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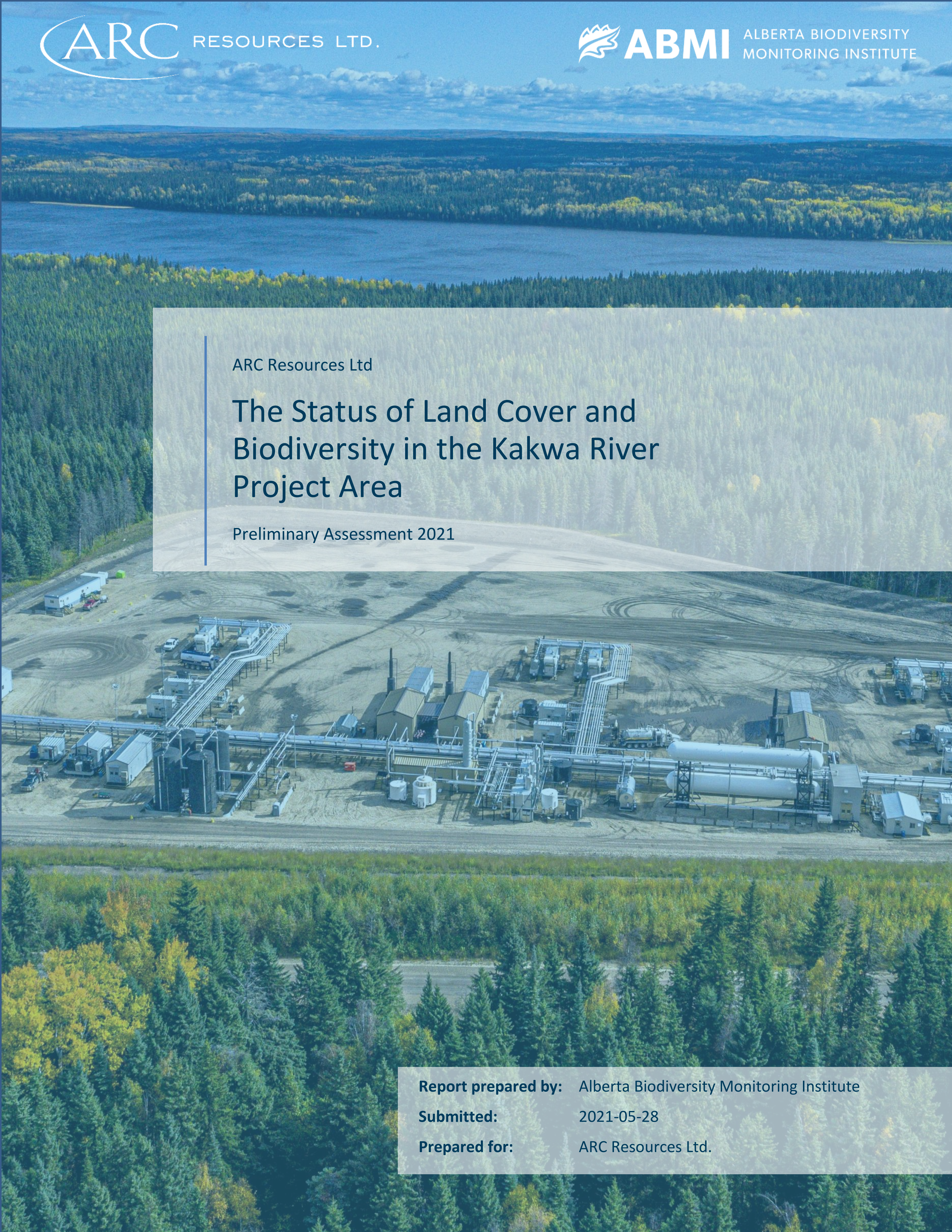
ABMI ALBERTA BIODIVERSITY MONITORING INSTITUTE



ARC Resources Ltd

The Status of Land Cover and Biodiversity in the Kakwa River Project Area

Preliminary Assessment 2021

Report prepared by: Alberta Biodiversity Monitoring Institute

Submitted: 2021-05-28

Prepared for: ARC Resources Ltd.

[THIS REPORT DESCRIBES THE STATUS OF HUMAN FOOTPRINT, NATIVE HABITAT, AND SPECIES IN THE KAKWA RIVER PROJECT AREA AND SURROUNDING REGION IN NORTHWESTERN ALBERTA]

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About Seven Generations (now ARC Resources Ltd.)

On April 6, 2021, Seven Generations Energy was acquired by ARC Resources Ltd., forming Canada's largest condensate producer and third largest natural gas producer. ARC Resources Ltd. is the largest pure-play Montney producer and one of Canada's largest dividend-paying energy companies, featuring low-cost operations and leading ESG performance. ARC's investment-grade credit profile is supported by commodity and geographic diversity and robust risk management practices around all aspects of the business.

ARC strives to deliver industry-leading performance in all aspects of its business. ARC has built a culture that fosters responsible resource development to deliver strong financial and operational results by prioritizing environmental and social responsibility efforts. Strong governance practices and an ongoing commitment from employees is critical in ARC delivering on this purpose.

Kakwa River Project

Located in the Montney formation in northwestern Alberta (approximately 100 km South of Grande Prairie), the liquids rich Kakwa River Project consists of more than 500,000 net acres of world-class resource. ARC employs pad-based, long-reach horizontal development practices that maximize productivity while minimizing land disturbance.

About the ABMI

The ABMI is an arm's-length, not-for-profit scientific organization. The business of the ABMI is to monitor and report on the status (current condition) and trends of Alberta's species, habitat, and human footprint. The goal of the ABMI is to provide relevant scientific information on the state of Alberta's biodiversity to support natural resource and land-use decision making in the province.

The ABMI is jointly delivered by InnoTech Alberta, the Royal Alberta Museum, the University of Alberta, and the University of Calgary. The ABMI Board of Directors includes representatives from the Government of Alberta; environmental non-governmental organizations; the forest, energy and agriculture sectors; and the research community.

The ABMI reports on a range of biodiversity indicators that act as a guide for establishing biodiversity-related management goals and tracking performance against those goals. Notwithstanding, the ABMI is not a management agency and does not make management recommendations.

The ABMI is guided by a core set of principles—it is independent, objective, credible, accessible, transparent, and relevant. The ABMI generates value-neutral, independent, publicly accessible data, and presents knowledge derived from the data in a value-neutral format.

REPORT SUMMARY

The Alberta Biodiversity Monitoring Institute (ABMI) measures and reports on the state of biodiversity and human footprint across the province. These biodiversity and human footprint data can be used to assess whether management activities are meeting their goal of maintaining species in the presence of the cumulative effects of development. This report presents data on several indicators of environmental health for the Kakwa River Project area where ARC Resources operates in northwestern Alberta.

About the Area

The Kakwa River Project area covers approximately 277,000 ha in northwestern Alberta. The state of the environment is assessed at two scales of analysis in this report:

- Region (2,300,000 ha), which is an ecologically-based analysis unit defined by five tertiary watersheds that overlap the Kakwa River Project area. All land cover and species metrics are summarized at this scale.
- Lease Area (277,000 ha), which is equivalent to the Kakwa River Project area; this is defined by the operating boundaries of ARC's Kakwa asset. Only land cover metrics are summarized at this scale.

Methods

The ABMI has 72 permanent monitoring sites in the Region. Between 2003 and 2019, we conducted field surveys at 42 of these sites. At each location, ABMI technicians recorded the species present, and measured a variety of habitat characteristics. The ABMI also remotely measured human footprint using satellite imagery at two spatial scales. Detailed assessment of human footprint was completed using a 3 x 7-km area around each of the 72 permanent monitoring sites between 1999 and 2019. A broad assessment of human footprint was also conducted through the creation of a wall-to-wall human footprint map for the entire province circa 2018. We used species distribution models and human footprint cover under current and reference conditions at the Region scale to assess the cumulative effects of disturbance and the impacts of energy footprint on species.

Status of Land Cover

As of 2018, the total human footprint in the Lease Area was 38.9%. Forestry was the predominant human footprint at 34.7%. Energy footprint covered 2.1%.

In the Lease Area, total human footprint increased by 18.3 percentage points between 2000 and 2019, from 20.7% to 39.0%. Increase was primarily driven by forestry footprint (16.8 percentage point increase) while energy footprint had a small increase of 0.8 percentage points.

Linear footprint density (circa 2018) was estimated to be 3.04 km/km^2 in the Lease Area and 3.46 km/km^2 in the Region. Conventional seismic lines are the predominant linear feature type, representing 54.4% of lines in the Lease Area.

The area of native habitat in the Lease Area was 61.1%, with 10.5% of that habitat at least 500 m from any human footprint.

Cumulative Effects of Human Disturbance on Species

The ABMI assessed the cumulative effects of land disturbance on 630 species in the Region as measured by the Biodiversity Intactness Index*; intactness was found to be, on average, 85.7%. Intactness for each species group was:

- 83.2% for native birds
- 88.2% for mammals
- 87.0% for soil mites
- 84.8% for native vascular plants
- 87.3% for mosses, and
- 83.6% for lichen.

The biggest changes to intactness are associated with increaser species i.e. species that are predicted to increase in abundance as a result of human footprint. These species thrive in areas with human development, such as Coyote and Black-billed Magpie.

Energy-specific Sector Effects

At the local scale, where energy footprint occurs, the predicted median change in relative abundance was relatively low for birds (-2.9%), mammals (-1.4%), and vascular plants (+7.9%) with similar numbers of species predicted to increase and decrease within energy footprint. For lichen (-70.5%), moss (-50.8%), and soil mites (-31.3%), the majority of species are predicted to be negatively impacted where energy footprint occurs. However, at the regional scale energy footprint is predicted to have relatively small impacts on regional populations for all taxonomic groups, ranging from -3% to +5% for most species, because energy footprint is sparse.

Additional Results of Note

- Species that prefer old-forest habitat, like Black-throated Green Warbler, Fisher, and Angel's Hair lichen, were less abundant than would be expected with no footprint.
- A total of 38 non-native vascular plant species were detected in the Region with non-native species detected at 57% of the sites surveyed. Where they were found, there was an average of 4.7 non-native species present.
- There are at least 61 species-at-risk† in the Region. The ABMI detected 36 species often enough to enable the calculation of species intactness. The majority were less abundant than expected.

This report describes regional ecological baseline conditions for several metrics of land cover and biodiversity. These findings can be used as a basis for operational planning and for evaluating future outcomes of resource management in northwestern Alberta. Over the next few years, the ABMI will broaden the assessment of biodiversity to include status of wetlands, and trends for all species groups.

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* The ABMI's Biodiversity Intactness Index is used to report on the cumulative effects of human disturbance on biodiversity, including birds, mammals, soil mites, vascular plants, mosses, and lichen within Alberta. The index ranges from 100% intact to 0% intact. An area with little evidence of human impact is nearly 100% intact, whereas a parking lot surrounded by big box stores is nearly 0% intact. The Biodiversity Intactness Index is a measure of how much more or less common a species is relative to its abundance if there was no human footprint present.

† Threat categories for species-at-risk as identified by the Government of Canada and/or the Government of Alberta. This assessment includes species identified by: Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered, Threatened, Special Concern, or Data Deficient; Canada's Species at Risk Act (SARA) as Endangered, Threatened, or Special Concern; Alberta's Ministry of Environment and Sustainable Resource Development (ESRD) as May be At Risk, At Risk, Sensitive, or Undetermined; Alberta's Endangered Species Conservation Committee (AB ESCC) as Endangered, Threatened, Special Concern, Data Deficient, In Process.

INTRODUCTION

The ABMI[‡] is part of Alberta's monitoring systems. We measure the health of biodiversity and changes in human land use (i.e., human footprint) in Alberta, including the Kakwa River Project area (Figure 1). Resulting biodiversity and human footprint data can be used to support the assessment of the impact of resource management on species diversity and natural ecosystems at large in the presence of cumulative effects of development.

The purpose of this report is to assess the status of select environmental indicators in the Kakwa River Project area and surrounding region. In this report we summarize:

- status of land cover including area of human footprint, density of linear features, and area of native habitat[§];
- cumulative effects of land disturbance on species habitat as measured by the Biodiversity Intactness Index, highlighting species most sensitive to human development activities;
- impacts of energy disturbance on species at local and regional scales;
- status of non-native species and species of conservation concern; and
- status of two species of management interest—Moose and Black-throated Green Warbler.

The information in this report can be used as a basis for evaluating the sustainability of resource development in the Kakwa River Project area.

Seven Generations Energy Ltd. (now ARC Resources Ltd.) commissioned the ABMI to write and produce this report, under terms and conditions set by the ABMI. The report supports the ABMI's mission to provide relevant and credible scientific information on Alberta's biodiversity to support natural resource and land-use decision-making. Data collected by the ABMI can be used to monitor the status and trends of species living in the region and evaluate the effectiveness of management activities to maintain regional biodiversity.

ARC's organizational purpose statement is: *Our energy creates a better world for everyone*. Through this organizational purpose, ARC strives to deliver industry-leading performance in all aspects of its business. Environmental, social, and governance (ESG) leadership is one of ARC's Guiding Principles. Protection of the environment is fundamental to ARC's commitment to being a responsible producer.

[‡] The ABMI is hereafter referred to in this report in the first person plural (i.e., "we"), such as "We collected biodiversity data," or in the possessive case (i.e., "our"), such as "Our biodiversity data."

[§] The ABMI defines "native habitat" as undeveloped native habitat that is distant enough from human footprint that it meets the particular management objectives of stakeholders.

Figure 1. The Kakwa River Project is located in northwestern Alberta and includes ARC's Lease Area and the five tertiary watersheds (Region) the project area overlaps.

About the Kakwa River Project Area

The status of land cover and biodiversity in the Kakwa River Project area is the focus of this report. The Kakwa River Project area covers approximately 277,000 ha in northwestern Alberta (Figure 2).

Vast forested areas support a wide range of wildlife and plants in the region and are home to species of conservation concern including Woodland Caribou, Grizzly Bear, and Wolverine.

The region where the Kakwa River Project area is located includes:

- Four of the six Natural Regions found in the province: Foothills (43%), Boreal Forest (34%), Rocky Mountains (20%), and Parkland (3%).
- Five tertiary watersheds that are part of the Peace River basin. The Smokey River and its tributaries flow through the centre of the region.
- Predominantly forested areas that support a wide range of wildlife and plants. These forests have been shaped by wildfire for thousands of years resulting in a mosaic of stands of different ages, from young forests to stands more than 150 years old.
- Habitat for species of conservation concern that roam widely in the region, such as Woodland Caribou, Grizzly Bear, and Wolverine.
- Large areas managed for natural resource extraction including forestry activities, oil and gas development, as well as associated infrastructure such as roads and utilities.

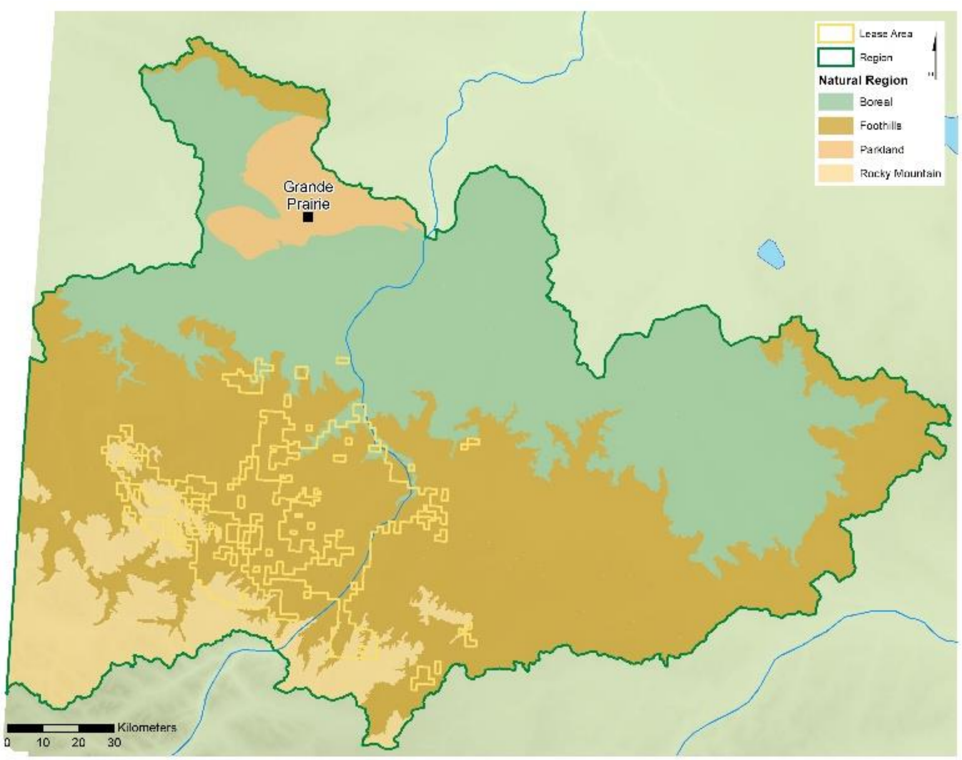


Figure 2. Overlap of the Kakwa River Project area with four Natural Regions: Rocky Mountains, Foothills, Boreal Forest, and Parkland.

