Cumulative effects assessment for Kainai First Nation

PREPARED FOR

Kainai First Nation and JFK Law

PREPARED BY

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JFK Law
Vancouver, BC

ATTENTION: Jeff Langlois
REFERENCE: Cumulative effects assessment for Kainai First Nation

Dear Jeff:

Please find below Integral Ecology Group's final report for an initial assessment of cumulative effects of land development on ecological indicators of cultural importance to the Kainai First Nation. We trust this information meets your requirements at this time. Thank you for Integral Ecology Group's involvement in this important work. Should you have any questions or comments about this document, please do not hesitate to contact me at the e-mail address or phone number listed below.

Yours sincerely,

<Original signed by>

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SUGGESTED CITATION

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ACKNOWLEDGEMENTS

We would like to thank the Kainai First Nation community members and staff who shared their time and expertise during the meetings for this project. We greatly appreciate the traditional knowledge and observations that were shared to inform this project. We would also like to acknowledge the contributions of staff at JFK Law staff, including Jeff Langlois and Clayton Leonard.

LIMITATIONS

The interpretations and conclusions in the report reflect the understanding of the authors, but do not necessarily provide a comprehensive portrayal of the perspectives of all collaborating community members.

EXECUTIVE SUMMARY

This report presents an initial assessment of cumulative effects of land development on ecological indicators of cultural importance to Kainai First Nation (Blood Tribe) in Alberta. This work employed the ALCES model to examine three issues of cumulative effects:

1. industrial and regulatory activities (including construction of development footprint and land-use zoning such as protected areas) that potentially restrict or exclude land uses by Blood Tribe members;
2. the loss of remaining relatively intact ecosystems within the Blood Tribe traditional territory; and,
3. the effects of current development activities on fish and wildlife on which Blood Tribe traditional land uses depend.

The study was conducted at two scales:

1. the regional study area, to assess impacts near the Blood Tribe reserve; and,
2. the focal study area, which involved a focussed analysis of effects in an area around the proposed Benga Grassy Mountain mine development.

Prior to European settlement, the regional study area's intact ecosystems would have supported abundant fish and wildlife populations of importance to Blood Tribe members. The prairies in the central and eastern portion of the region would have supported species associated with grassland such as elk and mule deer, whereas species associated with forest such as moose would have been more abundant to the west. Since European settlement, almost half of the regional landscape surrounding the Blood Tribe reserve has been converted to farmland and other anthropogenic footprints and larger patches of intact natural land cover are now largely restricted to protected areas. The loss of natural land cover has detrimentally affected fish and wildlife habitat and facilitated increased angling and hunting pressure. Habitat indices that incorporate the consequences of both habitat loss and risk of mortality are estimated to be substantially below natural levels. Elk and mule deer habitat is less than half of pre-industrial levels. These reductions in habitat imply high risk to wildlife and associated traditional land use. The fish index has also declined below its natural condition, mainly due to fragmentation of habitat and increased access for anglers by roads and other footprints, resulting in moderate risk.

Opportunities to fish and hunt are further restricted by inability to access the land for traditional land use due to private ownership, other land tenure (i.e., protected areas), and proximity to non-traditional land use activities. About 80% of the regional study area is estimated to be inaccessible for traditional land use. As a result, opportunity for traditional

land uses (e.g., hunting mule deer and elk) is less than half what would be suggested by habitat alone. These declines in habitat and low accessibility have resulted in reduced fishing and hunting opportunities, and increased the importance for traditional land use of comparatively intact landscapes to the west such as the focal study area.

In the focal study, loss of natural land cover has been lower than in the regional study area but is still substantial with 18% converted to anthropogenic footprint. Much of the eastern portion has been converted to farmland, and elsewhere natural land cover is fragmented by energy sector footprints (pipelines, seismic lines, well sites) and roads that provide access for hunting and angling. As a result, habitat is substantially below natural conditions, placing mule deer and elk, and associated traditional land use at moderate risk. The fish community is also impacted by fragmentation and access to anglers, resulting in moderate risk.

Projected growth in footprint over the next 50 years in the study area is relatively minor, and wildlife risk remained moderate whereas risk to the fish community increased to high in response to climate change (warming). The greatest contributor to footprint expansion during the 50-year simulation was mining, primarily from development of the Grassy Mountain mine. As such, the proposed mining development is projected to contribute to ongoing loss of habitat and associated opportunities for traditional land use, and impacts may be greater if potential impacts of water contamination (e.g., selenium, calcite) were to be considered. As was the case with the regional study area, accessibility of the land for traditional activities is also of concern with an estimated 40% being inaccessible. When inaccessibility is combined with habitat effectiveness, opportunity for hunting elk and mule deer declines to about one quarter of natural, resulting in an assessment of high risk to traditional land use.

Our analysis suggests that Blood Tribe members have experienced a substantial decline in hunting and fishing opportunities in areas close to their reserve, and thus have had these traditional-land-use activities displaced to more remote areas, including to the western focal study area. However, habitat values in this western area are also negatively impacted by land use and are lower overall due to natural conditions (high elevations, lower abundance of grassland) that are less favourable for ungulates. In addition to reduced habitat, accessibility for traditional land use is of concern due to the prevalence of private land and other impediments to traditional land use activities. When accessibility and habitat are both considered, risk to traditional land use is high in both the regional and focal study areas.

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1. INTRODUCTION

This report presents an initial assessment of cumulative effects of land development on ecological indicators of cultural importance to the Kainai First Nation (Blood Tribe) in Alberta. The report addresses three issues:

1. industrial and regulatory activities (including construction of development footprint and land-use zoning such as protected areas) that potentially restrict or exclude land uses by Blood Tribe members;
2. the loss of remaining relatively intact ecosystems within the Blood Tribe traditional territory; and,
3. the effects of current development activities on ecosystems and species on which Blood Tribe traditional land uses depend.

2. OBJECTIVES AND STUDY AREAS

The objectives of this project were to examine cumulative effects at two scales (Figure 1):

1. the focal study area:

   We completed a focussed analysis of effects in an area near the proposed Benga Grassy Mountain mine development, using the Upper Oldman Crowsnest Pass watershed as the study area. The watershed covers almost 6,000 km^2 and is one of 132 Hydrologic Unit Code (HUC) 6 watersheds in Alberta.[1]

2. the regional study area:

   We completed a broad analysis of effects in a large study area that covers approximately 62,904 km^2 and is made up of 14 HUC 6 watersheds. This study area was used to demonstrate regional impacts near the Blood Tribe reserves and a broader region identified by community members as being historically important for traditional land use. Much of the regional study area has been converted to agriculture and other land uses, and exploring

[1] HUC 6 watersheds are part of a hierarchically structured watershed classification system that ranges from HUC 2 (at the coarsest scale) to HUC 10 (as the finest scale). Watersheds are beneficial units for conservation planning (Schindler and Lee 2010) due to their organizing effect on ecosystems, as a result of hydrological connectivity and biophysical boundaries such as the Continental Divide which forms the western boundary of the watershed. Higher order (i.e., larger) watersheds typically support more biodiversity because they contain a wider range of habitats, whereas smaller watersheds are more sensitive to local disturbance. The Upper Oldman Crowsnest Pass watershed was selected to balance these considerations (i.e., diversity and sensitivity). The watershed contains the proposed mine, but also other land uses that are active in the region including forestry (in the C5 forest management unit), agriculture (in the eastern portion of the basin around Pincher Creek), and some oil and gas development.

cumulative effects at this scale provides the perspective to assess the importance of the relatively less-impacted focal study area. Results for the regional study area are summarized in the main body of the report and described in greater detail in an appendix.

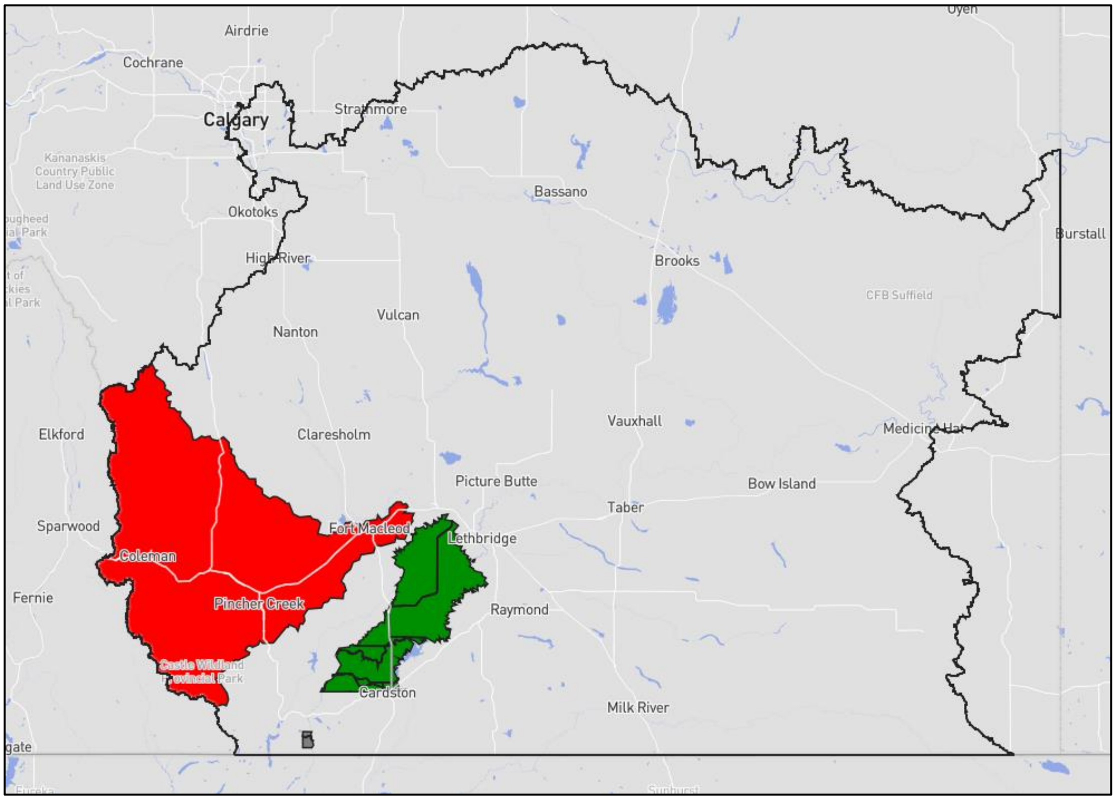

Figure 1 Study areas and reserves. The focal study area is shown in red within the regional study area, which has a black outline. Blood tribe reserves are shown in green and grey.

3. METHODS

This project applied the ALCES Online landscape simulation model (A Landscape Cumulative Effects Simulator [www.alces.ca]) to explore the effects of current and future land-use patterns on landscape, wildlife/fish, and TLU indicators in the study areas. ALCES Online is a landscape simulation tool for comprehensive assessment of the cumulative effects of multiple land uses and natural disturbances to ecosystems. ALCES Online has been used by government, First Nations, academic, industrial sectors and non-government organizations to inform land-use planning in multiple Canadian jurisdictions (Alberta, British Columbia, Ontario, Manitoba, Northwest Territories, Saskatchewan) and in India and Australia. The model operates by subjecting a cell-based representation of today's landscape to user-defined scenarios of past and future natural disturbance regimes and human land uses. Methods are summarized here; see Appendix A for more detailed description of the underlying assumptions of the model.

3.1. TIMEFRAMES FOR ANALYSIS

The timeframes used in our analysis differ by study area:

1. The focal study area – we analyzed current conditions for selected indicators, and contrasted these against two other time periods:
    a. Pre-industrial, or range of natural variation (RNV) – we removed development footprints from the landscape and simulated the fire regime in the absence of suppression to estimate the natural range of variation in forest age and wildlife indicators. These simulations provide reference conditions against which to compare current indicator performance. Greater departure from the simulated RNV entails greater risk to the indicator and associated traditional uses.
    b. Future forecast – we constructed a 50-year simulation of future landscape changes. The Benga Grassy Mountain mine footprint is relatively large in the focal study area, but there are also impacts from forestry, oil and gas, settlements, and recreation. We forecasted growth in these sectors to assess plausible future cumulative effects. The simulated rate of development was based on information obtained from coal mine environmental assessments, forestry management plans, energy development projections from the Alberta Energy Regulator and National Energy Board, and population projections from the Government of Alberta.
2. The regional study area – for the broader study area, we focussed on the contrast between pre-industrial RNV conditions and current conditions. A forecast simulation was not constructed for this broader study area.

3.2. SELECTION OF INDICATORS

We selected the following groups of indicators for assessment:

1. Development footprint and protected areas – direct disturbance of land by industrial/residential development, plus any clear indirect effects of land tenure such as parks with restricted uses.
2. Area of intact landscape/habitat – measuring intact ecosystems provides a way to characterize the proportion of a landscape that is undisturbed and not affected by edge of an anthropogenic (human-caused) feature. Many animal species prefer “core” (non-fragmented) habitat and respond negatively to anthropogenic edge due to

indirect sensory effects (e.g., noise, odours, etc.) or increased mortality. Indigenous land users are also affected by edge effects and will often avoid areas of the landscape that are not intact when practicing certain traditional land uses. For this assessment, ecosystem intactness was calculated with the following two indicators: intact core area, calculated as the total extent of 200 m cells that do not contain footprint or farmland; and intact patch size, calculated as the size of each patch of cells that does not contain footprint or farmland.

3. Wildlife – the treaties and law in Canada recognize and affirm the rights of indigenous people to hunt, fish, and practice their culture. We selected three wildlife species (moose, elk, mule deer) to assess species of hunting importance to Blood Tribe members. For each species, a habitat index was calculated that ranged from 0 (no habitat) to 1 (habitat capable of supporting maximum wildlife density). The status of habitat was interpreted by comparing current habitat to values from RNV simulations. Departure from RNV was interpreted using hazard categories from MacPherson et al. (2014): low risk if index is >=70% of the natural value; moderate risk if index is 50%-70% of the natural value; high risk if index is 20%-50% of the natural value; and very high risk if index is <20% of the natural value. Although we did not model the response of wildlife populations directly, these hazard categories are used to infer risk of decline in wildlife and associated hunting opportunities.

   Calculation of habitat indices integrated the effects of habitat quality, based on land cover and terrain, with the risk of mortality associated with linear footprint density. We refer to the availability of suitable land cover and terrain as potential habitat. Wildlife density may still be low despite the presence of high potential habitat if mortality is high. We use the term effective habitat to refer to habitat that also considers the effect of mortality, especially human-caused mortality. Human-caused mortality is an important driver of wildlife populations that are targeted by hunting; as such, effective habitat can be substantially lower than potential habitat. The wildlife habitat results presented in this report are for effective habitat. To explore the relative magnitude of potential and effective habitat in the analysis, the reader is referred to Appendix C.

   The density of linear footprints was used as an indirect measure of the risk of mortality. Linear footprints, including roads, seismic lines, pipelines, and transmission lines, are typically correlated with mortality because they facilitate access by hunters and other predators, as well as collisions with vehicles. For example, although cutblocks and burns in northwestern Ontario were found to be similar with respect to the quality of habitat they provide, moose density was 58% lower in the cutblocks (Rempel et al. 1997). The difference was attributed to hunter access which was low in the burns due to low road density. The effect of hunting is also illustrated by Elk Island National Park, where elk pellets were found to be more than six time more abundant inside the park than outside the park (Hood and Bayley 2008). Although the stark difference is likely influenced by other factors such as habitat quality and the presence of large carnivores, hunting is also likely to play a role. In general, survival rates of elk tend to be low in areas with high road density due to hunting pressure (Rowland et al. 2004). Linear features such as seismic lines have also been found to increase the risk of predation by other species such as wolves (e.g., McKenzie et al. 2012).

The relationship applied to incorporate the effect of linear footprint density on wildlife is based on professional opinion and assumes that adequate strategies are not in place to address the cumulative effect of multiple sources of mortality including regulated hunting, indigenous hunting, poaching, and collisions with vehicles. Although there is uncertainty with respect to the specifics of the relationship, evidence exists that each of the ungulate species can be negatively affected by human access (see Appendix C for further discussion). Managing this risk requires, in particular, management of hunting pressure. This study does not consider the efficacy of hunting regulations, other than assuming that hunting does not occur within national and provincial parks and ecological reserves. Nor does this study consider whether different types of linear features (e.g., roads versus conventional seismic lines) facilitate different levels of hunter access, but rather treats all types of linear features equally, with the exception that newer seismic lines are assumed to not facilitate hunting. These assumptions imply that the assessment of wildlife habitat represents a worst case associated with the landscape's composition. More detailed analysis that simulates the response of populations (as opposed to just habitat) is needed to explore the efficacy of strategies to manage human-caused mortality (e.g., hunting regulations).

4. Fish – for rationale similar to #3 above, we selected a fish-community index where effects of stressors (climate, linear footprint, stream fragmentation) are analyzed and averaged to yield an index ranging from 0 to 1. Index values correspond to risk levels as follows: >0.9 is low risk; >0.6 to 0.9 is moderate risk; >0.3 to 0.6 is high risk; and <=0.3 is very high risk. It is important to note that the fish indicator did not assess potential water contamination because the available relationship did not incorporate potential impacts from mining (e.g., selenium, calcite) and implications for human consumption of fish.

5. Traditional land use (TLU) – TLU refers to resource harvest activities (e.g., hunting, trapping, fishing, plant gathering, travelling, etc.) as well as to the particular

connections and uses of the lands and resources related to ceremonies, customs, cultural practices, traditional governance, trade and stories. In collaboration with Blood Tribe members, we developed a TLU accessibility indicator demonstrating the accessibility of the land for traditional land use. Accessiblity was based on land ownership, protected areas, proximity to development activities and community member avoidance due to concerns about contamination, safety, and overall negative experience on the land. The TLU accessibility indicator was integrated with two wildlife indicators (mule deer, elk) to assess TLU opportunity relative to natural conditions. The TLU opportunity metric is based on the rationale that capacity to practice TLU in the landscape is affected by the status of wildlife habitat and the ability of community members to access the landscape for the purpose of practicing TLU. The TLU opportunity metric ranges from 0 to 1, with a 1 indicating maximum habitat effectiveness and accessibility for TLU, and a 0 representing no habitat and/or accessibility for TLU.

4. RESULTS

A summary of results for the regional study area is presented to show pressures felt by Blood Tribe community members around their reserves and to provide context for why the community is increasingly concerned about relatively less-impacted areas such as the focal study area. More detailed results for the focal study area are then presented. Detailed regional results are presented in Appendix B.

4.1. REGIONAL STUDY AREA – SUMMARY

Prior to European settlement, the grassland natural region that makes up a majority of the study area would have supported grassland-associated species such as elk and mule deer, and forest-dwelling species such as moose would have been limited to forested landscapes such as mountain valleys to the west. Natural wildlife and fish populations would have supported traditional land use throughout the region. Since European settlement, however, a substantial transformation has occurred, with almost half of the regional landscape surrounding the Blood Tribe reserve converted to anthropogenic cover types (Figure 2). The largest footprint is farmland, which accounts for 45% (2,848,386 ha) of the study area and 92% of total footprint. The loss of natural land cover and increased hunting and angling pressure has detrimentally affected fish and wildlife habitat,[2] resulting in high risk to elk and mule deer, and moderate risk to the fish community. Relative to pre-industrial conditions, elk and

[2] The habitat metric presented for the three wildlife indicators is defined as "effective habitat," which refers to the availability of suitable land cover and terrain (i.e., potential habitat) combined with mortality risk facilitated by access via linear footprints (roads, seismic lines, pipelines, transmission lines).

mule deer habitat has declined by 63% and 54%, respectively, whereas conditions for fish have declined by 23% (Table 1). Moose habitat has increased relative to natural conditions due to conversion of grassland to cropland, but the increase is minor and the study area is still largely unsuitable for moose.

Overall, the declines in elk, mule deer and fish have resulted in reduced opportunities to fish and to hunt on the regional landscape, an issue compounded by limited accessibility for TLU due to private land ownership, non-traditional land use activities, and community member avoidance due to concerns about contamination, safety, and overall negative experiences on the land. It is estimated that 80% of the regional study area is inaccessible for traditional land use due to presence of private land, protected areas, and non-traditional land use activities.[3] When accessibility for TLU is considered, the opportunity for mule deer and elk hunting has declined from natural conditions by 87% and 88%, respectively (Figures 3 and 4). The low opportunity for TLU across much of the regional study area makes the comparatively intact landscapes along the foothills to the west critical for Blood Tribe members to be able to practice TLU activities.

Table 1. Modelled indicator performance and risk assessment for the regional study area. See section 3.2 or Appendix A for risk categories.

Indicator	Min. RNV (or 1)	Current estimate	Current decline (%) from min. RNV	Risk level
Moose habitat*	0.02	0.07	-	-
Elk habitat*	0.84	0.31	63	High
Mule deer habitat*	0.84	0.39	54	High
Prairie INFI (fish)	1.00**	0.77	23	Moderate

*Habitat refers to effective habitat, which accounts for availability of suitable land cover and terrain combined with mortality risk associated with linear footprints.

** For INFI, any decline from a value of 1 signifies degrading conditions for the indicator. As a result, the output for this indicator is compared to 1 rather than to mean RNV.

[3] The regional modeling results likely overestimate TLU accessibility because traditional land use depends on numerous factors that have not been numerically considered here. For example, members explained that often gates and restrictions prohibit them from accessing lands that are relatively intact. Further, as regulations increase for recreational activities on surrounding land (e.g., Castle Provincial Park) less regulated but intact crown lands become increasingly busy increasing the completion for resources (e.g., hunting, fishing, and camping spots).

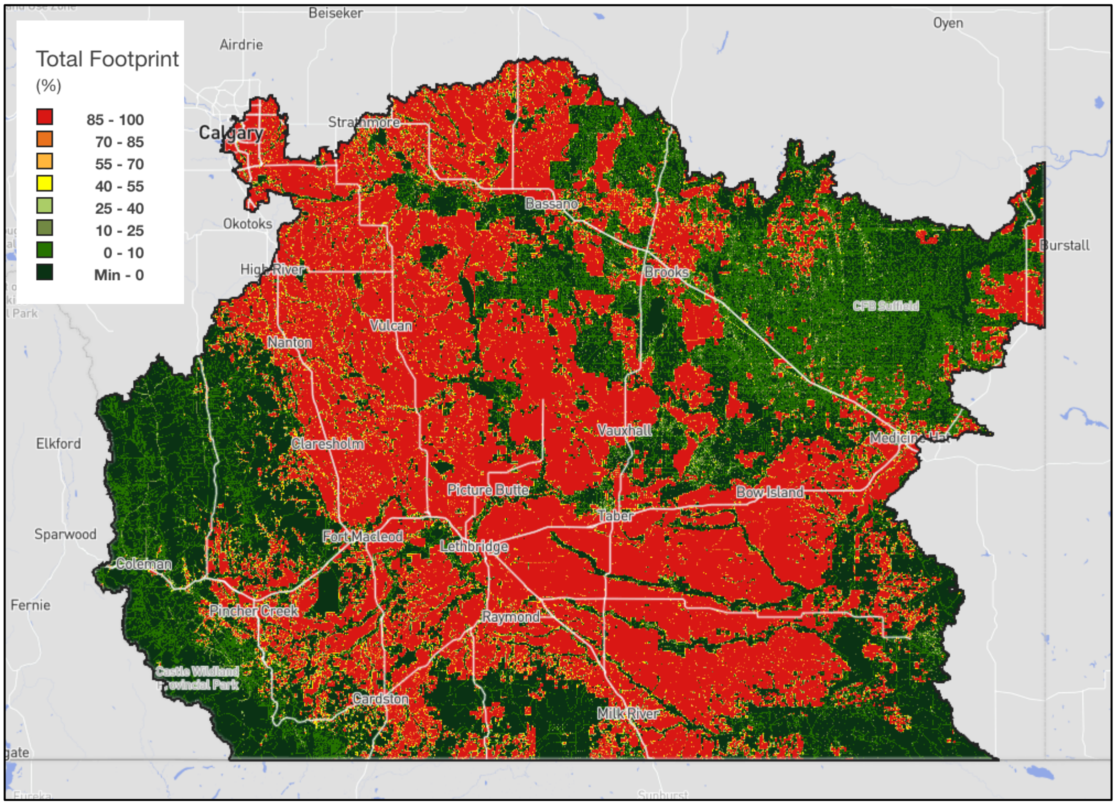

Figure 2 Current total anthropogenic footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

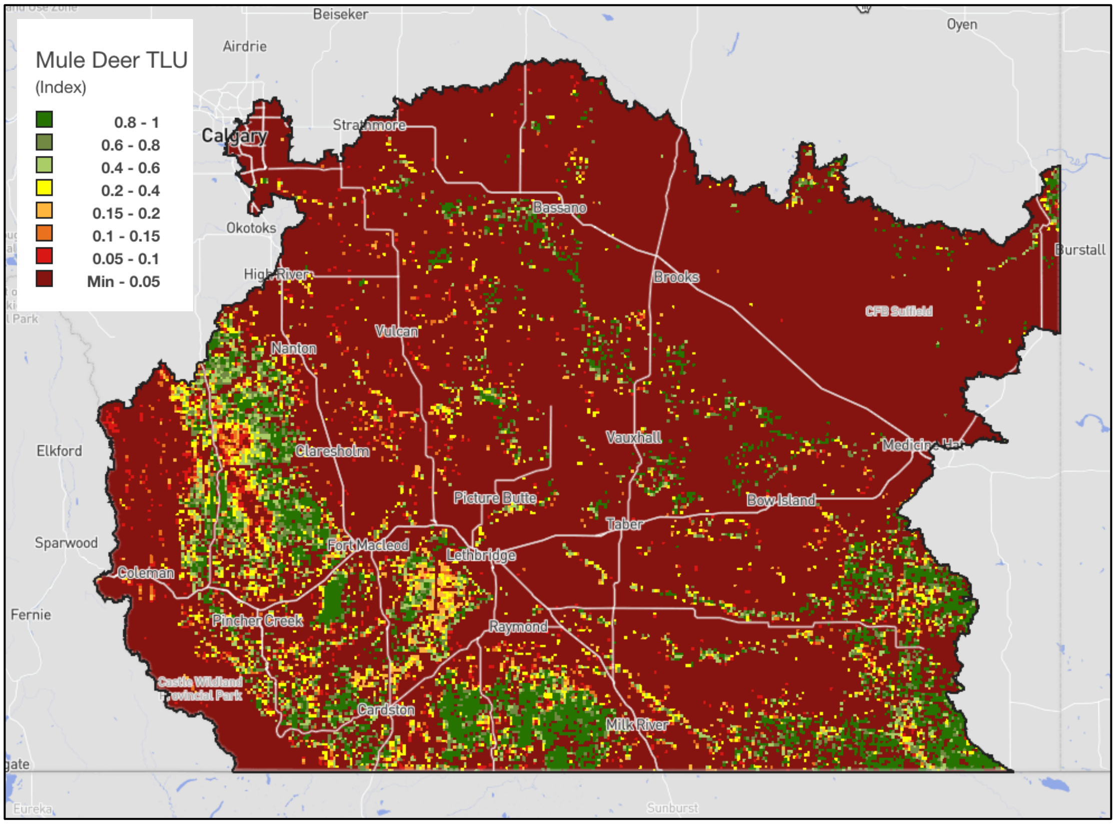

Figure 3 Mule deer TLU opportunity in the regional study area. Based on assumptions that were developed with input from community members. Higher values indicates greater opportunity.

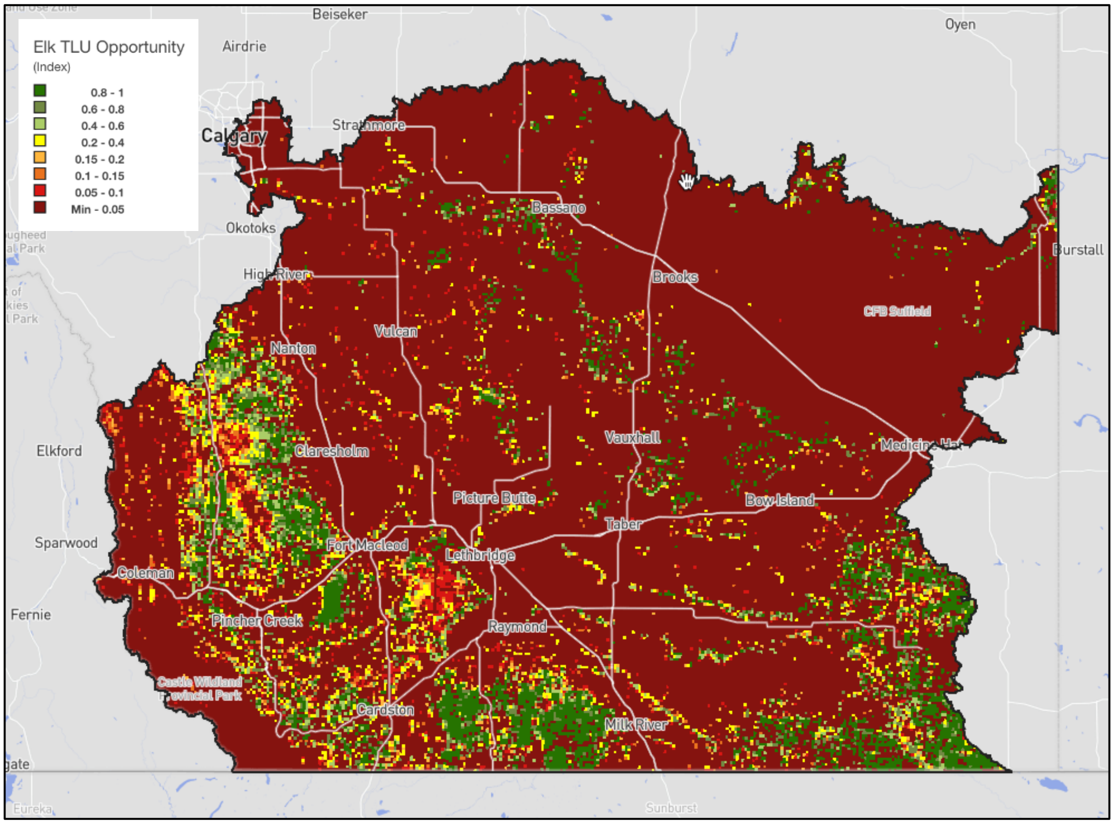

Figure 4 Elk TLU opportunity in the regional study area. Based on assumptions that were developed with input from community members. Higher values indicates greater opportunity.

4.2. FOCAL STUDY AREA

With the degradation of natural ecosystems surrounding their reserve, the Blood Tribe community relies on the more intact landscapes to the west, such as areas in the focal study area, to support traditional land use. There too, however, opportunities for traditional land use are impacted by the cumulative effects of land use and other drivers such as climate change. In this section we focus on a 6,000 km^2 landscape to evaluate the current landscape and its fish and wildlife habitat relative to natural conditions, and the potential consequences of land use and climate change over the next 50 years as simulated using ALCES Online.[4]

4.2.1. Protected areas and land use footprints

This section presents the various protected areas and anthropogenic footprints that may affect traditional land use in the study area either by restricting access to the land or by altering the capacity of the land to support wildlife. Community members discussed the effect of protected areas and footprints on TLU at a workshop. The discussion informed TLU accessibility and opportunity indicators that are presented later in this section and described in greater detail in the methods appendix (Appendix A).

Restrictive protected areas

Provincial parks and ecological reserves amount to nearly 5.4% (32,249 ha) (Figure 5).[5] These areas have hunting restrictions that could prevent Blood Tribe members from practicing TLU within portions of their traditional territory. We did not include wildland provincial parks and other natural areas in the study area because it is our understanding that these areas do not have restrictions on hunting.[6]

[4] The methods used to simulate land use, fire, and climate are described in Appendix A.

[5] Provincial parks in the study area include Beauvais Lake and Castle. Ecological reserves include Plateau Mountain and Westcastle Wetlands.

