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DEVELOPING AND MONITORING THE EFFICACY OF FUNCTIONAL RESTORATION OF LINEAR FEATURES FOR BOREAL WOODLAND CARIBOU – 1-YEAR SUMMARY OF MONITORING DATA

PARKER CARIBOU RANGE

Report Prepared for:
BC OIL AND GAS RESEARCH AND INNOVATION SOCIETY

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Report prepared for BC Oil and Gas Research and Innovation Society, April 2017

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EXECUTIVE SUMMARY

Environment Canada and the British Columbia Ministry of Environment have identified that habitat restoration is required to sustain woodland caribou populations in northeast British Columbia. However, woodland caribou habitats require decades to recover to pre-disturbance conditions. Functional restoration is therefore needed as an interim strategy to mitigate impacts while caribou habitats recover. The functional restoration of linear disturbances may benefit woodland caribou by reducing predator movement rates and enforcing spatial separation between caribou and predators.

The overarching goals of our research program are to develop (1) a non-invasive mitigation strategy that facilitates the functional restoration of linear disturbances at scales relevant to caribou demography, and (2) a monitoring design to measure the merit of mitigation strategies based on animal response data. The study follows a before after control impact design that measures how predators use a caribou range in both space and time. This entails monitoring the spatiotemporal patterns of large mammal use across an entire caribou range for 1 year under both disturbance and undisturbed conditions, deploying functional restoration treatments on linear feature disturbances, and then monitoring the rates of animal use following treatment deployment.

We developed a sampling design and deployed 85 motion-sensing monitoring cameras to monitor large mammal use on disturbed (linear features) and undisturbed (game trails) conditions across the Parker Caribou Range. Motion-sensing cameras collected continuous data from November 2015 to November 2016 to measure rates of large mammal use prior to the implementation of functional restoration mitigations (January to March 2017). Continued monitoring in the future will measure the efficacy of functional restoration treatments that were recently applied in the Parker Caribou Range.

Key results from the first year of remote-sensing camera monitoring data include (1) the rates of large mammal habitat use varied by species and season, (2) the mean rates of habitat use by wolves, caribou and moose were negatively related to snow depth, (3) the mean rates of habitat use by all of the large mammals being monitored, except for black bears, varied by feature type (linear feature or game trail), (4) winter snowmobile activity resulted in a packed snow condition on some linear developments and winter wolf habitat use was strongly tied to linear developments with a packed snow condition regardless of the habitat type, (5) the rates of use by caribou, moose, wolves, and black bears increased with speed of travel metrics, and (6) the mean rate of habitat use by caribou increased with lichen cover abundance. Overall, our monitoring program increased understanding of large mammal habitat use in the Parker Range and will be a key tool to inform future functional restoration works.

ACKNOWLEDGEMENTS

We would like to thank the BC Oil and Gas Research and Innovation Society (BC OGRIS) for funding this research program, and the Research and Effectiveness Monitoring Board (REMB) for providing feedback on the research program.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 PROJECT OBJECTIVES

The goal of this research program is to inform the development of mitigation strategies that facilitate the functional restoration of linear disturbances in the Parker Caribou Range by developing a complementary monitoring design to measure mitigation success using animal data.

2 PROJECT DESCRIPTION

Environment Canada and the British Columbia Ministry of Environment have identified that habitat restoration is required to sustain woodland caribou populations in northeast British Columbia. However, woodland caribou habitats require decades to recover to pre-disturbance conditions. Wilson (2015) identified that functional restoration is needed as an interim strategy to mitigate impacts while caribou habitats recover. Wilson defines functional restoration as the outcome of a management action that mitigates a risk from ecosystem disturbances.

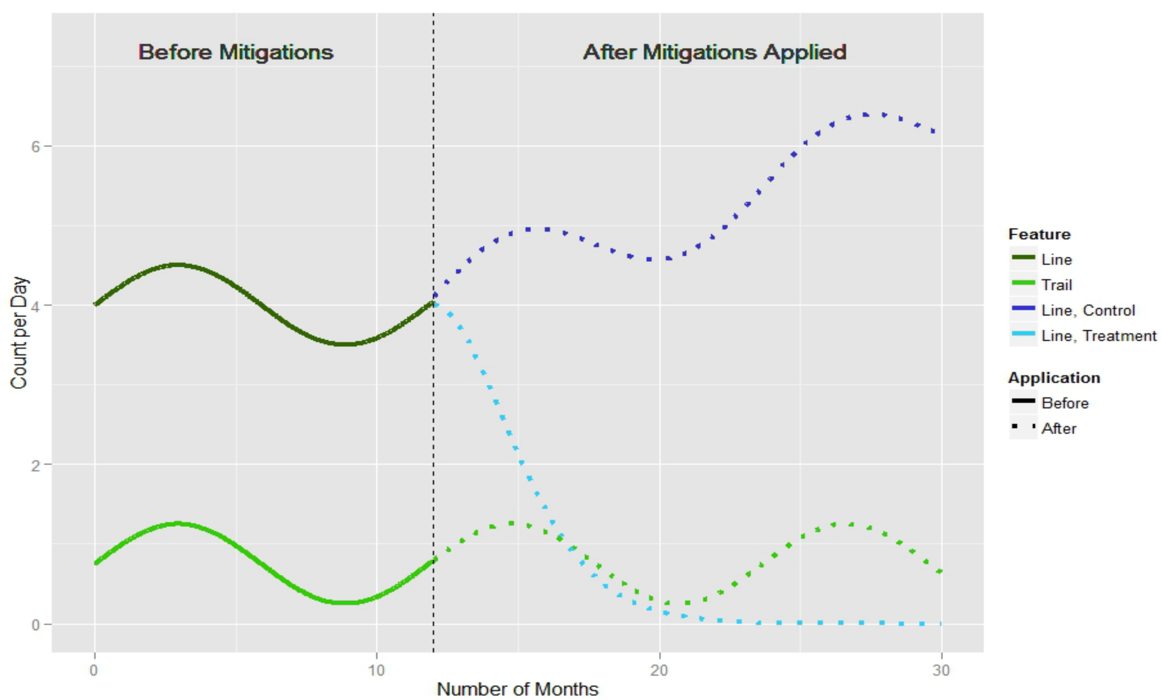
Caribou habitats have low overlap with predators. However, linear disturbances can reduce spatial separation and increase predator efficiency (DeCesare 2012) increasing encounters between predators and woodland caribou (Whittington et al. 2011; McKenzie et al. 2012). Studies show that predation is the most common source of mortality in adult woodland caribou (McLaughlin et al. 2005), and predation rates are influenced by encounter rates and population size (Hebblewhite et al. 2005; Messier 1994). Thus, mitigations that reduce encounter rates by reducing predator movement or enforcing spatial separation between caribou and predators must, necessarily, reduce predation given constant population size.

