Fort Nelson First Nation Boreal Caribou Habitat Restoration at The Kotcho Lake Restoration Area

Year 2 report prepared for the Habitat Conservation Trust Foundation
July 29 2021

Report authors: Anne Hervieux (Firelight Research Inc.), Jesse Tigner (SwampDonkey), Susan Leech (Firelight Research Inc.), Katherine Wolfenden (FNFN Lands and Resources Department

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DRAFT REPORT / July 30 2021

Prepared and authored by:

Anne Hervieux (Firelight Research Inc.), Jesse Tigner (Swamp Donkey Inc.), Susan Leech (Firelight Research Inc.), Katherine Wolfenden (FNFN Lands and Resources Department

On behalf of:

Fort Nelson First Nation

Submitted to:

Shannon West, Habitat Conservation Trust Foundation

Thanks and acknowledgements go to Fort Nelson First Nation members, elders, knowledge holders, land users, staff, and leadership who contributed. This report could not have been completed without their support and expert knowledge. Funding for this project was provided by the Boreal Caribou Restoration Fund through the Habitat Conservation Trust Foundation, and Natural Resources Canada. The following project team was involved in collecting, analysing, and writing this report:

- Principle Investigator: Katherine Wolfenden, Jesse Tigner, Susan Leech
- Researchers: Anne Hervieux, Aaron Jones
- Mapping and GIS: Jesse Tigner, Sashka Warner

Disclaimer:

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EXECUTIVE SUMMARY

This report provides a summary of the work completed during year 2 (2020-2021) of the boreal caribou habitat restoration work in the Kotcho Lake Restoration Area. The restoration area is located in northeastern British Columbia in the Snake-Sahtenah boreal caribou range. This 60,000 hectare area was selected by Fort Nelson First Nation as the highest priority for habitat restoration, primarily due to the following attributes: a) high caribou use; b) high portion of potentially suitable caribou habitat; c) area has low likelihood of future development and is proposed for protection under the BC's draft Boreal Caribou Protection and Restoration Plan; d) the area is highly disturbed with a high density of linear features (more than 16 km/km^2) and a high proportion of legacy seismic lines; e) the area is of high cultural importance to FNFN and has other important ecological values.

The questions we are attempting to answer through this work include:

- Is landscape scale restoration enough on its own to start to see an increasing caribou population over time?
- Can we do treatments in the fall, using cost-effective measures and approaches that are more acceptable to FNFN than conventional winter treatments such as mounding and planting?
- If yes, where should we focus these treatments? Which areas are most important to treat to achieve a widespread effect?
- How quickly do we see a vegetation response on the site?
- How does that affect site-level changes in wildlife movement?
- How does that translate into changes in use at a larger scale by caribou over time, and spatial separation of moose, wolves and caribou?
- And finally, how quickly does lambda start to recover in this area? This is the Snake Sahtaneh range, so caribou population growth has been below one for many years.

In 2020-21, we selected priority areas for treatment based on the intersection of large, legacy seismic lines and our experiences in 2019-2020. We treated the selected areas using a variety of approaches, including: a) whole hummock transplantation; b) scraping and planting; c) falling trees where suitable to block lines. To determine the effectiveness of these efforts, we continue to employ three levels of monitoring used in year 1 of this project: a) landscape level winter track surveys to determine the distribution of wildlife use across the study area and a larger survey area, primarily focused on the overlap between caribou, moose and wolves; b) wildlife cameras to track site-level wildlife use over time along treated and untreated lines; and c) vegetation plots to track vegetation responses to treatments. The report describes how this work was conducted in 2020-2021.

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1. Introduction

1.1. Overview

This interim report describes the work conducted by Fort Nelson First Nation (FNFN) to characterize the Kotcho Lake Restoration Area (KLRA) and restore linear features to support boreal caribou population recovery in the area. The report collates work conducted under the following funding agreements:

1. HCTF 7-490: This one year project, funded in 2018-19, included developing a prioritization scheme for identifying boreal caribou restoration areas in FNFN's territory, identifying high priority areas for restoration, and developing a restoration plan for the highest priority area. The detailed characterization of the KLRA is also included in earlier reports (FNFN 2019; Leech et al. 2020).

2. CHRF: Three year proposal to HCTF's Caribou Habitat Restoration Fund to restore habitat in the KLRA and monitor the effectiveness of this work. In year 1, work was done to further characterise the disturbance within the KLRA, select and restore seismic lines in the area, and to establish an effectiveness monitoring approach at various scales. This report summarizes the work conducted in 2020-21 to further restore seismic lines in the area, and to continue to implement the monitoring approach from year 1.

3. FNFN's proposal to the NRCAN Protection of Species at Risk program: Three year proposal to restore the KLRA and monitor the effectiveness of this work. This proposal is similar to the above and provides matching funds to ensure that additional work could be performed.

1.2. Report Content and Structure

This report is organized in three sections (excluding the introduction and the conclusion / next steps sections):

- Section 2: provides a full characterization of the KLRA based on a clean-up of the spatial data for the area, and initial field work to confirm seismic line types and locations within the project area;

- Section 3: describes the restoration work conducted;

- Section 4: summarizes the monitoring framework for the KLRA, the data collection conducted and the preliminary data analysis.

2. Characterization of the KLRA

2.1. KLRA Description

The Kotcho Lake Restoration Area (KLRA) is approximately 60,000 ha in size and centred approximately 80 km northeast of Fort Nelson, British Columbia. It is composed largely of black spruce muskeg (bogs, treed bogs, and fens). These areas are ideal for boreal caribou during all seasons but are particularly valuable during the calving season. There is a substantial amount of high valued boreal caribou habitat in the area, based on habitat suitability ranking conducted using Ducks Unlimited's enhancement wetland classification. FNFN identified the area around Kotcho Lake as the highest priority area for immediate and focused restoration work, based on a structured decision-making process that incorporated caribou use, habitat condition, tenure status, type of disturbance, likelihood of future disturbance, and cultural importance (FNFN 2019).

The KLRA has been heavily disturbed by previous PNG exploration, but little of the area is currently producing resources or under active PNG tenure. The most predominant disturbance feature within the KLRA is legacy seismic lines. Within the KLRA, it is estimated that there are approximately 4,726 linear km of anthropogenic linear disturbances (using the cleaned data; ~5,350 using uncleaned RSEA data). This translates to a linear density up to ~16 km/km^2. Even without the additional 500m spatial buffering for anthropogenic disturbances to account for reduced functional habitat for caribou, this level of disturbance is far above recommended thresholds for boreal caribou.

A variety of furbearers and other animals are common throughout the KLRA. The area has high importance for FNFN members and maintaining key access routes into the KLRA for cultural purposes is an important consideration of the restoration work.

The KLRA is an area of known high boreal caribou use based on telemetry data, FNFN Indigenous knowledge and winter snow tracking work conducted during February 2019. The area is home to the Snake-Sahtaneh caribou herd, which the Habitat Conservation Trust Foundation's CHRF listed as a high priority herd for restoration work in BC's boreal in the initial funding year (2019).

FNFN traditional knowledge suggests high wolf presence in the area (FNFN Indigenous Knowledge Interviews for Boreal Caribou, December 2018). Data from BC OGRIS on wolf use also suggests high wolf presence in the area generally, although no collared wolves were observed in the KLRA during their collaring work (see Map 8). Wolf prints were observed during field work conducted for HCTF 7-490 in September 2018 (S. Leech, pers obs.), and in the uplands along the western edge of the KLRA during winter tracking work as determined during winter tracking work as part of Year 1 of this project (see Map 9). Based on the available information, we are confident that restoring the habitat in this area will help bolster this area as a safe refuge for boreal caribou.

2.2. Spatial Analysis to Identify Priority Areas and Potential Treatment Sites

A spatial analysis was conducted to identify candidate areas for site-specific restoration treatments within the KLRA. The Regional Strategic Effects Assessment (RSEA) dataset was used as a base disturbance layer to identify linear features in the KLRA. The RSEA dataset was created in 2018 as a comprehensive disturbance dataset for conducting cumulative effects analyses in NE BC and used spatial data on PNG development, cutblocks and fire disturbances available through DataBC and the BC Oil and Gas Commission.

A major component to Year 1 planning was to address known shortcomings in the RSEA dataset to make those data better suited to the planning needs of this project. After data clean-up, there are 4,726.66 km of linear features in the KLRA, of which 4,264.62 km are classified as seismic lines.

Seismic lines within the KLRA were stratified by restoration priority into four classes (Priority 1, 2, 3, and no priority) based on line type and access. Based on our understanding of which areas are least likely to be regenerating naturally, we prioritized areas for treatment as follows:

- Priority 1: Winter roads and decommissioned pipelines
- Priority 2: Legacy seismic lines (identified based on their occurrence within older datasets)
- Priority 3: Newer seismic lines (generally first generation of low impact seismic lines)
- Not a priority: low impact seismic lines

Year 1 candidate areas for treatment were preferentially identified at intersections of legacy seismic lines so as to apply restoration treatments to multiple lines at once. Ducks Unlimited Enhanced Wetland data were filtered to select fen and bog features, and these features were merged together to create a dataset of fen and bog ecosystems. This layer was used to confirm that candidate areas for restoration treatments within the KLRA were located within fen and bog ecosystems for the benefit of caribou. Field reconnaissance flights were conducted over two days to survey candidate sites and verify the potential of the sites for restoration. These surveys made it clear that site assessments on the ground are critical for understanding what site-level conditions are and for developing appropriate site prescriptions.

Because of the imperfect spatial data and the inaccuracies of the land cover data and data on the state of line recovery, Year 2 treatment locations were identified differently from Year 1. The GIS and a priority framework outlined above were used to identify candidate “restoration zones” rather than specific, discrete sites. This method allowed for greater flexibility to make in-field decisions and to target the best available restoration opportunities. Additionally, restoration efforts were directed towards bogs (not fens) and the transition zones between uplands and lowlands. This change was made because of the challenges faced in the field in Year 1, and because bogs both typically respond better to restoration.

3. Summary of Restoration Treatments

3.1. Summary of Restoration Treatments Undertaken in 2019-2020

Site treatments were conducted in September 2019. Non-frozen, multi-step restoration treatments were applied through transplanting whole hummocks, scraping areas to remove competing vegetation, creating small mounds from scraping materials, and transplanting seedlings in the scraped and intact areas as well as along the lines within treatment areas. In 2019, the restoration team conducted approximately 350 applications each of mounding and planting, scraping and planting, whole hummock transplanting, and approximately 3,500 applications of tree planting. In total 22 sites were treated, and tree modifications were applied at and between treated sites. Direct treatment ranged between 50 and 200 m along single lines and across multiple lines at intersections. **In total, 15 km of seismic lines were functionally restored in 2019.**

3.2. Summary of Restoration Treatments Undertaken in 2020-2021

In summer of 2020, we delivered treatment to 13.44 km of linear feature. Treatments were done on a combination of conventional seismic lines, conventional seismic lines that were reopened using LIS techniques (e.g., mulching), and new mulched LIS seismic lines. The majority of treatments were delivered along conventional and reopened conventional lines.

Treatments were both clustered in space along lines, and focused at intersections in order to functionally restore a greater area. Specifically, clustered treatments result in segments of line with treatment areas interspersed with untreated segments. By treating lines in segments and focusing at intersections, restoration benefits are gained by line segments and lines even though they were not directly treated. Fifty-three treatment locations were completed in Year 2, and 33 were specifically delivered across individual line intersections (see Figure 1 and Figure 2). Additionally, tree modifications were done at treatment sites and between treatments. **In total 13.44 km of seismic lines were closed to wildlife movement, and were functionally restored** (3.23 km of conventional seismic lines, 4.26 km of conventional seismic lines that were reopened using LIS techniques, and 6.28 km of new mulched LIS seismic lines).

Outcomes from the restoration work in Year 1, and ongoing monitoring, indicated that using a combination of a small excavator and hand tools for the restoration treatments produced the best results. We employed these approaches to transplanting hummocks, planting seedlings and modifying trees. A total of 4.31 ha were directly treated with transplanting hummocks, planting seedlings, and modifying trees and are considered ecologically restored.

For a full list of the methods employed and how this data was recorded, see Appendix A for the restoration protocols and Appendix B for the field sheets.

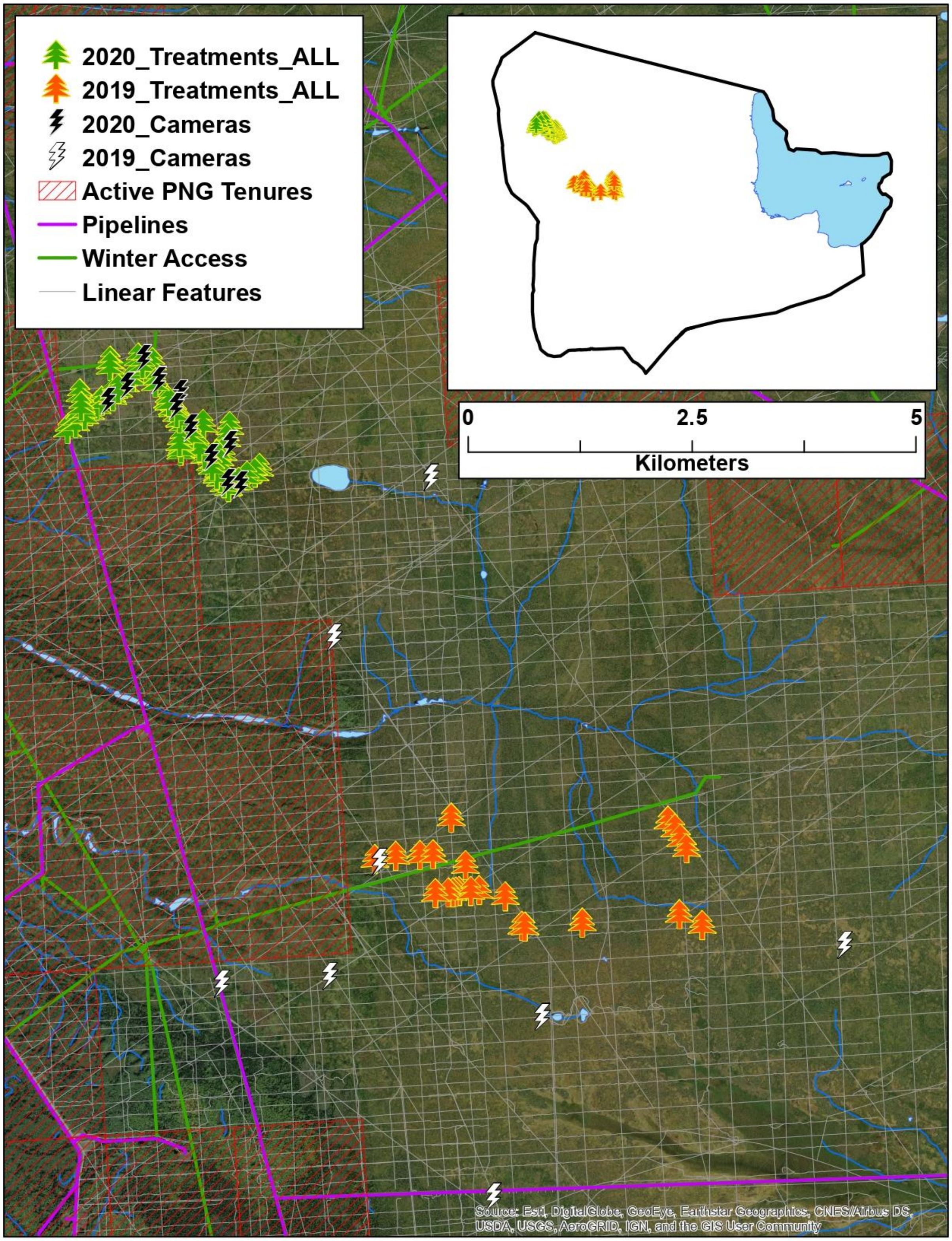


Figure 1. A map of the seismic line restoration treatment locations and wildlife camera stations within the KLRA study area from 2019 (Year 1) and 2020 (Year 2).