[6] This research was done with reference to provincial hunting information provided at: https://www.albertaparks.ca/albertaparksca/visit-our-parks/activities/hunting/#na

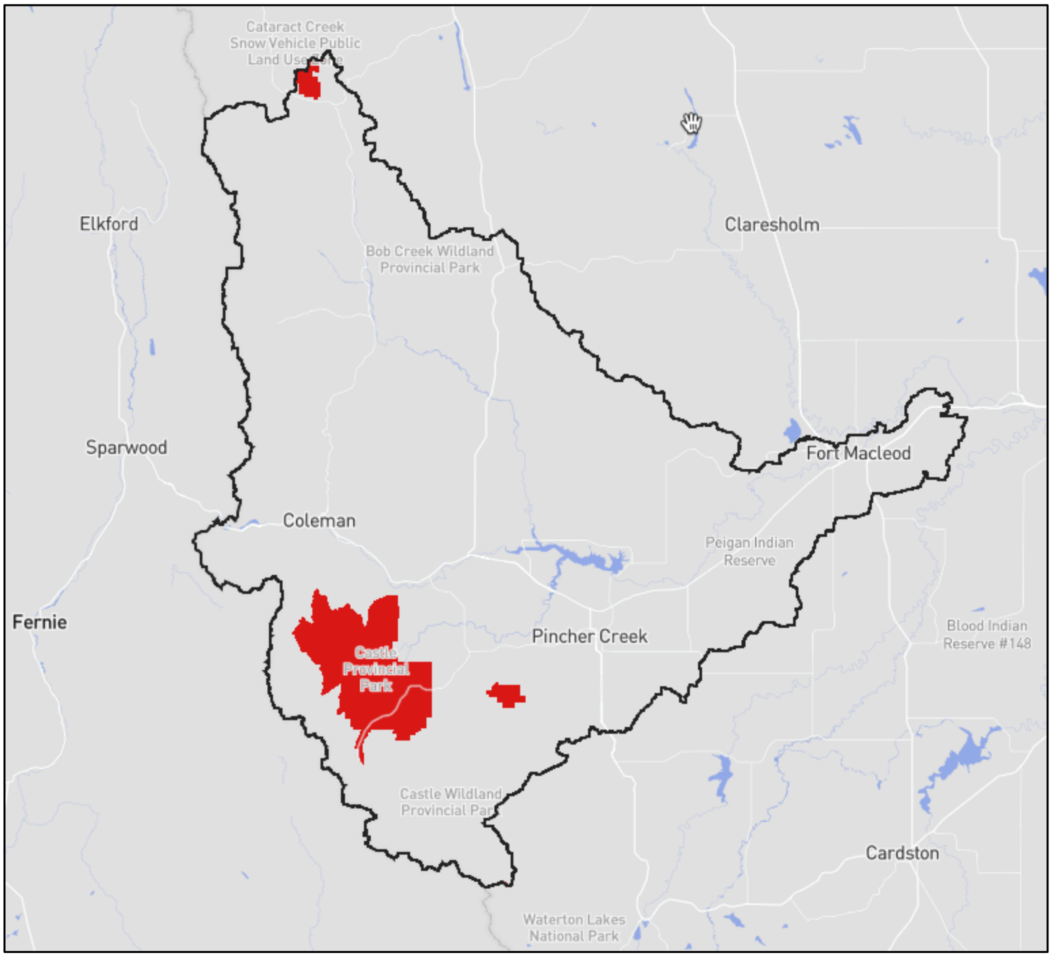

Figure 5 Locations in the focal study area of restrictive tenure types (i.e., provincial parks and ecological reserves) that may limit hunting opportunities for Blood Tribe members. Red indicates restrictive tenure.

Footprint types

Land use footprints account for 18% (105,087 ha) of the study area and are projected to increase by around 2,700 ha by the end of the 50-year forecast (Figures 6 and 7). The main contributor to this footprint is agriculture, which currently accounts for 15% (89,568 ha) of the study area and 85% of the total footprint in the study area (Figure 8). Agriculture footprint is projected to remain relatively stable during the 50-year forecast, falling slightly by 246 ha to 83% due to conversion to other land uses such as settlement (Figure 9). The greatest contributor to footprint expansion during the simulation period was from mining, which increased by 1,892 ha primarily from development of the Grassy Mountain mine (Figure 10). Figures 11 through 14 present more minor contributions to footprint from energy, transportation, settlement, and "other footprints,"[7] respectively.[8]

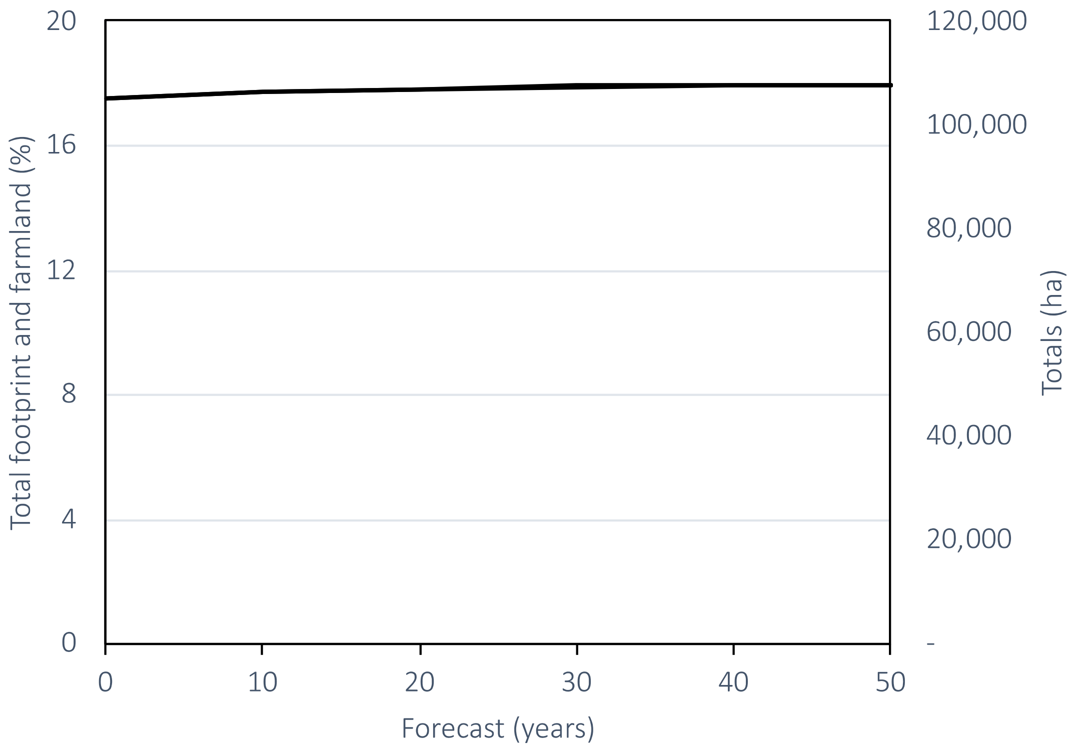

Figure 6 Current and simulated future footprint in the focal study area. Cutblocks are not included.

7 Includes cemeteries, industrial undifferentiated, lagoons, landfills, power generation, powerlines, recreation, and sumps.

8 Current and forecast maps are only presented for total footprint (Figure 7) and mining (Figure 10) whereas the other indicators (Figures 11-14) are only represented by a "current" map because their changes through the forecast are minor.

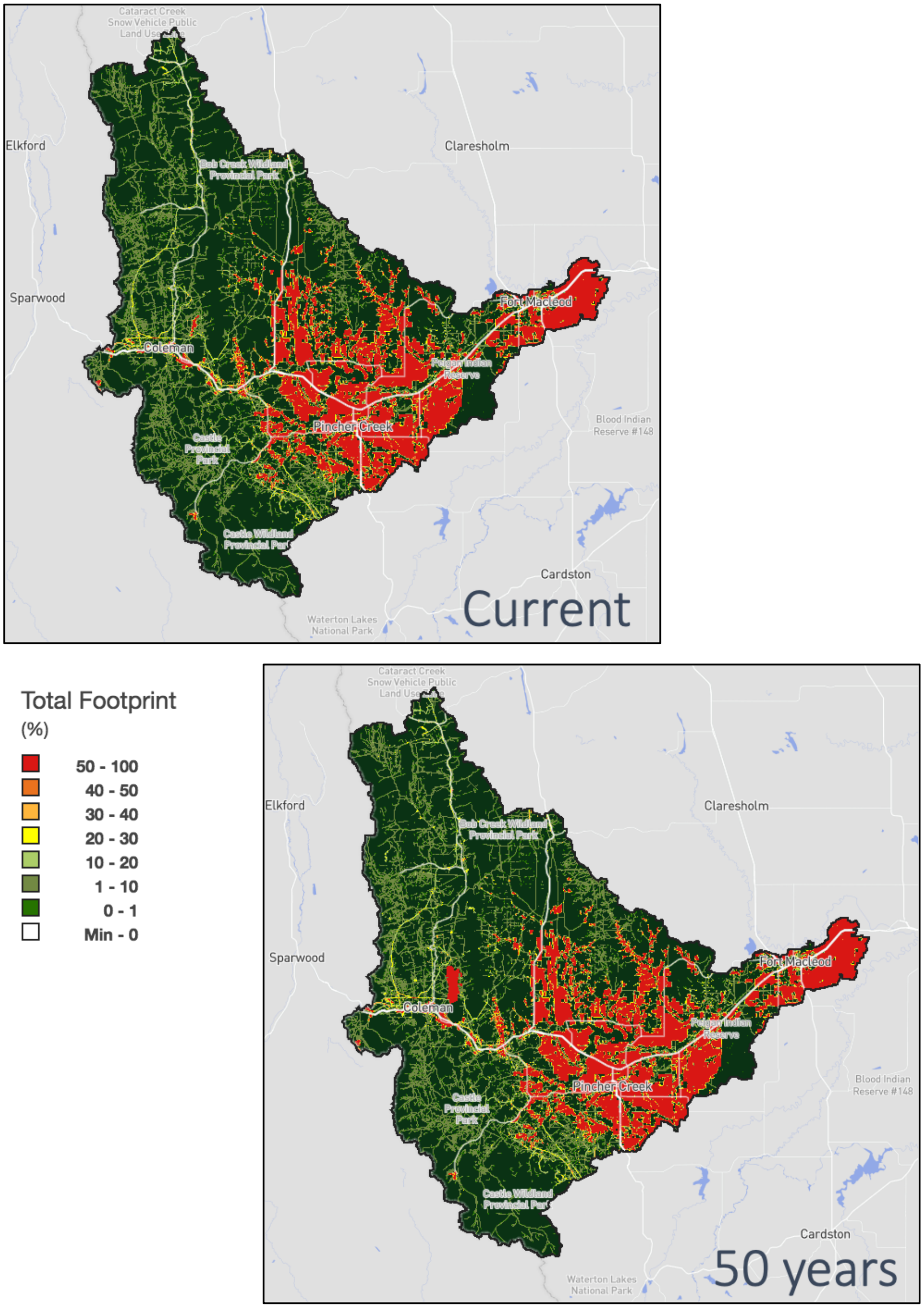

Figure 7 Current and simulated future development footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the proportion of each pixel occupied by footprint features.

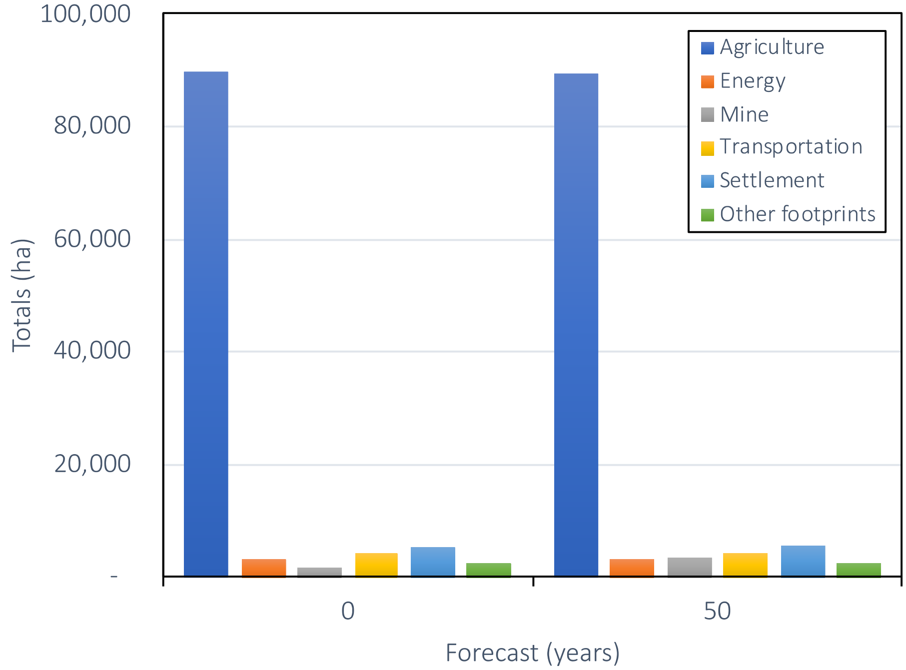

Figure 8 Current and simulated future footprint by land use in the focal study area.

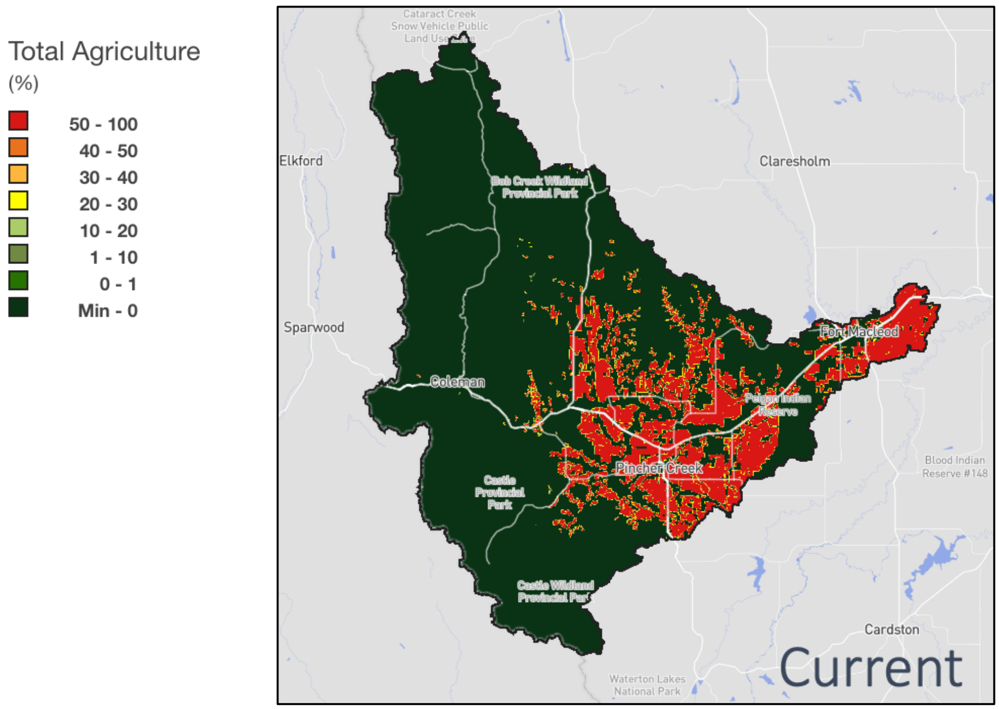

Figure 9 Current agricultural footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint.

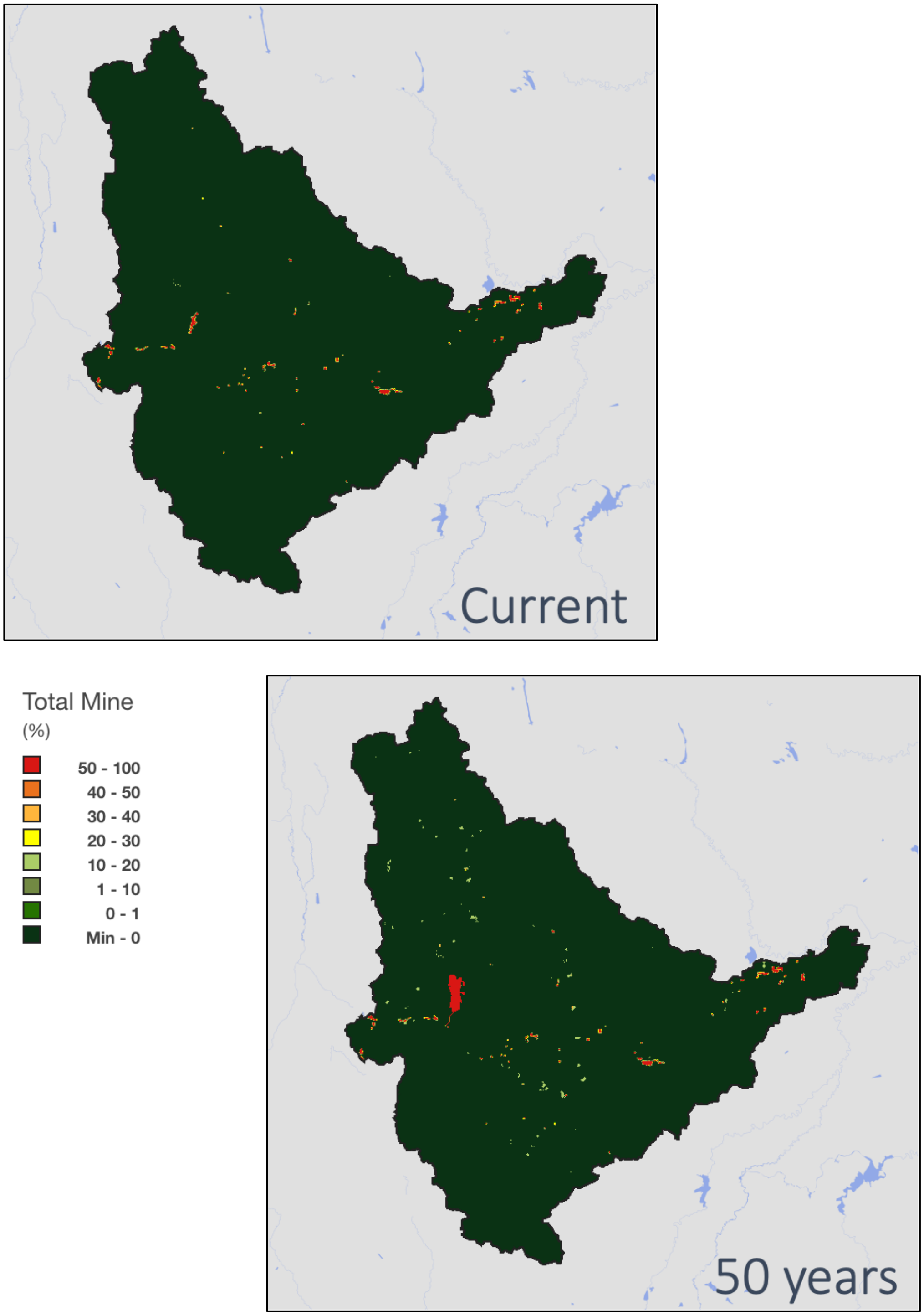

Figure 10 Current and simulated future mining footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the proportion of each pixel occupied by footprint features.

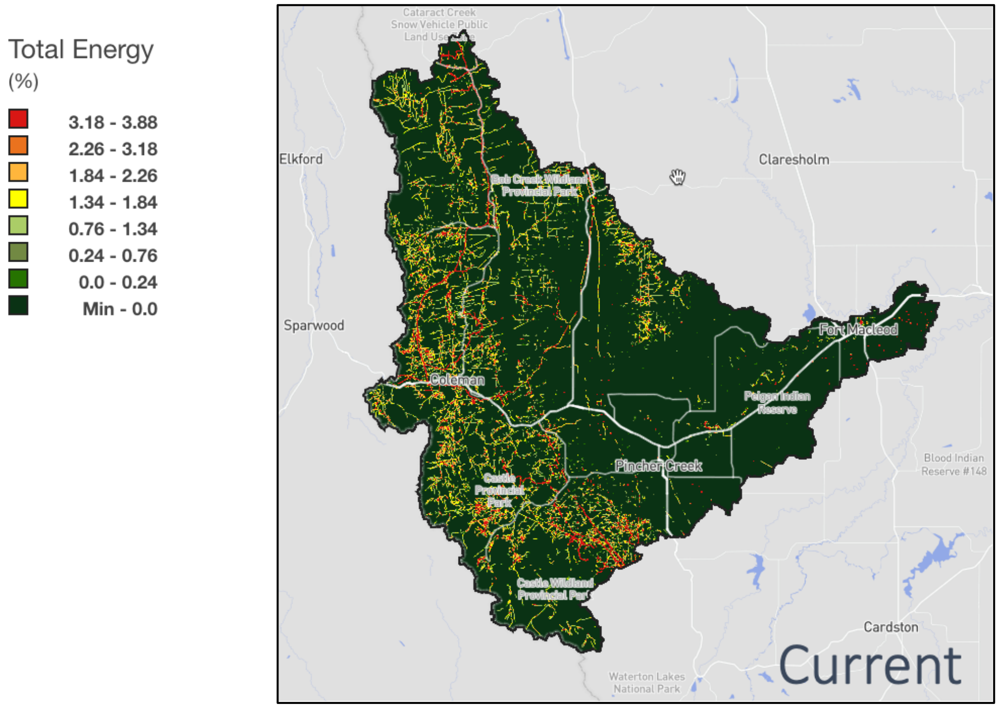

Figure 11 Current energy footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint.

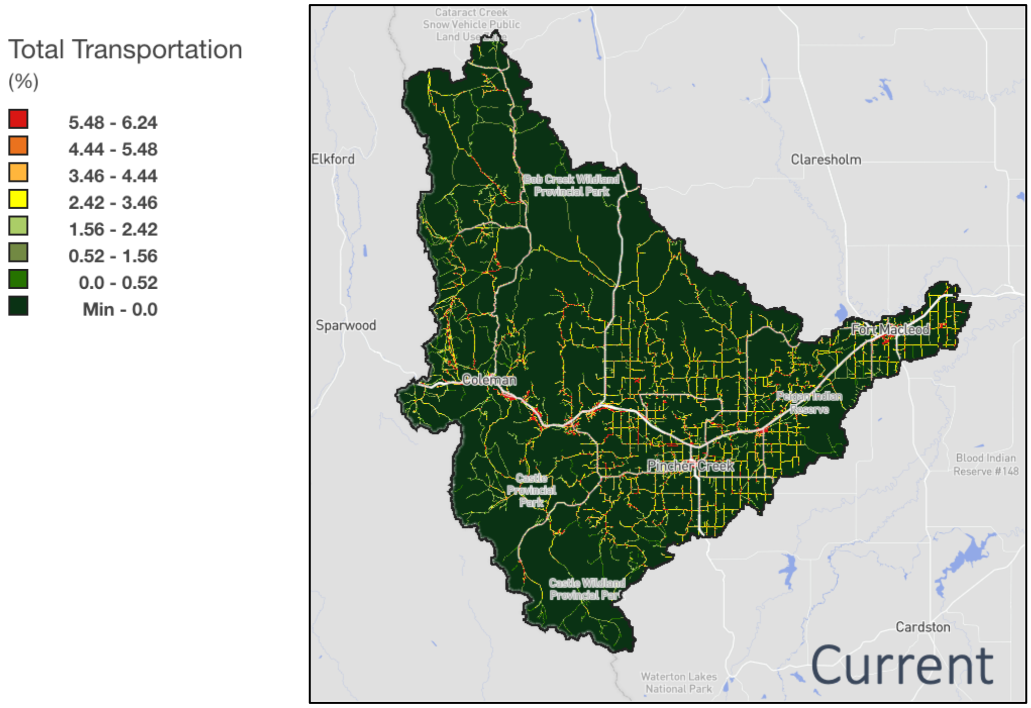

Figure 12 Current transportation footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint.

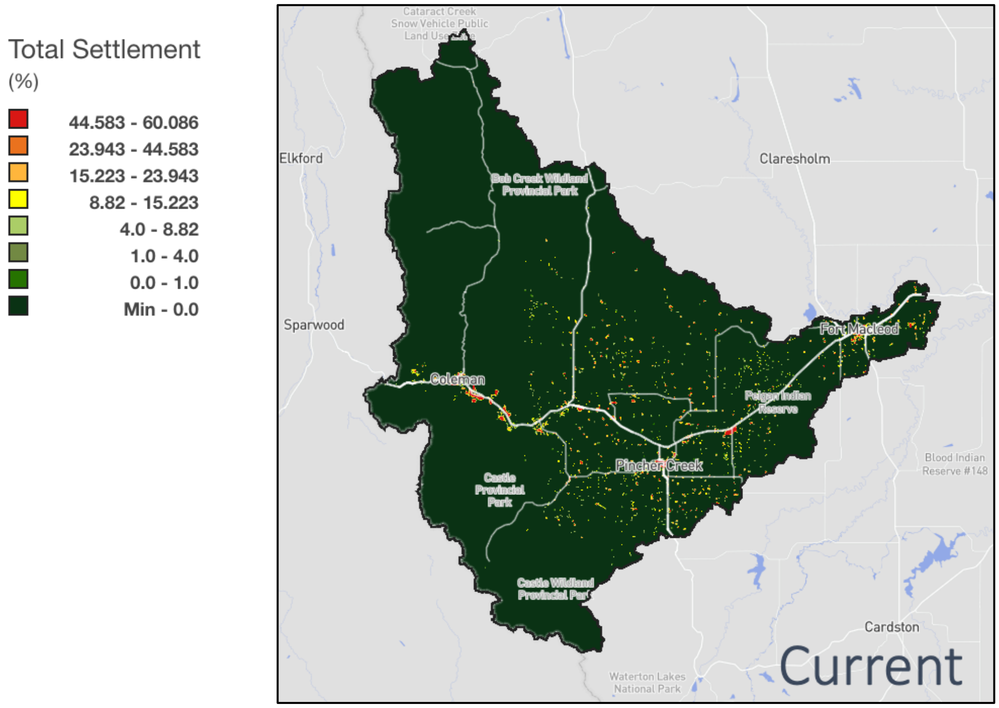

Figure 13 Current settlement and rural residential footprint in the focal study area. Red indicates high intensity footprint while green indicates low intensity footprint.

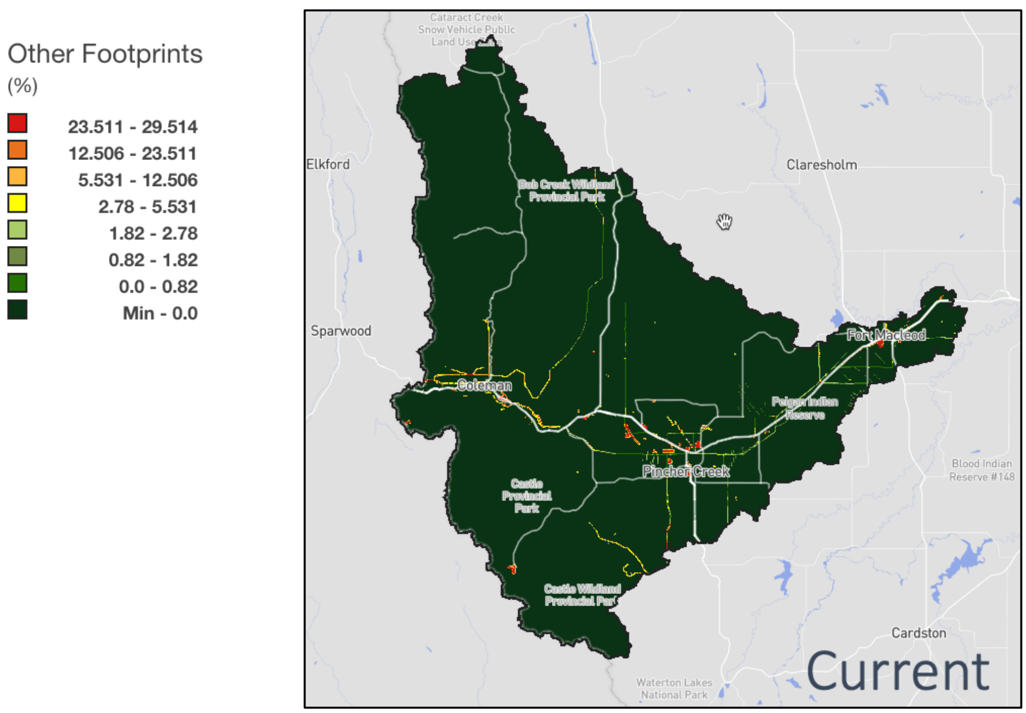

Figure 14 Other current footprints in the focal study area, including cemeteries, industrial undifferentiated, lagoons, landfills, power generation, powerlines, recreation, and sumps.

4.2.2. Remaining intact ecosystems

Effects of land disturbance to ecosystems were examined by analyzing impacts to (i) intact core area, and (ii) intact patch size.

Intact core area

The total extent of 200 m cells that do not contain footprint or farmland (intact core area) is currently around 55% (329,342 ha) of the focal study area. Intact core area declines slightly to 54% (324,372 ha) by the end of the 50-year forecast (Figure 15). Note that there are about 3,926 ha of waterbodies in the study area, which reduces intact core area by about 1% if only the terrestrial land base is considered.

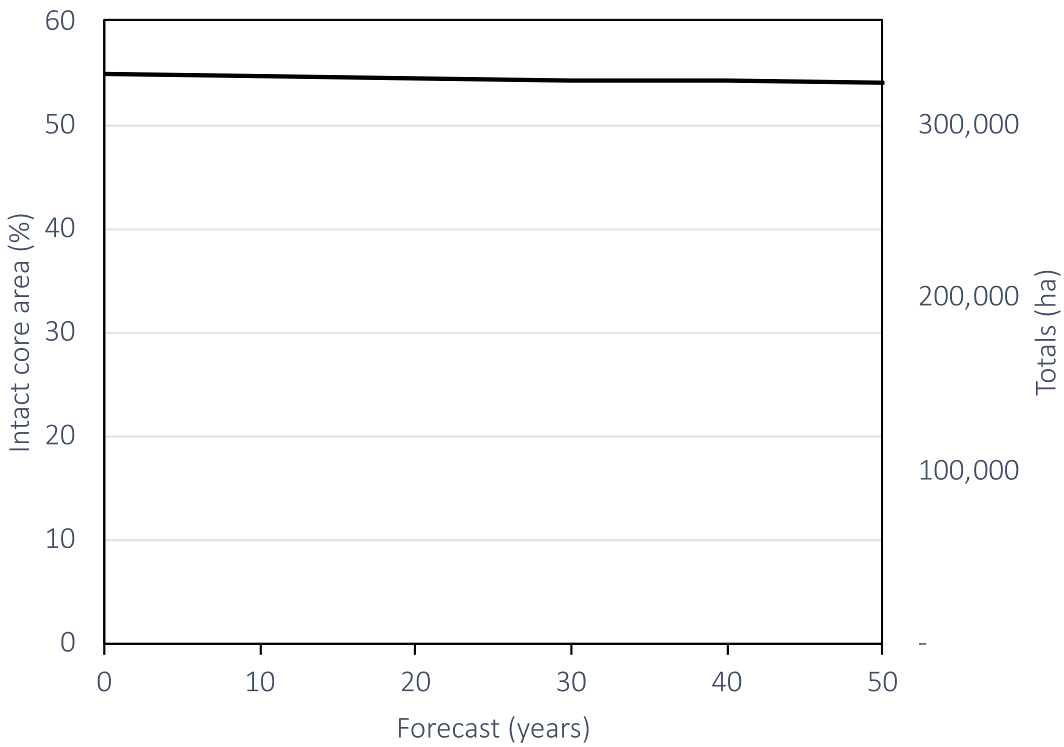

Figure 15 Current and simulated future coverage of the focal study area by intact patches at least 0.04 km² in size.

Intact patch size

For the focal study area, results show that average intact patch size across the terrestrial land base (i.e., not including lakes) is currently around 9,131 ha and it is projected to increase negligibly over the 50-year forecast to 9,143 ha (Figures 16). The insensitivity of intact patch size is due to the location of simulated new footprints being concentrated in the eastern portion of the study area where patch size is already low.

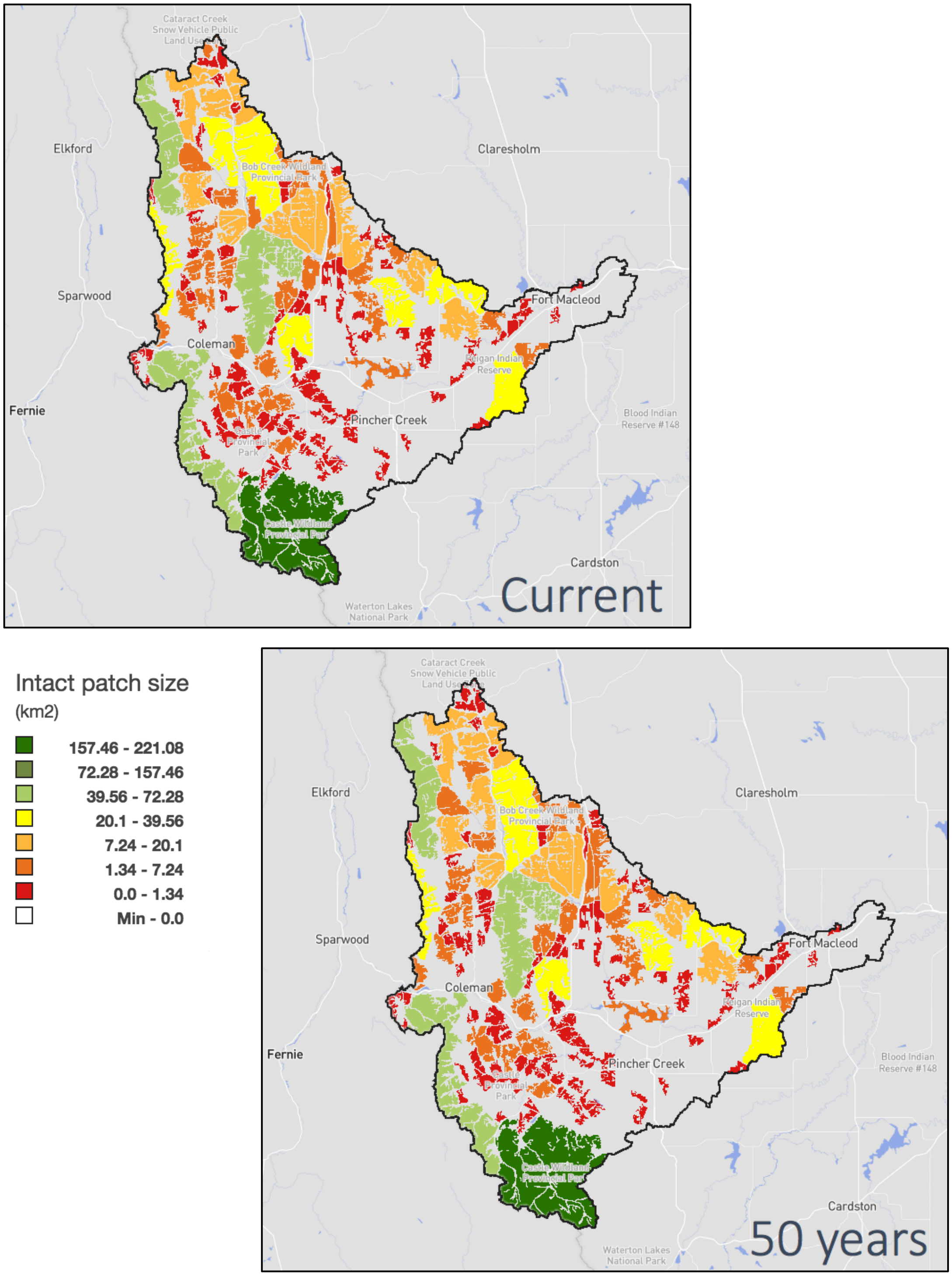

Figure 16 Current and simulated future size of intact patches of natural land cover in the focal study area.