A pilot study conducted by Keim et al. (2014) shows that log blocking treatments applied on linear disturbances can reduce use by wolves along 200 m segments of linear features. However, it is unclear if such mitigations disrupt the functional response between predators and caribou at larger spatial scales relevant to caribou demography (Wilson 2015). A Habitat Restoration Pilot Program (Golder Associates Ltd.; BCIP-2016-16) aimed at implementing large-scale habitat restoration is currently being conducted within the Parker Caribou Range. This research program facilitates the restoration pilot by providing animal use data, which can be used to guide the design of restoration treatments (i.e., placement and prescription). More broadly, the research program aims to provide non-invasive methods to recover and monitor functional woodland caribou habitat across portions of the Parker Caribou Range. The program is using motion-sensing cameras to collect habitat use data continuously across seasons on humans and large mammal species that interact in this ecosystem (e.g., humans, wolves, bears, caribou, moose, deer, etc.).

3 PROJECT APPROACH

In November 2015, we developed a science-based sampling design and deployed 85 motion-sensing monitoring cameras to monitor large mammal use on disturbed (linear features) and undisturbed (game trails) conditions across the Parker Caribou Range. Rates of habitat use are currently being collected for large mammal species that interact in this ecosystem (e.g., humans, wolves, bears, caribou, moose, and deer) at camera monitoring sites. The study was designed to answer the questions "how well does the restoration treatment reduce predator use?" and "are predators leaving the treatment area?" These questions are key to measuring how successful functional restoration is at reducing predator use and predator-caribou overlap. A schematic showing how predator use is hypothesized to change across time, mitigation treatment, and feature type is provided below. Success will be measured if the rate of predator use: (1) on linear features is lower in the treatment area than in similar control areas; (2) on linear features in the treatment area approaches the rate of use on game trails; and (3) on game trails within the treatment area remains constant or declines.

FIGURE 1 Predicted Response of Wolf Use before Mitigations and after Mitigations on Linear Features (Line) and Animal Trails (Trail)



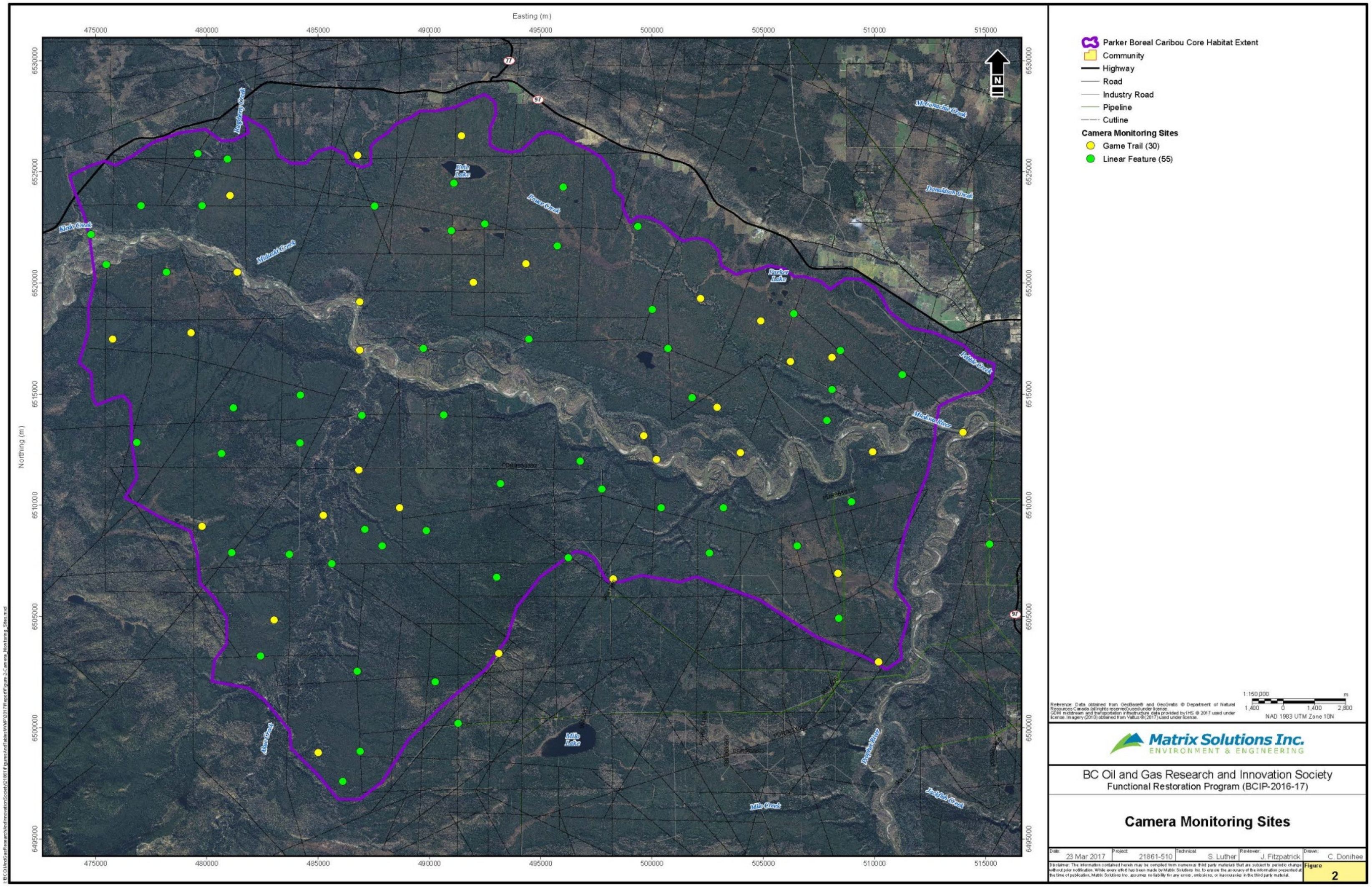
This report summarizes the sampling design, methods, and results for 1 year of motion-sensing camera data (November 2015 to November 2016) that was collected before restoration mitigations were implemented in the Parker Caribou Range (January to March 2017).