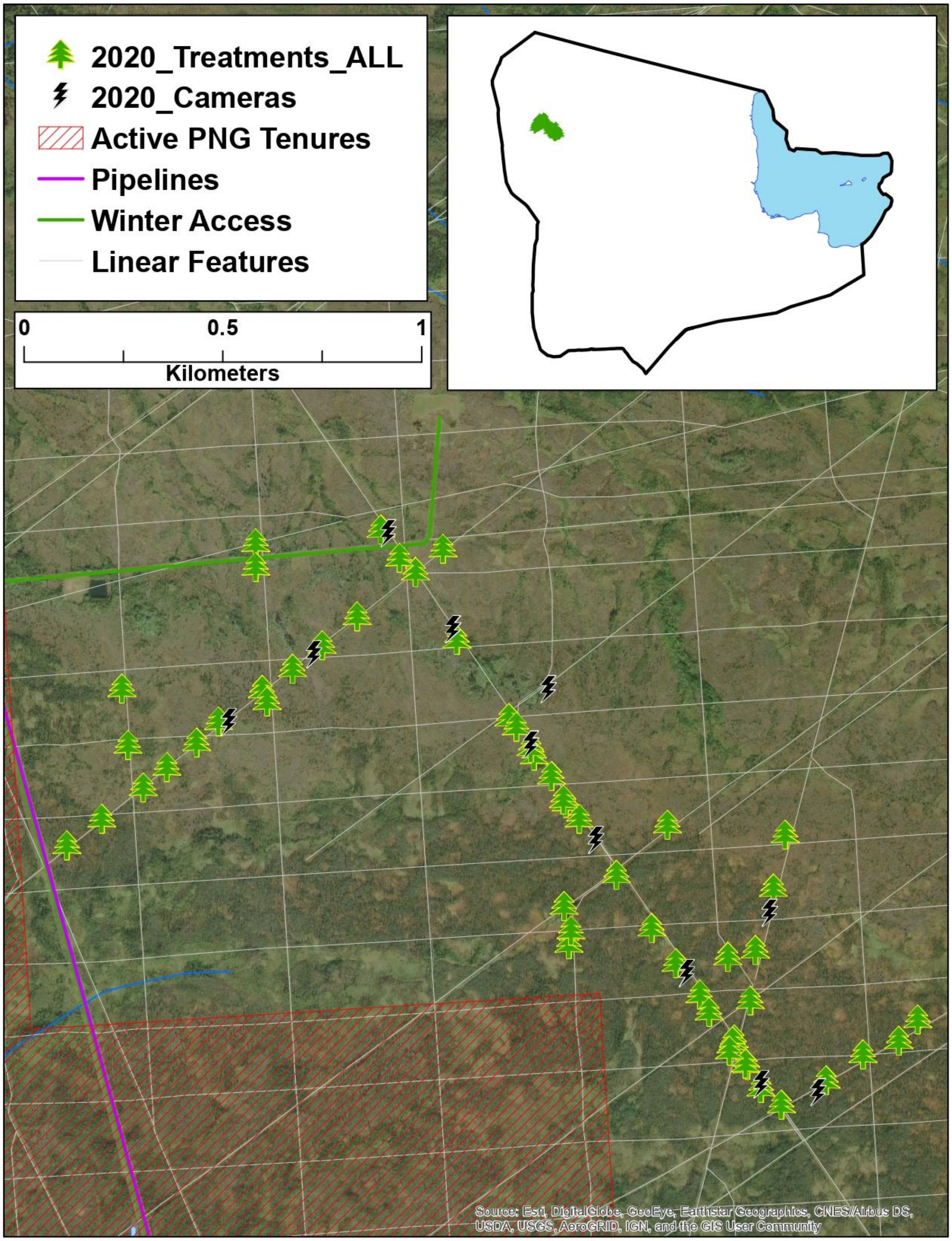


Figure 2. A map of the seismic line restoration treatment locations and wildlife camera stations within the KLRA study area from 2020 (Year 2).

3.3. Plans for Restoration Treatments in 2021-2022

Current results and ongoing monitoring have indicated that transplanting hummocks into microsites with sufficient moisture (typically scraped or prepped locations) and free planting seedlings into appropriate microsites (constructed and naturally occuring) work consistently well. As a result, we will continue to use hummock transplants and planting to treat lines in 2021-2022. Other results indicate that some types of tree modification do work, however, traditional hinging alone does not appear effective.

Next year we intend to expand on the successful treatments, and further develop restoration treatments. Concurrently, FNFN has been working on restoring another area of the Snake-Sahtaneh range using hummock transplants in the winter. Our learnings from this approach—in particular the increased productivity and safety associated with conducting work involving heavy machinery in frozen conditions—are contributing to a proposed movement in the KLRA towards hummock transplanting in the winter, followed by planting in the summer. We are working with HCTF to modify our work plan for 2021-22 to reflect this change.

In addition, we will continue to implement a range of tree modification techniques to leverage the natural growth pattern of black spruce and the responses of shrub species to disturbances. As tree hinging has not been successful, we will instead be using four alternatives: tree pushing, tree pushing and burying, tree hold-downs, and tree and shrub trimming. Tree and shrub modifications will be employed alongside other restoration methods, where feasible, primarily to obstruct line of sight and to create an immediate deterrent to movement along the seismic lines.

4. Summary of Monitoring

4.1. Landscape Level Wildlife Monitoring: Track Analysis

4.1.1. Overview

Snow tracking is being used in the KLRA to monitor landscape-scale wildlife use within the study area. The purpose of this monitoring is to determine a baseline of species use within discrete spatial extents and to evaluate how use may change in response to seismic line treatments. The design of the snow tracking surveys is meant to answer the following questions:

- What is the baseline distribution of mammals within the study area?
- How does use change in response to restoration treatments at a broad scale?

- What is the relative use across the study area by caribou and moose?
- Does landscape use by caribou and moose overlap within the study area and region, and does this use overlap with wolves?

4.1.2. Methods

As in previous years, we surveyed the KLRA and surrounding areas for tracks, animals, and other animal sign (marten and larger) from the air using a helicopter. We surveyed along established transects embedded into 10 km^2 hexagons. We used hexagons as the base spatial extent as they are useful for addressing land management actions regionally, and are biologically meaningful for a variety of species of interest. Six 1.7 km long transects cross each hexagon, passing from one of the six edges and through to the centre of the hexagon (Figure 3).

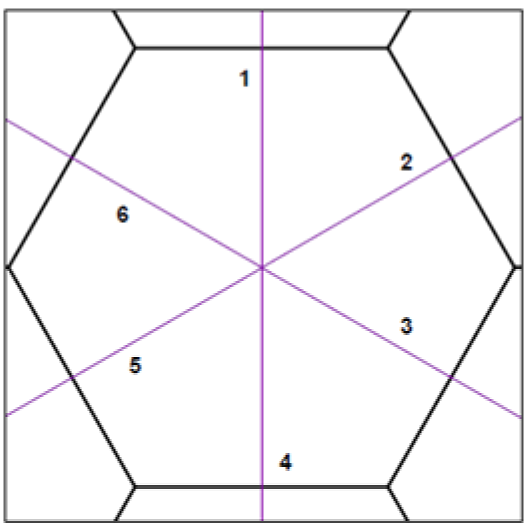


Figure 3. A single 10 km2 hexagon with six 1.7 km long survey transects.

To conduct surveys, we searched one to six transects per hexagon while flying between 60 and 100 knots and 20 and 100 m above the ground as needed to clearly identify tracks. We circled and or followed tracks until a positive identification could be made and then returned to the point of departure along a transect to continue surveys. In 2021 we used one spotter (front seat, right side) and one spotter/recorder (rear, left) to search for track and sign; the same helicopter pilot has flown all surveys and also assisted in locating and identifying tracks and sign. In 2019 , a fourth person participated (rear seat, right side) with the primary task of recorder. We recorded all observed tracks and sign that had accumulated since the last snowfall to species, and marked all locations with a waypoint. All observed ungulates were also classified to sex and age and any collars were noted.

To evaluate the influence of line restoration treatments on observed caribou use at the hexagon scale, we compared counts of caribou detections within treated and adjacent hexagons before and after treatment delivery. We considered all detections equivalently when generating counts for comparison (e.g., no differentiation was made between observations of animals, tracks, or craters, and the number of unique observations were tallied even if multiple animals, tracks, or craters were observed), and pooled treated and adjacent hexagons as a single class. We ran two series of analyses to compare potential change in use one year and two years after treatments. For the one year series we used all hexagons treated in fall 2019 and 2020 to make a comparison in use between winter 2019 to 2020 and winter 2020 and 2021, respectively (n = 14). For the two year series we used all hexagons treated in fall 2019 to make a comparison in use between winter 2019 and 2021 (n = 7). In both series we used a generalized linear mixed model to compare counts among hexagons before and after treatment (glmmTMB in r; Brooks et al. 2017) with a negative binomial family structure to account for overdispersion calculated as a quadratic parameterization with a log link function. We treated hexagon as a random effect (i.e., hexagon as the grouping factor with a constant effect).

4.1.3. Results and Discussion

Consistently high detection probabilities in 2019 and 2020 significantly improved survey efficiency by reducing the overall required survey effort per hexagon (e.g., fewer transects were needed as species were observed consistently along multiple transects within a given hexagon). This allowed us to increase the spatial extent of the surveyed area to include more area in the northeast where additional caribou sign had been observed in previous years and during previous survey flights. On March 3 and 5 in 2021 we surveyed a total of 77 hexagons (1-6 transects per hexagon; Figure 4). Of these hexagons, 60 overlapped the original KLRA area surveyed in all years (from 2019 through 2021; Figure 5). Within the KLRA study area boundary: in 2019 we surveyed 560.65 km across 295 transects in 63 hexagons ; in 2020 we surveyed 466.95 km across 244 transects in 61 hexagons ; and in 2021 we surveyed 371.18 km across 218 transects in 60 hexagons (Figure 5, top middle and bottom panels respectively).

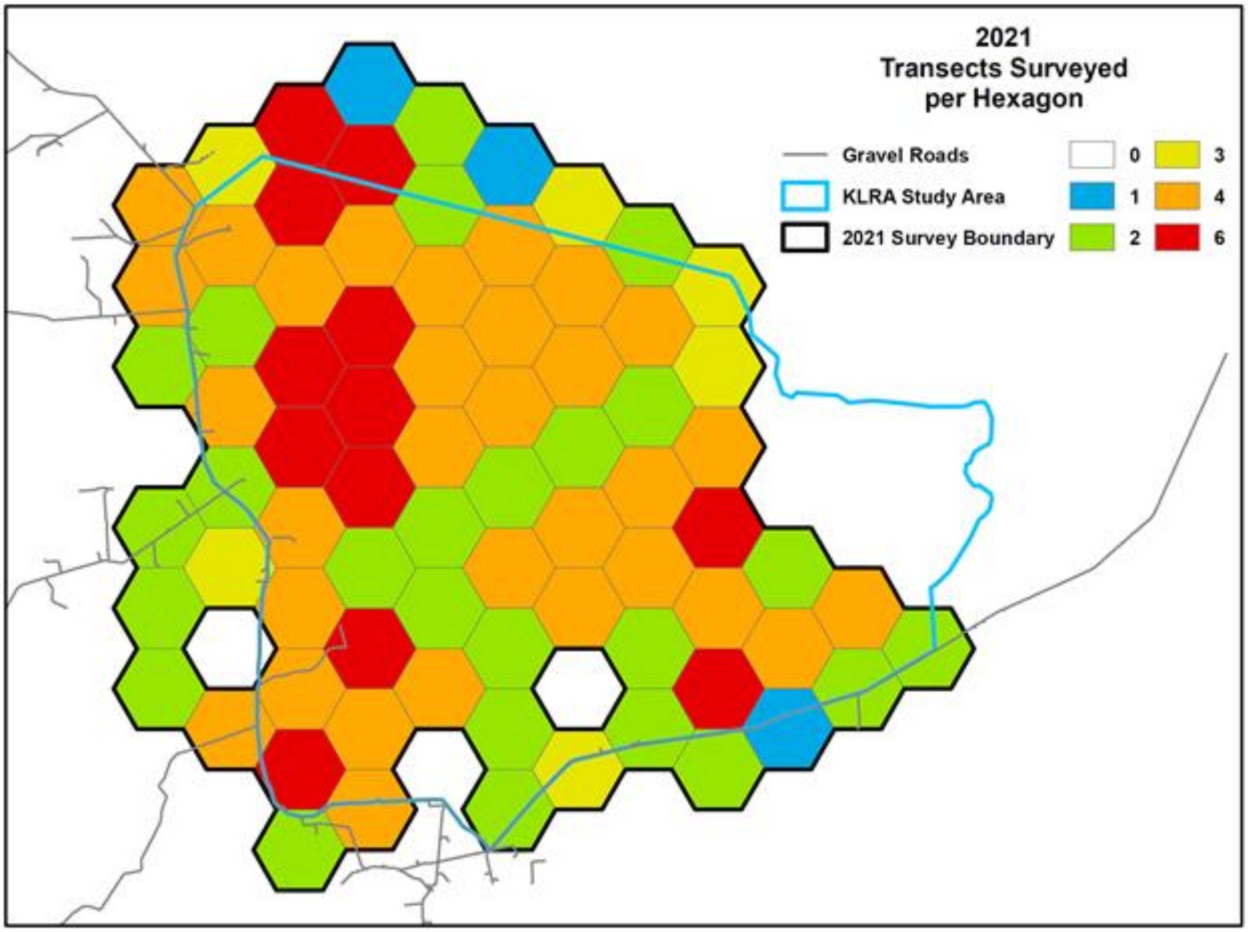


Figure 4. In March 2021, snow tracking surveys were conducted along between one and six transects (color codes in the map legend) within 77 hexagons in the greater KLRA study area in NE BC.

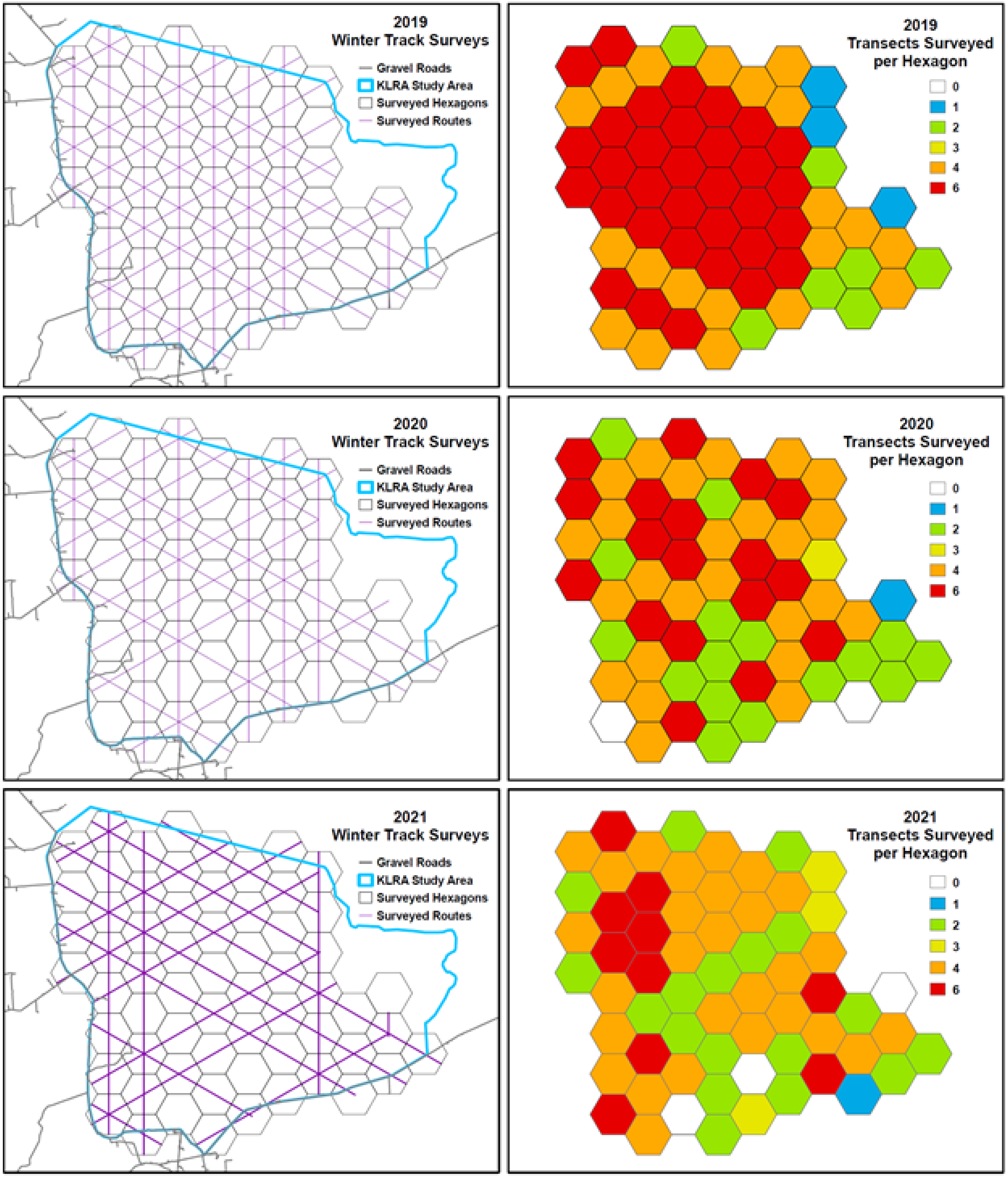


Figure 5. Repeated snow tracking survey effort within the KLRA study area in 2019, 2020, and 2021.

Despite the lower overall survey effort within the KLRA study area in 2021, the observed unique detections of tracks and sign across all species was comparable to other years (Table 1).

