Caribou in Northern British Columbia

An Assessment of Range Condition and Population Status

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Cover Photos:
Front cover: Northern Mountain Caribou in the Horseranch caribou range. (© Garth Lenz) Back cover: Carcross caribou foraging in high elevation alpine summer habitat in northern BC in June. (Donald Reid)

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WCS CANADA CONSERVATION REPORT #16
JUNE 2022

CARIBOU IN NORTHERN BRITISH COLUMBIA:

AN ASSESSMENT OF RANGE CONDITION AND POPULATION STATUS

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BRITISH COLUMBIA

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We would like to thank the following individuals from the BC MFLNRORD for providing information and sharing their knowledge on caribou and their ranges in northern British Columbia: Kevin Hoekstra, Bill Jex, Mike Klaczek, Agnès Pelletier, Justin Strong, Conrad Thiessen, Megan Watters, and Mark Williams (retired). We also thank Blair Ells with the BC MFLNRORD for sharing the spatial dataset of anthropogenic habitat disturbance in northwestern British Columbia, Kelsey Russell with Yukon Government for providing information on transboundary caribou populations, and Norm MacLean for sharing an overview of recent information collected by the Tahltan Wildlife Department on the Tsenaglode caribou population. Don Reid (Wildlife Conservation Society Canada) and Agnès Pelletier reviewed an earlier draft of the report. Special thanks to Viktor Brumovsky, Wildlife Infometrics Inc., who conducted the GIS component of this project and to Conrad Thiessen for securing funding from BC MFLNRORD.

A Note About the Report

This report focusing on caribou and their ranges in northern British Columbia is a summary of available technical information only. A much broader understanding of caribou in northern British Columbia would be gained by the addition of Indigenous Knowledge, especially for long-term changes in population trend and distribution, for which only limited technical information is available.

This report benefitted from information provided to us by BC government biologists. We acknowledge that not all government biologists were able to provide a thorough review, and that interpretations of information presented in this report are our own.

Summary

Caribou in Northern British Columbia: An Assessment of Range Condition and Population Status.

Most populations of caribou (*Rangifer tarandus*) in southern British Columbia (BC) have undergone dramatic declines, especially in the last 10-20 years, with seven herds already extirpated and another ten having fewer than 50 individuals. By comparison, information available on caribou numbers in northern BC suggests that populations are typically larger than in the south, but recent population estimates are not available for many herds, and quantitative information on their range condition is lacking.

A bull caribou in high elevation alpine habitat in the Horseranch caribou range. (© Garth Lenz)

We know from abundant scientific information that caribou have a low tolerance for habitat disturbance, particularly from the combined impacts of anthropogenic (human-caused) habitat disturbance (e.g., from resource extraction activities and associated infrastructure) and fire, which results in changes to predator/prey dynamics. While not believed to be in as precarious a situation as their southern counterparts, there are still considerable concerns about the condition of northern caribou populations and their ranges, particularly due to: continued pressures from resource extraction activities, including mining, oil and gas exploration and development, and forest harvesting; roads associated with resource extraction, which can have wide impacts over large areas; and, limited information available about caribou population sizes and trends.

In this report we assess the level of anthropogenic habitat disturbance and fire combined as an indicator of the condition of individual herds and their ranges. We also discuss potential future habitat trends, and review and summarize available information on population sizes and trends. This report is a summary of available technical information only. A much

broader understanding of caribou in northern BC would be gained by the addition of Indigenous Knowledge.

Caribou in the Northern Mountain National Ecological Area (NMNEA) are currently listed as Special Concern under the federal *Species at Risk Act*. Although the Special Concern status does not invoke the general prohibitions under the Act as the current Threatened status of the caribou in the southern part of the province in the Southern Mountain National Ecological Area (SMNEA) does, the Special Concern listing indicates that they "may become a threatened or an endangered species because of a combination of biological characteristics and identified threats".

We focused on a study area that covers 17 caribou ranges in the mountainous portion of northern BC that stretches from approximately 57° latitude to the Yukon border and that lies west of Fort Nelson. Six of those ranges extend north into Yukon. Although information on exact range boundaries was lacking for some ranges, boundaries were still sufficient to provide a coarse filter view of the level of habitat disturbance on those ranges.

We then adapted a methodology developed by Environment and Climate Change Canada (ECCC) that estimates the level of habitat disturbance on caribou ranges, to the information that was available in our study area. Those methods and data sources are described in full on page 6.

The national recovery strategy for Southern Mountain Caribou identified critical habitat as habitat with minimal disturbance in high elevation winter and summer caribou range as well as in low elevation summer range, and a maximum of 35% habitat disturbance in low elevation winter range and matrix. Matrix range consists of areas within and adjacent to the annual range that caribou may or may not use, but where habitat disturbance will affect caribou through far-reaching effects on predator/prey dynamics.

Because complete information on caribou range use was lacking for northern ranges, we categorised the thresholds as follows: 1) for low elevation areas where large-scale natural disturbances such as fire play a significant role in driving overall habitat disturbance, we adopted the 35% maximum disturbance threshold and 2) for high elevation areas where fire plays a minor role we adopted the minimal (close to 0%) threshold. Matrix range was then assigned to either group based on elevation.

Although these levels of disturbance are not an absolute threshold (i.e., caribou may struggle at lower levels of disturbance or may tolerate higher levels), they are a good guide to the point at which disturbance should trigger concerns for individual caribou ranges.

For each caribou range, we summarized the extent of: each individual type of habitat disturbance; all anthropogenic habitat disturbance combined; and, total habitat disturbance (all types of anthropogenic habitat disturbance combined, plus fire).

Total habitat disturbance (low plus high elevation ranges) makes up about 15% of the combined area of all 17 ranges, with nine ranges above 10%. The three ranges with the highest level of disturbance (Pink Mountain, Muskwa, Liard Plateau) are the three easternmost caribou ranges in the study area, with the majority of habitat disturbance within them in their eastern halves.

Total habitat disturbance in low elevation range equals or exceeds the 35% threshold in five adjacent ranges, including the three easternmost ranges (Liard Plateau, Muskwa, Pink Mountain) and the two southernmost ranges (Finlay, Thutade). Total habitat disturbance in low elevation range is between 20% and 35% on three ranges: Horseranch, Little Rancheria, and Tsenaglode. (We discuss the sources of disturbance, which varies between ranges, on page 7.)

Total habitat disturbance in high elevation range exceeds the minimal (i.e. close to 0%) threshold in all 17 caribou ranges. However, in seven ranges it is less than 5% and in three it is less than 3%. The highest levels of total habitat disturbance in high elevation range are in the Muskwa, Pink Mountain and Tsenaglode ranges.

Total habitat disturbance is higher in the 20 km and 30 km matrices surrounding all 17 caribou ranges combined, than in the caribou ranges themselves. The surrounding 20 km and 30 km matrices include more low elevation range (where habitat disturbance is more prevalent) than in the caribou ranges themselves.

Caribou in low elevation habitat in the Muskwa caribou range in April. (Donald Reid)

Future trends in levels of habitat disturbance (particularly anthropogenic) for these ranges are difficult to predict. Mineral and coal claims and leases, environmental assessment applications, and timber supply reviews indicate that interest exists in resource extraction activities in the region. Where and to what extent this development will happen is more difficult to predict.

With climate change, wildfires and forest insect outbreaks are also expected to increase. Overall, climate change is expected to result in longer fire seasons and increased fire intensity for this region.

For each caribou range, we also summarized population size and trend information from available technical reports, using information from the 2014 COSEWIC status report as a baseline and updating population size and trend information where more recent information was available. (See Appendix 3 for summaries of population information for individual caribou ranges.) We were only able to determine long-term population trends for four of the 17 populations. Two were increasing (Atlin and Carcross), and two were decreasing (Liard Plateau and Pink Mountain).

Of the two populations that are experiencing known long-term declines in numbers, Pink Mountain had the highest level of anthropogenic habitat disturbance and Liard Plateau had the highest level of fire disturbance across the total range. Those two populations were also two of the three with the highest levels of total habitat disturbance over the whole range, and among the five with the highest levels of total habitat disturbance in the low elevation portions of their ranges. This is consistent with studies that have linked federally-listed Boreal Caribou population condition to habitat disturbance, and with greater impacts on ranges where habitat disturbance was primarily due to anthropogenic habitat disturbance.

Our study points to the need for proactive action for caribou ranges in northern BC, to avoid the precarious situation that caribou in the southern part of the province are in. This will require a coordinated approach across all ranges in northern BC, making caribou conservation a priority and restricting anthropogenic disturbance from core areas. We know from experience in southern BC and other areas that recovering caribou populations once they are declining is very difficult and expensive, requires the application of multiple coordinated recovery actions, and has so far resulted in limited success. Recovery to self-sustaining population status as a result of recovery efforts in caribou ranges in southern BC has yet to be achieved. Further, habitat recovery, even with restoration, can take decades. In northern BC, we still have the ability to take simpler and much more effective steps to conserve caribou if we act now.

We provide the following recommendations to help shift the existing regulatory and policy regimes to ones that provide stronger limits on the amount and spatial extent of landscape disturbances generally and thereby lessen the risk of Northern Mountain Caribou becoming threatened or endangered. All eight recommendations will need to be implemented in keeping with the *BC Declaration on the Rights of Indigenous Peoples Act* (2020) and the Declaration on the Rights of Indigenous Peoples Act Action Plan.

1. Make caribou conservation a priority in northern BC.

2. To better ensure persistence of Northern Mountain Caribou in northern BC, manage all 17 populations and ranges together as a unit.

3. Develop and implement a better system for tracking and sharing data of anthropogenic habitat disturbance (and habitat recovery) for all natural resource extraction sectors to support cumulative effects analysis and management.

4. Protect caribou habitat to provide deliberate and sustained protection of key seasonal ranges and connectivity between populations.

5. Improve our understanding of seasonal range and habitat use, and seasonal range and habitat requirements for Northern Mountain Caribou in northern BC.

6. Develop and implement priorities for habitat restoration across all 17 ranges.

7. Improve monitoring of caribou population status.

8. Revise caribou range boundaries with best available information.

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Abbreviations

BC CDC: BC Conservation Data Centre
BC MFLNRORD: BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development
COSEWIC: Committee on the Status of Endangered Wildlife in Canada
DU: Designatable Units (from COSEWIC)
EC: Environment Canada (presently ECCC)
ECCC: Environment and Climate Change Canada (previously EC)
IWMS: Integrated Wildlife Management Strategy
NEA: National Ecological Area
NMNEA: Northern Mountain National Ecological Area
NMP: Northern Mountain Population (as defined by the NMNEA in EC 2012a)
SARA: *Species at Risk Act* (Canada)
SMNEA: Southern Mountain National Ecological Area

Biogeoclimatic zones:
BAFA: Boreal Altai Fescue Alpine
BWBS: Boreal White and Black Spruce
ESSF: Engelmann Spruce-Subalpine Fir
SBS: Sub-Boreal Spruce
SWB: Spruce-Willow-Birch

Introduction

Most attention on caribou (*Rangifer tarandus*) in British Columbia (BC) has been focused in the southern part of the province, where many populations have undergone dramatic declines, especially in the last 10-20 years, with seven of 31 populations in southern BC currently considered extirpated, and another ten populations having fewer than 50 individuals (BC Caribou Recovery Program 2021). Considerably less is known about the condition of caribou populations and ranges in the mountainous region of northern BC (EC 2012a, COSEWIC 2014, BC Caribou Recovery Program 2021). Northern BC represents one of the last remaining landscapes in the province where the cumulative pressures from natural resource development remain relatively low. Yet continued interests in mineral development, oil and gas, and forestry, together with proposals for protection by Indigenous communities, demand better understanding of the status of sensitive and culturally-important wildlife like caribou, which can serve as barometers of change.

Landscape in the west-central portion of the Rabbit caribou range. (© Garth Lenz)

Together with a number of populations in Yukon and the Northwest Territories (NWT), caribou in northern BC are known as Northern Mountain Caribou – one of 11 caribou "designatable units"[1] recognized federally (COSEWIC 2014); in BC, they belong to the "northern" ecotype of caribou (IWMS 2004). These caribou live in areas where the snow is shallow enough during winter that they can dig through the snow, either in low elevation forests or on windswept alpine slopes, to feed on lichens and other forage growing on the ground (IWMS 2004). They may also eat lichens that grow on trees, both in low elevation forests and in higher elevation subalpine forests. During summer, these caribou prefer to use high elevation alpine and subalpine habitats, but also use low elevation habitat, especially when travelling between winter and summer ranges.

[1] Designatable Units are recognized by COSEWIC as discrete and evolutionarily significant units of a taxonomic species.

Caribou in northern BC in the Northern Mountain National Ecological Area (NMNEA) are currently listed as Special Concern in Schedule 1 of the *Species at Risk Act*, while caribou in southern BC in the Southern Mountain National Ecological Area (SMNEA) are currently listed as Threatened (Table 1). In 2014, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) grouped mountain-dwelling caribou in western Canada into three Designatable Units (DUs): Northern Mountain (DU7), Central Mountain (DU8), and Southern Mountain (DU9) (COSEWIC 2014). The population numbers and trends for the Central Mountain and Southern Mountain DUs met the criteria for Endangered status, while Northern Mountain DU caribou were assessed as Special Concern (COSEWIC 2014, Ray et al. 2015). As of this writing, the Minister of Environment and Climate Change Canada (ECCC) had not yet implemented COSEWIC's recommendations. The 2014 assessments were recently referred back to COSEWIC for further information or consideration due to uncertainties relating to DU delineation (including lack of inclusion of Indigenous Knowledge in delineating DUs), insufficient genetic information, and recent changes in population sizes of some herds (Government of Canada 2022). Therefore, current listings and designatable units for mountain-dwelling caribou on the *Species at Risk Act* (SARA) public registry do not reflect the latest COSEWIC assessments (Table 1). Regardless of when Schedule 1 of the *Species at Risk Act* is updated with COSEWIC's 2014 status recommendations, the current status of mountain-dwelling caribou in the northern part of BC will remain Special Concern, which indicates that they "may become a threatened or an endangered species because of a combination of biological characteristics and identified threats". As such, they are not subject to general prohibitions under the Act, nor is there any obligation to identify or protect critical habitat.

While there is ample evidence for predation as the main direct cause of boreal and mountain caribou population declines in Canada and of extirpation of many caribou populations (Seip 1992, Wittmer et al. 2005, Serrouya et al. 2011), habitat disturbance and loss from a combination of industrial activities and fire, which result in changes to predator/prey dynamics and to energy budgets, is considered the ultimate cause (Festa-Bianchet et al. 2011, Nagy-Reis et al. 2021). Increased habitat loss on caribou ranges has been linked to: reduced spatial separation between caribou and other prey or predators (Peters 2010);

Table 1. Current and recommended designations for caribou in British Columbia.

<table>
<tr><th>Area</th><th>Ecotype (IWMS 2004)[1]</th><th>Nationally Significant Population (COSEWIC 2002)/ Current SARA Designation[1]</th><th>Designatable Unit (COSEWIC 2014)/ 2014 COSEWIC Recommended Designation[1]</th><th>BC CDC population and Status (2017)[1]</th></tr>
<tr><td>Northeastern BC</td><td>Boreal</td><td>Boreal (Threatened)</td><td>Boreal (Threatened)</td><td>Boreal (Red)</td></tr>
<tr><td>Northern BC</td><td rowspan="4">Northern</td><td>Northern Mountain (Special Concern)</td><td rowspan="3">Northern Mountain (Special Concern)</td><td rowspan="3">Northern Mountain (Blue)</td></tr>
<tr><td>North central BC</td><td rowspan="3">Southern Mountain (Threatened)</td></tr>
<tr><td>West central BC</td></tr>
<tr><td>East central BC</td><td>Central Mountain (Endangered)</td><td>Central Mountain (Red)</td></tr>
<tr><td>Southeastern BC</td><td>Mountain</td><td>Southern Mountain (Endangered)</td><td>Southern Mountain (Red)</td></tr>
</table>

[1] CDC = Conservation Data Centre; COSEWIC = Committee on the Status of Endangered Wildlife in Canada; IWMS = Integrated Wildlife Management Strategy; SARA = *Species at Risk Act* (Canada)

reduced occupancy by caribou (Smith et al. 2000, Apps and McLellan 2006, Wittmer et al. 2007); reduced calf recruitment (McCarthy et al. 2011); displacement of caribou (Chubbs et al. 1993, Schaefer and Mahoney 2007, Weir et al. 2007); reduced adult caribou survival (Smith 2004, Wittmer et al. 2007); caribou population declines (Wittmer et al. 2007); and effects on caribou health (Ewacha et al. 2017, Bondo et al. 2018). Industrial activities can also affect caribou directly through impacts on forage lichens (Kranrod 1996, Sulyma 2001, Miège et al. 2001, Stevenson and Coxson 2007). For Boreal Caribou ranges, the degree of habitat disturbance (i.e., physical change to vegetation/land) on a range caused by human activities negatively affects the viability of caribou populations (EC 2011, Johnson et al. 2020).

Current survey information available on the status of caribou populations and their ranges in northern BC is limited, given the remoteness of the region and the relative infrequency of aerial surveys (EC 2012a, COSEWIC 2014). Although current population sizes are typically larger than those in southern BC, recent estimates (<5 years old) are available for only 3 out of 17 populations of Northern Mountain Caribou in northern BC (BC Caribou Recovery Program 2021). For the other 14 populations, estimates are more than 5 years old or not available (surveys were conducted for purposes other than estimating population size). Habitat disturbance due to industrial activities and corresponding risk levels are assumed to be lower for caribou ranges in northern BC than in the south. This report provides a compilation of the recent available information on levels of habitat disturbance and population status for 17 Northern Mountain Caribou ranges in northern BC, covering an area of approximately 16 million hectares.

Little Rancheria caribou in low elevation winter range. (Hilary Cooke)

The management plan for the Northern Mountain Caribou population (in the NMNEA) recommends mapping and evaluating current habitat availability in relation to habitat disturbance (human footprint, fire, forest disease outbreaks, access and development), hunting activity, and habitat connectivity, and also recommends conserving key habitats (EC 2012a). Because Special Concern species are not legally required to have critical habitat identified under SARA, the management plan does not provide specific direction related to habitat protection. By contrast, the federal recovery strategy for the threatened Southern Mountain Caribou "population" in southern BC does identify critical habitat for all herds, including nine herds that are members of the revised Northern Mountain Caribou designatable unit (EC 2014). For those "Northern Group" herds, effective protection of critical habitat includes a requirement to maintain a minimum of 65% undisturbed area within low elevation winter range and matrix (see Range categories and thresholds in Methods).

Our objectives with this technical report are:

1. to assess the levels of both fire and anthropogenic (human-caused) habitat disturbance on caribou ranges in northern BC using available GIS datasets;

2. to identify information gaps, data issues and potential future habitat trends; and,

3. to provide updated population information for caribou herds in northern BC where new survey data are available since the COSEWIC (2014) status assessment.

This report is a summary of available technical information only. A much broader understanding of caribou in northern BC would be gained by the addition of Indigenous Knowledge.