4.2.3. Effects to wildlife and fish

Current and simulated future wildlife and fish habitat in the focal study area relative to natural conditions is summarized in Table 2 and discussed below.[9]

Table 2. Modelled indicator performance and risk assessment for the focal study area. See section 3.2 or Appendix A for risk categories.

Indicator	Min. RNV (or 1)	Model estimates		% change from min. RNV (or 1)		Risk level
		Current	50 years	Current	50 years	
Moose habitat	0.05	0.05	0.05	-	-	-
Elk habitat	0.42	0.22	0.21	-48	-51	Moderate
Mule deer habitat	0.42	0.25	0.25	-40	-41	Moderate
Foothills/Montane INFI (fish)	1.00*	0.66	0.52	-34	-48	Moderate/ High

* For INFI, any decline from a value of 1 signifies degrading conditions for the indicator. As a result, the output for this indicator is compared to 1 rather than to mean RNV.

Moose

Moose habitat has likely always been low in the study area due to the grassland to the east and high elevation to the west, and habitat remains low today. At the scale of the study area, moose habitat has declined marginally to the lower edge of the RNV. The negative impacts of habitat loss and elevated mortality risk due to access are partially offset by minor increases in habitat in the eastern portion of the study area where grassland has been converted to cropland which provides better forage. However, the best habitat remains lower elevation forests in the parkland and mountain valleys to the west.

[9] The habitat metric presented for the three wildlife indicators is defined as “effective habitat,” which refers to the availability of suitable land cover and terrain (i.e., potential habitat) combined with mortality risk facilitated by access via linear footprints (roads, seismic lines, pipelines, transmission lines).

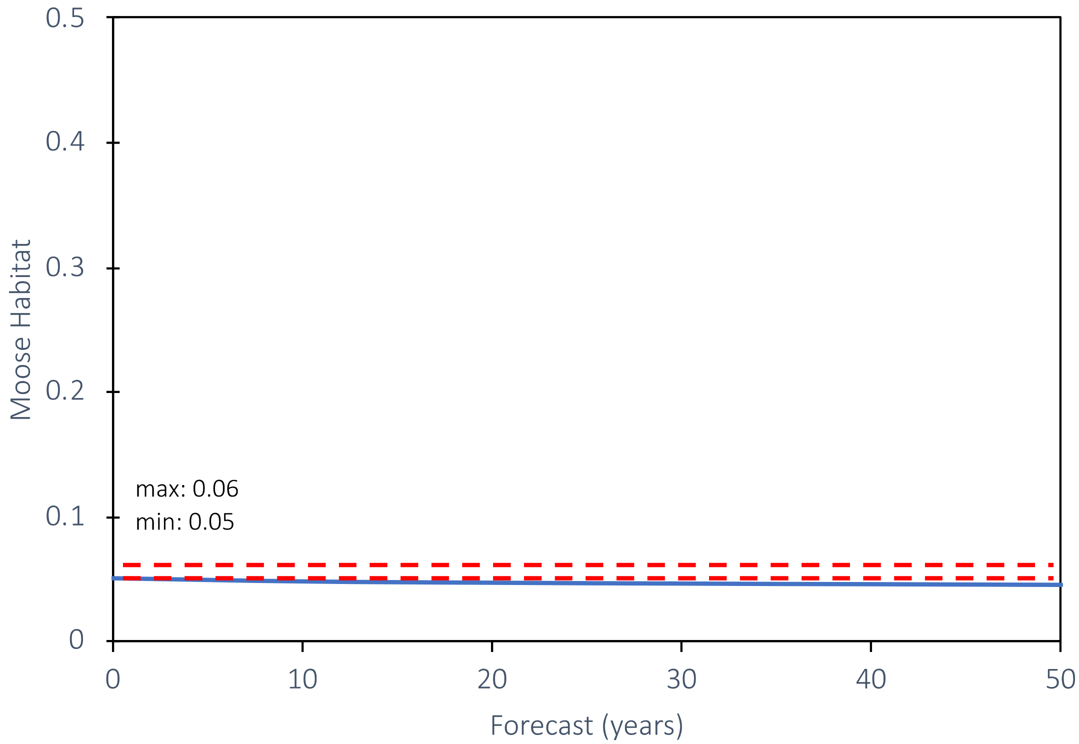

Figure 17 Current and simulated future moose habitat in the focal study area (blue line). The red dashed lines identify the estimated range of natural variation as a baseline for comparison.

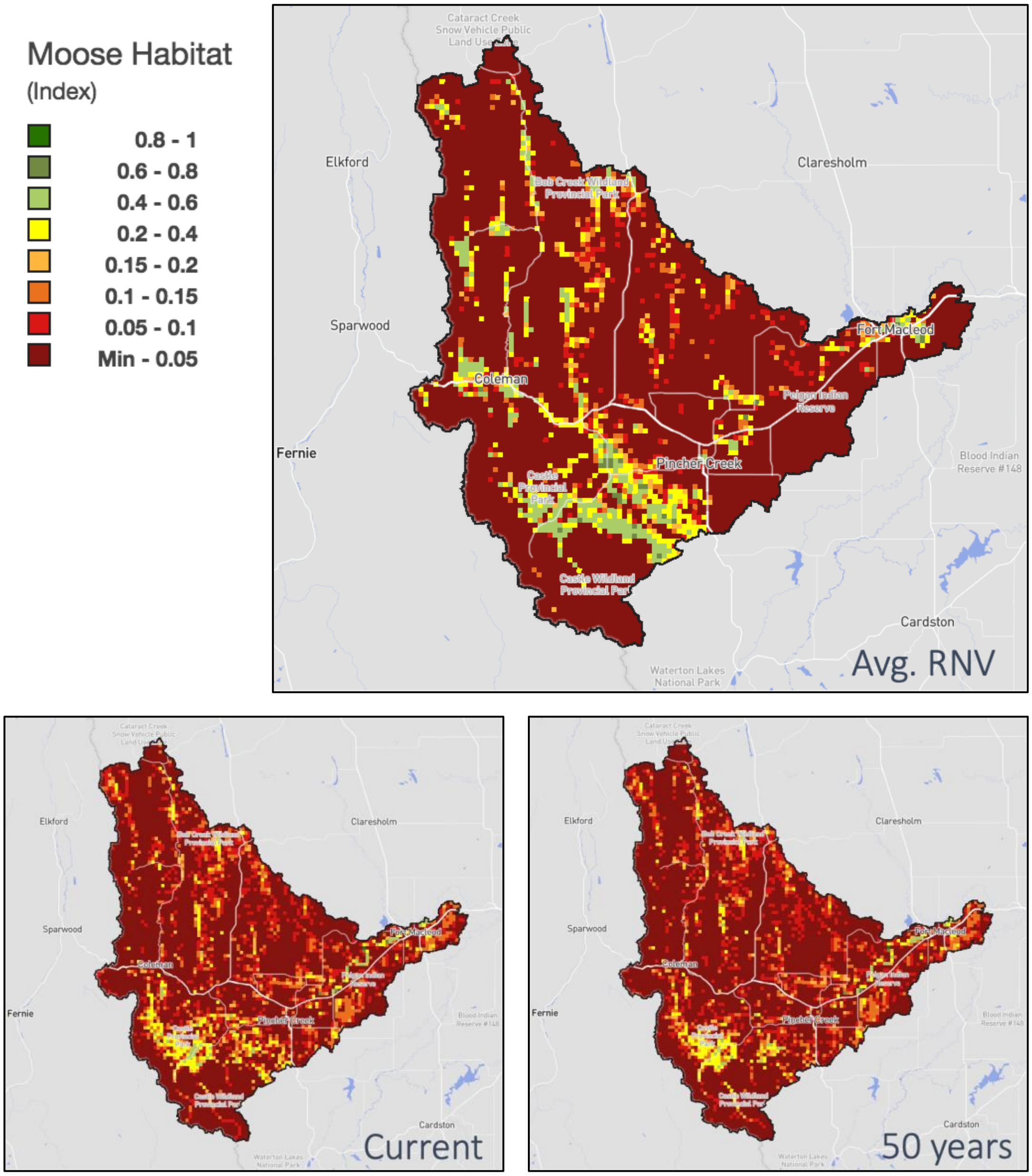

Figure 18 Natural, current, and simulated future moose habitat in the focal study area. A value of 1 identifies maximum effectiveness.

Elk habitat

Elk habitat has declined by 48% in the focal study area relative to natural conditions (Table 2, Figure 20). This decline corresponds to an assessment of moderate risk to elk and associated hunting opportunities. Elk habitat was likely highest in the grasslands in the eastern portion of the focal study area prior to European settlement (Figure 21), but habitat in this area has since declined due to conversion to agriculture and mortality risk associated with linear footprints. Remaining elk habitat is now focused in remaining grassland with lower linear footprint density. In the forecast, elk habitat dropped slightly to below 50% of natural at the end of the 50-year forecast.

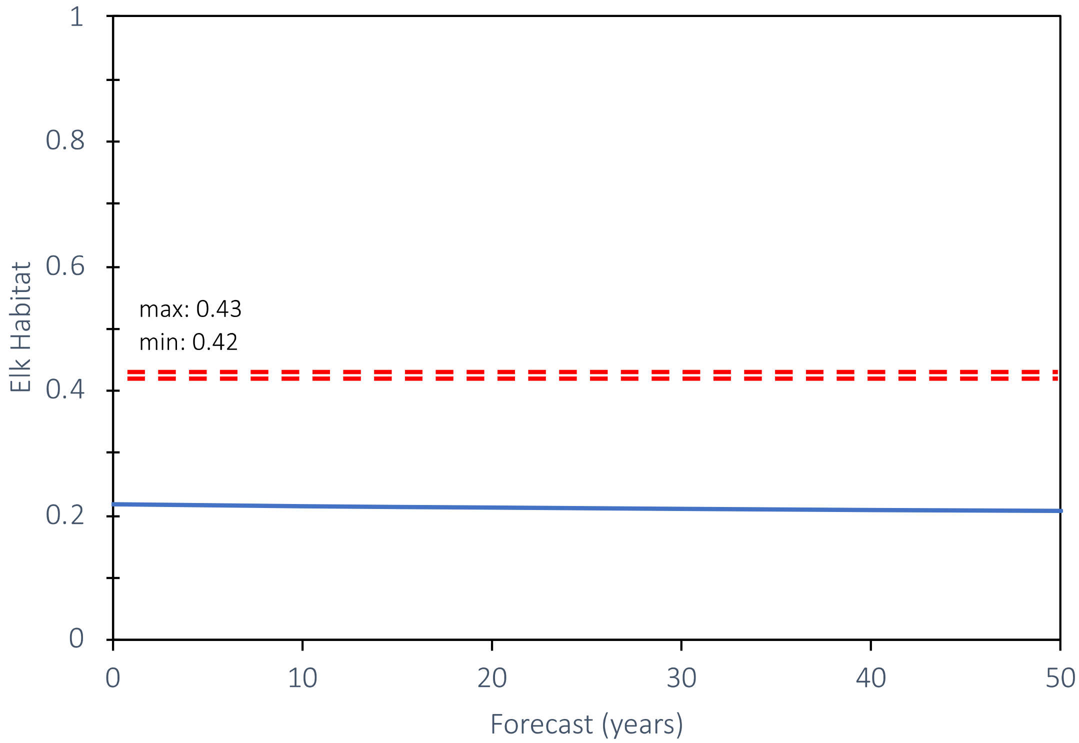

Figure 19 Current and simulated future elk habitat index in the focal study area (blue line). The red dashed lines identify the estimated range of natural variation as a baseline for comparison.

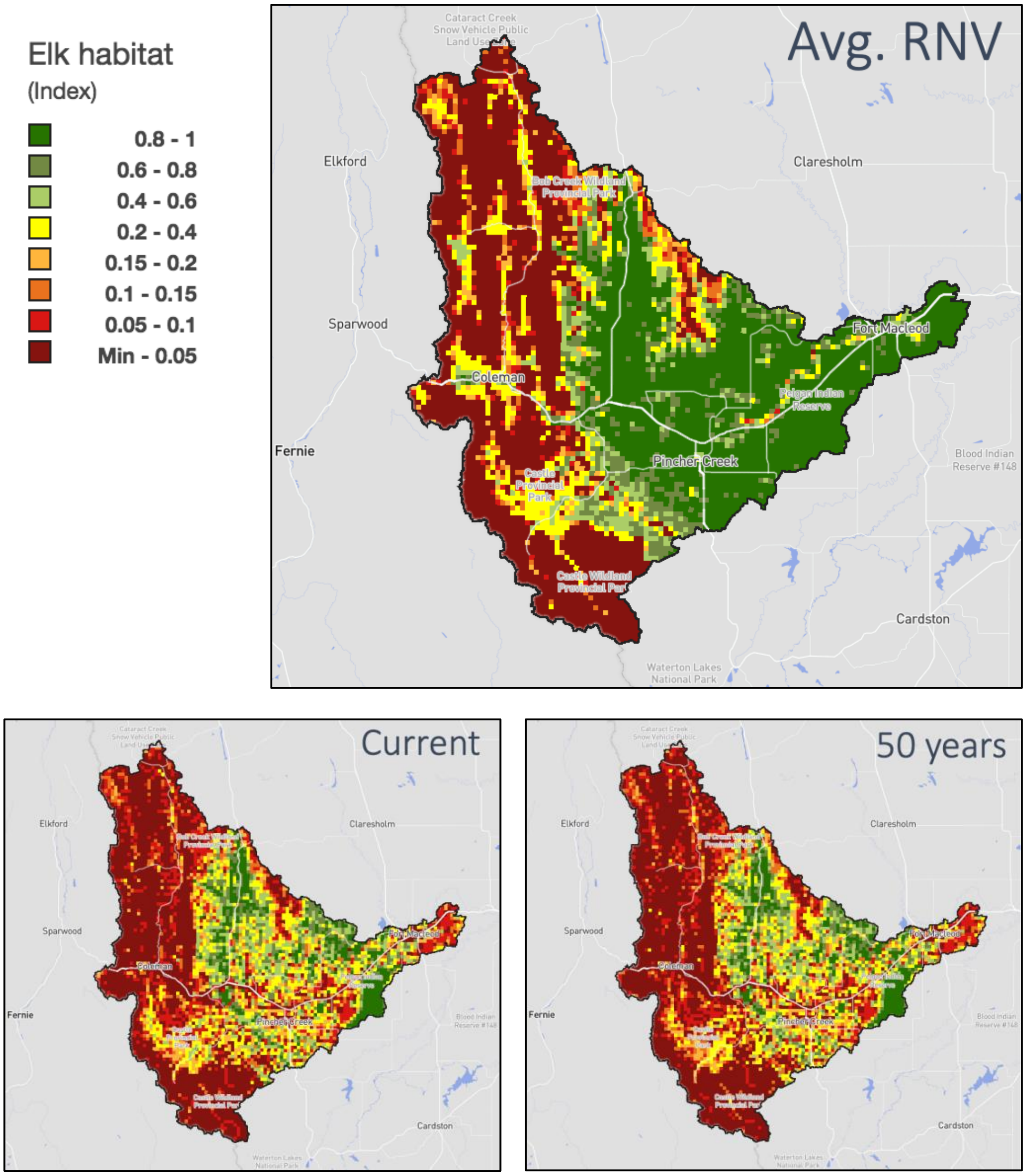

Figure 20 Natural, current, and simulated future elk habitat in the focal study area. A value of 1 identifies maximum effectiveness.

Mule deer habitat

Mule deer habitat has declined by 40% relative to natural conditions in the focal study area (Table 2, Figure 22). This decline corresponds to an assessment of moderate risk to mule deer and associated hunting opportunities. Under natural conditions, suitable mule deer habitat was focused in the eastern portion of the study area but this area has since undergone a decline in habitat due to conversion to farmland and linear footprints that facilitate human access (Figure 23). Remaining elk habitat is now focused in remaining grassland as well as pasture with lower linear footprint density. In the forecast, mule deer habitat decreased only slightly over time to 41% of natural at the end of the 50-year forecast.

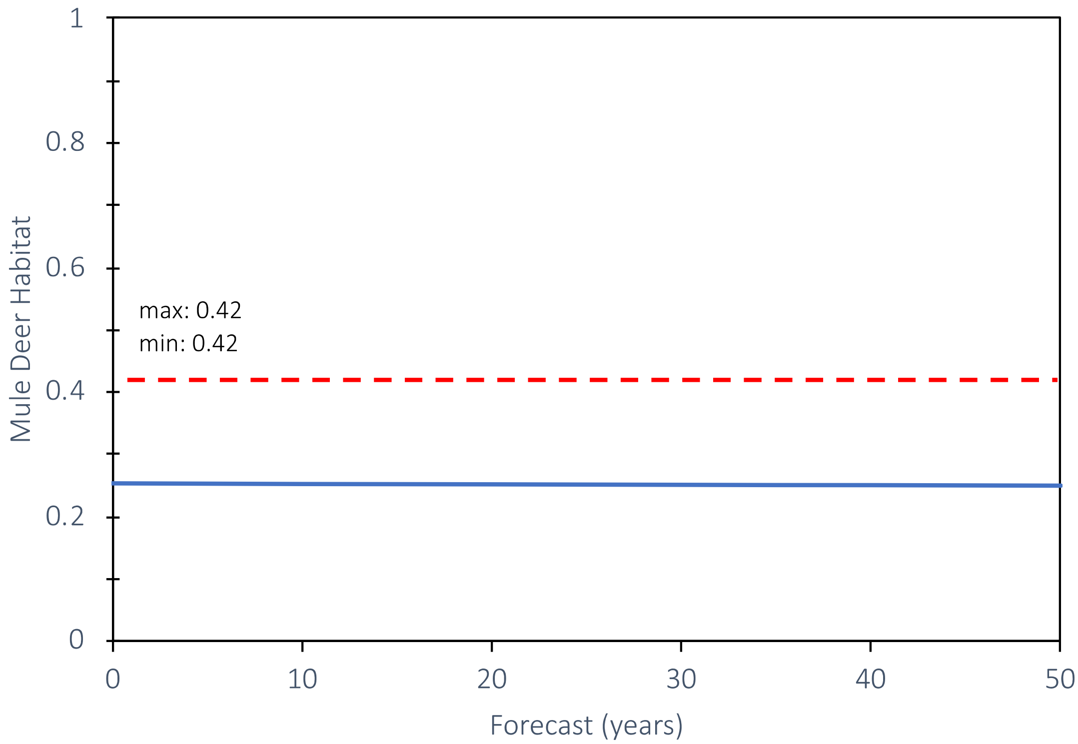

Figure 21 Current and simulated future mule deer habitat index in the focal study area (blue line). The red dashed line identifies the estimated range of natural variation as a baseline for comparison.

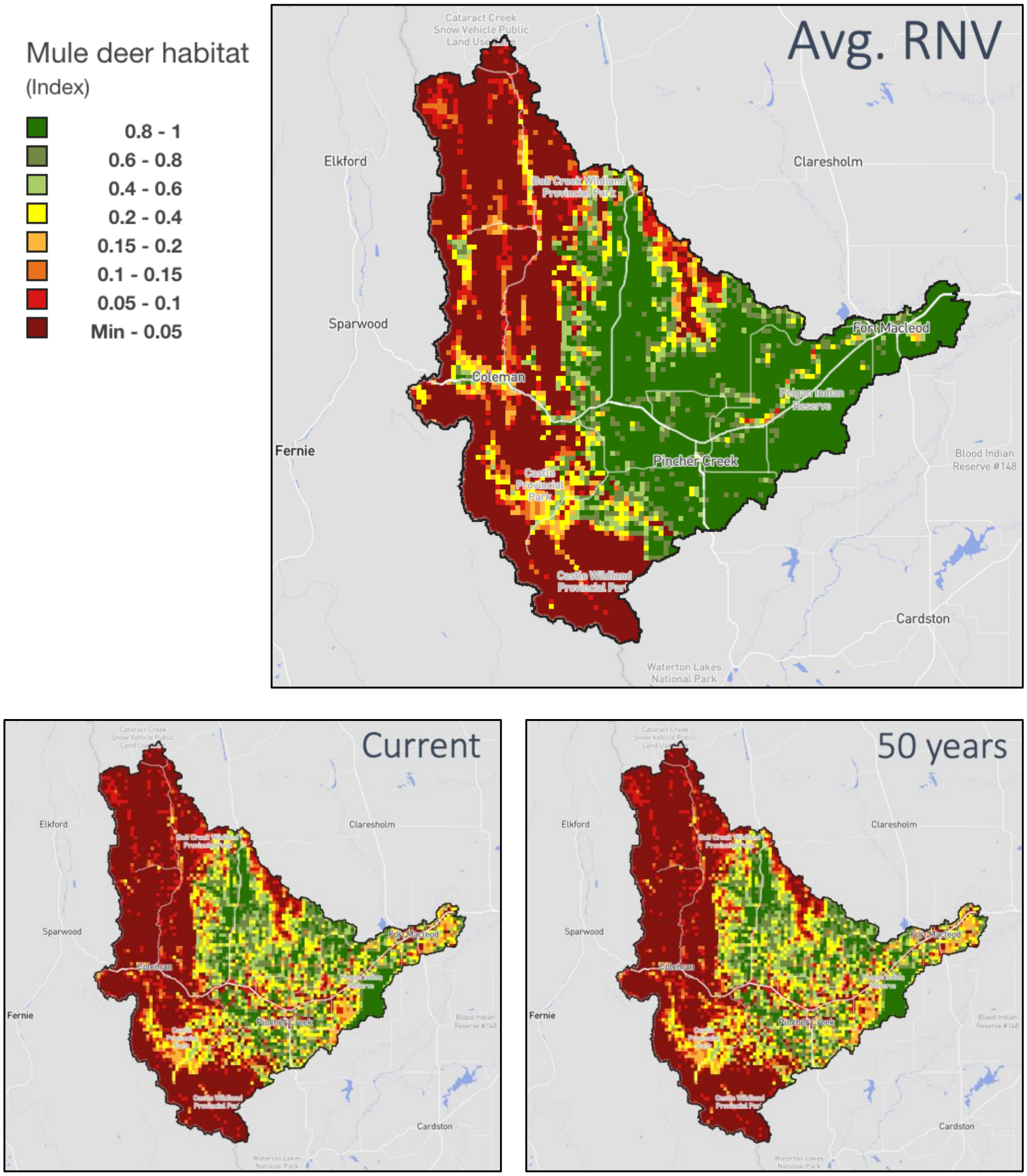

Figure 22 Natural, current, and simulated future mule deer habitat in the focal study area. A value of 1 identifies maximum effectiveness.

Index of Native Fish Integrity (INFI)

The fish community index (INFI) is projected to fall from a current value of 0.66 (a 34% decline from RNV) to 0.52 (a 48% decline from RNV) (Table 2, Figure 24), suggesting a shift from moderate to high risk over the next five decades. INFI was calculated as the average value across three effects: linear edge, stream fragmentation, and climate. Currently, linear edge and stream fragmentation levels are consistent with high risk, whereas climate is consistent with low risk (Figure 25). During the simulation, however, rising temperature causes the climate effect to elevate to moderate and overall risk to increase to high. Current and simulated future INFI values for watersheds are illustrated in Figure 26. Lower risk watersheds are concentrated in the prairie portion of the watershed, where fishing pressure is likely limited by private land and fish habitat is dominated by rivers that are less susceptible to fragmentation by culverts, and in the southern portion of the watershed where footprint is lower due to protection.

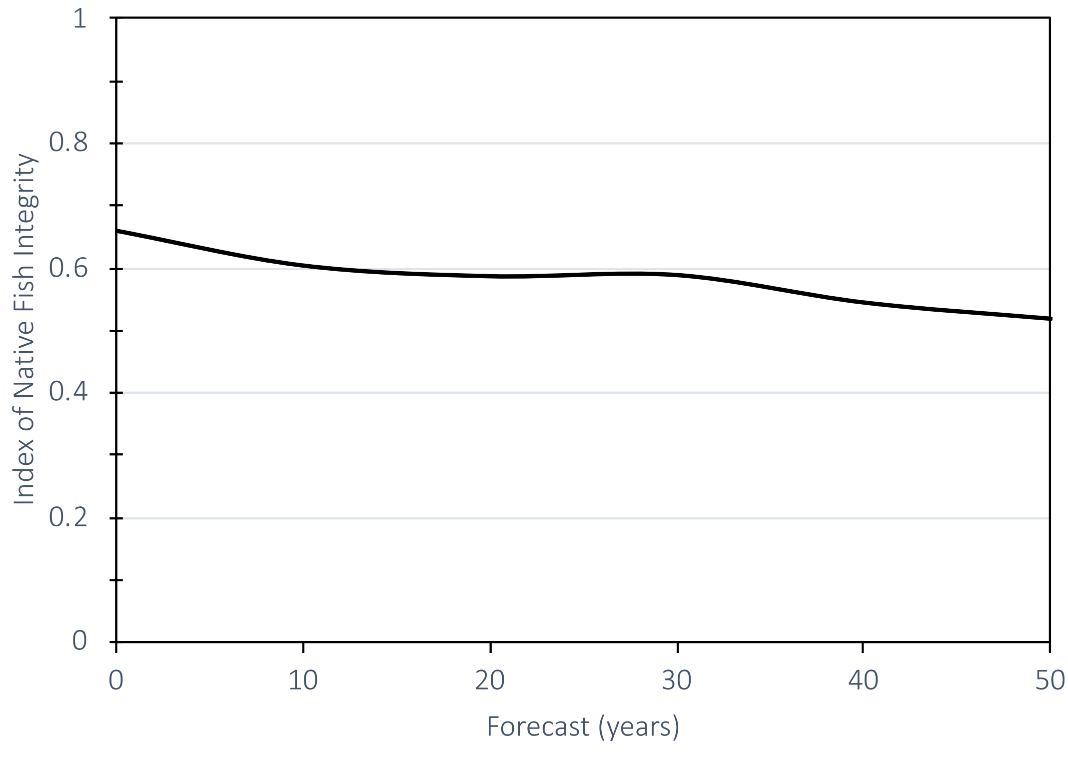

Figure 23 Current and simulated future index of native fish community integrity in the focal study area.

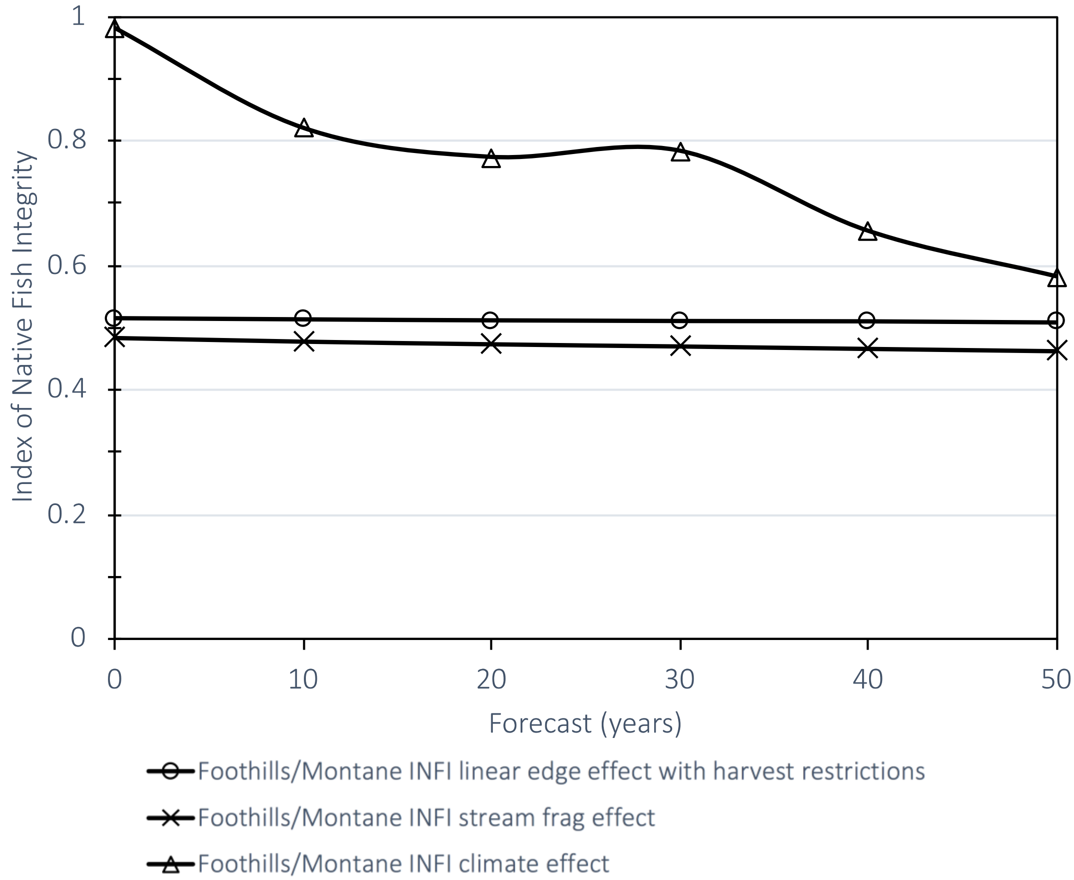

Figure 24 The effect of stressors on INFI in the focal study area. Lower values indicate greater impact.

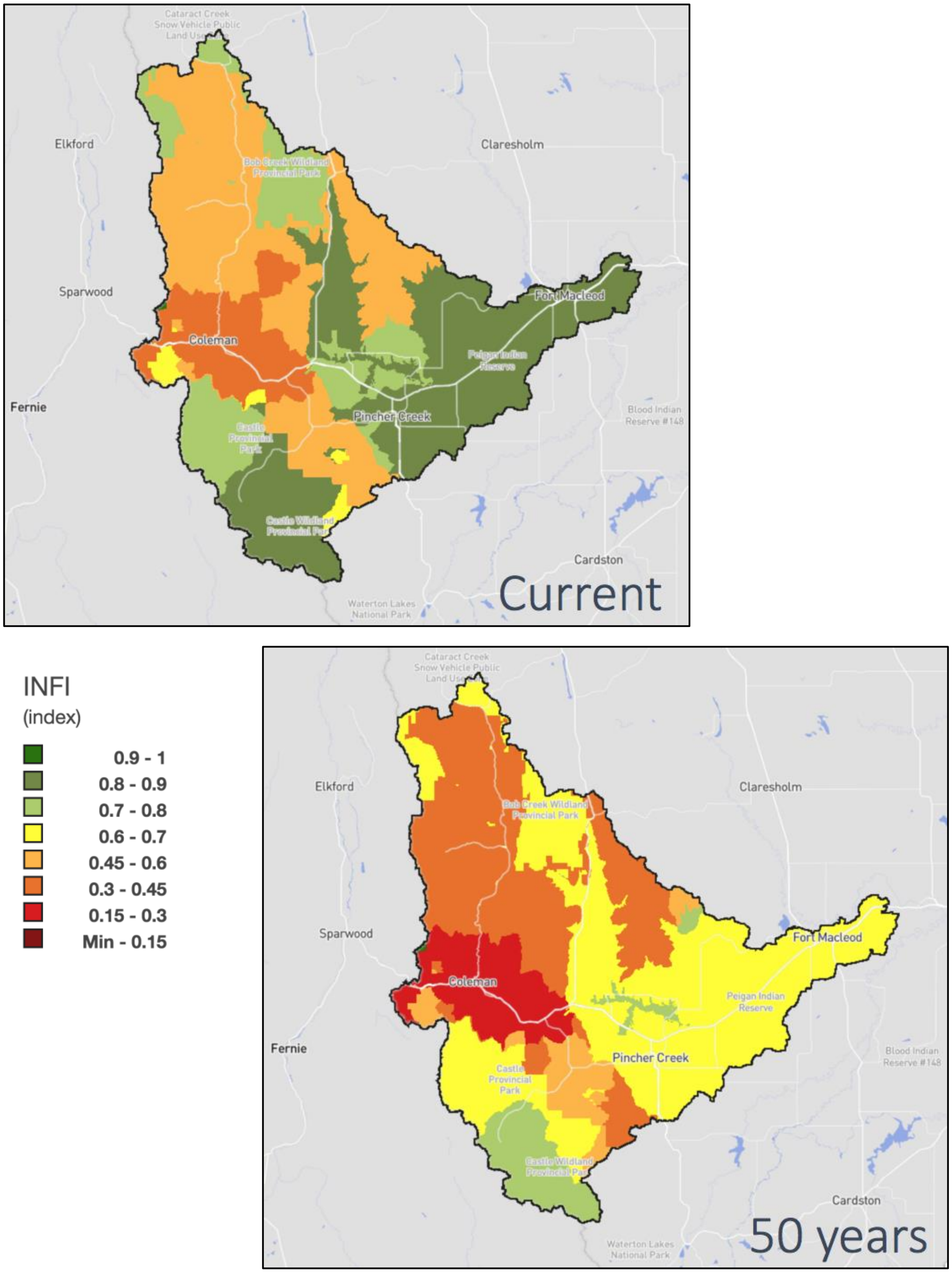

Figure 25 Current and simulated future index of native fish community integrity (INFI) in the focal study area. Higher values (i.e., greener colours) indicate lower risk.

