TECHNICAL REPORT

Habitat Restoration of Legacy Petroleum and Natural Gas Features in the Klinse-Za Caribou Range

Applying an Analytical Framework for Assessing Implementation and Effectiveness of Restoration

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EXECUTIVE SUMMARY

Reducing the effects of disturbances in habitats used by populations of woodland caribou (*Rangifer tarandus*) through habitat restoration is one component of a long-term strategy to sustain and recover at-risk populations of caribou in British Columbia. Habitat restoration, together with protection of habitat and access management, is fundamental for populations of caribou to reach a self-sustaining condition. Reaching a self-sustaining condition would not only satisfy a legal requirement of the Species at Risk Act but is a desirable outcome eliminating the need for costly and invasive interim measures currently being used to avert population extirpation.

Caribou habitat restoration in the Klinse-Za caribou range has been underway since 2018. The program is focused on altering the characteristics of linear disturbance features such that they are considered to no longer contribute to the disturbance footprint of the landscape in which they are located. Our focus with this program is intended to capture high return on restoration investment and to expedite changes to linear feature function that benefit caribou rather than their predators. We think our focus on functional restoration of linear features will complement existing ecological restoration of polygonal disturbances that is largely being undertaken and monitored through regulated standards on industrial developments.

Our objectives in this report were to develop an analytical framework for assessing restoration activities generally and to apply the framework specifically to three legacy Petroleum and Natural Gas linear features in the Klinse-Za caribou range. We designed this framework to consider effectiveness metrics across a broad hierarchical geographic scale (sampling unit -> range) to help practitioners and policy-makers quantitatively assess whether habitat restoration efforts applied in caribou herd ranges of concern can lead towards the eventual (long-term) goal of improving the ecological and demographic conditions for caribou in those ranges.

We designed field sampling to include an *operational* component for monitoring the state of restoration and a *research* component for assessing effectiveness. Particularly with respect to effectiveness of functional restoration, we used spatial analyses of landscape state at different geographic levels linked through databases of time-series of animal and human responses (detections captured at camera sites). We then developed statistical models to assess the strength of changes in response metrics and rolled up aggregate measures of landscape change from the site level to the meso-watershed level and above.

Our analyses of restoration applied on two sites with 3-4 years of data (Amoco Road and Mt Frank Roy) suggest that restoration is beginning to contribute to small decreases in detections of predators and humans along legacy linear features. However, sample sizes of detections are small and this, together with untangling spatial effects (e.g., influences of elevation, distances to entry points to the lines, spatial layout of treatments) coupled with the relatively early stages of restoration at present, challenges our ability to unambiguously link restoration activities to functional effectiveness. Metrics of implementation at the intermediate level of meso-watersheds, suggest that restoration efforts appear to be, or have the potential to, reduce aggregate measures of area disturbed, although these changes are still relatively small.

The evolving analysis framework for monitoring across broad levels of geographic scale is intended to aid in assessing: 1) has *implementation* of restoration activities on linear features met the goal of addressing the potential to reduce levels of disturbance; and 2) has restoration of linear features been *effective* in reducing *functional* use of linear features for travel by predator species and by humans? Given the time horizons of restoration (i.e., growth rates, stabilization of restored features), we believe the framework has potential for integrating diverse data into a consistent set of interlocking metrics for assessing restoration success.

ACKNOWLEDGEMENTS

This project was financed by the Nîkanêse Wah tzee Stewardship Society on behalf of its funding partners which included: the Province of BC and Environment and Climate Change Canada (Indigenous Conservation Fund); the Petroleum & Natural Gas Legacy Sites Restoration Program on behalf of its funding partners the Province of British Columbia, the Government of Canada, and the BC Oil and Gas Research and Innovation Society; the Habitat Conservation Trust Foundation's Caribou Habitat Restoration Fund; and the Peace Region, Fish and Wildlife Compensation Program, a partnership between BC Hydro, the Province of BC, Fisheries and Oceans Canada, First Nations, and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

LIMITATIONS

This report has been prepared by caribou subject matter experts on behalf of the Nîkanêse Wah tzee Stewardship Society to support the information needs of West Moberly First Nations and Saulteau First Nations in relation to their interests and governance rights associated with caribou management. This report, including findings and recommendations contained herein, should not be interpreted as reflecting the perspectives of the community's leadership or representatives.