4 METHODS

4.1 Sampling Design

The sampling design was developed by randomly distributing a grid of potential sampling units across the Parker Caribou Range with a minimum separation of 1 km between sampling sites and then selecting a random subset for monitoring. This approach was utilized to (1) reduce spatial inter-dependence among sampling sites, (2) ensure that monitoring considered the range of geographic conditions across the caribou range; and (3) reduce the sampling frame from continuous space to a finite population framework, which simplified the design while maintaining statistical rigor. A total of 85 sampling units were randomly selected for monitoring linear disturbances (n=55) and game trails (n=30) across the Parker Caribou Range (Figure 2).

FIGURE 2 Camera Monitoring Sites



4.2 Data Collection

Wildlife use data were collected using Reconyx PC900 Hyperfire Professional Covert IR cameras. These motion-sensing cameras capture high-definition images using a combination of colour (daytime) and monochrome infrared (nighttime) photos. Each camera is powered using 12 AA size lithium batteries, allowing the camera to remain operational for 6 to 12 months in varying operating temperatures. Images are stored on a programmable SD memory card. Motion-sensing cameras were programmed to capture five consecutive photographs for each motion trigger event. In addition, each camera was programmed to collect one daily time lapse photograph to confirm camera operation and provide information on daily snow conditions at each camera monitoring site.

The motion sensing cameras were deployed across the Parker Caribou Range in November 2015. The monitoring sites were revisited in June and November of 2016 to service the cameras and maintain continual data collection across the 1 year pre-mitigation sampling period. During each visit, a field crew replaced camera batteries, desiccant, and downloaded images from each cameras memory card. In addition, data on ecological (e.g., forest composition) and monitoring feature conditions (e.g., width, vegetation cover, and game trail and linear feature definition) was collected to support statistical analyses of animal use.

Vegetation data were collected using a 4 m by 4 m plot to characterize plant communities at each monitoring site and in a paired control plot in undisturbed conditions adjacent to each monitoring feature. Vegetation data was collected to characterize the ecosystem and the abundance of ground cover plant species (e.g. lichens, mosses, forbs/herbs, and graminoids), shrub cover species, and tree species.

Movement resistance data were collected at each monitoring location to assess relative differences in an animal's ability to move down a monitoring feature. Similar to the vegetation plot data, movement resistance data was collected on paired transects along monitoring features (linear features and game trails) and in the surrounding forest stand. Movement resistance data included the following: (1) time – how much time (seconds) did it take the field crew to walk 70 m; (2) rate of speed – average rate (km/h) during a 70 m walk; (3) count of steps - number of steps it took to walk 70 m; (4) visibility distance – looking parallel with the ground at 1.3 m height, how far down a 70 m transect a crew member was visible; and (5) resistance class - a ranking of resistance between 1 and 5, wherein 1 was the lowest resistance to movement and 5 was highest resistance to movement.

4.3 Data Entry and Compilation

Motion-sensing cameras often record multiple photographs of individuals walking in front of the cameras' field of view. Since the count of photographs by species is of no value for our monitoring program, data was interpreted on an event-by-event basis. One count event is defined as an individual, or group of individuals of the same species, detected across a discrete time-period in front of a camera.

Defining a count event is important to avoid inflating counts as animals often trigger a camera multiple times by moving back and forth in front of the monitoring station. Multiple photographs collected continuously of a single animal that remains in front of a camera (e.g., feeding or standing) is considered one count event. When multiple individuals of the same species (e.g., a pack of wolves) trigger a camera, we consider this a single, multiple-individual count event. If an individual animal triggered a camera, left the monitoring station, and then returned less than 10 minutes after the original trigger, we considered this two count events. For each individual event, data was recorded on species, sex, age class, time, date, and the count of animals or humans counted.

We also collected data on snow depth and snow condition by visually interpreting the daily time-lapse photographs at each monitoring site. For each date that a camera was operational, we collected continuous snow depth (cm) data and a categorical snow condition data (i.e., no snow, unpacked snow, and packed snow). Snow condition was termed packed snow in conditions where human mechanical packing (e.g., snowmobile, grader) had packed snow in front of the camera. In addition, each monitoring camera was attributed with location variables for environmental characteristics, including plant cover, habitat types, terrain conditions, stream areas, and river valleys. The environmental conditions were characterized using a combination of desktop GIS data and plot data collected during field surveys.