4.2.4. Effects to traditional land use

Effects to traditional land use were examined by analyzing impacts to three indicators:

1. accessibility for traditional land use;
2. mule deer TLU opportunity; and,
3. elk TLU opportunity.

Results by indicator are discussed below.

Note that the results presented are likely an overestimation (i.e., optimistic view) of actual conditions for TLU accessibility and opportunity. For instance, from a land use standpoint, harvesting activities do not necessarily occur where there is accessible and suitable habitat, but rather depend on numerous logistical and cultural factors that have not been numerically considered here. Some of the factors that have not been integrated in the modeling include distance from home, ease of access, gates and restrictions that prohibit access,[10] familiarity and knowledge of location, cultural history in the area, competition for resources (e.g., hunting, fishing, and camping sites), among others. As an example, there may be locations that have suitable habitat but are not valuable for hunting because they are too far from home and in unfamiliar locations. Hunting in remote locations requires commitment of increased time and resources that some members cannot afford, and success in unfamiliar locations is not guaranteed. The result of the combination of these factors is that not all of the habitat that is modeled as suitable/accessible in this study necessarily presents a good TLU opportunity for community members.

[10] Community members described two specific access points (the Shell plant and Birdseye Ranch) that have been gated in recent years, cutting off access to a large land use zone and associated network of roads.

Accessibility for traditional land use

The amount of land that is currently accessible for traditional land use is estimated to equal 60% (359,998 ha) of the focal study area (Figure 27). This area declines slightly to 58% (345,453 ha) by the end of the 50-year forecast. Current and simulated future values are illustrated in Figure 28. Throughout the simulation, much of the accessible land for TLU occurs in the western foothills and mountains.

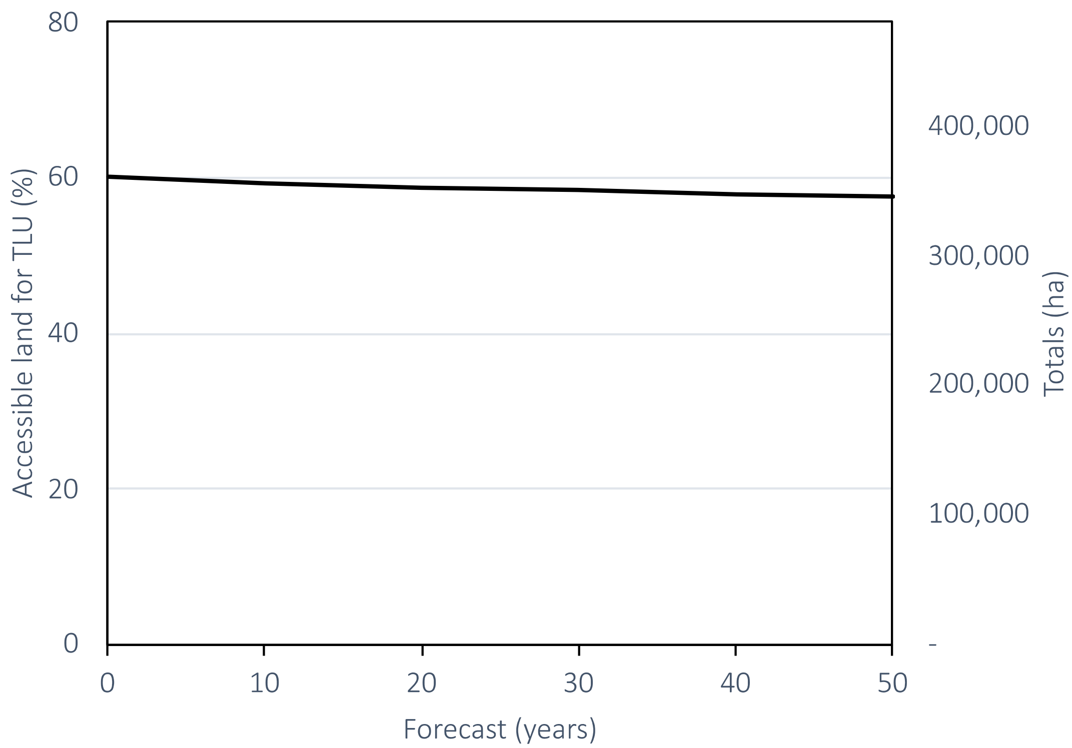

Figure 26 Percent of the focal study area that is accessible for traditional land use. Based on assumptions that were developed with input from community members.

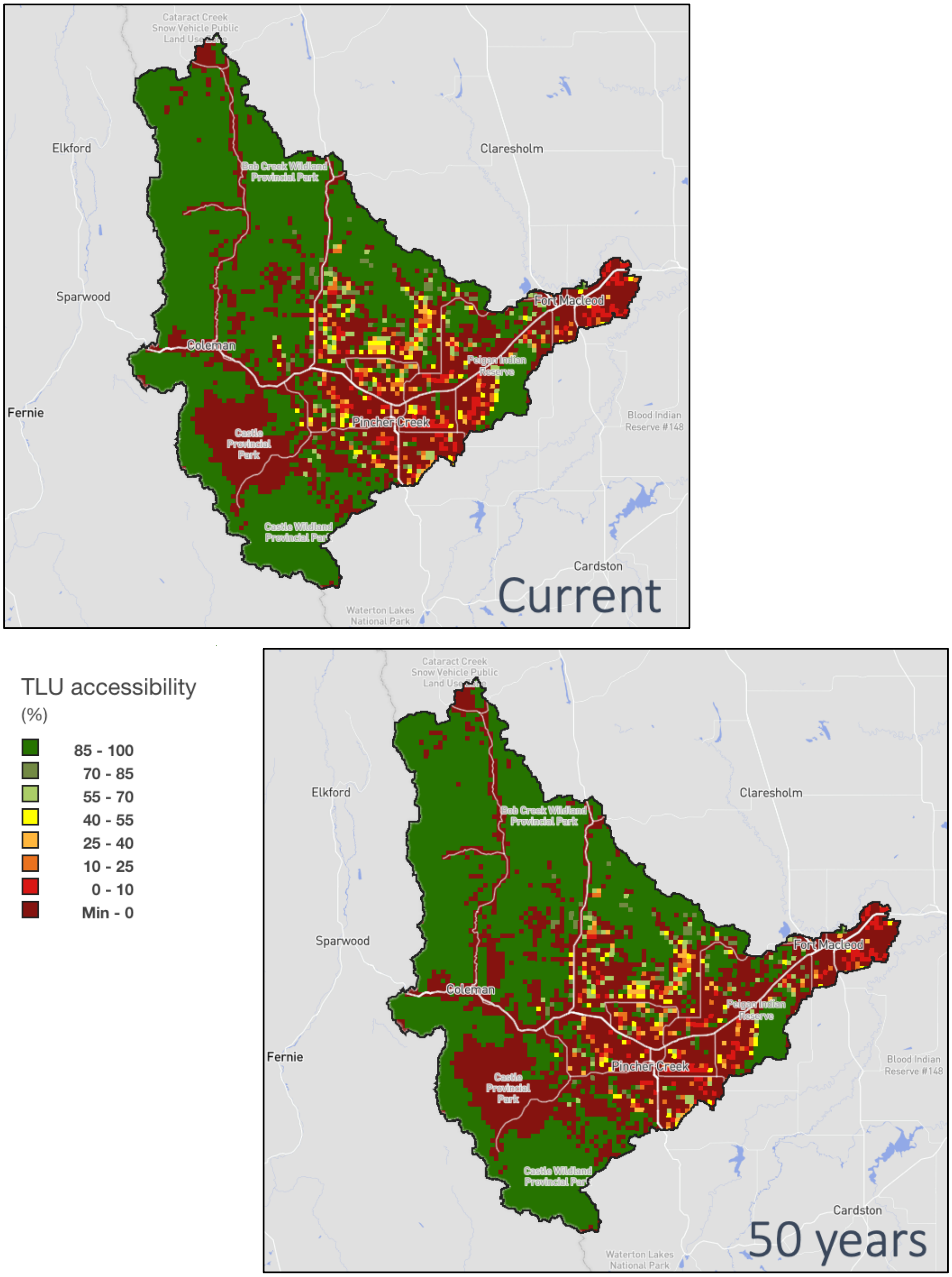

Figure 27 Current and simulated future accessibility for traditional land use in the focal study area. Based on assumptions that were developed with input from community members. Higher values indicate greater accessibility.

Mule deer TLU opportunity

Current mule deer TLU opportunity (0.13) in the focal study area is about 48% lower than current mule deer effective habitat (0.25) presented in section 4.2.3 (see Figure 22). By the end of the forecast, mule deer TLU opportunity is projected to decline by about 7% due to expansion of development activities (Figures 29 and 30).

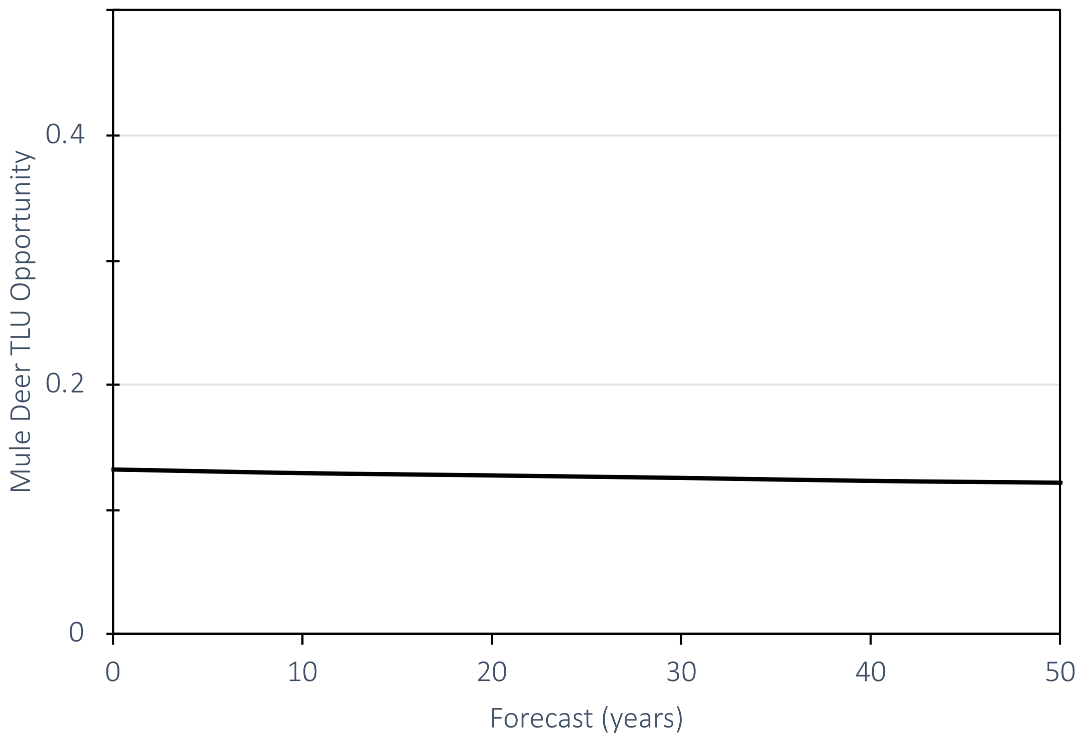

Figure 28 Current and simulated future mule deer traditional land use opportunity in the focal study area. Based on assumptions that were developed with input from community members.

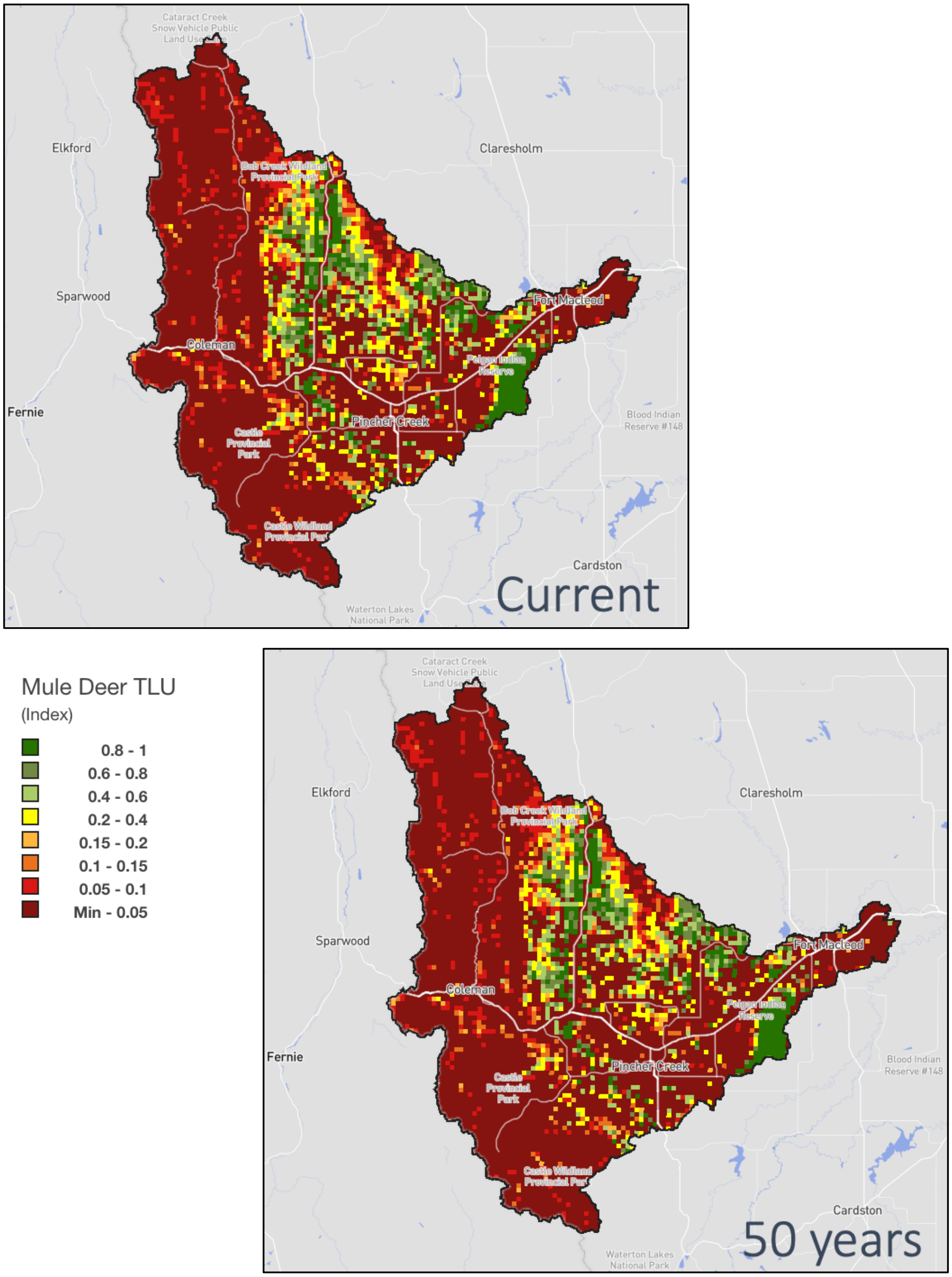

Figure 29 Current and simulated future mule deer TLU opportunity in the focal study area. Based on assumptions that were developed with input from community members. Higher values indicate greater opportunity.

Elk TLU opportunity

Current elk TLU opportunity (0.13) in the focal study area is about 41% lower than current elk effective habitat (0.22) presented in section 4.2.3 (see Figure 20). By the end of the forecast, elk TLU opportunity is projected to decline by around 10% due to expansion of development activities (Figures 31 and 32).

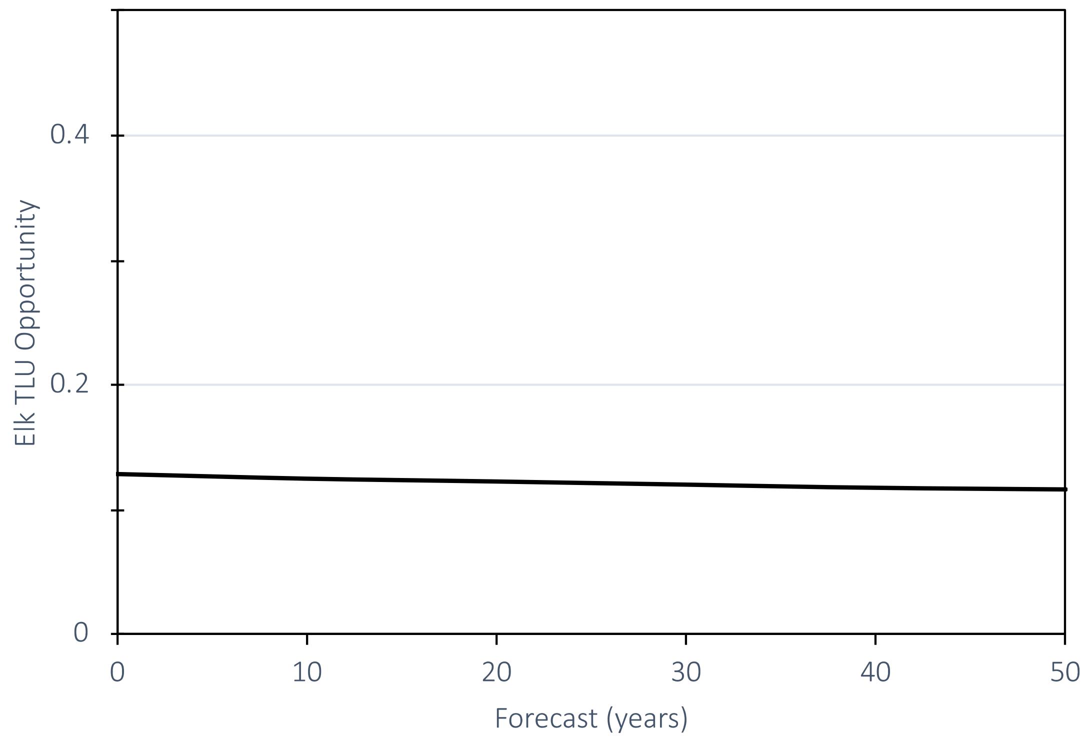

Figure 30 Current and simulated future elk traditional land use opportunity in the focal study area. Based on assumptions that were developed with input from community members.

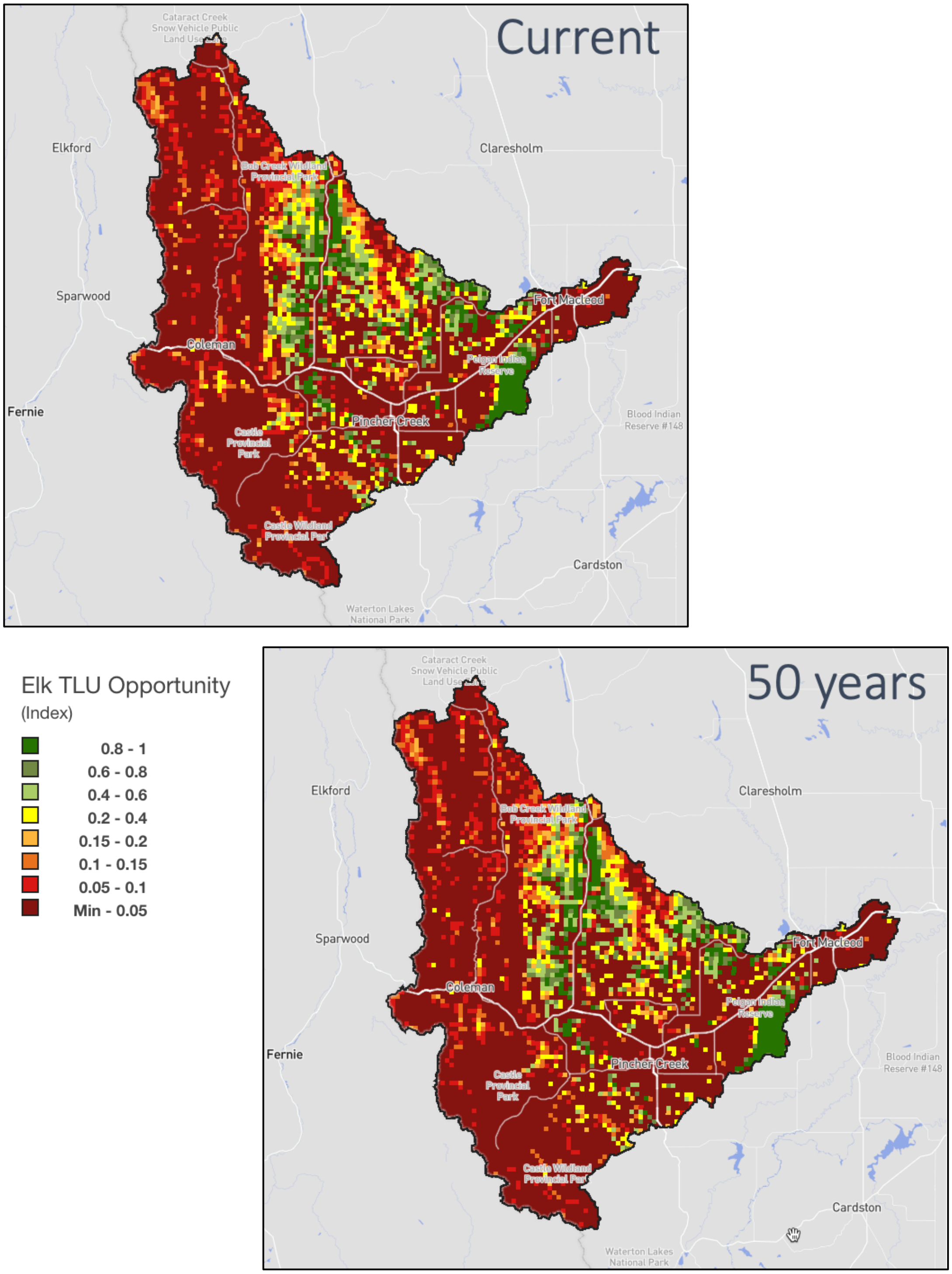

Figure 31 Current and simulated future elk TLU opportunity in the focal study area. Based on assumptions that were developed with input from community members. Higher values indicate greater opportunity.

5. SUMMARY

The majority of the regional landscape surrounding the Kainai First Nation reserve has been converted to anthropogenic cover types, primarily farmland. The loss of natural land cover and high linear footprint densities have detrimentally affected fish and wildlife, resulting in moderate risk to the fish community and high risk to elk and mule deer. Accessibility of the land for traditional activities is also of concern, with only 20% of the land estimated to be accessible. These impacts have resulted in substantially reduced opportunities for Blood Tribe members to fish and to hunt in the region, which has made the comparatively intact landscapes to the west important for traditional land use.

In the focal study area, loss of natural land cover has been lower but is still substantial, and much of the remaining natural land cover is fragmented by energy sector footprints and roads that provide access for hunting and angling. As a result, habitat is substantially below natural conditions, placing mule deer and elk, and associated traditional land use at moderate risk. The fish community is also impacted by fragmentation and access to anglers, resulting in moderate risk which increased to high over the next 50 years in response to warming. The analysis identifies risk to wildlife of not addressing the cumulative effect of habitat quality, climate change, and multiple sources of mortality including regulated hunting, indigenous hunting, poaching, and vehicle collisions. The extent to which wildlife populations are actually at risk requires more detailed analysis to assess the response of wildlife populations to multiple sources of mortality under current and alternative wildlife management strategies.

Although simulated footprint growth for the next five decades is relatively minor at the scale of the focal study area, the Grassy Mountain mine accounts for the majority of projected footprint growth in the watershed. The mine would contribute to ongoing loss of habitat and associated opportunities for traditional land use, and impacts may be greater if consequences of water contamination (e.g., selenium, calcite) were to be considered. Any further decline in opportunities for traditional land use may be of concern given that risk to traditional land use is already assessed as high.

6. REFERENCES

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APPENDIX A: TECHNICAL METHODS

APPENDIX A: KAINAI FIRST NATION CUMULATIVE EFFECTS ASSESSMENT TECHNICAL METHODS

TABLE OF CONTENTS

1. INTRODUCTION

ALCES Online is a web-based simulator for exploring the consequences of past and potential future land use and natural disturbance trajectories to a wide range of environmental and socioeconomic indicators. The document describes assumptions used to prepare simulations that assess cumulative effects for the focal and regional study areas. Two types of simulations were completed: RNV simulations approximate landscape composition and forest age dynamics in the absence of resource development and post-European settlements. The forecast simulation explores potential future changes over the next 50 years in the presence of continued resource development in the focal study area.

Application of the ALCES Online toolkit required: a) estimation of preindustrial and current landscape composition; b) simulation of a plausible future land use scenario that incorporates the suite of land uses operating in the region; c) simulation of natural fire dynamics in the absence of land use; and d) application of indicator relationships to simulated landscape dynamics to assess and potential future consequences to environmental indicators relative to natural conditions. Each of these components of the analysis is now described in turn.

2. STUDY AREAS

The analysis explored the cumulative effect of land use on ecological indicators of cultural importance. Cumulative effects were assessed at two spatial scales: 1) the Regional Study Area, which refers to a 62,904 km^2 landscape in southern Alberta within which the Blood reserves are located as well as regional landscapes that are important for traditional use; and 2) the Focal Study Area, which refers to Upper Oldman River – Crowsnest Pass watershed covering 5,966 km^2, within which the Grassy Mountain coal mining project is located. Assessing cumulative effects at the scale of the Regional Study Area explores land-use pressures that have affected opportunities to practice traditional land uses near the reserves and that have increased the importance of relatively less impacted areas such as the focal study area. Assessing cumulative effects at the scale of the Focal Study Area provides a more focussed analysis of effects near the mine.

Forecast and RNV simulations were completed for the Focal Study Area to compare current and potential future response of ecological indicators to natural condition. For the Regional Study Area, RNV simulations were completed to compare current indicator status to natural condition.

3. CURRENT AND PREINDUSTRIAL LANDSCAPE COMPOSITION

Forecast and RNV simulations tracked land use and landscape composition at the scale of 200 m and 1000 m cells,[11] respectively. Each cell's composition is multivariate, tracking the proportion of the cell belonging to a range of natural and anthropogenic cover types.

The current composition of the study area, including natural and anthropogenic cover types (Table A-1), was based on the integration of multiple land cover products including the ABMI Wall-to-Wall Land Cover Inventory and Human Footprint Data[12], Grassland Vegetation Inventory[13], Combined Wetlands Inventory, AltaLis Hydrography, and numerous additional footprint inventories from Open Street Map, AltaLIS, CanVec, Alberta Energy Regulator, Alberta Environment and Parks, National Rail Network, ESRI Basemap, Trans Canada Trail, QuadSquad, HikeAlberta, and municipalities (e.g., City of Edmonton, City of Calgary, City of Grande Prairie). An additional land cover dataset was prepared from which all anthropogenic features were removed to estimate preindustrial landscape composition. The removal of anthropogenic features resulted in some areas for which natural land cover was undefined. These areas were classified using a pre-settlement base layer developed by the Alberta Tomorrow Foundation. The pre-settlement base layer classifies the province into three pre-settlement types (forest, wetland, and grassland[14]) based on landcover and soils data. Preindustrial wetland extent was estimated using the combined wetlands inventory.

Table A-1. Natural and anthropogenic cover types used to define Alberta's landscape composition.

Name	Type
Forest Coniferous	Terrestrial Landscape
Forest Deciduous	Terrestrial Landscape
Forest Mixed	Terrestrial Landscape
Grassland	Terrestrial Landscape
Shrubland	Terrestrial Landscape
Exposed Land	Terrestrial Landscape
Rock Rubble	Terrestrial Landscape
Snow Ice	Terrestrial Landscape
Wetland Total	Terrestrial Landscape
Water Lentic	Aquatic Landscape
Water Lotic	Aquatic Landscape
Agriculture Crops	Agricultural Landscape
Agriculture Pasture	Agricultural Landscape
Airport	Footprint

[11] Larger cells were used for the RNV simulations to reduce the computational load required to complete multiple simulations each of which span 400 years. Increasing the cell size to 1000 m was deemed acceptable because the simulated fires tend to exceed 1 km^2 in size. Smaller cells (i.e., 200 m) were used for the land use forecast because land use footprint tend to be smaller in size than fires.

[12] http://www.abmi.ca/home/data-analytics/da-top/da-product-overview/GIS-Human-Footprint-Land-Cover-Data/Land-Cover.html

[13] http://www.albertapcf.org/native-prairie-inventories/gvi

[14] Forest and wetland classes from the pre-settlement base layer were reclassified into the more detailed ABMI forest (deciduous, coniferous, mixed) and wetland (treed, shrub, herbaceous) classes based on the dominant forest and wetland class within each ALUF planning region.

Name	Type
Cemetaries	Footprint
Feedlots	Footprint
Industrial	Footprint
Lagoons	Footprint
Landfill	Footprint
Major Road	Footprint
Mine Coal	Footprint
Mine Oilsands	Footprint
Mine Peat	Footprint
Mine Pits	Footprint
Minor Road	Footprint
CBM Well	Footprint
Gas Well	Footprint
Oil Well	Footprint
Other Well	Footprint
Water Well	Footprint
Pipelines	Footprint
Rail	Footprint
Recreation	Footprint
Rural Settlement	Footprint
Seismic Lines	Footprint
Sump	Footprint
Urban	Footprint
Towers	Footprint
Trails	Footprint
Trail/Winter Road	Footprint
Water Anthropogenic	Footprint

The current age (i.e., time since disturbance) of forested landscapes was derived from a Canadian forest age dataset (Pan et al. 2011), corrected to incorporate more detailed age information from ABMI cutblock, Government of Alberta wildfire data, and the Grassland Vegetation Inventory. The cutblock and fire datasets superseded the Canadian forest age dataset due to their higher resolution (disturbance polygons of various sizes as opposed to the Canadian forest age dataset's 1 km^2 resolution). Age of cutblock or fire polygons was based on the year of disturbance .

4. FOCAL STUDY AREA FORECAST SIMULATION

Simulation of future land use in the focal study area required derivation of development trajectories for each influential land use in the study area, including energy, forestry, human settlements, mining, and transportation, as well as fire. In addition to the rate of development, assumptions were required regarding the intensity and spatial distribution of associated footprints. Assumptions governing the simulation of future land use and natural disturbance are now described.

4.1. HYDROCARBON SECTOR FORECAST ASSUMPTIONS

The rate of oil and gas[15] well completions during the first decade of the simulation was based on projections developed by AER for 2018 to 2027 (AER 2018). After 2027, completion rates are assumed to continue at the 2027 rate from the AER projection because longer term projections for Alberta suggest that the rate of hydrocarbon development over the period is expected to remain relatively stable. Under the NEB[16]'s (2017) reference case, gas well completions (across types) is projected to increase from 935 in 2027 to 1061 in 2040 (13% increase) and conventional light oil production is projected to increase from 341.97 thousand barrels per day to 421.23 thousand barrels per day (23% increase).

The conventional oil and conventional gas well completion projections from AER are by Petroleum Services Association of Canada (PSAC) region. PSAC regions AB1 and AB2 overlap with the study area. Projections for these regions were adjusted (i.e., reduced) based on the proportion of each PSAC region's oil and gas wells that occur within the study area.[17] The location of new oil and gas wells was based on the location of existing oil and gas wells, respectively.[18]

Exploration wells and seismic line footprint was created based on the relative abundance of these features and wells on the current landscape. Exploratory wells were created at a rate of 0.14 exploratory wells per development well (i.e., productive oil and gas wells), which is the ratio between exploratory and development wells drilled in western Canada over the past decade (CAPP Statistical Handbook). Seismic line footprint area was created at a rate 1.22 times that of well footprint area, based on the relative abundance of seismic and well footprint in Alberta.[19] Pipelines were created as needed to link development wells to the existing pipeline network. Roads were created as needed to link all wells to the existing road network.

For all well types, completions were assumed to occur within 5 km of existing wells of that type, with higher likelihood of completions in closer proximity to the wells. Each well pad is

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[15] Shale gas wells were not included in the simulation because the study area accounts for a negligible portion of the provincial shale deposit.
[16] AER (2018) was used instead of NEB (2017) as the source for the projected rate of well completions because it provides greater spatial detail (by PSAC region instead of provincial) and greater detail on well type.
[17] The study area accounts for 0.84% and 0.08% of the Petrowell Oil Unityb footprint in PSAC AB1 and AB2, respectively; and 9.36% and 0.00% of the Petrowell Gas Unityb footprint in PSAC AB1 and AB2, respectively.
[18] The location of existing wells was used instead of a hydrocarbon deposit layer (Mossop and Shetsen 1994) to inform the location of future wells because existing wells in the study are do not tend to occur within hydrocarbon deposit polygons.
[19] The ratio between seismic and well footprint in the study area is much higher (6.90) than it is in Alberta (1.22). The ratio for Alberta was used to avoid possible exaggeration of future seismic line development.

assumed to house one well cover 1 ha. Seismic footprint was simulated to occur within 10 km of new well completions, with higher likelihood of completions in closer proximity to new wells. The intensity of seismic footprint (i.e., simulated footprint per cell) was based on current seismic footprint pattern in the study area (average and maximum seismic footprint coverage per cell of 2% and 12%, respectively).