The authors would like the readers to be aware that this report has yet to undergo a substantive technical peer review process.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Klinse-Za caribou (*Rangifer tarandus*) population in northern British Columbia (BC) is part of the Central Group of Southern Mountain Caribou, which is listed as Threatened under Schedule 1 of the federal *Species at Risk Act* (SARA; EC 2014). Following the SARA listing, the Central Group was re-assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2014). The Central Group is also assigned to the provincial red list by the BC Conservation Data Centre (BCCDC 2017). Although an implication of the SARA listing is that populations of caribou are to be managed to a self-sustaining condition, two of six Central Group populations have been extirpated in the last decade. The proximate cause of population decline in the Central Group has been predation by wolves (*Canis lupus*; Seip and Jones 2015) but Johnson et al. (2015) demonstrated that the unsustainable population demographics ultimately results from disturbance to caribou range caused by resource extraction industries and by natural disturbances such as wildfire. In the Klinse-Za caribou range, more than 80% of the land below 1,300 m has been disturbed due to industrial and natural causes (WMFN 2014). To address the ultimate cause of declining populations, and to ensure long-term sustainability of the Klinse-za population, habitat restoration became a priority management action (McNay et al. 2013) as one component of an Indigenous-led caribou recovery program (Lamb et al. 2022, McNay et al. 2022).

The overall goal of habitat restoration is to expeditiously restore caribou habitat to a level that will help endangered caribou populations to achieve a self-sustaining condition and to eventually provide for a meaningful harvest of caribou by First Nations. Habitat restoration has been generally described according to its achievement of functional and/or ecological objectives (DeMars and Benesh 2016, Dickie et al. 2021). Functional restoration is the process of altering the short-term functioning of the ecosystem (Latham et al. 2011, DeMars and Benesh 2016). The goal of functionally restoring caribou habitat is to implement treatments which reduce the efficiency of travel by predators and humans. Ecological restoration is a longer-term process of managing or assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed to a state that resembles the undisturbed condition (CBD 2016). The goal of ecologically restoring caribou habitat is to implement treatments which reduce forage resources used by the primary prey of predators and to return ecosystems to those that increase arboreal and/or terrestrial forage and other resources preferentially sought-after or required by caribou.

We focused the Klinse-Za caribou habitat restoration program on functional restoration of linear disturbance features, including mining exploration trails, fire guards, oil and gas access roads, oil and gas exploration seismic lines, unofficial recreation trails, and forestry roads. Although other types of linear features, such as powerlines, pipelines, and other resource development roads contribute to the degradation of caribou habitat, these are ineligible for restoration due to their operational status and necessity of facilitating accessibility for maintenance of critical infrastructure. Our focus on linear rather than polygonal disturbances is because, per unit area of disturbance footprint, restoring linear features provides a higher return of restored habitat on the restoration investment. Also, polygonal disturbances usually have associated regulations obligating restoration of the disturbed area post-use, but most linear features do not. Changing the functional use of linear features is also potentially more pragmatic in the near term compared to ecological restoration because management to restore function directly and more expediently addresses caribou encounters with, and mortality from, predators. By comparison, the response time for ecological vegetation succession within polygonal disturbances will be much longer exceeding the temporal scope of individual restoration monitoring projects. Monitoring response of ecological restoration is more suited therefore for long-term meta-analysis above the individual project level and so will not be assessed here. Our focus on functional restoration is not intended to deflate or minimize the importance of ecological restoration. Ecological restoration is at least equally important to pursue but can mostly be accomplished by existing regulated standards and monitored within existing programs using currently acceptable methods. We therefore forward the notion that our focus on functional linear feature restoration complements existing ecological restoration efforts and by doing so, expediates the overall return of functioning range for Klinse-za caribou.