4.4 Analytical Methods

Analyses methods followed those described in Keim et al. 2017a. We considered data as counts of events occurring over time (Cook and Lawless 2007), and estimated the average count of animal use per day on linear features as a function of covariates using Poisson regression. Where a large number of zero counts were present, a zero-inflated Poisson regression model (Lambert 1992) was used to analyze the data. Zero-inflated Poisson regression models enable the simultaneous estimation of conditions that affect both the probability of an inflated zero count and the count of events.

Models were estimated for caribou, moose, wolves, and black bears. The response variable for each species was defined as the count of animals detected per day. Predictor covariates included a combination of spatial and temporal covariates. Temporal covariates such as date of year and snow condition were adopted to explore and account for how individual wildlife species may exhibit seasonal shifts in their habitat use patterns. Identifying seasonal patterns accounts for variation that, if omitted, might otherwise mask or inflate effects related to other effects (e.g., project mitigations or habitat effects). The predictor covariates considered in the analyses are identified in Table 1.

TABLE 1 Labels and Definitions of Covariates

Covariate Type	Covariate Label	Covariate Definition
Temporal	Season	Continuous variable; sine transformation of date where the peak and low point of the sine function were optimized for each species.
	Snow Depth	Continuous variable describing depth of snow (cm). Snow depth was interpreted from daily time-lapse photographs captured by motion-sensing cameras.
	Snow Condition	Discrete variable describing whether there is no snow, unpacked snow, or packed snow.
	Counts of Wildlife and Humans	Continuous variable describing the count/day of each wildlife species and humans detected at a camera monitoring station.
Spatial	Monitoring Feature Type	Discrete variable describing whether a camera monitoring location was monitoring a linear feature (e.g., seismic line) or a game trail.
	Monitoring Feature Classification	Discrete variable describing categorical restoration plan recommendations for linear features (Golder Associates Ltd.; BCIP-2016-16).
	Lichen Cover	A continuous variable describing proportion of lichen cover at vegetation plots located in front of monitoring stations
	Speed of Travel	A continuous variable measured by calculating the average rate (km/h) of movement while walking a 70 m transect.
	Normalized Difference Vegetation Index (NDVI)	A continuous variable describing NDVI averaged within a 250 m radius of each camera monitoring location.
	Riparian Area	A discrete variable describing whether a camera monitoring location was in a creek or river valley.
	Muskwa River Location	A discrete variable describing whether a camera monitoring location was north or south of the Muskwa River.

To illustrate key results for each species, the fitted values from final models were plotted against covariates relating to spatial and temporal effects, as appropriate (Section 3.2, Figures 3 to 7). The plotted effects represent the combined effects across all of the covariates in each of the final species-specific models (i.e., the marginal effect). For plotting continuous covariate effects a smoothed relationship was fit across the fitted values and a 95% confidence interval in the relationship was estimated using a generalized additive model function (Wood and Augustin 2002).

5 RESULTS

5.1 Summary of Data Collected

Motion-sensing cameras collected continuous data on large mammals and humans over a 1 year duration within the Parker Caribou Range. One of 85 motion-sensing cameras deployed was lost due to hardware malfunction. The remaining 84 motion-sensing cameras captured monitoring data between November 2015 and November 2016. In total, this includes data collected across 31,093 camera monitoring days. A summary of large mammal and human counts detected on linear features and game trails is provided in Table 2.

TABLE 2 Summary of Large Mammal and Human Detections on Linear Features and Game Trails

Species	Count of Individuals Detected		
	Linear Features	Game Trails	Total
Caribou	667	210	877
Black Bears	478	296	774
Humans	609	0	609
Moose	335	236	571
Wolves	189	67	256
Elk	16	233	249
Bison	73	0	73
White-Tailed Deer	3	5	8
Grizzly Bears	6	0	6
Total Camera Monitoring Days	**20,322**	**10,771**	**31,093**

In addition to the species listed in Table 2, the motion-sensing cameras detected a number of additional species as listed below:

- American beaver (*Castor canadensis*)
- American marten (*Martes americana*)
- Canada goose (*Branta canadensis*)
- Canada lynx (*Lynx canadensis*)
- Common raven (*Corvus corax*)
- Coyote (*Canis latrans*)
- Fisher (*Martes pennanti*)
- Gray jay (*Perisoreus canadensis*)
- Great gray owl (*Strix nebulosa*)
- Mallard (*Anas platyrhynchos*)
- Red fox (*Vulpes vulpes*)
- Red squirrel (*Tamiasciurus hudsonicus*)

- Ruffed grouse (*Bonasa umbellus*)
- Sandhill crane (*Grus canadensis*)
- Sharp-tailed grouse (*Tympanuchus phasianellus*)
- Snowshoe hare (*Lepus americanus*)
- Spruce grouse (*Falcipennis canadensis*)
- Wolverine (*Gulo gulo*)

5.2 Key Results

A full synopsis of analytical methods and results will be available in a manuscript currently in preparation by Keim et al (2017b). To illustrate the key results, fitted-values from the final models were plotted against covariates relating to date, snow condition, linear feature type, and other effects, as appropriate (Figures 3 to 7). Each plot illustrates the mean, marginal effect of the covariate on the x-axis. Plots were created by estimating a smoothed relationship between the fitted values from each (multi-variate) species-specific model and the covariate on the x-axis (solid line). A 95% confidence interval in the relationship is depicted in grey shading.

Key results from the first year of remote-sensing camera monitoring data include the following:

- Human activity was concentrated to only 7 of the 84 monitoring sites in the Parker Caribou Range. The seven monitoring locations having human activity were located in the northeast section of the range located nearest Fort Nelson, British Columbia. Human activity was seasonal and primarily occurred during winter months coincident with recreational snowmobiling activity in the area. Winter snowmobile activity resulted in a packed snow condition on some linear developments, which was tracked by the study on daily basis for employment as a covariate in the analyses of animal use.