Similarly, the distribution of all species' detections was also comparable across years (Figure 6). Notably, we observed a sharp increase in wolf activity across the study area, including both evidence of wolf packs and lone individuals (Figure 7). We also recorded fewer detections of lynx in many fewer hexagons, and anecdotally, fewer snowshoe hare tracks. Most detections were of single tracks or sign, but in some cases multiple individual tracks were observed together. All caribou craters and moose yards were considered a single detection because it was typically difficult to count individual craters or to differentiate individual tracks. Work is ongoing to evaluate species-specific detection probabilities and to incorporate those metrics into further analyses; however raw 2021 survey results support previous observations of very high detection probabilities across species within the study area.

Table 1. Total number of detections, per species, during snow tracking flights between 2019 - 2021 in the Kotcho Lake Restoration Area, NE BC.

	Caribou	Moose	Ungulate	Wolf	Wolverine	Lynx	Marten	Otter
				KLRA (repeated extent area)				
2019	70	73	7	5	25	107	50	0
2020	73	72	3	3	10	172[a]	108[a]	1
2021	63	72	0	17	22	68[b]	72	0

[a] Two animals were observed, but not included in this count.
[b] One animal was observed, but not included in this count.

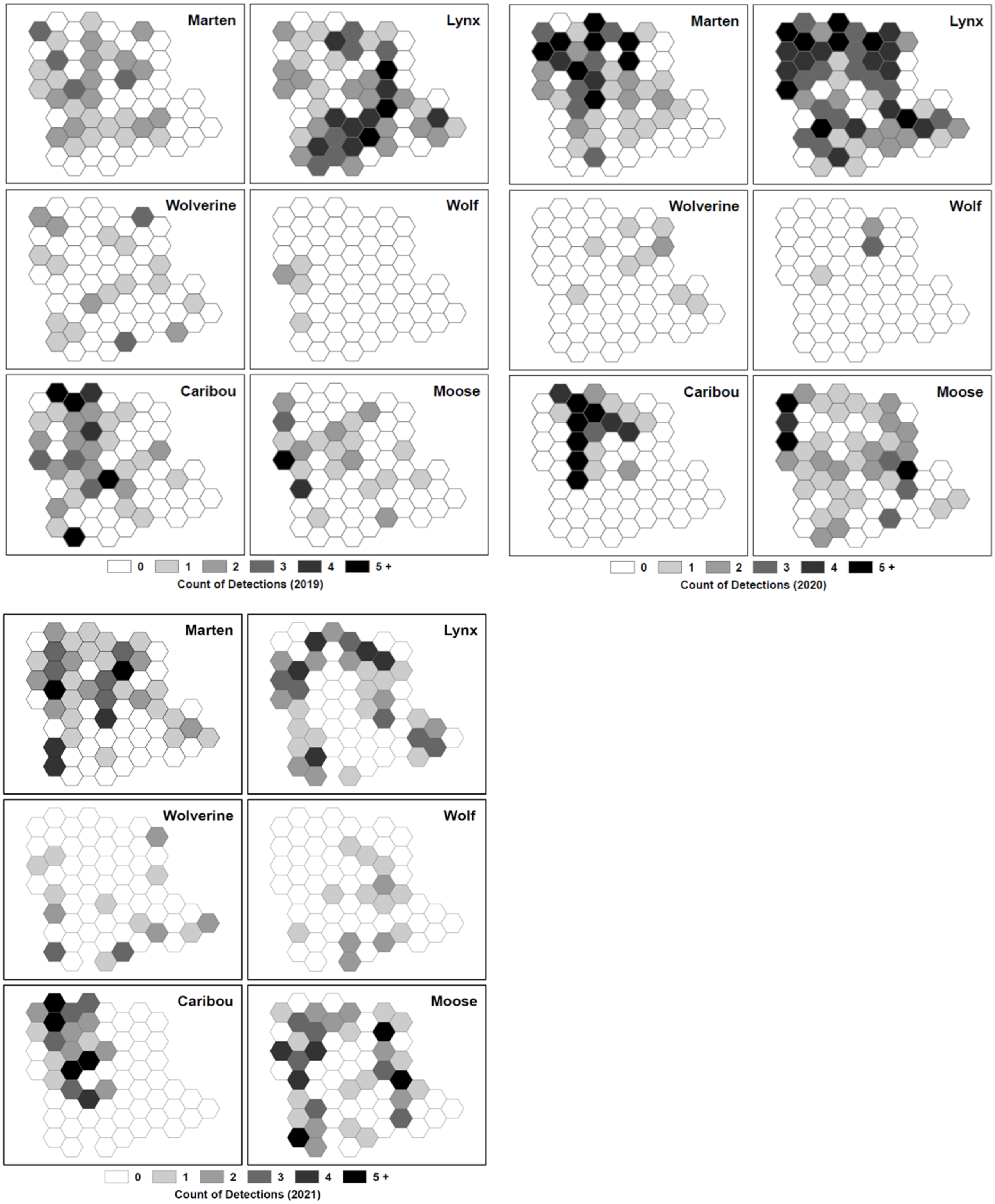


Figure 6. Count of target species detections, per hexagon, within the KLRA in 2019, 2020, and 2021 from helicopter-based snow tracking surveys.

Figure 7. Tracks from a wolf pack around a beaver lodge (top) and a kill site (middle) along the southern edge of the KLRA near the SYD road. Killed site was of a moose. Lone wolf crossing a small lake just north of the KLRA study area (bottom).

Within the KLRA study area in 2021 we observed more individual moose, and an equivalent number of caribou compared to other years (Table 2). Four distinct groups of caribou were observed, including two groups of two and two groups of six individuals. It is noteworthy that unlike in previous years, no collared caribou were observed in 2021. To our knowledge none of the deployed collars observed in past years have been removed or dropped off. This observation suggests that a different subset of caribou is using the area compared to previous years; reviewing use of the KLRA by collared caribou could confirm whether there has been a shift of collared caribou out of this area. No moose were believed to be double counted and no collars on moose were observed. Like caribou, use by moose appears to be increasing in the KLRA.

Table 2. Moose and caribou observations during snow tracking flights between 2019 - 2021 in the core Kotcho Lake Restoration Area, NE BC.

	Moose					**Caribou**					
	Total	**Cow**	**Calf**	**Bull**	**Unclassed**	**Total**	**Cow**	**Calf**	**Bull**	**Unclassed**	**Collared[1]**
KLRA (core area repeated each year)											
2019	9	1	1	0	7	14[a]	4	0	5	5	1
2020	14	0	0	3	11	8[b]	1	0	6	1	2
2021	24	1	6	10	7	14[c]	2	0	0	14	0

[a] Three distinct groups of animals were observed including one group of 2 individuals, one group of 9 individuals, and one group of 3 individuals. The group of 3 individuals was observed twice, but counts and classification here include that group only once.
[b] Two distinct groups of animals were observed including one group of 1 individual and one group of 7 individuals. The group of 7 individuals was observed twice, but counts and classification here include that group only once.
[c] Four distinct groups of animals were observed including two groups of 2 individuals and two groups of 6 individuals.
[1] In 2019 one animal in the group of 9 caribou was collared and in 2020 two animals in a group of 7 caribou were collared. No collars were observed in 2021.

Across the broader 77 hexagons sampled in 2021 we surveyed a total of 454.91 km across 267 transects. We observed a total of 361 unique track detections of caribou, moose, wolves, wolverine, lynx, and marten (Table 3) and 26 and 17 individual moose and caribou, respectively (Table 4). Across the broader area few additional detections were made, though additional caribou use was detected in a suspected area of higher use (Figure 8).

Table 3. Total number of detections, per species, during snow tracking flights in 2021 in the Kotcho Lake Restoration Area, NE BC.

Caribou	Moose	Wolf	Wolverine	Lynx	Marten
75	79	19[a]	30	74[b]	84

[a] Includes one wolf and one kill site observation.
[b] Excludes one observed animal.

Table 4. Moose and caribou observations during snow tracking flights in 2021 in the Kotcho Lake Restoration Area, NE BC.

Moose					Caribou				
Total	Cow	Calf	Bull	Unclassed	Total	Cow	Calf	Bull	Unclassed
26	1	6	10	9	17[a]	5	0	0	14

[a] Five distinct groups of animals were observed including two groups of 2 individuals, two groups of 6 individuals, and one group of 3 individuals.

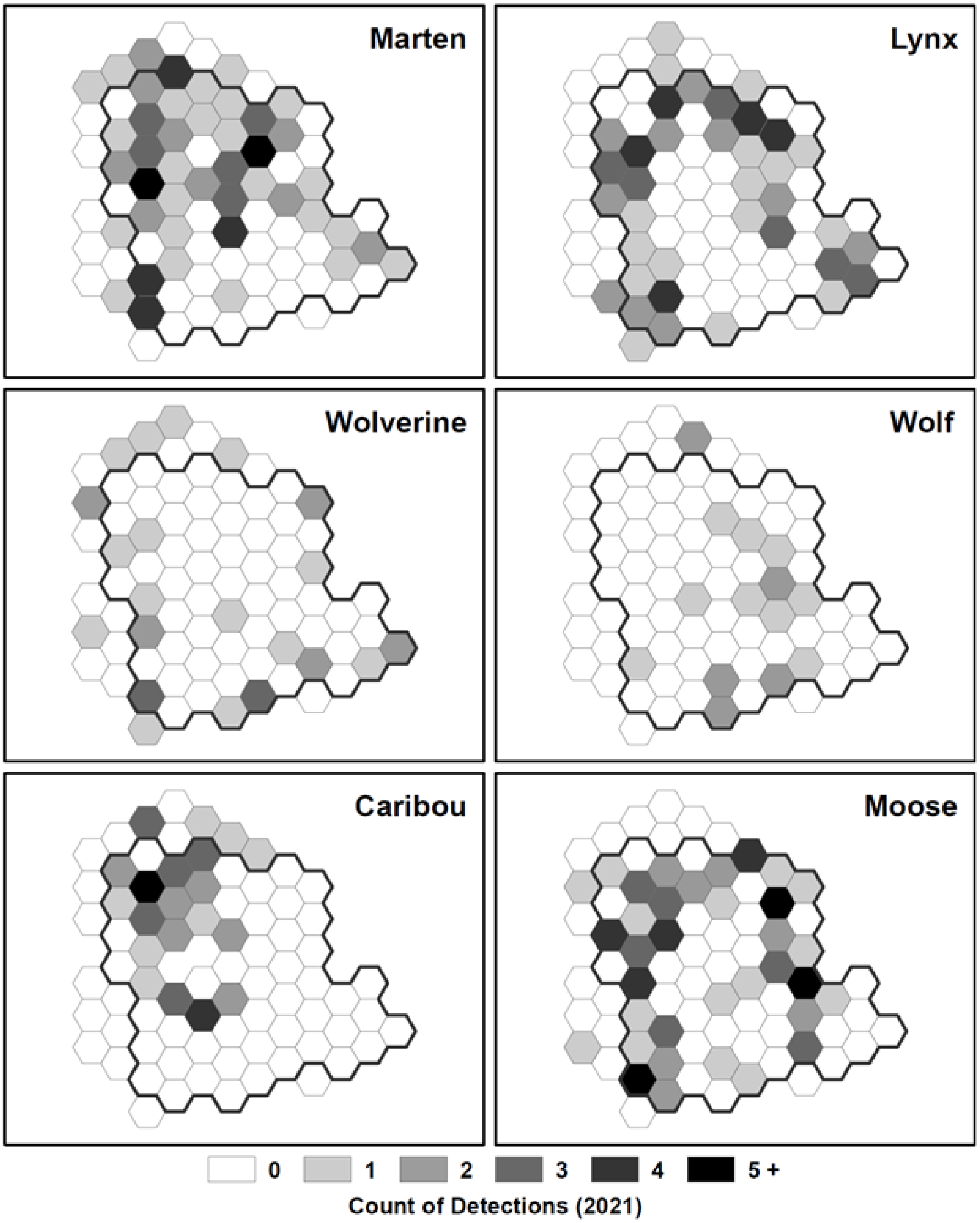


Figure 8. Count of target species detections, per hexagon, within all hexagons surveyed in 2021 across the broader KLRA study area. The thick grey outline represents the KLRA area resampled in 2019, 2020, and 2021.

Do caribou use treated hexagons differently after delivery of restoration treatments?

Within the KLRA we consistently detected caribou, moose, and wolves, although the distribution of those detections changed between years (Figures 9 and 10).

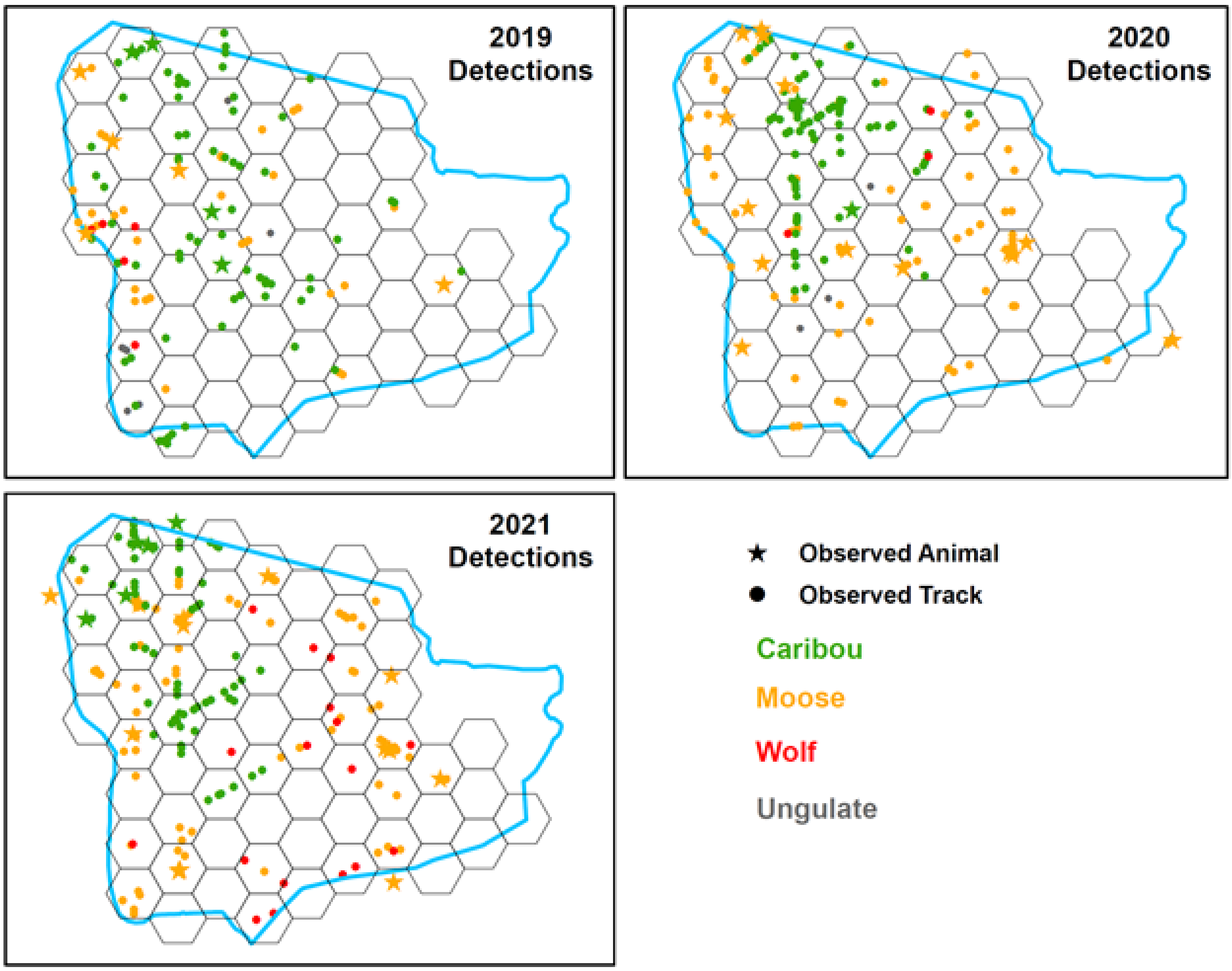
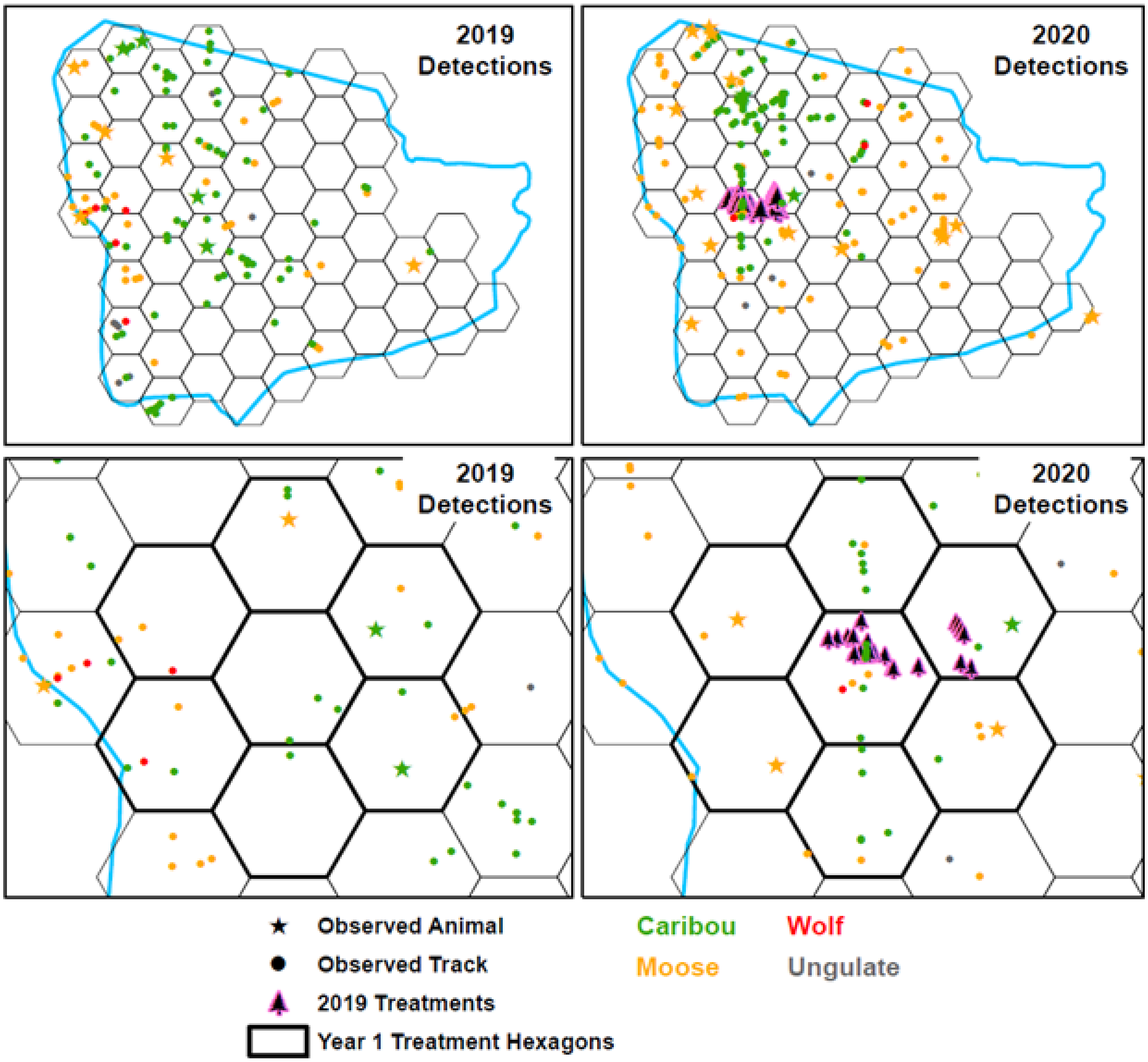