With the exception of recent seismic lines, energy sector footprints were considered permanent in the context of a 50 year simulation. Seismic lines built within the past decade were assumed to be low impact and had a lifespan of 20 years. Older seismic lines were assumed to be permanent, based on a retrospective study of 35 year old seismic lines in northern Alberta that found over 90% of the disturbance to remain in a disturbed state (Lee and Boutin 2006). Seismic lines did not persist in farmland and grassland, and pipeline right of ways did not persist in farmland.

4.2. COAL FORECAST ASSUMPTIONS

New footprint at the Grassy Mountain mine included pits, rock disposal areas, topsoil storage areas, ponds, ditches, coal handling and processing plan infrastructure, a covered conveyor/access road/powerline right of way, a railway loop, and a proposed golf course area identified in the environmental assessment for the Grassy Mountain Coal Project (Riversdale Resources 2016). The proposed project is to be developed over the next 23 years. Development of the handling and processing plant infrastructure, ponds and ditches, railway loop, right of way, and topsoil storage occurred in the first decade of the simulation. Development of pits and rock disposal areas was spread across the next 23 years, with growth occurring outwards towards the perimeter of the pit and disposal area polygons.

Reclamation of coal footprint was not simulated. This is a conservative approach that likely exaggerates the impact of mining on wildlife, because reclamation is likely to improve wildlife habitat. Reclamation was not included because realistic reclamation of coal footprint was beyond the scope of the analysis, especially reclamation of coal mine footprint existing at the start of the simulation. To explore the sensitivity of wildlife indicators to coal mine reclamation, a simulation was completed that reclaimed new (i.e., simulated) coal mine footprint 20 years after the coal footprint was created. Coal mine footprint was reclaimed to shrubland, given that reclaimed mine footprint is likely to remain at an early successional stage by the end of the 50-year simulation. Reclamation had only a minor effect on wildlife habitat at the scale of the focal study area; elk and mule deer habitat increased by 0.37% and 0.04%, respectively, compared to a simulation that did not incorporate reclamation of simulated mining footprint.

4.3. FORESTRY FORECAST ASSUMPTIONS

Forest harvest area was based on planned harvest area for each forest management unit (FMU) occurring in the study area (C5(176), C5(179), and C5(181)). Planned coniferous harvest was simulated, and any deciduous and mixedwood harvest was assumed to be incidental. Planned harvest area for the first four decades was as projected under the preferred forest management scenario (The Forest Corp. 2006). The preferred forest management scenario from the timber supply analysis calls for harvest at 120% of coniferous AAC the first 2 decades to reduce susceptibility to mountain pine beetle, and then a reduction to 90% of coniferous AAC thereafter. Harvest in the first 2 decades is focused on FMU's C5 (176) and C5 (179) where pine is more abundant. Timber harvest in the fifth decade equaled the average of the third and fourth decades (i.e., following the reduction to 90% AAC). Planned harvest area was adjusted (i.e., reduced) based on the proportion of the FMU's total coniferous forest occurring within the study area. The spatial distribution of harvest was proportional to each FMU's planned harvest intensity (i.e., planned harvest area per total forest area) and was also influenced by forest age (oldest first). To be eligible for harvest, forest was required to be older than the minimum harvest age for coniferous forest (90 years) (Forestry Corp 2006). The size of harvest patches was based on the size of forest patches harvested in the study area between 2000 and 2009 according to harvest data from ABMI. Forest recovered to the pre-harvest forest type, with no regeneration lag. Roads were developed as required to link harvest patches to the road network. Inblock roads were assumed to regenerate with cutblocks, and were therefore not simulated.

4.4. URBAN AND RURAL RESIDENTIAL FORECAST ASSUMPTIONS

Settlement footprint was simulated to grow at the rate of population growth according to the medium population growth projection from Alberta Government for the period of 2016 to 2041.[20] The population projection was extended out to 2065 by assuming constant population growth after 2041.[21] Population projections were available by census division (CD). The rate of population growth used in the simulation was the mean population growth rate across CD's occurring in the study area, weighted based on the current area of settlement footprint in each CD. Simulated rural settlement footprint took the form of acreages[22] located within 1 km of existing rural settlement development. Simulated urban footprint occurred at the periphery of existing settlements. For both rural and urban settlement footprint, the relative likelihood of development was proportional to the patch size of existing developments (i.e.,

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[20] http://finance.alberta.ca/aboutalberta/population-projections/index.html

[21] Constant as opposed to exponential population growth was assumed because the population projection for the period of 2016 to 2041 exhibited linear growth.

[22] The size of individual rural residential footprints equaled the current average size of rural residential footprint per cell (7692 m2).

higher likelihood of development adjacent to larger existing developments). Roads were developed as needed to link acreages to the road network. Settlement footprint was excluded from protected areas.

4.5. AGGREGATE FORECAST ASSUMPTIONS

It was assumed that the primary reason for aggregate mining in the study area is road building. As such, the development of new aggregate pits was tied to the rate at which road footprint was created during the simulation. Aggregate pit footprint was created at a rate 33% that of new road footprint, based on the ratio between aggregate pit and road footprint in the study area today. The size of each new pit equaled the average size of pits existing in the study area today. Pits were located in aggregate deposits (Alberta Geological Survey 2009) located adjacent to new road footprint.

4.6. AGRICULTURE FORECAST ASSUMPTIONS

Agricultural land did not expand during the forecast. Census divisions that overlap with the study area have exhibited a decline in farmland in recent years.

4.7. FIRE FORECAST ASSUMPTIONS

The simulated fire rate was 0.06% x 2.5= 0.15% for the first 2 decades and 0.06% x 2.76=0.17% for the last 3 decades of the simulation. The historical rate for the Southern Cordillera homogenous fire regime zone (within which the study area is located) is 0.06%/year (Boulanger et al. 2014). The predicted increases in fire rate relative to historical for the 2011-2040 and 2041-2070 periods is 2.5 and 2.7, respectively, under climate scenario RCP2.6 (Boulanger pers. comm.). Fire was assumed to burn forest and shrub cover types. Fire location was stochastic but influenced by relative burn probabilities as per fire selection ratios by forest cover and age class (Bernier et al. 2016). Fire selection ratios were only available for forest types (deciduous, coniferous , mixedwood); shrubland was assumed to have the same relative burn probability as young deciduous forest, the forest category exhibiting the lowest fire selection ratio. Burns were distributed across size classes based on the size class distribution of fires according to Alberta’s historical wildfire data.

5. RANGE OF NATURAL VARIABILITY (RNV) SIMULATIONS

RNV simulations were prepared for both the focal and regional study areas. For each study area, five simulations of the stochastic fire regime were completed, each spanning 400 years. Fire was assumed to burn forest and shrub cover types.

Pre-suppression fire rate and size class distribution was based on research completed for the C5 FMU, which covers much of the forested portion of the study areas (Rogeau 2005). The average natural fire return interval, by natural subregion, was estimated to be 116 years for the Subalpine and 92 years for the Montane natural subregions. The relatively small area of the Alpine natural subregion located in the study areas is assumed to have the same return intervals as the Subalpine.

The natural fire rate was simulated as a stochastic process in order to approximate the effect of a variable fire regime on forest age and related indicators. The stochastic fire regime was simulated as random draws from a lognormal distribution, a distribution well suited for characterizing variable fire regimes (Armstrong 1999). The standard deviation in burn area was derived from the coefficient of variation in natural burn area estimated for northeastern Alberta (2.843; Armstrong 1999). Mean and standard deviation of the natural logarithm of annual burn area was then derived from the mean and standard deviation of burn area, and applied to generate random draws from the lognormal distribution. The maximum burn rate was truncated at 50% when drawing from the lognormal distribution, based on an assumption that it is unlikely that more than half of the region's forest would burn in any year.

Fire location was stochastic but influenced by relative burn probabilities as per fire selection ratios by forest cover and age class (Bernier et al. 2016). Fire selection ratios were only available for forest types (deciduous, coniferous , mixedwood); shrubland was assumed to have the same relative burn probability as young deciduous forest, the forest category exhibiting the lowest fire selection ratio. The fire size class distribution was based on an estimate of natural fire sizes in the C5 FMU (Rogeau 2005).

Forest age was initialized at 106 years across all cells, the average forest age expected in the Upper Oldman Crowsnest Pass in the presence of assumed overall average burn rate. The first 300 years of a 400 year simulation was used to initialize the spatial distribution in forest age to a pattern consistent with the assumed natural fire regime. The last 100 years of a 400 year simulation were used to estimate the range of natural variability in forest age and related indicators. Forest age was reported at 10-year intervals, creating 9 maps of forest age for each preindustrial simulation.

Fire was not simulated in the Parkland and Grassland portion of the study area. Presettlement fire behaviour in Parkland ecosystems is poorly understood, but it is thought that the Parkland was dominated by grassland due to grazing by Bison and frequent burning (Stockdale 2011). Bailey and Anderson (1980) estimate that brush cover was less than 10% in the Parkland region in the early 20th century. The location of what little forest did exist was likely stable, confined to wetter and cooler areas such as riparian areas and slopes with northerly and easterly aspects (Stockdale 2011). Given that grassland likely dominated the Parkland region prior to settlement, the presettlement landscape was estimated by assuming that forest was limited to within 200 m cells that either contain permanent water (river, stream, or lake) or have aspects between 70 and 90%. This results in forest coverage of 8.2% in the Parkland portion of the regional study area. Fire is not simulated within forests located in the Parkland because the forest is assumed to have been at low risk of fire because of its wet and relatively fragmented location.

6. INDICATORS

The following indicators were assessed to explore the cumulative effect of land use on opportunity to practice traditional land use:

1. Development footprint – the taking up of land by development was assessed as direct disturbance of land by industrial, settlement, and agricultural footprint and associated infrastructure.
2. Intact landscapes – natural land undisturbed by development. Cells (200 m) without any type of development or settlement footprint were considered intact.
3. Wildlife – moose, elk, and mule deer habitat indices were assessed to explore the response of species that are important for hunting.
4. Fish – a fish habitat index was assessed to explore cumulative effects to the fish community.
5. Traditional Land Use – accessibility for traditional land use was calculated and combined with wildlife indicators to assess TLU opportunity.

6.1. DEVELOPMENT FOOTPRINT

Total development footprint included the full set of anthropogenic features tracked in the simulations: energy sector footprints (wells, seismic lines, pipelines); settlement footprints (residential); mining footprints (coal mines and gravel pits); agricultural footprints (pasture and cropland); and other footprints (cemeteries, undifferentiated industrial, lagoons, landfills, power generation stations, powerlines, recreational footprint, and sumps).

6.2. INTACT LANDSCAPES

Intact core area was calculated as the total extent of cells that do not contain footprint or farmland. Intact patch size was calculated as the size of each patch of cells that does not contain footprint or farmland.

6.3. WILDLIFE HABITAT

Wildlife habitat indices (moose, elk, mule deer) were calculated for the current landscape, the simulated future landscape, and the simulated natural landscape. Risk to wildlife was assessed based on change in habitat relative to natural conditions. Risk levels were based on hazard categories from MacPherson et al. (2014): low risk if index is >=70% of the natural value; moderate risk if index is 50%-70% of the natural value; high risk if index is 20%-50% of the natural value; and very high risk if index is <20% of the natural value.

The habitat indices incorporate both potential and effective habitat. Potential habitat refers to the availability (and quality) of suitable land cover and terrain, and is calculated by applying coefficients (0.00 to 1.00 where 0 reflects no habitat value and 1.00 reflects maximum value) to maps of natural and anthropogenic cover types, elevation, and slope. Effective habitat modifies potential habitat to incorporate the negative impact of linear features through elevated hunting, predation, road-kill, and noise displacement, etc. These mortality risks are incorporated through a relationships with linear footprint density outside of protected areas, due to the importance of linear footprints for providing access for hunting. Linear footprints that are included in the analysis are roads, truck trails, pipelines, powerlines, rail, and conventional seismic lines. Conventional seismic lines are older cutlines that, due to their width, persist through time and are used for vehicular access. Conventional seismic lines are assumed to be those created at least 10 years ago. New seismic lines are assumed to be created using low impact methods that are intended to avoid the creation of cutlines that can be used for vehicular access.

The underlying methodology deployed when calculating habitat was developed by a joint ALCES Group and Alberta Fish and Wildlife Division (AFWD) discussion about how to best define potential and effective habitat for wildlife species. Coefficients were developed by Dr. Brad Stelfox and Shawn Wasel (ALCES Group) and discussed with AFWD wildlife biologists.[23] The coefficients reflect a suite of input data sources that include: literature review (both published and unpublished); comparison to historical wildlife populations from aerial surveys at the scale of WMUs; comparison to historical wildlife harvest data at the scale of WMUs; discussions with government, academic and industrial biologists; qualitative ranking of habitat and footprint types based on a general delphi approach within ALCES Group; and where possible, input from hunters of First Nation communities.

Coefficients for each species are now described.

6.3.1. Moose

Coefficients are applied to cover types (Table A-2), forest age (Table A-3), and terrain

[23] AFWD is in the process of building a set of AFWD endorsed coefficients for each wildlife species and this process is likely to take a few years to complete.

variables (Tables A-4 and A-5) to calculate a moose potential habitat index ranging from 0 (no habitat) to 1 (habitat capable of supporting maximum wildlife density). Moose effective habitat is calculated by multiplying potential habitat by a modifier that is based on the length of linear footprint (Table A-6).

Table A-2. Coefficients for various landscape and footprint types associated with the moose habitat index.

Landscape and footprint type	Habitat value
Coniferous forest	0.80
Deciduous forest	1.00
Mixedwood forest	1.00
Shrubland	0.70
Grassland	0.00
Rock, Ice, Exposed	0.00
Wetland	1.00
Lentic riparian	0.50
Lotic	0.45
Cropland	0.15
Pasture	0.00
Tracks	1.00
Recreation features	0.60
Wellsites	0.20
Pipelines	0.40
Transmission lines	0.20
Other footprints	0.00

Table A-3. Habitat modifiers for forest ages associated with the moose habitat index.

Forest Age	Habitat modifier
0-20	1.00
21-40	0.90
41-60	0.70
61-80	0.50
81-100	0.30
101-120	0.50
121-140	0.50
141-160	0.50
161-180	0.65
>180	0.80

Table A-4. Slope habitat modifiers for the moose habitat index.

Slope	Habitat modifier
0.0	1.00
2.5	0.95
5.0	0.90
7.5	0.85
10.0	0.80
12.5	0.40
15.0	0.00
17.5	0.00
20.0	0.00
22.5	0.00
25.0	0.00

Table A-5. Elevation habitat modifiers for the moose habitat index.

Elevation	Habitat modifier
1300	1.00
1470	0.97
1640	0.92
1810	0.90
1980	0.80
2150	0.55
2320	0.30
2490	0.00
2660	0.00
2830	0.00
3000	0.00

Table A-6. Linear footprint length modifiers for the moose habitat index.

Linear footprint (km/km^2)	Habitat modifier	
	With hunting	Without hunting[24]
0.0	1.00	1.00
0.4	0.96	1.00
0.8	0.92	1.00
1.2	0.87	1.00
1.6	0.69	1.00
2.0	0.46	1.00
2.4	0.30	1.00
2.8	0.15	1.00
3.2	0.09	1.00
3.6	0.05	1.00
4.0	0.00	1.00

[24] Hunting is assumed to not occur in national and provincial parks and ecological reserves.

6.3.2. Elk

Coefficients are applied to cover types (Table A-7), forest age (Table A-8), and terrain variables (Tables A-9 and A-10) to calculate an potential habitat index ranging from 0 (no habitat) to 1 (habitat capable of supporting maximum wildlife density). Elk effective habitat is calculated by multiplying potential habitat by a modifier that is based on the length of linear footprint (Table A-11).

Table A-7. Coefficients for various landscape and footprint types associated with the elk habitat index.

Landscape and footprint type	Habitat value
Coniferous forest	0.35
Deciduous forest	0.90
Mixedwood forest	1.00
Shrubland	0.35
Grassland	1.00
Rock, Ice, Exposed	0.00
Wetland	0.02
Lentic riparian	0.00
Lotic	0.65
Cropland	0.075
Pasture	0.20
Tracks	1.00
Recreation features	0.20
Wellsites	0.20
Pipelines	0.20
Other footprints	0.00
Coniferous forest	0.35

Table A-8. Habitat modifiers for forest ages associated with the elk habitat index.

Forest Age	Habitat modifier
0-20	1.00
21-40	0.90
41-60	0.70
61-80	0.50
81-100	0.40
101-120	0.40
121-140	0.40
141-160	0.50
161-180	0.60
>180	0.70

Table A-9. Slope habitat modifiers for the elk habitat index.

Slope	Habitat modifier
0.0	1.00
2.5	1.00
5.0	1.00
7.5	1.00
10.0	1.00
12.5	0.85
15.0	0.57
17.5	0.33
20.0	0.00
22.5	0.00
25.0	0.00

Table A-10. Elevation habitat modifiers for the elk habitat index.

Elevation	Habitat modifier
1300	1.00
1470	1.00
1640	1.00
1810	1.00
1980	1.00
2150	1.00
2320	0.85
2490	0.64
2660	0.34
2830	0.12
3000	0.00

Table A-11. Linear footprint length modifiers for the elk habitat index.

Linear footprint (km/km^2)	Habitat modifier	
	With hunting	Without hunting[25]
0.0	1.00	1.00
0.4	0.96	1.00
0.8	0.92	1.00
1.2	0.87	1.00
1.6	0.69	1.00
2.0	0.46	1.00
2.4	0.30	1.00
2.8	0.15	1.00
3.2	0.09	1.00
3.6	0.05	1.00
4.0	0.00	1.00

[25] Hunting is assumed to not occur in national and provincial parks and ecological reserves.

6.3.3. Mule Deer

Coefficients are applied to cover types (Table A-12) and terrain variables (Tables A-13 and A-14) to calculate a mule deer potential habitat index ranging from 0 (no habitat) to 1 (habitat capable of supporting maximum wildlife density). Mule deer effective habitat is calculated by multiplying potential habitat by a modifier that is based on the length of linear footprint (Table A-15).

Table A-12. Coefficients for various landscape and footprint types associated with the mule deer habitat index.

Landscape and footprint type	Habitat value
Coniferous forest	0.15
Deciduous forest	1.00
Mixedwood forest	0.90
Shrubland	0.20
Grassland	1.00
Rock	0.00
Ice, Exposed	0.00
Wetland	0.00
Lentic riparian	0.10
Lotic Water	0.50
Cropland	0.175
Pasture	0.85
Powerlines	0.20
Urban	0.05
Tracks	1.00
Recreation features	0.20
Wellsites	0.10
Pipelines	0.20
Other Footprints	0.00

Table A-13. Slope habitat modifiers for the mule deer habitat index.

Slope	Habitat modifier
0.0	1.00
2.5	1.00
5.0	1.00
7.5	1.00
10.0	1.00
12.5	0.85
15.0	0.57
17.5	0.33
20.0	0.00
22.5	0.00
25.0	0.00

Table A-14. Elevation habitat modifiers for the mule deer habitat index.

Elevation	Habitat modifier
1300	1.00
1470	1.00
1640	1.00
1810	0.85
1980	0.80
2150	0.72
2320	0.62
2490	0.42
2660	0.35
2830	0.00
3000	0.00

Table A-15. Linear footprint length modifiers for the mule deer habitat index.

Linear footprint (km/km^2)	Habitat modifier	
	With hunting	Without hunting[26]
0.0	1.00	1.00
0.4	0.96	1.00
0.8	0.92	1.00
1.2	0.87	1.00
1.6	0.69	1.00
2.0	0.46	1.00
2.4	0.30	1.00
2.8	0.15	1.00
3.2	0.09	1.00
3.6	0.05	1.00
4.0	0.00	1.00

6.3.4. Index of native fish integrity

The index of native fish integrity (INFI) conveys changes in abundance and composition of fish species with a value ranging from 0 (highly disturbed community) to 1 (undisturbed community). An INFI value greater than 0.9 indicates low (acceptable) disturbance, between 0.6 and 0.9 indicates moderate (unacceptable) disturbance, between 0.3 and 0.6 indicates high (serious) disturbance, and below 0.3 indicates very high risk (severe disturbance) (Sullivan 2009). INFI response to simulated landscapes is estimated using relationships with access density[27], watershed discontinuity, and climate developed for the Foothills/Montane and Prairie natural regions from expert opinion (Sullivan 2009). The various INFI relationships

[26] Hunting is assumed to not occur in national and provincial parks and ecological reserves.

[27] Two versions of the relationship between access density (i.e., roads, seismic lines, trails) and INFI are provided by Sullivan (2009): restricted access and unrestricted access. Restricted access was applied to the following zones based on the assumption that motorized access is more limited: national and provincial parks, wildland areas, natural areas, and public land use zones. The relationship that assumes unrestricted access was applied elsewhere.

used are presented in Tables A-12, A-13, and A-14. Although an INFI relationship with water quality was also available (Table A-15), it was not included because it did not incorporate potential contaminants from industrial development such as mining. INFI performance was tracked at the scale of hydat watersheds. INFI relationships developed for the foothills and montane (Sullivan 2009) were applied in the montane portion of the study area, whereas INFI relationships developed for the prairies (Sullivan 2009) were applied to the grassland and parkland portion of the study area.

Table A-12 Relationship between INFI and stream fragementation.

INFI	Stream Fragmentation (%)	
	Foothills	Prairie
1	0	0
0.95	1	20
0.75	20	30
0.45	30	100
0.15	50	na
0	100	na

Table A-13 Relationship between INFI and temperature.

INFI	Change in temperature (C)[28]	
	Foothills	Prairie
1	0	0
0.95	2.5	
0.75	4	1
0.45	5	5
0.15	6	8

Table A-14 Relationship between INFI and linear edge density (assuming restricted access).

INFI	Linear edge (km/km2) with unrestricted access	
	Foothills	Prairie
1	0	0
0.95	1	1
0.75	2	5
0.45	3	na
0.15	5	na

Table A-15 Relationship between INFI and the water quality index (WQI).

INFI	WQI

[28] Change in annual average temperature was relative to the average temperature during the first half of the 20th century. The climate forecast applied the RCP 4.5 emission scenario.

	Foothills	Prairie
1	1	1
0.95	0.33	0.5
0.75	0.2	0.33
0.45	0.125	0.25
0.15	0.1	0.125

To permit calculations of INFI watershed discontinuity was also calculated, as described below.

Stream crossings and watershed discontinuity

Stream crossings with the potential to impede fish movement were assumed to occur at the intersection of roads and permanent and indefinite streams[29] because culverts are likely to be utilized. In contrast, bridges instead of culverts were assumed to be used where roads intersect with rivers, and recurring streams were assumed to be non-fish bearing. Stream crossing density was assessed for each HUC8 level watershed as the number of road crossings per km of permanent/indefinite stream. Stream crossings increased during simulations in response to expansion of the road network, in proportion with the existing density of crossings per km of road in a watershed.

Culverts can become impassable by fish over time due to effects such as blockage and scouring. Fifty percent of culverts were assumed to be hanging based on the findings of a study of culverts in northeastern Alberta (Park et al. 2008). By blocking fish movement, an impassable (i.e., hanging) culvert renders upstream habitat inaccessible. Stream fragmentation due to impassable culverts was assessed using a relationship between the density of impassable culverts (#/stream km) and the percent of stream habitat lost, as derived from actual and simulated stream crossings for the Christina, Calling, Swan, and Notikiwin watersheds in northern Alberta (Michael Sullivan, pers. comm.). The data from the northern watersheds were summarized using the equation $y = 1.6445x^{0.7381}$ (R^2=0.939), where y is the proportion of stream habitat lost and x is the number of impassable culverts per km of stream.

6.4. Traditional Land Use

We used participatory principles for developing and examining the TLU accessibility and potential indicators for the Blood Tribe. We worked with ten community knowledge holders (e.g., elders and hunters) with a specific interest and experience using the land to practice

[29] Indefinite refers to a perennial or intermittent stream whose channel cannot be clearly distinguished due to vegetation or high water. Because such streams may be permanent (i.e., perennial), they may be fish bearing and culverts may be used at crossings.

activities such as hunting (e.g., deer, moose, elk), fishing, and other TLU activities (e.g., harvesting medicinal plants, picking berries, conducting ceremonies). We engaged knoweldge holders for guidance to broadly identify: (i) how members use the land; and, (ii) what are the challenges that members face when accessing and using the land. This approach helped us to understand "lived experience" from the perspective of community members and to ensure that our interpretations were relevant, useful and meaningful to Blood Tribe members. The following points of community input provided the basis for developing the TLU indicators.

- Community members expressed that the conversion of TLU suitable crown lands to private property and other restricted land uses (e.g., parks, ecological reserves) is the primary driver of decreased access to TLU suitable lands. We were unable to obtain a land ownership data layer and instead used cropland and cultivated pasture to indicate the presence of private land. This likely underestimates the extent of private land.
- Community members conveyed that they do not hunt or fish in national parks, provincial parks, and ecological reserves, so these areas were deemed inaccessible for traditional land use.
- Community members conveyed that they do not hunt or fish in close proximity (~500 m) to well sites. Based on this input, land cover within 500 m[30] of well sites and other industrial sites (coal mines, industrial features, power generation sites) were excluded from traditional land use. It was also assumed that hunting and fishing does not occur within 500 m of settlements, rural residence, and other features (major highways, recreational features like golf courses, cemeteries, landfills, airports) that are used frequently by humans for non-TLU activities.
- Agricultural land within the Blood reserves was accessible for TLU, but land in proximity to footprints was excluded following the rules described above.

Drawing from community input, a TLU accessibility indicator was developed to reflect the cumulative effects of land development on their access to TLU suitable lands. Overall, TLU accessiblity was based on land ownership, protection, proximity to non-traditional land use activities and community member avoidance due to concerns about contamination, safety, and overall negative experience on the land.

[30] To approximate a 500 m buffer, 1000 m cells with any of the listed footprint types were assumed to be inaccessible. The rationale is that a footprint within a 1000 m cell will be, on average, 500 m from the edge of the cell. This assumption was required because 1000 m cells were used for the calculation of wildlife habitat. Community members also conveyed that they do not hunt adjacent (~100 m) to all roads. This buffer was not implemented because it is small relative to the cell size used during wildlife modeling (1000 m).

TLU accessibility was applied to wildlife effective habitat to assess TLU opportunity. The TLU opportunity metric is based on the rationale that capacity to practice TLU in the landscape is affected by the availability of wildlife habitat and the ability of community members to access the landscape for the purpose of practicing TLU. The TLU opportunity metric ranges from 0 to 1, with a 1 indicating maximum habitat effectiveness and accessibility for TLU, and a 0 representing no habitat and/or accessibility for TLU.

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APPENDIX B: DETAILED REGIONAL RESULTS

APPENDIX B: DETAILED REGIONAL RESULTS

The results presented below are the detailed version associated with the summary of results for the regional study area presented in section 4.1 above. For ease of referencing, we have repeated Figure 1 and Table 1 below as Figure B-1 and Table B-1.

1. PROTECTED AREAS AND LAND USE FOOTPRINTS

This section presents the various protected areas and land uses that may affect traditional land use in the regional study area either by restricting access to the land or by altering the capacity of the land to support wildlife. Community members discussed the effect of protected areas and footprints on TLU at a workshop. The discussion informed TLU accessibility and opportunity indicators that are presented later in this section and described in greater detail in the methods appendix (Appendix A).

Restrictive protective areas

Restrictions on land use in the regional study area are related to national parks, provincial parks, and ecological reserves, amounting to 3% (91,826 ha) of the regional study area (Figure B-1).[31] These areas have various harvesting restrictions that prevent Blood Tribe members from practicing TLU within portions of their traditional territory. We did not include wildland provincial parks and other natural areas in the study area because it is our understanding that these areas do not have restrictions on hunting.[32]

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[31] National parks in the study area include: Waterton Lakes. Provincial parks in the study area include: Castle, Police Outpost, Beauvais Lake, Woolford, Park Lake, Chain Lakes, Willow Creek, Little Bow, Wyndham-Carseland, Fish Creek, Tillebrook Trans-Canada Campsite, Kinbrook Island, Dinosaur, Writing on Stone, Castle. Ecological reserves include Plateau Mountain, West Castle Wetland, Kennedy Coulee. There are no wilderness areas in the regional study area as defined by Alberta Parks: https://www.albertaparks.ca/albertaparksca/library/land-reference-manual/parks-by-class/?id=Wilderness%20Area.

[32] This research was done with reference to provincial hunting information provided at: https://www.albertaparks.ca/albertaparksca/visit-our-parks/activities/hunting/#na

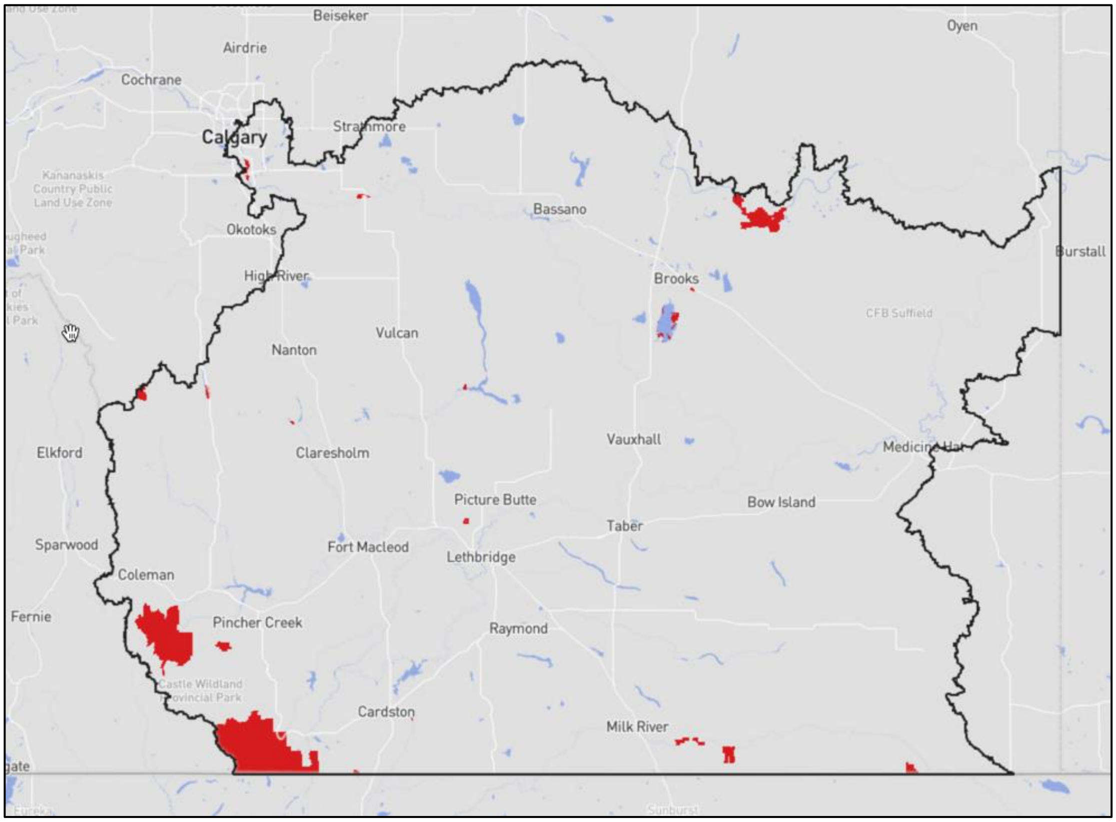

Figure B-1 Locations in the regional study area of the restrictive tenure types (i.e., national parks, provincial parks, ecological reserves) that may limit hunting opportunities for Blood Tribe members. Red indicates restrictive tenure.

Footprint types

Total footprint in the regional study area involves a variety of non-natural (anthropogenic) activities[33] and amounts to 49% (3,087,672 ha) of the study area (Figure B-2). The relative contributions of six land use types are displayed in Figure B-3. The main contributor to total footprint is farmland, which occurs throughout the study area and accounts for 45% (2,848,386 ha) of the study area and 92% of total footprint in the study area (Figure B-4). Figures B-5 through B-9 present the more minor contributions to non-natural footprint for energy, mining, transportation, settlement, and "other footprints,"[34] respectively.

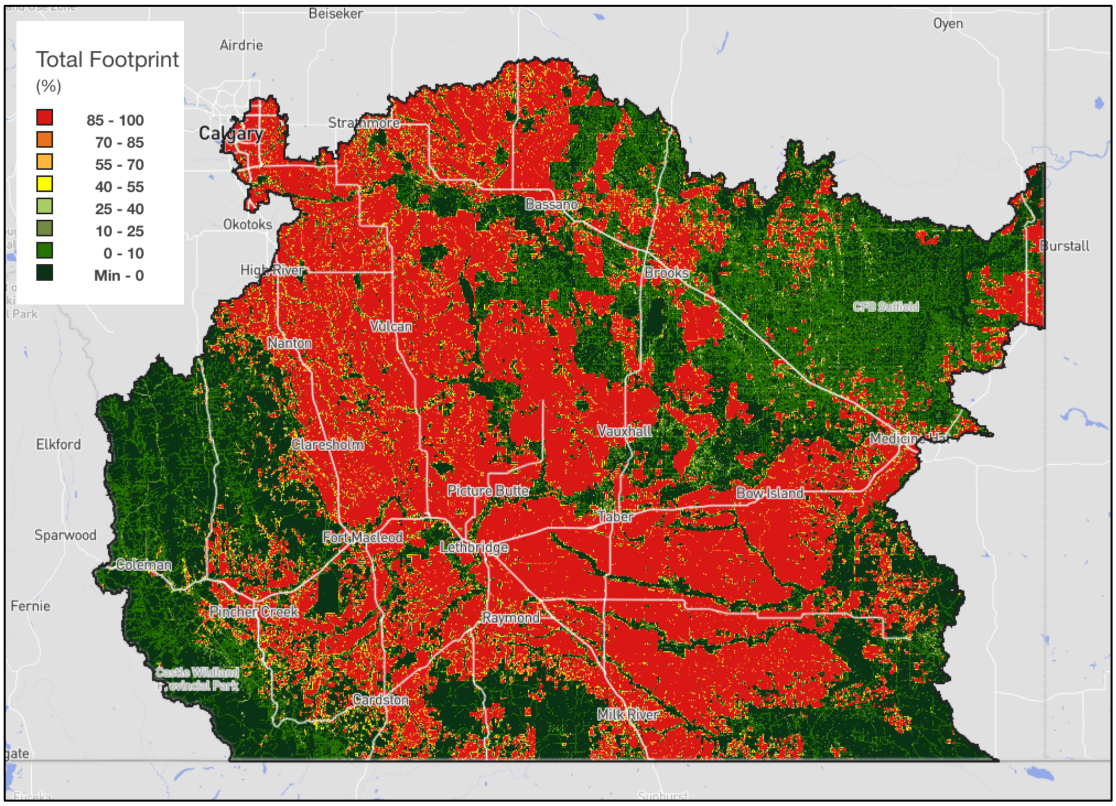

Figure B-2 Current total anthropogenic footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the proportion of each pixel occupied by footprint features.