By undertaking the Klinse-za habitat restoration program, we are supporting the implementation of the restoration strategies and techniques as directed under the following management plans:

a) Implementation Plan for the Ongoing Management of South Peace Northern Caribou (*Rangifer tarandus caribou* pop. 15) in British Columbia (Aitkens 2013).
b) Recovery Strategy for the Woodland Caribou, Southern Mountain population (*Rangifer tarandus caribou*) in Canada (Environment Canada 2014),
c) A Strategy for the Recovery of Northern Caribou in the Southern Mountains Ecological Area in British Columbia (NCTAC 2004),
d) Action Plan for the Klinse-Za herd of woodland caribou (*Rangifer tarandus caribou*) in Canada (McNay et al. 2013).
e) Preliminary Tactical Restoration Plan for the South Peace Northern Caribou Ranges (Golder 2018).

OBJECTIVES

Our objectives in this report were to: 1) develop an analytical framework for assessing implementation and effectiveness of restoration activities generally and 2) apply the framework, or the relevant portions of it, specifically to three legacy Petroleum and Natural Gas (PNG) linear features in the Klinse-Za caribou range where restoration treatments had already been undertaken. With the framework, we address two general questions: 1) how well has *implementation* of restoration activities on linear features met the goal of addressing the potential to reduce levels of disturbance and 2) has restoration of linear features been *effective* in reducing *functional* use of linear features for travel by predator species and by humans?

More specifically, these questions are applied across broad levels of a hierarchical geographic scale to help practitioners and policy-makers quantitatively assess whether habitat restoration efforts applied in caribou herd ranges of concern can lead towards the eventual (long-term) goal of improving the ecological and demographic conditions for caribou in those ranges.

1. Implementation Monitoring:

  a. *Linear feature (site) level*: how well do the cumulative restoration treatments, once applied, match the restoration prescription for the site? Metrics are based on comparisons of the actual treatment types and their extents compared with the initial prescription for the site.
  b. *Meso-watershed level*: has the level of disturbance in each meso-watershed been potentially reduced compared with pre-treatment levels (assuming restoration efforts are, or will eventually become, effective)? Metrics are the % decrease in disturbance/meso-watershed and the % decrease in non-overlapping buffered area of disturbance/meso-watershed. Note that presently we are focusing on the linear feature component of disturbance in our analysis. Tracking the dynamics of polygonal disturbances is part of further development of the framework.
  c. *Project level*: this is similar to the meso-watershed level, using a roll-up of the metrics collected for the meso-watersheds included in each project.
  d. *Range level*: is the spatial contiguity of meso-watersheds with < 35% buffered disturbances increasing over time (assuming restoration efforts are, or will eventually become, effective)? Metrics are: 1) abundance: the change in number and proportion of range area meeting this target relative to the start of the program; 2) contiguity: length of contiguous polygon boundaries connecting adjacent meso-watersheds with < 35% disturbance.
2. Effectiveness Monitoring:
  a. *Linear feature (site) level*: has use of treated linear features declined post-treatment compared to pre-treatment (and where applicable) to control sites? Metrics are:
    i. the mean numbers of detections of species (including humans) in each time period.
    ii. The mean movement speeds of detected species (including human uses) in each time period.
  b. *Meso-watershed & project level*: has mean use of treated linear features by species (including human uses) declined post-treatment compared to untreated sites (i.e., pre-treatment conditions and, where applicable, control sites) in the same meso-watershed and project? Metrics are the same as defined above for the linear feature level.
  c. *Range level*: are there spatial dependencies in the changes in use of treated linear features compared to untreated linear features? Of particular interest is determining if restoration treatment causes a displacement of use rather than a reduction of use within the meso-watershed and/or range. Metrics are spatial and temporal correlations between projects and meso-watersheds using least-cost distance linkages to represent the spatial relationship between sites among meso-watersheds and projects.

FIRST NATIONS PARTICIPATION

The Klinse-Za caribou habitat restoration program was founded and is led by the Nîkanêse Wah tzee Stewardship Society; a not-for-profit collaboration between West Moberly First Nations and Saulteau First Nations. The restoration program aligns with the two communities' vison for caribou recovery within the territory of Treaty 8 and is also consistent with caribou habitat restoration programs being conducted by other Treaty 8 First Nations (e.g., Fort Nelson First Nation[1]), the Province of BC (e.g., Golder 2018), and funding agencies including the Fish and Wildlife Compensation Program[2] and the Caribou Habitat Restoration Fund[3]. Our habitat restoration program continues to use traditional ecological knowledge and science-based information to identify restoration sites that will provide a large return on investment by restoring all linear features in priority zones across the Klinse-Za caribou herd area.