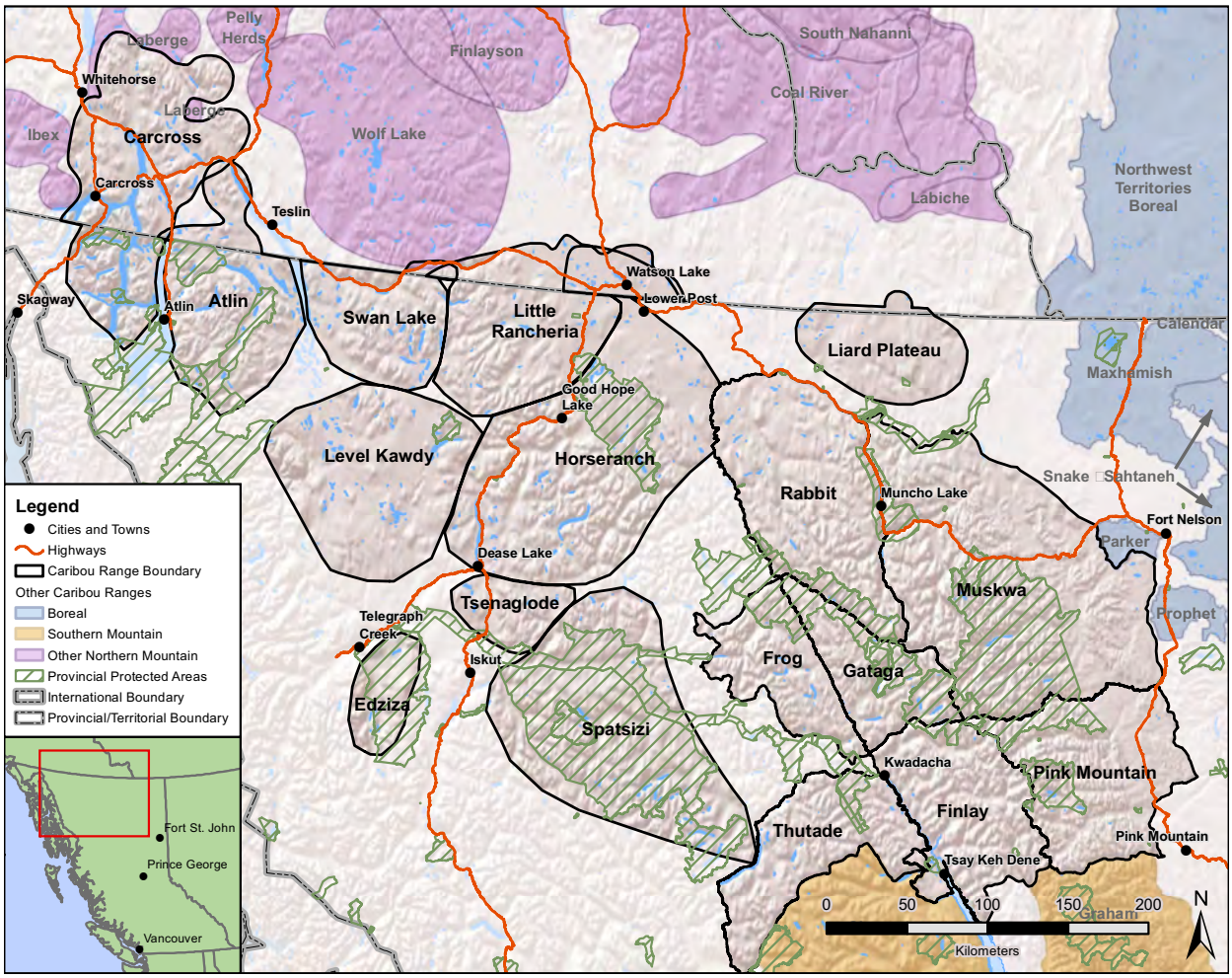
Study Area

The study area includes 17 caribou ranges in the mountainous portion of northern BC north of approximately 57° latitude to the Yukon border and west of Fort Nelson, six of which overlap with Yukon (Figure 1):

- Carcross,
- Atlin,
- Swan Lake,
- Little Rancheria,
- Horseranch,
- Level Kawdy,
- Edziza,
- Tsenaglode,
- Spatsizi,
- Liard Plateau,
- Rabbit,
- Muskwa,
- Frog,
- Gataga,
- Pink Mountain,
- Finlay, and,
- Thutade.

Low elevation areas throughout the study area lie within the Boreal White and Black Spruce (BWBS) biogeoclimatic zone, other than in the southernmost portions of the Finlay, Atlin and Carcross ranges where low elevations are made up of the Sub-Boreal Spruce (SBS) zone (Meidinger and Pojar 1991). The Spruce-Willow-Birch (SWB) zone lies above the BWBS in most of the study area except in portions of the Finlay, Thutade, Frog, Gataga, Spatsizi, Mt Edziza, and Carcross ranges, where higher elevation forested areas consist of the Engelmann Spruce-Subalpine Fir (ESSF) zone. The Boreal Altai Fescue Alpine (BAFA) zone covers the highest elevation areas throughout the study area.

Figure 1. Location of caribou ranges that are wholly or partially in northern British Columbia. The northwestern boundary of the Muskwa range and the northeastern boundary of the Rabbit range are partially overlain by the Alaska Highway.



Methods

Caribou population and range use characteristics

We conducted interviews with regional Fish and Wildlife biologists and/or caribou specialists with the BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development (BC MFLNRORD) and the Yukon Ministry of Environment to: assemble technical information collected on population size or trend for caribou in northern BC (including populations/ranges shared with Yukon) since the COSEWIC status report (2014); identify potential short-term (0-10 years) and long-term (10-50 years) industrial developments on and adjacent to caribou ranges to estimate potential future risks; and, identify seasonal ranges where possible. We also reviewed available reports and published literature to summarize existing technical information on caribou seasonal range use, population size and population trend. Our interpretations of this information are our own, and have not been reviewed in depth by government biologists.

Caribou range boundaries

We talked to BC MFLNRORD regional biologists to assess whether any caribou range boundaries required adjusting prior to the analysis. Although regional biologists felt that new information merited some adjustments, they were unable to provide us with revised boundaries at this time, other than the addition of the Thutade range that covered a portion of the area between currently delineated ranges that had previously been considered to contain few caribou (see Sittler et al. 2015). Consequently, we used currently available BC caribou range boundaries, which were finalized in 2008, and the Thutade range boundary provided by BC MFLNRORD. For the Yukon portion of the ranges, we used range boundaries defined by Yukon (Hegel and Russell 2013).

Calculating habitat disturbance within caribou ranges to estimate range condition

Habitat disturbance categories and datasets

To assess range condition as a function of levels of habitat disturbance on caribou ranges in northern BC, we used the following procedure, which is based on methods used by ECCC for Boreal Caribou (EC 2011), and for the identification of critical habitat for Boreal Caribou (EC 2012b) and Southern Mountain Caribou (EC 2014):

1. We categorized habitat disturbance (using provincially-available data layers) into categories that were consistent with those used by ECCC (Table 2, EC 2011, EC 2014).

2. For anthropogenic habitat disturbance, we applied a 500 m buffer around both area-based disturbances (e.g., clearcuts, mines) and linear disturbances (e.g., roads, seismic lines) (EC 2011, 2014). The 500 m buffer was not applied to reservoirs (e.g., Williston Lake).

3. For all types of anthropogenic habitat disturbance, we dissolved the buffer around each individual type of habitat disturbance with adjoining overlapping buffers of the same type of disturbance to eliminate "double-counting" of areas within overlapping buffers (see Appendix 1). Similarly, for all anthropogenic habitat disturbance combined, we dissolved the footprints of all types of anthropogenic habitat disturbance and buffers to eliminate double-counting overlapping disturbances and their buffers.

4. To calculate total habitat disturbance, we merged the total combined anthropogenic habitat disturbance layer with the total area of fires that were less than 40 years old. Any area that was subjected to both disturbance types was dissolved to prevent "double-counting" the area in the calculation of the total area affected by habitat disturbance. Consistent with ECCC methods, areas affected by forest insects were not included in the calculation of total habitat disturbance.

Other than forest harvesting, most anthropogenic habitat disturbance is considered permanent or semi-permanent, where vegetation has been permanently removed and is not undergoing "natural" vegetation succession or has not been actively restored (Table 2). Forest harvesting and "natural" disturbances are considered temporary habitat disturbances, where vegetation eventually recovers naturally or is actively restored following the initial disturbance.

Table 2. Categories of habitat disturbance used for assessing levels of habitat disturbance on caribou ranges that are wholly or partially in northern British Columbia.

Habitat disturbance category	Habitat disturbance type	
	Permanent/ semi-permanent[1]	Temporary[2]
Anthropogenic habitat disturbance		
Settlement	X	
Agriculture	X	
Recreation	X	
Airstrip	X	
Reservoir	X	
Dam	X	
Powerline	X	
Road/trail	X	
Railroad	X	
Mine	X	
Oil/gas facility	X	
Pipeline	X	
Oil/gas well		X
Seismic line		X
Forest harvesting		X
Natural disturbance		
Fire		X
Mountain pine beetle		X
Spruce bark beetle		X
Balsam bark beetle		X

[1] The disturbed area is maintained as a permanent or long-lasting feature on the landscape where vegetation has been permanently removed and is not undergoing "natural" vegetation succession or has not been actively restored.

[2] The disturbed area is not maintained as a permanent or long-lasting feature; therefore, vegetation can re-establish following the initial disturbance either naturally or through restoration activities. Although we classified wells sites and seismic lines as temporary habitat disturbances, some of those disturbed sites are likely to require active restoration.

We assessed habitat disturbance levels by type within caribou ranges in northern BC using spatial data layers that were publicly available through the BC data warehouse and the BC Oil and Gas Commission's data portal. An additional spatial dataset that was collected for a cumulative effects project in northwestern BC that included mine footprints and mining roads, was provided by BC MFLNRORD. For the six ranges that overlapped Yukon (Carcross, Atlin, Swan Lake, Little Rancheria, Horseranch, Liard Plateau), we accessed spatial habitat disturbance data for the Yukon portion of those ranges through the Geomatics Yukon FTP site. A detailed listing of data sources is included in Appendix 2. Apart from forest harvest, dates of most anthropogenic disturbances are not available.

For determining the occurrence of anthropogenic habitat disturbance, our methods differed from those of ECCC (EC 2011, 2012b, 2014) in that ECCC mapped anthropogenic habitat disturbances that could be detected using 1:50,000 scale Landsat satellite imagery (from 2008 to 2010) and using other sources of data to aid in categorizing the type of disturbance (EC 2011). On the other hand, our methods for assessing natural disturbances were similar to those of ECCC (2011) in using provincial spatial data layers to map fires. ECCC

(2011) limited the age of fires to less than 40 years because fire data were only available for a maximum of 40 years in some provinces. We also used fires up to 40 years of age in the calculation of total habitat disturbance (consistent with EC (2011)), but there was sufficient information to assess fires up to 50 years of age, so our summary tables included both fires less than 40 years (used by EC 2011) and fires less than 50 years.

Although we used spatial data layers to quantify and delineate anthropogenic habitat disturbance while ECCC (EC 2011, 2012b, ECCC 2014) identified anthropogenic habitat disturbance from 1:50,000 scale satellite photos, we expect that the distribution and relative levels of anthropogenic habitat disturbance on the landscape would be very similar using both methods.

We accessed spatial datasets in 2017. As a result, the 40-year fire dataset includes fires from 1978 to 2017, and the 50-year fire dataset includes fires from 1968 to 2017.

In addition, we calculated the area affected by mountain pine beetles (*Dendrotonus ponderosae*) and spruce beetles (*Dendroctonus rufipennis*) from 2000 to 2017 from spatial layers that were publicly available from the BC data warehouse. Area of forest insect attack is not included as part of the overall habitat disturbance calculation by ECCC (2014) and therefore we also do not include it in our calculation of habitat disturbance. However, we report it in our summary of levels of individual types of habitat disturbances because extensive mountain pine beetle attack is present in low elevation areas in the southeastern portion of the study area.

Range categories and thresholds

To assess the significance of the level of habitat disturbance on caribou ranges in northern BC, we used the habitat disturbance thresholds identified for critical habitat that applied to the "Northern Group" of caribou in the federal recovery strategy for Southern Mountain Caribou (EC 2014) as a surrogate and adapted them to fit data that were available in our study. Of the four critical habitat attributes required by caribou to carry out life processes, three included habitat disturbance thresholds and one included a predator density threshold (Table 3). Matrix range consists of areas either within (Type 1) or surrounding (Type 2) caribou ranges where predator/prey dynamics influence predation on caribou within their annual range (EC 2014). Although caribou may not use these areas regularly, or use them less often than they use other parts of their range (such as during travel between seasonal ranges), habitat disturbance in matrix range will affect caribou through effects on predator/

Table 3. Habitat disturbance thresholds associated with critical habitat attributes for Southern Mountain Caribou that are applicable to "Northern Group" caribou (from EC 2014).

Critical habitat attribute	Habitat disturbance threshold[1]
High elevation winter and/or summer range	Minimal (i.e. close to 0%)
Low elevation summer range	Minimal (i.e. close to 0%)
Low elevation winter range + Type 1 matrix range	35%
Type 2 matrix range[3]	NA[4]

[1] Total habitat disturbance = anthropogenic habitat disturbance (including a 500 m buffer) + fire (no buffer)
[2] Type 1 matrix range = matrix range within the annual range (from EC 2014)
[3] Type 2 matrix range = matrix range surrounding annual range (from EC 2014)
[4] Threshold is a wolf density of < 3 wolves/1000 km (from EC 2014)

prey dynamics. Overall, critical habitat in the recovery strategy has been defined as minimal to no habitat disturbance in high elevation winter and/or summer range and in low elevation summer range, and a maximum of 35% habitat disturbance in low elevation winter range and matrix (Table 3).

Top: Example of Horseranch and Little Rancheria caribou low elevation winter range with extensive mature coniferous forests. Bottom: During winter, caribou use open mature coniferous stands with an abundant ground cover of lichens (light colour). (Donald Reid)

The 35% habitat disturbance threshold for low elevation winter range + Type 1 matrix range is based on a meta-analysis that was conducted for Boreal Caribou ranges in Canada (EC 2011, EC 2014). Although a similar analysis for Southern Mountain Caribou is not available, the 35% habitat disturbance threshold was chosen as a reference level because low elevation winter ranges and matrix range in "Northern Group" caribou ranges are ecologically similar to Boreal Caribou ranges (EC 2014). That is, fire plays a significant role in natural disturbance dynamics in low elevation winter ranges and adjacent matrix range for "Northern Group" caribou, which is similar to the role of fire in natural disturbance dynamics in Boreal Caribou ranges (EC 2014).

It is, however, important to stress that the threshold applied originally to identify critical habitat in the Boreal Caribou recovery strategy (EC 2012b) and then used to characterize Southern Mountain Caribou critical habitat (EC 2014) is a "management threshold" informed by science, i.e., an empirical relationship between landscape disturbance and population health, as indicated by recruitment (EC 2011). Because the "disturbance-recruitment relationship" is in reality characterized by a continuum of risk, and not an inflection point (Johnson and Ray 2021), the management threshold associated with critical habitat identification reflects a social decision accepting a 60% probability of persistence. In this report, we use habitat disturbance levels within caribou ranges relative to these thresholds to relate recent habitat conditions to the likelihood of population persistence derived from the critical habitat model (EC 2011).

To apply ECCC's (EC 2014) habitat disturbance thresholds as a management indicator, we required information on individual critical habitat attributes for each range in northern BC. However, there was insufficient information for most caribou ranges in BC for MFLNRORD regional biologists to provide us with seasonal or matrix ranges. Therefore, we simplified the categories into "high elevation range" and "low elevation range" and applied habitat disturbance thresholds from ECCC (2014) that reflected natural disturbance dynamics (Table 4). That is, we used the 35% threshold for low elevation range where large

Table 4. Range categories and habitat disturbance thresholds used for analysis of habitat disturbance on caribou ranges that are wholly or partially in northern British Columbia, adapted from EC (2014).

Range category	Maximum habitat disturbance[1]
High elevation range[2]	Minimal (i.e. close to 0%)
Low elevation range[3]	35%

[1] Habitat disturbance = anthropogenic habitat disturbance (including a 500 m buffer) + fire (no buffer)
[2] Includes high elevation Type 1 matrix range
[3] Includes low elevation Type 1 matrix range

scale natural disturbances such as fire play a significant role in driving overall habitat disturbance, and used the minimal (i.e. close to 0%) threshold for high elevation ranges where fire plays a minor role. Low elevation Type 1 matrix range is included in the "Low elevation range" category and High elevation Type 1 matrix range is included in the "High elevation range" category.

High elevation alpine habitat in the Horseranch caribou range. (© Garth Lenz)

In the absence of previously delineated high and low elevation ranges, we used the BAFA, ESSF and SWB biogeoclimatic zones to represent high elevation range, and the remaining area (BWBS and SBS zones) to represent low elevation range. We considered these reasonable ecological approximations that could be applied consistently across all ranges. High elevation ranges include areas above about 800-1200 m (depending on location within the study area), based on the lower boundary of the high elevation biogeoclimatic zones (Banner et al. 1993, DeLong 2004). For the Yukon portions of the six transboundary ranges, we estimated the extent of high elevation range using Yukon Territory's Bioclimate Zones data set. We considered any area covered by the Boreal Alpine Tundra, Boreal High, or Boreal Subalpine zones to be high elevation range with the remainder (i.e. Boreal

Low) classed as low elevation range. Initially, for the Yukon portion of the caribou ranges, we attempted to approximate high elevation range by determining the average elevation of the boundary between the BWBS and SWB zones at the BC/Yukon boundary, but this approach did not capture the biogeoclimatic variability of the landscape as well as the bioclimate zone data did. Additionally, a small portion of the 30 km matrix (see below) extends into the state of Alaska (~40 850 ha). In that case, we approximated the high and low elevation zones using manual digitization based on Bing Maps imagery using the adjacent BC biogeoclimatic mapping as a guide. This was only feasible due to the small size of the area that needed to be mapped.

In addition to assessing habitat disturbance levels within currently-delineated caribou range boundaries in northern BC, we conducted similar assessments in areas surrounding each range within 20 km and within 30 km of each range boundary. The two distances provide options for assessing the level and types of habitat disturbance in matrix range that surrounds individual caribou ranges. The surrounding area also provides spatial context for where habitat disturbance is located if adjustments are made to caribou range boundaries in the future.

Range condition summaries

For each caribou range, for both high elevation and low elevation portions, we summarized:

- the extent of habitat disturbance due to: each type of anthropogenic habitat disturbance; and, each type of natural disturbance (fires <40 years, fires <50 years, forest insect attack);
- the extent of anthropogenic habitat disturbance for all types combined;
- the extent of total habitat disturbance (all types of anthropogenic habitat disturbance combined plus fires less than 40 years old); and,
- within 20 km and 30 km surrounding each caribou range, the extent of habitat disturbance due to: each type of habitat disturbance; all types of anthropogenic habitat disturbance combined; and, total habitat disturbance (including fire).

For the six transboundary caribou ranges, we summarized the habitat disturbance information described above for the BC portion of each range, and for the total area of each range (BC + Yukon).

We also summarized the information described above for individual ranges and for the aggregated area of all caribou ranges combined, including the extent of habitat disturbance within 20 km and 30 km surrounding each range and the aggregated area.

The results section contains roll-ups of information across all caribou ranges in the study area. Maps and summaries of information for individual caribou herds and their ranges are provided in Appendix 3.

Population status

For each caribou herd, we summarized population information from available technical reports. We used information from the 2014 COSEWIC status report (COSEWIC 2014) as a baseline and updated population size and trend information where more recent information was available. Detailed summaries for each caribou herd are provided in Appendix 3.

Where possible, we assessed population trend, based on consecutive population surveys or measures of calf recruitment (see detailed methods in Appendix 3). We explored the relationship between habitat disturbance levels on individual ranges to their corresponding population trends. Subsequent to our initial compilation of population information, the BC Caribou Recovery Program developed a summary of population size and trend information for all caribou populations in BC (BC Caribou Recovery Program 2021), which we checked against the estimates we derived. For population trend, we used long-term population trend information summarized from Appendix 3.

Caribou ranges

We identified several potential issues with range boundaries in the study area (Table 5) including:

- the BC and Yukon boundaries for the six transboundary ranges did not line up, as they were derived independently in each jurisdiction;
- most range boundaries in northwestern BC were coarsely drawn, resulting in gaps between ranges that likely do not reflect actual gaps in distribution;
- discussions with BC MFLNRORD biologists, and telemetry and observation data suggest that:
    - some ranges may need to be expanded into areas that are currently not included in any caribou ranges;
    - distribution of several caribou populations overlap and therefore range boundaries should overlap in those areas;
- the large gap between caribou ranges in the centre of the study area is known to contain caribou (see Appendix 3: Range Summaries – Low density area) and may need to be incorporated into adjacent ranges, or added as new range(s); and,
- the Edziza caribou range is offset from the known range, excluding the eastern portion of the Mt Edziza mountain block.

We could not address these boundary issues at this time (see Caribou range boundaries); therefore, we used the currently available caribou boundaries.

High elevation plateaus, such as the Spatsizi Plateau, are used by caribou during both summer and winter. (Deborah Cichowski)

Approximately two-thirds of the combined area in currently-delineated caribou ranges in northern BC consists of high elevations as defined by the SWB, ESSF or BAFA biogeoclimatic zones (Table 6, Figure 2). The other third consists of low elevations, primarily in the BWBS. Within individual caribou ranges, the extent of high elevation range varies from 47% in the Little Rancheria range to 89% in the Frog, Thutade and Tsenaglode ranges.

Table 5. Potential boundary issues for caribou ranges that are wholly or partially in northern British Columbia.