Area of Analysis

The state of the environment is assessed at two scales of analysis in this report:

Region (2,300,000 ha)

- The analysis unit "Region" is equivalent to the Kakwa River Project assessment area, defined by five tertiary watersheds that are part of the Smokey River watershed.
- This is an ecologically-based analysis unit because it is defined by the overlap of the Kakwa River Project area with these five tertiary watersheds.
- This unit was defined in consultation with ARC Resources.

Lease Area (277,000 ha)

- The analysis unit "Lease Area" is equivalent to the Kakwa River Project area, which follows the operating boundaries of ARC's Kakwa asset.
- While the lease area is where ARC Resources operates, other industry such as forestry and other energy companies are also active in the area.

Land cover variables, including human footprint and interior native habitat area, are reported for the two scales of analysis. Biodiversity variables are reported at the Region scale only.

METHODS

The ABMI Measures Biodiversity

From the boreal forest in the north to the grasslands in the south, the ABMI monitors the state of Alberta's biodiversity. To do this, we employ a systematic grid of 1,656 site locations, spaced 20 km apart, to collect biodiversity information at terrestrial and wetland sites (Figure 3).

At each location, ABMI technicians record the species that are present, and measure a variety of habitat characteristics. For species that cannot be identified in the field (e.g., mites and lichen), ABMI taxonomists sort, identify, and archive samples to complete the species-level dataset. Through our field and laboratory efforts, the ABMI tracks over 3,000 species.

The ABMI also monitors the state of Alberta's human footprint and habitat using fine-resolution aerial photography and satellite imagery[1]. The ABMI Geospatial Centre conducts analyses of human footprint at two spatial scales:

3 × 7-km Samples

1. We use human footprint data measured annually at a 1:5,000 scale to track changes in human footprint over time. Detailed annual samples of human footprint are measured in a 3 × 7-km rectangular area centred near each of our 1,656 sites, which when summed across all sites amounts to ~5% of the province's land surface. ABMI human footprint trend data are available from 1999 to 2019, except for 2000-2003 (inclusive), and 2018.

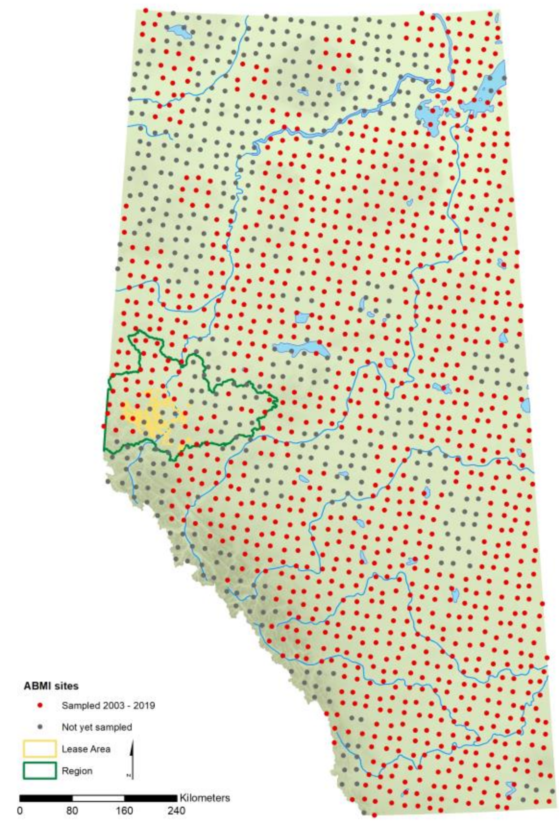


Figure 3. The ABMI has 72 of our 1,656 survey sites in the Region—42 sites have been sampled to date. Data from across the forested region is used to strengthen analysis.

Provincial Scale

2. At the provincial scale, the ABMI merges 20 human footprint sub-layers (based on 117 feature types) into a single integrated layer by applying a specific order of precedence to create the ABMI Human Footprint Inventory (HFI), circa 2018. Some of these 20 sub-layers are created by the ABMI and Government of Alberta as part of the Alberta Human Footprint Monitoring Program. We use the HFI 2018 for two purposes in this report: to generate maps of human footprint in the assessment area, and to standardize the 3 × 7-km trend estimates before reporting. This product is updated annually.

These mapped products are updated at regular intervals to track changes in human footprint and habitat over time. Human footprint data and metadata are available at abmi.ca.

Land Cover and Biodiversity Indicators in This Report

Habitat loss is a major driver of biodiversity decline on the planet[2]. In the Lease Area and surrounding Region, habitat is being modified or lost to forestry, energy and agricultural industrial operations as well as urban expansion. Responsible development of this Region depends on understanding the complex interactions between different human footprint types, species, and native terrestrial habitat. The ABMI assesses indicators of land cover and species status in the following ways.

Human Footprint:

The ABMI defines human footprint as the visible alteration or conversion of native ecosystems to temporary or permanent residential, recreational, agricultural, or industrial landscapes[3]. The definition includes all areas under human use that have lost their natural cover for extended periods of time, such as cities, roads, agricultural fields, and surface mines. It also includes land that is periodically reset to earlier successional conditions by industrial activities such as forest harvest areas and seismic lines. Some human land uses, such as grazing, hunting, and trapping, or the effects of pollution, are not yet accounted for in our human footprint status and trend analyses.

To assess the **status of human footprint**, the ABMI calculates the percentage of land directly altered by human activities, which is interpreted as follows:

- 0% means there is no visible human footprint
- 100% means the landscape has been completely modified by human footprint

In general, cities and cultivated fields have high human footprint, while protected and undeveloped areas have low human footprint. Change in human footprint through time (i.e., trend) is based on the detailed 3 × 7-km human footprint data.

We report on six categories of human footprint: agriculture, energy, forestry, human-created waterbodies, transportation, and urban/industrial footprint.

In addition to the area of human footprint, linear disturbance is also summarized as density of linear footprint in km/km^2.

Interior Native Habitat:

The ABMI HFI allows areas of interior native habitat to be identified—in other words, those areas in the province that have not been visibly disturbed by humans, although natural disturbances (e.g., wildfire, insect outbreaks) and invisible effects of humans (e.g., pollution) still occur. Further, the ABMI can track the amount of interior native habitat that is effectively “away” from the influence of human footprint due to edge effects. To report on the status of native vegetation, we present:

- The percentage area of land cover that has no visible human footprint (although land uses like grazing may still occur).
- The percentage area of interior native vegetation using three edge distances applied outwards from human footprint—50 m and 200 m following recommendations from Huggard and Kremsater (2015)[4], and 500 m to represent the longest reported edge effects, such as those for Woodland Caribou. These three edge distances are called “base” distances. The base distances are narrowed to account for two factors (for detailed methods see Huggard and Kremsater 2015):
  - **Width of human footprint**. For narrow human footprint types like linear features, the edge influence that extends into native habitat is reduced because these openings have little surface wind, are shaded in most orientations, and are considered to be under “forest influence” for many species.
  - **Recovery of successional footprint.** The edge distance is reduced as forestry footprint recovers (ages). This calculation is currently only applied to forestry, but could include any human footprint

types that are non-permanent and that can recover toward natural conditions, such as reclaimed or restored seismic lines, pipelines, wellpads, etc.

Species:

Cumulative Effects of Human Disturbance on Species

To assess the **status of species,** the ABMI collects and analyzes data on breeding birds, mammals, soil mites, vascular plants, mosses, and lichen[5]. The Biodiversity Intactness Index[6] (intactness) is used to assess the combined status of common species in the assessment area. Intactness estimates how the predicted current species abundances have changed relative to a reference condition, based on measured species responses to cumulative land disturbance. This approach does not account for non-footprint effects (e.g., edge effects, pollution, noise), or complexities like interactions between sectors (e.g., weedy species entering one sector's footprint after they were introduced by another sector). The index ranges from 0% to 100% and is interpreted as follows:

- An intactness value of 100% indicates current species abundance is equal to what would be expected under undisturbed reference conditions (i.e., zero human footprint).
- Increases and decreases in species abundance both represent deviations from reference conditions, and result in lower intactness scores. The bigger the difference between current and reference abundances, the lower the intactness. Species that rely on undisturbed habitat are less abundant when there is human disturbance (decreasers), while those that do well near human activities are more abundant (increasers) than under reference conditions (Figure 4).
- The overall estimate of intactness for the region for a given taxonomic group (e.g., birds, mammals) is calculated by averaging the intactness values of all individual species within that taxonomic group. Thus, a group can have relatively high intactness, while still seeing significant changes in individual species.

Energy-specific Sector Effects

Energy-specific sector effects[7] analysis is used to assess the impacts of human footprint from the energy sector on species groups in the Region. Two aspects of sector effects are reported[5]:

- Local Scale Effects: indicate how much the abundance of a species is expected to differ from reference conditions in the area right where energy sector footprint occurs.
- Regional Population Effects: show how much the total population across the region is expected to have changed due to energy sector footprint. This incorporates both the area of energy footprint, and surrounding areas of native habitat type(s) within the target region.

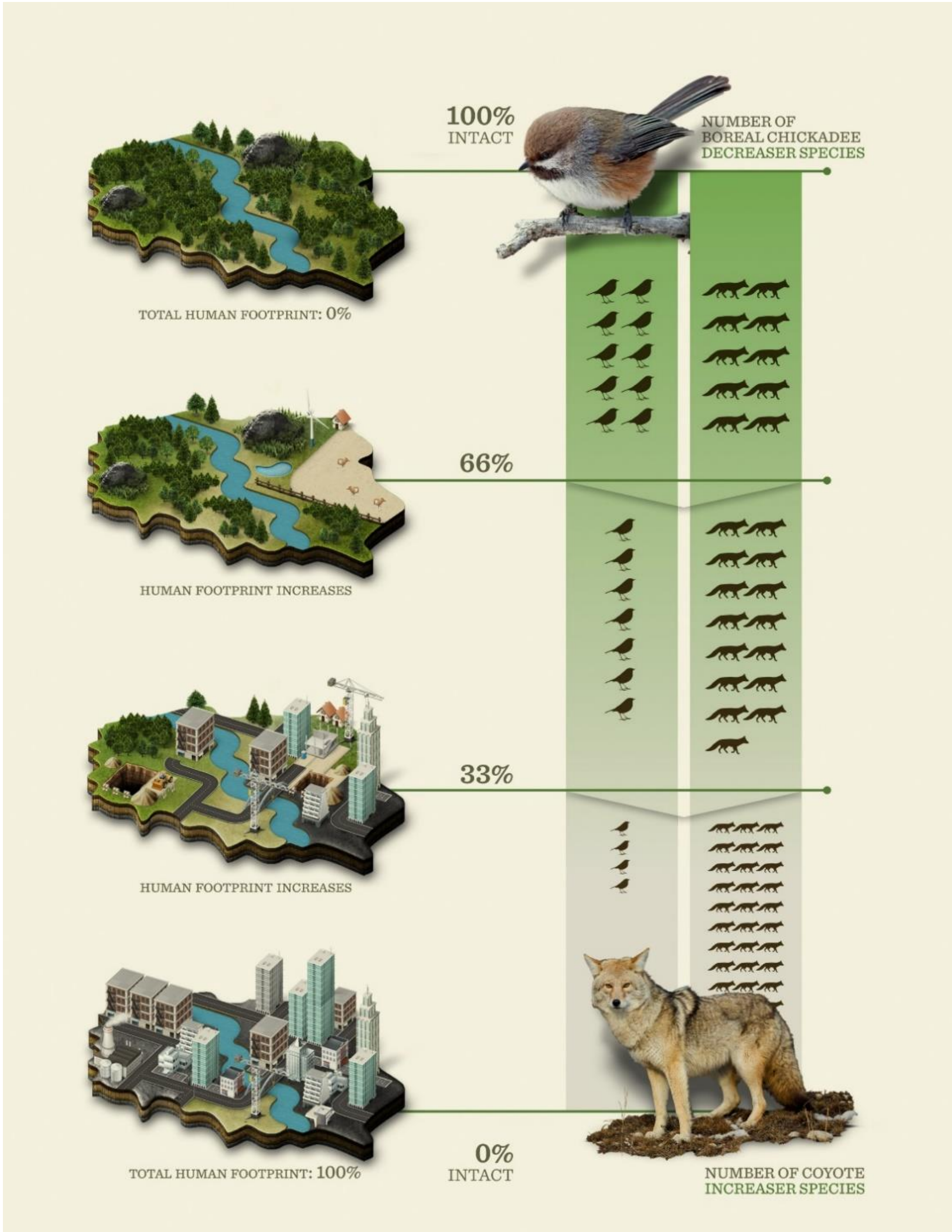


Figure 4. The ABMI Biodiversity Intactness Index

In Figure 4, we illustrate how intactness changes for:

- a "decreaser" species, the boreal chickadee, and
- an "increaser" species, the coyote.

Intactness ranges from 0% to 100%. At 100% intact, the current abundance of both species is equal to the reference abundance expected in an undisturbed area-one with 0% human footprint. As intactness declines toward 0%, it reflects a change in the current abundance of a species in response to human footprint:

- for the chickadee, a decrease in abundance is observed
- for the coyote, an increase in abundance is observed.

LAND COVER RESULTS

Human footprint data, including footprint type and amount, provide the context for interpreting intactness. In this section of the report, we summarize the current status of human footprint (circa 2018), trend in human footprint (2000-2019), and density of linear features. We also summarize the area of interior native habitat at different distances from human footprint.

Status of Human Footprint

The conversion of natural landscapes to ones dominated by human land use is the greatest threat to biodiversity[2]. Mapping and quantifying human land use patterns—such as forest harvest areas, well pads, roads, and urban areas—is increasingly being used as a land-use planning tool to monitor the status of landscapes[8]. This includes measurements of linear footprint (e.g., seismic lines, pipelines, and roads), which occupy a small percentage area of the landbase but which can have disproportionate impacts on biodiversity. The extent of human land use in any given area is collectively defined as human footprint.

Area of Human Footprint

Total human footprint (circa 2018) in the Lease Area was 38.9%. Forestry was the predominant human footprint type at 34.7%. Energy footprint covered 2.1% (Figure 5; Figure 6).

Highlights

- Forestry footprint was the dominant human footprint type in both the Lease Area (34.7%) and the Region (17.4%).
- Harvest areas represent a range of forest ages depending on the year of harvest. The recovery of these areas partially mitigates increases in forestry footprint from new harvesting. Total area of forestry footprint that is considered recovered is 8.0% in the Lease Area, and 5.7% at the Region scale, which accounts for over 20% of the total area of forestry footprint at each scale, and 20% of the total area of human footprint in the Lease Area.
- After forestry footprint, agriculture footprint (8.1%) is the second most common footprint type at the Region scale, but this footprint does not occur in the Lease Area.
- Energy footprint is similar at both scales of analysis, covering 2.1% and 2.4% of the Lease Area and Region, respectively.
- Transportation footprint covered 1.7% of each area, while urban/industrial footprint and human-created waterbodies each covered < 1%.

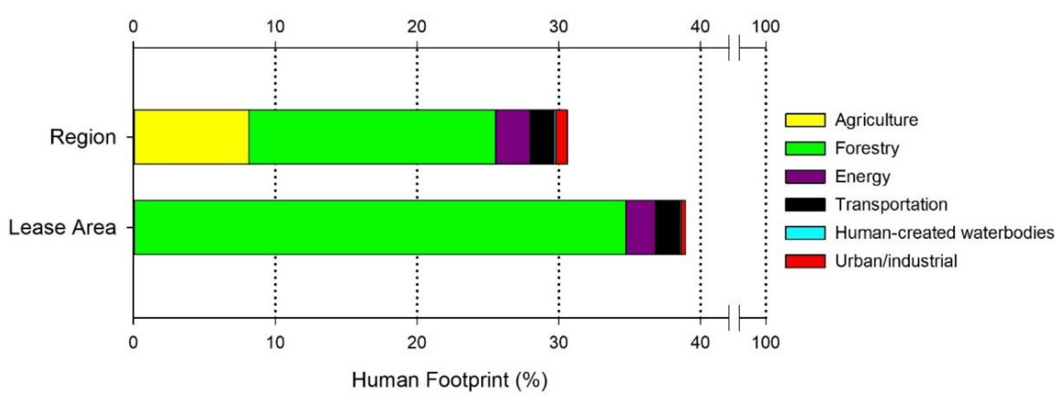
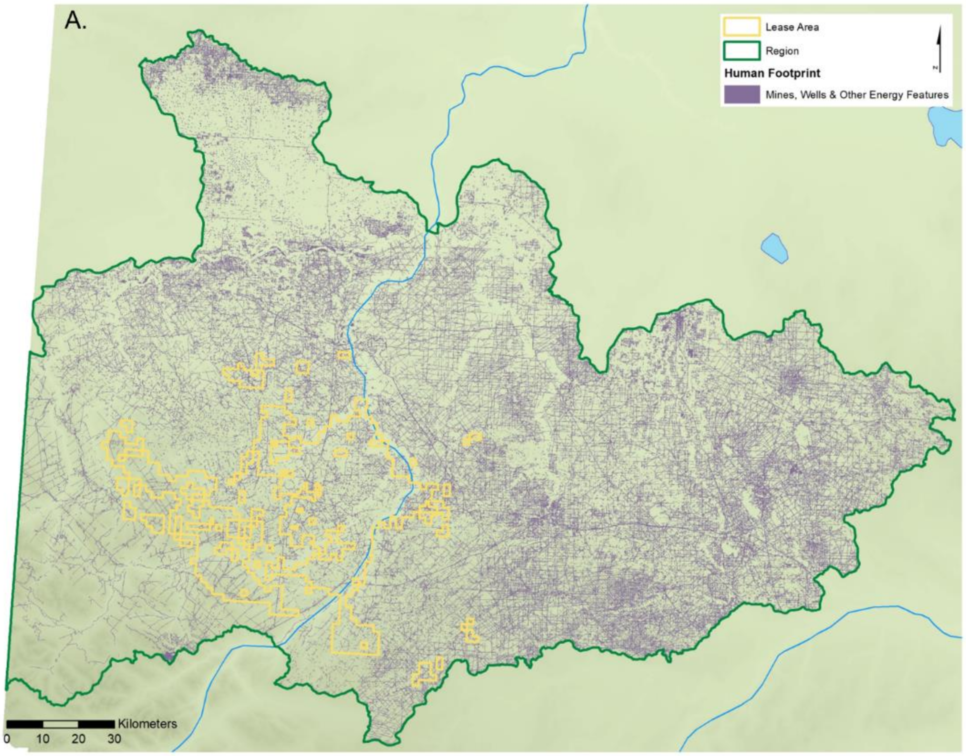


Figure 5. Summary of percentage area of total human footprint (circa 2018) broken down by human footprint category in the Region and Lease Area.