PROJECT LOCATION AND LEGACY STATUS

We treated three legacy oil and gas exploration roads in the Klinse-Za caribou herd area in 2018 and 2020, resulting in a total of 18 km of legacy oil and gas sites treated. These sites include Bickford Mtn.-Fisher Creek Forest Service Road (FSR), Amoco Road, and Mt. Frank Roy (Figure 1). These sites were identified as priorities for restoration based on their proximity to caribou habitat, current caribou use, location within critical core habitat, direct connection of low-elevation to high-elevation areas, and the level of use by predators and motorized vehicles. The specific sites are described in detail below and a description of the broader Klinse-Za caribou herd area is provided in Appendix A.

Bickford Mtn.-Fisher Creek FSR

The Bickford Mtn. site (Figure 2) is an extension of the Fisher Creek Forest Service Road that was installed for oil and gas exploration. Well authorization was granted in 1994; however, at that time, roads on crown land for oil and gas activities were not tenured. The road is approximately 14 ha in size and 8.5 km long, terminating at a well pad located in the alpine zone of Bickford Mtn. The site is unique as it originates from 1,220 m in elevation, is sited through subalpine and alpine terrain, peaking at 1,558 m, and dropping down the opposing side of the mountain, and terminating at 1,439 m in a sub-alpine basin. The site is almost entirely located in critical core habitat and is in a designated caribou Wildlife Habitat Area (WHA) and an Ungulate Winter Range (UWR). A 2.3 km section of the 8.5 km road had functional treatments applied (i.e., deactivated) in 2017 and ecological treatments applied through reforestation activities in 2018. The Bickford Mtn.-Fisher Creek FSR site will be located in the newly expanded Klinse-Za Park, ensuring restoration work will be permanent and not at risk of being undone by later industrial activities.

[1] Kotcho Lake Restoration Project - https://hctf.ca/project-profile-kotcho-lake-restoration-project/?hctf-project-tag=caribou

[2] Restoring Caribou Habitat in the Klinse-Za/Scott East Herd - https://fwcp.ca/project/restoring-caribou-habitat-for-peace-region-herd/

[3] Habitat Restoration Across the Klinse-Za Caribou Herd Range - https://hctf.ca/habitat-restoration-across-the-klinse-za-caribou-herd-range/?hctf-project-tag=caribou; Amoco Road Restoration (CHRF Project #7-528; https://hctf.ca/project-profile-amoco-road-restoration-project/?hctf-project-tag=caribou), Peck Creek-Upper Carbon (CHRF Project #7-543), and Doonan Creek (CHRF Project #7-544), and Rochfort (CHRF Project #7-557).