Figure 9. All data on wolves, caribou and moose in the KLRA.


2019
Detections
2020
Detections
2019
Detections
2020
Detections
Observed Animal
Observed Track
2019 Treatments
Year 1 Treatment Hexagons
Caribou
Wolf
Moose
Ungulate

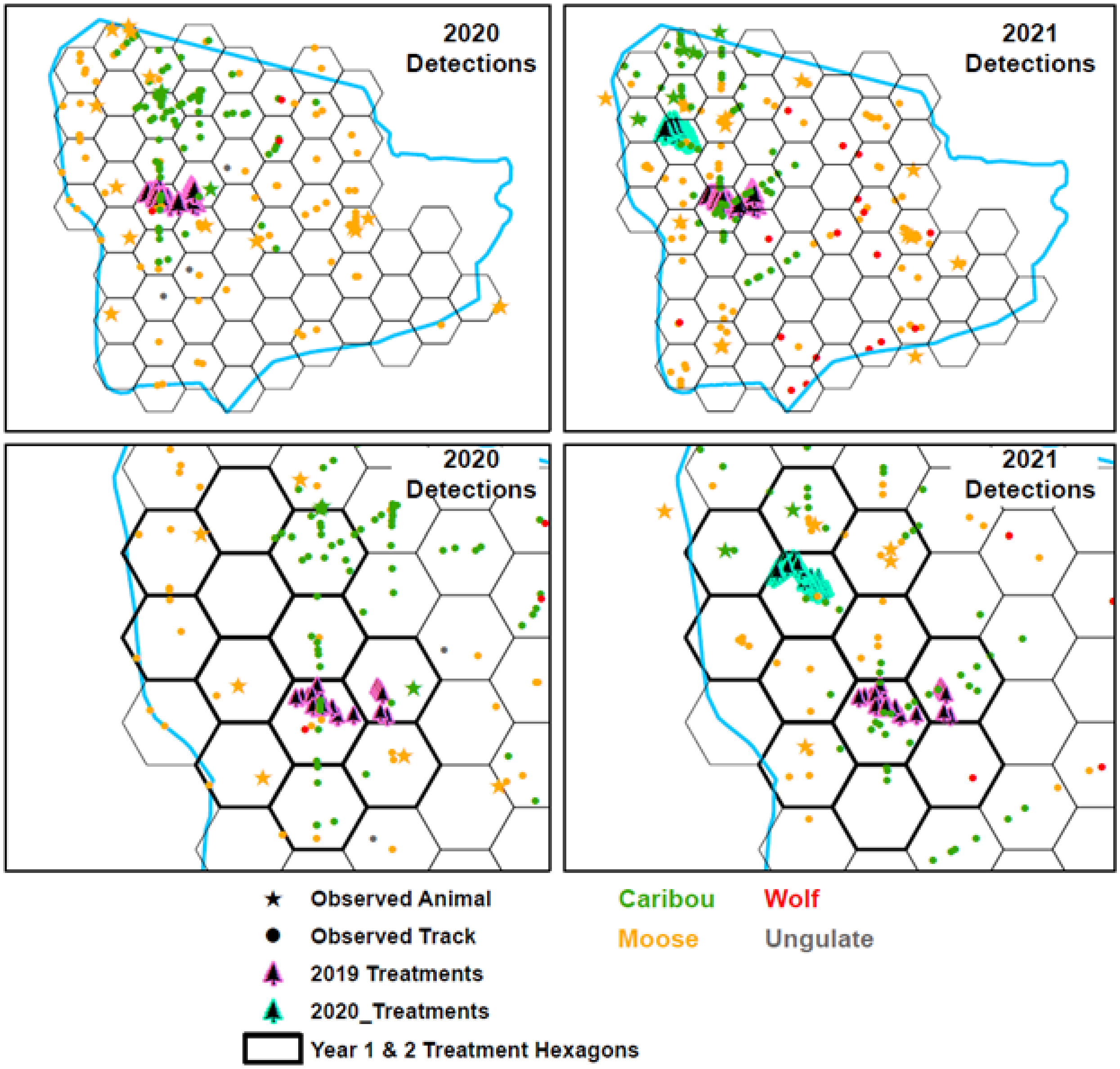


Figure 10. Caribou detections pre- and post-treatment (A) between 2019 and 2020 (e.g., Year 1 treatments) and (B) between 2020 and 2021 (e.g., Year 2 treatments).

After both one- and two-years post-treatment, we observed evidence of increased caribou use of treated hexagons (Figures 11 and 12). The average number of detections in hexagons one-year post-treatment increased relative to the untreated hexagons. This increase in use was even greater after two years. Despite the observed trend, these results were not statistically significant (after one year, $p = 0.657$; after two years, $p = 0.264$). Moreover, caribou use is variable among hexagons across years, making the overall patterns difficult to interpret. It is not unexpected to see weak patterns in how caribou use changes after only a couple years of treatment, though it is encouraging to see trends at this stage.

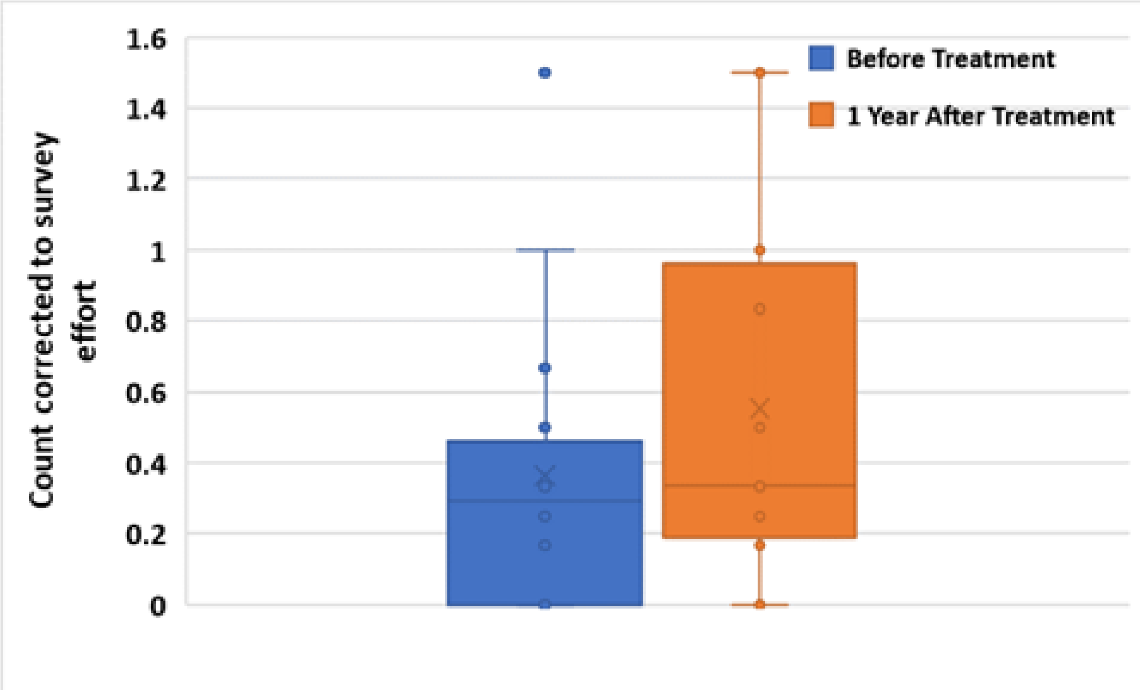


Figure 11. Boxplot comparing caribou use before and one year post-treatment in treated landscape hexagons (n = 14 hexagons total, combing years 2019 to 2020 and years 2020 to 2021).

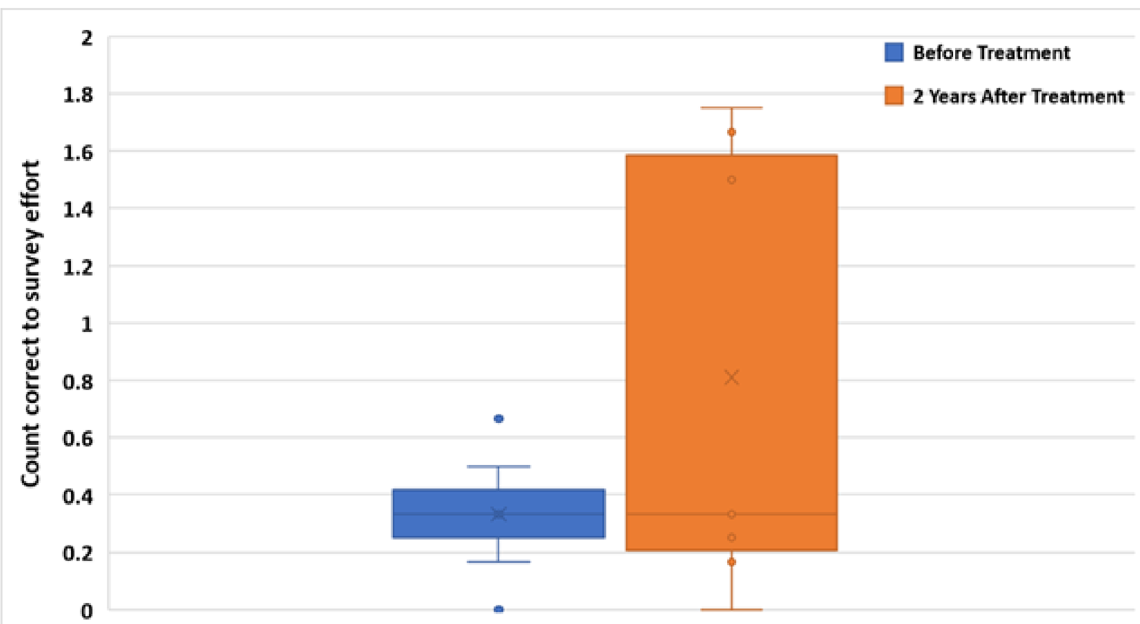


Figure 12. Boxplot comparing caribou use before and two years post-treatment in treated landscape hexagons (n = 7 hexagons total, using years 2019 to 2021).

4.2. Site Level Wildlife Monitoring: Wildlife Cameras

4.2.1. Overview

Wildlife camera traps are employed in the KLRA to monitor wildlife use of seismic lines to determine whether seismic line treatments alter wildlife use of these lines. Camera trap data collection has a low environmental impact and causes minimal disturbance to wildlife (Wearn and Glover-Kapfer 2017).

The design of the wildlife camera trap deployment will answer the following questions:

- Does seismic line treatment result in reduced use of seismic lines by the target species (wolves, caribou and moose)?
- Does the movement pattern along the treated lines change relative to the use of the untreated seismic lines?
- Do the movement patterns change relative to background wildlife movement (i.e., along existing game trails)?

The analysis documents what species have thus far been captured in the camera trap footage, and documents both the daily and seasonal patterns in wildlife use by species.

The original experimental design involved the establishment of wildlife cameras at control and experimental sites to monitor the movement of wildlife before treatment for at least one year prior to treatment. Once treatments were implemented, monitoring would then continue for at least five years to determine the effectiveness of the treatments at reducing wildlife activity. This camera deployment plan follows a before-after-control-impact (BACI) design (Green 1979). The BACI approach has been critiqued over time (e.g., see various papers by Underwood; 1991, 1992, 1993, 1994) but is still considered one of the best models for environmental effects monitoring programs (Smokorowski and Randall, 2017).

Due to helicopter access restrictions, only eight cameras were deployed in 2019. Thus far, only data from these 8 cameras has been analysed. Eleven additional cameras were deployed in 2020, with SD cards retrieved in June of 2021. Data from these cameras will be analysed for the final report for this project. See Appendix A for more details on camera deployment protocols.

4.2.2. Methods for Data Analysis

Reconyx HP2X HyperFire 2 Professional Covert IR Cameras are used in this study, with standard camera settings. The camera traps use remote-triggered infrared to take photographs, and at the moment of capture, the date, time and temperature are recorded. The cameras are configured to capture a series of five pictures after the camera's motion sensor is triggered.

In May 2019, cameras were set up at eight treatment sites along connected legacy seismic lines (Figure 1 and Figure 13). Eleven additional cameras were set up in 2020 (Figures 1 and 2). The seismic lines vary from 6 to 12 meters in width and typically have minimal natural regeneration. Cameras were installed along the side of the seismic lines to ensure that any animals traveling along these corridors would be photographed. Site characteristics, common plants, seismic line information and supplementary notes were recorded at camera deployment (see Table 5 for details). Camera sites were revisited to replace batteries and SD cards in December 2019 and July 2020. The cameras have been left for ongoing data collection. The camera data summarized in this report is from May 26, 2019 to July 13, 2020.

After SD card retrieval, data was stored on an external hard drive. Photographs were organised by camera location and photographed species. Animals were identified from the clear, unobstructed photograph(s) within each of the five photograph series captured after each infrared trigger. Photographs showing a clearly identifiable animal or part of an animal were retained for subsequent analysis. Photographs depicting unidentifiable animals, humans and machinery were archived and excluded from the analysis. Caribou were identified from the wildlife camera photographs based on documented distinguishing features (see Alaska Department of Fish and Game 2017). In order to avoid double counting an animal, a photograph of an animal was defined and counted as a new record only if 60 minutes had passed since the last photograph of the same species. A picture with multiple individuals of the same species (e.g., three caribou) was also only counted as one record as our approach did not include any information on the number of individuals per picture.

R Version 4.1 was used for processing and analysis. The data was summarized by station, species and month, and the CamtrapR package (Niedballa et al. 2016) was used to sort the images and process the camera metadata. The distribution of caribou activity records by time of day, as well as the overlap in daily periods of activity with key predators (wolves and bears) was examined with CamtrapR.