Potential boundary issue	Carcross	Atlin	Swan Lake	Little Rancheria	Horseranch	Level Kawdy	Edziza	Tsenaglode	Spatsizi	Liard Plateau	Rabbit	Muskwa	Pink Mountain	Gataga	Frog	Finlay	Thutade
BC/Yukon caribou range boundaries do not line up	X	X	X	X	X					X							
Range boundaries coarsely drawn resulting in gaps between ranges	X	X	X	X	X	X		X	X								
Telemetry and observation data suggest boundaries should be expanded into some areas that are currently not included in any caribou ranges									X						X		
Telemetry data suggest overlap between adjacent ranges			X	X	X	X		X	X				X			X	
The large gap between caribou ranges in the centre of the study area is known to contain caribou					X			X	X		X				X		
Boundaries coarse and offset from known range use							X										
Available information insufficient to evaluate issues with boundaries											X			X	X		

Table 6. High and low elevation proportions (%), and total area of each caribou range and of the 20 km and 30 km matrix surrounding ranges for caribou ranges that are wholly or partially in northern British Columbia.

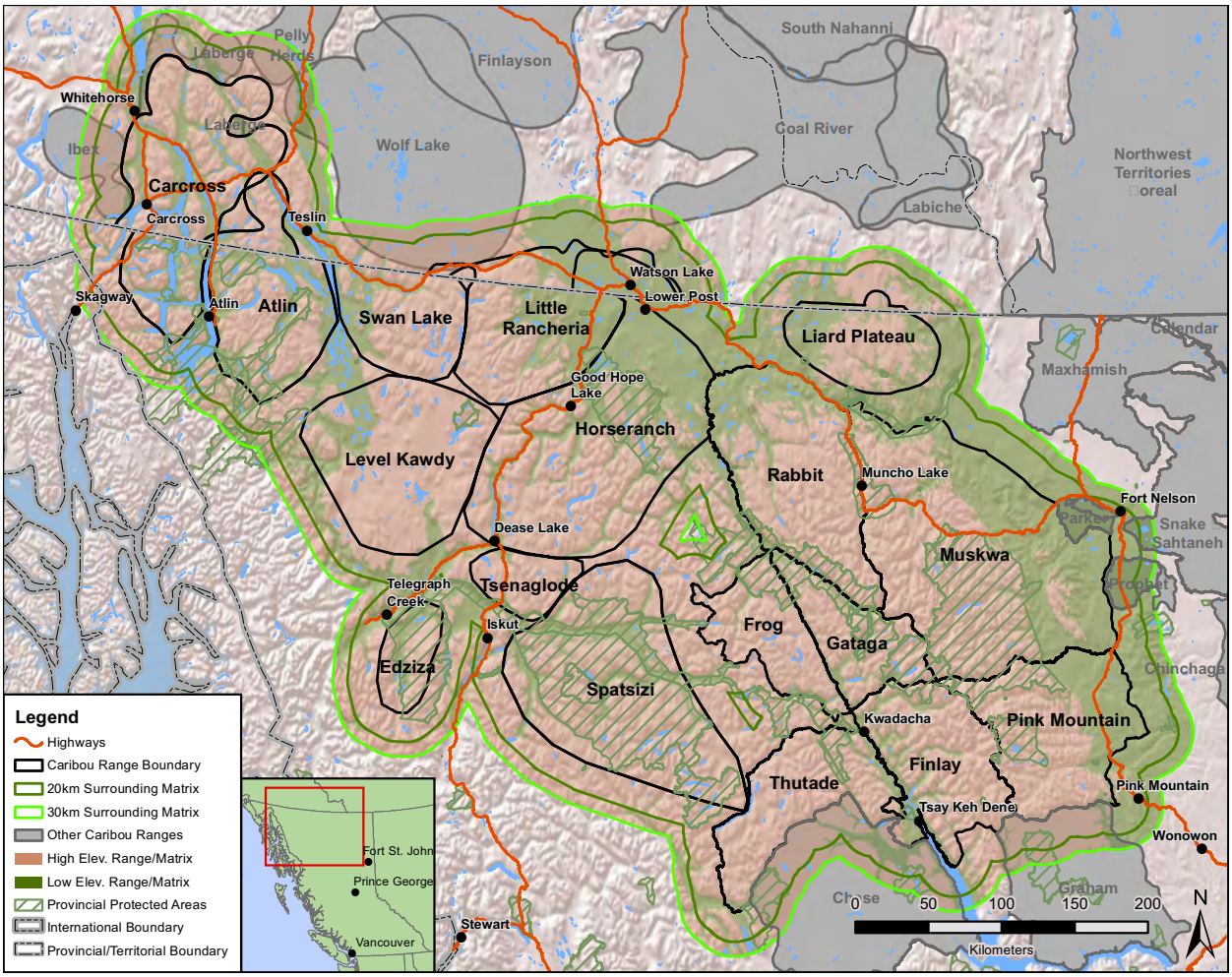
	Range			0-20 km matrix surrounding range				0-30 km matrix surrounding range			
	Low elevation[1]	High elevation[2]	Total Range (ha)	Low elevation[1]	High elevation[2]	Total Range (ha)	% of matrix in adjacent range[3]	Low elevation[1]	High elevation[2]	Total Range (ha)	% of matrix in adjacent range[3]
Atlin (Total)	40.3	59.7	858 401	54.2	45.8	959 801	35.7 (NM)	53.0	47.0	1 516 826	41.0 (NM)
Atlin (BC only)	41.9	58.1	695 385	62.8	37.2	566 293	30.7 (NM)	59.9	40.1	893 837	37.2 (NM)
Carcross (Total)	40.7	59.3	1 273 592	32.7	67.3	1 203 133	41.2 (NM)	29.5	70.5	1 870 606	41.6 (NM)
Carcross (BC only)	49.0	51.0	324 060	36.2	63.8	413 599	20.4 (NM)	30.7	69.3	632 286	25.6 (NM)
Edziza	27.3	72.7	235 185	36.4	63.6	514 300	0	39.6	60.4	865 688	0.2 (NM)
Finlay	24.1	75.9	817 094	23.8	76.2	982 244	62.7 (NM) 22.1 (SM)	20.9	79.1	1 525 168	60.4 (NM) 25.6 (SM)
Frog	11.3	88.7	504 069	22.9	77.1	885 050	41.0 (NM)	21.5	78.5	1 392 243	63.1 (NM)
Gataga	22.3	77.7	500 703	18.7	81.3	845 787	92.3 (NM)	16.4	83.6	1 352 795	90.6 (NM)
Horseranch (Total)	47.3	52.7	1 945 173	51.4	48.6	1 473 971	57.2 (NM)	48.5	51.5	2 272 285	57.3 (NM)
Horseranch (BC only)	42.9	57.1	1 779 688	45.8	54.2	1 195 352	63.3 (NM)	43.8	56.2	1 807 609	65.7 (NM)
Level Kawdy	14.3	85.7	1 135 902	36.8	63.2	921 841	36.6 (NM)	36.5	63.5	1 477 004	41.5 (NM)
Liard Plateau (Total)	48.9	51.1	520 304	74.2	25.8	690 962	8.9 (NM)	76.2	23.8	1 128 170	15.8 (NM)
Liard Plateau (BC only)	49.1	50.9	475 350	91.5	8.5	435 358	14.2 (NM)	89.9	10.1	696 906	25.6 (NM)
Little Rancheria (Total)	53.4	46.6	1 055 816	45.3	54.7	1 054 289	58.5 (NM)	42.7	57.3	1 662 553	60.6 (NM)
Little Rancheria (BC only)	46.0	54.0	698 569	41.2	58.8	612 209	83.3 (NM)	41.6	58.4	957 387	85.7 (NM)
Muskwa	41.8	58.2	2 158 213	56.6	43.4	1 481 104	54.4 (NM) 9.9 (Boreal)	56.0	44.0	2 281 006	56.4 (NM) 8.4 (B)
Pink Mountain	34.8	65.2	957 542	45.7	54.3	1 067 608	53.3 (NM) 15.2 (SM)	44.1	55.9	1 669 138	51.4 (NM) 15.0 (SM) 0.1 (Boreal)
Rabbit	31.7	68.3	1 179 409	47.9	52.1	1 093 947	64.7 (NM)	45.1	54.9	1 721 485	67.5 (NM)
Spatsizi	17.7	82.3	1 565 613	9.3	90.7	1 169 526	22.6 (NM)	9.5	90.5	1 848 437	27.1 (NM)
Swan Lake (Total)	23.2	76.8	585 080	26.1	73.9	748 067	68.7 (NM)	25.0	75.0	1 212 853	73.7 (NM)
Swan Lake (BC only)	24.3	75.7	557 190	32.0	68.0	472 321	71.6 (NM)	30.5	69.5	753 031	77.4 (NM)
Thutade	11.2	88.8	711 930	27.0	73.0	1 033 466	30.6 (NM) 27.9 (SM)	25.2	74.8	1 619 076	33.2 (NM) 26.7 (SM)
Tsenaglode	11.2	88.8	247 008	35.0	65.0	521 447	58.8 (NM)	35.0	65.0	876 415	61.9 (NM)
All Ranges (Total)	32.1	67.9	16 049 860	44.5	55.5	7 214 147	–	44.2	55.8	9 919 904	–
All Ranges (BC only)	30.8	69.1	14 537 257	46.3	53.7	5 557 502	–	46.0	54.0	7 383 130	–

[1] Low elevation defined as that portion of the range that lies within the Boreal White and Black Spruce (BWBS) or Sub-Boreal Spruce (SBS) biogeoclimatic zones

[2] High elevation defined as that portion of the range that lies within the Spruce Willow Birch (SWB), Engelmann Spruce-Subalpine Fir (ESSF) or Boreal Altai Fescue Alpine (BAFA) biogeoclimatic zones

[3] Indicates how much of the surrounding matrix lies within neighbouring caribou ranges; Boreal = ranges in Boreal National Ecological Area (NEA); NM = ranges in Northern Mountain NEA; SM = ranges in Southern Mountain NEA

Figure 2. The extent of low and high elevation ranges within each caribou range and within the 20-km and 30-km surrounding matrix for caribou ranges that are wholly or partially in northern British Columbia.



The matrix range surrounding the combined area of caribou ranges in northern BC contains more low elevation areas than the caribou ranges themselves (Table 6). High elevations make up 56% of the surrounding matrix range within both 20 km and 30 km of the combined range boundary, and vary from 9-10% for the BC portion of the Liard Plateau range to 91% for the Spatsizi range.

Most caribou ranges in northern BC lie adjacent to other caribou ranges and overlap in some areas (Figure 2). The Edziza range is the only caribou range where the 20 km and 30 km surrounding matrices do not overlap with any other caribou ranges, although they overlap 20 km and 30 km surrounding matrices of other ranges (Table 6).

Otherwise, between 9% and 92% of the 20 km surrounding matrix, and between 16% and 91% of the 30 km surrounding matrix overlap adjacent ranges. The majority of the overlap occurs with other Northern Mountain National Ecological Area (NEA) ranges, but some also occurs with Boreal NEA and Southern Mountain NEA ranges (Table 6, see Figure 1).

Results

Range condition

Total habitat disturbance (anthropogenic + 500 m buffer, and fires <40 years old) makes up about 15% of the area in all 17 caribou ranges combined (Table 7). Nine of the 17 ranges each contain more than 10% habitat disturbance. The three caribou ranges with the highest levels of habitat disturbance (Pink Mountain, Muskwa, Liard Plateau) are the three easternmost caribou ranges in the study area, with the majority of habitat disturbance located in the eastern portions of their ranges (Figure 3). The lowest levels of total habitat disturbance (<8% disturbance) are in the Frog, Gataga, Level Kawdy, Rabbit and Spatsizi ranges, and in the BC portion of the Carcross range (Table 7).

The amount of anthropogenic habitat disturbance is greater than the amount of fire in most (8/9) ranges with >10% habitat disturbance (Table 7). Fire plays a larger role in driving total habitat disturbance levels in ranges with <10% habitat disturbance, where half (4/8) of the ranges contain more fire than anthropogenic habitat disturbance (Table 7).

Figure 3. Distribution of fire and anthropogenic habitat disturbance on caribou ranges that are wholly or partially in northern British Columbia.

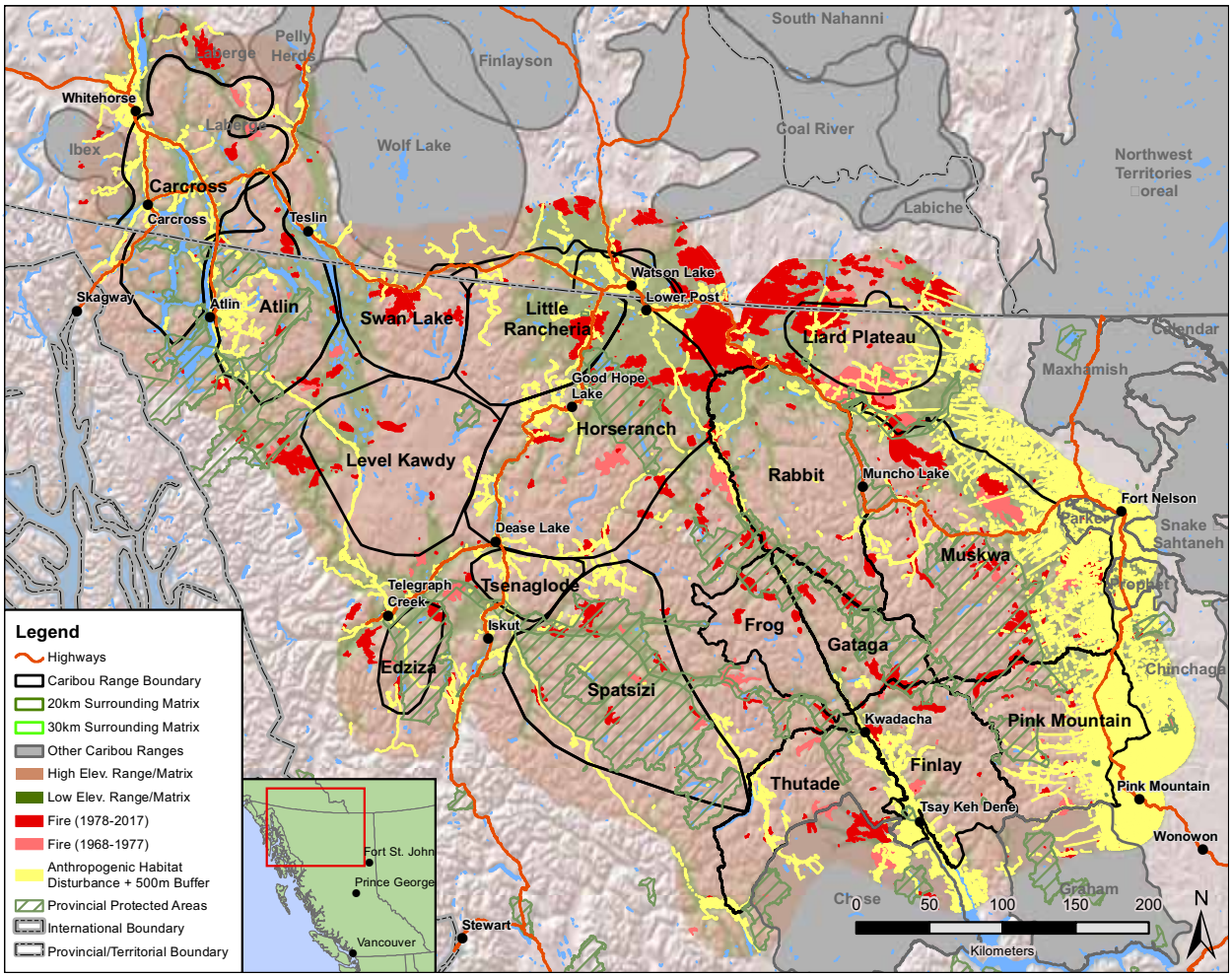


Table 7. Proportion (%) of each caribou range, and of the 20 km and 30 km matrix surrounding ranges, consisting of fires <40 years old, total anthropogenic habitat disturbance, and total habitat disturbance (fires <40 years old + anthropogenic habitat disturbance), for caribou ranges that are wholly or partially in northern British Columbia.

	Range				0-20 km matrix surrounding range				0-30 km matrix surrounding range			
	Area	Fire <40 years	Total Anthro. Disturbance	Total[1] Habitat Disturbance	Area	Fire <40 years	Total Anthro. Disturbance	Total[1] Habitat Disturbance	Area	Fire <40 years	Total Anthro. Disturbance	Total[1] Habitat Disturbance
Atlin (Total)	858 401	1.9	9.6	11.5	959 801	1.7	5.0	6.6	1 516 826	1.8	4.3	6.0
Atlin (BC only)	695 385	0.8	10.7	11.5	566 293	2.5	3.3	5.7	893 837	2.4	2.8	5.2
Carcross (Total)	1 273 592	0.4	8.4	8.8	1 203 133	1.9	10.7	12.5	1 870 606	1.6	9.6	11.1
Carcross (BC only)	324 060	0	2.6	2.6	413 599	0.2	10.4	10.5	632 286	0.1	10.4	10.5
Edziza	235 185	4.8	5.1	9.5	514 300	4.2	6.4	9.9	865 688	3.3	7.7	10.6
Finlay	817 094	3.3	13.3	16.1	982 244	5.7	15.5	20.8	1 525 168	5.4	13.3	18.4
Frog	504 069	4.2	0.1	4.3	885 050	3.5	2.0	5.3	1 392 243	3.7	2.4	5.6
Gataga	500 703	5.1	1.7	6.8	845 787	5.8	1.2	6.9	1 352 795	6.1	2.3	8.0
Horseranch (Total)	1 945 173	5.7	9.2	14.4	1 473 971	12.1	10.4	21.0	2 272 285	12.5	8.6	19.7
Horseranch (BC only)	1 779 688	5.9	7.0	12.5	1 195 352	12.7	10.4	21.4	1 807 609	12.0	8.6	19.0
Level Kawdy	1 135 902	1.4	1.6	3.0	921 841	4.4	5.1	9.4	1 477 004	3.6	6.5	9.9
Liard Plateau (Total)	520 304	11.6	11.0	20.9	690 962	21.8	14.4	33.2	1 128 170	23.6	13.4	33.7
Liard Plateau (BC only)	475 350	10.4	11.1	19.9	435 358	16.1	20.0	32.3	696 906	17.8	19.2	32.5
Little Rancheria (Total)	1 055 816	5.4	11.7	16.1	1 054 289	6.7	10.3	16.4	1 662 553	10.8	8.3	18.4
Little Rancheria (BC only)	698 569	6.7	7.0	12.5	612 209	5.7	11.0	15.9	957 387	9.1	8.5	16.7
Muskwa	2 158 213	8.4	19.4	25.8	1 481 104	5.1	29.1	32.7	2 281 006	4.4	29.3	32.5
Pink Mountain	957 542	2.2	33.9	35.4	1 067 608	3.2	34.1	36.7	1 669 138	4.7	34.7	37.9
Rabbit	1 179 409	3.6	3.6	6.7	1 093 947	13.2	8.4	19.7	1 721 485	15.6	7.2	20.8
Spatsizi	1 565 613	2.4	3.3	5.5	1 169 526	0.8	6.6	7.2	1 848 437	0.8	5.8	6.4
Swan Lake (Total)	585 080	6.2	3.5	9.4	748 067	0.7	6.0	6.7	1 212 853	0.8	4.8	5.5
Swan Lake (BC only)	557 190	6.5	3.0	9.2	472 321	0.9	2.8	3.7	753 031	1.0	1.9	2.9
Thutade	711 930	1.8	10.1	11.3	1 033 466	4.7	13.1	17.3	1 619 076	3.0	11.6	14.3
Tsenaglode	247 008	0	11.4	11.4	521 447	3.3	12.3	15.2	876 415	3.4	10.3	13.4
All Ranges (Total)	16 049 860	4.2	9.9	13.6	7 214 147	6.5	15.7	21.5	9 919 904	7.1	16.3	22.5
All Ranges (BC only)	14 537 257	4.4	9.7	13.5	5 557 502	6.0	17.7	22.8	7 383 130	6.0	19.5	24.4

[1] Total habitat disturbance takes into account overlap between fire and anthropogenic habitat disturbance (anthropogenic habitat disturbance includes a 500 m buffer). Therefore, the amount of total habitat disturbance is less than the sum of the two types of habitat disturbance on ranges where overlaps between fire and anthropogenic habitat disturbance occur. Grey shading indicates ranges with >10% total habitat disturbance.

Total habitat disturbance is higher in the surrounding 20 km and 30 km matrices than in the caribou ranges themselves for all 17 caribou ranges combined (Table 7). Overall, the surrounding 20 km and 30 km matrices include more low elevation range than the caribou ranges (see Table 6).

In all 17 caribou ranges, the level of total and anthropogenic habitat disturbance is higher in low elevation range than in high elevation range (Table 8). The percent of area affected by fires <40 years is higher in low elevation range than in high elevation range in most (13/17) caribou ranges (Table 8). The extent of anthropogenic habitat disturbance is higher than the extent of fire disturbance in low elevation range in 10 of 17 ranges, and in high elevation range in 11 of 17 ranges (Table 8).

