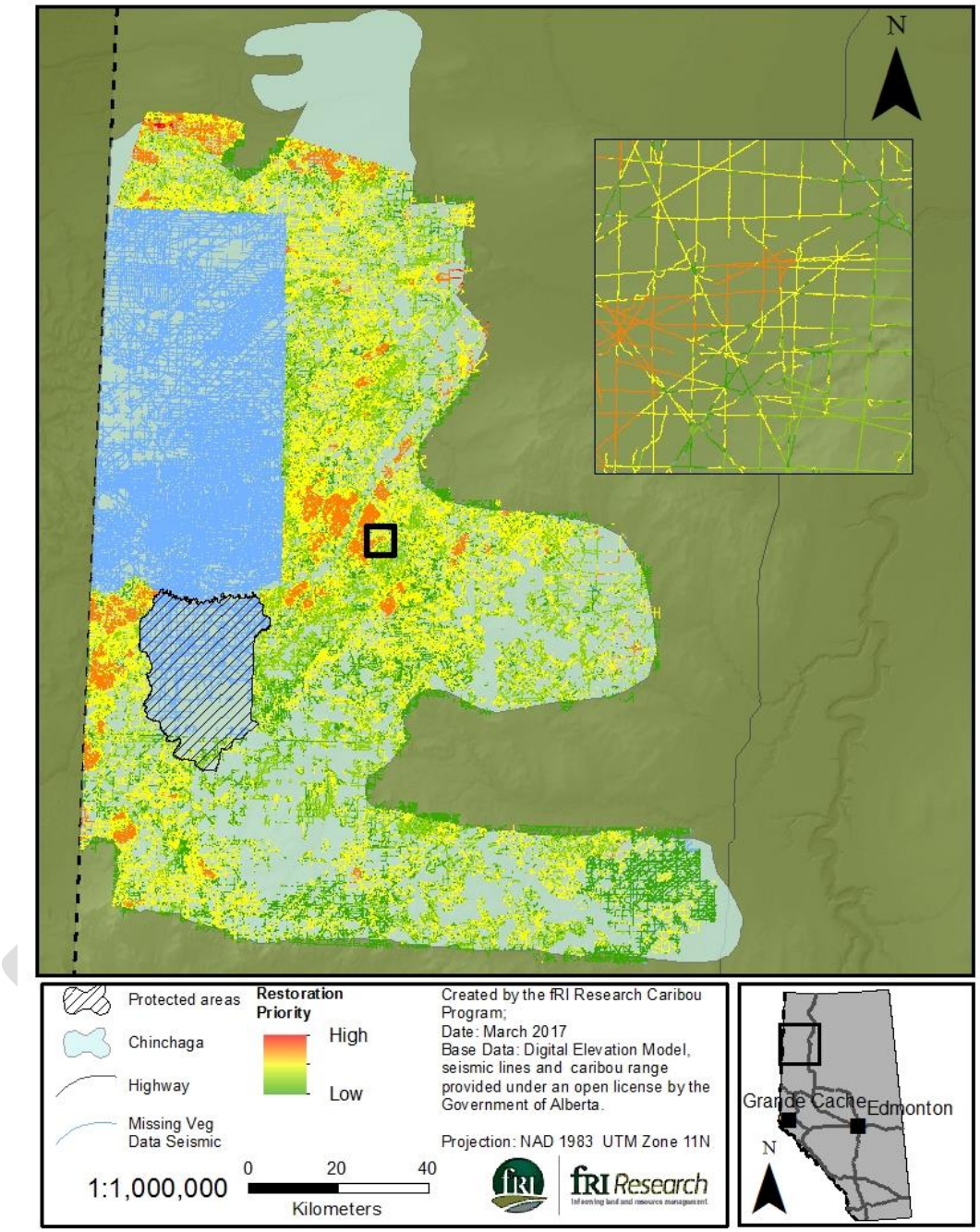

Figure 6.2. Seismic line priority ranking for restoration based on the occurrence and abundance of understory species in the Chinchaga range in north-west Alberta. Blue shading on seismic lines indicates areas where GIS data for prediction were missing. Maps were created based on landscape characteristics in 2015.