- The rates of large mammal habitat use varied by species and season (Figure 3). The highest mean rates of use were measured for black bears in mid-summer. As would be expected, black bear habitat use was constrained to the non-hibernating period (April to October). Rates of habitat use by caribou were highest during the winter and lowest during the spring season. Both moose and black bear habitat use increased in the growing season (April to August) and declined in the fall. Wolf habitat use peaked in the fall and winter and was lowest during spring.

- The mean rates of habitat use by wolves, caribou, and moose were negatively related to snow depth (Figure 4). Wolves showed the greatest response to snow depth as defined by a steeper declining slope in the relationship. Wolf habitat use was also found to be strongly and positively tied to linear developments that have a packed snow surface from snowmobile activity during winter. Moose avoid packed snow conditions but the mean rates of habitat use remained relatively constant (compared to wolves and caribou) as snow depth increased (Figure 4).

- The mean rates of habitat use by all of the large mammals being monitored, except for black bears, varied by feature type (linear feature or game trail). The mean rates of habitat use by caribou and moose were significantly greater on game trails than linear features. In contrast, wolf habitat use was greater on linear features with the magnitude of the effect varying by season (Figure 5); the mean rate of wolf use was considerably greater on linear features, relative to game trails, during the winter season. This result in part reflects the positive response of wolves to a packed snow condition on linear developments during winter.

- During the growing season, wolf habitat use was greatest in riparian corridors (areas adjacent to streams and rivers). However, during the winter wolf habitat use was strongly tied to linear developments with a packed snow condition regardless of the habitat type.

- The rate of speed at which a person could walk down a linear feature during the growing season was related to the rates of habitat use by all of the large mammals evaluated. The rates of use by caribou, moose, wolves, and black bears increased with the speed of travel metric (Figure 6). Movement resistance data is related to a number of factors including ground saturation, terrain complexity, and vegetation growth.

- The mean rate of habitat use by caribou increased with lichen cover abundance (Figure 7). The magnitude of this effect varied by season. The slope of the relationship between caribou habitat use and the abundance of lichens increased in the winter, during times of higher snow depths (approximately 60 cm). We suspect that caribou expend more energy to move when the snow is deeper and that they may be congregating in areas with greater abundances of lichen forages during winter to limit the energetic cost of movements through deep snow.

- Wood Bison were observed at four locations within a large fen-bog complex on the north side of the Muskwa River. The bison observations were of interest because they were occurred outside of the known distribution of bison within British Columbia. BC MoE personnel reported that these were likely animals that had recently escaped from a local bison ranch.

FIGURE 3 Seasonal Habitat Use by Large Mammals in the Parker Caribou Range

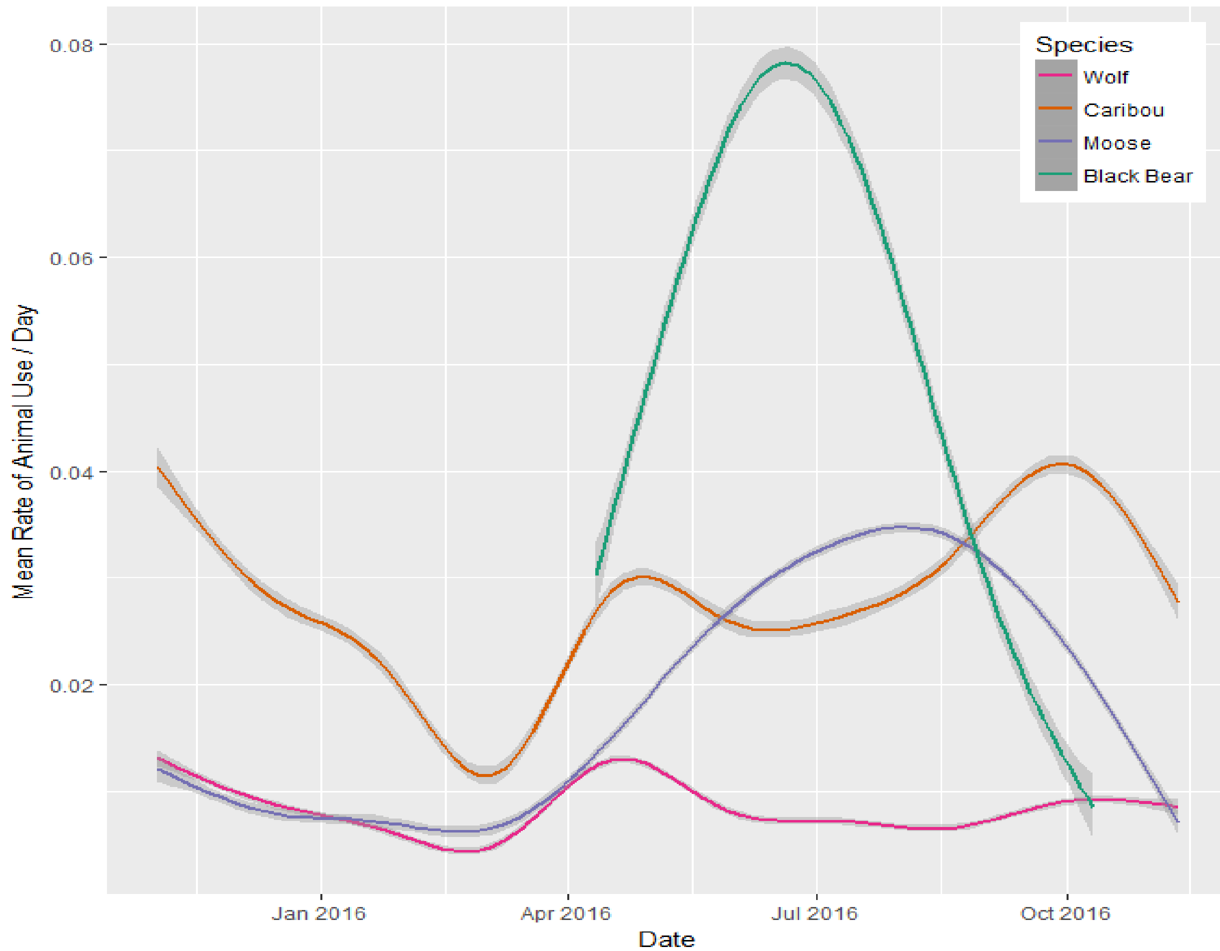


FIGURE 4 Mean Rate of Habitat Use by Wolves, Caribou and Moose by Snow Depth (cm)