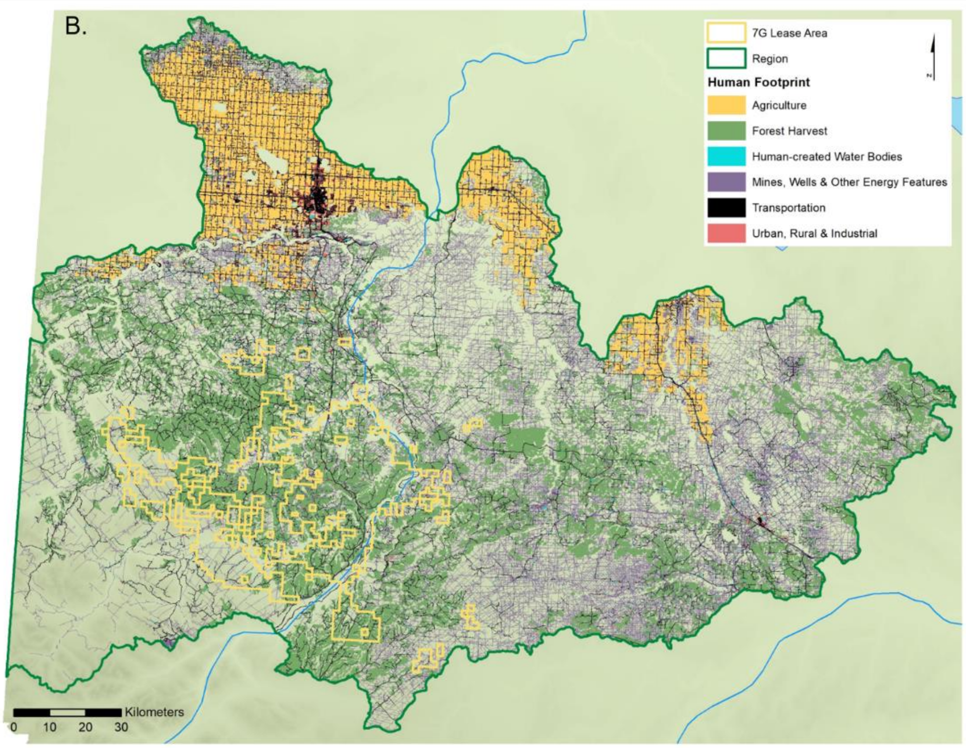


Figure 6. Distribution of A. energy footprint and B. total human footprint in the Region and Lease Area, circa 2018.

Trend in Human Footprint

In the Lease Area, total human footprint increased by 18.3 percentage points between 2000 and 2019, from 20.7% to 38.0%. Increase was primarily driven by forestry footprint (+16.9%) while energy footprint had a small increase of 0.8 percentage points (Figure 7).

Highlights

- Forestry footprint was the main land use driving increase in total human footprint in the Lease Area, increasing by 16.8 percentage points between 2000 and 2019, from 18.0% to 34.8%.
- However, the increase in forestry footprint is lower when forest recovery is considered; forestry footprint increased 11.3 percentage points in the Lease Area when the extent of regenerating forest over the same time period is discounted from unadjusted forestry footprint.
- The increase in total human footprint was smaller in the Region than in the Lease Area at 9.6 percentage points over 2000-2019, with forestry footprint making up 8.7% of that increase.
- All other footprint, including energy, showed small increases (i.e., < 1%) over 2000-2019 in the Lease Area and Region.
- In 1950 and 1980, there was no human footprint in the Lease Area. At the Region scale, human footprint—which mostly consisted of agriculture footprint—occupied 5.6% and 8.7% of the landbase, respectively, in 1950 and 1980.

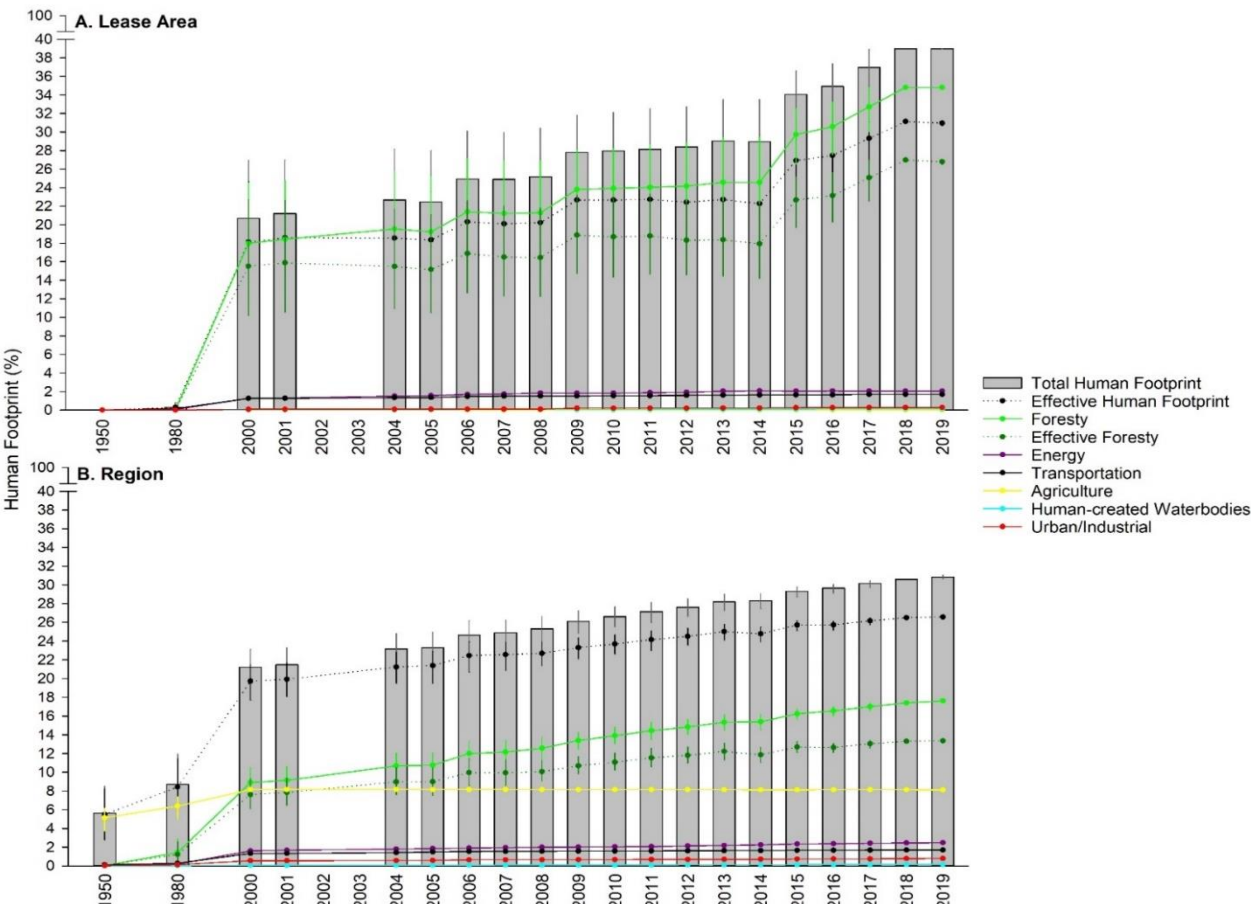


Figure 7. Trend in the percentage area of total human footprint (grey bars), and by human footprint category between 2000 and 2019 in the A. Lease Area and B. Region.

Linear Footprint Density

Linear footprint density (circa 2018) was estimated to be 3.04 km/km^2 in the Lease Area and 3.46 km/km^2 at the Region scale (Figure 8; Figure 9).

Highlights

- Seismic lines are the predominant linear feature type, representing 54.4% of lines in the Lease Area and 62.6% of lines in the Region.
- Pipelines and roads (major and minor) each represent between 18.1% and 23.2% of line types at both scales, with densities ranging from 0.62 km/km^2 to 0.71 km/km^2.
- Transmission lines and railway lines have very low densities across the Region, each representing < 1.0% of line types.

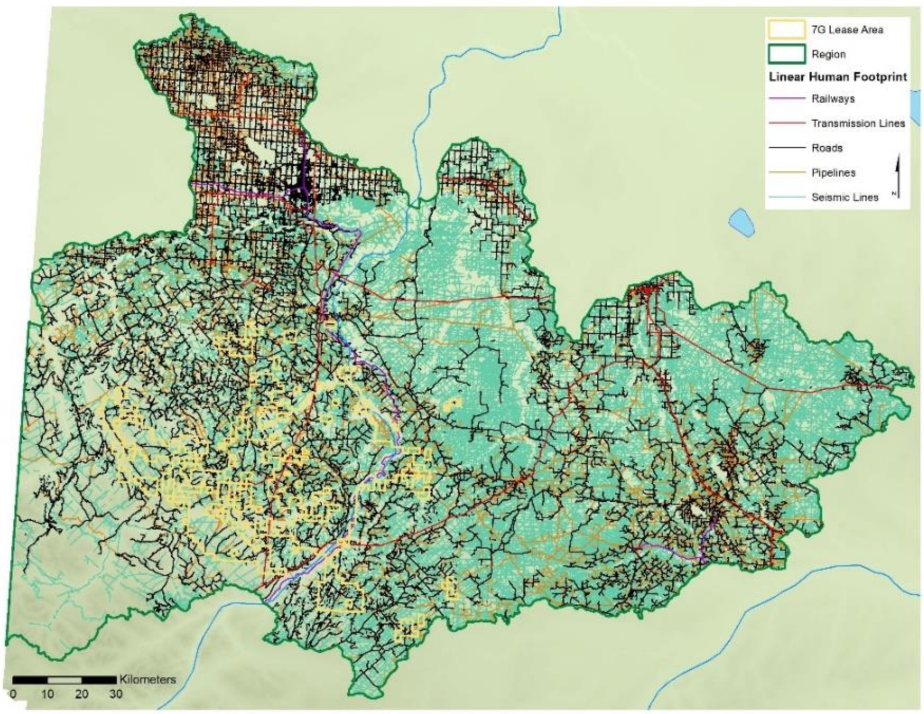


Figure 8. Linear footprint seperated by line type (circa 2018) in the Region and Lease Area.

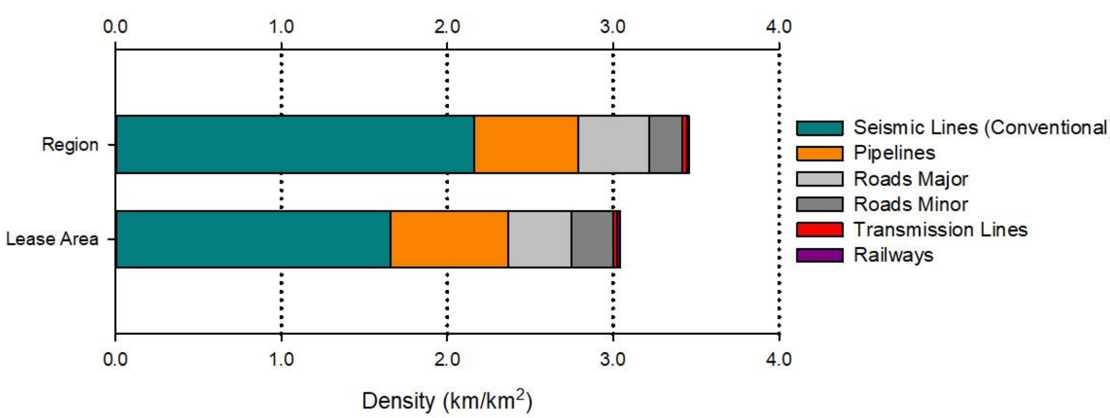


Figure 9. Density (km/km^2) of linear features (circa 2018) overall and broken down by linear footprint category in the Region and Lease Area.

Status of Interior Native Habitat

Habitat loss due to human disturbance is a primary threat to biological diversity. In addition to the loss of native habitat, proximity of human footprint can also affect species populations in adjacent native habitats both positively and negatively. Some species, such as Dark-eyed Junco and Chipping Sparrow, use native habitat that is adjacent to human footprint[9]. Other species require "interior" habitat that is more distant from human footprint, Woodland Caribou being the most well-known example.

Area of Interior Native Habitat

The area of interior native habitat in the Lease Area was 61.1%, with 10.5% of that habitat at least 500 m from any human footprint (Figure 10; Figure 11).

Highlights

- The total area of native habitat is slightly lower in the Lease Area (61.1%) than in the Region (69.4%). The difference in native habitat reflects the amount of human footprint in each area.
- Approximately 50% of native habitat area is at least 50 m away from human footprint at both scales; this amount decreases to 25.6% and 26.7% of the Lease Area and Region, respectively, when only interior native habitat at least 200 m away from human footprint is included.
- The area of interior native habitat at least 500 m away from human footprint makes up 10.5% and 12.5% of the Lease Area and Region, respectively.
- The distribution of human footprint, particularly linear features, results in similar amounts of interior native habitat in the Lease Area and Region at 50 m, 200 m, and 500 m away from human footprint.

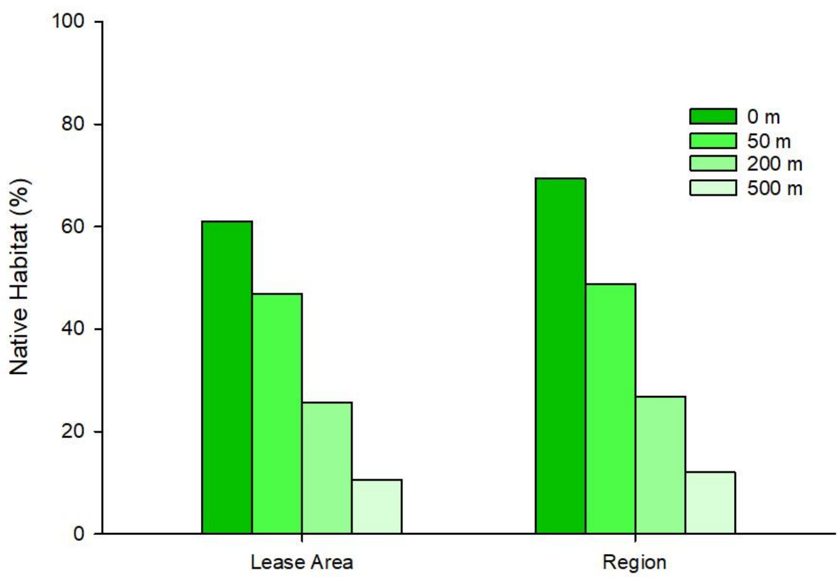


Figure 10. Percent (%) area of interior native habitat, circa 2018, at the Region and Lease Area scales of analysis. Interior native habitat is buffered from human footprint using four base edge distances (0 m, 50 m, 200 m, and 500 m) with buffers from human footprint features adjusted to account for successional recovery and linear feature width.