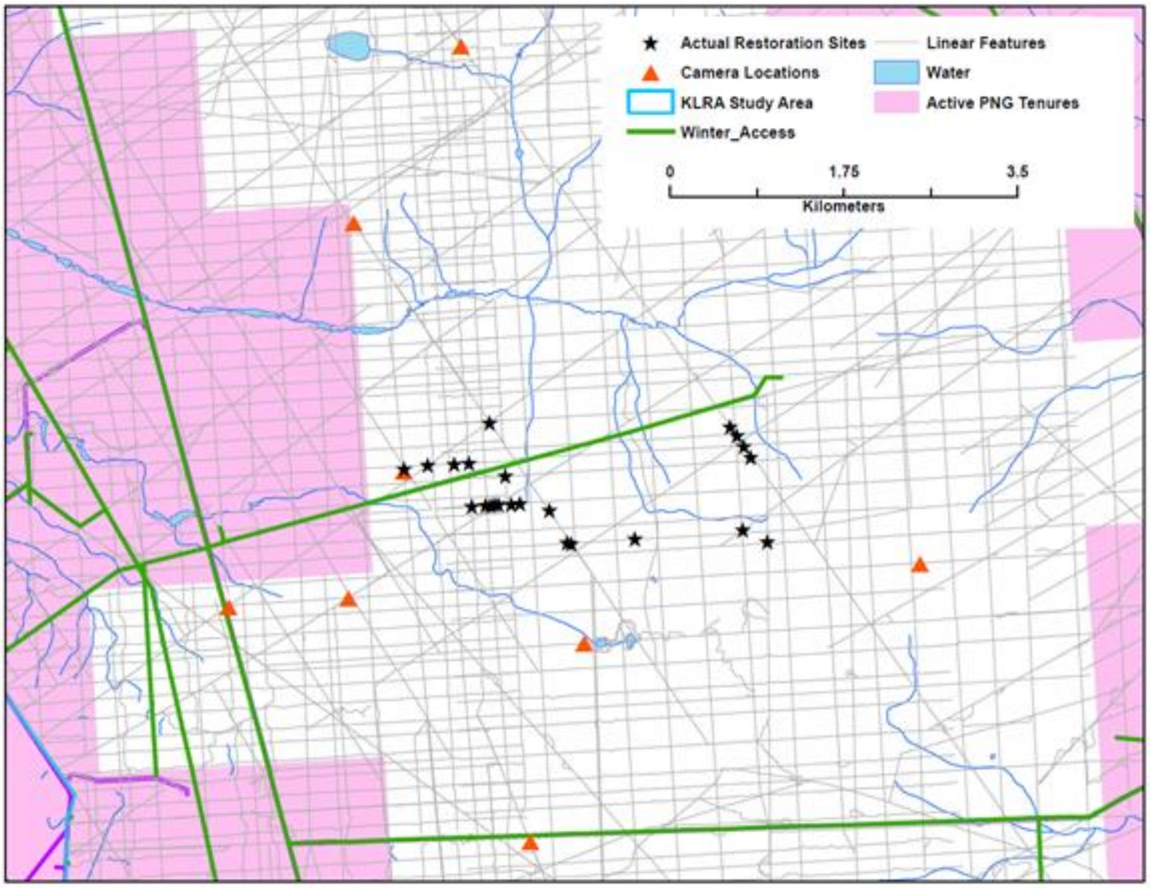


Figure 13. A map of the wildlife camera stations (orange triangles) and restoration sites (black stars) within the KLRA study area from year 1 (2019).

Table 5. Camera station information including if the site is a treatment or a control site, a description of the landscape and vegetation at the site, location details, and information on the camera malfunctions.

Station	Treatment or Control	Site Description	Location Notes	Camera Malfunctions
KLRA-2019-01	Treatment	Tree bog with 2-metre-tall spruce, labrador tea, lots of blueberries, and bog birch in the understory. Very few black spruce seedlings on seismic lines.	Camera facing West on a North-South seismic line. Close to the intersection of a larger line running East-West. Majority of regen are shrubs less than 50cm tall.	Camera took a photo every 3 hours from 2019-12-05 until 2020-04-17. Then, took a set of photos every minute or every 3 hours starting from 2020-04-18 . 2 files were damaged and

				look like they only loaded half the picture.
KLRA-2019-02	Treatment	Black spruce, tamarack, labrador tea, and grasses are common on site. Spruce and tamarack saplings growing on seismic lines. Dead tree in background of camera.	Camera facing East of intersecting lines, one running Southeast-Northwest the other East-West. Majority of regen is shrubs and seedlings less than 50cm tall.	Camera took photos every 3 hours. Camera sometimes had snow covering the infrared light or camera. Wind triggered the camera frequently.
KLRA-2019-03	Control	Black spruce, tamarack, grasses, and shrubs common on this rich fen.	Camera facing Northwest towards junction with a pipeline running perpendicular to a North-South line. A mix of regen is shrubs growing less than and taller than 50 cm.	7 damaged photos did not load or could not be opened.
KLRA-2019-04	Treatment	Poor fen with minimal regeneration. Grasses and shrub clearing in front of the camera and black spruce in the background.	Camera facing Northeast on line running Southeast-Northwest, with 2 other intersecting lines Southwest-Northeast and another Southwest-Northeast. Minimal regen with most being shrubs less than 50cm tall.	Wind triggered the camera frequently.
KLRA-2019-05	Control	Rich fen with tall shrubs in front of the camera. Spruce and tamarack in the background.	Camera facing Northeast on a line that runs Northwest-Southeast. Some regeneration with 30-60% seedlings taller than 50cm.	Camera had shrubs that triggered pictures, often resulting in large files with very few pictures of animals

KLRA-2019-06	Treatment	Tree bog with spruce, labrador tea, small shrubs, and moss.	Camera facing Northwest on a line that runs East-West close to a North-South line intersection. Poor regen with the majority of shrubs less than 50 cm tall.	Camera took some photos that were covered with snow
KLRA-2019-07	Treatment	Tree bog with spruce labrador tea, shrubs, and grasses. Drier mound with grass in front of camera.	Camera facing Northwest along a trail leading to two intersecting lines; one East-West the other North-South. Majority of regen is shrubs less than 50cm, but signs of good bog birch regen.	Camera started taking 1 photo every second on 2020-04-19 until 2020-04-23
KLRA-2019-08	Treatment	Tree bog with spruce, labrador tea, small shrubs, and moss. Clearing in front of the camera is dry and spruce trees in the background.	Camera facing Northeast on a line going East-West and another going Southeast-Northwest. Majority of regen is shrubs less than 50 cm and some spruce regen.	Two damaged photos that were half taken or totally blank with no date or temperature info stamped on the top. Some photos have an error message stating "Could not be opened". A total of 6 photos were damaged.

4.2.3. Results

Black bear (Ursus americanus), coyote (Canis latrans), ermine (Mustela erminea), grey wolf (Canis lupus), grouse (species unidentified), lynx (Lynx canadensis), moose (Alces alces), pine marten (Martes Americana), rabbit (species unidentified), sandhill crane (Antigone canadensis), small bird (species unidentified), wolverine (Gulo gulo) and Woodland caribou (Rangifer tarandus caribou) were observed in the photographs. Caribou was the only species to be recorded at all eight camera stations, and had the greatest number of total camera trap sightings with 169 records (Table 6). Sandhill cranes were the second most frequently recorded with 19 records, and black bears and pine martens were the third most frequently recorded with 14 records each (Table 6).

Table 6. Kotcho Lake restoration area wildlife camera records, summarizing the number of records of different species captured per camera.

Species	**KLRA-2019-08**	**KLRA-2019-07**	**KLRA-2019-01**	**KLRA-2019-02**	**KLRA-2019-03**	**KLRA-2019-04**	**KLRA-2019-05**	**KLRA-2019-06**	**Total**
Black Bear	5	0	0	1	3	4	0	1	**14**
Caribou	22	18	4	35	19	21	13	37	**169**
Coyote	0	0	0	0	0	0	1	0	**1**
Ermine	0	0	2	0	0	0	0	0	**2**
Grey Wolf	0	0	0	0	2	0	0	3	**5**
Grouse	0	2	0	0	0	0	1	1	**4**
Lynx	3	0	1	3	0	1	0	0	**8**
Moose	2	0	0	0	7	3	0	0	**12**
Pine Marten	0	5	3	0	1	5	0	0	**14**
Rabbit	1	1	1	0	8	1	1	0	**13**
Sandhill Crane	1	2	0	1	2	1	2	10	**19**
Small Bird	0	1	2	0	0	0	1	1	**5**
Wolverine	1	0	0	0	1	0	0	0	**2**
Number of species	**7**	**6**	**6**	**4**	**8**	**7**	**6**	**6**	**13**

Total records	**35**	**29**	**13**	**40**	**43**	**36**	**19**	**53**	**268**

Recorded animal activity was highest in July 2019 (with 47 records), and May 2020 (with 42 records). Overall recorded animal activity in 2019 was highest in mid-summer through June and July, as well as in early fall in September (Figure 14). In 2020, recorded animals increased in the spring and remained high until the memory cards were collected in July (Figure 14). Caribou monthly activity records mirrored those of the overall recorded activity with the highest levels of activity in mid-summer and september of 2019, and spring to mid-summer of 2020 (Figure 14). Daily recorded caribou activity was greatest in the morning from around 6 am to 11 am, and in the evening from 10 pm to 11 pm (Figure 15). Recorded caribou activity was lowest from 1 am to 2 am (Figure 15). The overlap in daily activity between caribou and grey wolves, and caribou and black bears can be seen in Figure 16 and Figure 17 respectively.

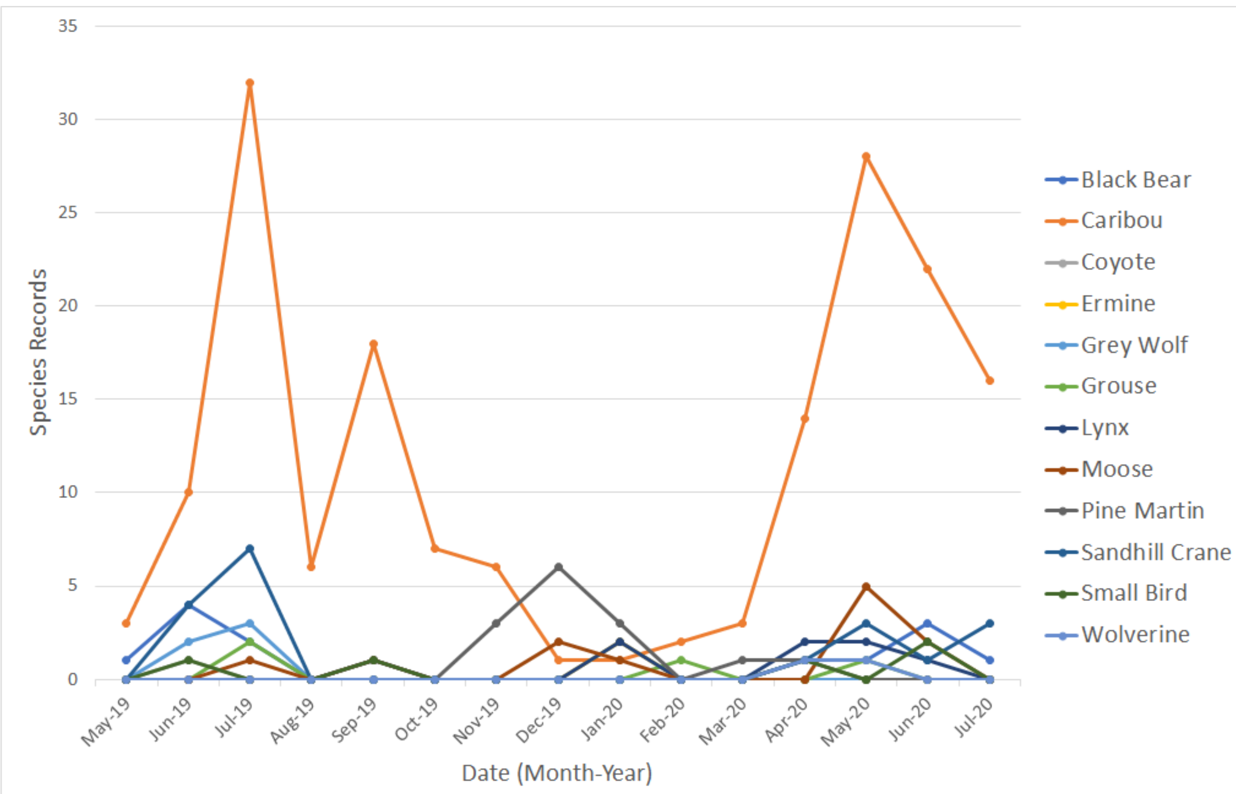


Figure 14. Wildlife camera trap species activity by month in the Kotcho Lake restoration area. The data collection period was May 26, 2019 to July 13, 2020, and the data comes from 8 cameras across the study area.

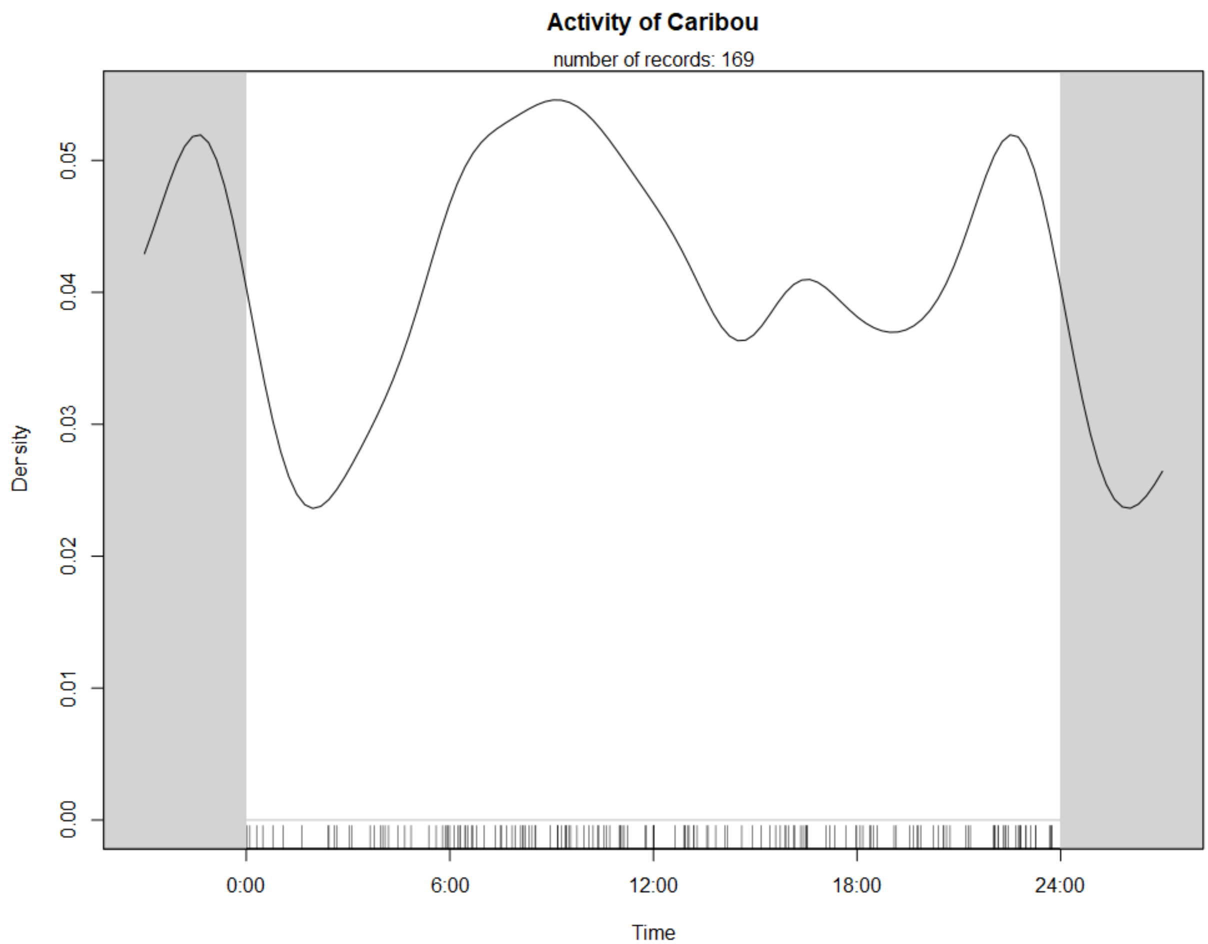


Figure 15. The kernel density estimation of caribou activity by time of day, based on camera trap records from the Kotcho Lake wildlife camera. The data collection period was May 26, 2019 to July 13, 2020, and the data comes from 8 cameras across the study area. 169 caribou records were captured.