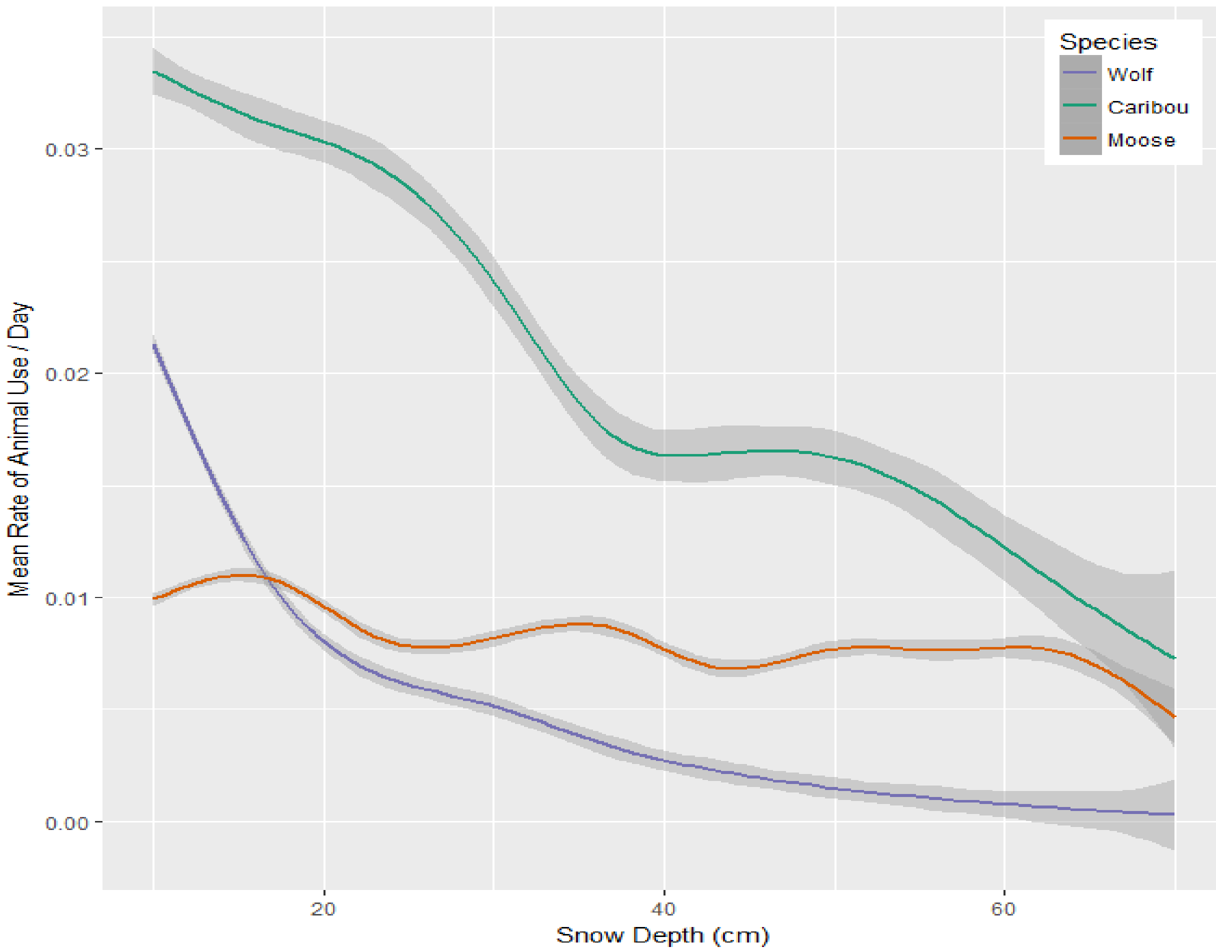


FIGURE 5 Habitat use by Wolves on Linear Features and Game Trails by Date

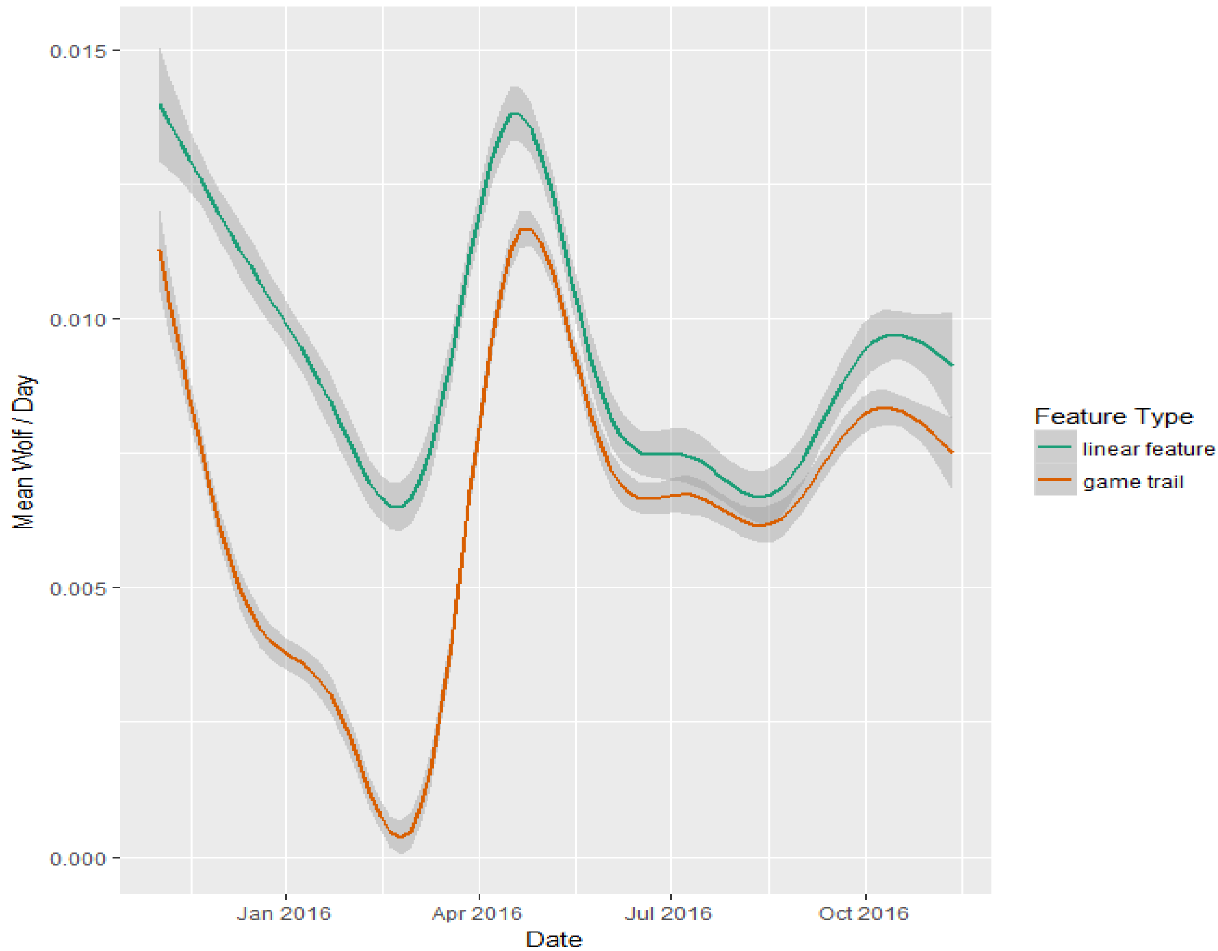


FIGURE 6 Use by Large Mammals Relative to Rate (km/h) at Which Humans Walked Down 70 m of Monitoring Feature (Movement Resistance Measure)