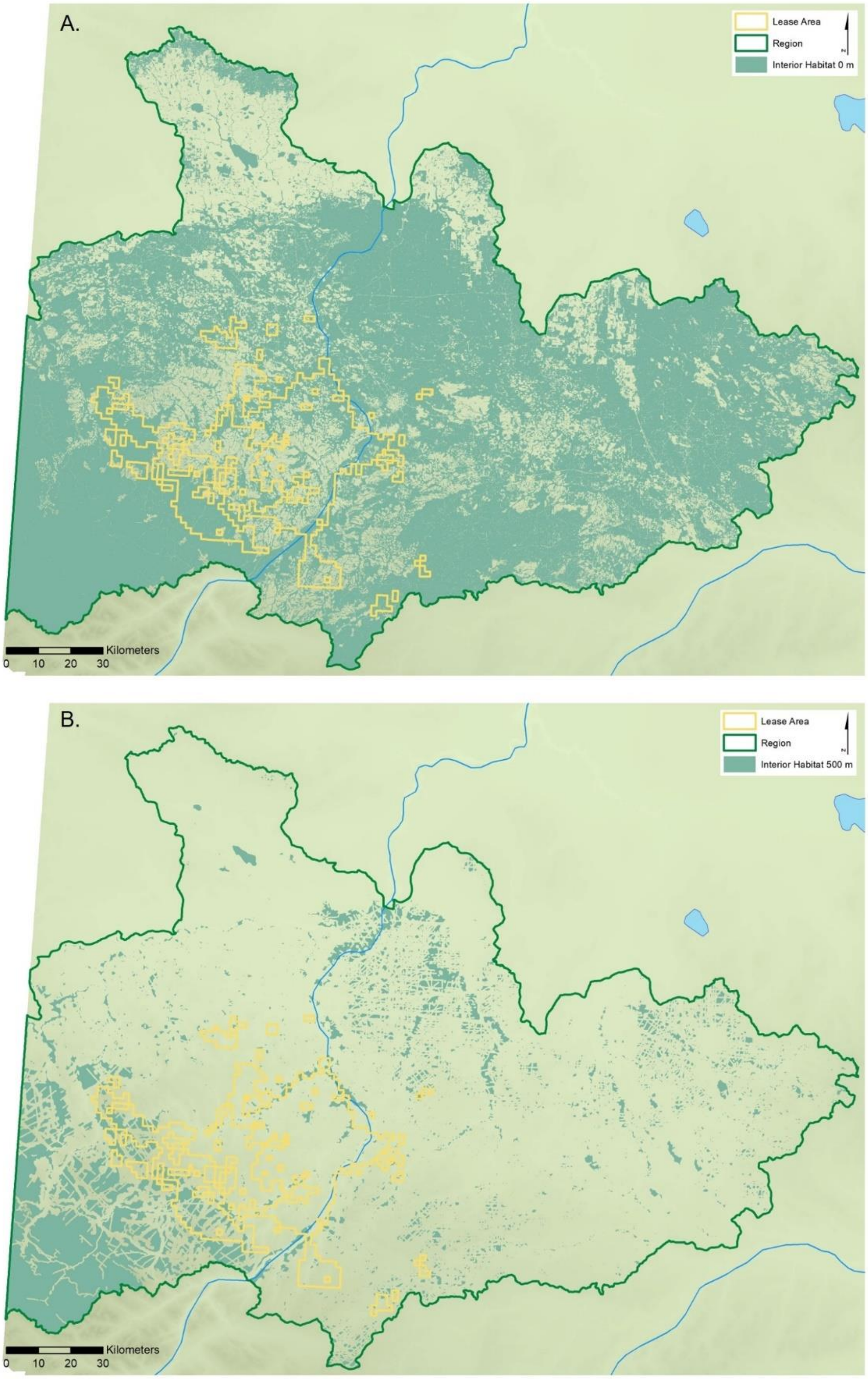


Figure 11. Distribution of interior native habitat, circa 2018, that is A. 0 m and B. 500 m away from human footprint in the Region and Lease Area.

BIODIVERSITY RESULTS

For each taxonomic group addressed in this section of the report, we profile results for species that showed the biggest difference from reference conditions including species that were more and less abundant than expected. We provide a summary of non-native plants and species-at-risk in the Region. Finally, we profile two species of management interest—Black-throated Green Warbler and Moose.

Status of Biodiversity

Thousands of animal and plant species live in northwestern Alberta where the Kakwa River Project area is located. The ABMI assessed the status of species using the Biodiversity Intactness Index for six taxonomic groups—native birds, mammals, soil mites, vascular plants, mosses, and lichens—which represent a diverse subset of all species in the region. Intactness shows the degree to which human footprint has affected species due to changes to habitat suitability. Habitats with minimal disturbance have high intactness scores compared to highly modified habitats, which have low intactness scores.

Cumulative Effects of Land Disturbance on Overall Biodiversity

The status of overall biodiversity as measured by the Biodiversity Intactness Index was found to be, on average, 85.7%, (Figure 12; Figure 13; Table 1). Deviation in intactness from reference conditions was due to both decreaser species that were less abundant than expected and increaser species that were more abundant than expected in the assessment area (Figure 12).

Highlights

- Average intactness ranged from 83.2% for birds to 87.3% for mammals in the Region.
- For mosses and lichens, the deviation from reference was mainly due to decreaser species that decline in response to human footprint. Many moss and lichen species are most abundant in older forests and are negatively affected by activities that alter their preferred habitat.
- For birds, mites, and vascular plants, deviation from intact reference conditions was due in large part to increaser species that were more abundant than expected in the Region. These species benefit from human footprint and are otherwise uncommon in native vegetation.

Table 1. Intactness* for six taxonomic groups at the Region scale.

	Species Count	Average Intactness (%)
Birds	83	83.2
Mammals	14	88.2
Mites	88	87.0
Vascular Plants	235	84.8
Lichen	99	83.6
Mosses	111	87.3
Total*	630	85.7

*Overall intactness is calculated as the average of the intactness values of the six taxonomic groups as opposed to the average of all individual species' intactness values.

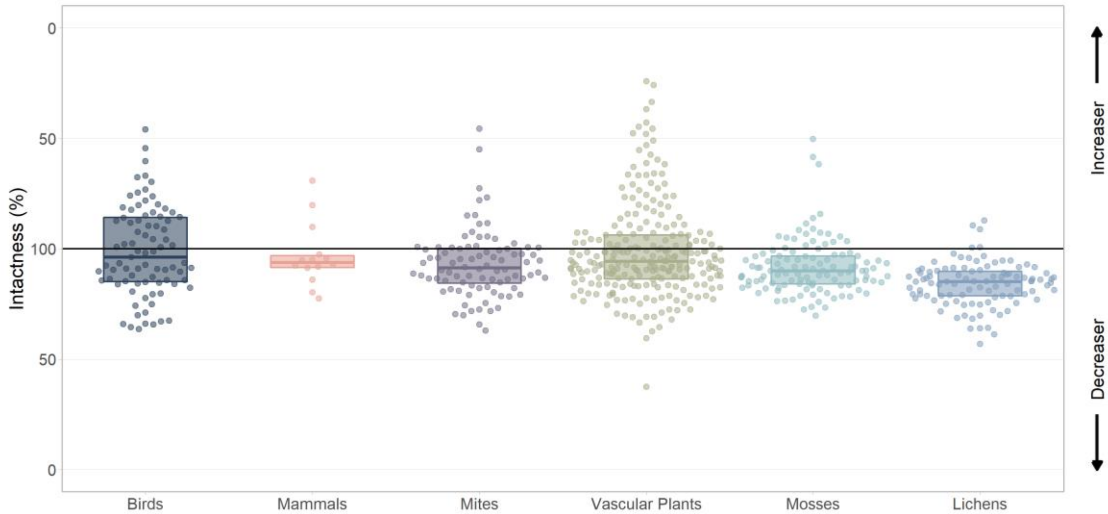


Figure 12. Distribution of species intactness by taxonomic group in the Region. Solid line at 100% indicates no difference in predicted relative abundance between the current landscape with human footprint and the modelled reference landscape without human footprint. Both positive and negative deviations from reference conditions result in lower intactness. Each dot represents an individual species. Box plot represents: lower hinge = 25% quartile | middle = median | upper hinge = 75% quartile.

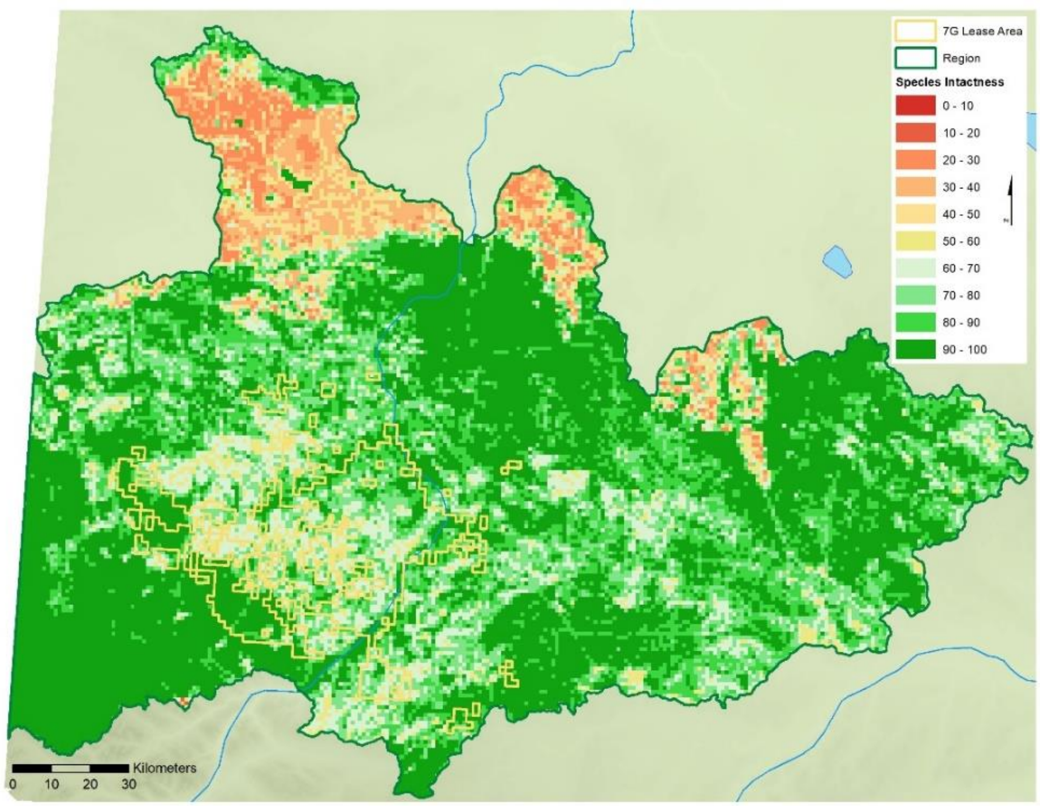


Figure 13. Spatial distribution of average biodiversity intactness (0-100%) in the Lease Area and Region. Red indicates areas with greater difference between current and reference abundance (intactness is lower) while dark green areas indicate areas with less difference (intactness is higher). Map resolution is 1 km^2**.**

Status of Birds

Introduction

Habitat for many different bird species is found within the Kakwa River Project area and surrounding landbase. These varied habitats are the result of heterogeneity in vegetation and climate across four natural regions, including:

- The conifer-covered slopes of the mountains which provide habitat for species that are not found elsewhere in Alberta, like Varied Thrush, Clark's Nutcracker, and Townsend's Warbler.
- The Foothills Natural Region which sustains a variety of mountain, boreal, and parkland-associated species. For instance, the Pileated Woodpecker excavates holes in large dead and dying trees to nest; once vacated, these cavities are used by many other species.
- The Boreal Natural Region which supports numerous songbirds, including many warbler species common to these northern forests.

Intactness and energy-specific sector effects are summarized for common native birds in the Region.

Cumulative Effects of Land Disturbance on Birds

The overall intactness of 83 bird species as measured by the Biodiversity Intactness Index was found to be, on average, 83.2% in the Region. Change in intactness was due to both decreaser species that were less abundant than expected and increaser species that were more abundant than expected in the assessment area.

Birds species predicted to be less abundant than expected

- Habitat suitability was predicted to decrease for 45 bird species.
- The decreaser species that showed the largest departures from intact reference conditions are all considered old-forest specialists.
- These specialists, like the Western Tanager, require old forest habitat for nesting and feeding.

Intactness for biggest decreasers:

- Brown Creeper: 63.6%
- Canada Warbler: 64.5%
- Black-throated Green Warbler: 65.7%
- Western Tanager: 65.8%
- Bay-breasted Warbler: 66.1%

Bird species predicted to be more abundant than expected

- Habitat suitability was predicted to increase for 38 bird species.
- The largest increases were predicted for species associated with young forest and open habitats (e.g., grass and shrub habitats) that respond positively to human land use—forestry activities in particular.
- For example, the Alder Flycatcher is abundant in young, harvested stands.

Intactness for biggest increasers:

- Song Sparrow: 46.0%
- Alder Flycatcher: 54.4%
- Killdeer: 60.3%
- American Crow: 66.9%
- Le Conte's Sparrow: 67.6%

Effects of Energy Footprint on Birds

The relative abundance of bird species showed a median decrease of 2.9% within energy footprint. Where energy footprint occurs, there were similar numbers of species with predicted increases and decreases (Figure 14A).

Highlights

- The abundance of 22 bird species is predicted to decrease by more than 50% in energy sector footprint compared to the native habitat it replaced. These species mainly include old-forest dependant birds—such as Black-throated Green Warbler and Brown Creeper—that simply do not live in energy sector footprint.
- The abundances of 21 bird species are predicted to increase by more than 50% in energy sector footprint compared to the original habitat. These species—such as Alder Flycatcher, American Robin, and White-crowned Sparrow—are generally associated with young forest and/or open, grassy habitats and respond positively to human land use.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 14B). The predicted changes in total regional populations of birds ranged from -2% to +2% for most species. The largest predicted changes in regional populations are associated with increasing abundances of species that benefit from the creation of open habitats, a common outcome of energy development.

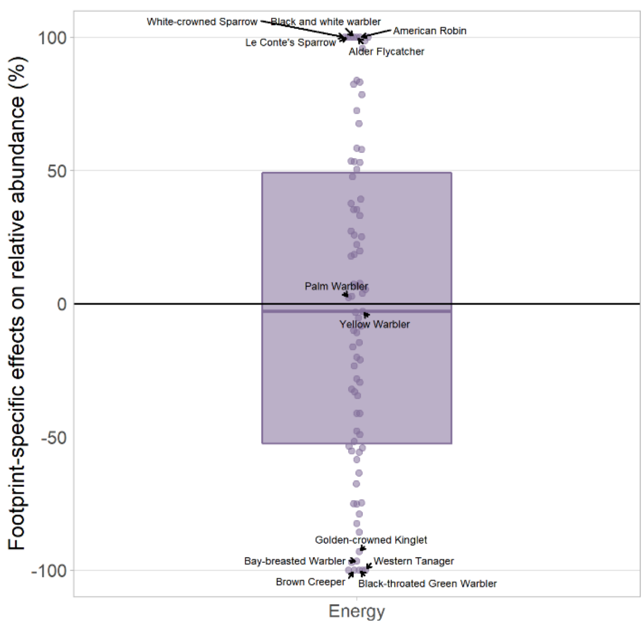


Figure 14A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced, for common birds in the assessment area. Sector effect values < 0% indicate fewer birds in that type of footprint than in the original habitat; greater than 0% indicate more birds. Each point represents an individual bird species.

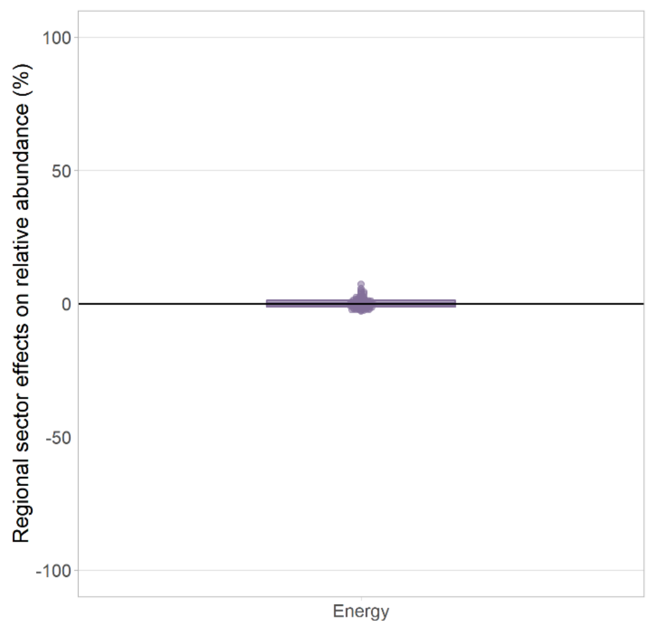


Figure 14B. Predicted changes in the total regional populations of bird species due to energy footprint in the Region. Each point represents an individual bird species. Regional sector effect values < 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values greater than 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Spotlight: Black-throated Green Warbler

A neotropical migrant, the Black-throated Green Warbler breeds in the Boreal Forest and Foothills Natural Regions including in the Kakwa River Project area and surrounding region.

- Considered a mature/old (> 80 years) forest specialist with a preference for interior habitat, the Black-throated Warbler is most common in old deciduous, mixedwood, and white spruce stands in Alberta[10].
- It is often associated with large white spruce trees which are preferred foraging sites[11]. The Black-throated Green Warbler gleans insects from the outer reaches of the branches, allowing them to co-exist with warbler species that inhabit other parts of the tree crown.
- Black-throated Green Warbler is sensitive to activities that remove its preferred mature forest habitat.

Black-throated Green Warbler is considered an indicator of mature interior forest habitat.

Species-Habitat Associations in the Forested Region of Alberta

- Black-throated Green Warbler relative abundance is highest in mature/old mixedwood stands followed by deciduous forests; relative abundance increases with forest age in these stands (Figure 15).
- It is moderately abundant in mid-seral white spruce forests but is essentially absent from all other vegetation and human footprint types.