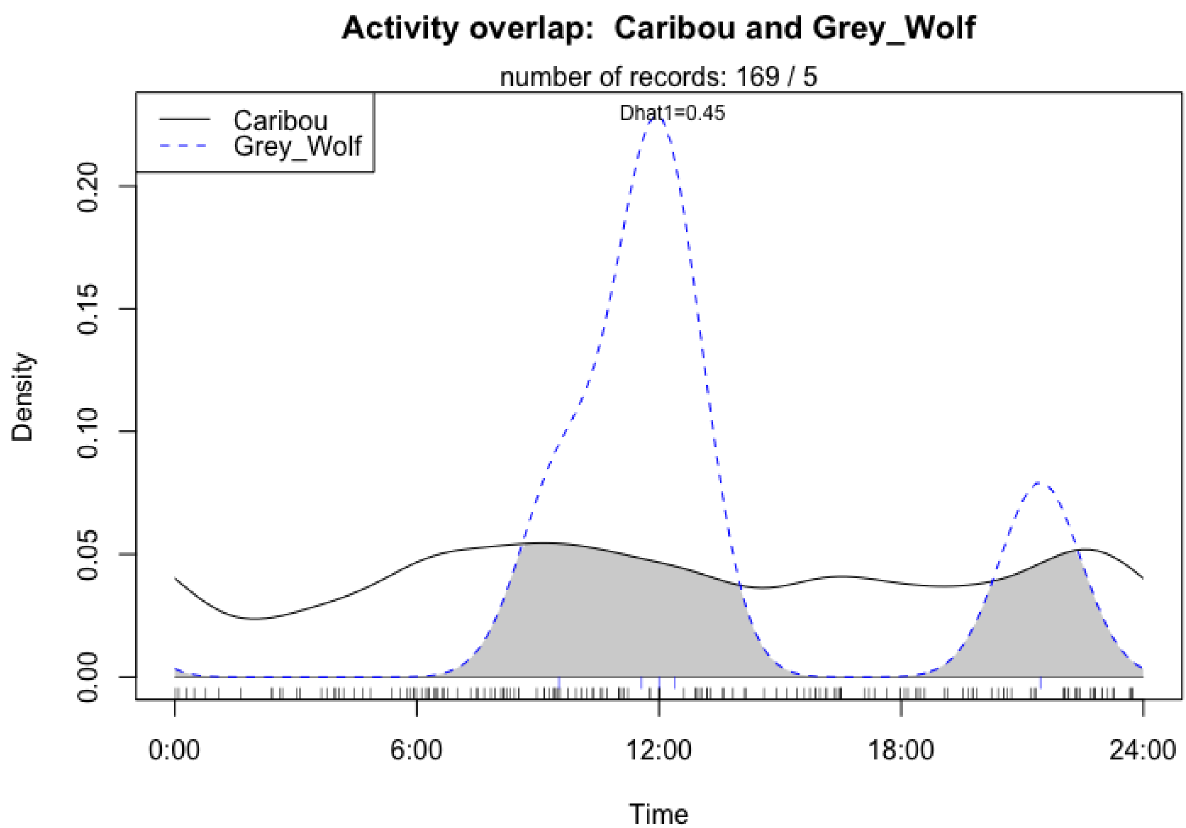


Figure 16. The activity overlap between caribou and grey wolves. Caribou (black) and grey wolf (blue) kernel density activity estimates by time of day are overlaid for comparison. The activity estimates are based on camera trap records from the Kotcho Lake wildlife camera. Eight cameras were deployed from May 26, 2019 to July 13, 2020 across the study area. 169 caribou and 5 grey wolf records were captured. The overlap coefficient is 0.45.

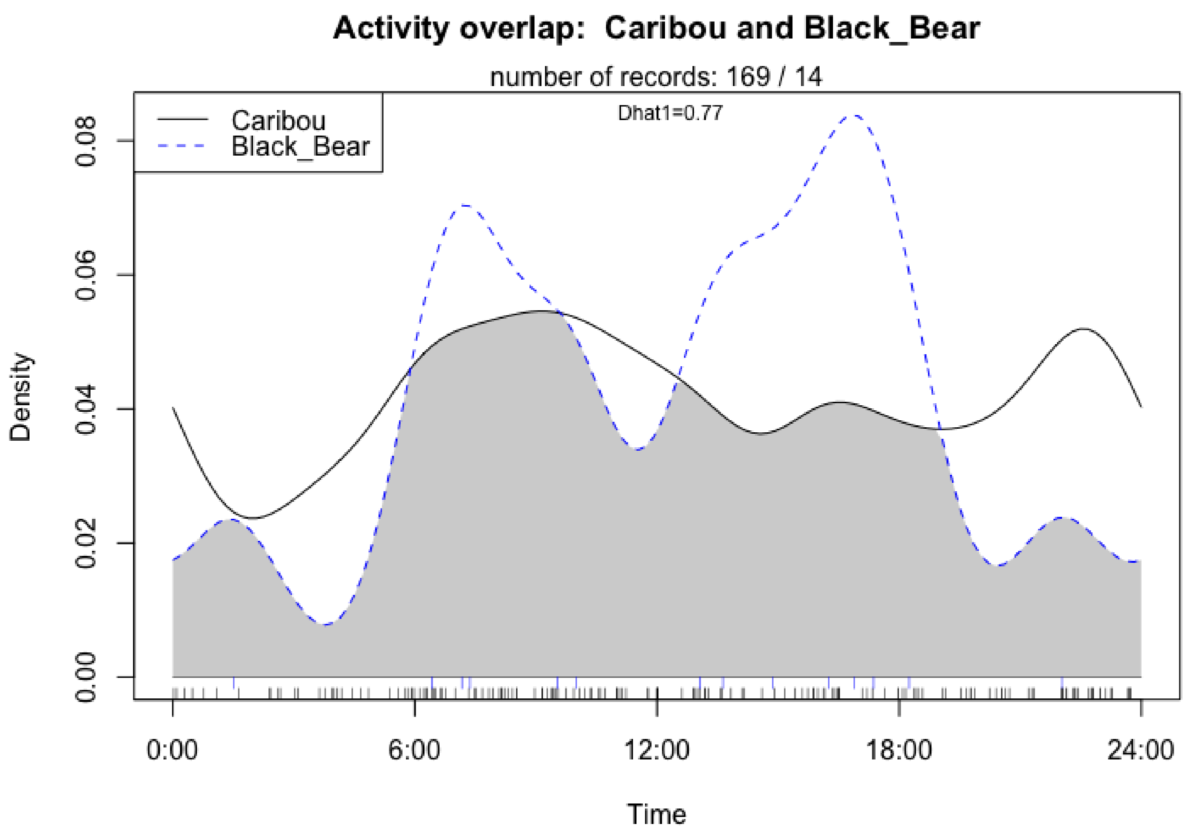


Figure 17. The activity overlap between caribou and black bears. Caribou (black) and black bear (blue) kernel density activity estimates by time of day are overlaid for comparison. The activity estimates are based on camera trap records from the Kotcho Lake wildlife camera. Eight cameras were deployed from May 26, 2019 to July 13, 2020 across the study area. 169 caribou and 14 black bear records were captured. The overlap coefficient is 0.77.

4.2.4. Discussion

Caribou activity was greatest in mid-summer and fall of 2019, and spring to mid-summer of 2020. Because the data collection did not start until May 26, 2019, and finished July 13, 2020, only one full spring and fall have been captured by the data. It is likely that the activity of caribou was quite similar between years. Caribou rutting season typically occurs from September to mid-October in the study area (Goddard 2009). The apparent increase in caribou activity in September may align with the rutting season, or may be simply due to a period of 'fattening up' in the fall (e.g. University of Maryland 2019). Overall animal activity - including grey wolf and black bear activity - was highest in the summer, however the low number of records for species other than caribou make it hard to infer much from the data. As the cameras are left out for more seasons, seasonal trends will likely become more apparent for both caribou and other species.

The periods of highest daily activity of caribou overlaps with those of grey wolves, both have high activity mid-morning and just before midnight. It is possible that the activity of these species are correlated, however there are not enough wolf records to infer anything with confidence. There is a high amount of overlap in the daily activity estimates of caribou and black bears, although black bears peak activity period from about 2 pm to 6 pm does not coincide with a high activity period for caribou. As more data is collected, the relationship between species activity can be further examined, possibly even comparing daily activity overlap between seasons.

Data collection in 2019-20 was limited by the unforeseen challenges involved with placing cameras in the field. It was more difficult than anticipated to land the helicopter near planned treatment locations and thus the planned camera traps were not all deployed. While the original experimental design planned for camera deployment before treatment (i.e., the BACI design originally proposed), access and budgetary limitations have meant that cameras are deployed when treatments are established in the field, and only at sites that are within a 0.5 km radius of a helicopter landing pad.

Reconnaissance efforts in summer 2020 identified and mapped helicopter landing locations throughout the KLRA to facilitate camera deployment, resulting in a much improved distribution of cameras relative to treatment areas in 2020 (see Figure 2). The team is reviewing camera data now to determine next steps for analysis, in particular to determine how to compare treatment vs. non-treatment sites in our next report.

4.3. Site Level Vegetation Response Monitoring: Vegetation Plots

4.3.1. Overview

Site-level restoration treatments are being used to improve recovery along linear features. Our goal for treatments is to achieve both functional and ecological restoration to improve caribou habitat and ecosystem integrity, respectively. The purpose of this monitoring is to determine whether the physical restoration treatments translate to expected vegetation and ecological responses.

To evaluate the vegetation response of delivered treatments, we collected and analyzed a range of field data. Treatments were delivered as clustered groups, each cluster including: a transplanted hummock, a created duff pile and scrape, and greenhouse grown seedlings planted in naturally occurring microsites, on duff piles, and in scrapes. In July 2020 we collected data at 57 clusters of treatments across 15 sites (a total of 81 clusters were delivered across 21 sites in fall 2019). At each cluster we recorded data on a variety of vegetation and site characteristics, as well as data about on- and off-line reference conditions. For a full list of measures taken, and methods employed, see Appendix C for the monitoring protocols and D for the field sheets.

To measure the efficacy of treatments, we compared vegetation responses and site outcomes using a series of t-tests and regressions, comparing average conditions and possible factors influencing outcomes, respectively. The comparisons were intended to examine (a) changes in the delivered treatment after a one year growing season (e.g., 2019 to 2020) and (b) variation in the outcome between different methods (e.g., site preparation method or treatment method).

4.3.2. Hummock Transfer

Hummock transferring is a relatively novel method of restoration that simply transplants a whole, live hummock from the adjacent area onto a target restoration site. The intended benefit of the technique is both increased efficiency and efficacy. Rather than construct a mound or hummock in one season and then plant the constructed mound in a subsequent season, all requisite steps are accomplished during transplant. Further, hummocks support miniature ecosystems including mosses and vascular plants, and often much larger trees than are available or feasible for a typical planting operation. Thus, if successful, transplanted hummocks can establish not only large trees on lines, but also a range of ecosystem components. Transplanting success is based, in part, on the live moss growing from transplanted hummocks onto target sites to anchor and integrate the transplants into target sites. Because the method has not yet been widely employed, we were interested in evaluating whether transplants survived, integrated, and how they may have changed over a year, and whether treatment methods or site characteristics influenced survival and persistence.

1. Settling

A principle failing of the constructed hummocks used previously in the region is collapse and disintegration; after construction, freeze-thaw cycles and other factors caused a deterioration of constructed hummocks such that they did not provide the requisite microtopography to sufficiently alter line conditions to recover vegetation. If transplanted hummocks die or otherwise collapse, they may be of limited value as a restoration tool.

Of the 57 hummocks remeasured in 2020, none collapsed or broke apart, but two hummocks were damaged by hinged trees.

To measure changes in hummock dimension, we compared the change in hummock height and overall size between 2019 and 2020 using a two-tailed t-tests for unequal variances, as determined by comparing sample variance using an F-test. We compared hummock height as a change in total height (in cm) from hummock bottom to crown to evaluate a “sinking” effect, and overall hummock size as a change in the total summed dimensions (length + width + height measures) to evaluate a "shrinking" effect. Both sinking and shrinking could reduce the amount of rooting space above saturated conditions and or the moisture holding capacity of transplanted hummocks.

The mean height of hummocks was lower in 2020 compared to 2019 (2019 = 30.6 cm, n = 55; 2020 = 22.54 cm, n = 54) (F-statistic = 2.112, $p = 0.004$; t-statistic = 7.017, $p < 0.001$), but the mean dimension was not statistically different (2019 = 170.64 cm, n = 55; 2020 = 170.85 cm, n = 54) (F-statistic = 0.564, $p = 0.019$; t-statistic = -0.031, $p < 0.975$).

It is not surprising that transplanted hummocks sunk. Because transplants were placed at target sites, they settled into location over the following year. It is surprising the overall hummock dimensions remained unchanged, given a statistically significant change in heights year to year. A review of the raw data shows somewhat inconsistent measures of hummock length and width from 2019 to 2020. This is likely in part due to hummocks integrating into transplant sites and becoming less obvious as novel or "separate" features. As hummocks integrate into the site ecology where they start and stop become less clear and less easily measurable.

We did not collect data on adjacent hummock dimensions in 2020 so could not compare whether the settled, transplanted hummocks were equivalent in size to adjacent ones. These data were collected in 2021 for comparison. Anecdotally, settled, transplanted hummocks were of equivalent size to undisturbed, offline ones.

2. Anchoring

To evaluate whether transplanted hummocks were integrating into target sites we measured how much of the hummock was "anchored". Anchoring was measured as the percentage of the hummock-to-transplant site edge with live moss growth that was no longer distinguishable as separate pieces.

On average, a transplanted hummock was 40% anchored (range of 0% to 100%) anchored.

We transplanted hummocks into both raw and scraped sites along lines (e.g., directly onto unprepped locations of target lines and onto prepped locations where competing vascular plants and a thin layer of moss was scraped away, respectively). We compared anchoring success between raw and scraped sites as the mean amount of anchoring using a two-tailed t-test for equal variances, as determined by comparing sample variance using an F-test.

The mean amount of anchoring of hummocks was not statistically different across site types (raw = 44.32% n = 22; scraped = 35.33%, n = 33) (F-statistic = 0.918, $p = 0.427$; t-statistic = 1.028, $p < 0.309$).

Despite no statistical difference, higher mean anchoring at raw sites was counter to anecdotal evidence observed in the field, which suggested scraped sites had better success. The distance moss grew out from transplants appeared further in scrapes than on raw sites, though this was not measured explicitly in the field.

We did not explicitly compare transplant to adjacent hummocks as we assumed adjacent hummocks were 100% anchored.

3. Moss Persistence and Recovery

To evaluate moss persistence on hummocks and response to transplanting we measured the total amount of live moss on hummocks as a percent (e.g., what percentage of total moss coverage on the hummock was alive), and as the number of live moss shoots (i.e., individual stems of live growing moss) per cm^2 at the hummock crown and toe (e.g., the very top and lowest point, respectively). Because hummock transplanting depends on mosses growing and anchoring, understanding moss persistence and change is critical to understanding transplant success. Here we can interpret percent cover as the persistence of moss following transplanting (did existing moss survive?) and the number of live shoots as the recovery of moss following transplanting (did new moss grow?). Hummocks are composed of various different species of moss from toe to crown, depending on moisture gradient, and both persistence and new growth vary by species. Here we did not consider species separately, but we did measure new growth at both the toe and crown assuming the highest and lowest moisture contents, respectively.

We compared both metrics in several ways. First, we compared moss cover and live crown and toe shoots on transplanted hummocks to adjacent offline hummocks, then we compared moss cover and live and toe shoots on transplanted hummocks in raw and scraped sites, and finally we compared live and toe shoots on transplants at raw sites to corresponding adjacent hummocks and scrapes to adjacent hummocks. In all cases made comparisons using two-tailed t-tests for equal or unequal variances, as determined by comparing sample variance among comparison groups with F-tests.

The mean amount of live moss was lower on transplanted hummocks compared to adjacent hummocks (transplanted = 87.56%, n = 52; adjacent = 96.9%, n = 50) (F-statistic = 10.873, $p < 0.001$; t-statistic = -2.736, $p < 0.008$). Neither the number of live crown nor live toe shoots were statistically different on transplanted hummocks compared to adjacent hummocks (crown transplanted = 28.39, n = 53; adjacent = 30.02, n = 46; F-statistic = 1.321, p = 0.171; t-statistic = -0.602, p = 0.548) (toe transplanted = 26.28, n = 53; adjacent = 26.84, n = 45; F-statistic = 1.036, p = 0.454; t-statistic = -0.228, p = 0.820).

The mean amount of live moss was higher on hummocks on raw sites compared to scraped sites, but the difference was not statistically significant (raw = 91.4%, n = 20; scraped = 85.16%, n = 32) (F-statistic = 0.365, p = < 0.012; t-statistic = 1.038, p = 0.304). The mean number of live crown shoots was higher at raw sites and the number of live toe shoots was higher at scraped sites, but neither differences were statistically significant (crown raw = 30.29, n = 21; crown scraped = 27.16, n = 32; F-statistic = 0.791, p = 0.295; t-statistic = 0.781, p = 0.439) (toe raw = 24.90, n = 21; toe scraped = 27.19, n = 32; F-statistic = 0.676, p = 0.181; t-statistic = -0.642, p = 0.524).