[33] Direct footprint construction activities include: agricultural crops and pasture, airports, cemeteries, feedlots, industrial features, lagoons and other water features, landfills, major and minor roads, mining, oil and gas wells, pipelines, power-generation facilities, powerlines, rail lines, recreational features, urban and rural settlements, seismic lines, and trails and winter roads. The dataset is based on disturbance layers from the Alberta Biodiversity Monitoring Institute and 2015 AltaLIS data.

[34] Includes cemeteries, industrial undifferentiated, lagoons, landfills, power generation, powerlines, recreation, and sumps.

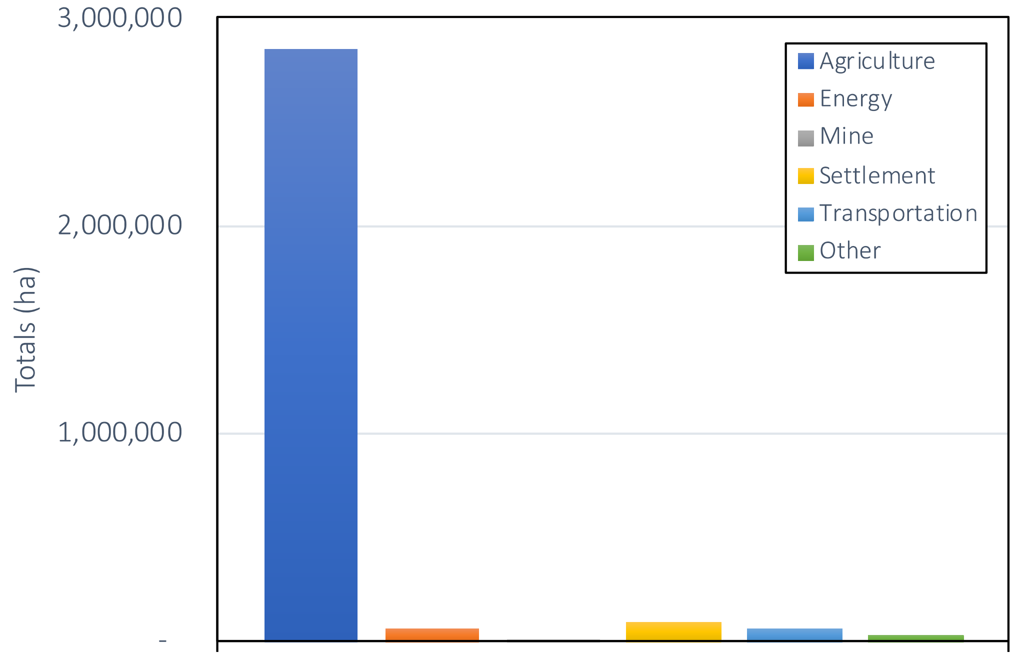

Figure B-3 Current development footprint by land use type in the regional study area.

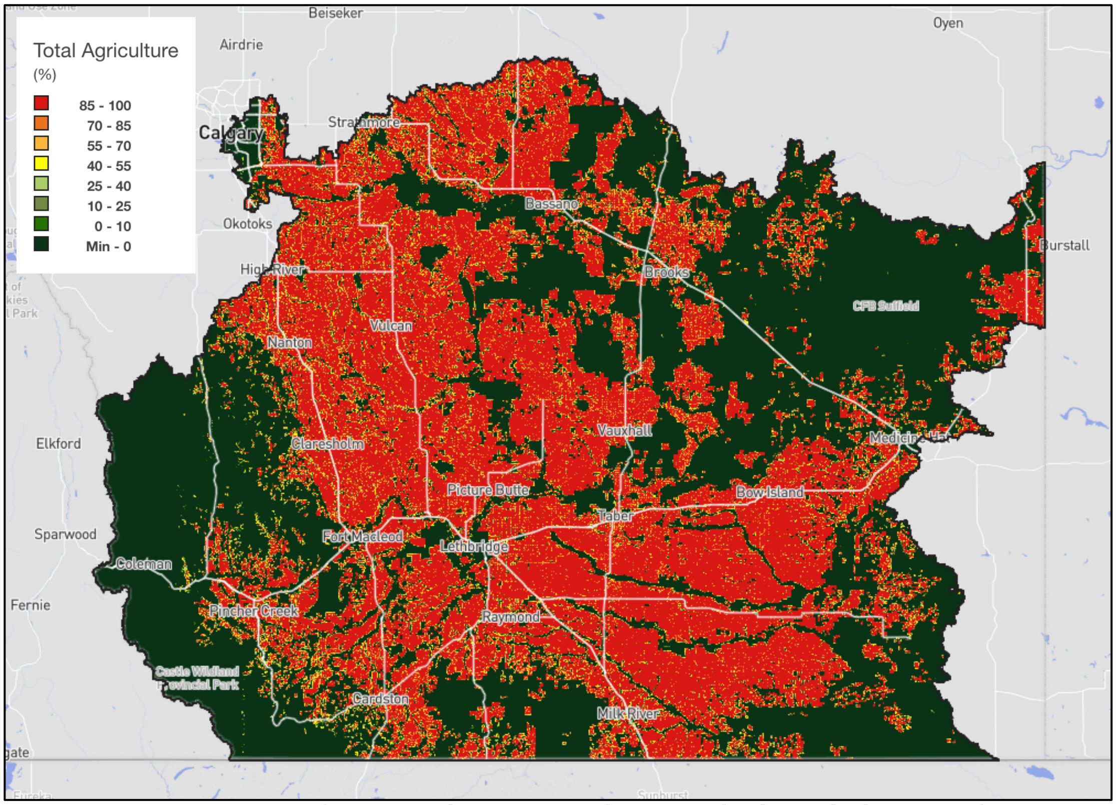

Figure B-4 Current agricultural footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

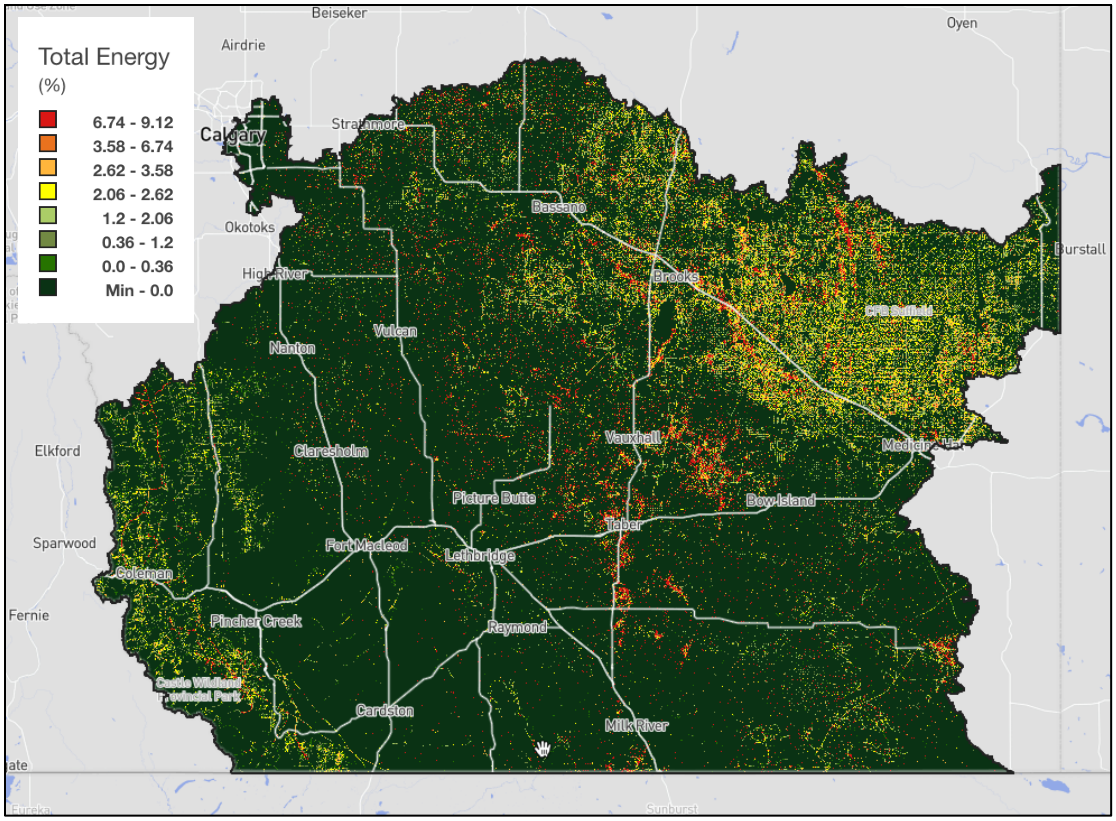

Figure B-5 Current energy footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

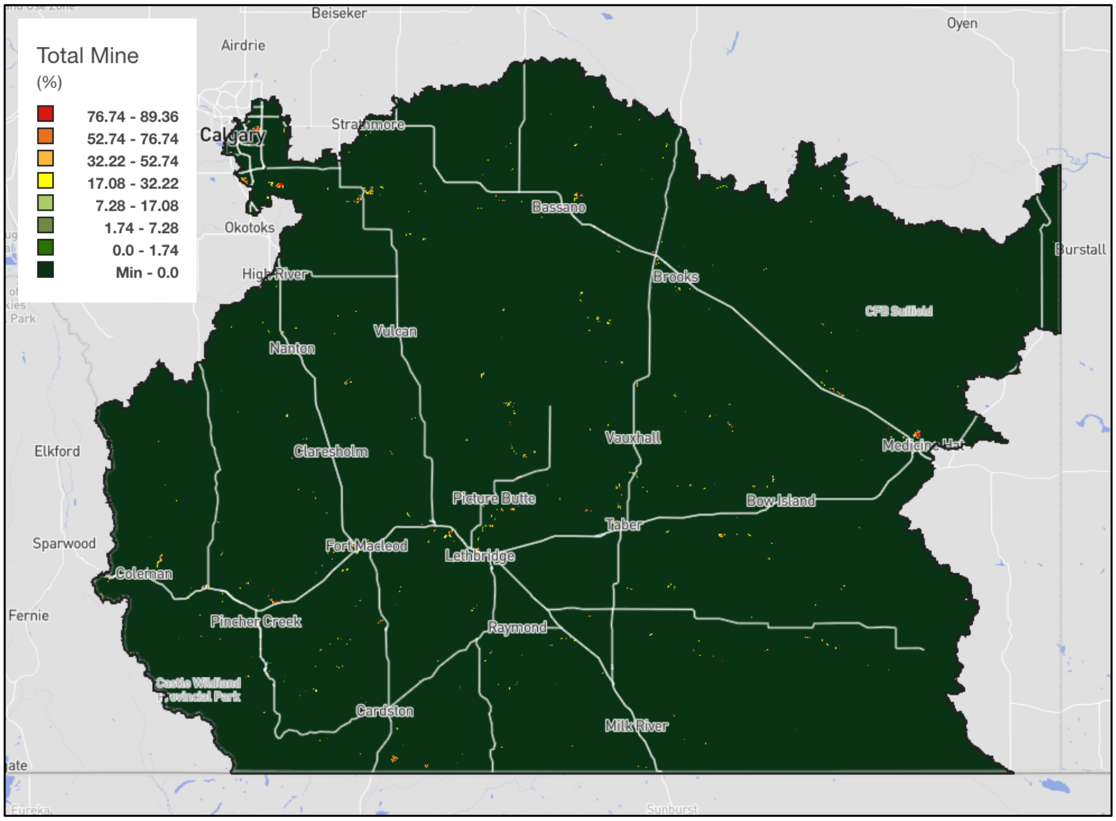

Figure B-6 Current mining footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

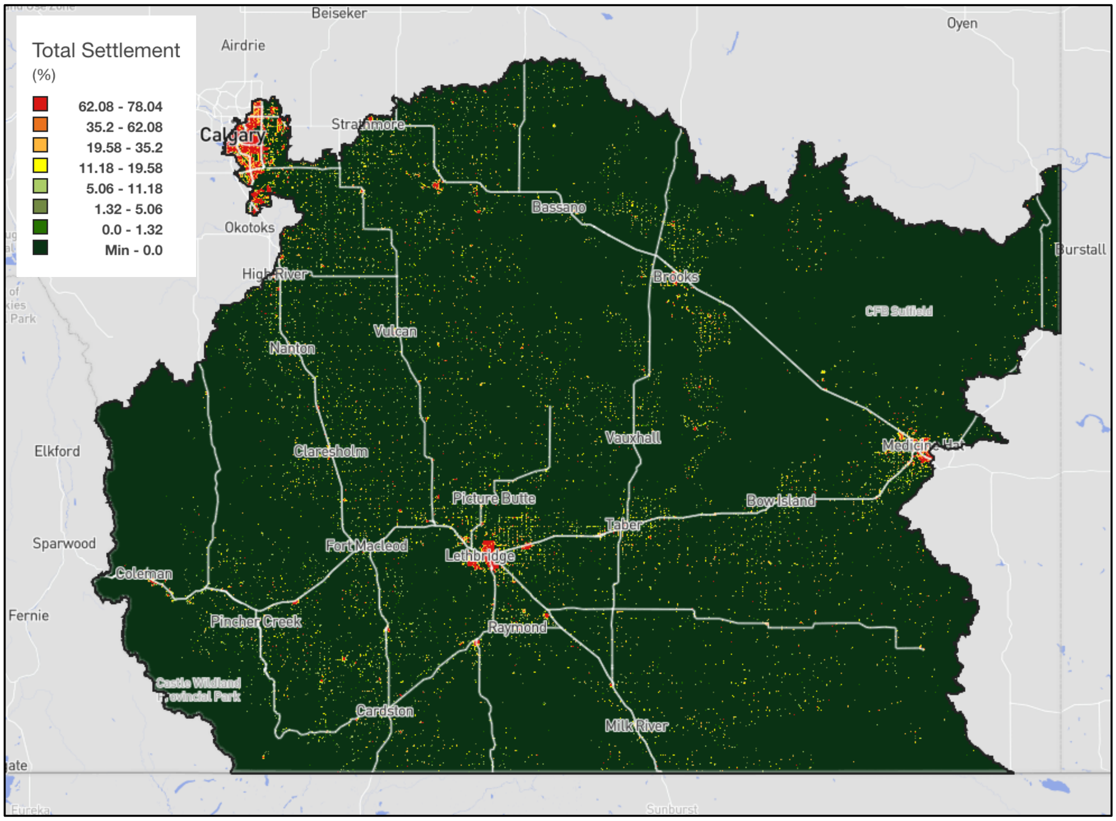

Figure B-7 Current settlement and rural residential footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

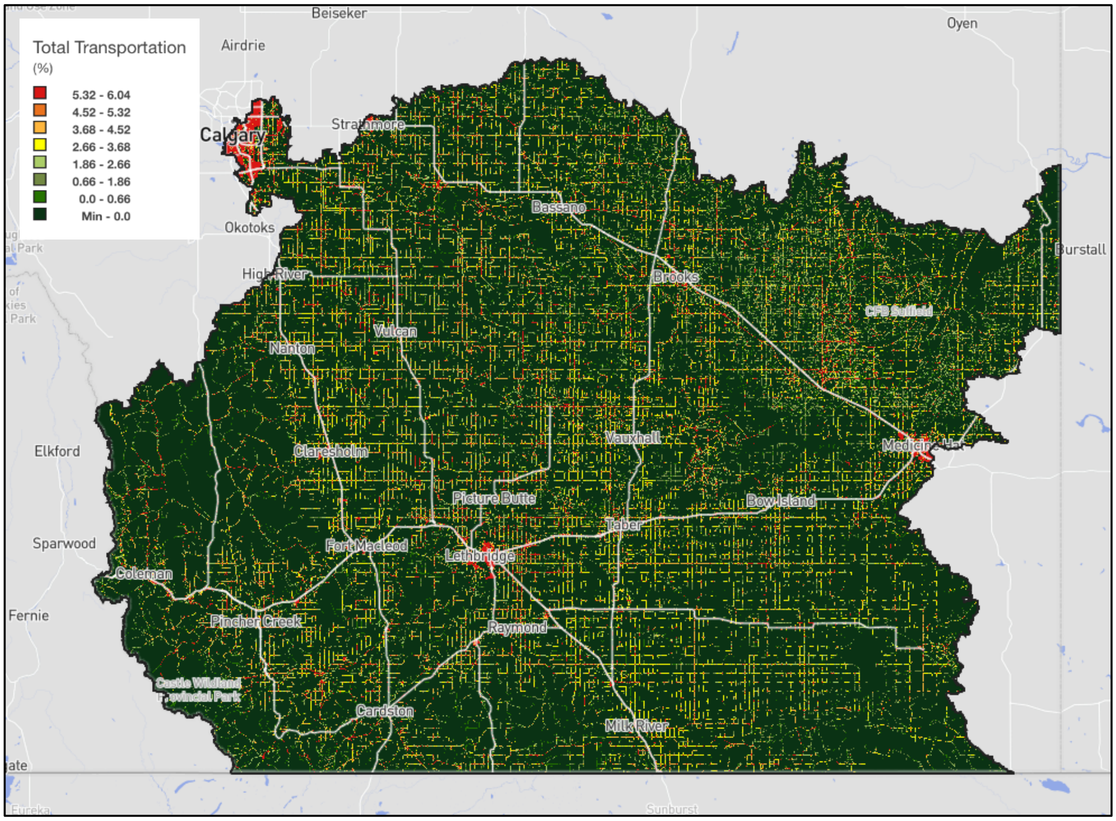

Figure B-8 Current transportation footprint in the regional study area. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

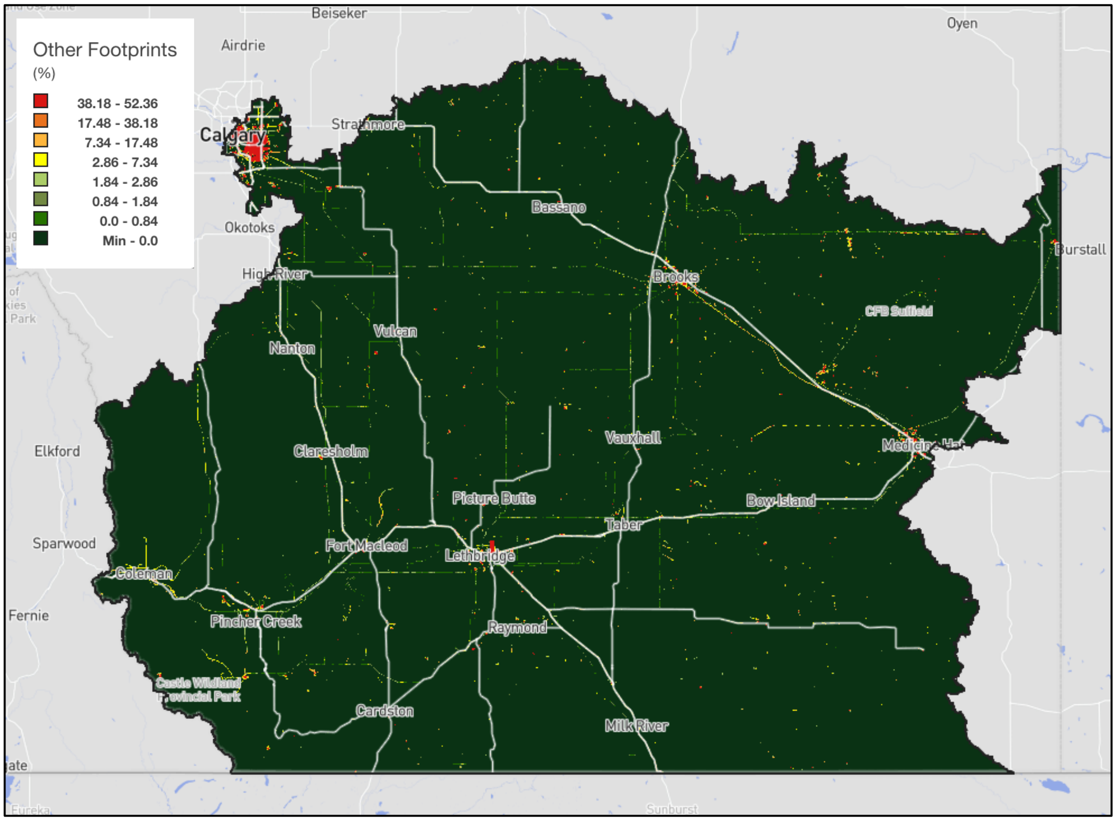

Figure B-9 Other current footprints in the regional study area, including cemeteries, industrial undifferentiated, lagoons, landfills, power generation, powerlines, recreation, and sumps. Red indicates high intensity footprint while green indicates low intensity footprint. The legend shows the percent of each pixel occupied by footprint features.

2. REMAINING INTACT ECOSYSTEMS

Effects of land disturbance to ecosystems were examined by analyzing impacts to (i) forest age, (ii) intact core area, and (iii) intact patch size.

Forest age

For the regional study area, the current average forest age in the Rocky Mountain portion of the study area (where most forest occurs) is 80 years, which is slightly lower than the mean across RNV simulations (83 years). The current distribution of forest age across the study area is shown in Figure B-10.

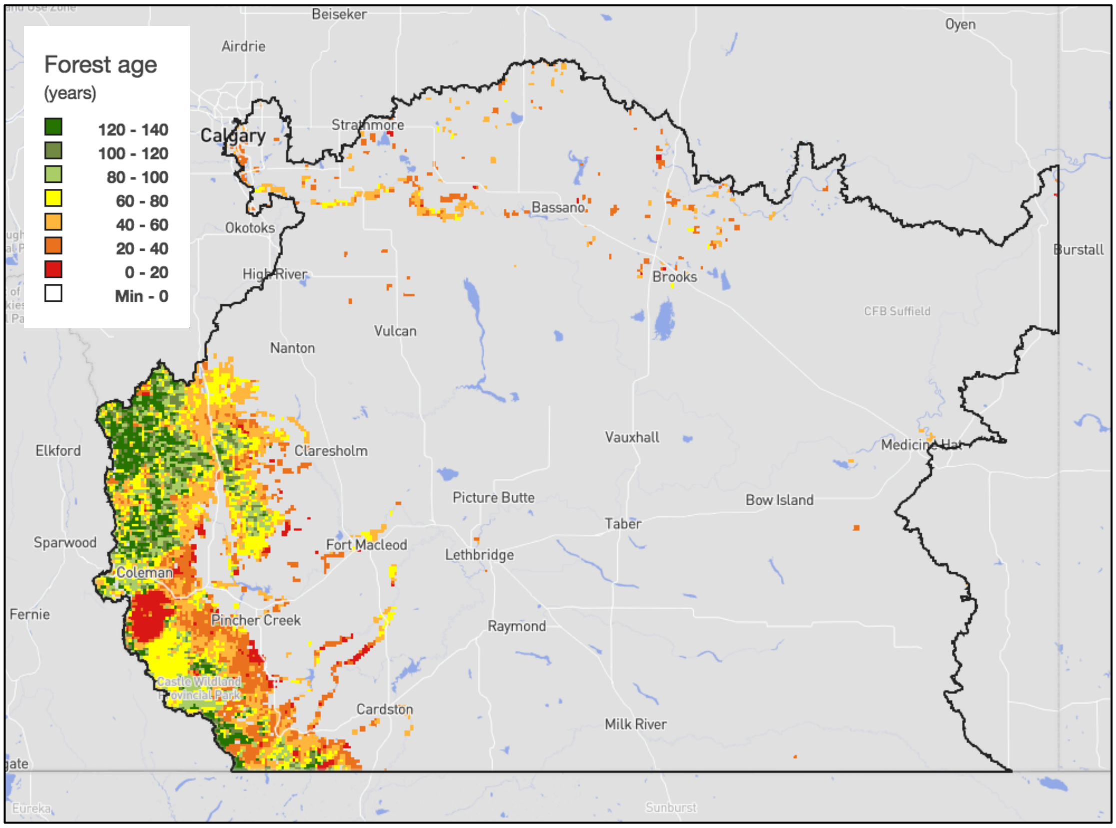

Figure B-10 Current forest age in the regional study area. The oldest age category (120-140) includes forest older than 140 years. Transparent cells indicate the absence of forest.

Intact core area

There is currently only about 28.7% (1,803,202 ha) of the study area that is intact (i.e., 200 m cells that do not contain footprint or farmland). Of this area, a portion (134,881 ha) is comprised of waterbodies, leaving only about 27% of the study area intact if only the terrestrial land base is considered. Much of the intact area occurs in the western portion of the study area, which is characterized by foothills and mountains and includes a large protected area (i.e., Waterton Lakes National Park).

Intact patch size

Average intact patch size across the terrestrial land base of the regional study area (i.e., not including lakes) is about 9,224 ha (Figure B-11). Larger patches of intact land cover are generally limited to mountainous and protected areas to the west as well as several large registered natural areas to the south.[35]

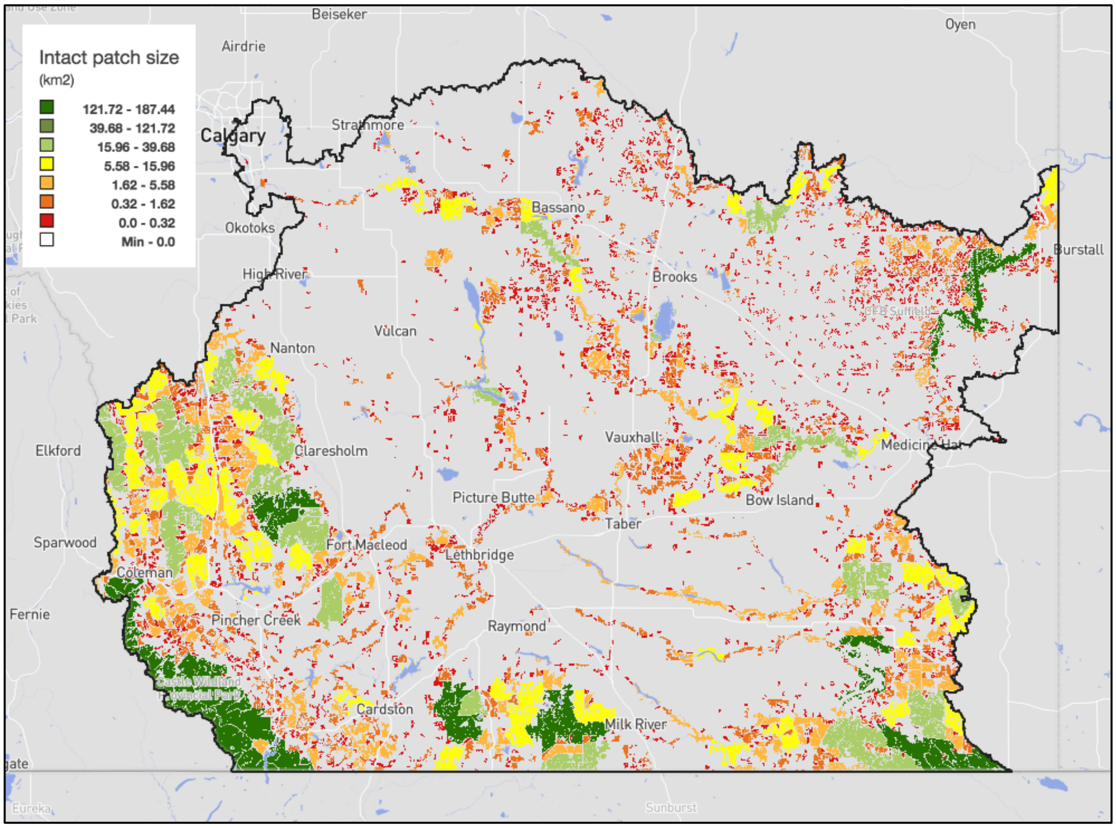

Figure B-11 Current intact patches of natural land cover in the regional study area. Green indicates large intact patch sizes, red indicates small sizes, and clear indicates the absence of intact patches.

[35] Natural areas in the southern portion of the study include Ross Lake, Twin River Heritage Rangeland, Milk River, and Onefour Heritage Rangeland

3. EFFECTS TO WILDLIFE AND FISH

Cumulative effects to wildlife and fish were examined by analyzing impacts to four animal indicators (i.e., animal species or groups of animals) that are culturally important to the Blood Tribe people:

1. moose;
2. elk;
3. mule deer; and,
4. fish.

Results of the analyses and a risk assessment are summarized in Table B-1. Results by indicator are discussed below.

Table B-1. Modelled indicator performance and risk assessment. See section 3.2 or Appendix A for risk categories.

Indicator	Min. RNV (or 1)	Current estimate	Current decline (%) from min. RNV	Risk level
Moose habitat*	0.02	0.07	-	-
Elk habitat*	0.84	0.31	63	High
Mule deer habitat*	0.84	0.39	54	High
INFI (fish)	1.00**	0.77	23	Moderate
INFI linear edge effect with harvest restrictions	1.00**	0.71	29	Moderate
INFI stream frag effect	1.00**	0.70	30	Moderate
INFI climate effect	1.00**	0.91	9	Low

* Habitat refers to effective habitat, which accounts for availability of suitable land cover and terrain combined with mortality risk associated with linear footprints.

** For INFI, any decline from a value of 1 signifies degrading conditions for the indicator. As a result, the output for this indicator is compared to 1 rather than to mean RNV.

Moose

Prior to industrial development, the majority of the regional study area was grassland and thus unsuitable for moose, with the exception of relatively small pockets of forest, such as mountain valleys in the western portion of the study area (Figure B-12). In subsequent decades, moose habitat in the study area has increased relative to natural conditions (Table B-1), largely driven by the conversion of grassland to cropland, which has a slightly higher value to moose. The value of cropland is still low relative to the preferred forest habitat, however, and linear access is high in the agricultural portion of the landscape. Therefore, although moose habitat is higher than the estimated natural level in the agricultural area, moose habitat is still very low. The best moose habitat likely remains the forested mountain valleys to the west, where habitat has declined relative to natural due to habitat loss and mortality risk associated with access. Overall, effective moose habitat in study area is low.

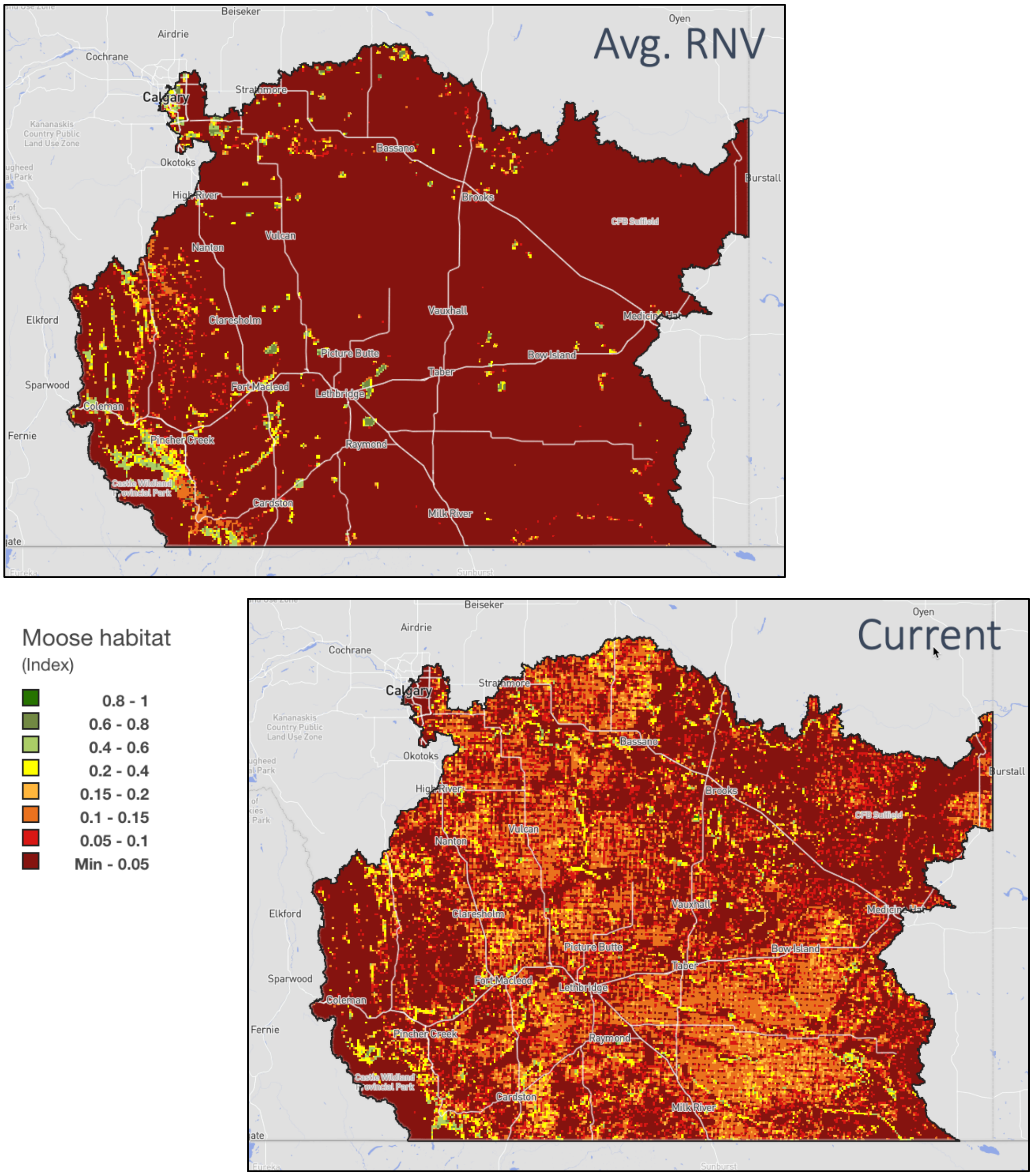

Figure B-12 Natural and current moose habitat in the regional study area. A value of 1 identifies maximum effectiveness.