In all 17 caribou ranges combined, total habitat disturbance is 30% in low elevation range, and 8% in high elevation range (Table 8). Total habitat disturbance in high elevation range exceeds the "Minimal (i.e. close to 0%)" threshold in all 17 caribou ranges; in seven ranges it is less than 5%, and in three less than 3%. The highest level of total habitat disturbance in high elevation range is in the Muskwa, Pink Mountain and Tsenaglode ranges (Table 8). Total habitat disturbance in low elevation range equals or exceeds the 35% threshold in five adjacent ranges including the three easternmost ranges (Liard Plateau, Muskwa, Pink Mountain) and the two southernmost ranges (Finlay, Thutade; Table 8, Figure 3, Figure 4). Total habitat disturbance in low elevation range is between 20% and 35% on three ranges: Horseranch, Little Rancheria, and Tsenaglode.

For most caribou ranges, the majority of fires were <40 years of age, except in the Liard Plateau range where over half of the fires <50 years of age were 40-50 years old (Table 9, Figure 3). Forest insect disturbance levels were most prominent in the Finlay and Thutade ranges (Table 9, Figure 5), most of which was due to mountain pine beetles (*Dendroctonus ponderosae*). Disturbances caused by forest insects were also present in the Pink Mountain, Frog and Gataga ranges, but to a lesser extent. Although we do not provide information on balsam bark beetles (*Dryocoetes confusus*), they are present throughout the study area.

Seismic lines in the eastern portion of the Pink Mountain caribou range. (Satellite image from Google Earth)

Linear features (e.g., roads, trails, seismic lines and pipelines), primarily roads/trails, were the most prominent anthropogenic habitat disturbance on all caribou ranges (Table 9), at both high and low elevations (Table 10, Table 11). From the spatial data layers we were using, there was a high degree of overlap between roads and trails, therefore we were unable to distinguish between those two types of linear features using spatial layers. Also, roads and trails varied from hiking/horse trails to paved highways, resulting in a wide range of types of access that we were not able to distinguish between. There was also overlap between seismic lines and roads/trails.

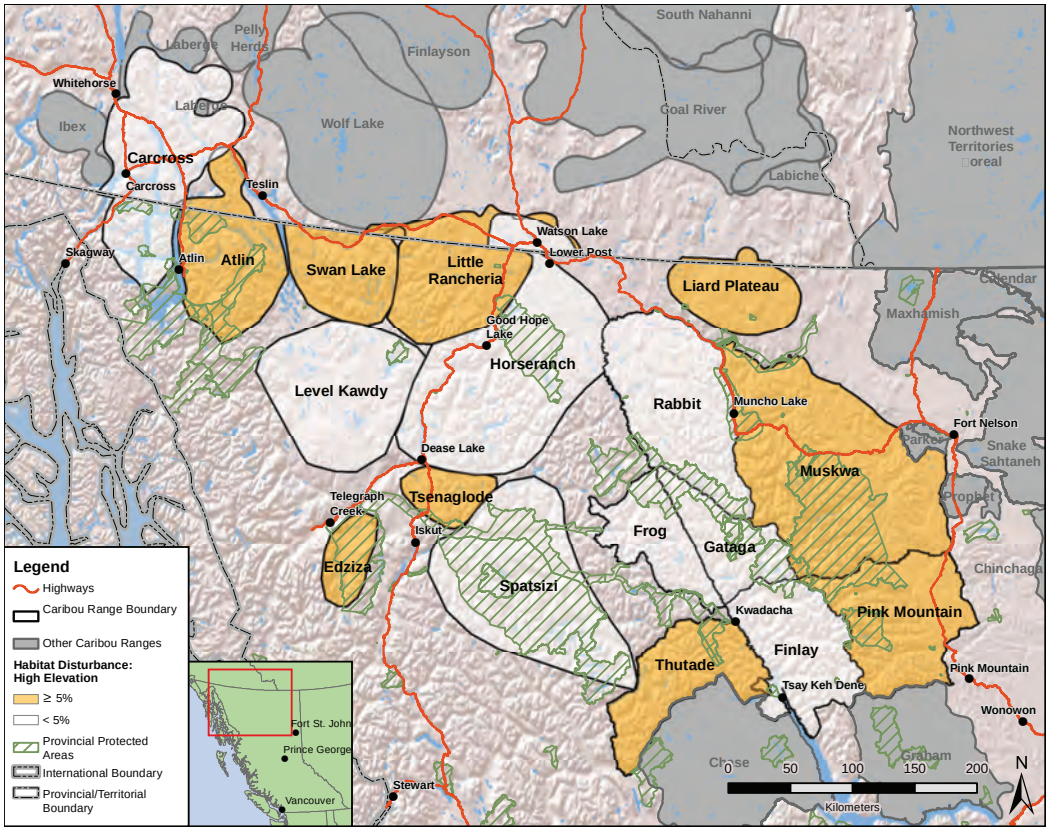
Table 8. Proportion (%) of total range, low elevation range, and high elevation range consisting of fires <40 years old, total anthropogenic habitat disturbance, and total habitat disturbance (due to fires <40 years old + anthropogenic disturbance) on caribou ranges that are wholly or partially in northern British Columbia.

	Total[1]				Low elevation[1]				High elevation[1]			
	Area (ha)	Fire <40 years	Total Anthro. Habitat Disturbance	Total[2] Habitat Disturbance	Area (ha)	Fire <40 years	Total Anthro. Habitat Disturbance	Total[2] Habitat Disturbance	Area (ha)	Fire <40 years	Total Anthro. Habitat Disturbance	Total[2] Habitat Disturbance
Atlin (Total)	858 401	1.9	9.6	11.5	346 303	4.0	14.2	18.2	512 097	0.5	6.5	7.0
Atlin (BC only)	695 385	0.8	10.7	11.5	291 045	1.6	14.3	15.9	404 341	0.2	8.1	8.3
Carcross (Total)	1 273 592	0.4	8.4	8.8	518 781	0.2	17.9	18.1	754 811	0.5	2.0	2.5
Carcross (BC only)	324 060	0	2.6	2.6	158 865	0	5.0	5.0	165 196	0	0.2	0.2
Edziza	235 185	4.8	5.1	9.5	64 255	10.5	7.3	17.8	170 929	2.7	4.2	6.4
Finlay	817 094	3.3	13.3	16.1	197 112	7.1	46.7	51.9	619 983	2.1	2.7	4.8
Frog	504 069	4.2	0.1	4.3	57 099	10.9	1.1	12.0	446 969	3.4	0	3.4
Gataga	500 703	5.1	1.7	6.8	111 491	10.7	5.3	16.0	389 212	3.6	0.6	4.2
Horseranch (Total)	1 945 173	5.7	9.2	14.4	920 489	10.7	15.2	24.9	1 024 684	1.1	3.8	4.9
Horseranch (BC only)	1 779 688	5.9	7.0	12.5	762 958	12.3	11.4	22.7	1 016 730	1.2	3.7	4.9
Level Kawdy	1 135 902	1.4	1.6	3.0	161 995	3.4	3.8	7.1	973 907	1.1	1.2	2.3
Liard Plateau (Total)	520 304	11.6	11.0	20.9	254 275	22.6	15.1	34.3	266 029	1.1	7.2	8.2
Liard Plateau (BC only)	475 350	10.4	11.1	19.9	233 434	20.1	15.6	32.5	241 916	1.0	6.9	7.8
Little Rancheria Total)	1 055 816	5.4	11.7	16.1	563 685	9.7	15.9	23.8	492 131	0.5	6.8	7.2
Little Rancheria (BC only)	698 569	6.7	7.0	12.5	321 110	14.5	8.0	19.7	377 459	0.2	6.2	6.4
Muskwa	2 158 213	8.4	19.4	25.8	901 281	11.3	39.4	46.2	1 256 932	6.3	5.1	11.1
Pink Mountain	957 542	2.2	33.9	35.4	332 894	2.2	71.8	72.3	624 647	2.2	13.7	15.7
Rabbit	1 179 409	3.6	3.6	6.7	374 007	8.4	8.2	15.2	805 402	1.4	1.4	2.8
Spatsizi	1 565 613	2.4	3.3	5.5	277 677	7.4	4.2	11.0	1 287 936	1.3	3.1	4.4
Swan Lake (Total)	585 080	6.2	3.5	9.4	135 756	6.4	8.2	13.9	449 324	6.1	2.1	8.1
Swan Lake (BC only)	557 190	6.5	3.0	9.2	135 228	6.5	8.0	13.9	421 963	6.5	1.4	7.8
Thutade	711 930	1.8	10.1	11.3	79 848	7.3	47.6	50.4	632 082	1.1	5.4	6.3
Tsenaglode	247 008	0	11.4	11.4	27 740	0	29.5	29.5	219 268	0	9.1	9.1
All Ranges (Total)	16 049 860	4.2	9.9	13.6	5 158 612	8.5	22.4	29.3	10 891 248	2.2	4.0	6.1
All Ranges (BC only)	14 537 257	4.4	9.7	13.5	4 482 822	9.2	22.3	29.6	10 045 117	2.3	4.1	6.3

[1] Total range, low elevation range and high elevation range include only the area within a caribou herd's range and do not include the 20 km or 30 km surrounding matrix.

[2] Total habitat disturbance takes into account overlap between fire and anthropogenic habitat disturbance (anthropogenic habitat disturbance includes a 500 m buffer). Therefore, the amount of total habitat disturbance is less than the sum of the two types of habitat disturbance on ranges where overlaps between fire and anthropogenic habitat disturbance occur. For low elevation range, orange shading indicates ranges with ≥35% total habitat disturbance and yellow shading indicates ranges with 20-34% total habitat disturbance. For High elevation range, orange shading indicated ranges with ≥5% total habitat disturban

Figure 4. Caribou ranges that are wholly or partially in northern British Columbia with total habitat disturbance in high elevation range ≥5% (orange) and <5% (white) (top), and in low elevation range ≥35% (orange), 20-34% (yellow) and <20% (white) (bottom).



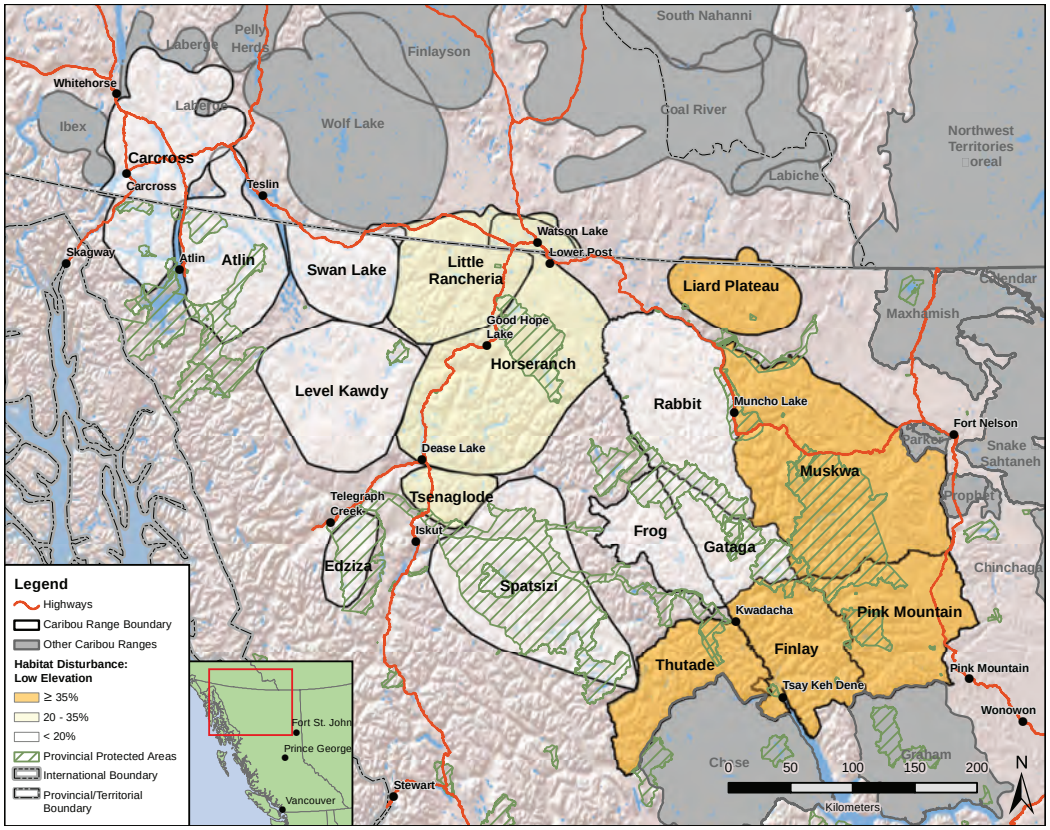


Table 9. Proportion (%) of total area in each habitat disturbance category in caribou ranges that are wholly or partially in northern British Columbia.

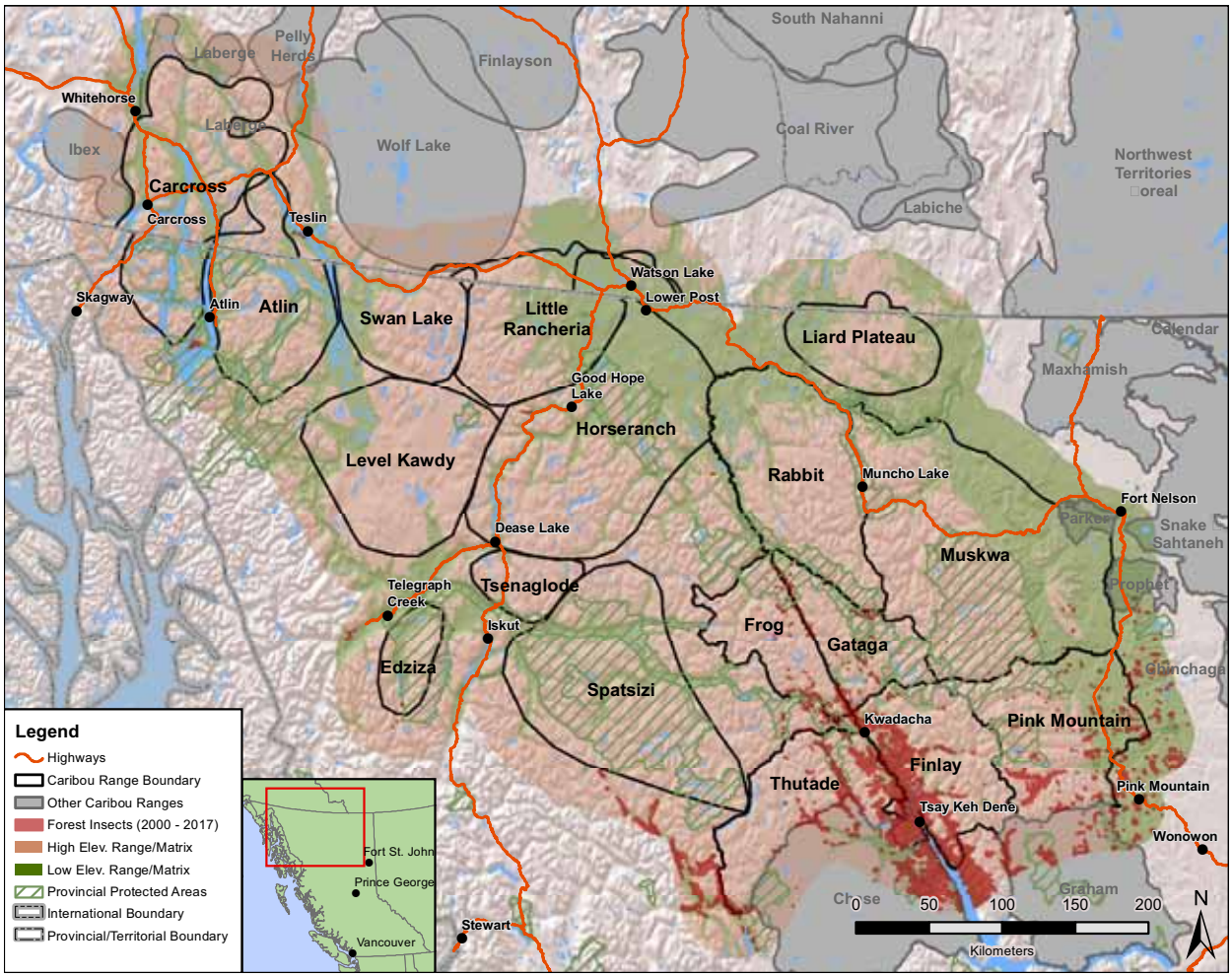
	Caribou Range Area (ha)	Habitat disturbance category[1,2]																			
		Fire <40 years	Fire <50 years	Forest Insects	Reservoirs	Agriculture	Airstrip	Forest harvesting	Dam	Mine	Oil facility	Well	Pipeline	Powerline	Railroad	Road	Seismic	Settlement	Trail	Road and Trail[3]	Total Road/Trail[3]
Atlin (Total)	858 401	1.9	2.0	0	0	0	0	0.2	0	1.7	0	0	0	0	0	8.7	0.1	0.1	3.8	3.2	9.3
Atlin (BC only)	695 385	0.8	0.9	0	0	0	0.1	0.2	0	2.1	0	0	0	0	0	10.1	0.1	0.1	3.6	3.3	10.4
Carcross (Total)	1 273 592	0.4	0.9	0	0	0.1	0	0.8	0	0.4	0	0	0.7	0.6	0.7	4.5	0.1	1.1	7.3	4.1	7.7
Carcross (BC only)	324 060	0	0	0.1	0	0	0	0.1	0	0.1	0	0	0	0	0	2.3	0	0	2.0	1.8	2.5
Edziza	235 185	4.8	5.7	0	0	0	0.1	0	0	0	0	0	0	0	0	5.1	0	0.1	0	0	5.1
Finlay	817 094	3.3	4.3	16.6	0	0	0.1	9.5	0	0	0	0	0	0	0	12.1	0	0.1	0	0	12.1
Frog	504 069	4.2	4.4	2.3	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0	0	0.1
Gataga	500 703	5.1	5.3	1.4	0	0	0	0	0	0	0	0	0	0	0	1.7	0	0	0	0	1.7
Horseranch (Total)	1 945 173	5.7	6.8	0	0	0	0	1.8	0	0.6	0	0	0	0	0	6.8	0.1	0.4	2.5	1.3	8.0
Horseranch (BC only)	1 779 688	5.9	7.2	0	0	0	0	0	0	0.6	0	0	0	0	0	6.5	0.1	0.3	1.0	0.6	6.9
Level Kawdy	1 135 902	1.4	1.5	0	0	0	0	0	0	0	0	0	0	0	0	1.2	0	0	0.9	0.6	1.6
Liard Plateau (Total)	520 304	11.6	23.4	0	0	0	0	0	0	0	0	0	0	0.3	0	7.2	2.6	0.2	4.8	2.6	9.3
Liard Plateau (BC only)	475 350	10.4	23.4	0	0	0	0	0	0	0	0	0	0	0.4	0	7.9	2.8	0.3	4.3	2.9	9.2
Little Rancheria (Total)	1 055 816	5.4	5.4	0	0	0.1	0	3.8	0	0.3	0	0	0	0	0	6.9	0.2	0.3	7.2	4.7	9.4
Little Rancheria (BC only)	698 569	6.7	6.7	0	0	0	0	0.2	0	0.2	0	0	0	0	0	6.6	0.1	0	4.0	3.7	6.9
Muskwa	2 158 213	8.4	11.2	0	0	0.1	0	2.1	0	0	0.4	0.5	0.1	0	0	14.5	7.4	0.1	1.1	0.8	14.8
Pink Mountain	957 542	2.2	3.5	3.2	0	0.2	0	0.9	0	0	3.7	2.6	2.6	0	0	25.7	20.4	0.2	1.4	1.3	25.8
Rabbit	1 179 409	3.6	4.0	0	0	0	0.1	0	0	0	0	0	0	0	0	3.4	0	0	0.5	0.4	3.5
Spatsizi	1 565 613	2.4	3.0	0	0	0	0	0	0	0.3	0	0	0	0	0	3.2	0.1	0.1	0	0	3.2
Swan Lake (Total)	585 080	0.7	1.1	0	0	0.2	0	0	0	0.1	0	0	0	0	0	3.0	0.1	0.1	5.4	2.5	5.9
Swan Lake (BC only)	557 190	6.5	6.5	0	0	0	0	0	0	0.1	0	0	0	1.0	0	2.6	0	0.1	1.9	1.6	2.9
Thutade	711 930	1.8	3.1	7.9	0	0.1	0.1	4.8	0	0	0	0	0	0.6	0.1	9.5	0	0.1	0	0	9.5
Tsenaglode	247 008	0	0	0	0.3	0	0	0	0.1	0.1	0	0	0	0	0	11.0	0	0.4	0	0	11.0
All Ranges (Total)	16 049 860	4.2	4.2	1.5	0	0	0	1.3	0	0.3	0.3	0.2	0.2	0.1	0.1	7.8	2.3	0.2	1.9	1.3	8.4
All Ranges (BC only)	14 537 257	4.4	4.4	1.6	0	0	0	1.1	0	0.2	0.3	0.2	0.2	0.1	0	8.0	2.6	0.1	1.1	0.9	8.2

1 The anthropogenic habitat disturbance footprint includes a 500 m buffer consistent with the 500 m buffer used for anthropogenic habitat disturbance in EC (2014).