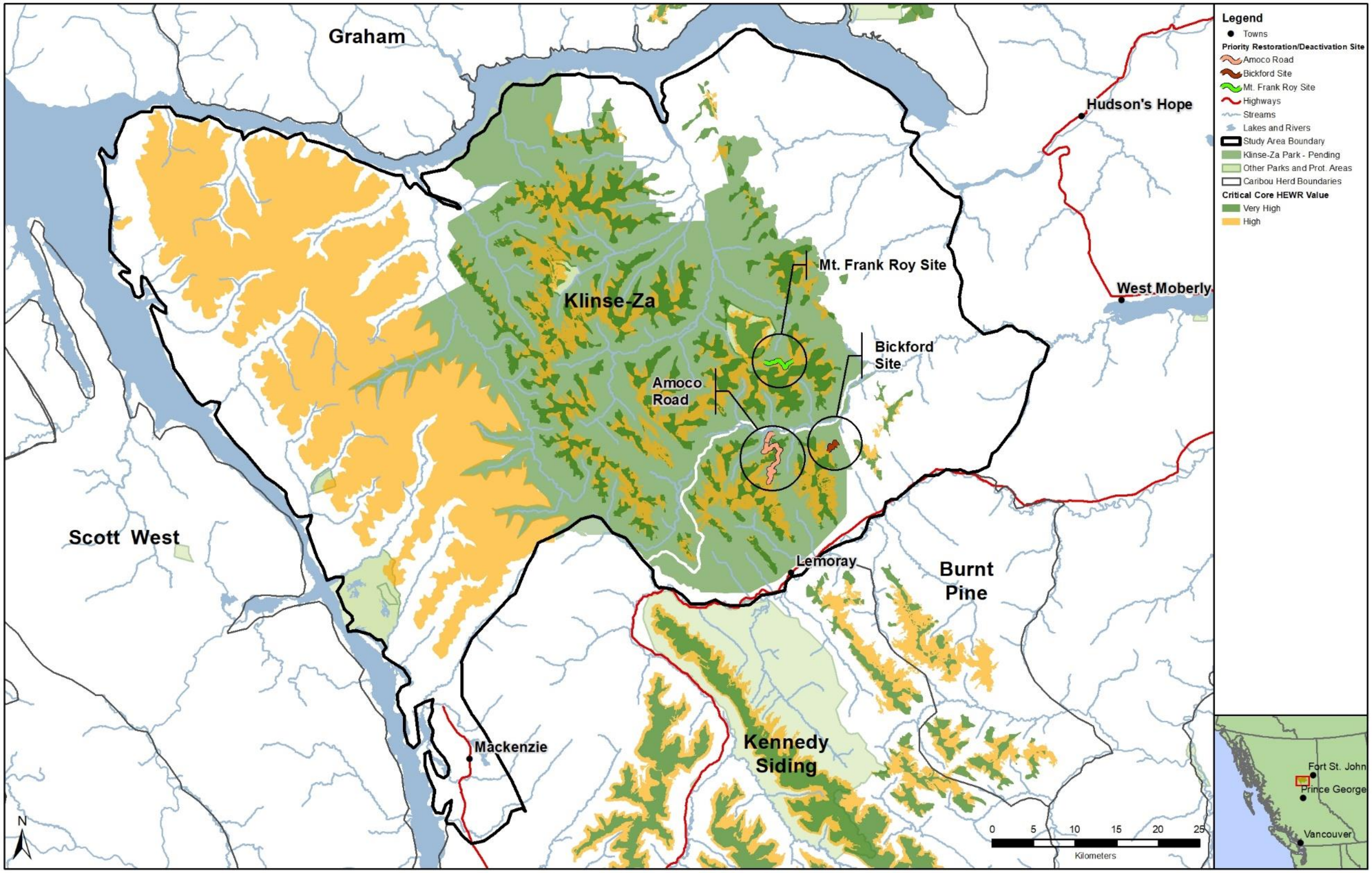

Figure 1. Locations of three legacy oil and gas roads restored in the Klinse-Za Caribou Herd, Klinse-Za Caribou Habitat Restoration Program.