Elk habitat

Elk habitat has declined by an estimated 63% relative to natural conditions in the regional study area (Table B-1). Elk habitat was likely highest in grasslands occurring in the central and eastern (i.e., Prairie) portion of the regional study area prior to industrial development (Figure B-13). Elk habitat has since declined substantially due to agricultural conversion and high linear footprint densities and associated access for hunting. This decline corresponds to an assessment of high risk to elk and to associated hunting opportunities. Remaining elk habitat occurs primarily in protected areas where linear footprint density and hunter access are low.

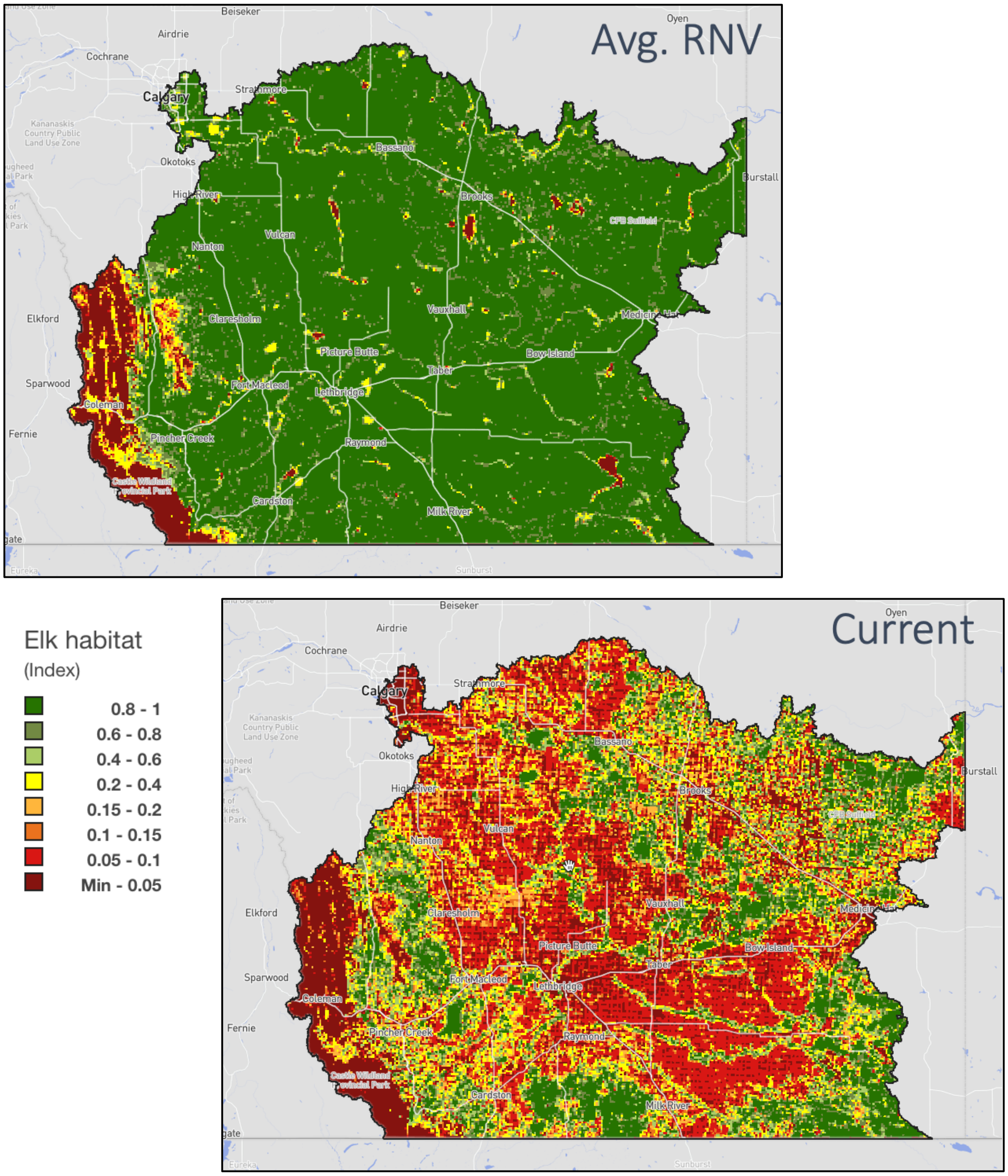

Figure B-13 Natural and current elk habitat in the regional study area. A value of 1 identifies maximum effectiveness.

Mule deer habitat

Mule deer habitat has declined by 54% relative to natural conditions in the regional study area (Table B-1). Under natural conditions, suitable mule deer habitat was highest in the central and eastern (i.e., Prairie) portion of the regional study area due to the availability of grassland. Habitat has since undergone significant declines due agricultural conversion and high linear footprint densities that facilitate hunter access (Figure B-14). This decline corresponds to an assessment of high risk to mule deer and to associated hunting opportunities. Remaining habitat occurs primarily in protected areas and other pockets where linear footprint density are low.

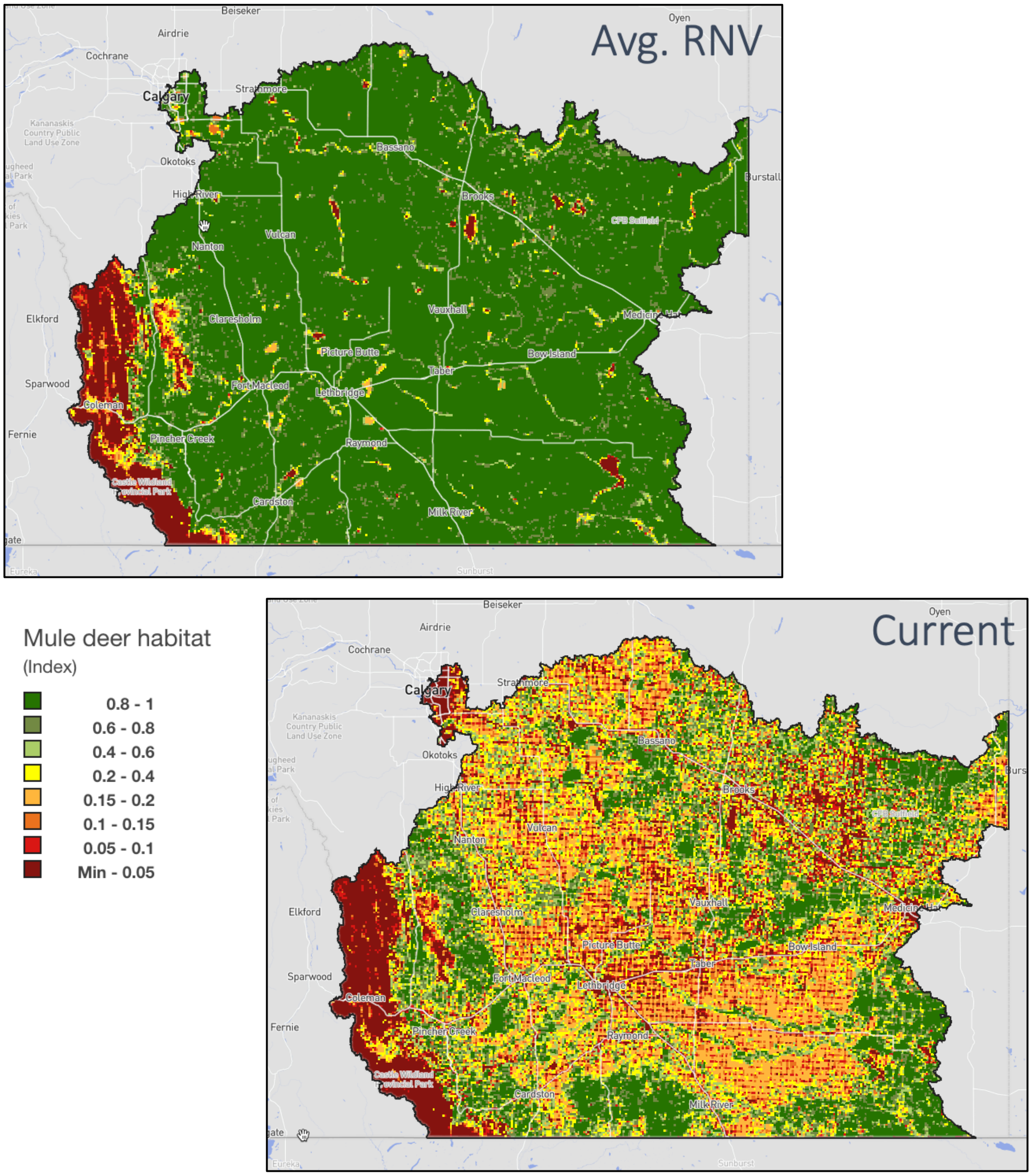

Figure B-14 Natural and current mule deer habitat in the regional study area. A value of 1 identifies maximum effectiveness.

Index of Native Fish Integrity (INFI)

The average current value of INFI in the regional study area is approximately 0.77, which is a 23% decline in the index from pre-contact conditions (Table B-1) and suggests moderate risk to the fish community. INFI was calculated as the average value across three effects: linear edge, stream fragmentation, and climate. The levels of linear edge and stream fragmentation effects are consistent with moderate risk whereas the level of climate effects suggests low risk (Table B-1). Current INFI values for watersheds are illustrated in Figure B-15. Risk is higher to the west due to higher sensitivity in montane areas to fishing pressure (due to more crown land and therefore greater fishing access) and stream fragmentation (due to greater abundance of streams where culverts are used for crossings, as opposed to rivers where bridges are typically used).

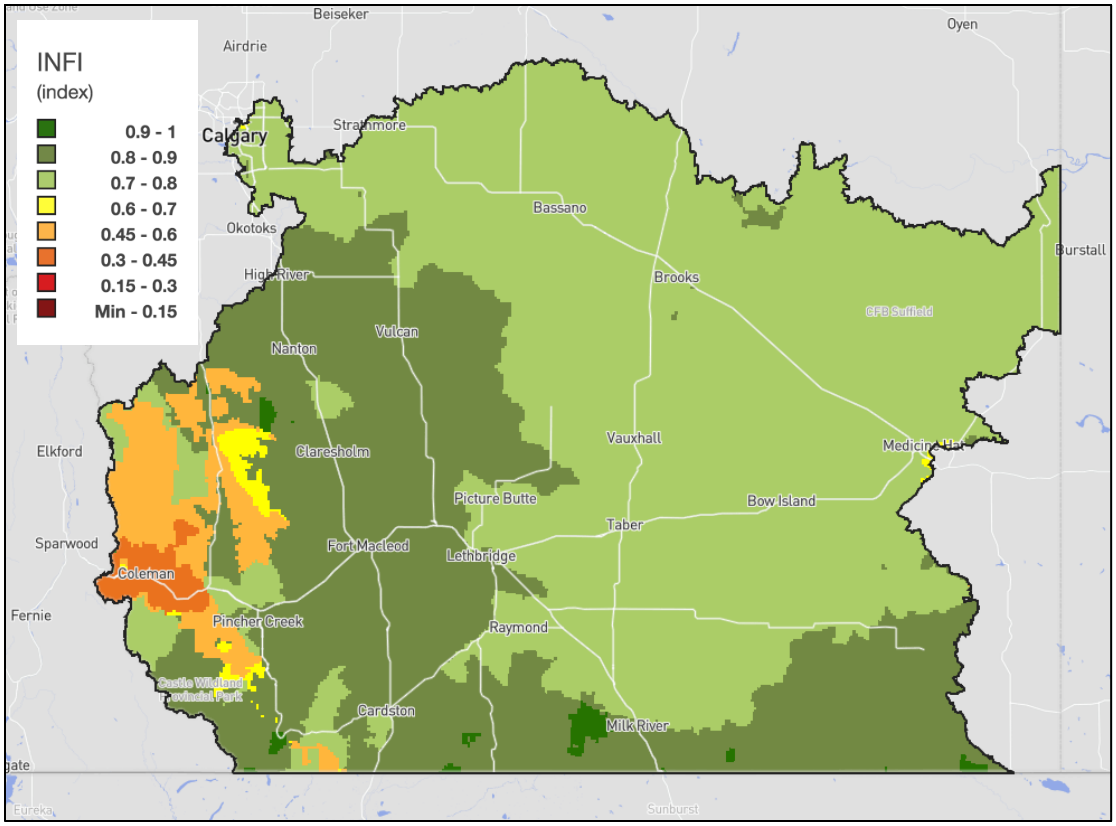

Figure B-15 Current Index of Native Fish Integrity (INFI) values by watershed for the regional study area. Higher values (i.e., greener colours) indicate lower risk.

4. EFFECTS TO TRADITIONAL LAND USE

Effects to traditional land use were examined by analyzing impacts to three indicators:

4. accessibility for traditional land use;
5. mule deer TLU opportunity; and,
6. elk TLU opportunity.

Results by indicator are discussed below.

Note that the results presented are likely an overestimation (i.e., optimistic view) of actual conditions for TLU accessibility and opportunity. For instance, from a land use standpoint, harvesting activities do not necessarily occur where there is accessible and suitable habitat, but rather depend on numerous logistical and cultural factors that have not been numerically considered here. Some of the factors that have not been integrated in the modeling include distance from home, ease of access, gates and restrictions that prohibit access,[36] familiarity and knowledge of location, cultural history in the area, competition for resources (e.g., hunting, fishing, and camping sites), among others. As an example, there may be locations that have suitable habitat but are not valuable for hunting because they are too far from home and in unfamiliar locations. Hunting in remote locations requires commitment of increased time and resources that some members cannot afford, and success in unfamiliar locations is not guaranteed. The result of the combination of these factors is that not all of the habitat that is modeled as suitable/accessible in this study necessarily presents a good TLU opportunity for community members.

[36] Community members described two specific access points (the Shell plant and Birdseye Ranch) that have been gated in recent years, cutting off access to a large land use zone and associated network of roads.

Accessibility for traditional land use

There is currently about 20% (1,285,848 ha) of the study area that is accessible for traditional land use (Figure B-16). Of this area, a large portion (134,881 ha) is comprised of waterbodies, leaving only about 18% of the study area available for land use if only the terrestrial land base is considered. Much of the accessible area occurs in the western foothills and mountains as well as in the Blood Tribe reserve.

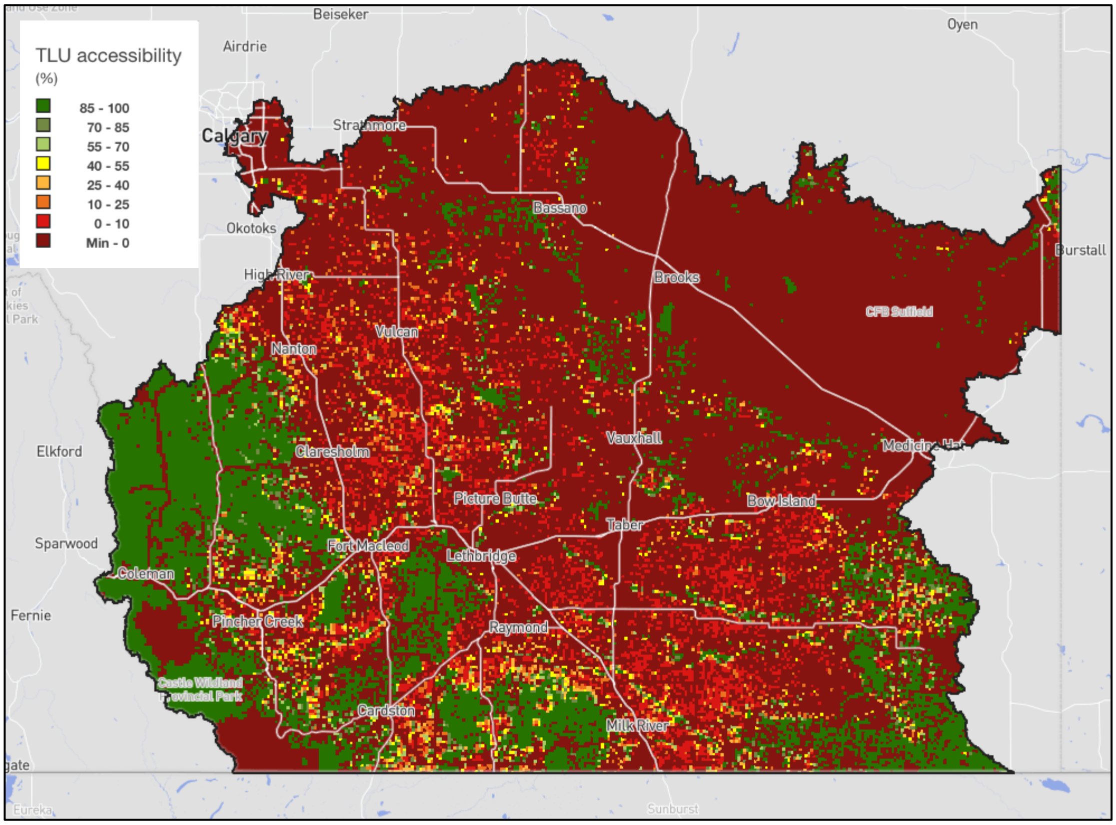

Figure B-16 Accessibility for traditional land use in the regional study area. Based on assumptions that were developed with input from community members. Higher values indicates greater accessibility.

Mule deer TLU opportunity

Current average mule deer TLU opportunity (0.11) in the regional study area is around 87% lower than natural conditions (i.e., min. RNV) and 72% lower than current effective habitat (0.39) presented for mule deer in section 3 of this appendix (see Table B-1). This indicates that there is limited opportunity for mule deer hunting in the regional study area due to land ownership, protected areas, and proximity to non-traditional land use activities. Mule deer TLU opportunity is highest in the foothills to the west and in the Blood Tribe reserve (Figure B-17).

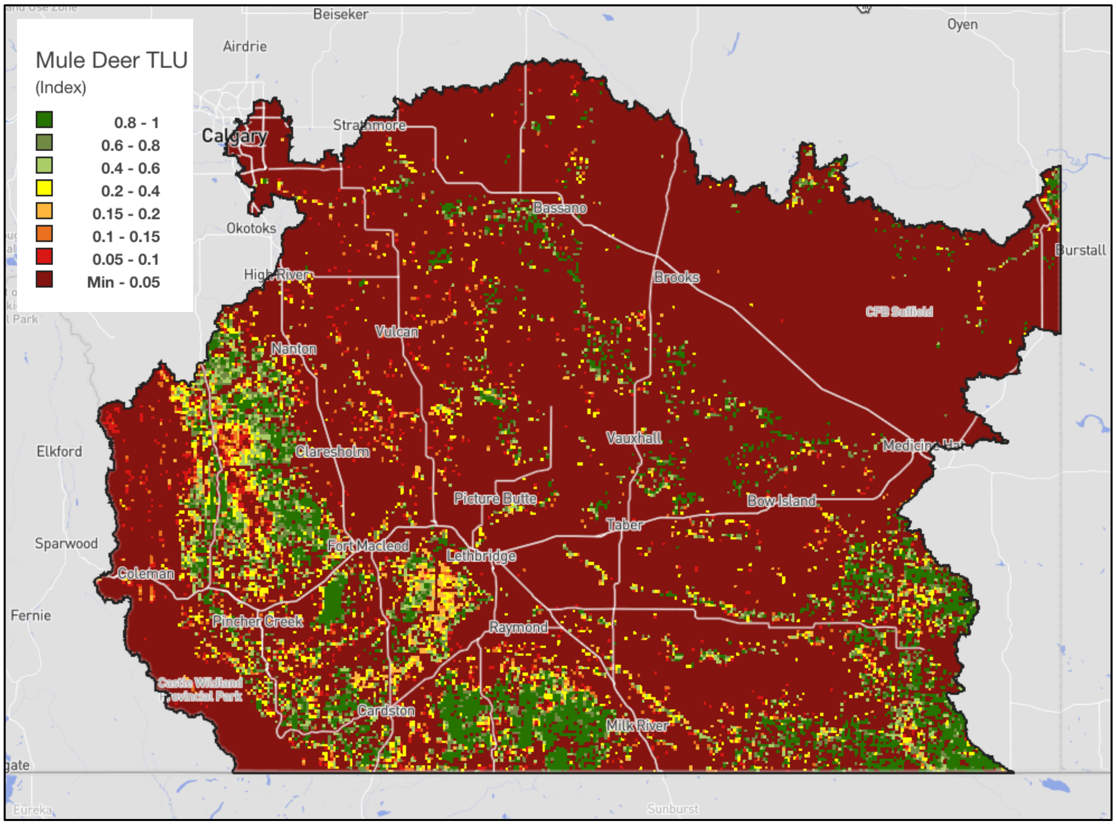

Figure B-17 Mule deer TLU opportunity in the regional study area. Based on assumptions that were developed with input from community members. Higher values indicates greater opportunity.

Elk TLU opportunity

Current average elk TLU opportunity (0.10) in the regional study area is around 88% lower than natural conditions (i.e., min. RNV) and 68% lower than current average effective habitat (0.31) presented for elk in section 3 of this appendix (see Table B-1). This indicates that there is limited elk hunting opportunity in the regional study area due to land ownership, protected areas, and proximity to non-traditional land use activities. Elk TLU opportunity is highest in the foothills to the west and in the Blood Tribe reserve (Figure B-18).

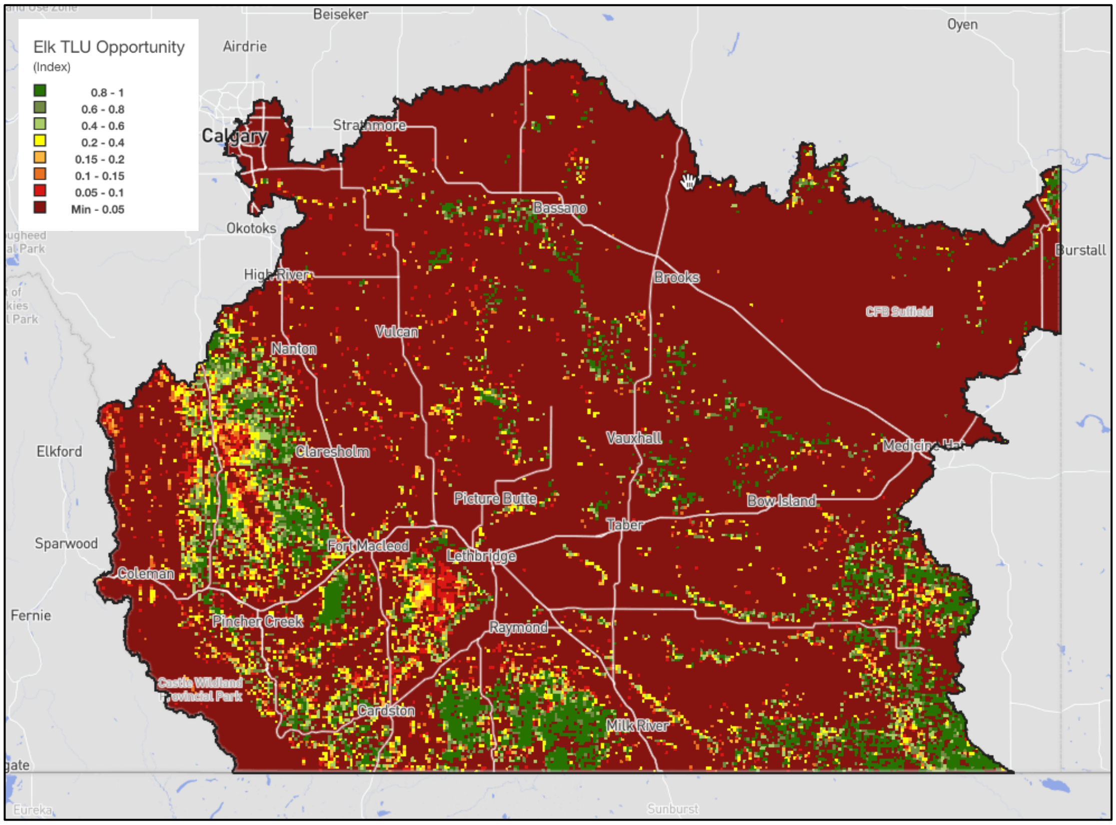

Figure B-18 Elk TLU opportunity in the regional study area. Based on assumptions that were developed with input from community members. Higher values indicates greater opportunity.

APPENDIX C: WILDLIFE HABITAT ANALYSIS

APPENDIX C: WILDLIFE HABITAT ANALYSIS OF EFFECTIVE AND POTENTIAL HABITAT

The wildlife habitat metrics analysed in this project integrated the consequence of habitat quality, based on land cover and terrain, with the risk of mortality associated with linear footprint density. We refer to the availability of suitable land cover and terrain as potential habitat. Wildlife density may still be low despite the presence of high potential habitat if sources of mortality are high. We use the term effective habitat to refer to habitat that also considers the effect of mortality, especially human-caused mortality. Human-caused mortality is an important driver of wildlife populations that are targeted by hunting; as such, effective habitat can be substantially lower than potential habitat. The wildlife habitat results presented in the main body of the report reflect effective habitat. In this appendix, we present potential as well as effective habitat to demonstrate their relative magnitude in the assessment. Results for the focal study area are presented first, followed by results for the regional study area.

1. FOCAL STUDY AREA

Due to conversion of land to agriculture, potential elk habitat is assessed to be below natural conditions, and high linear disturbance density causes still lower levels for effective habitat. The same is true for mule deer habitat, although the departure of potential habitat from natural condition is less severe because tame pasture is a preferred habitat for that species. Potential habitat is above natural for moose because conversion of grassland to crops has provided improved forage; potential habitat is still low, however, due to the scarcity of preferred habitat (forest) and effective habitat is lower due to high linear disturbance density. Results for each wildlife indicator (moose, elk, mule deer) are presented below.

Table C-1. Comparison of current estimates for potential and effective habitat for three wildlife indicators in the focal study area.

Indicator	Min RNV	Model estimates (current, future)		% change from min RNV (current, future)	
		Effective habitat	Potential habitat	Effective habitat	Potential habitat
Moose habitat	0.05	0.05, 0.05	0.08, 0.07	-5, -14	+56, +41
Elk habitat	0.42	0.22, 0.21	0.29, 0.28	-48, -51	-30, -33
Mule deer habitat	0.42	0.25, 0.25	0.35, 0.35	-40, -41	-17, -17

1.1. MOOSE

Potential moose habitat has increased relative to natural conditions due to conversion of grassland to cropland, which has a slightly higher value to moose than grassland (Table C-1, Figure C-1). This increase, however, is minor and the study area is still has low suitability for moose. Effective habitat is less than potential habitat due to high linear disturbance density.

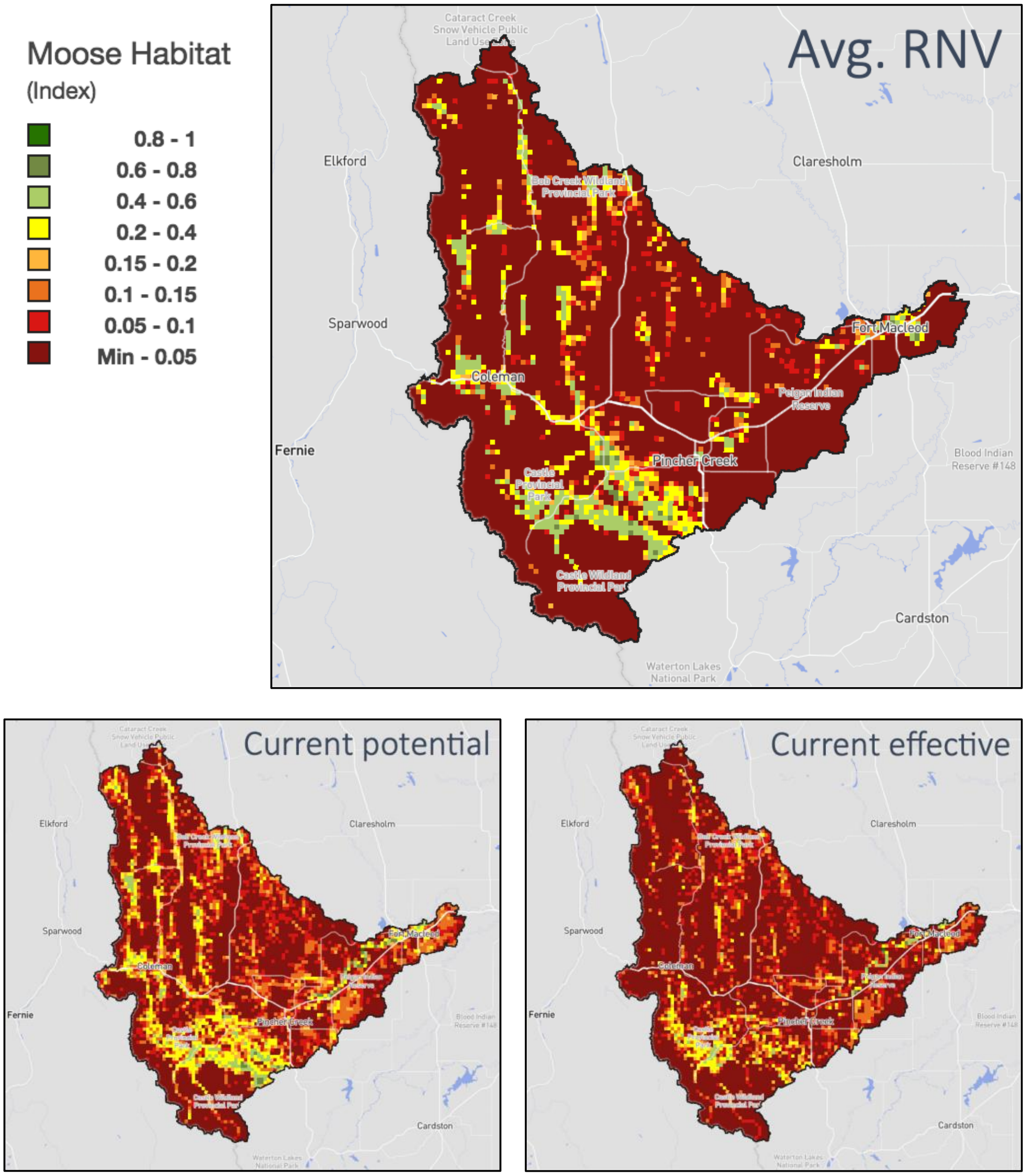

Figure C-1 Natural moose habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the focal study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

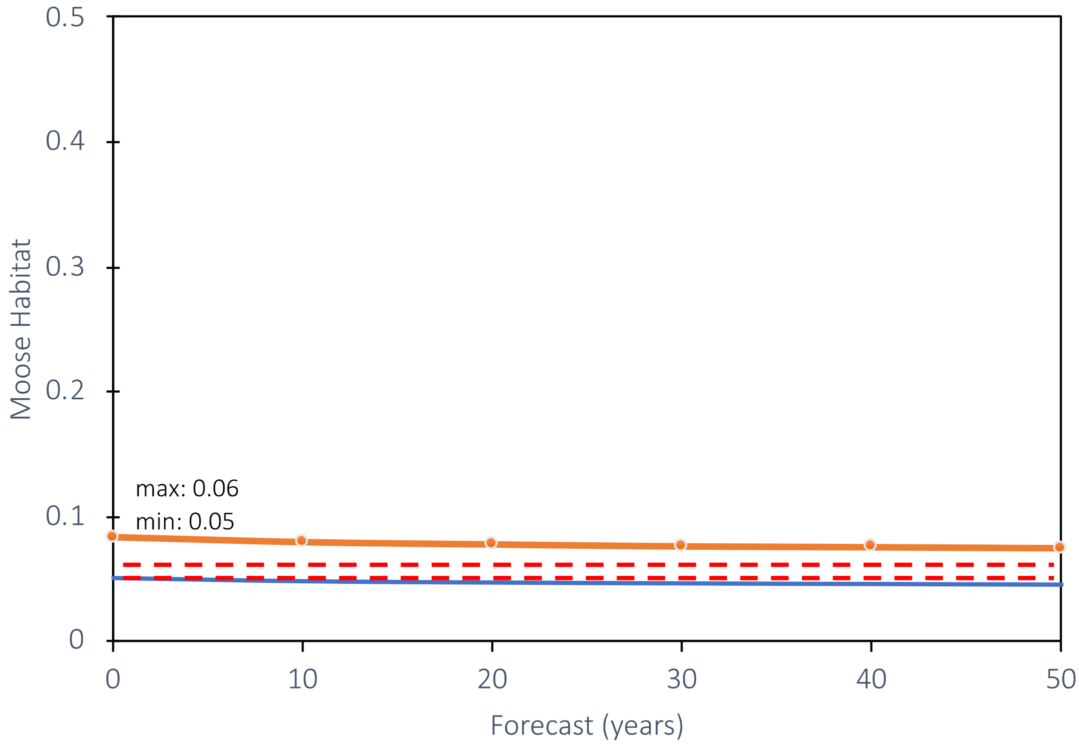

Figure C-2 Current and simulated future moose effective habitat in the focal study area (blue line). As a baseline for comparison, the red dashed lines identify the estimated range of natural variation. The orange line identifies potential habitat based on suitable land cover and terrain, but not incorporating the impact of linear features. The difference between the orange and blue line represents the negative effects (e.g., hunting, predators, vehicular collisions) facilitated by access via linear footprints.