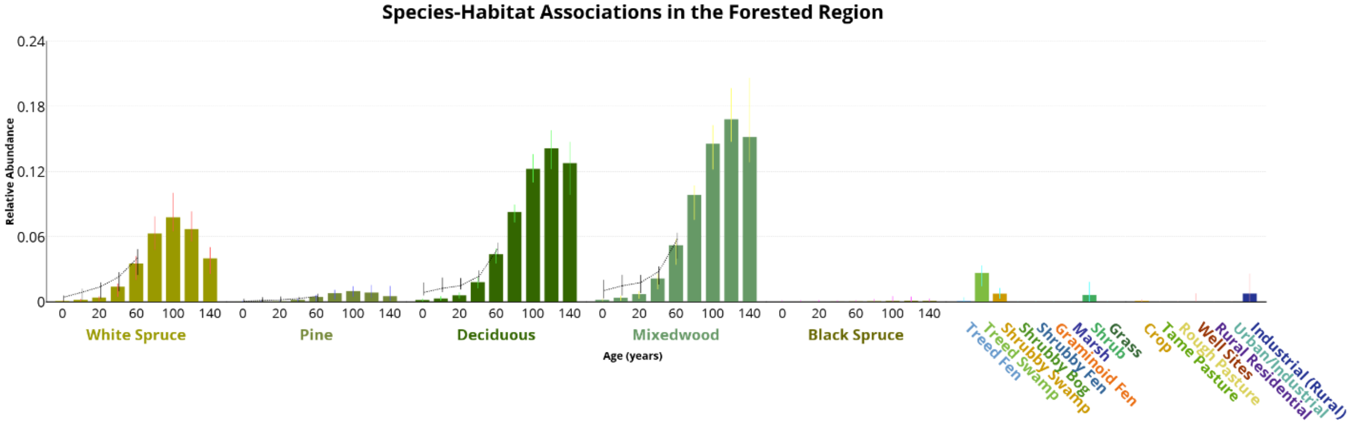


Figure 15. Predicted Black-throated Green Warbler relative abundance (bars) as a function of vegetation and human footprint type in the forested region. Dotted lines show the predicted species abundance in harvested forest stands of various ages. Vertical lines represent 90% confidence intervals.

Cumulative effects of land disturbance

The intactness of Black-throated Green Warbler was 65.7% in the Region, reflecting the cumulative effect of human footprint on this species (Figure 16). This species is predicted to be less abundant than expected compared to reference conditions.

- At the Region scale, some of the landscape provides suitable habitat for Black-throated Green Warbler.
- The habitat currently available in the Kakwa River Project area itself is predicted to be of lower suitability due in part to human development activities that impact the Black-throated Green Warbler's preferred old forest habitat.

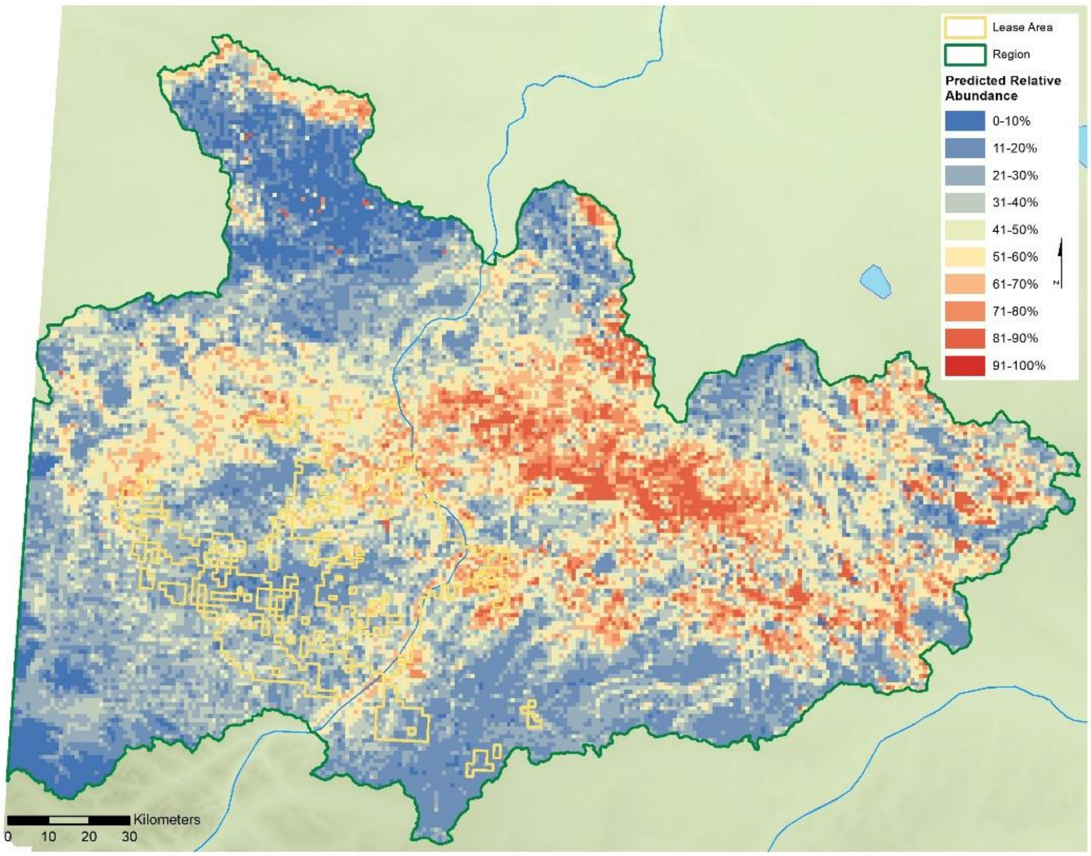


Figure 16. Predicted relative abundance of Black-throated Green Warbler in the Kakwa River Project Area and surrounding region under current habitat conditions. Predictions were made for each 1 km^2 pixel. Red areas have higher predicted relative abundances of Black-throated Green Warbler (and therefore more suitable habitat) than blue areas.

Effects of Energy Footprint

- Black-throated Green Warbler relative abundance was predicted to decrease by 100% in energy sector footprint compared to the habitat it replaces in the Region (Figure 14A). This species cannot live in areas where forested habitat has been removed.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region. The regional population of Black-throated Green Warbler was predicted to decrease by 2.4% compared to reference conditions, as a result of energy footprint in the region.

Status of Mammals

Introduction

The Kakwa River Project assessment area supports a wide range of habitats that are home to many mammal species. Mammal populations in the region have long been affected by hunting and trapping but more recent human activities, like forestry and energy development, are also impacting populations.

- Some mammals play an important ecological role in foothill ecosystems as top predators (e.g., Gray Wolf), while others provide hunting and trapping opportunities to local communities (e.g., Moose, Fisher).
- Some species, like Coyote, benefit from many forms of human development, while other species become less common as human land use intensifies.
- The process of subdividing contiguous tracts of forest into smaller patches impacts species that require large undisturbed areas, such as Wolverine and Woodland Caribou, as well as smaller forest-dwelling mammals, like Fisher and Marten.

Cumulative Effects of Land Disturbance on Mammals

The overall intactness of 14 mammal species as measured by the Biodiversity Intactness Index was found to be, on average, of 88.2% in the Region. Change in intactness was largely due to decreaser species that were less abundant than expected in the assessment area rather than increaser species that were more abundant than expected.

Mammal species that are less abundant than expected

- Habitat suitability was predicted to decrease for 11 mammal species.
- Habitat suitability is generally reduced for forest-dependant species (e.g., Marten and Fisher), and for species that require large areas of remote habitat away from human development activities (e.g., Wolverine).

Intactness of decreaser species:

- Wolverine: 77.5%
- Marten: 80.2%
- Cougar: 86.0%
- Fisher: 91.4%
- Elk: 91.8%
- Snowshoe Hare: 92.3%
- White-tailed Deer: 92.9%
- Gray Wolf: 94.7%
- Black Bear: 94.9%
- Mule Deer: 95.6%
- Moose: 97.5%

Mammal species that are more abundant than expected

- Habitat suitability was predicted to increase for three mammal species: Red Fox, Coyote, and Canada Lynx.
- The largest increases were predicted for habitat generalists—Red Fox and Coyote. These species can use a wide range of habitats, and often benefit from human activities.

Intactness of increaser species:

- Red Fox: 69.1%
- Coyote: 80.2%
- Canada Lynx: 90.2%

Effects of Energy Footprint on Mammals

The relative abundance of mammal species showed a median decrease of 1.4% within energy footprint. Where energy footprint occurs, seven mammal species are predicted to increase in abundance compared to reference conditions, and seven species are predicted to decrease (Figure 17A).

Highlights

- The abundance of Wolverine and Marten are predicted to decrease by more than 50% in energy sector footprint compared to the original habitat. Energy footprint divides the contiguous areas preferred by Wolverine and removes the old-forest habitat preferred by Marten.
- The abundance of Moose, Snowshoe Hare, Cougar, and Fisher were predicted to decrease between 49.2% and 33.5%, and that of White-tailed Deer by 5.7%. These species use a variety of habitats but all are associated with forest habitats which are reduced in energy footprint (Figure 17A).
- The abundance of Red Fox, Gray Wolf, Canada Lynx, Black Bear, and Coyote are predicted to increase by more than 50% in energy sector footprint compared to the original habitat. Wolves and bears make use of energy features, such as seismic lines and pipelines, to move through the landscape[12].
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 17B). The predicted changes in total regional populations of mammals ranged from -2.0% to +4.1%.

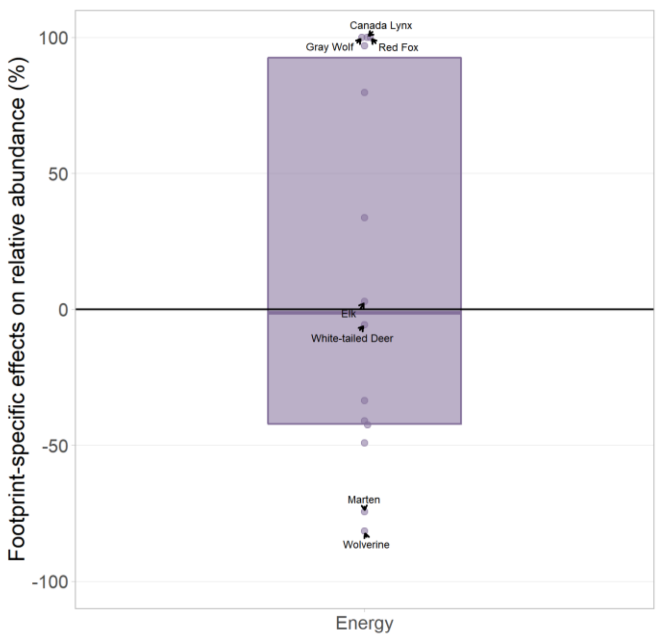


Figure 17A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced for mammals in the Region. Each point represents an individual mammal species. Sector effect values < 0% indicate fewer mammals in that type of footprint than in the original habitat; greater than 0% indicate more mammals.

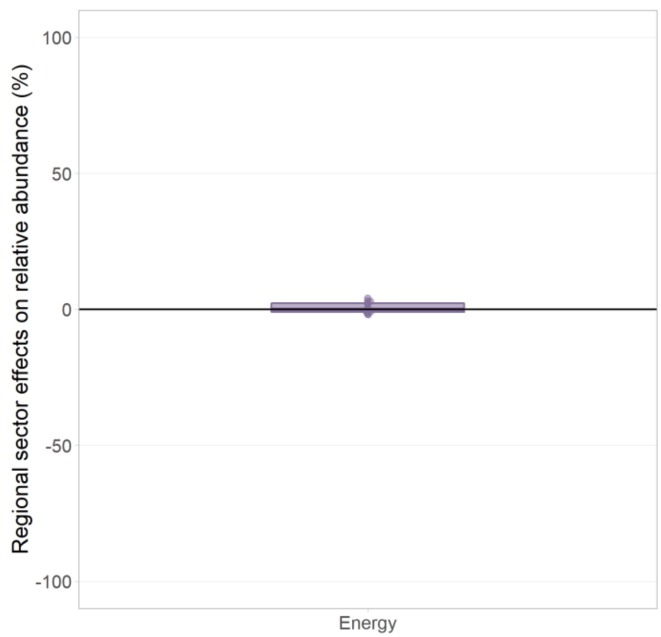


Figure 17B. Predicted changes in the total regional populations of mammal species due to energy footprint in the Region. Each point represents an individual mammal species. Regional sector effect values < 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values greater than 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Spotlight: Moose

Moose are a wetland-loving ungulate commonly found throughout northern Alberta, including the Boreal Forest and Foothills Natural Regions in the Kakwa River Project area and surrounding landbase[13].

- Moose browse on woody deciduous shrubs and forage in a wide variety of open habitats in the summer, such as burns, forest harvest areas, riparian areas, and shrublands. Moose also frequent wetlands and lake margins where they forage for salt-rich, submerged vegetation.
- In the winter, mature/old forests with good snow interception interspersed with open areas with extensive shrub growth provide bedding sites, thermal cover, security cover, and foraging habitat.

Moose are an important component of predator-prey systems and a socially valued species.

Species-Habitat Associations in the Forested Region of Alberta

- Moose use a wide variety of habitats; their relative abundance is highest in open habitats such as grass and shrub vegetation types, as well as young mixedwood stands that originated from natural disturbances and mature/old deciduous forest (Figure 18).
- Moose relative abundance is also high in wetland habitats such as marshes, graminoid fens, and treed swamps.

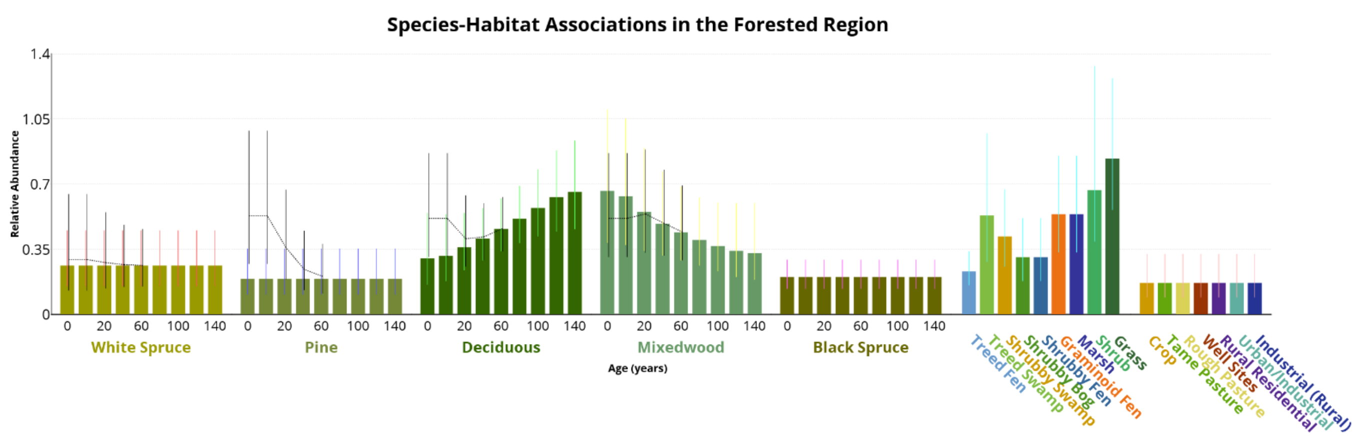


Figure 18. Predicted Moose relative abundance (bars) as a function of vegetation and human footprint type in the forested region. Dotted lines show the predicted species abundance in harvested forest stands of various ages. Vertical lines represent 90% confidence intervals.

Cumulative effects of land disturbance

The intactness of Moose was 97.4% in the Region, reflecting the cumulative effect of human footprint on this species (Figure 19). This species is predicted to be slightly less abundant than expected compared to reference conditions.

- In the Kakwa River Project area and surrounding region, most of the landscape provides suitable habitat for Moose (Figure 19).
- The habitat currently available in the Kakwa River Project area itself is mostly predicted to be of higher quality likely due in part to forestry activities that increase the amount of the young forest and shrub habitat preferred by Moose.

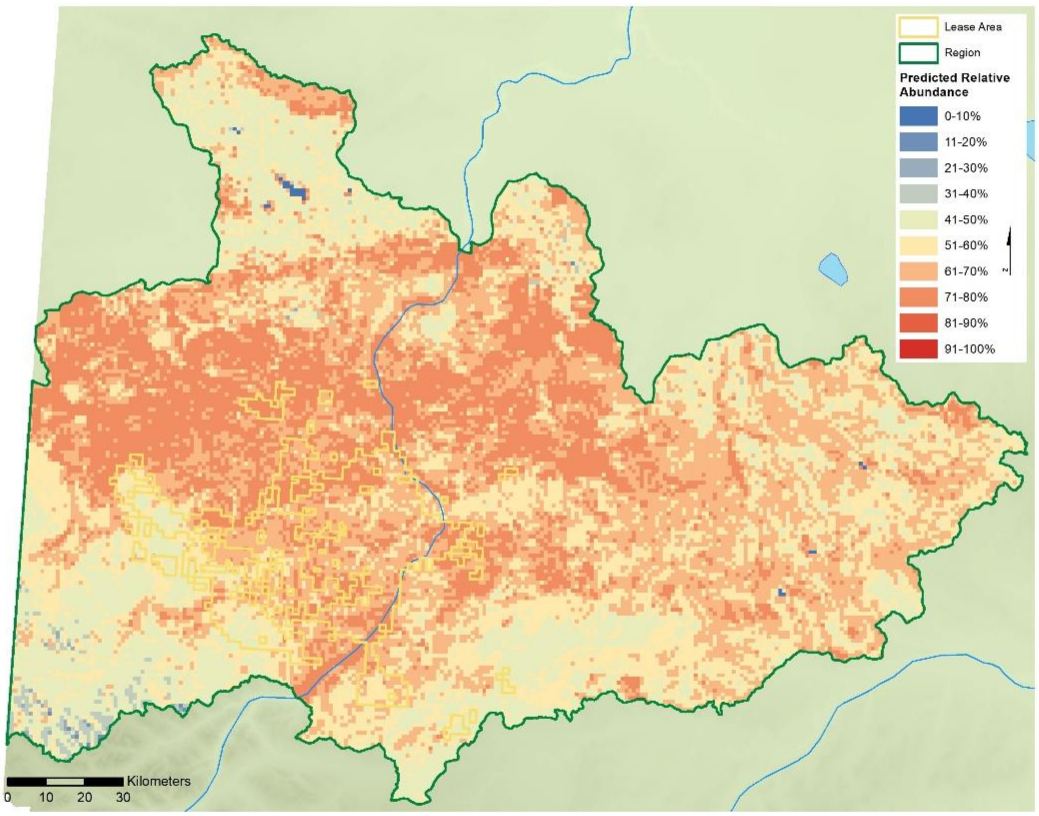


Figure 19. Predicted relative abundance of Moose in the Kakwa River Project area and surrounding region under current habitat conditions. Predictions were made for each 1 km^2 pixel. "Hotter"-coloured areas (orange and red) have higher predicted relative abundances of Moose (and therefore more suitable habitat) than "cooler"-coloured areas (blue).