2 As a result of overlapping types of habitat disturbance and overlapping buffers for anthropogenic habitat disturbance, some habitat disturbance polygons are identified as more than one type of habitat disturbance (e.g. a "settlement" polygon will overlap with a "road" polygon). As a result, one polygon could include the footprint of more than one type of habitat disturbance and therefore adding up the area of individual types of anthropogenic habitat disturbance will exceed the combined area of "Total anthropogenic habitat disturbance" (see Tables 7 and 8), which merges all anthropogenic habitat disturbance and their buffers to eliminate overlaps. Similarly, "Total habitat disturbance" (see Tables 7 and 8) also merges the footprints of fires <40 years and anthropogenic habitat disturbance to eliminate double-counting overlapping habitat disturbance (e.g. a cutblock that was subsequently consumed in a fire).

3 "Road and trail" indicates the portions of the "Road" and "Trail" categories that were identified as both a road and a trail; "Total Road/Trail" is the combined total of roads and trails and accounts for overlap between the two categories.

Figure 5. Distribution of forest insect attack (mountain pine beetles, spruce beetles) from 2000 to 2017 in the British Columbia portion of caribou ranges that are wholly or partially in northern British Columbia.



Seismic lines contributed to anthropogenic habitat disturbance in the Pink Mountain and Muskwa ranges, and to a lesser extent in the Liard Plateau range (Table 9, Figure 3). Only the Pink Mountain and Muskwa ranges contained oil facilities and wells, while pipeline right-of-ways were located in the Pink Mountain, Muskwa and Carcross ranges (Table 9).

The proportion of the total caribou range affected by forest harvesting was highest in the Finlay and Thutade ranges, and covered one-third of the low elevation range in both caribou ranges (Table 9, Table 10). After linear features, forest harvesting was the next highest contributor of anthropogenic habitat disturbance in the Finlay, Thutade, Horseranch and Little Rancheria ranges (Table 9). Forest harvesting in the Horseranch and Little Rancheria ranges is primarily located in the Yukon portion of their ranges.

The footprint from mining activity was the next highest contributor of anthropogenic habitat disturbance in the Atlin range, after linear disturbances, and contributed to anthropogenic habitat disturbance to a lesser extent in the Carcross, Horseranch, Little Rancheria, Swan Lake, Spatsizi and Tsenaglode ranges (Table 9). Although we were not able to distinguish between roads/trails that were constructed for mining and those constructed for other purposes using our dataset, mining activity was commonly associated with road networks, especially in the Atlin caribou range.

Table 10. Proportion (%) of total low elevation range area in each habitat disturbance category in caribou ranges that are wholly or partially in northern British Columbia.

	Low Elevation Range Area (ha)	Habitat disturbance category[1,2]																			
		Fire <40 years	Fire <50 years	Forest Insects	Reservoirs	Agriculture	Airstrip	Forest harvesting	Dam	Mine	Oil facility	Well	Pipeline	Powerline	Railroad	Road	Seismic	Settlement	Trail	Road and Trail[3]	Total Road/Trail[3]
Atlin (Total)	346 303	4.0	4.2	0	0	0	0.1	0.5	0	1.6	0	0	0	0	0	12.5	0.2	0.2	6.9	5.6	13.9
Atlin (BC only)	291 045	1.6	1.8	0	0	0	0.1	0.5	0	1.8	0	0	0	0	0	13.4	0.3	0.2	5.8	5.3	13.9
Carcross (Total)	518 781	0.2	0.8	0	0	0.3	0	1.9	0	0.9	0	0	1.7	1.5	1.7	10.5	0.1	2.7	15.3	9.6	16.3
Carcross (BC only)	158 865	0	0	0.1	0	0	0	0.3	0.1	0.3	0	0	0	0	0	4.6	0	0	3.9	3.6	5.0
Edziza	64 255	10.5	10.7	0	0	0	0	0	0	0	0	0	0	0	0	7.3	0	0	0	0	7.3
Finlay	197 112	7.1	9.6	41.5	0.1	0	0.5	32.7	0	0	0	0	0	0	0	43.2	0	0.4	0	0	43.2
Frog	57 099	10.9	11.5	12.5	0	0	0	0	0	0	0	0	0	0	0	1.1	0	0	0	0	1.1
Gataga	111 491	10.7	11.2	4.1	0	0	0	0	0	0	0	0	0	0	0	5.3	0	0	0	0	5.3
Horseranch (Total)	920 489	10.7	11.4	0	0	0.1	0.1	3.7	0	0.7	0	0	0	0	0	10.3	0.3	0.8	5.3	2.7	12.9
Horseranch (BC only)	762 958	12.3	13.0	0	0	0	0.1	0.1	0	0.6	0	0	0	0	0	10.2	0.2	0.6	2.3	1.3	11.3
Level Kawdy	161 995	3.4	3.6	0	0	0	0	0	0	0	0	0	0	0	0	3.0	0	0	3.3	2.6	3.8
Liard Plateau (Total)	254 275	22.6	33.7	0	0	0	0	0	0	0	0	0	0	0.7	0	11.0	3.2	0.4	6.4	4.4	12.9
Liard Plateau (BC only)	233 434	20.1	32.2	0	0	0	0	0	0	0	0	0	0	0.7	0	11.9	3.4	0.5	6.2	4.8	13.2
Little Rancheria (Total)	563 685	9.7	9.7	0	0	0.1	0	6.9	0	0.3	0	0	0	0	0	8.2	0.4	0.5	9.8	6.2	11.8
Little Rancheria (BC only)	321 110	14.5	14.5	0	0	0	0	0.5	0	0.1	0	0	0	0	0	7.3	0.2	0	5.0	4.4	7.9
Muskwa	901 281	11.3	16.9	0	0	0.2	0.1	5.0	0	0	1.0	1.2	0.2	0	0	28.1	17.3	0.1	1.4	0.7	28.8
Pink Mountain	332 894	2.2	3.6	2.7	0	0.7	0.1	2.5	0	0.1	9.8	6.5	7.6	0	0	57.6	46.5	0.4	1.0	0.9	57.6
Rabbit	374 007	8.4	9.1	0.1	0	0.1	0.1	0	0	0	0	0	0	0	0	7.9	0	0.1	1.2	1.0	8.2
Spatsizi	277 677	7.4	9.5	0	0	0	0	0.1	0	0.2	0	0	0	0	0	4.1	0	0.3	0	0	4.1
Swan Lake (Total)	135 756	1.7	3.2	0	0	0	0	0.2	0	0.3	0	0	0	0	0	2.5	0	0.1	3.8	2.4	3.9
Swan Lake (BC only)	135 228	6.5	6.5	0	0	0	0	0	0	0.4	0	0	0	3.8	0	7.2	0	0.2	6.1	5.5	7.8
Thutade	79 848	7.3	8.3	33.0	0	0	0.2	33.5	0	0	0	0	0	0	0.8	44.5	0	0.4	0	0	44.5
Tsenaglode	27 740	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28.9	0	3.9	0	0	28.9
All Ranges (Total)	5 158 612	8.5	8.5	2.5	0	0.1	0.1	3.8	0	0.4	0.8	0.6	0.7	0.3	0.2	17.2	6.3	0.6	4.4	2.9	18.7
All Ranges (BC only)	4 482 822	9.2	9.2	2.8	0	0.1	0.1	3.3	0	0.3	0.9	0.7	0.6	0.2	0	18.2	7.2	0.3	2.3	1.8	18.7

1 The anthropogenic habitat disturbance footprint includes a 500 m buffer consistent with the 500 m buffer used for anthropogenic habitat disturbance in EC (2014).

2 As a result of overlapping types of habitat disturbance and overlapping buffers for anthropogenic habitat disturbance, some habitat disturbance polygons are identified as more than one type of habitat disturbance (e.g. a "settlement" polygon will overlap with a "road" polygon). As a result, one polygon could include the footprint of more than one type of habitat disturbance and therefore adding up the area of individual types of anthropogenic habitat disturbance will exceed the combined area of "Total anthropogenic habitat disturbance" (see Tables 7 and 8), which merges all anthropogenic habitat disturbance and their buffers to eliminate overlaps. Similarly, "Total habitat disturbance" (see Tables 7 and 8) also merges the footprints of fires <40 years and anthropogenic habitat disturbance to eliminate double-counting overlapping habitat disturbance (e.g. a cutblock that was subsequently consumed in a fire).

3 "Road and trail" indicates the portions of the "Road" and "Trail" categories that were identified as both a road and a trail; "Total Road/Trail" is the combined total of roads and trails and accounts for overlap between the two categories.

Table 11. Proportion (%) of total high elevation range area in each habitat disturbance category in caribou ranges that are wholly or partially in northern British Columbia.

	High Elevation Range Area (ha)	Habitat disturbance category[1,2]																			
		Fire <40 years	Fire <50 years	Forest Insects	Reservoirs	Agriculture	Airstrip	Forest harvesting	Dam	Mine	Oil facility	Well	Pipeline	Powerline	Railroad	Road	Seismic	Settlement	Trail	Road and Trail[3]	Total Road/Trail[3]
Atlin (Total)	512 097	0.5	0.5	0	0	0	0	0	0	1.8	0	0	0	0	0	6.1	0	0	1.7	1.5	6.3
Atlin (BC only)	404 341	0.2	0.3	0	0	0	0	0	0	2.3	0	0	0	0	0	7.7	0	0	2.0	1.9	7.8
Carcross (Total)	754 811	0.5	1.0	0	0	0	0	0	0	0.1	0	0	0	0	0	0.3	0.1	0	1.8	0.3	1.8
Carcross (BC only)	165 196	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.1	0	0	0.2	0.1	0.2
Edziza	170 929	2.7	3.8	0	0	0	0.1	0	0	0	0	0	0	0	0	4.2	0	0.1	0	0	4.2
Finlay	619 983	2.1	2.6	8.7	0	0	0	2.1	0	0	0	0	0	0	0	2.1	0	0	0	0	2.1
Frog	446 969	3.4	3.5	1.0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gataga	389 212	3.6	3.6	0.7	0	0	0	0	0	0	0	0	0	0	0	0.6	0	0	0	0	0.6
Horseranch (Total)	1 024 684	1.1	2.7	0	0	0	0	0.1	0	0.6	0	0	0	0	0	3.6	0	0.1	0	0	3.6
Horseranch (BC only)	1 016 730	1.2	2.8	0	0	0	0	0	0	0.6	0	0	0	0	0	3.7	0	0.1	0	0	3.7
Level Kawdy	973 907	1.1	1.1	0	0	0	0	0	0	0	0	0	0	0	0	0.9	0	0	0.5	0.3	1.2
Liard Plateau (Total)	266 029	1.1	13.6	0	0	0	0	0	0	0	0	0	0	0	0	3.6	2.0	0	3.2	0.9	5.9
Liard Plateau (BC only)	241 916	1.0	14.9	0	0	0	0	0	0	0	0	0	0	0	0	4.0	2.2	0.1	2.4	1.0	5.4
Little Rancheria (Total)	492 131	0.5	0.5	0	0	0	0	0.1	0	0.3	0	0	0	0	0	5.4	0.1	0	4.3	3.1	6.6
Little Rancheria (BC only)	377 459	0.2	0.2	0	0	0	0	0	0	0.4	0	0	0	0	0	5.9	0.1	0	3.1	3.0	6.1
Muskwa	1 256 932	6.3	7.1	0	0	0	0	0	0	0	0	0	0	0	0	4.8	0.3	0.1	0.8	0.8	4.8
Pink Mountain	624 647	2.2	3.4	3.5	0	0	0	0	0	0	0.3	0.5	0	0	0	8.8	6.6	0.1	1.6	1.5	8.9
Rabbit	805 402	1.4	1.6	0	0	0	0	0	0	0	0	0	0	0	0	1.3	0	0	0.3	0.2	1.4
Spatsizi	1 287 936	1.3	1.6	0	0	0	0	0	0	0.4	0	0	0	0	0	3.0	0.1	0.1	0	0	3.0
Swan Lake (Total)	449 324	0.4	0.4	0	0	0.3	0	0	0	0.1	0	0	0	0	0	3.2	0.1	0.1	5.9	2.6	6.6
Swan Lake (BC only)	421 963	6.5	6.5	0	0	0	0	0	0	0	0	0	0	0.1	0	1.1	0	0.1	0.6	0.3	1.3
Thutade	632 082	1.1	2.4	4.8	0.1	0.2	0.1	1.2	0	0	0	0	0	0.6	0	5.1	0	0	0	0	5.1
Tsenaglode	219 268	0	0	0	0.3	0	0	0	0.1	0.1	0	0	0	0	0	8.8	0	0	0	0	8.8
All Ranges (Total)	10 891 248	2.2	2.2	1.0	0	0	0	0.2	0	0.2	0	0	0	0	0	3.3	0.5	0	0.8	0.5	3.6
All Ranges (BC only)	10 045 117	2.3	2.3	1.1	0	0	0	0.2	0	0.2	0	0	0	0	0	3.5	0.5	0	0.6	0.5	3.6

[1] The anthropogenic habitat disturbance footprint includes a 500 m buffer consistent with the 500 m buffer used for anthropogenic habitat disturbance in EC (2014).

[2] As a result of overlapping types of habitat disturbance and overlapping buffers for anthropogenic habitat disturbance, some habitat disturbance polygons are identified as more than one type of habitat disturbance (e.g. a "settlement" polygon will overlap with a "road" polygon). As a result, one polygon could include the footprint of more than one type of habitat disturbance and therefore adding up the area of individual types of anthropogenic habitat disturbance will exceed the combined area of "Total anthropogenic habitat disturbance" (see Tables 7 and 8), which merges all anthropogenic habitat disturbance and their buffers to eliminate overlaps. Similarly, "Total habitat disturbance" (see Tables 7 and 8) also merges the footprints of fires <40 years and anthropogenic habitat disturbance to eliminate double-counting overlapping habitat disturbance (e.g. a cutblock that was subsequently consumed in a fire).

[3] "Road and trail" indicates the portions of the "Road" and "Trail" categories that were identified as both a road and a trail; "Total Road/Trail" is the combined total of roads and trails and accounts for overlap between the two categories.

The highest contribution of settlements to overall habitat disturbance levels was in the Yukon portion of the Carcross range, and the highest contribution of powerlines was in the Swan Lake range (Table 9). Agriculture, airstrips, railroads, reservoirs and dams played relatively minor roles in all caribou ranges (Table 9).

Roads/trails, mines and seismic lines were located in both low elevation and high elevation portions of the ranges, while forest harvesting, oil facilities, wells, pipeline right-of-ways, powerlines, settlements, agriculture, airstrips, and railroads were located primarily in low elevation ranges (Table 10, Table 11).

The main anthropogenic habitat disturbances in high elevation ranges other than roads/trails were seismic lines (Liard Plateau and Pink Mountain), mining (Atlin), and forest harvesting (Finlay, Thutade; Table 11).

Potential future habitat disturbance

Mineral exploration and mining activities, forest harvesting, oil and gas exploration and development, and road networks associated with industrial activities all have the potential to increase within Northern Mountain Caribou ranges assessed in this report. Natural resources in northern BC are viewed as key contributors to the provincial economy. Much employment and business activity in the region is driven, directly and indirectly, by natural resource extraction activities, and figures prominently in plans for future prosperity of the region (e.g., Initiatives Prince George Development Corporation and Northern Development Initiative Trust 2020). However, it is not always possible to predict where, and at what intensity, industrial activities are most likely to occur in the future. For example, while mining claims provide a good indication of areas of potential interest for mineral exploration activities (Figure 6), it is not possible to use this information to predict the location of viable ore deposits and which mines will ultimately be developed. While information on mining projects for which environmental assessment processes have been initiated can be used to predict potential location of mines, by the time projects enter these processes, they are already advanced in planning and feasibility studies.

The BC Environmental Assessment Office lists a number of mining projects that have initiated environmental assessment processes in caribou ranges and their surrounding matrix (Table 12). Two of the projects were withdrawn in 2016 and the certificate for one project expired in 2017. Two projects in the Spatsizi caribou range (Kutcho) and 20 km matrix (Arctos Anthracite) are listed as in the pre-application phase. The Arctos Anthracite (metallurgical coal) project is located just outside the southwestern boundary of the Spatsizi caribou range in the Klappan area, and includes a 147-km extension to an existing railway. In 2015, the Province of BC acquired the coal licenses in the Klappan to allow for time for the Province and the Tahltan Nation to develop a shared vision for the Klappan (Government of BC 2015). As part of the agreement, Fortune Minerals and POSCO Canada have a 10-year option to buy back the licenses after the Province and the Tahltan Nation have agreed on the shared vision. The Kutcho project lies within the northern portion of the Spatsizi caribou range and includes upgrading approximately 40 km and realigning approximately 80 km of the Jade-Boulder road (which currently supports seasonal use for industrial activities) to a one lane radio-controlled road supporting year-round use. One project in the Finlay caribou range was approved prior to the Environmental Assessment Act but development did not proceed. A certificate was issued for the Galore Creek open

Figure 6. Mineral and placer claims and leases, and coal licenses and leases, in and adjacent to the British Columbia portion of caribou ranges that are wholly or partially in northern British Columbia.

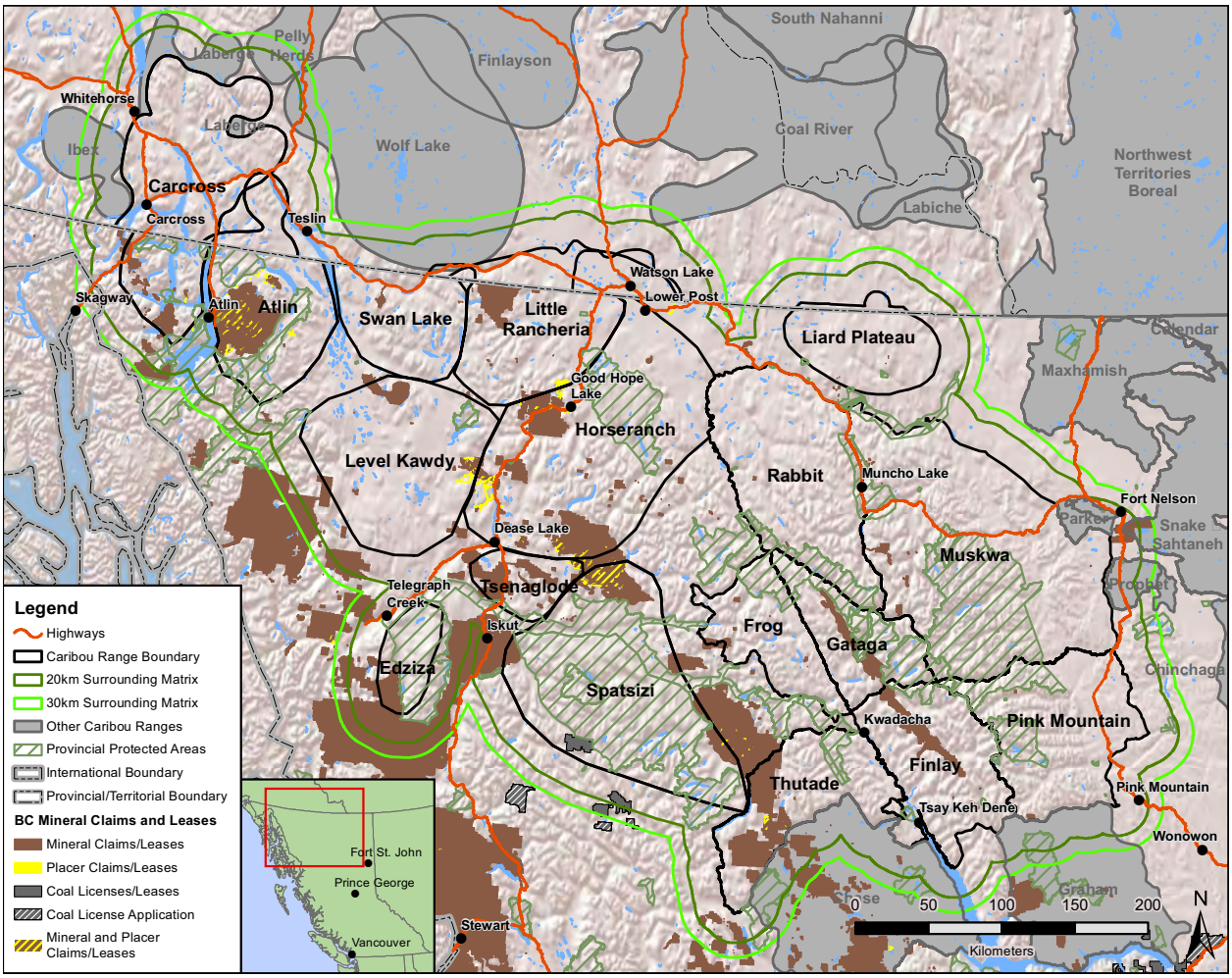


Table 12. Projects listed on the BC Environmental Assessment Office (EAO) website for caribou ranges that a wholly or partially in northern British Columbia.