1.2. Elk

Elk effective habitat has currently declined by 48% relative to natural conditions, whereas elk potential habitat has declined by 30% relative to natural conditions (Table C-1, Figure C-3). In the forecast, elk potential and effective habitat both decreased slightly due to increased footprint. Elk effective habitat dropped below 50% of natural at the end of the 50-year forecast.

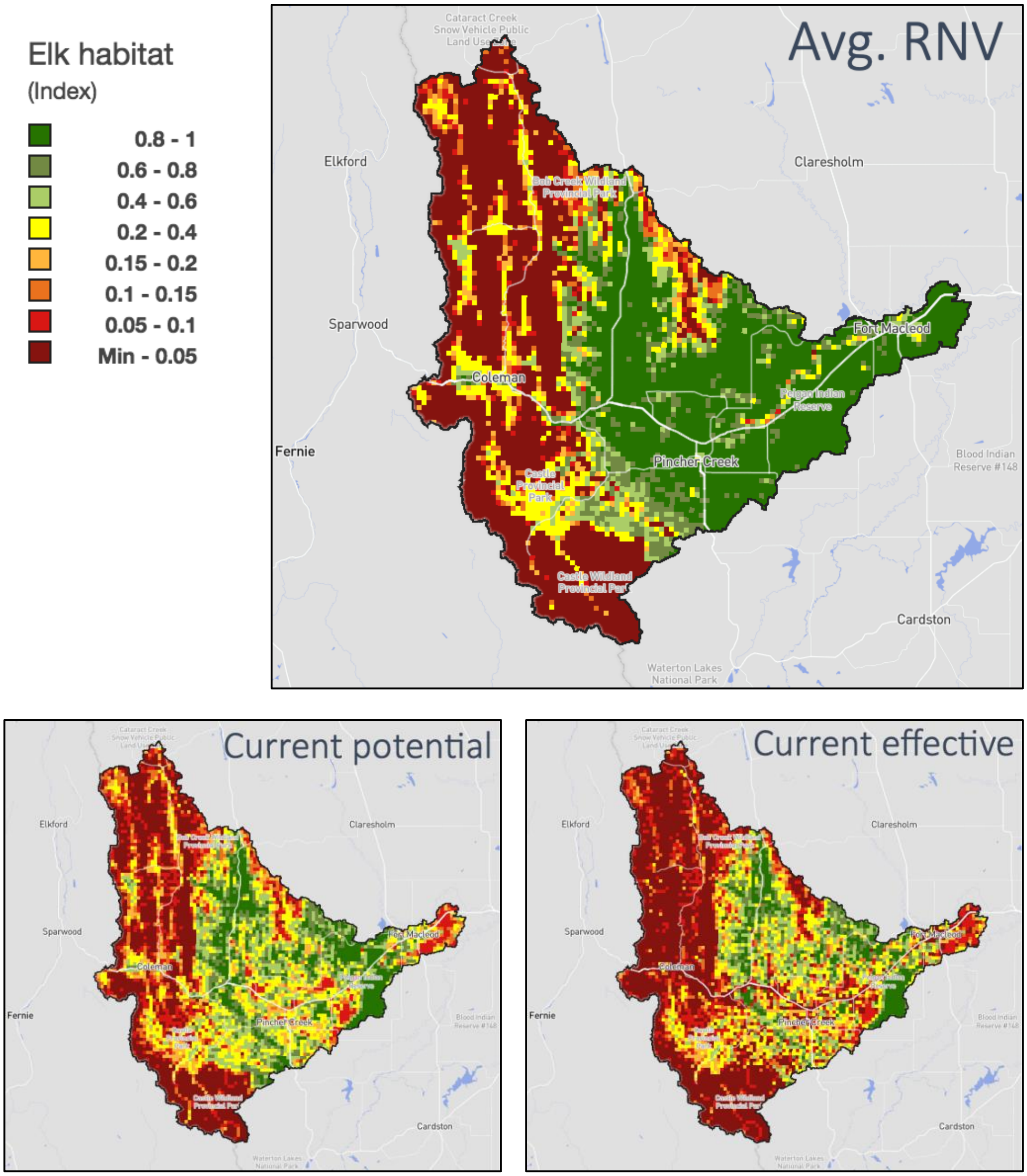

Figure C-3 Natural elk habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the focal study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

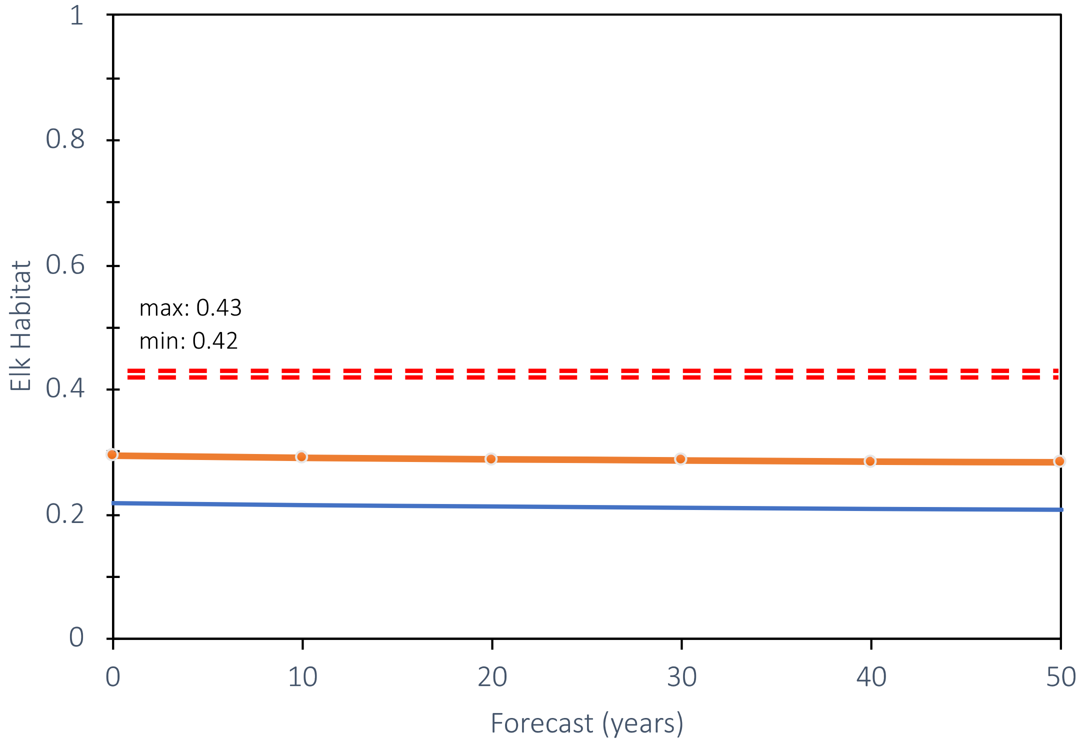

Figure C-4 Current and simulated future elk effective habitat in the focal study area (blue line). As a baseline for comparison, the red dashed lines identify the estimated range of natural variation. The orange line identifies potential habitat based on suitable land cover and terrain, but not incorporating the impact of linear features. The difference between the orange and blue line represents the negative effects (e.g., hunting, predators, vehicular collisions) facilitated by access via linear footprints.

1.3. Mule deer

Mule deer effective habitat has currently declined by 40% relative to natural conditions, whereas mule deer potential habitat declined by 17% relative to natural conditions (Table C-1, Figure C-5). During the forecast, mule deer potential and effective habitat declined only slightly by the end of the 50-year forecast (Figure C-6).

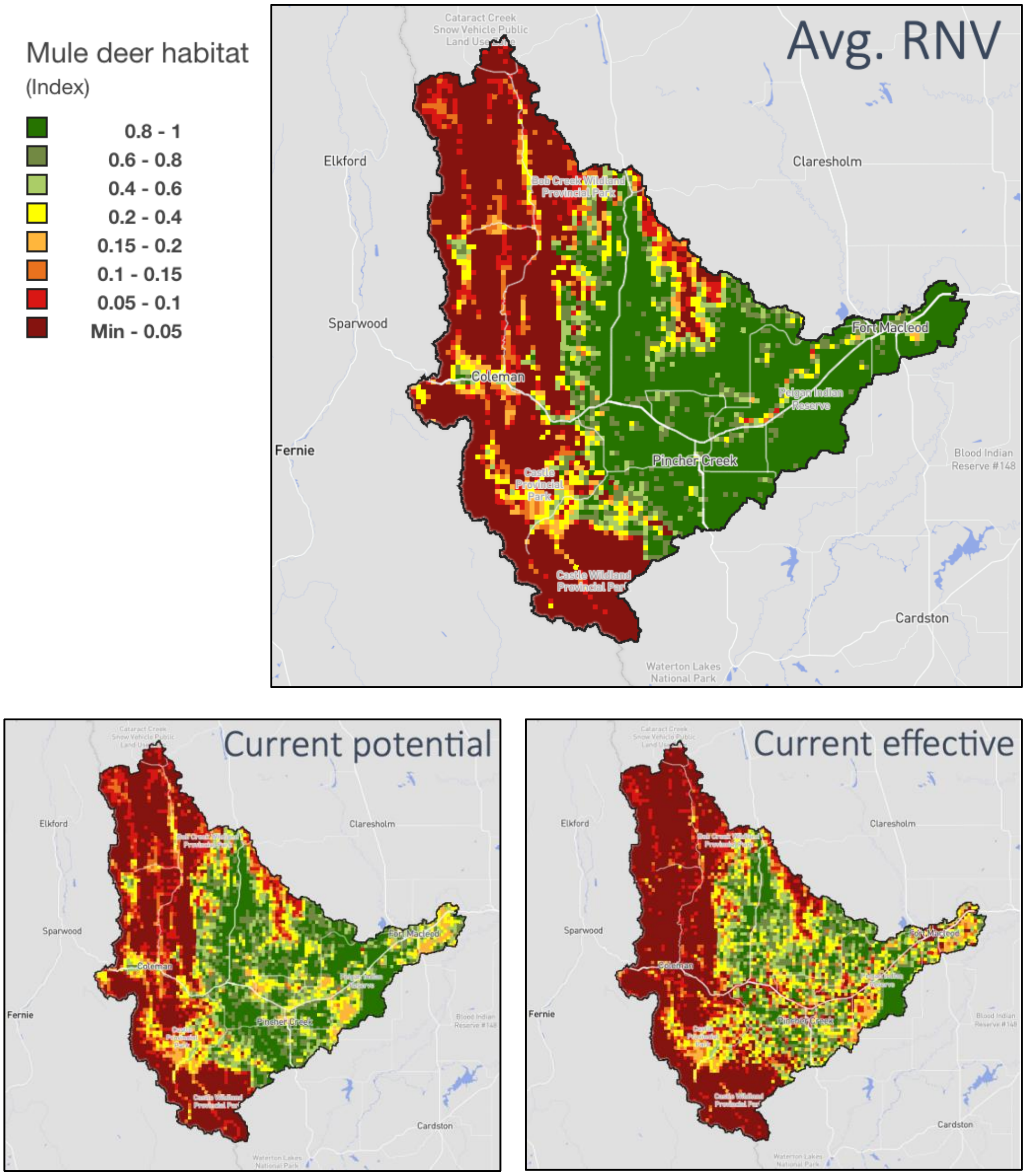

Figure C-5 Natural mule deer habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the focal study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

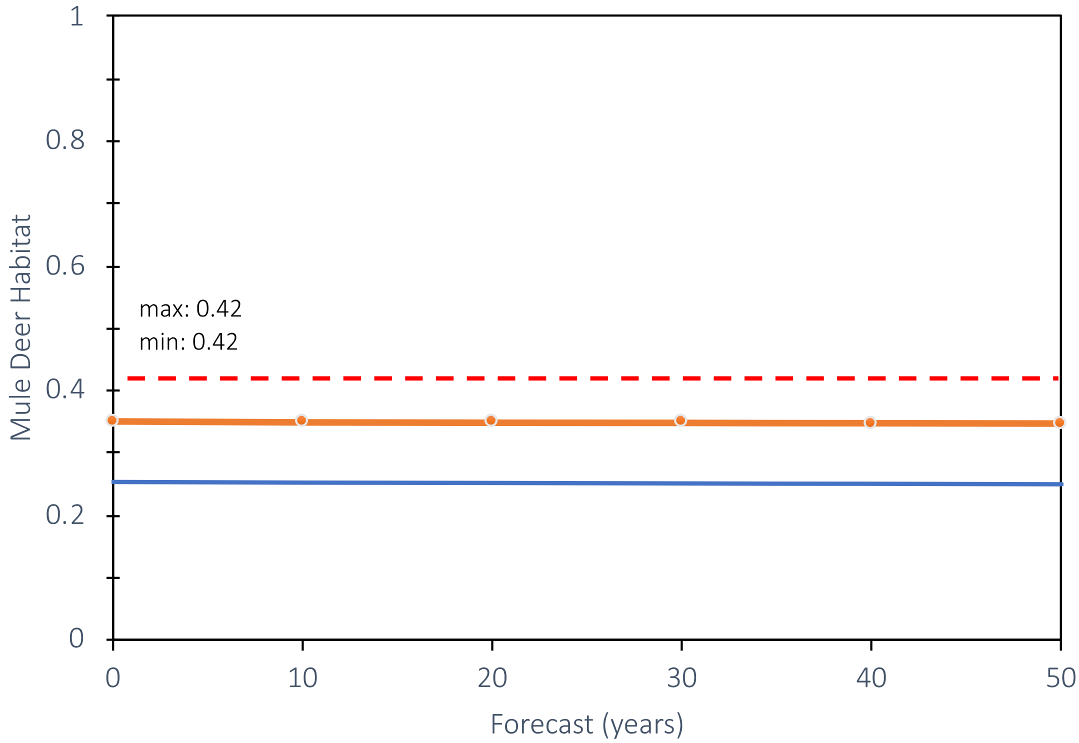

Figure C-6 Current and simulated future mule deer effective habitat in the focal study area (blue line). As a baseline for comparison, the red dashed line identifies the estimated range of natural variation. The orange line identifies potential habitat based on suitable land cover and terrain, but not incorporating the impact of linear features. The difference between the orange and blue line represents the negative effects (e.g., hunting, predators, vehicular collisions) facilitated by access via linear footprints.

2. REGIONAL STUDY AREA

In the regional study area, where conversion to farmland is substantially higher than in the focal study area, potential habitat is assessed to be below natural conditions (except for moose), and high linear disturbance density causes still lower levels for effective habitat. Results for each wildlife indicator (moose, elk, mule deer) are presented below.

Table C-2. Comparison of current estimates for potential and effective habitat for three wildlife indicators.

Indicator	Min RNV	Model estimates (current)		% change from min RNV (current)	
		Effective habitat	Potential habitat	Effective habitat	Potential habitat
Moose habitat	0.02	0.07	0.10	-	-
Elk habitat	0.84	0.31	0.43	-63	-49
Mule deer habitat	0.84	0.39	0.55	-54	-35

2.1. Moose

Potential moose habitat has increased relative to natural conditions due to conversion of grassland to cropland, which has a slightly higher value to moose than grassland (Table C-2, Figure C-7). This increase, however, is minor and the study area is still largely unsuitable for moose. Effective moose habitat is lower than potential habitat due to high density of linear footprint.

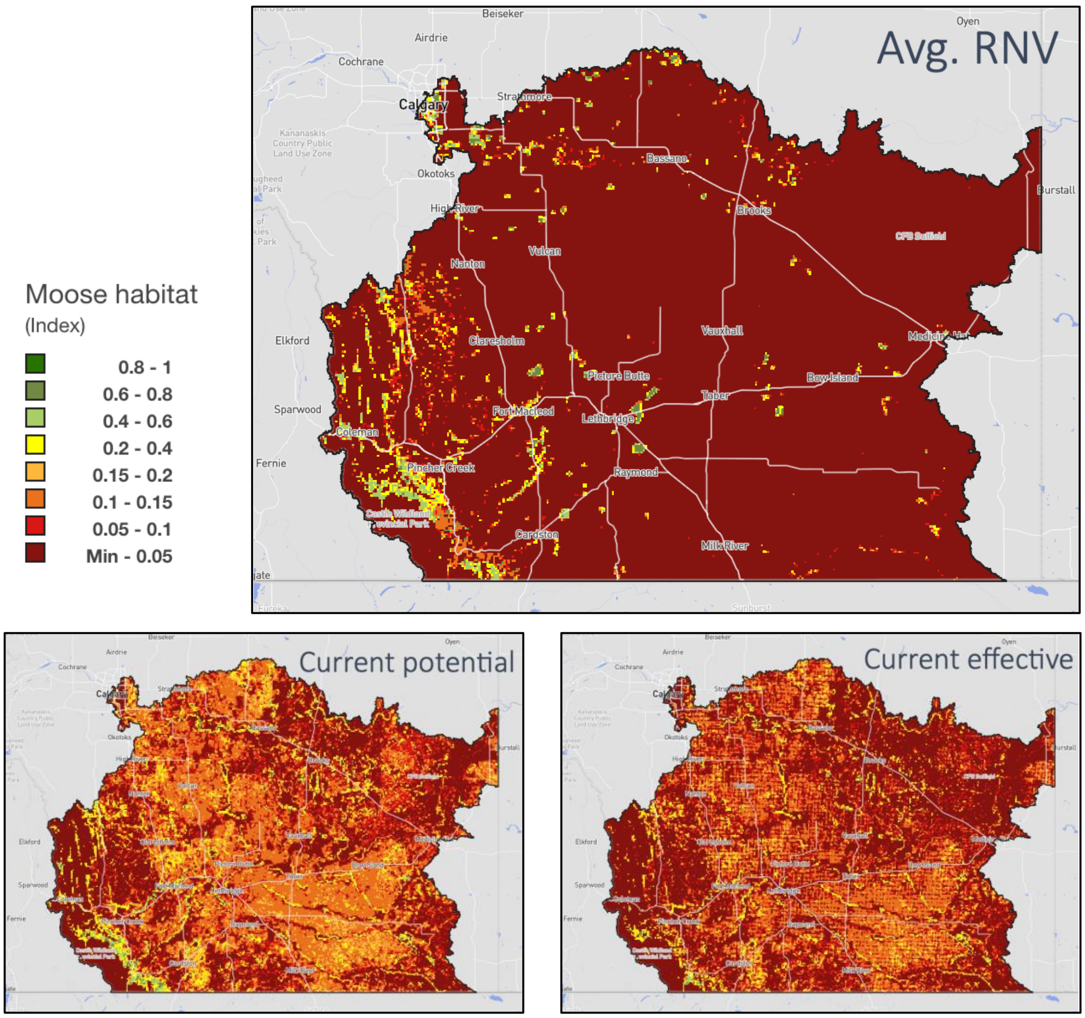

Figure C-7 Natural moose habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the regional study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

2.2. ELK

Potential elk habitat has declined by an estimated 49% relative to natural conditions largely due to conversion of grassland to agriculture. Effective elk habitat is lower than potential due to high density of linear footprint (Table C-2, Figure C-8).

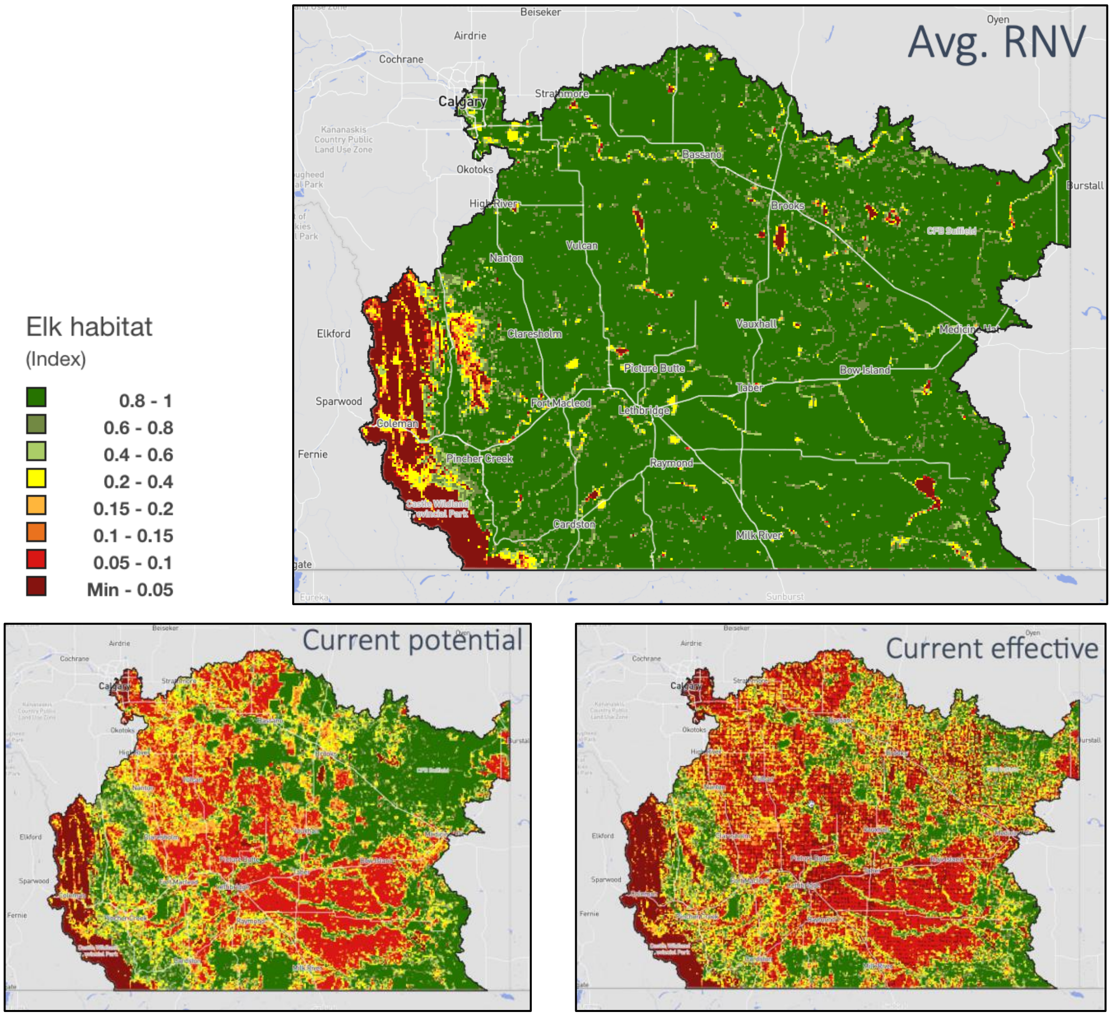

Figure C-8 Natural elk habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the regional study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

2.3. MULE DEER

Effective mule deer habitat has declined by 54% relative to natural conditions, whereas mule deer potential habitat has remained at natural conditions (Table C-2, Figure C-9).

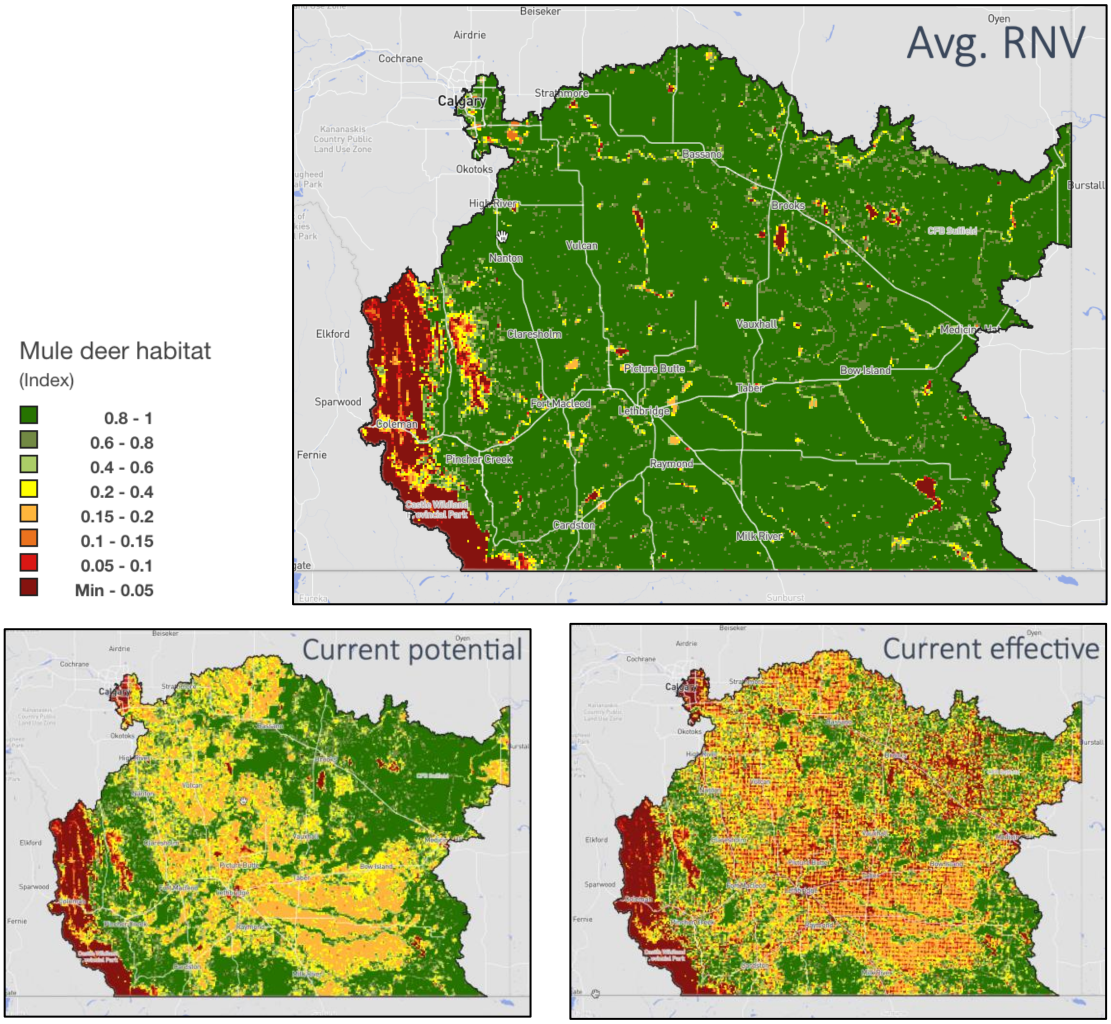

Figure C-9 Natural mule deer habitat (top) compared to current potential habitat (bottom left) and effective habitat (bottom right) in the regional study area. Potential habitat accounts for availability of preferred land cover and terrain, whereas effective habitat also incorporates that impact of access. A value of 1 identifies maximum effectiveness.

3. DISCUSSION

The large difference between effective and potential habitat identifies linear features to be an important risk to ungulates due to human-caused mortality that they facilitate. More detailed analysis that simulates the response of populations (as opposed to just habitat) is needed to explore the effectiveness of strategies to manage human-caused mortality. Another area for further investigation is the relative contribution of various types of linear features to risk of wildlife mortality. However, as discussed below, identification of access as an important risk factor is consistent with evidence from elsewhere.

A key concern of biologists managing sustainable populations of wildlife relates to the concept of “access” and how increased access can directly or indirectly increase mortality of wildlife species or reduce the amount and/or quality of habitat available to wildlife. In a most general sense, access refers to those linear and curvilinear man-made (anthropogenic) features that increase the ability of humans or predators to gain “access” to or travel through areas proximal to wildlife populations or their habitat.

Examples of linear features that can provide increased access include:

1. Access roads and in-block roads associated with the forest sector
2. Access roads to wellsites (energy sector)
3. Seismic lines, pipelines, and transmission lines of the energy sector
4. Municipal or private roads that provide access to rural residences
5. Recreation trail network intended for hiking, biking, horseback riding.

Examples of access that can have negative effects on wildlife populations include:

1. Direct mortality of wildlife populations from vehicular collisions
2. Direct mortality of wildlife populations from hunters who gain easy access to wildlife populations by using linear features (roads, seismic lines, transmission lines, pipelines,) with various modes of transportation (walking, driving, OHVs, horses, snowmobiles)
3. Direct mortality of wildlife populations from natural predators that benefit from improved travel efficiency and prey capture rates by using linear features
4. Loss of wildlife habitat quality or use because of displacement caused by excessive noise, smell or sight associated with human and industrial activities along linear features

It should be noted that the edges of linear features can also convey habitat benefits to wildlife species where man-made features improve thermal, concealment and forage conditions. These improved habitat conditions are negated, however, if the associated linear features contribute to elevated mortality rates that prevent populations from achieving the densities that can be supported by the improved habitat.

Because many hunters prefer to hunt along and in habitat adjacent to linear features (access), and these regions often experience elevated mortality rates to wildlife, there can emerge a view that wildlife populations have experienced a regional collapse. While this may be the case, it is also possible that wildlife populations can exhibit two distinctly different density patterns, with densities high in low access regions and densities low in high access regions. Habitat with high levels of linear features (access) can operate as mortality sinks for regional wildlife populations due to high levels of hunting and vehicular mortality. Conversely, areas of good habitat distant from linear features can act as source populations that replenish those depleted from mortality sinks. However, as the density of linear features increases, habitat distant from linear features declines, with the implication that regional population decline can occur as source populations become insufficient to replenish animals depleted from mortality sinks.

Examples of mitigation strategies that are available to address adverse effects of access to wildlife populations include:

1. Establishment of a network of provincial, national parks and sanctuaries where hunting is prohibited. These areas provide refugia for wildlife and act as source areas for repopulating adjacent areas where mortality rates may be higher.
2. In a sense, Alberta's hunting "constraint" regulations (number of available tags, when and where one can harvest) reflect the basic understanding that hunters with extensive "access" to the regional landscape of a wildlife species can, if unregulated, create a combined mortality rate that is excessive relative to population objectives. The greater the extent to which the hunting community can access wildlife habitat with vehicles (including OHVs), the greater the need for regulatory constraints.
3. Road sanctuary buffers on selected roads. These buffers are generally applied to roads where hunting is prohibited within 365 m of the road right of way.
4. Prohibition of some forms of transportation (such as OHVs) along selected linear features (roads, seismic lines) during defined times of the day or week.
5. Integrated landscape management strategies that seek to reduce the quantity of linear footprint that is needed to extract natural resources.

Alberta biologists (Ministry of Environment and Parks) regularly prepare provincial and regional wildlife plans to assist in the sustainable management of hunted species. A review of the management plans related to deer (white-tailed, mule), elk, moose, caribou and bighorn sheep include historic examples where increased density of linear features (and hence access by motorists and hunters) have presumably caused elevated mortality rates that have in turn lead to reductions in wildlife populations. A few examples below highlight the complex relationship between access features, hunting opportunities, and responses of wildlife populations.

Wildlife and Linear Edge in Alberta

Numerous studies in Alberta have suggested that motorized use of linear features (roads, seismic lines, pipelines) can have negative effects on wildlife species (e.g., Frair et al. 2008, Quinn and Chernoff 2010, Ciuti et al. 2012, Hebblewhite and Merrill 2008, Muhly et al. 2013, Gaines et al. 2003, Farr et al. 2017). The nature of the relationship between road density and wildlife is altered by whether the population is being harvested by hunters, and by the dynamics of the predator community.

A study by Frair et al (2008) showed that elk mortality increased with increasing road densities and reduced availability of refugia (habitat >1 km from roads). Whereas a road density threshold of 1.6 km/km^2 generally reflected a level of landscape fragmentation that precluded refugia, significant adverse effects to elk were detected at road densities as low as 0.5 km/km^2. In this study ~90% of cow elk home ranges occurred in habitat with road densities less than 0.5 km/km^2.

Elk Island National Park (EINP)

Linear edge may not adversely affect wildlife as shown in landscapes where hunting is low or absent. For example, EINP (no hunting but moderate densities of roads) generally supports relatively high densities of elk and moose compared to adjacent Blackfoot Grazing Reserve where road use is prohibited but hunting is allowed. Areas adjacent to EINP and BGR with similar habitat but with roads and hunting generally have no or lower populations of elk and moose.

Reduced moose populations in the logged boreal landscape

Although logging can improve the quality of habitat for both moose and elk (through increases in browse and herbaceous forage), it is common to observe (through aerial surveys) populations declining following the construction of new access roads into areas where active logging is occurring. The hunting community is keenly aware of newly constructed roads and opportunistically use these new access routes to hunt areas that were previously difficult to access.

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