Effects of Energy Footprint

- Moose relative abundance was predicted to decrease by 49.2% in energy sector footprint compared to the habitat it replaces in the Region (Figure 17A). Moose prefer forested habitats adjacent to wetlands, meaning they are negatively impacted by development activities that remove trees and drain wetlands.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region. The regional population of moose was predicted to decrease by 1.25% compared to reference conditions, as a result of energy footprint in the Region.

Status of Soil Mites

Introduction

Soil mites are highly diverse and a critical component of Alberta's soil biodiversity. No larger than the tip of a ballpoint pen, soil mites can number in the hundred thousands in a cubic metre of healthy topsoil. Most soil mites are detritivores (i.e., feed on dead plant and animal material). As a result, mites play an important role in decomposition and nutrient cycling, and the formation and maintenance of soil structure.

The use of land for human activities, such as forestry and energy development, can change the quantity and quality of the habitat available to soil mites. Mites can function as potential bioindicators of soil recovery where ecosystems have been disturbed[14].

Intactness and energy-specific sector effects are summarized for soil mites in the Region.

Cumulative Effects of Land Disturbance on Mites

The overall intactness of 88 soil mite species as measured by the Biodiversity Intactness Index was found to be, on average, 87.0% in the Region. Change in intactness was due to both decreaser species that were less abundant than expected and increaser species that were more abundant than expected in the Region.

Soil mite species that are less abundant than expected

- Habitat suitability was predicted to decrease for 66 soil mite species.
- Human activities can have differing effects on soil structure. Less disruptive footprints such as forestry disturb soil structure less than footprints that remove native soil entirely, such as urban/industrial footprint, resulting in different influences on the abundance and species of soil mites found in those footprints.
- The soil mite species with the lowest intactness—such as *Oribatella jacoti*—are mainly associated with mature/old deciduous or mixedwood forests that are targeted by forestry.

Intactness for biggest decreasers:

- *Oribatella jacoti*: 62.9%
- *Anachipteria howardi*: 65.7%
- *Eupelops septentrionalis*: 69.9%
- *Roynortonella gildersleeveae*: 70.4%
- *Dorycranosus acutidens*: 71.7%

Soil mite species that are more abundant than expected

- Habitat suitability was predicted to increase for 22 soil mite species.
- The largest increases were predicted for species associated with open and wetland habitats (e.g., grass, shrub, and marsh), as well as species that respond positively to human activities—particularly cultivation.

Intactness for biggest increasers:

- *Oribatula sp.* 1 DEW: 45.7%
- *Banksinoma spinifera*: 55.1%
- *Malaconothrus mollisetosus*: 72.7%
- *Tectocepheus sarekensis*: 76.9%
- *Punctoribates palustris*: 78.0%

Effects of Energy Footprint on Soil Mites

The relative abundance of soil mite species showed a median decrease of 31.3% within energy footprint. Where energy footprint occurs, 68% of species were predicted to decrease in abundance compared to reference conditions (Figure 20A).

Highlights

- The abundance of 28 soil mite species is predicted to decrease by more than 50% in energy sector footprint compared to the original habitat. These species mainly include old-forest dependant soil mites, such as *Eremaeus translamellatus*, *Dentizetes rudentiger*, and *Eueremaeus tetrosus*, that do not do well in open energy footprint.
- The abundance of 16 soil mite species is predicted to increase by more than 50% in energy sector footprint compared to the original habitat. Some of these species—such as *Tegoribates americanus*, *Tectocepheus sarekensis*, and *Banksinoma spinifera*—are associated with open grassy and shrubby wetland habitats.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 20B). The predicted changes in total regional populations of soil mites ranged from -2.6% to +4.9% for most species. Eight species greatly benefited from the creation of open habitats and had large predicted changes in the regional population, increasing by up to 23.3% in response to energy footprint.

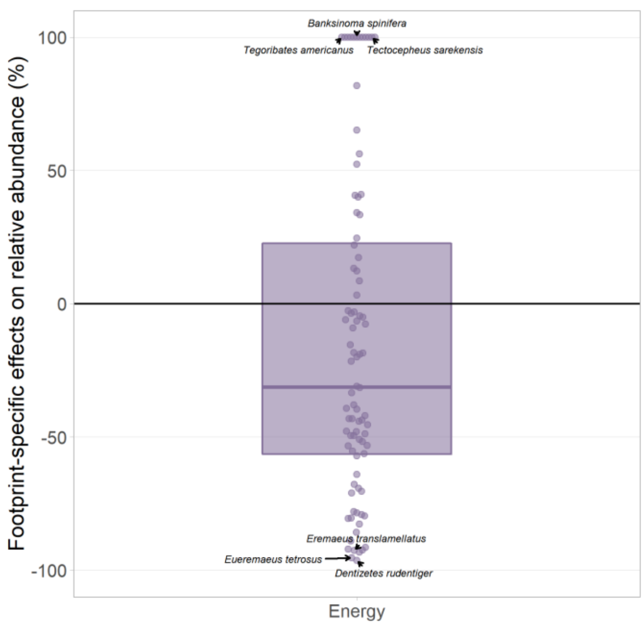


Figure 20A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced, for soil mites in the Region. Each point represents an individual soil mite species. Sector effect values < 0% indicate fewer soil mites in that type of footprint than in the original habitat; greater than 0% indicate more soil mites.

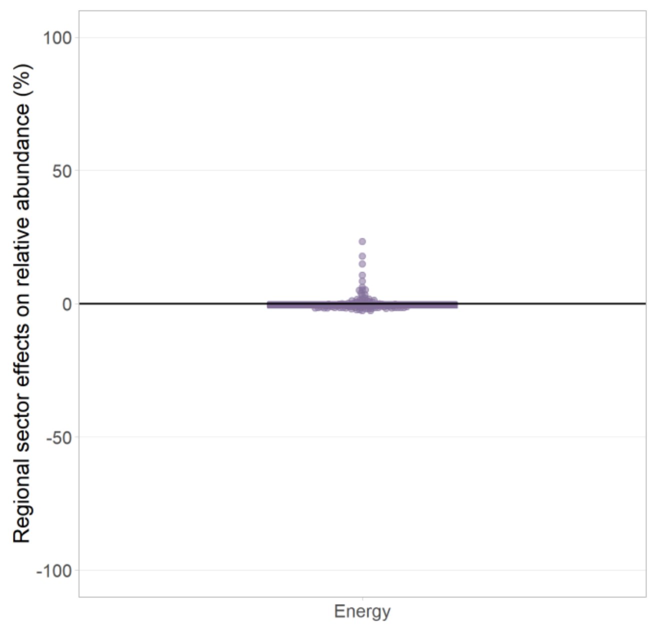


Figure 20B. Predicted changes in the total regional populations of soil mites due to energy footprint in the Region. Each point represents an individual soil mite species. Regional sector effect values < 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values greater than 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Status of Vascular Plants

Introduction

The variation in topography and climate of the assessment area results in a diversity of ecosystems including four of Alberta's six natural regions in a relatively small geographical area. These natural regions each have characteristic vegetation communities adapted to regional environmental conditions:

- The subalpine of the Rocky Mountain Natural Region includes coniferous forests of Engelmann Spruce, Subalpine Fir, Lodgepole Pine, and White Spruce, and their shaded understory.
- The Foothills Natural Region is a zone of mixed deciduous and coniferous forests, rolling fields and rocky outcrops which include a mix of vascular plant species from surrounding natural regions.
- The Boreal Forest Natural Region is a mosaic of upland forests interspersed with lowland forest and low-lying wetlands including bogs and fens. A high diversity of plant species can be found depending on environmental conditions.
- The Parkland Natural Region only covers a small pocket in the north of the assessment area and has mainly been converted to agricultural lands.

Overall, plant communities in the ecosystems across the Kakwa River Project area are an important component of biodiversity, providing vital food resources and habitat for wildlife in the region, and supporting the development of healthy forests and soil.

Intactness and energy-specific sector effects are summarized for native vascular plants in the Region.

Cumulative Effects of Land Disturbance on Vascular Plants

The overall intactness of 235 native vascular plant species as measured by the Biodiversity Intactness Index was found to be, on average, 84.8% in the Region. Change in intactness was due to both decreaser species that were predicted to be less abundant than expected in the Region and increaser species that were predicted to be more abundant than expected.

Vascular plants that are predicted to be less abundant than expected

- Habitat suitability was predicted to decrease for 65% of native plant species.
- The decreaser species that showed the largest departures are generally quite rare in the region, and while they occur in a variety of native habitat types, these species are intolerant of habitat alterations.
- For example, Spreading Sweet Cicely, a species that prefers old forest habitats, is predicted to be less abundant than expected.

Intactness for biggest decreasers:

- Spreading Sweet Cicely: 62.5%
- Hairy Fruited Sedge: 66.6%
- Pin Cherry: 68.0%
- Ground Cedar: 69.0%
- Cut Leaved Anemone: 69.2%

Vascular plant species that are predicted to be more abundant than expected

- Habitat suitability was predicted to improve for 35% of plant species.
- Increaser species generally prefer open habitats and disturbed soil and are often abundant in human footprint such as forest harvest areas, roadsides, and industrial sites.
- Narrow-leaved Hawkweed is an increaser species that occurs in a wide variety of habitats and disturbed sites.

Intactness for biggest increasers:

- Toad Rush: 24.1%
- Yellow Rattle: 25.9%
- Foxtail Barley: 33.5%
- Hay Sedge: 36.9%
- Slough Grass: 43.0%

Effects of Energy Footprint on Vascular Plants

The relative abundance of vascular plant species showed a predicted median increase of 7.9% within energy footprint. Where energy footprint occurs, there were similar numbers of species that were predicted to increase and decrease (Figure 21A).

Highlights

- The abundance of 59 vascular plant species is predicted to decrease by > 50% in energy footprint compared to the original habitat. These species, such as One-sided Wintergreen, Ground Juniper, and Rattlesnake Plantain, live in a range of native habitats but are intolerant of disturbance.
- The abundance of 85 vascular plant species is predicted to increase by > 50% in energy sector footprint compared to the original habitat, including 64 species that are predicted to increase by more than 100%. These species— such as Rough Cinquefoil, Foxtail Barley, and Many-flowered Yarrow—all respond positively to human land use.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 21B). The predicted changes in total regional populations of vascular plants ranged from -3% to +5% for most species. The largest predicted changes in regional populations (i.e., > 5% increase) were associated with predicted increases in relative abundance for species that readily colonize disturbed soils and benefit from high light levels in open habitats.

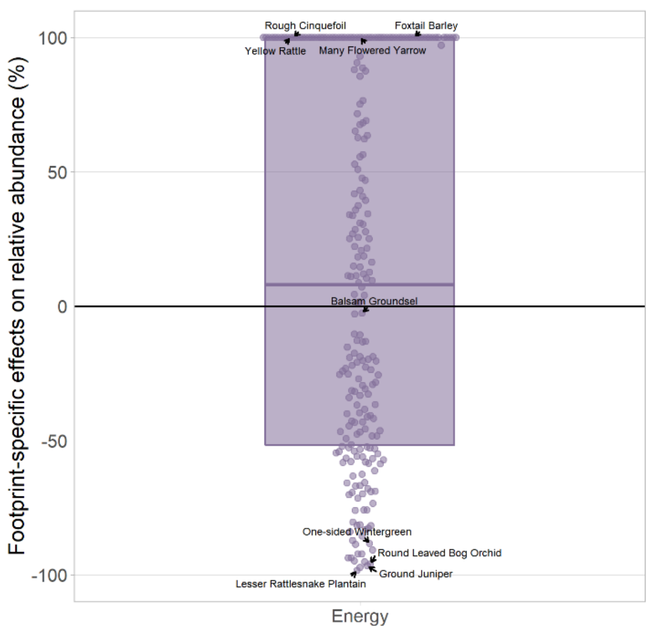


Figure 21A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced, for common vascular plants in the assessment area. Each point represents an individual plant species. Sector effect values < 0% indicate fewer vascular plants in that type of footprint than in the original habitat; > 0% indicate more plants.

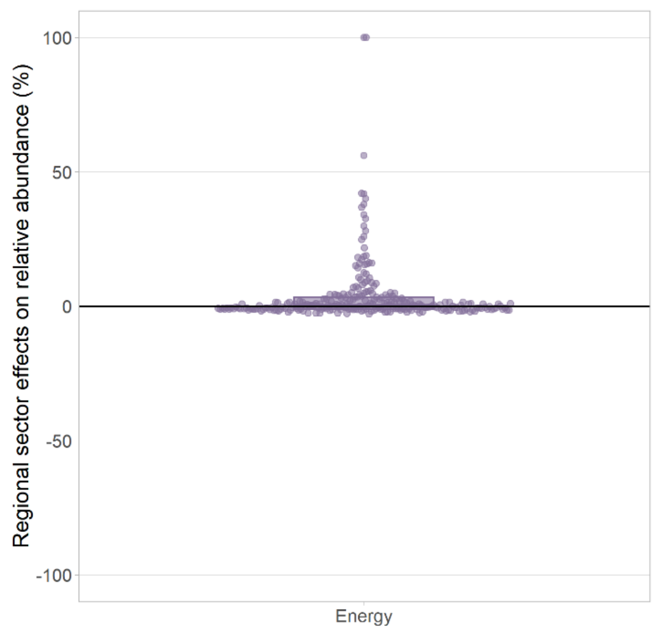


Figure 21B. Predicted changes in the total regional populations of vascular plant species due to energy footprint in the assessment area. Each point represents a vascular plants species. Regional sector effect values < 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values > 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Status of Non-native Vascular Plants

Introduction

Non-native plants are those species that have been introduced, intentionally or otherwise, into new areas beyond their natural habitat. While not all non-native species represent a threat to biodiversity, given the right conditions, non-native species can become a major ecological concern.

Results

38 species of non-native plants were detected in the Region (Table 2).

Highlights

- Non-native plants were detected at 56.8% of ABMI sites that have been sampled in the Region. At sites where non-native plants were found, an average of 4.7 non-native species were detected.
- Relative richness was predicted to be highest in areas outside the Lease Area, where agriculture footprint predominates (as indicated by areas in orange and red in Figure 22). In fact, several species detected are planted as forage crops in Alberta, such as Timothy, clover species, and Alfalfa.
- Common Dandelion was the most abundant non-native plant occurring at 45.5% of sites surveyed, followed by Timothy at 25.0% of sites, and Red Clover at 18.2% of sites.
- Creeping Thistle and Perennial Sow Thistle—detected at 6.8% and 2.2% of sites, respectively—are listed under the *Alberta Weed Control Act* as noxious weeds.

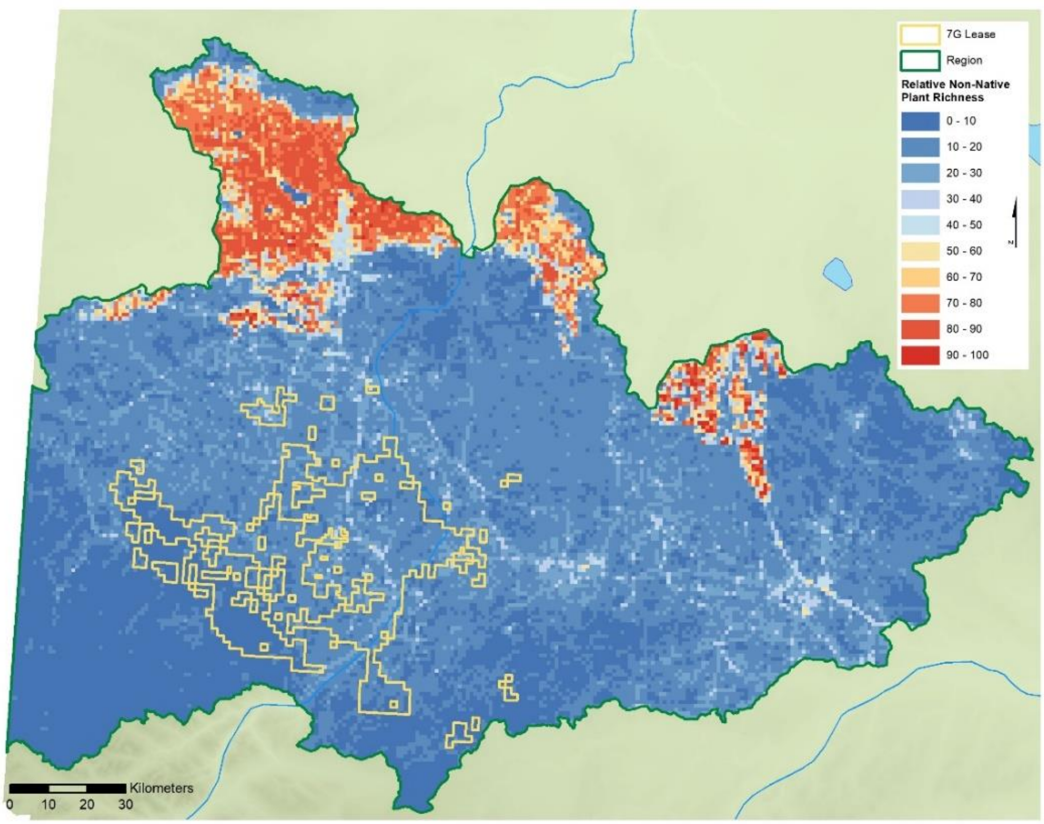


Figure 22. Predicted relative richness of non-native vascular plant species in the Region and Lease Area. Blue indicates areas where non-native species richness is predicted to be low or absent, and red are areas predicted have high species richness.