Range	Zone	Project	Type	EAO Stage
Atlin	Range	Ruby Creek	Open pit molybdenum mine and mill	Certificate expired 2017
Edziza	Range	Schaft Creek	Open pit copper-gold-molybdenum-silver mine	Withdrawn 2016
	30 km matrix	Galore Creek	Open pit copper-gold-silver mine	Certificate issued 2007
Spatsizi	Range	Kutcho	Underground copper-zinc mine	Pre-application[1]
	20 km matrix	Arctos Anthracite	Open pit coal mine	Pre-application[1]
Finlay	Range	Stronsay	Open pit lead-zinc mine	Pre-EA Act approval
Thutade	Range	Sustut	Open pit copper mine	Withdrawn 2016

[1] There are no time limits on the pre-application phase (BC Environmental Assessment Office 2020)

pit copper-gold-silver mine in 2007, but the mine has not been developed yet. The Galore Creek project is located in the southwestern portion of the 30 km matrix surrounding the Edziza range. The Northwest Transmission Line from Terrace to the Iskut area, which was completed in 2014, is expected to support development of new mines in northwestern BC (BC Hydro 2014).

Forest harvest cutblocks in the Thutade caribou range, west of Kwadacha. (© Garth Lenz)

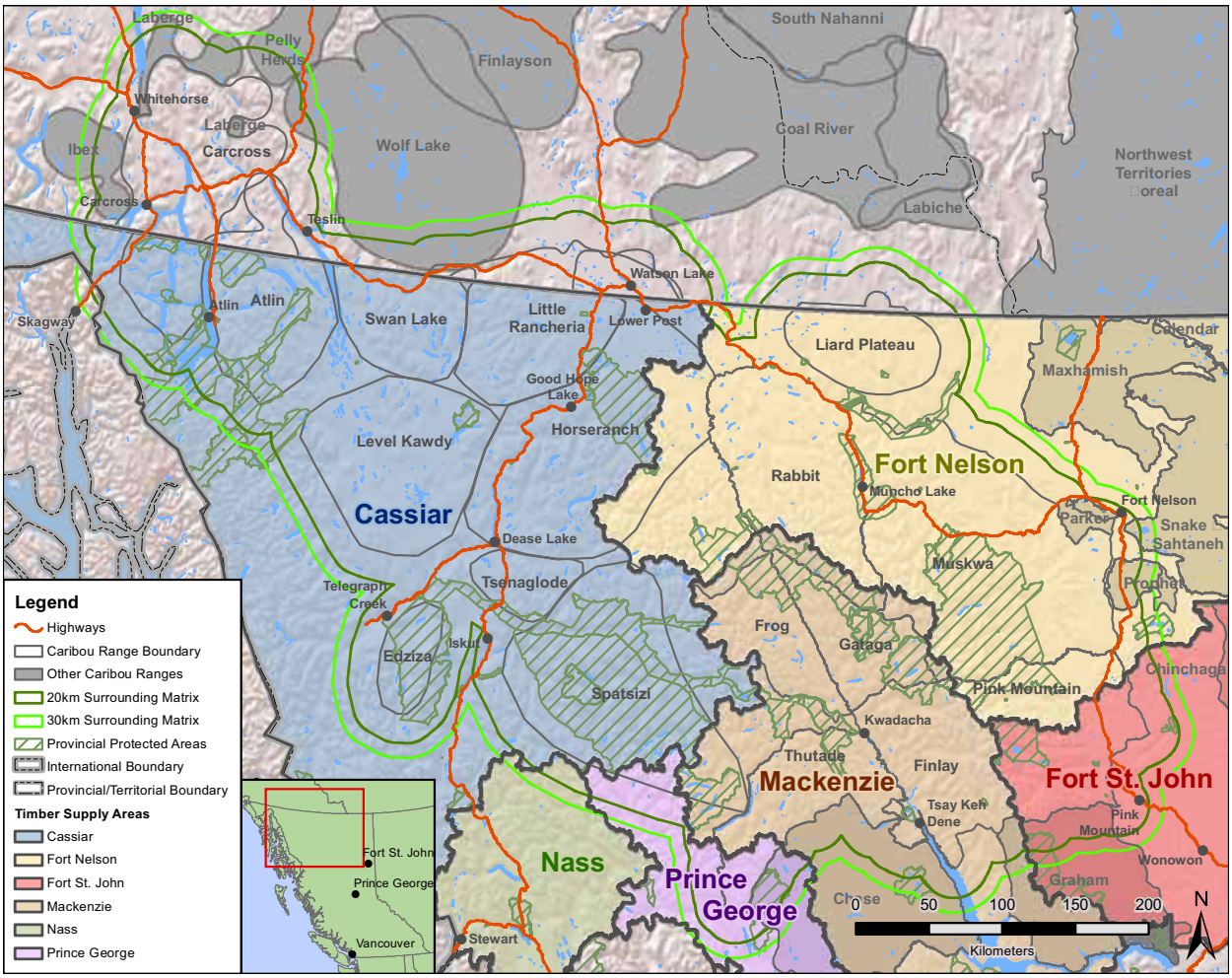
Future oil and gas and forestry development are both likely to be focused in and around areas of current or past activity. Oil and gas development (conventional and nonconventional) is currently concentrated in the Western Sedimentary Basin of northeastern BC, which overlaps the Liard Plateau, Muskwa and Pink Mountain caribou ranges; expansion of activities is expected to continue within that area (Government of BC 2022a). The Bowser Basin and Whitehorse trough are interior basins with identified coal, oil and gas potential in northwestern BC (Government of BC 2022a). In 2012, the Province of BC reached a tripartite agreement with the Tahltan Central Council and Shell Canada in which Shell Canada ceased exploration activities for natural gas and relinquished its tenures in the Klappan area within the Bowser Basin (Government of BC 2012), which overlaps the western portion of the Spatsizi caribou range. The Province of BC also committed to not issuing future petroleum and natural gas tenure in the area.

Natural gas pipelines that have been discussed or proposed in BC are all located outside the study area (Government of BC 2019), but potential routes for an "Alberta to Alaska Railway" freight rail line project have been proposed in the northerneastern part of the region near the Yukon border (Van Horne Institute 2015) in the Rabbit, Liard Plateau, Horseranch and Little Rancheria ranges and surrounding matrix.

The study area overlaps portions of six timber supply areas (TSAs) (Figure 7). In 2014, the allowable annual cut (AAC) in the Mackenzie TSA was increased, with the intent of targeting MPB-killed stands (Nicholls 2015a). Areas currently considered operable in the Mackenzie TSA include low elevation areas in the Thutade and Finlay caribou ranges (BC MFLNRORD 2020). In the recent AAC determination in the Fort St John TSA, the AAC remained unchanged, but a limit was set on the harvest level within the 'core' of the TSA, effectively directing more harvesting into the 'periphery' (Nicholls 2018), which includes the Pink Mountain caribou range. Forest harvesting has not yet occurred in the western part of the Pink Mountain caribou range because this area is in the Muskwa-Kechika Management Area and prior to harvesting requires approved landscape unit objectives, which have not yet been developed (Nicholls 2018). However, increased harvesting in the eastern portion of the range could occur as a result of increased harvesting pressure in the 'periphery'.

Most of the caribou ranges and surrounding matrix in the western part of the study area are located in the Cassiar TSA and to a lesser extent in the northern portions of the Nass and Prince George TSAs (Figure 7). The five operable areas in the Cassiar TSA are generally focused around existing road networks (BC MFLNRO 2013) and overlap portions of all caribou ranges in northwestern BC except Carcross. Commercial forest harvesting is not permitted in virtually all of the Carcross caribou range and portions of the Atlin caribou

Figure 7. Timber supply areas (TSAs) in British Columbia that overlap caribou ranges that are wholly or partially in northern British Columbia.



range in the BC portion of the ranges, outside of protected areas (Government of BC 2014). Although the more remote 'Iskut B' area, which includes parts of the Level Kawdy, Horseranch, Tsenaglode and Spatsizi caribou ranges, was not included in the timber harvesting landbase (THLB) in the current AAC determination, it could be reconsidered for inclusion in the next determination that is due to be completed in 2025 (Nicholls 2015b). Forest harvesting was recently deferred for 20 years in the Sacred Headwaters zone in the Klappan area (Tahltan Central Government and Province of BC 2019). Most of the portion of the Nass TSA that overlaps matrix that surrounds caribou ranges in our study area was excluded from the THLB in the recent timber supply review due to the high cost of access development into the area (BC MFLNRORD 2019). In the Prince George TSA, potential new connector roads could make forest harvesting more viable in more remote portions of the TSA (Nicholls 2017), such as in the northern portion that overlaps caribou ranges and surrounding matrix in our study area.

In addition to potential future anthropogenic habitat disturbance, with climate change, wildfires and forest insect outbreaks are expected to increase (Price et al. 2013, Wotton et al. 2016). In northern BC, mean summer and winter temperature are predicted to increase and mean summer and winter precipitation are expected to increase slightly with an overall decrease in precipitation falling as snow (Foord 2016, Wang et al. 2016, Zhang et al. 2019). However, the increase in precipitation is likely not sufficient to balance increased evaporation due to increased temperatures (Foord 2016, Wotton et al. 2016). Overall, climate change is expected to result in longer fire seasons and increased fire intensity (Wotton et al. 2016).

Climate change is also expected to result in changes to ecological conditions. In our study area, by 2100, climatic conditions in the high elevation Spruce-Willow-Birch and low elevation Boreal White and Black Spruce biogeoclimatic zones are expected to transition to climatic conditions associated with the Engelmann Spruce-Subalpine Fir and Sub-Boreal Spruce zones respectively, with some lower elevations in the southern and western portions of the study area transitioning to the Interior Cedar Hemlock zone and a potentially novel zone at some lower elevations in the northeast and north-central portions of the study area (Wang et al. 2016).

Population status

Table 13 summarizes population size and trends for caribou herds in northern BC. Current population trend assessed during this study (increasing, stable, declining) was based on three or more calf recruitment surveys conducted within the last 9 years (1 generation). Of the 17 currently-defined caribou herds in northern BC, current and long-term trend (over 2-3 generations) is unknown for most (13) herds, decreasing for two herds, and increasing for two herds (Table 13). Although numerous composition surveys (i.e., for sex and age) have been conducted for several herds since aerial surveys began in the late 1960s, information on current population size and current and long-term population trend is lacking because: 1) for most herds, few or no population surveys have been conducted that can be used to compare population size over time; 2) the majority of composition surveys for most herds were conducted in the 1970s and 1980s, and/or during 3-5 year duration radio-telemetry studies in the 1990s and early 2000s, making population trend inferred from calf recruitment indices from those surveys out of date; and 3) since 2010, very few or no surveys have been conducted for most herds although there has been an increase in effort for some herds in the last 3-5 years (see Appendix 3).

Table 13. Population estimates and trends for caribou herds that are wholly or partially in northern British Columbia.

Range[1]		Estimate[1]	Survey year	Current trend[2]	Long-term trend[2]	Total Habitat Disturbance[3] (Anthropogenic habitat disturbance with 500m buffer + fires <40 years)		
						Low elevation	High elevation	Total Range
Atlin	AT	1527[4]	2018	Stable or increase	Increase	18.2	7.0	11.5
Carcross	CA	775[5]	2007	Increase	Increase	18.1	2.5	8.8
Edziza	ED	151[6]	2006	Unknown	Unknown	17.8	6.4	9.5
Finlay	FI	96[7]	2020	Unknown	Unknown	51.9	4.8	16.1
Frog	FR	245[8,9]	2001	Unknown	Unknown	12.0	3.4	4.3
Gataga	GA	265[8,10]	2000	Unknown	Unknown	16.0	4.2	6.8
Horseranch	HO	800-1000[11]	2000	Unknown	Unknown	24.9	4.9	14.4
Level Kawdy	LK	1538	1998	Unknown	Unknown	7.1	2.3	3.0
Liard Plateau	LP	131	2020	Unknown	Decrease	34.3	8.2	20.9
Little Rancheria	LR	800-1600	1999	Unknown	Unknown	23.8	7.2	16.1
Muskwa	MU	917	2004	Unknown	Unknown	46.2	11.1	25.8
Pink Mountain	PM	533[12]	2021	Decrease	Decrease	72.3	15.7	35.4
Rabbit	RA	1300[13]	2007	Unknown	Unknown	15.2	2.8	6.7
Spatsizi	SP	2681	1994	Unknown	Unknown	11.0	4.4	5.5
Swan Lake	SL	600-800	2007	Unknown	Unknown	13.9	8.1	9.4
Thutade	TH	114[8]	2019	Unknown	Unknown	50.4	6.3	11.3
Tsenaglode	TS	450-650[14]	2022	Unknown	Unknown	29.5	9.1	11.4

1 All population estimates were derived from surveys (and extrapolated in most cases).
2 Recent trend based on evaluation of data collected during the most recent generation (9 years – see COSEWIC 2014); Long-term trend based on data collected over 2-3 generations (18-27 years); see data summarized in Appendix 3
3 For transboundary caribou ranges, total habitat disturbance is for the total range (BC + Yukon); see Table 8
4 From BC Caribou Recovery Program (2021); confidence interval: 1077-1927
5 2007 population estimate includes Yukon's Laberge herd (Caribou Recovery Program 2021); confidence interval: 642-935; Carcross population estimate based on a 2019 survey is currently being prepared (Thiessen, pers. comm.)
6 The most recent estimate was based on a survey conducted in March 2006; since then 23 caribou were counted in October 2017 (see Appendix 3) and less than 30 have been counted during surveys in the last few years (N. MacLean, pers. comm.)
7 From Klaczek and Anderson (2020); confidence interval: 65-127
8 Grey lettering indicates number of caribou counted during the survey and does not represent a population estimate
9 In March 2020, 114 caribou were counted during a composition survey (A. Pelletier pers. comm.; see Appendix 3)
10 In March 2007, 138 caribou were counted during a sheep survey in a portion of the Gataga range; see Appendix 3
11 Since 2000, 514 caribou were counted in Feb/Mar 2009 and 133 were counted during a composition survey in fall 2015; see Appendix 3
12 From BC Caribou Recovery Program (2021); confidence interval: 333-879
13 Since 2007, 362 caribou were counted in 2021 (BC Caribou Recovery Program 2021)
14 From Tahltan Wildlife Department (pers. comm. 2022); based on minimum counts during seasonal composition surveys from 2020 to 2022

There is some indication that historical numbers of caribou were larger in northern BC than they are today. Francis & Nishi (2015) mention oral history that indicates that caribou in southern Yukon prior to the Klondike Gold Rush were much more numerous (in the thousands) and widespread than today, and that there was a significant commercial harvest during the Klondike Gold Rush. Also, as a result of wide-scale wolf poisoning programs that were conducted in BC in the 1950s and early 1960s (Hoffos 1987, BC MFLNRO 2014), caribou populations were likely higher in the 1960s and 1970s than they are currently.

Total habitat disturbance (anthropogenic + natural) was highest in the two caribou ranges with declining populations over the long term (Pink Mountain, Liard Plateau) and in the Muskwa range with an unknown population trend (Figure 8). The same general pattern was evident in the low elevation portion of caribou ranges, except that the Muskwa, Thutade and Finlay ranges (all with unknown population trends) were also included in the five ranges with the highest levels of habitat disturbance. Total habitat disturbance in high elevation range was also highest in the two ranges with declining populations and in the Muskwa range (Figure 8). Levels of total habitat disturbance in the total, low and high elevation ranges for the two populations with increasing long-term trends were intermediate relative to other ranges (Figure 8).

Of the two populations that are experiencing known long-term declines in numbers, Pink Mountain had the highest level of anthropogenic habitat disturbance and Liard Plateau had the highest level of fire disturbance across the total range (Figure 9). The Pink Mountain caribou range also had the highest level of anthropogenic habitat disturbance in its low elevation and high elevation ranges of all 17 ranges in northern BC (Figure 9). Levels of both fire and anthropogenic habitat disturbances were much lower in high elevation range, with both declining populations included in three ranges with the highest levels of anthropogenic disturbance (Figure 9).

Muskwa caribou near Muncho Lake in April. (Donald Reid)

Discussion

Our study represents the latest effort to bring together various sources of information to provide an updated status assessment of range and population condition for 17 Northern Mountain Caribou herds in BC. The picture that emerges is one whereby most caribou ranges in the region are affected to some degree by various agents of human and natural habitat disturbance. Meanwhile, our knowledge of population trends in the face of changing circumstances is largely unknown.

Further, some range boundaries did not fully or accurately represent the distribution of caribou. For example, the currently delineated Edziza caribou range is offset in a way that it does not contain the entire mountain block that the Edziza caribou herd occupies. Also, for a number of herds there is insufficient information to delineate range-specific seasonal

Figure 8. Total habitat disturbance (fire<40 years + anthropogenic habitat disturbance) in the total range (top), low elevation portion of the range (centre) and high elevation portion of the range (bottom), for caribou ranges that are wholly or partially in northern British Columbia. See Table 13 for codes for caribou ranges. Symbol colours indicate population trend: green = stable or increasing; red = declining; grey = unknown.