There were no statistical differences in either crown or toe live shoots at either treatment type compared to corresponding offline hummocks (crown raw line = 30.28, n = 21; crown raw adjacent = 30.05, n = 19; F-statistic = 1.899, p = 0.088; t-statistic = 0.063, p = 0.950) (crown scraped line = 27.15, n = 23; crown scraped adjacent = 30.0, n = 27; F-statistic = 1.105, p = 0.401; t-statistic = -0.747, p = 0.458) and (toe raw line = 24.9, n = 21; toe raw adjacent = 27.56, n = 18; F-statistic = 1.069, p = 0.449; t-statistic = -0.752, p = 0.457) (toe scraped line = 27.19, n = 32; toe scraped adjacent = 26.37, n = 27; F-statistic = 1.197, p = 0..332; t-statistic = 0.239, p = 0.811). However, at scraped sites there were more live toe shoots than in adjacent sites.

There was a significantly higher percent cover off line than on line, and there were more live top shoots off line than on, but there was an even number of toe shoots. More cover and more top and bottom shoots were observed on raw sites compared to scraped. But, there were more toe shoots on scrapes compared to off line than there were raw toe shoots compared to offline.

However, the number of live toe shoots in both locations was nearly identical, and the number of toe shoots was higher at the scrapes. This is important because anchoring is occurring at the toe, so increased moisture facilitates more growth of moss, aiding in the eventual anchoring.

4. Vascular Plants

To evaluate the fate of vascular plants on transplanted hummocks, we compared the persistence of overall vascular cover regardless of species, and the persistence and new growth of target trees on each hummock.

5. Vascular Cover

To evaluate the persistence of vascular cover on hummocks, we measured the percentage of the total amount of live vascular plant cover on hummocks – excluding the target tree (e.g., what percentage of total vascular plant coverage on the hummock was alive). Because one benefit of hummock transplanting is an intact package of live material, understanding the persistence of vascular plant biomass is important to understanding transplant success. Here we can interpret percent cover as the persistence of woody material following transplanting – did the existing woody plants on transplanted hummocks survive.

Like the comparisons of moss, we compared vascular cover in multiple ways. First, we compared cover on transplanted hummocks to adjacent offline hummocks, and next we compared cover on transplanted hummocks in raw and scraped sites. In both cases we made comparisons using two-tailed t-tests for equal or unequal variances, as determined by comparing sample variance among comparison groups with F-tests.

The mean amount of live vascular plant cover was lower on transplanted hummocks compared to adjacent hummocks, but that difference was not statistically significant (transplanted = 92.71%, n = 55; adjacent = 97.98%, n = 55) (F-statistic = 25.65, p = < 0.001; t-statistic = -1.828, p = 0.073). The mean amount of live vascular plant cover was nearly identical and not significantly different on raw and scraped sites, though cover was higher on scraped sites (raw = 92.23, n = 22; scraped = 93.03, n = 33; F-statistic = 0.762, p = 0.259; t-statistic = -0.138, p = 0.891). Because neither metric was significant, we did not compare raw site and scraped site transplants to corresponding adjacent hummocks separately.

6. Target Trees

Arguably, the most important comparison of hummock success is whether or not target trees survived. Each transplanted hummock supported at least one tree. Of the 57 hummocks remeasured in 2020, only 1 tree died (because a tree hinged onto and snapped the target tree). The mean height of revisited target trees was 113 cm tall (range 39 – 250 cm).

Because almost all transplanted trees survived, we evaluated success as the amount of new growth the transplanted trees put on in 2020. Like other comparisons, we first looked at the amount of new growth or terminal growth in cm (e.g., new growth on the tree leader since the terminal bud broke in 2020). First, we compared terminal growth between trees in hummock transplants and adjacent trees. Next, we compared trees transplanted into raw and scraped sites and the corresponding adjacent hummocks separately. In both instances we used a paired, two-tailed t-test. Finally, we compared raw to scraped hummocks using a two-tailed t-test for equal variances.

Mean terminal growth of trees in transplanted hummocks was significantly less than in adjacent hummocks (transplanted = 1.34 cm, adjacent = 2.85 cm, n = 56 pairs; t-statistic = -4.540, p < 0.001), for both raw and scraped sites (raw transplanted = 1.2 cm, raw adjacent = 2.76 cm, n = 21 pairs; t-statistic = -3.486, p = 0.002) (scraped transplanted = 1.4 cm, adjacent = 2.9 cm, n = 34 pairs; t-statistic = -3.141, p = 0.003). Interestingly, the average difference in height was less for scraped sites than for raw sites, suggesting improved tree growth for those trees supported by transplanted hummocks in scrapes. This pattern carries forward to the comparison between mean terminal growth of trees in raw and scraped transplants. While not statistically significant, the mean terminal growth of trees in raw transplants was less than that of trees in scraped transplants (raw transplanted = 1.2 cm, n = 22; scraped transplanted = 1.42 cm, n = 34) (F-statistic = 0.846, p = 0.349; t-statistic = -0.798, p = 0.428).

Comparisons suggested that availability to moisture likely influenced the amount of terminal growth trees put on. To explore this relationship further, we also compared terminal growth to correlates of available moisture as a linear regression. In 2019 sampled depth to groundwater was measured in cm (e.g., how far under the ground surface until liquid water was reached), and in 2020 we sampled percent cover of water in scrapes, and maximum depth of water pooled in scrapes (in cm). Of those measures, only depth to groundwater was a significant predictor of terminal growth (depth to $\beta = -0.021$, $p = 0.009$, % cover $\beta < 0.001$, $p = 0.886$, max pooled $\beta = -0.003$, $p = 0.508$). The relationship between terminal growth and depth to water was negative suggesting that a deeper water table occurred where there was less terminal growth, or that less available water was linked to less growth (Figure 18). When terminal growth on raw and scraped transplants were regressed separately, no significant relationships between available water and treatment type were observed (Figure 19). This suggests that it is available moisture – rather than transplanting a hummock onto a raw or scraped site – that is most important to drive tree growth.

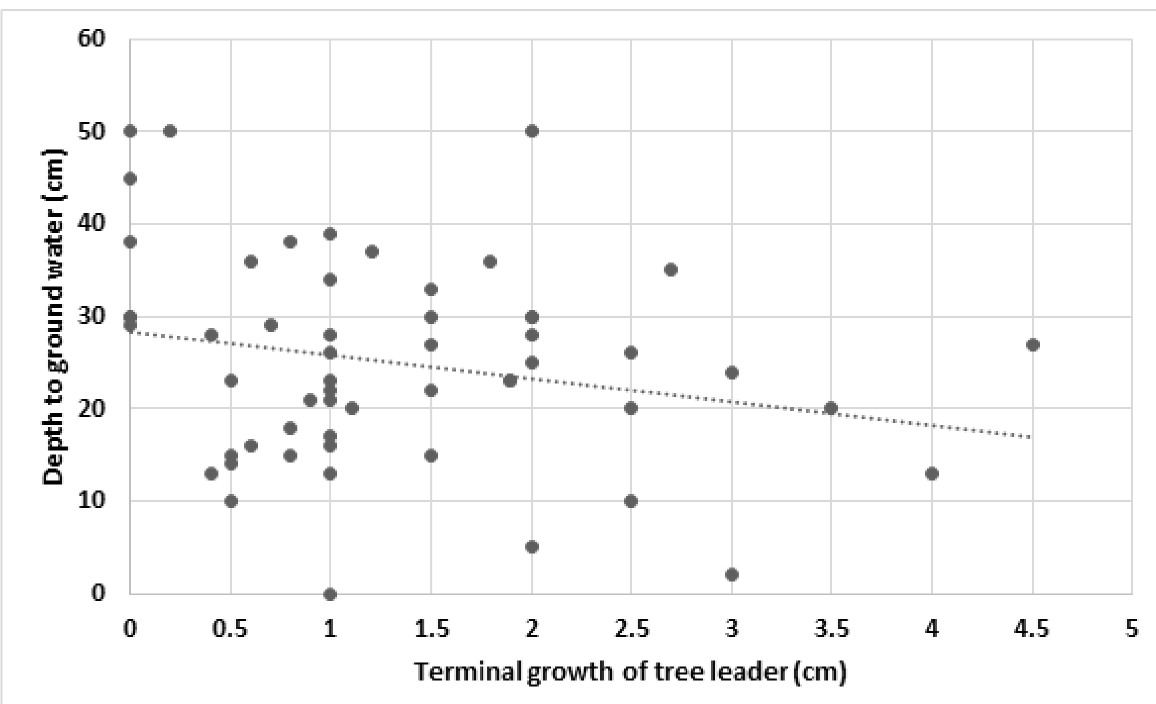


Figure 18. Relationship of terminal growth of tree leaders in transplanted hummocks to the depth of available groundwater at transplant sites.

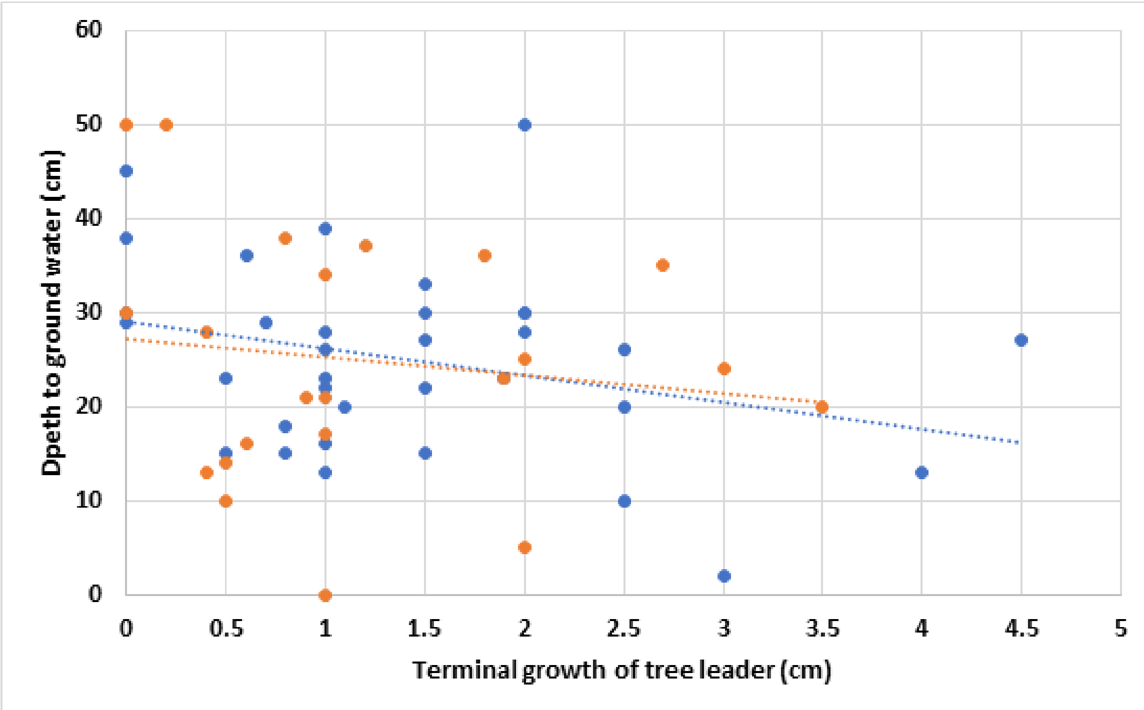


Figure 19. Relationship of terminal growth of tree leaders in transplanted hummocks to the depth of available groundwater at transplant sites at raw sites (orange) and scraped sites (blue).

Importantly, however, scraping sites drive the availability of moisture on legacy seismic lines for transplanted hummocks. At all sites we estimated the ground cover in 1 × 1 m plots, and of the 57 sites visited in 2020, only 6 had standing surface water (range of 5 -15%). In contrast, 38 of 57 scrapes contained some standing water. By scraping a site and transplanting into that site, it is more likely a hummock will come into contact with water, thereby increasing available moisture.

4.3.3. Duff Piles

Constructing mounds is a common restoration technique to create microtopography along compacted and flattened legacy seismic lines. Created microtopography serves a variety of ecological functions, primarily to facilitate favourable germination and recruitment conditions for tree species. Past research has shown mound construction can be difficult, and often successful construction techniques incur undesirable impacts including creation of large pits along lines and associated changes to water cycles (beyond and in addition to changes initially incurred by initial line construction).

Here we created small mounds using primarily surface and near surface layers of moss. Our intent was actually to simply remove potential competition for planted seedlings and transplanted hummocks. But, rather than "do nothing" with the scraped materials, we piled shaped scrapings into piles to emulate hummocks. Scraped materials were composed almost entirely of moss, and attempts were made to maintain live moss in an upright position to facilitate potential continued moss growth and eventual anchoring.

Here we evaluated the fate of duff piles similarly to those evaluations of transplanted hummocks. Our interests in evaluation were in part to assess the fate of the duff piles and in part to compare the efficacy of duff piles to transplanted hummocks.

1. Settling

Of the 57 duff piles remeasured in 2020, one completely died and disintegrated, and two were buried by hinged trees. Though the buried piles appeared alive, they were not measured.

Like hummocks, we measured changes in duff pile dimensions by comparing the change in height and overall size between 2019 and 2020 using a two-tailed t-tests for unequal variances, as determined by comparing sample variance using an F-test. We compared height as a change in total height (in cm) from pile bottom to crown to evaluate a "sinking" effect, and overall pile size as a change in the total summed dimensions (length + width + height measures) to evaluate a "shrinking" effect.

The mean height of duff piles was lower in 2020 compared to 2019 (2019 = 41.59 cm, $n = 56$; 2020 = 30.57 cm, $n = 53$) (F-statistic = 1.351, $p = 0.138$; t-statistic = 7.059, $p < 0.001$), but the mean dimension was not statistically different (2019 = 275.43 cm, $n = 56$; 2020 = 266.63 cm, $n = 53$) (F-statistic = 0.636, $p = 0.049$; t-statistic = 1.292, $p = 0.199$).

Like the hummocks, we suspect the non-significant change in the overall dimension of duff piles was driven by their integration into treatment sites. A review of the raw data also showed inconsistent measures of length and width from year to year.

We also wanted to compare the amount of change between hummocks and duff piles. Because duff piles were easy to create, if they also produced equivalent microtopography to transplanted hummocks, creation of duff piles may be an efficient restoration option. To do so we first compared settled heights of duff piles and transplanted hummocks (e.g., 2020 heights). Next, we compared the change in heights between the two groups (e.g., 2020 height – 2019 heights between hummocks and duff piles).

The mean settled height of duff piles was significantly taller than that of transplanted hummocks (2020 duff = 30.57 cm, $n = 53$; 2020 hummocks = 22.54 cm, $n = 54$) (F-statistic = 2.425, $p = 0.008$; t-statistic = 6.576, $p < 0.001$). The mean change in height was also significantly different with duff piles settling more than transplanted hummocks (duff = 12.02 cm, $n = 53$; hummocks = 7.89 cm, $n = 54$) (F-statistic = 1.635, $p = 0.032$; t-statistic = 2.111, $p =$

0.037). It is not surprising duff piles settled more than transplanted hummocks because hummocks were intact units when transplanted whereas duff piles were “fluffy” after construction. Interestingly, and somewhat unexpectedly, duff piles retained height. Even in 2020 those piles remained somewhat fluffy, and were quite dry (see below). Interestingly, early results from 2021 show that duff piles appear to have consolidated and rebounded with another growing season. Most piles have similar amounts of live moss and similar moisture content as compared to transplanted hummocks.

2. Anchoring

On average duff piles and hummocks were anchored to virtually the same degree; duff piles were 38% anchored (range of 0% to 100%), and hummocks were 39% anchored. There was no statistical difference between the two groups (duff = 37.64%, n = 53; hummocks = 38.93% cm, n = 55; t-statistic = -0.221, p = 0.825).

3. Moss persistence and recovery

To evaluate moss persistence on duff piles and response to transplanting we measured the total amount of live moss on hummocks as a percent (e.g., what percentage of total moss coverage on the duff pile was alive), and as the number of live moss shoots (i.e., individual stems of live growing moss) per cm^2 at the duff pile crown and toe. Like hummocks, we did not consider moss species separately here.

We compared outcomes of duff piles to those of transplanted hummocks, because our goal was to evaluate the relative success of the two metrics, not compare duff piles to a hypothetical undisturbed state. In all cases we made comparisons using two-tailed t-tests for equal or unequal variances, as determined by comparing sample variance among comparison groups with F-tests.

There was significantly less live moss coverage on duff piles than on transplanted hummocks in 2020 (duff = 71.51%, n = 53; hummocks = 87.56%, n = 52) (F-statistic = 1.335, p = 0.152; t-statistic = -3.232, p = 0.002), though there was no difference in the mean number of live crown or toe shoots (duff crown = 27, n = 50; hummocks crown = 28.39, n = 53; F-statistic = 0.738, p = 0.143; t-statistic = -0.533, p = 0.595) and (duff toe = 23.71, n = 52; hummocks toe = 26.28, n = 53; F-statistic = 0.513, p = 0.009; t-statistic = -1.205, p = 0.231).