Table 2. Percent occurrence of 38 non-native vascular plants detected in the Region. Species listed as noxious weeds under the *Alberta Weed Control Act* are also identified.

Common Name	Scientific Name	Occurrence (%)	Status
Common Dandelion	*Taraxacum officinale / erythrospermum*	45.5	
Timothy	*Phleum pratense*	25.0	
Alsike Clover	*Trifolium hybridum*	20.5	
Red Clover	*Trifolium pratense*	18.2	
Awnless Brome	*Bromus inermis*	15.9	
White Clover	*Trifolium repens*	15.9	
Annual Hawk's Beard	*Crepis tectorum*	11.4	
Hemp Nettle	*Galeopsis tetrahit*	9.1	
Yellow Sweet Clover	*Melilotus officinalis*	9.1	
Common Plantain	*Plantago major*	6.8	
Creeping Thistle	*Cirsium arvense*	6.8	Noxious
Quack Grass	*Elymus repens*	6.8	
White Sweet Clover	*Melilotus albus*	6.8	
Alfalfa	*Medicago sativa*	4.5	
Pineappleweed	*Matricaria discoidea*	4.5	
Silvery Cinquefoil	*Potentilla argentea*	4.5	
Stinkweed	*Thlaspi arvense*	4.5	
Wheat	*Triticum*	4.5	
Argentine Canola	*Brassica napus*	2.3	
Bieber's Meadow Brome	*Bromus riparius*	2.3	
Bird's Foot Trefoil	*Lotus corniculatus*	2.3	
Black Medick	*Medicago lupulina*	2.3	
Buckwheat	*Fagopyrum esculentum*	2.3	
Canada Bluegrass	*Poa compressa*	2.3	
Canola	*Brassica rapa*	2.3	
Cleavers	*Galium aparine / spurium*	2.3	
Common Groundsel	*Senecio vulgaris*	2.3	
Common Mouse Ear Chickweed	*Cerastium fontanum*	2.3	
Corn Spurry	*Spergula arvensis*	2.3	
Indian Mustard	*Brassica juncea*	2.3	
King Devil Hawkweed	*Pilosella piloselloides*	2.3	
Lake Huron Tansy	*Tanacetum vulgare*	2.3	
Lamb's Quarters	*Chenopodium album*	2.3	
Parsnip	*Pastinaca sativa*	2.3	
Perennial Sow Thistle	*Sonchus arvensis*	2.3	Noxious
Sheep Fescue	*Festuca ovina*	2.3	
Shepherd's Purse	*Capsella bursa-pastoris*	2.3	
Wild Oat	*Avena fatua*	2.3	

Status of Mosses

Introduction

Mosses and liverworts are an abundant component of many ecosystems in Alberta, carpeting the forest floor of many forest types in the Rocky Mountain, Foothills, and Boreal Forest Natural Regions. Moss beds provide several important functions, such as:

- Insulating the soil, releasing important nutrients like nitrogen, and absorbing carbon.
- Affecting the understory plant community by limiting the establishment of understory plants and tree seedlings. In the case of non-native plants, the moss layer may function as a buffer, limiting their establishment [16].
- Providing habitat to diverse communities of micro-organisms, such as fungi, bacteria, and mites that play critical roles in decomposing plant material and maintaining healthy soil[17].

Intactness and energy-specific sector effects are summarized for moss species in the Region.

Cumulative Effects of Land Disturbance on Mosses

The overall intactness of 111 moss species as measured by the Biodiversity Intactness Index was found to be, on average, 87.3% in the Region. Change in intactness was largely due to decreaser species that were less abundant than expected compared to reference conditions in the assessment area.

Moss species that are less abundant than expected

- Habitat suitability was predicted to decrease for 91 moss species.
- The decreaser species that showed the largest departures from intact reference conditions are generally associated with old-forest habitats.
- Many of these species, like Red-mouthed Leafy Moss (*Mnium spinulosum*), rely on the large tree bases and rotten stumps and logs that are common in old-forest habitats.

Intactness for biggest decreasers:

- Red-mouthed Leafy Moss (*Mnium spinulosum*): 69.8%
- Elegant Lanceolated leaf Rock Moss (*Orthotrichum elegans/speciosum*): 72.4%
- Copper Wire Moss (*Pohlia cruda*): 73.3%
- Fuscous Moss (*Dicranum fragilifolium*): 73.7%
- Heller's Notchwort (*Anastrophyllum hellerianum*): 75.9%

Moss species that are more abundant than expected

- Habitat suitability was predicted to increase for 20 moss species.
- The largest increases were predicted for species associated with either young forest or wetland habitats (e.g., shrubby bog and marsh), and that respond positively to human land use—particularly forestry and agriculture.
- For example, Bonfire Moss (*Funaria hygrometrica*) is naturally abundant in young forests and therefore benefits from the young, harvested stands in the Region.

Intactness for biggest increasers:

- Bonfire Moss (*Funaria hygrometrica*): 50.3%
- Bird's Claw Screw Moss (*Barbula convoluta*): 58.5%
- Bird's Claw Beard Moss (*Barbula unguiculata*): 61.7%
- Juniper Polytrichum Moss (*Polytrichum commune*): 84.3%

Effects of Energy Footprint on Mosses

The relative abundance of moss species showed a median decrease of 50.8% within energy footprint. Where energy footprint occurs, 80% of species were predicted to decrease in abundance compared to reference conditions (Figure 23A).

Highlights

- The abundance of 56 moss species is predicted to decrease by > 50% in energy sector footprint compared to the original habitat. These species mainly include old-forest dependent mosses, such as Hatcher's Pawwort (*Barbilophozia hatcheri*), Heller's Notchwort (*Anastrophyllum hellerianum*), and Glaucous-headed Earwort (*Scapania glaucocephala*), that do not do well in open energy footprint.
- The abundance of nine moss species is predicted to increase by > 50% in energy sector footprint compared to the original habitat, including Bonfire Moss (*Funaria hygrometrica*), commonly found in young forests, and Rigid Bog-moss (*Sphagnum teres*), which thrives in wetland habitats.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 23B). The predicted changes in total regional populations of mosses ranged from -3.0% to +4.0% for most of the species. The same five moss species that were predicted to increase directly in energy footprint also had large predicted changes in their regional population due to energy footprint, with predicted increases ranging from 7.0% to 20.8%.

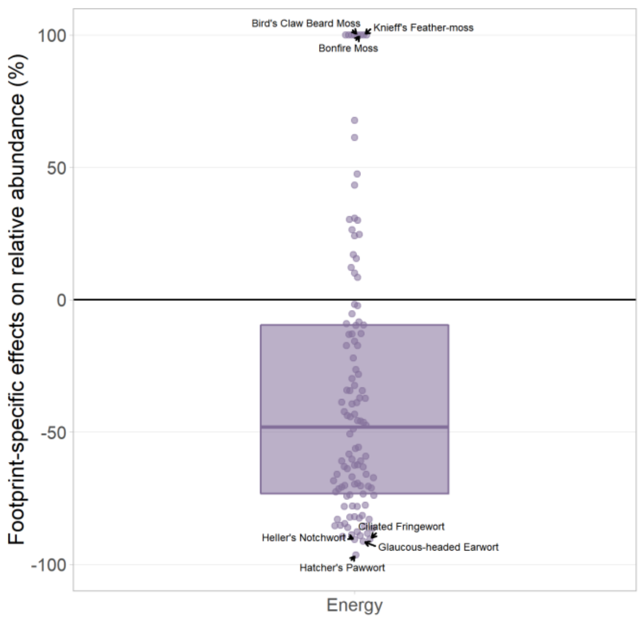


Figure 23A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced, for mosses in the Region. Each point represents an individual moss species. Sector effect values < 0% indicate fewer mosses in that type of footprint than in the original habitat; > 0% indicate more mosses.

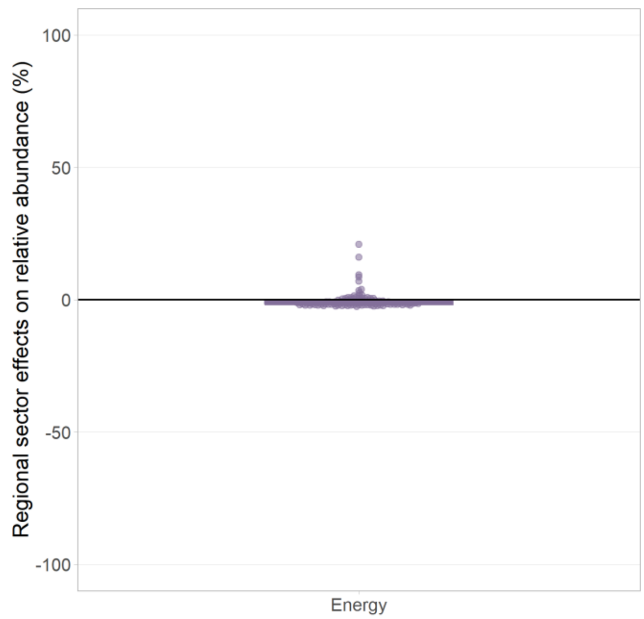


Figure 23B. Predicted changes in the total regional populations of mosses due to energy footprint in the Region. Each point represents a moss species. Regional sector effect values < 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values > 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Status of Lichen

Introduction

Lichen species are a diverse component of many forest ecosystems, including terrestrial species that grow on the forest floor as well as epiphytic lichen that grow on tree trunks and branches. Lichen—which are plant-like life forms that arise from symbiotic partnerships between at least one fungus and one photosynthetic alga or cyanobacterium[18]—provide several functional benefits[19]:

- Lichen can play an important role in nutrient cycling by fixing atmospheric nitrogen and making it available to other plants through leaching and decomposition.
- Influence hydrology through their water absorption and storage capacity.
- Serve as microhabitat for mosses, invertebrates and other fungi.
- Lichen are a source of food for a host of herbivores, such as caribou and Flying Squirrels and invertebrates. In fact, lichens are a critical winter food source for Woodland Caribou[20].

Many lichens tend to increase in abundance with forest age and may rely on habitat elements that are more common in older forests such as large decaying logs, large trees, and complex canopy structure.

Intactness and energy-specific sector effects are summarized for common lichen in the Region.

Cumulative Effects of Land Disturbance on Lichen

The overall intactness of 99 lichen species as measured by the Biodiversity Intactness Index was found to be, on average, 83.6% in the Region. Change in intactness was due almost entirely to decreaser species that were predicted to be less abundant than expected in the assessment area.

Lichen species that are less abundant than expected

- Habitat suitability was predicted to decrease for 95% of lichen species.
- The lichen species with the lowest intactness are all associated with mature forests.
- For example, Angel's Hair (*Ramalina thrausta*) which typically grows on the bark of conifer trees, is associated with mature white spruce forests.

Intactness for biggest decreasers:

- Angel's Hair (*Ramalina thrausta*): 61.2%
- Blister Paw (*Nephroma resupinatum*): 63.9%
- Milky-skin Centipede Lichen (*Heterodermia galactophylla*): 63.9%
- Lung Lichen (*Lobaria pulmonaria*): 64.1%
- Cat Paw (*Nephroma bellum*): 68.3%

Lichen that are more abundant than expected

- Habitat suitability was predicted to increase for only four lichen species.
- These increaser species—such as Lesser Green Reindeer Lichen (*Cladonia arbuscula* ssp. *mitis*)—commonly occur in a variety of native forest types and vegetation types and typically benefit from forestry footprint.

Intactness for increasers:

- Peg-leg Soldiers (*Cladonia cariosa*): 87.2%
- Laddered Pixie-cup (*Cladonia verticillata*): 89.4%
- Wooden Soldiers (*Cladonia botrytes*): 91.2%
- Lesser Green Reindeer Lichen (*Cladonia arbuscula ssp. mitis*): 99.3%

Effects of Energy Footprint on Lichen

The relative abundance of lichen species is predicted to have a median predicted decrease of 70.5% within energy footprint with relative abundance predicted to be lower for 96 of 99 lichen species assessed (Figure 24A).

Highlights

- The abundances of 83 lichens species (or 84% of the 99 species) were predicted to decrease by more than 50% in energy sector footprint compared to the original habitat. The species predicted to have the largest decreases are generally uncommon and are often associated with old conifer forests, such as Sponge Pelt (*Peltigera retifoveata*) and Witch's Hair (*Alectoria sarmentosa ssp. sarmentosa*).
- Only three species are predicted to increase within energy footprint—Peg-leg Soldiers (*Cladonia cariosa*), Fan Ramalina (*Ramalina sinensis*), and Poplar Needles (*Phaeocalicium populneum*). These species are generally associated with young forests and/or open, grassy habitats.
- Regional effects of energy on predicted abundance are much less than local scale effects because energy footprint area makes up a small portion of the Region (Figure 24B). The predicted changes in total regional populations of lichens ranged from -3% to +2% for all species.

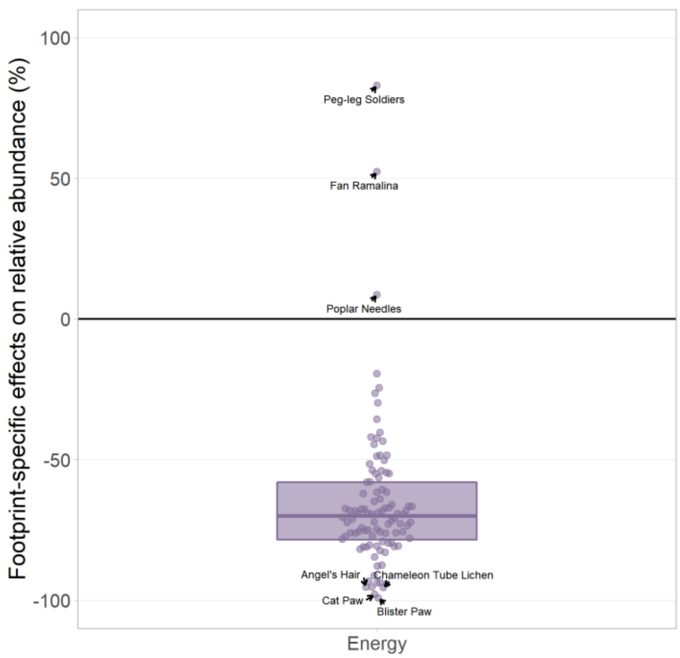


Figure 24A. Predicted changes to species' relative abundance inside areas disturbed by energy activities compared to the habitat it replaced, for common lichens in the Region. Sector effect values < 0% indicate fewer lichens in that type of footprint than in the original habitat; greater than 0% indicate more lichens. Each point represents an individual lichen species.

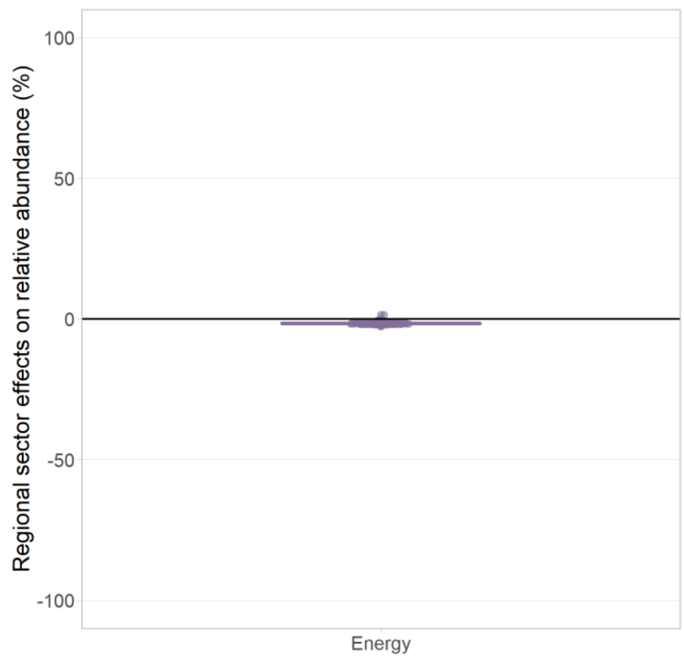


Figure 24B. Predicted changes in the total regional populations of lichen species due to energy footprint in the Region. Each point represents an individual lichen species. Regional sector effect values less than 0% indicate a predicted decrease in the regional population due to the energy sector footprint and values greater than 0% indicate a predicted increase. Note that sector effects consider only the direct impact of disturbed areas and do not consider edge effects or other non-footprint effects (e.g., noise, pollution).