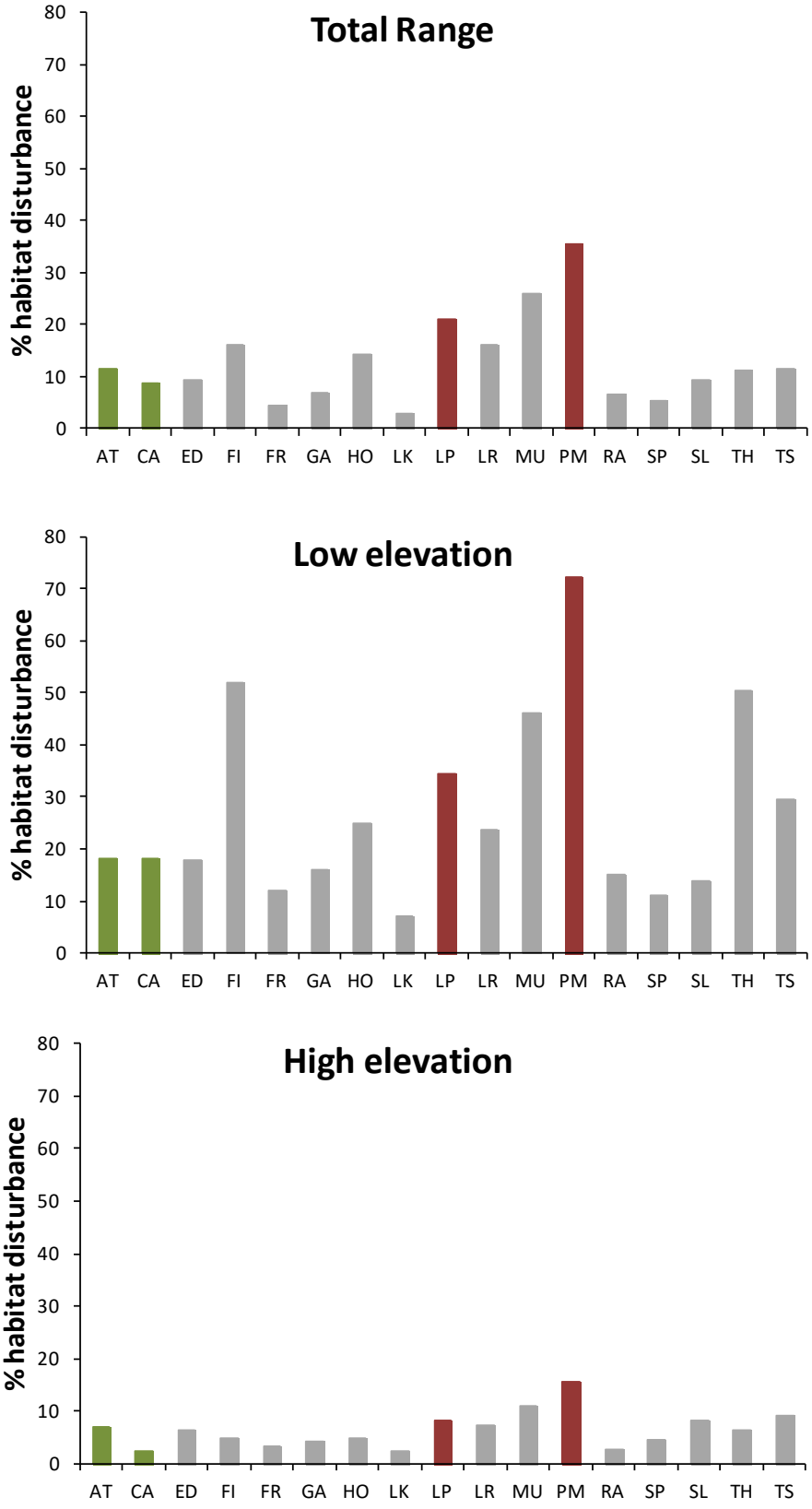
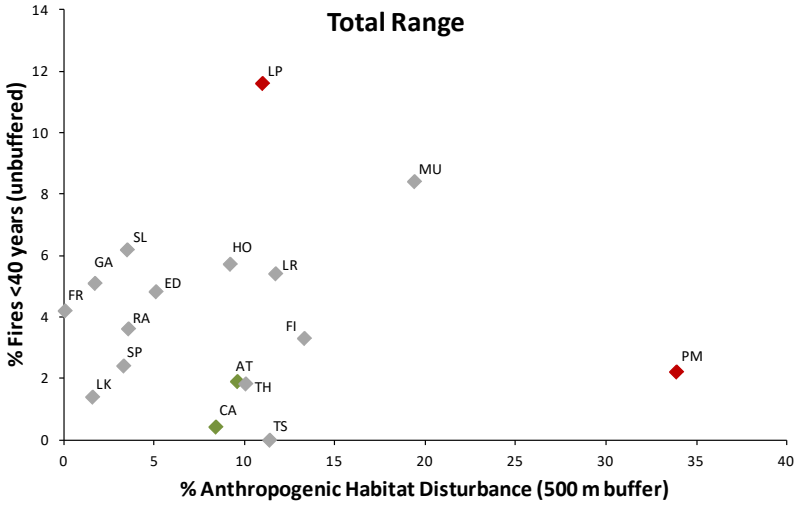
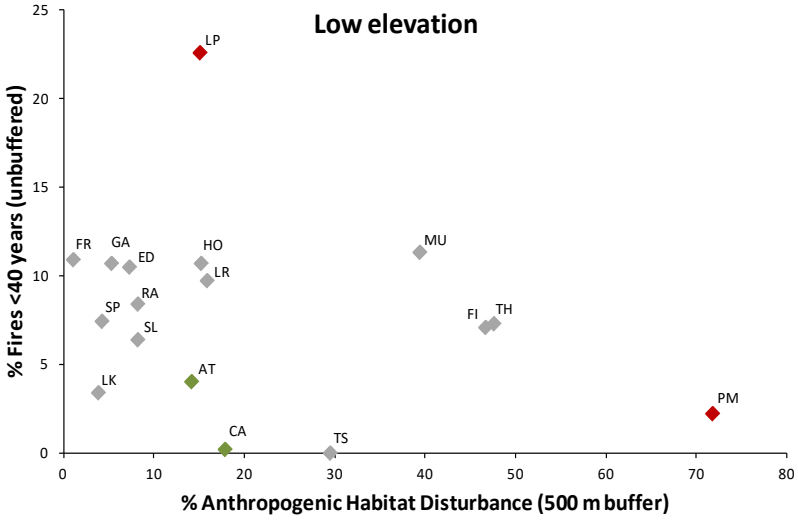
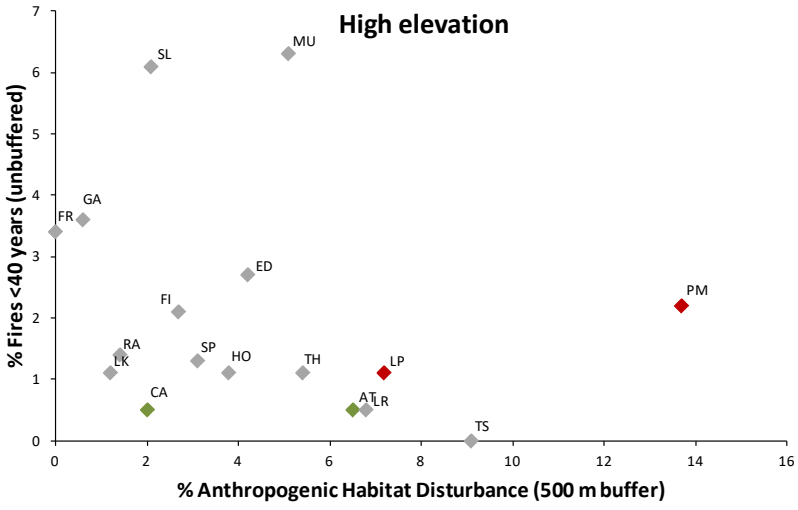


Figure 9. Contribution of fires <40 years (unbuffered) and anthropogenic disturbance (500 m buffer) to total habitat disturbance on the whole range (top), low elevation portion of the range (centre) and high elevation portion of the range (bottom), for caribou ranges that are wholly or partially in northern British Columbia. See Table 13 for codes for caribou ranges. Symbol colours indicate population trend: green = stable or increasing; red = declining; grey = unknown.







ranges. Instead, we used biogeoclimatic zones as a coarse filter approach for distinguishing between low elevation and high elevation ranges, which could potentially result in overestimation of the extent of one or the other.

Accurate range boundaries are necessary to tailor management actions to individual herds and to address their annual and seasonal needs. Range boundaries should not necessarily be expected to remain static, and regular monitoring will be needed to make appropriate amendments to caribou range boundaries, a number of which currently require revisions. Although revised range and seasonal range boundaries would result in different habitat disturbance levels for individual ranges than those presented in this report, the distribution of existing habitat disturbance would not change, nor do we expect the relative levels of habitat disturbance across individual ranges to change. That is, the ranges that currently contain the highest levels of habitat disturbance would still contain the highest levels of habitat disturbance even if boundaries are adjusted. With the inclusion of 20 km and 30 km matrices around each range and around the total area of all the ranges, we have a complete picture of the current distribution of habitat disturbance across all ranges that should also encompass most, if not all, boundary adjustments within the area.

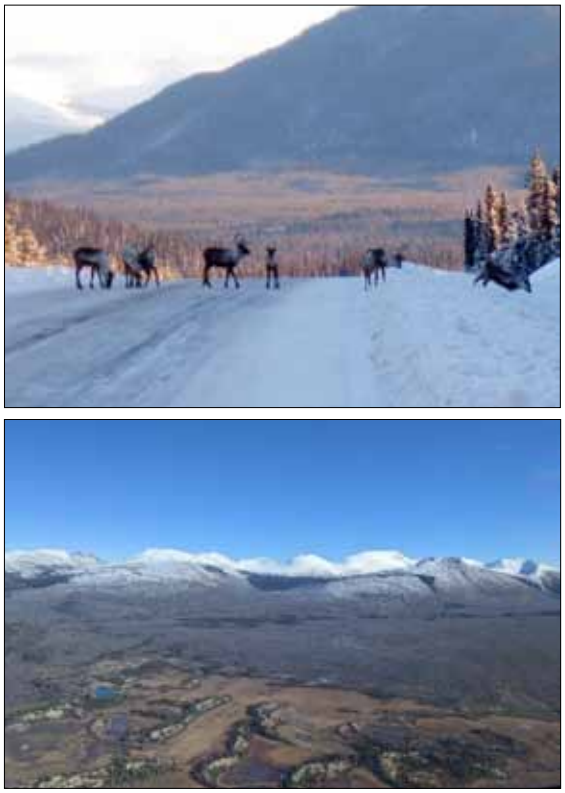
Patterns of habitat disturbance and population status

Although we encountered uncertainties with caribou range boundaries (see above) and other data limitations (see Appendix 4), some distinct patterns of habitat disturbance across the 17 caribou ranges were evident:

- the highest levels of habitat disturbance across the total range were in the Pink Mountain (35%), Muskwa (26%), and Liard Plateau (21%) ranges;
- the lowest levels of habitat disturbance across the total range were in the Frog (4%), Gataga (7%), Level Kawdy (3%), Rabbit (7%) and Spatsizi (6%) ranges;
- total habitat disturbance levels equal or exceed the 35% management threshold on low elevation ranges in five ranges: Liard Plateau, Muskwa, Pink Mountain, Finlay, and Thutade;
- roads and trails were the dominant type of anthropogenic habitat disturbance on all ranges in both high and low elevation ranges;
- other types of anthropogenic habitat disturbance were important in individual ranges including:
    - forest harvesting in the Finlay, Thutade, Horseranch, and Little Rancheria ranges;
    - mines in the Atlin range;
    - seismic lines in the Pink Mountain, Muskwa, and Liard Plateau ranges; and,
    - oil facilities and wells in the Pink Mountain and Muskwa ranges;
- mines and seismic lines were located in both low elevation and high elevation portions of ranges, although seismic lines were more abundant at low elevations than at high elevations;

- forest harvesting, oil facilities, wells, pipelines, powerlines, settlements, agriculture, airstrips and railroads were located primarily in low elevation portions of ranges; and,
- in caribou ranges with <10% total habitat disturbance, fire was the dominant type of habitat disturbance on the landscape, while anthropogenic habitat disturbance played a larger role in caribou ranges with >10% total habitat disturbance.

The role of potential future habitat disturbance must also be considered when assessing the current level of habitat disturbance on caribou ranges in northern BC. Given the reality of a warming climate, wildfires and forest insect outbreaks will also increase. Caribou avoid burns, especially during winter, and therefore increased fire frequency and severity will result in increased levels of winter habitat loss in the short to medium term (Palm et al. 2022). Fire could also potentially contribute to ecological changes. For example, in boreal forests, regeneration following fire in some black spruce (*Picea mariana*) stands has been found to favour deciduous canopy species because of complete or partial failure of black spruce to regenerate soon after the fire (Baltzer et al. 2021). Following fire, any permanent changes to ecosystem condition that negatively affects the ability of the ecosystem to support lichens, the primary winter food source for caribou, may effectively remove portions of caribou habitat from the range.



Top: Roads and other linear features increase mortality risk from predation, collisions, and hunting. (Maria Leung) Bottom: Example of a wildfire that burned 30,212 ha in the Swan Lake caribou range in 2004 (Oliver Holt).

Planning for increases in natural disturbances will be important when considering potential future cumulative habitat disturbance from anthropogenic activities, especially for ranges where disturbance levels already exceed or are nearing habitat management thresholds. Although strategic land use plans cover most of the study area, they are focused on resource management rather than conservation outcomes. Regulatory processes related to the management of natural resources have generally occurred on a sector or project-specific basis (Council of Canadian Academies 2019). This makes it challenging to implement a cumulative effects approach that will be necessary to safeguard caribou and other wide-ranging and sensitive species in the face of environmental change.

While amount of habitat disturbance is an important indicator for assessing the level of potential impacts on caribou, spatial distribution of habitat disturbance also needs to be considered. Even low levels of habitat disturbance could result in significant impacts if they occur in sensitive habitats. For example, an active mine or large exploration camp that is located in important calving range, even if it is serviced by a single road, could lead to increased mortality risk if access to calving range is improved for predators and/or caribou are displaced into habitats with higher predation risk. Due to limited information available on seasonal ranges in many of the caribou ranges, we were not able to assess the significance of spatial distribution of habitat disturbance in each range.

Although population size and trend data are limited for the 17 caribou ranges in northern BC, the two populations that were identified as declining over the long term were two of the three with the highest levels of habitat disturbance over the whole range, and among the five with the highest levels of habitat disturbance in the low elevation portions of their ranges. These results are consistent with studies that have linked Boreal Caribou population condition to habitat disturbance (e.g. EC 2011, Rudolph et al. 2017, Johnson et al. 2020). Reid et al. (2013) found that population growth rate models based on habitat disturbance developed for Boreal Caribou reasonably approximated population status of the Carcross caribou population, but were limited by their inability to deal with seasonal ranges and permanent shrub or sparsely vegetated habitats. Johnson et al. (2020) found that Boreal Caribou populations were more vulnerable on ranges where habitat disturbance was primarily due to anthropogenic habitat disturbance. Although Boreal Caribou models may not be useful in predicting population growth rates for Northern Mountain Caribou, our results suggest that where population trend information is available, that higher levels of habitat disturbance, especially anthropogenic, are associated with declining population trends.

Both herds with increasing population trends (i.e. Carcross and Atlin) are part of the Southern Lakes Caribou Recovery Program, which, since 1993, in Yukon, has included elimination of licensed hunting and a voluntary cessation of hunting by First Nations. The Southern Lakes area is the most densely populated portion of Yukon, and overhunting was thought to be the main cause of caribou declines (Farnell 2009). Following the elimination of Yukon harvests, and along with continued intense fire suppression in Yukon, populations increased (Farnell 2009), and appear to have continued to increase (see Table 13). Levels of anthropogenic disturbance and access in most of the other caribou ranges in our study area (except for the northeastern and southeastern ranges) is currently lower than in the Southern Lakes area, and therefore current potential for overhunting in those ranges is also likely lower.

Management actions focused on mountain-dwelling caribou in western Canada have often been initiated once populations have already declined or been reduced to small numbers, necessitating intensive measures (Ray et al. 2015, Johnson et al. 2015, Palm et al. 2020). Many Northern Mountain Caribou ranges in northern BC remain in relatively intact condition, but habitat disturbance is higher on some ranges, especially the southern and eastern-most ranges. Habitat disturbance in the five caribou ranges in the eastern and southeastern portion of the study area (Liard Plateau, Muskwa, Pink Mountain, Finlay, Thutade) is already at high levels, which increases the importance of ranges with currently lower levels of habitat disturbance and strengthens the case for proactive attention. Special

Concern species are defined under SARA as those that "may become threatened or endangered because of a combination of biological characteristics and identified threats". One of three purposes of the Act is "to manage species of special concern to prevent them from becoming endangered or threatened".

In southern BC, many caribou populations are declining, in some places dramatically, and becoming increasingly isolated as habitat disturbance continues to increase in and adjacent to their ranges (Palm et al. 2020; Nagy-Reis et al. 2021). By contrast, there is a unique opportunity to conserve caribou in northern BC while large areas of intact range with minimal or no anthropogenic habitat disturbances still remain. In this region, conserving caribou will require a coordinated approach across all ranges; making caribou conservation a priority; and, restricting anthropogenic habitat disturbance from core areas. The existing system of provincial protected areas protects portions of a number of the 17 caribou ranges in this study, but important habitat for Northern Mountain Caribou is not well represented in the eastern portion of the study area (Weaver 2019).

Dune Za Keyih Provincial Park in northern BC includes portions of the Frog, Gataga and Rabbit caribou ranges, and a portion of the low density area. (© Garth Lenz)

We know from experience that recovering caribou populations once they are declining is very difficult and expensive, requires the application of multiple coordinated recovery actions, and so far has resulted in limited success. In BC, recovery efforts involving two or more recovery actions (i.e. predator management, maternity penning, primary prey management, habitat restoration) have helped to avoid extirpation of some herds (BC Caribou Recovery Program 2019; Serrouya et al. 2019), but recovery to self-sustaining populations has yet to be achieved. Complete restoration of caribou habitat will take decades even with concerted effort because of the lag time between when restoration activities occur, and when disturbed (and even subsequently restored) areas are mature enough to become

less attractive to other ungulates, and to start exhibiting characteristics of preferred caribou habitat (e.g., lichens for forage, canopies for snow interception). Therefore, not disturbing habitat in the first place is the most effective method for conserving caribou and their habitat in both the short and long terms.

Recommendations

The federal Special Concern status of Northern Mountain Caribou (including those in Yukon and the NWT) required the development of a management plan under SARA, which was issued 10 years ago (EC 2012a). That plan recommended a series of management actions under eight objectives that called for coordinated actions with a goal "to prevent the NMP[2] from becoming threatened or endangered, by having responsible agencies cooperatively work together to care for caribou and their habitat." Although the federal Minister of the Environment is obliged under SARA to monitor the implementation of this plan and formally assess progress every five years, to our knowledge this has not occurred to date. Although the BC government acknowledges growing concerns with the condition of Northern Mountain Caribou populations (Government of BC 2022b), the conservation of these herds remains to be reliant only on sector-specific habitat management "tools".

Within this context, we offer the following recommendations to help shift the existing regulatory and policy regimes to ones that provide stronger limits on the amount and spatial extent of landscape disturbances generally (Yahey v British Columbia, 2021) and thereby lessen the risk of Northern Mountain Caribou becoming threatened or endangered (EC 2012a). In view of the BC *Declaration on the Rights of Indigenous Peoples Act* (2020) and the province's Declaration on the Rights of Indigenous Peoples Act Action Plan (Government of BC 2022c), all First Nations having Traditional Territories overlapping the ranges of Northern Mountain Caribou in northern BC will need to be consulted to garner input of knowledge about caribou and on how Indigenous-led conservation efforts could improve future conditions for Northern Mountain Caribou in northern BC.

1. **Make caribou conservation a priority.** Among wildlife species in northern BC, caribou are one of the most sensitive to the cumulative impacts of anthropogenic and natural habitat disturbances. Caribou habitat is defined by extensive areas of mature and undisturbed landscapes (COSEWIC 2014) and many areas in northern BC are relatively undisturbed. Monitoring, managing and protecting habitat for caribou today will be essential if we want to avoid the need to conduct intensive and expensive recovery actions in the future, which may result in only limited success and require a long-term commitment. While there are important information gaps, caribou are well-studied relative to other less-visible elements of biodiversity, and management efforts that successfully maintain caribou populations should also better preserve animal assemblages (Bichet et al. 2016).

[2] NMP = Northern Mountain Population as defined by the Northern Mountain National Ecological Area (see EC 2012a)

2. **To better ensure persistence of Northern Mountain Caribou in northern BC, manage all 17 populations and ranges together as a unit**, such that the land management and habitat disturbances on one caribou range are considered in terms of their implications to the whole system, rather than just to the individual caribou population and range. Managing all populations as one unit will also foster a stronger focus on maintaining connectivity between ranges.

3. **Develop and implement a better system for tracking and sharing data of anthropogenic habitat disturbance (and habitat recovery) for all natural resource extraction sectors, to support cumulative effects analysis and management**. Currently, availability and accuracy of spatial and temporal data for anthropogenic habitat disturbances varies among natural resource sectors and among different types of habitat disturbances. As a result of Yahey v British Columbia (2021), requirements for conducting cumulative effects assessments are potentially expanding beyond only those for Environmental Assessments for major projects. A reliable source of consistent and readily available information on anthropogenic habitat disturbances will be essential for enabling all industrial sectors to assess cumulative effects on caribou in northern BC.

4. **Protect caribou habitat to provide deliberate and sustained protection of key seasonal ranges and connectivity between populations**. There are a number of existing Indigenous-led, and other proposals for protected areas (e.g., Kaska Dena Council 2019, Weaver 2019) that address protection of important caribou habitat. Where feasibility of protected areas is limited, use areas of temporary (e.g., 30 years) deferrals from industrial use to conserve sufficient habitat (e.g., 300,000 ha) to maintain caribou herds in a self-sustaining condition. Temporary deferral areas could be opened to industrial interests once adjacent disturbed areas have been fully restored to conditions suitable for use by caribou.

5. **Improve our understanding of caribou seasonal range and habitat use, and seasonal range and habitat requirements.** A better understanding of seasonal range and habitat use and requirements is essential to clarify understanding of the implications of habitat disturbances on those seasonal ranges and for assessing and managing cumulative effects. Information should be gathered in an approach that considers all forms of available knowledge and information together. The approach should include two phases: 1) immediately compile all currently available information to update our understanding; and, 2) collect and analyze more technical information and/or more Indigenous Knowledge as needed.

6. **Develop and implement priorities for habitat restoration across all 17 ranges** using results from this study. To determine priorities, an approach could be used similar to that used in the tactical plans for restoration of habitat for the Northern and Southern Groups of Southern Mountain Caribou (Cichowski et al. 2021a,b).