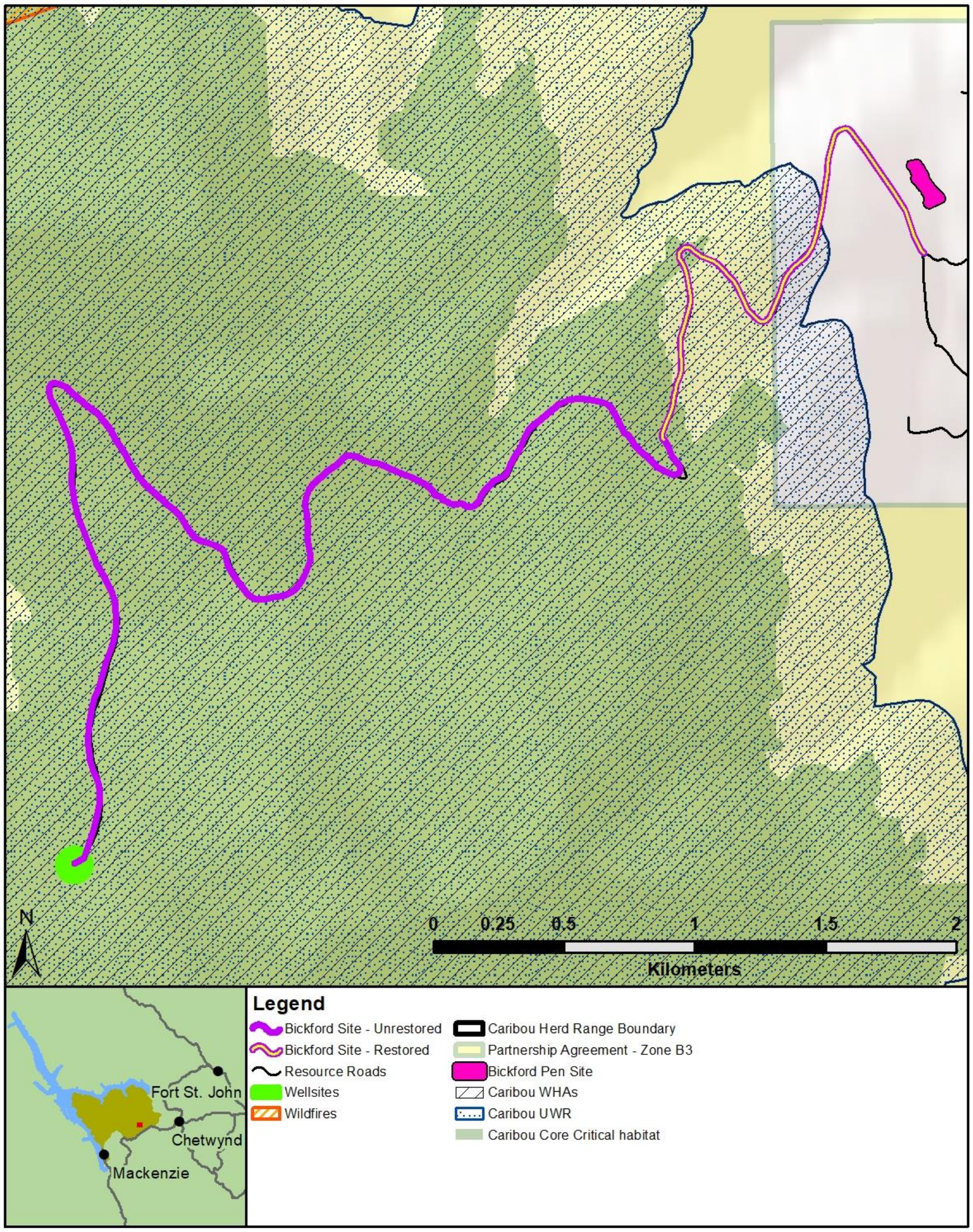

Figure 2. Bickford Mtn.-Fisher Creek FSR restoration site, Klinse-Za Caribou Habitat Restoration Program.

Amoco Road

The Amoco Road site (Figure 3) is a legacy oil and gas road that includes an abandoned well pad and additional sites cleared to support the construction of the road which took place between 1998-2002. Similar to the Bickford Mtn.-Fisher Creek FSR site, the road was not tenured. The original proponent at the Amoco site, BP Canada Energy Company, cancelled their permit without fully developing the wellsite. The site is approximately 30 ha in size and 15 km long, and is located in critical core habitat and designated WHA and UWR. The site will be located in the expanded Klinse-Za Park.