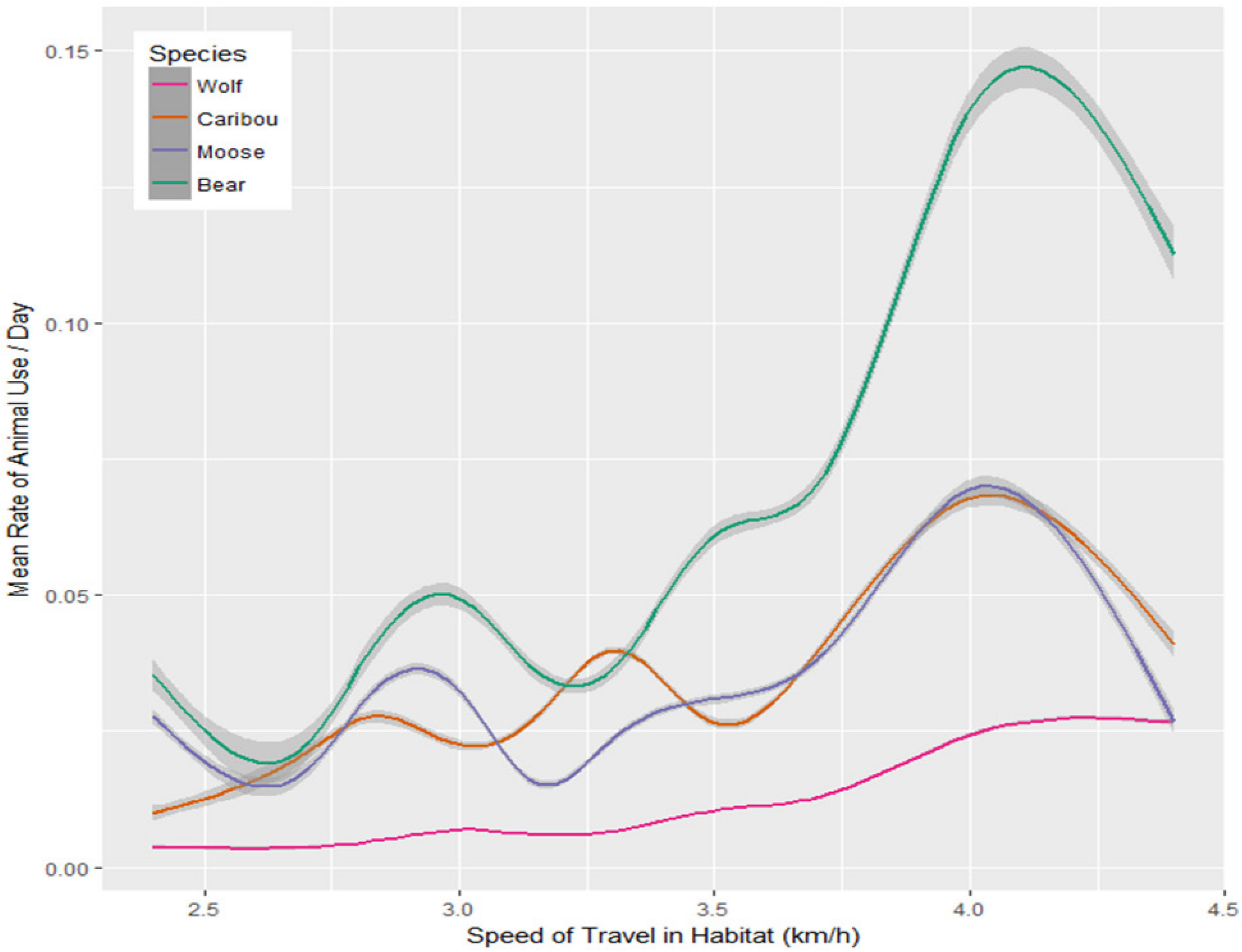
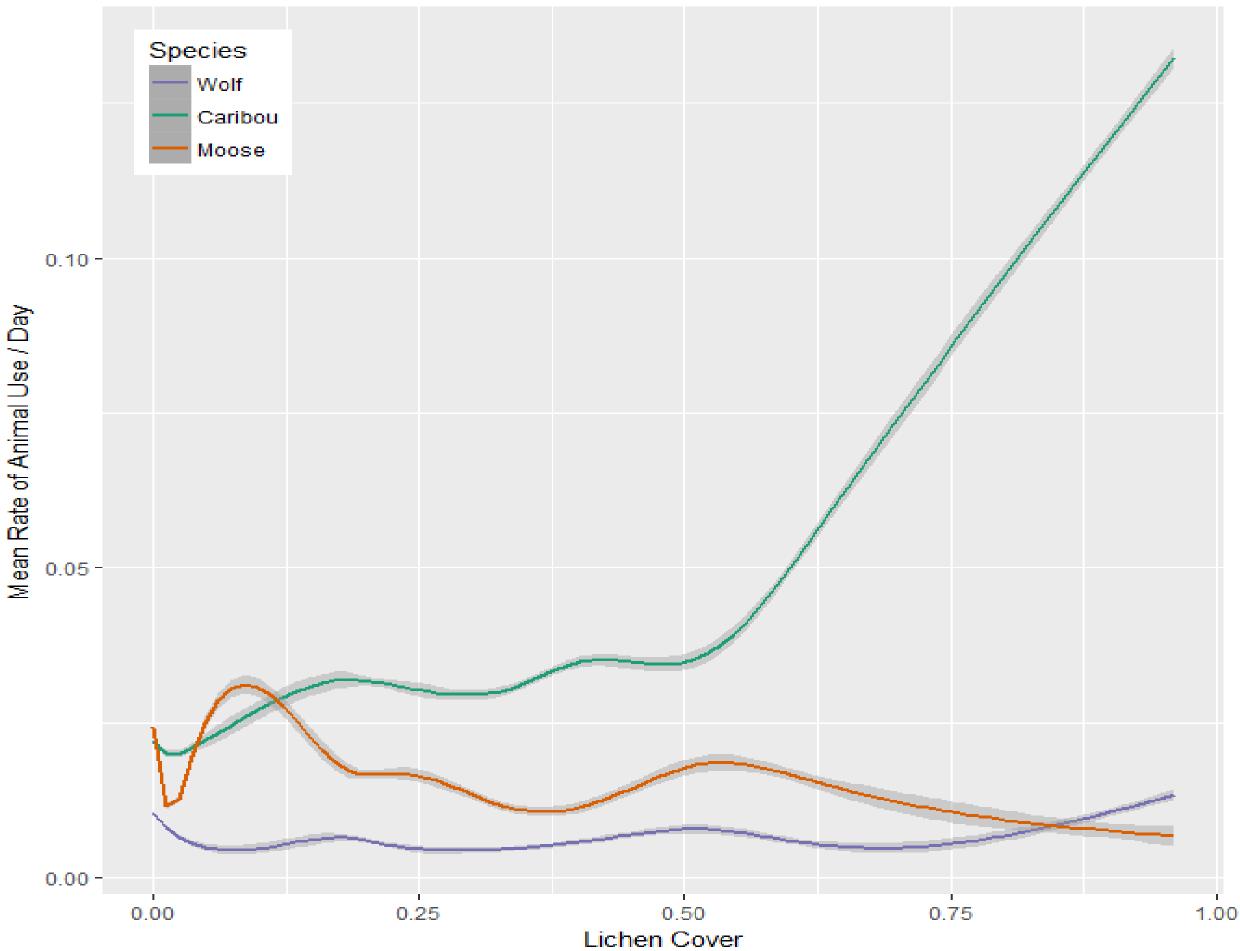


FIGURE 7 Mean rate of Use by Wolves, Caribou in Moose with Increasing Proportion of Lichen Cover



6 IMPLICATIONS AND NEXT STEPS

Results from the first year of monitoring have increased our understanding of wildlife and human use in the Parker Range and can help inform future functional restoration works. Specifically, the pre-mitigation treatment results suggest that the following restorations actions should be prioritized:

- **Human winter access:** The packing of snow on seismic lines changed the distribution of wolf habitat use in the Parker Range. Managing the spatial locations of snowmobiling in caribou range could be prioritized as a functional restoration technique to conserve caribou.

- **Lichen abundance:** Caribou were found to spatially congregate in areas of greater forage lichen abundance. Restoration treatments could be prioritized to reduce human/predator access to areas of high lichen abundance to reduce caribou-predator encounter rates.

- **Travel resistance:** Movement metrics influenced the rates of habitat use by all of the large mammal species evaluated by this study. Restoration treatments could be prioritized toward conditions that provide for easier movement / travel on seismic lines and seismic line segments.

- **Low impact seismic lines:** Low impact seismic lines influenced the distribution of wolf habitat use in the Parker Caribou Range and should be evaluated for restoration treatment.

The initial year of pre-restoration treatment camera monitoring in the Parker Caribou Range successfully met the design specifications, intent, and hypotheses of the study. We accordingly recommend continued monitoring to better understand the temporal patterns in large mammal habitat use within the Parker Caribou Range and to measure the efficacy of functional habitat restoration treatments that are being applied to conserve caribou in this range.

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