7. **Improve monitoring of caribou population status** through more extensive and regular population surveys to support assessment of habitat disturbance effects on populations.

    - Develop a monitoring strategy for all 17 ranges that enables consistent survey efforts so that trends can be evaluated over time.

    - Adopt standards and a protocol for collecting population data, including methods for calculating population estimates, data that should be included in reports (e.g. survey composition numbers, adult mortality rates for radio-collared caribou studies [including information on how they were calculated]), and a schedule for data collection and reporting.

8. **Revise caribou range boundaries** where needed to better reflect currently available information on caribou distribution and re-run habitat disturbance analyses using the updated range boundaries.

    - Revise total range boundaries (where needed) and delineate seasonal ranges using both technical information and Indigenous Knowledge.

    - If knowledge gaps still exist, revise portions of boundaries where information is sufficient to do so based on best available information and acknowledge that additional boundary revisions may be needed once additional information is collected.

    - Once caribou range boundaries and range-specific seasonal ranges have been updated, compare the spatial dataset to satellite imagery to identify any potential missing habitat disturbances.

9. **Enhance the spatial dataset collected for this study** so that linear features can be measured by length. We were unable to do so because the data, collected from multiple sources, did not distinguish among types of linear features, not all features were represented in their entirety, and some features were duplicated many times. Having a measure of length would help in tactical plans for habitat restoration.

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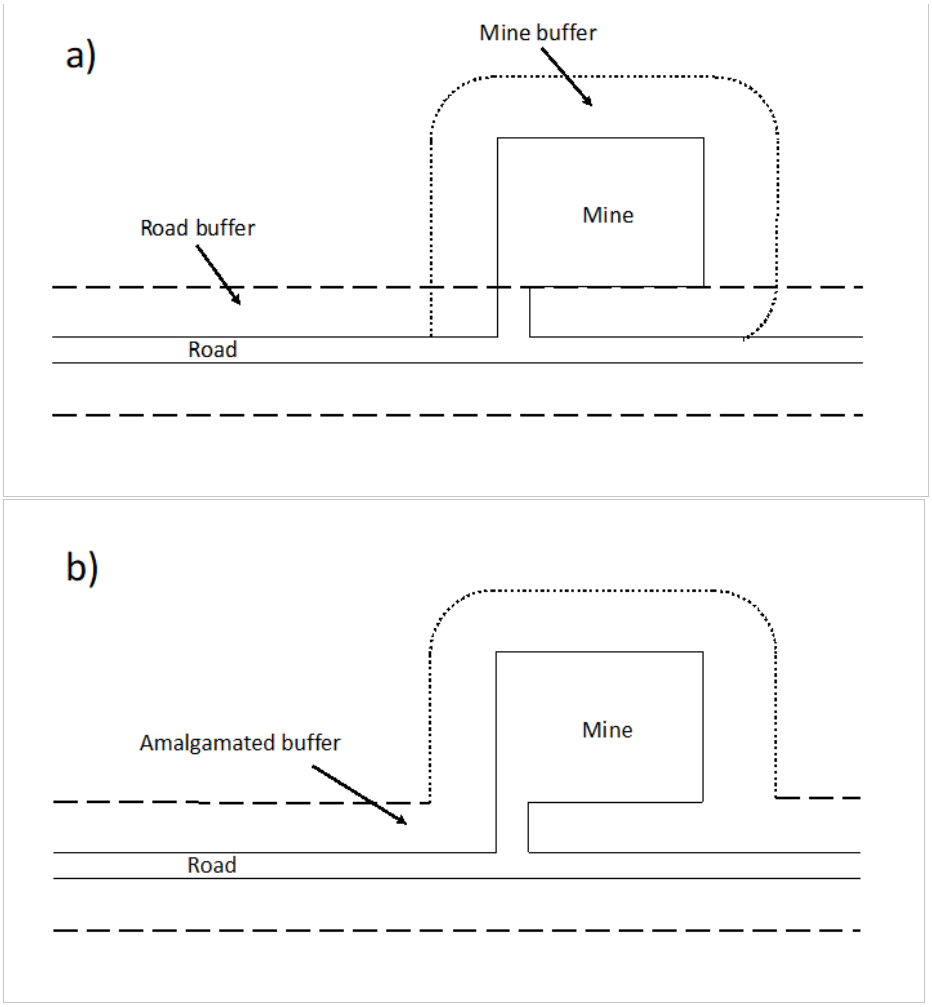
Appendix 1. Amalgamating overlapping buffers

The following two illustrations show a) individual buffers around individual anthropogenic habitat disturbances resulting in overlaps of portions of those buffers, and b) the amalgamated buffer, which is the result of dissolving the portions of the boundaries of individual buffers that lie within the combined buffer area.



Appendix 2. Summary of spatial layers used in the habitat disturbance analysis

Table A1. Spatial data sources for low versus high elevation range lines.

Name	Notes	Source
u_bc_bec_v10_170412_Clip_Dissolve2	High Elevation zones were selected: BAFA, CMA, ESSF, MH, SWB	https://catalogue.data.gov.bc.ca/dataset/biogeoclimatic-ecosystem-classification-bec-map
u_AK_HighLow	Small portion of the study area 30km buffer is in Alaska (40,847ha, 0.16%), high and low elevation areas were approximated with hand-digitization based on Bing Maps imagery using the adjacent BEC mapping as a guide	digitized from Bing Maps imagery
u_YT_HighLow_S05_erase	Good partner to BEC for areas north of 60N, selected Boreal High, Boreal Subalpine, and Boreal Alpine Tundra classes to approximate high-elevation range	ftp://ftp.geomaticsyukon.ca/GeoYukon/Biophysical/Bioclimate_Zones_and_Subzones/

Table A2. Spatial data sources for habitat disturbances.

Layer	Class	Data Type	Used in Project	Description	Source
Raw_YT_Agriculture_Land_Dispositions	Agriculture	Polygon	Yes	Agricultural footprints in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Land_Tenure/Agriculture_Land_Dispositions/
Raw_BC_btm_agriculture	Agriculture	Polygon	Yes	Agricultural footprints in BC	https://catalogue.data.gov.bc.ca/dataset/baseline-thematic-mapping-present-land-use-version-1-spatial-layer
Raw_BC_airports_point	Airstrip	Point	For Reference	Locations of airstrips in BC	https://catalogue.data.gov.bc.ca/dataset/bc-airports/resource/03fdc03b-5487-4a2e-b7e3-a82e53d-b9ea1
Raw_BC_airports_point	Airstrip	Point	Yes	Locations of airstrips in BC	features are either digitized from Bing Maps imagery or copied from 'urban' features in BTM mapping
Raw_YT_Forest_Openings_Pre_1990	Cutblocks	Polygon	Yes	Cutblocks pre-1990 in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Forestry/Forest_Openings_Pre_1990/
Raw_YT_Forest_Openings	Cutblocks	Polygon	Yes	post-1990 cutblocks in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Forestry/Forest_Openings/
Raw_BC_consolidated_cutblocks_171123	Cutblocks	Polygon	Yes	Harvested areas in BC	https://catalogue.data.gov.bc.ca/dataset/harvested-areas-of-bc-consolidated-cutblocks-
Raw_YT_dams	Dam	Line	Yes	Locations of dams in YT	2 features digitized from Bing maps imagery
Raw_BC_dams	Dam	Line	Yes	Locations of dams in BC	https://catalogue.data.gov.bc.ca/dataset/b-c-dams/resource/c361739f-5514-457f-866a-b832ebaf06b3
Raw_YT_Placer_Land_Use_Permits_50k	Mining	Polygon	Yes	Placer mining land permits, active and expired	ftp://ftp.geomaticsyukon.ca/GeoYukon/Mining/Placer_Land_Use_Permits_50k/
Raw_YT_Gravel_Pits_25k	Mining	Point	No	Locations of gravel pits associated with roads, not polygonal and doesn't add a lot of area, might not contribute much over roads alone	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Gravel_Pits_25k/
Raw_YT_Cultural_Features_Mining_Areas_50k	Mining	Polygon	Yes	Mining perimeters on the landscape, mostly gravel pits	ftp://ftp.geomaticsyukon.ca/GeoYukon/Culture_and_Heritage/Cultural_Features_Polygon_50k/
Raw_BC_SKE_MineFP_Jan2018	Mining	Polygon	Yes	Mine footprints in NW BC digitized by Blair Ells BC FLNRO	N/A
Raw_BC_btm_mining	Mining	Polygon	Yes	Mine footprints in BC	https://catalogue.data.gov.bc.ca/dataset/baseline-thematic-mapping-present-land-use-version-1-spatial-layer
u_veg_comp_lyr_r1_poly_abiotic_disturbance_only	NaturalAbiotic	Polygon	Yes	VRI derived abiotic disturbance	https://catalogue.data.gov.bc.ca/dataset/vri-forest-vegetation-composite-polygons-and-rank-1-layer
Raw_YT_Forest_Health_Abiotic_Disturbance	NaturalAbiotic	Polygon	Yes	Abiotic forest disturbance in YT (e.g. flooding, windthrow, etc.)	https://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/2016/
Raw_YT_Forest_Health_Aerial_Overview_Pest_Disturbance	NaturalPest	Polygon	Yes	Forest pest disturbance in YT (records go back to 1994, none in our area before 2009 for bark beetles with a severe or very severe infestation rating)	ftp://ftp.geomaticsyukon.ca/GeoYukon/Forestry/Forest_Health_Aerial_Overview_50k/
Raw_BC_Forest_Health_Aerial_Overview_Pest_Disturbance	NaturalPest	Polygon	Yes	Forest pest disturbance in BC, annual layers combined and any bark beetle polygon (FHF = IBB, IBM, or IBS) with a severe or very severe infestation level was considered a disturbance, records go back to 1999, no records meeting criteria show up in the study area before 2000	https://www.for.gov.bc.ca/ftp/HFP/external/!publish/Aerial_Overview/
Raw_YT_Utilities_Pipelines_50k	Oil and Gas	Line	Yes	Pipelines in YT, buffered by 15m (30m width) to closely simulate right-of-way to allow combination into single layer with BC data	ftp://ftp.geomaticsyukon.ca/GeoYukon/Utilities_and_Communication/Utilities_Line_50k/
Raw_YT_Oil_and_Gas_Wells_50k	Oil and Gas	Point	Yes	Locations of oil and gas well heads, points buffered by 50m to approximate clearings as per EC well site procedure	ftp://ftp.geomaticsyukon.ca/GeoYukon/Oil_and_Gas/Oil_and_Gas_Wells_50k/
Raw_BC_well_surface_hole_locations_permitted	Oil and Gas	Point	Yes	Oil and gas well surface hole locations, points buffered by 50m to approximate clearings as per EC well site procedure	https://data-bcogc.opendata.arcgis.com/datasets/9149cb556e694617970a5774621af8be_0
Raw_BC_sump_locations	Oil and Gas	Point	Yes	Oil and gas sump locations in BC, points buffered by 50m to approximate clearings as per EC well site procedure	https://data-bcogc.opendata.arcgis.com/datasets/01df1e822ff84ddc8d4808e68b322101_0
Raw_BC_Pipeline_Rights_of_Way_Permitted	Oil and Gas	Polygon	Yes	Oil and gas pipelines in BC	https://data-bcogc.opendata.arcgis.com/datasets/6434890915cd4d25817037c0600040b1_1
Raw_BC_Geophysical_Ancillary_Points	Oil and Gas	Point	No	Oil and gas ancillary geophysical point locations (e.g. clearings)	https://data-bcogc.opendata.arcgis.com/datasets/7fd246f6c212469eb07acf6467b2f8bd_0
Raw_BC_Facility_Locations_Pre2016	Oil and Gas	Point	Yes	Oil and gas facility point locations in BC, points buffered by 50m to approximate clearings as per EC well site procedure	https://data-bcogc.opendata.arcgis.com/datasets/e2014a76454545abb0509afa2444876b_0
Raw_BC_Associated_and_Ancillary_Areas_Permitted	Oil and Gas	Polygon	Yes	Oil and gas ancillary features in BC (e.g. campsites, workspaces, deck sites, etc.)	https://data-bcogc.opendata.arcgis.com/datasets/bbd11f8029a949fb9ce6012f32111e31_1
Raw_YT_Railroads_50k_Canvec	Railway	Line	Yes	Railroads in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Railroads_50k_Canvec/
Raw_BC_NRWN_tracks_bc_Clip	Railway	Line	Yes	Railroads in BC	http://ftp.geogratis.gc.ca/pub/nrcan_rncan/vector/geobase_nrwn_rfn/bc/
Raw_YT_Reservoirs	Reservoir	Polygon	Yes	Locations of man-made water reservoirs in YT	2 features digitized from Bing maps imagery
Raw_BC Reservoirs	Reservoir	Polygon	Yes	Locations of man-made water reservoirs in BC	https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-lakes/resource/9595d129-03cc-40bb-b216-6ce3a1337143
Raw_YT_Vegetation_Inventory_Roads_40k	Roads	Line	Yes	Forestry roads in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Forestry/Vegetation_Inventory_Roads_40k/
Raw_YT_Roads_National_Road_Network	Roads	Line	Yes	Federal NRN road network in YT and BC	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Roads_National_Road_Network/
Raw_YT_Bridges_25k	Roads	Point	No	point location of bridges in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Bridges_25k/
Raw_YT_Blocked_Road_Passages_National_Road_Network	Roads	Point	No	impassable points on existing roads in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Blocked_Road_Passages_National_Road_Network/
Raw_BC_u_FTN_RD_SGM_line_Clip	Roads	Line	Yes	Forest tenure road segments in BC	https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-segment-lines
Raw_BC_SKE_Roads_Jan2018	Roads	Line	Yes	Mining Roads digitized by Blair Ells BC FLNRO	N/A
Raw_BC_Petroleum_Development_Roads_Pre2006_Clip	Roads	Line	Yes	Petroleum development roads in BC approved pre-20061030	https://data-bcogc.opendata.arcgis.com/datasets/5861465cbe5649de93d521117cdf3a6a_0
Raw_BC_OGC_Road_Segments_Permitted_Clip	Roads	Line	Yes	Road centre-lines associated with oil and gas approved after 20061030	https://data-bcogc.opendata.arcgis.com/datasets/b073031723eb44578e1e881939757fe2_0
Raw_BC_DRA_Transport_Line_Clip	Roads	Line	Yes	Roads in BC	https://catalogue.data.gov.bc.ca/dataset/digital-road-atlas-dra-master-partially-attributed-roads
Raw_YT_Oil_and_Gas_Seismic_Lines	Seismic	Line	Yes	Seismic lines in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Oil_and_Gas/Oil_and_Gas_Seismic_Lines/
Raw_YT_Cut_Lines_50k_Canvec	Seismic	Line	Yes	Cut lines in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Cut_Lines_50k_Canvec/
Raw_BC_Geophysical_Plans_20022006	Seismic	Line	Yes	Seismic lines in BC	https://data-bcogc.opendata.arcgis.com/datasets/c27b9f1a3754436cb7816b27ece5cb28_0
Raw_BC_Geophysical_Plans_19962004	Seismic	Line	Yes	Seismic lines in BC	https://data-bcogc.opendata.arcgis.com/datasets/81d619920b6848e9a3f0f0201d126cae_0
Raw_BC_Geophysical_Lines_Permitted	Seismic	Line	Yes	Seismic lines in BC	https://data-bcogc.opendata.arcgis.com/datasets/bd0a685c1f614b4b89ace6564e5e3cc4_0
Raw_YT_Yukon_Communities	Settlements	Point	For Reference	Locations of Yukon Communities	ftp://ftp.geomaticsyukon.ca/GeoYukon/Reference/Yukon_Communities/
Raw_YT_Places_1M	Settlements	Point	For Reference	Locations of communities across the study area	ftp://ftp.geomaticsyukon.ca/GeoYukon/Base/Places_1M/
Raw_YT_Municipal_Boundaries	Settlements	Polygon	No	Municipal boundaries in YT, poor reflection of developed area	ftp://ftp.geomaticsyukon.ca/GeoYukon/Land_Planning/Municipal_Boundaries/
Raw_YT_Cultural_Features_Camps_50k	Settlements	Polygon	Yes	Camps in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Culture_and_Heritage/Cultural_Features_Polygon_50k/
Raw_YT_Cultural_Features_BuiltUp_Areas_50k	Settlements	Polygon	Yes	Built up areas in YT e.g. dumps, buildings, runways, etc., digitized 29 missing features noticed in the vicinity of Whitehorse	ftp://ftp.geomaticsyukon.ca/GeoYukon/Culture_and_Heritage/Cultural_Features_Polygon_50k/
Raw_YT_Community_Boundaries	Settlements	Polygon	For Reference	Community boundaries in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Land_Planning/Community_Boundaries/
Raw_YT_Communities_and_Subdivisions_Surveyed	Settlements	Polygon	Yes	Built up areas in YT e.g. subdivisions	ftp://ftp.geomaticsyukon.ca/GeoYukon/Land_Tenure/Communities_and_Subdivisions_Surveyed/
Raw_BC_btm_urban	Settlements	Polygon	Yes	Footprint for human occupation	https://catalogue.data.gov.bc.ca/dataset/baseline-thematic-mapping-present-land-use-version-1-spatial-layer
Raw_YT_Whitehorse_Trails_10k	Trails	Line	Yes	Trails in and around Whitehorse	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Whitehorse_Trails_10k/
Raw_YT_Trails_50k_Canvec	Trails	Line	Yes	Trails in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Trails_50k_Canvec/
Raw_YT_Trails_50k	Trails	Line	Yes	Trails in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Transportation/Trails_50k/
RAW_BC_Trails_FTN_REC_LN	Trails	Line	Yes	Trails in BC	https://catalogue.data.gov.bc.ca/dataset/forest-tenure-recreation-lines
Raw_YT_Utilities_Transmission_Line_50k	Transmission Lines	Line	Yes	Electricity transmission lines in YT	ftp://ftp.geomaticsyukon.ca/GeoYukon/Utilities_and_Communication/Hydro_Energy/
Raw_YT_Utilities_Polygon_50k	Transmission Lines	Polygon	No	Transformer station outside of Whitehorse, only one feature in a residential area, inconsequential	ftp://ftp.geomaticsyukon.ca/GeoYukon/Utilities_and_Communication/Utilities_Polygon_50k/
RAW_BC_u_bc_transmission_lines_Clip	Transmission Lines	Line	Yes	Electricity transmission lines in BC	https://catalogue.data.gov.bc.ca/dataset/bc-transmission-lines
Raw_YT_Fire_History	Wildfire	Polygon	Yes	Wildfire boundaries in YT <=40 years old, and <=50 years old (evaluated separately)	ftp://ftp.geomaticsyukon.ca/GeoYukon/Biophysical/Fire_History/
Raw_BC_u_mofr_fire_polygons	Wildfire	Polygon	Yes	Wildfire boundaries in BC <=40 years old, and <=50 years old (evaluated separately)	https://catalogue.data.gov.bc.ca/dataset/fire-perimeters-historical
Raw_BC_C_FIRE_PLY_2017_clip	Wildfire	Polygon	Yes	Current wildfire boundaries in BC from 2017	https://catalogue.data.gov.bc.ca/dataset/bc-wildfire-fire-perimeters-current-internal

Appendix 4. Data limitations

In addition to issues with range boundaries, the spatial data layers for roads and trails resulted in duplication of data in some cases, and did not allow us to distinguish between roads and trails, which has bearing on use (e.g., motor vehicles vs. hiking and horses). Also, population size and trend information was limited, making it difficult to assess population status as it related to habitat disturbance.

For roads and trails, although some linear features were duplicated in the spatial layers we used, the application of the 500 m buffer around linear features eliminated double-counting of those features, since they were all incorporated into one amalgamated buffer. As a result, we could only represent the extent of linear features as an area-based metric, and we were not able to report extent of linear features as a distance. However, because the habitat disturbance thresholds that we were using also included linear features as an area-based metric, representing linear features this way did not compromise our analysis.

Another limitation for roads and trails was that we were unable to distinguish between roads and trails using the spatial datasets. Although some data distinguished between the two, it was not consistent across all data. As a result, we had to combine roads and trails into one category since it was beyond the scope of this project to investigate each linear feature to identify whether it was a road or a trail.

Although roads/trails are the dominant anthropogenic habitat disturbance on caribou ranges in northern BC, there are additional ATV/UTV trail networks that are not represented in the BC government's datasets, and therefore additional effort will be needed to identify and map them (B. Jex, pers. comm. 2019).

Ideally, we would have sufficient data to compare levels of habitat disturbance on individual ranges to population status. However, due to the limited information on population size and status, we were constrained in what inferences we could make from the data.

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