Compared to transplanted hummocks, persistence of moss was significantly lower on duff piles, but recovery of moss was statistically equivalent between the two groups. However, the lower average number of both live crown and toe shoots was consistent with anecdotal observations of drier conditions on duff piles.

5. Conclusion

5.1. Summary and Recommendations

This report provides a preliminary summary of Year 2 of site treatments at the KLRA. In it, we explain how the focal treatment area for year 2 was selected, how sites were treated, and how monitoring is being conducted to determine what the response is at the site and landscape level. We also explain how we plan to modify our work in year 3 based on our learnings in year 1 and 2. We will continue to evaluate the effectiveness of our treatments to date to determine which ones should be continued into the future. Our streamlined approach to implementing restoration treatments and our monitoring will allow us to continue to effectively treat a large area, and constantly improve our treatment methods. Monitoring will continue to determine whether this work eventually elicits positive benefits for caribou in terms of calf survival and increasing the spatial separation between caribou, moose and wolves.

5.2. Closure

Should you wish to discuss any aspect of this Report further, please do not hesitate to contact Katherine Wolfenden at the number below.

Sincerely,

ORIGINAL SIGNED

Katherine Wolfenden
FNFN Lands and Resource Coordinator
katherine.wolfenden@fnnation.ca
p. (250) 774-6313

Appendix A - Restoration Treatment Protocol

Kotcho Lake Restoration Area 2020 Field Protocol

The goal of Fall 2020 restoration program is to apply learnings from the 2019 season into delivering proven restoration treatments at a production scale. Three types of treatments will be applied in three different combinations in three different treatment zones. Several pieces of data will be collected to evaluate the efficiency of delivering treatments and to later assess treatment efficacy. Remote wildlife cameras will also be deployed.

Restoration treatments

Hummock Transplants

Transplant live hummocks with a main tree stem of up to 1 m in height.

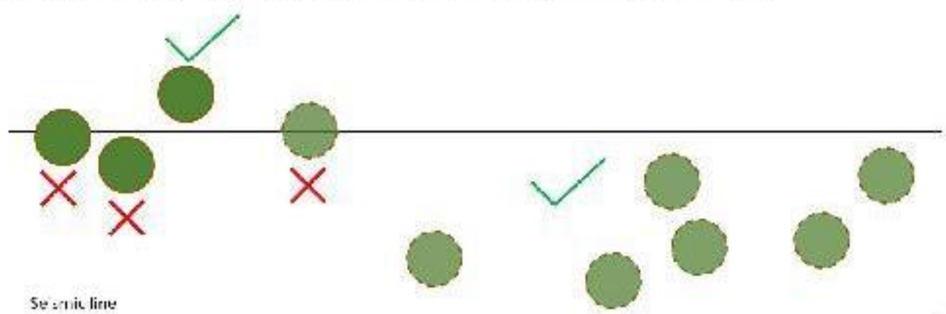
Hummocks should be:

- Taken from the bush next to a seismic line (ie, not taken from a line and moved to a different place on the line)
- Scrapped off the surface, not dug out (ie, do not create borrow pits)
- Transplanted in a prepped site on the line. The site should be scrapped gently with the hoe bucket or a Pulaski to break up the moss and remove any competing vegetation.
  - Do not need to spend a lot of time scrapping – just a quick poke. Not every transplant site will need a scrape.

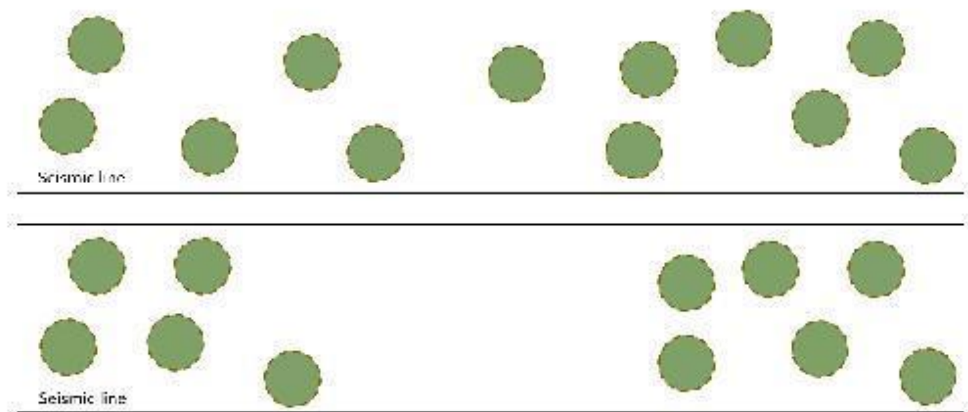
Hummocks should be transplanted at ~ 2 – 10 m spacing along a line and up to ~ 2 m spacing across a line.

Transplanting can be done evenly or clustered as most efficient. If clustering, several hummocks can be clustered somewhat closely together and then another cluster can be spaced a short distance away.

Transplanting should be well dispersed across a line footprint to help "close the line".



Borrowed hummocks (solid circles) should be taken from offline, not from the edge of a line. Transplanted hummocks (dashed circles) should be planted online, not on the edge of a line. Transplanted hummocks should be transplanted randomly all across a line footprint to block travel.



Transplanted hummocks can be placed continuously along and across a line footprint (top), or clustered in small groups (bottom). If treatments are clustered, clusters should be ~ 50 m continuous with gaps of 50 – 100 m between clusters.

Planting Seedlings

Plant greenhouse-grown seedlings.

Seedlings should be:

- Planted sufficiently deep to protect roots and stems
- Planted in naturally occurring microtopography, as possible

Planting density should match estimated density in surrounding forest type.

Tree Modification

Trees will be modified using hinge and felling across lines to slow and prevent animal movement and to create "living fences" as possible.

The primary goal of modifying trees is to hinge trees to create living fences, the secondary goal is to fell trees to create obstacles for movement. Whenever possible, trees should be hinged to obscure line of sight and travelability from a wolf and black bear perspective (ie, 50 – 100 cm above the ground).

Decisions around hinging and felling will be site and operator specific. In some locations hinging and felling may not be feasible (ie, trees are two small).

Tree modification should block the entire line footprint and should use trees from both sides of a line.

Treatment sites and design

A number of lines were identified for treatment (see 2020 maps) from the air in summer 2020. Lines were scouted to determine presumed restoration need (was the line open?) and access (was the line dry and solid enough to drive on?). Treatment should begin on scouted, mapped lines, as feasible, but all lines within the treatment area are permitted for restoration and any line (e.g., any mapped grey seismic line) can be treated as encountered.

Treatments are to be delivered in three different combinations in the three different mapped treatment zones, as feasible.

Yellow

All treatments, delivered everywhere.

Hummocks, planting seedlings, and tree modification (as feasible) are intermingled and all treatments occur in all locations. Treatments can be clustered with small gaps between clusters or continuous, as per feasibility and efficiency. If treatments are clustered, clusters should be ~ 50 m continuous with gaps of 50 – 100 m between clusters.

Red

All treatments, delivered at line intersections only.

Hummocks, planting seedlings, and tree modification (as feasible) are intermingled and all treatments occur only at line intersections.

Blue

All treatments delivered at line intersections only, tree modification (as feasible) between intersections.

Hummocks, planting seedlings, and tree modification (as feasible) are intermingled at line intersections, trees are modified along line segments between intersections.

Note, there may be wet lines and portions of lines where only tree modification is feasible (ie, where conditions may not support the AT-20). In those areas hummocks should not be transplanted. Based on field scouts it is likely these areas occur mostly in the blue zone, but they could occur anywhere across the treatment area.

Data collection & monitoring

Restoration treatments will be marked and recorded for later monitoring. Wildlife cameras will also be deployed to monitor the response of animals to treatments.

All monitoring plots and cameras should be deployed near to established helipads. In total, 8 pads have been prepared in the 2020 treatment area.

Treatments (vegetation)

At each pad between 25 – 50 transplanted hummocks and 25 – 50 planted seedlings should be monitored. Data is to be filled on datasheets; all monitored hummocks and seedlings should be marked with a numbered pin flag in the field (to correspond to numbering on the datasheets.

Monitored hummocks and seedlings can be clustered in groups to maximize efficiency and minimize the number of 1x1m plots required. It is probably possible to cluster ~ 5 hummocks several meters apart around 1 1x1m plot. Several clusters per helipad spread across several lines and intersections is good.

Clusters should be located at line intersections and along line segments, and clusters should be located on different lines in different orientations.

A GPS location of all monitored clusters should be recorded.

Cameras

At each pad between 4 – 5 cameras should be deployed. In total, the goal is to deploy 10 cameras per treatment zone (2 cameras are currently deployed in the blue zone).

Cameras should be placed near to helipads to maximize efficiency of later monitoring and revisiting (up to ~ 1 km away maximum).

Cameras should be:

- Deployed along treated lines approximately between intersections, as possible. Cameras should NOT be deployed at intersections.
- Placed on different lines or ≥ 500m apart if on same line
- Programed as per previous deployments

Treatment Efficiency & Monitoring

The total amount of treatment delivered, and delivery efficiency should be monitored daily.

The following information should be tracked, per day, per crew:

- Time leave camp, return camp
- Time start treatment, end treatment per segment
- GPS start treatment, end treatment per segment
- Approximate amount / number of each treatments done per line segment

If travelling between treatment sites, note travel times

Sufficient detail should be recorded to ensure precise treatment locations, amount, and timing is accurately recorded.

Appendix B - Restoration Treatment Field Sheet

2020 KLRA HUMMOCK & FREE PLANT DATA COLLECTION	Date / Crew	Helipad Number
Treatment Block / Line description relative to helipad (where/direction)	GPS of cluster	
Treatment Location: Center / Line; Line width in m	If on line, line orientation: N-S / E-W / NE-WS / NW-SE; If in center, width in m (both diagonals)	

One sheet per treatment cluster (line segment or center) - Take GPS at treatment cluster

Every hummock gets 1 pin flag - Every free plant gets 1 pin flag

All pin flags numbered with hummock number (HU) or free plant number (FP)

Transplanted Hummocks

Measure dimensions as widest width and length of hummock, height from ground surface to highest point of hummock.

Note if hummock is transplanted to raw or scraped ground.

Measure height and species of all natural conifer seedlings growing on transplanted hummock.

Number	Dimensions (cm)	W ______	L ______	H ______		Ground		Raw	Scraped
	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______ Ht ______
Number	Dimensions (cm)	W ______	L ______	H ______		Ground		Raw	Scraped
	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______ Ht ______
Number	Dimensions (cm)	W ______	L ______	H ______		Ground		Raw	Scraped
	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______ Ht ______
Number	Dimensions (cm)	W ______	L ______	H ______		Ground		Raw	Scraped
	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______ Ht ______
Number	Dimensions (cm)	W ______	L ______	H ______		Ground		Raw	Scraped
	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______ Ht ______

1 x 1 m plots

Percent ground cover in plot must add to 100%, list "other".

Count of all shrub stem in plot & list most common height - Measure height and species of conifer seedlings

Do as many 1 x 1 m plots as needed in treatment cluster to capture variation

Water	______	Lichen	______	Moss	______	Herb / Low	______	Wood	______
Carex	______	Grass	______	Dead	______	Other (list)	______		
# stems	______	Height (cm)	______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______
Water	______	Lichen	______	Moss	______	Herb / Low	______	Wood	______
Carex	______	Grass	______	Dead	______	Other (list)	______		
# stems	______	Height (cm)	______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______
Water	______	Lichen	______	Moss	______	Herb / Low	______	Wood	______
Carex	______	Grass	______	Dead	______	Other (list)	______		
# stems	______	Height (cm)	______	Sp ______	Ht ______	Sp ______	Ht ______	Sp ______	Ht ______

Free plants

List each planted tree to species

Number	Species	Number	Species	Number	Species	Number	Species	Number	Species
Number	Species	Number	Species	Number	Species	Number	Species	Number	Species
Number	Species	Number	Species	Number	Species	Number	Species	Number	Species

Notes

Ap

Kotcho Lake Restoration Area 2020 Vegetation Monitoring Protocol

The goal of this protocol is to gather data with which to evaluate outcomes of the restoration treatments delivered in unfrozen ground conditions during Fall of 2019.

Hummock transfer technique (HTT)

Hummock

Can hummock be picked up? Yes / No

Hummock dimensions (W × L × H), in cm

% of hummock edge anchored to ground

% of hummock surface area (moss) live / dead *

% of vascular live / dead *

Number of live shoots per unit area (top and toe) *

Average length increment of cyclic branch (innate marker from nivial curvature pigment or axis switch) (top and toe), in cm *

Trees

Is target tree alive? Yes / No

New terminal growth, in cm *

Are non-target trees alive? Yes / No, per stem

New terminal growth, in cm, per stem *

* Paired measures on offline hummock

Scrapes

% ground cover (within 1 × 1 m plot) of standing water, lichen, moss, herb, Carex spp., grass, wood, dead (to 100%) *

Number of all shrub stems (within 1 × 1 m plot) and mode height in cm *

Count of new germinated conifers (within 1 × 1 m plot), in cm to species per stem *

Depth of deepest water in scrape, in cm *

Are planted seedlings alive? Yes / No, per planted stem

New terminal growth of planted seedlings, in cm per planted stem

* Paired measures in adjacent, online, 1 × 1 m plot

Free planted trees

Are transplanted trees alive? Yes / No, per planted stem

New terminal growth, in cm per planted stem

Duff Pile

Duff pile

Can duff pile be picked up? Yes / No

Duff pile dimensions (W x L x H), in cm

% of duff pile edge anchored to ground

% of hummock surface area (moss) live / dead

Number of live shoots per unit area (top and toe)

Average length increment of cyclic branch (innate marker from nivial curvature pigment or axis switch) (top and toe), in cm

Trees

Are planted seedlings alive? Yes / No, per planted stem

New terminal growth of planted seedlings, in cm per planted stem

Are volunteer stems alive? Yes / No, per planted stem

New terminal growth of volunteer stems, in cm per stem

Machine tracks

Track dimensions (W × D), in cm (Hägglunds and Cat tracks)

Water pooling in tracks, depth in cm (Hägglunds and Cat tracks)

% standing water, dead (within 1 × 1 m plot) (centered on Hägglunds and Cat tracks)

Burrow Pit

% standing water in borrow

Depth of deepest water in borrow, in cm

If standing water around borrow, extent of water from borrow edge in cm

If dead moss around borrow, extent of dead from borrow edge in cm

Appendix D - Vegetation Monitoring Field Sheet

2020 KLRA TREATMENT MONITORING	Date	Site ID
	Crew	Treatment

Transplanted Hummock

% Edge Anchored	_______
% Moss Total	_______
% Moss Live	_______
% Lichen Total	_______
% Lichen Live	_______
% Vascular Total	_______
% Vascular Live	_______
Num Live Shoots, top	_______
Num Live Shoots, toe	_______
Dimensions (cm)	W _______ L _______ H _______

Trees (circle target, X if dead)

Species	Height	Tr Growth

Adjacent Hummock

% Moss Total	_______
% Moss Live	_______
% Lichen Total	_______
% Lichen Live	_______
% Vascular Total	_______
% Vascular Live	_______
Num Live Shoots, top	_______
Num Live Shoots, toe	_______

Trees (Main trees only)

Species	Height	Tr Growth

Scrape

% filled, water	_______
Deepest depth (cm)	_______

Planted seedling (X if dead)

Species	Height	Tr Growth

Adjacent 1 x1 m plot

Germinated Seedlings

Species	Height

Free Planted Trees

Planted seedling (X if dead)

Species	Height	Tr Growth

1 x 1 m plot

Must add to 100%				Germinated Seedlings	
Water	_______	Carex	_______	Species	Height
Lichen	_______	Grass	_______		
Moss	_______	Wood	_______		
Herb / low	_______	Bare	_______		

Borrow Pit

% filled, water	_______
Deepest depth (cm)	_______
% water around pit (cm)	_______
Max water from pit (cm)	_______
% Dead moss around pit	_______
Max dead moss from pit (cm)	_______

Duff Pile

% Edge Anchored	_______
% Moss Live	_______
% Lichen Live	_______
% Vascular Live	_______
Num Shoots, top	_______
Num Shoots, toe	_______
Dimensions (cm)	W _______ L _______ H _______

Trees (X if dead)

Species	Height	Tr Growth

Trees (X if dead)

Species	Height	Tr Growth

Machine Tracks

Hagglunds			
Depth	_______	Width	_______
Water, cm	_______		

Cat			
Depth	_______	Width	_______
Water, cm	_______		

1 x 1 m plot, Hagg

% surface water	_______
% dead	_______

1 x 1 m plot, Cat

% surface water	_______
% dead	_______

Notes

Flags numbering: Site # - Treatment # - Treatment Type

Yellow flags = treatments; orange = burrow and tracks