Species of Conservation Concern

Introduction

The health of biodiversity in a region includes an assessment of species that are naturally rare or that have demonstrated a significant decline in abundance. These are species of conservation concern because future declines in their abundance may result in the loss of the species from an area.

Results

There are at least 61 species of conservation concern from different taxonomic groups in the Region. The ABMI detected 36 species often enough to calculate intactness (Table 3).

Highlights

- Seven species detected in the Region are listed as Threatened or of Special Concern by the Government of Canada and/or by the Government of Alberta: Olive-sided Flycatcher, Rusty Blackbird, Sprague's Pipit, Canada Warbler, Evening Grosbeak, Barn Swallow, and Bank Swallow. No species detected are listed as Endangered.
- Of the 36 species where intactness was calculated, 30 were decreaser species that were predicted to be less abundant than expected compared to reference conditions with intactness ranging from 63.6% to 96.7%. Species with the largest predicted decreases in relative abundance are associated with old forest habitat, such as Canada Warbler, Cat Paw lichen, and Glaucous-headed Earwort.
- Six species were increasers with intactness ranging from 54.4% intact to 99.3% intact. These species are generally associated with young forest and open habitats (e.g., grass and shrub habitats) that respond positively to human land use.

Example of Increaser

79.9% intact

Habitat suitability is predicted to improve for a few species of conservation concern that are associated with open habitat types, such as the Common Yellowthroat.

Example of Decreaser

63.6% intact

Many species of conservation concern that were less abundant than expected—like the Brown Creeper—are associated with mature forest habitats.

Table 3. Summary of species of conservation concern detected with enough frequency to calculate intactness in the Kakwa River Project area.

Common Name	Scientific Name	Occurrence (%)	Biodiversity Intactness (%)	Above or Below Reference Conditions	Status[1]
Birds					
Olive-sided Flycatcher	*Contopus cooperi*	18.6	99.3	Increaser	COSEWIC – Threatened | SARA - Schedule 1, Threatened | General Status - May Be at Risk
Western Wood Pewee	*Contopus sordidulus*	30.2	93.5	Decreaser	General Status - May Be at Risk
Least Flycatcher	*Empidonax minimus*	46.5	93.3	Decreaser	General Status - Sensitive
Pileated Woodpecker	*Dryocopus pileatus*	16.3	90.4	Decreaser	General Status - Sensitive
Baltimore Oriole	*Icterus galbula*	2.3	85.0	Increaser	General Status - Sensitive
Rusty Blackbird	*Euphagus carolinus*	4.7	81.4	Increaser	COSEWIC - Special Concern | SARA - Schedule 1, Special Concern | General Status - Sensitive
Common Yellowthroat	*Geothlypis trichas*	23.3	79.9	Increaser	General Status - Sensitive
Evening Grosbeak	*Coccothraustes vespertinus*	18.6	79.5	Decreaser	COSEWIC - Special Concern
Eastern Kingbird	*Tyrannus tyrannus*	4.7	76.4	Increaser	General Status - Sensitive
Black-backed Woodpecker	*Picoides arcticus*	2.3	71.0	Decreaser	General Status - Sensitive
Cape May Warbler	*Setophaga tigrina*	20.9	69.8	Decreaser	General Status - Sensitive
Bay-breasted Warbler	*Setophaga castanea*	4.7	66.1	Decreaser	General Status - Sensitive
Western Tanager	*Piranga ludoviciana*	48.8	65.8	Decreaser	General Status - Sensitive
Black-throated Green Warbler	*Setophaga virens*	34.9	65.7	Decreaser	General Status - Sensitive
Canada Warbler	*Cardellina canadensis*	23.3	64.5	Decreaser	COSEWIC – Threatened | SARA - Schedule 1, Threatened | General Status - At Risk
Brown Creeper	*Certhia americana*	18.6	63.6	Decreaser	General Status - Sensitive
Alder Flycatcher	*Empidonax alnorum*	39.5	54.4	Increaser	General Status - Sensitive
Mammals					
Fisher	*Martes pennanti*	30.8	91.4	Decreaser	General Status - Sensitive
Canada Lynx	*Lynx canadensis*	46.2	90.2	Increaser	General Status - Sensitive
Lichen					
Mealy-Forked Lichen	*Cladonia scabriuscula*	9.5	96.7	Decreaser	Srank - S2S3
Gray's Pixie-cup	*Cladonia grayi*	45.2	95.8	Decreaser	Srank - S1S2
Lilliput Vinyl	*Leptogium tenuissimum*	4.8	91.7	Decreaser	Srank - S2S3
Alder Stickpin	*Stenocybe pullatula*	16.7	91.0	Decreaser	Srank - S2S4
Alder Needles	*Phaeocalicium compressulum*	11.9	87.5	Decreaser	Srank - S1
Wine Pixie-cup	*Cladonia merochlorophaea*	38.1	87.4	Decreaser	Srank - S2S3

Black-footed Reindeer Lichen	*Cladonia stygia*	7.1	86.8	Decreaser	Srank - S2S3
Bottlebrush Frost Lichen	*Physconia detersa*	7.1	78.8	Decreaser	Srank - S2S3
Gritty Whiskered Shadow	*Phaeophyscia kairamoi*	4.8	76.7	Decreaser	Srank - S2S3
Yellow-collar Stubble Lichen	*Calicium trabinellum*	9.5	75.7	Decreaser	Srank - S2
Cat Paw	*Nephroma bellum*	23.8	68.3	Decreaser	Srank - S2S3
Mosses					
Mueller's Pouchwort	*Calypogeia muelleriana*	5.0	96.6	Decreaser	Srank - S2S4
Tufted Moss	*Aneura pinguis*	2.5	95.8	Decreaser	Srank - S2S4
Willow Feather-moss	*Hygroamblystegium varium*	7.5	90.0	Decreaser	Srank - S2S3
Nees' Pouchwort	*Calypogeia neesiana*	2.5	88	Decreaser	Srank - S2S4
Saber Tooth Moss	*Plagiomnium ciliare*	2.5	79.7	Decreaser	Srank - S2S3
Glaucous-headed Earwort	*Scapania glaucocephala*	12.5	76.2	Decreaser	Srank - S2S4

[1]Threat categories for species at risk as identified by the Government of Canada and/or the Government of Alberta, including: listing by Canada's Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as Endangered, Threatened, or Special Concern; listed under Canada's Species at Risk Act (SARA) as Endangered, Threatened, or Special Concern; recognized by Alberta's Ministry of Environment and Parks (AEP) as Endangered, Threatened, or Special Concern; listed by AEP in General Status (2015) as At Risk, May be at Risk, Sensitive or Undetermined, and; species that included S1 or S2 as part of their ranking as determined by AEP and tracked as part of the Alberta Conservation Information Management System.

CONCLUSION

Sustainable development of energy resources requires a clear understanding of not only the environmental costs linked to the continued expansion of energy infrastructure, but the opportunities to preserve environmental values. The land cover and biodiversity indicators set out in this report establish the current conditions that will be used to help judge environmental outcomes in the future.

In this report we describe the current status of land cover and biodiversity in the Kakwa River Project area and surrounding Region. We found:

- As of 2018, the total human footprint in the Lease Area was 38.9%. Covering 34.7% of the Lease Area, forestry was the largest human footprint while energy footprint covered 2.1%. In the Lease Area, total human footprint increased by 18.3 percentage points between 2000 and 2019, an increase driven by the creation of forestry footprint.
- Linear footprint density (circa 2018) was estimated to be 3.04 km/km^2 in the Lease Area with conventional seismic lines representing 54.4% of lines in the Lease Area
- Overall, 61.1% of the Lease Area is composed of native habitat with a 0 m buffer from human footprint, with 10.5% of this native habitat being 500 m or further away from human footprint.
- The cumulative effects of land disturbance on 630 species in the Region resulted in an overall intactness score of 85.7%, as measured by the Biodiversity Intactness Index**.
- Predicted intactness of species ranged from 83.2% for birds up to 87.3% for mosses. However, intactness was lower for some individual species. Deviation from intactness was due to species predicted to be less abundant than expected as well as more abundant than expected compared to reference condition.
- Many species were predicted to have strong responses to energy footprint where this footprint occurs. But overall impacts on regional populations were much smaller because energy footprint occupies up a small portion of the Region.

Results from this report set the stage for openly addressing key questions such as:

1. What components of biodiversity are the most sensitive to energy development, and what might be done to minimize impacts?
2. What are the cumulative effects of resource development on biodiversity and how effective are efforts to manage regional cumulative effects?
3. What is the impact of energy development on biodiversity as compared to other land uses, such as agriculture and forestry?

With the Region at 85.7% intact today, there is significant opportunity for land and resource managers to make informed and deliberate choices to maintain or increase biodiversity intactness over time. As development continues to unfold in the region, the ABMI will continue to measure and report on the changing state of land cover and biodiversity.

** The ABMI's Biodiversity Intactness Index is used to report on the cumulative effects of human disturbance on biodiversity, including birds, mammals, soil mites, vascular plants, mosses, and lichen within Alberta. The index ranges from 100% intact to 0% intact. An area with little evidence of human impact is nearly 100% intact, whereas a parking lot surrounded by big box stores is nearly 0% intact. The Biodiversity Intactness Index is a measure of how much more or less common a species is relative to its abundance if there was no human footprint present; both positive and negative deviations result in lower intactness scores.

GENERAL TERMS

Limitations

The ABMI's monitoring program is designed primarily as a proactive tool used to identify the status, trends, and correlative relationships among common species, habitats, and human footprint. While the status and trends of some rare species and species-at-risk can be evaluated using the ABMI monitoring program, the monitoring program cannot directly evaluate all rare and endangered species.

The ABMI indices are based on the establishment of current, intact reference conditions that are statistical predictions designed to account for human footprint. These reference conditions and subsequent ABMI analyses and reporting do not account for historical changes in the overall abundance of a species (i.e., the ABMI cannot account for any change in a species that occurred before 2003). ABMI reference conditions have statistical uncertainty for individual species. This uncertainty will decrease as the ABMI surveys more sites in the Region.

Looking Forward

The ABMI has made considerable strides in supporting biodiversity management in Alberta; however, we are just beginning. The ABMI continues to build momentum and is committed to:

- Ensuring the effective delivery of relevant, timely, and scientific biodiversity information
- Improving biodiversity management by contributing knowledge to decision-making systems
- Supporting governments and industries in meeting their domestic and international reporting obligations
- Eliminating duplication and redundancy in provincial biodiversity monitoring
- Facilitating the transfer of information to government, industry, the research community, and the public

Scientific Integrity

The ABMI is committed to the responsible analysis and evaluation of data. The ABMI holds itself to the highest ethical standards, including operational transparency, honesty, conscientiousness, and integrity. The ABMI strongly encourages the responsible and ethical evaluation and interpretation of the knowledge contained in this report. For a complete discussion of the ethical behaviour endorsed by the ABMI, please see *Honor in Science*, published by Sigma Xi (1997), available at http://www.sigmaxi.org/programs/ethics/Honor-in-Science.pdf. A broader discussion about the use of ABMI data and information can be found in *Scope and Application of the ABMI's Data and Information* (00048), Version 2008-01-04, Alberta Biodiversity Monitoring Institute, Alberta, Canada. This report is also available at www.abmi.ca under "Reports/Core Reports."

Disclosure

Data used in the preparation of this report is available on the ABMI's website and include species and habitat data collected between 2003 and 2019, and remotely sensed data collected between 2000 and 2019. The scientific methods used in analyses of data for this report are described in the following documents:

1. Sólymos, P., E.T. Azeria, D.J. Huggard, M-C. Roy, and J. Schieck. 2019. Chapter 4. Predicting species status and relationships. *In* ABMI 10-year Science and Program Review.
2. Geospatial Centre – Alberta Biodiversity Monitoring Institute. 2020. ABMI Human Footprint Inventory: Wall-to-Wall Human Footprint Inventory. 2018. Edmonton, AB: Alberta Biodiversity Monitoring Institute and Alberta Human Footprint Monitoring Program, March 2020. Available at: https://ftp-public.abmi.ca/GISData/HumanFootprint/2018/HFI2018v1_Metadata.pdf.

Terms and Conditions of Report

Preparation

In 2021, Seven Generations (now ARC Resources) requested that the ABMI produce a custom biodiversity status report specific to the Kakwa River Project area and surrounding region. Seven Generations (now ARC Resources) funded the creation of this report. The following terms were applied as a condition of the ABMI preparing this report:

1. The ABMI reports on a standardized list of biodiversity indicators that are relevant to regional planning, policy, and management. Developed by the ABMI, these indicators were consistently applied.
2. The ABMI maintains full control over all language and messaging in this report.
3. This biodiversity status report encompasses the Region and cannot be localized to smaller landscapes within the Region unless already specified in this report.
4. This biodiversity status report uses data collected between 2003 and 2019.
5. The report is released publicly in a timely manner.

Image Credits

cover page: energy footprint photo, credit: ARC Resources/p.4: aerial photo of human footprint, credit: ARC Resources/p.10: grizzly bear, credit: Frank Vassen/p.24: western tanager, credit: Jerry Mcfarland/p.24: alder flycatcher, credit: Don Henise/p.26: black-throated green warbler, credit: Paul Reeves/p.28: american marten, credit: Nick Parayko/p.28: red fox, credit: Robin Young/p.30: moose, credit: Thomas Haeusler/p.32: *Oribatella jacoti*, credit: Dave Walter/p.32: *Oribatula sp.* 1 DEW, credit: Dave Walter/p.36: creeping thistle, credit: Jean Mottershead/p.38: red-mouthed leafy moss, credit: Brittney Miller/p.38: bonfire moss, credit: Adrian Castillo Rivera/p.40: angels hair, credit: Richard Droker/p.40: lesser green reindeer lichen, credit: Richard Droker/p.42: common yellowthroat, credit: Becky Matsubara/p.42: brown creeper, credit: Paul Reeves

Preferred Citation

Alberta Biodiversity Monitoring Institute. 2021. The Status of Land Cover and Biodiversity in the Kakwa River Project Area: Preliminary Assessment. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Report available at www.abmi.ca.

References

1. Geospatial Centre – Alberta Biodiversity Monitoring Institute. 2020. ABMI Human Footprint Inventory: Wall-to-Wall Human Footprint Inventory. 2018. Edmonton, AB: Alberta Biodiversity Monitoring Institute & Alberta Human Footprint Monitoring Program, March 2020. Available at: https://ftp-public.abmi.ca/GISData/HumanFootprint/2018/HFI2018v1_Metadata.pdf.
2. Sanderson et al. 2002. Bioscience 52(10):891-904.
3. Alberta Biodiversity Monitoring Institute. 2020. Status of human footprint in Available at: https://abmi.ca/home/reports/2020/human-footprint.
4. Huggard, D. and L. Kremsater. 2015. Recommendations for forest interior and old-forest indicators for the Biodiversity Management Framework. Unpublished report.
5. Sólymos et al. 2019. Chapter 4. Predicting species status and relationships. *In* ABMI 10-year Science and Program Review. Available at: https://abmi10years.ca/10-year-review/resources/.
6. ABMI. 2017. ABMI Essentials: Biodiversity Intactness. Alberta Biodiversity Monitoring Institute, Alberta, Canada. Available at: https://abmi.ca/home/publications/451-500/496.
7. Sólymos, P. and J. Schieck. 2016. Effects of industrial sectors on species abundance in Alberta. ABMI Science Letters, Issue 5, October, 2016. Available at: https://abmi.ca/home/newsletters/scienceletter-past-issues.html.
8. Leu M. et al. 2008. Ecological Applications 18(5):1119-1139.
9. Bayne, E., H. Lankau, and J. Tigner. 2011. Ecologically-based criteria to assess the impact and recovery of seismic lines: the importance of width, regeneration, and seismic density. Report No. 192. Edmonton, AB. 98 p.
10. Alberta Biodiversity Monitoring Institute and Boreal Avian Modelling Project. 2020. Black-throated Green Warbler (*Setophaga virens*). Available at: https://abmi.ca/home/data-analytics/biobrowser-home/species-profile?tsn=99001402.
11. Norton, M.R. 1999. Status of the Black-throated Green Warbler (*Dendroica virens*) in Alberta. Alberta Environment, Fisheries, and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 23, Edmonton, AB. 24 pp.
12. DeMars C.A. and S. Boutin. 2018. Journal of Animal Ecology 87(1):274-284.
13. Alberta Biodiversity Monitoring Institute. 2020. Moose (*Alces alces*). Available at: https://abmi.ca/home/data-analytics/biobrowser-home/species-profile?tsn=180703.
14. Behan-Pelletier, V.M. 1999. Agriculture, Ecosystems and Environment 74(1999):411-423.
15. McAdams, B.N., et al. 2018. Forest Ecology and Management 422(2018):281-293.
16. Sanderson, L.A. et al. 2012. Forestry 85: 329-339.
17. Turestsky, M.R. et al. 2012. New Phytologist 196: 49-67.
18. Mark, K., et al. 2020. New Phytologist 227: 1362-1375. doi.org/10.1111/nph.16475.
19. Asplund, J. and D.A. Wardle. 2017. Biological Reviews 92. doi.org/10.1111/brv.12305.
20. Thomas, D.C. et al. 1996. Rangifer 16: 37-342. doi.org/10.7557/2.16.4.1275.

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