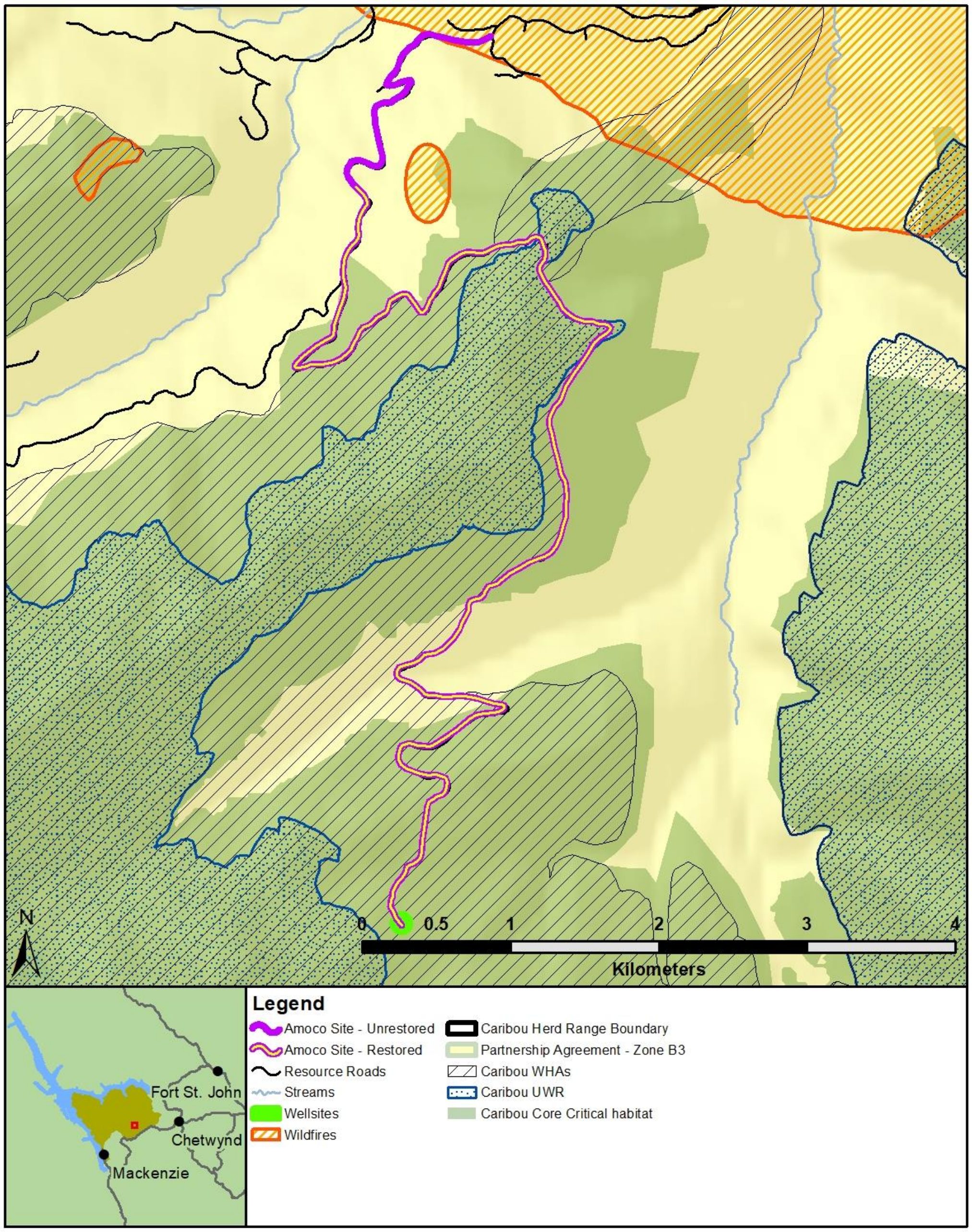

Figure 3. Amoco Road restoration site, Klinse-Za Caribou Habitat Restoration Program.

Mt. Frank Roy

The Frank Roy site (Figure 4) is also a legacy oil and gas road leading to a well pad at the terminus. The original proponent, BP Canada Energy Company, received the exploration permit in 1998. The tenure holder changed to Husky Oil Operations Limited in 2009 and the company continues to hold the active tenure on the lease site; however, Husky Oil Operations Limited's obligations do not include the access route to the road, as it was not tenured at the time of development. Approximately 14.0 ha in size and

13.7 km long, construction is believed to have occurred in the early 2000s. The site originates from 1,182 m in elevation, terminating at 1,410 m in a subalpine basin adjacent to alpine complexes of Mount Monteith and Twin Sisters. The corridor is located in critical core habitat and overlaps with designated caribou WHAs. The site will also be located in the expanded Klinse-Za Park.

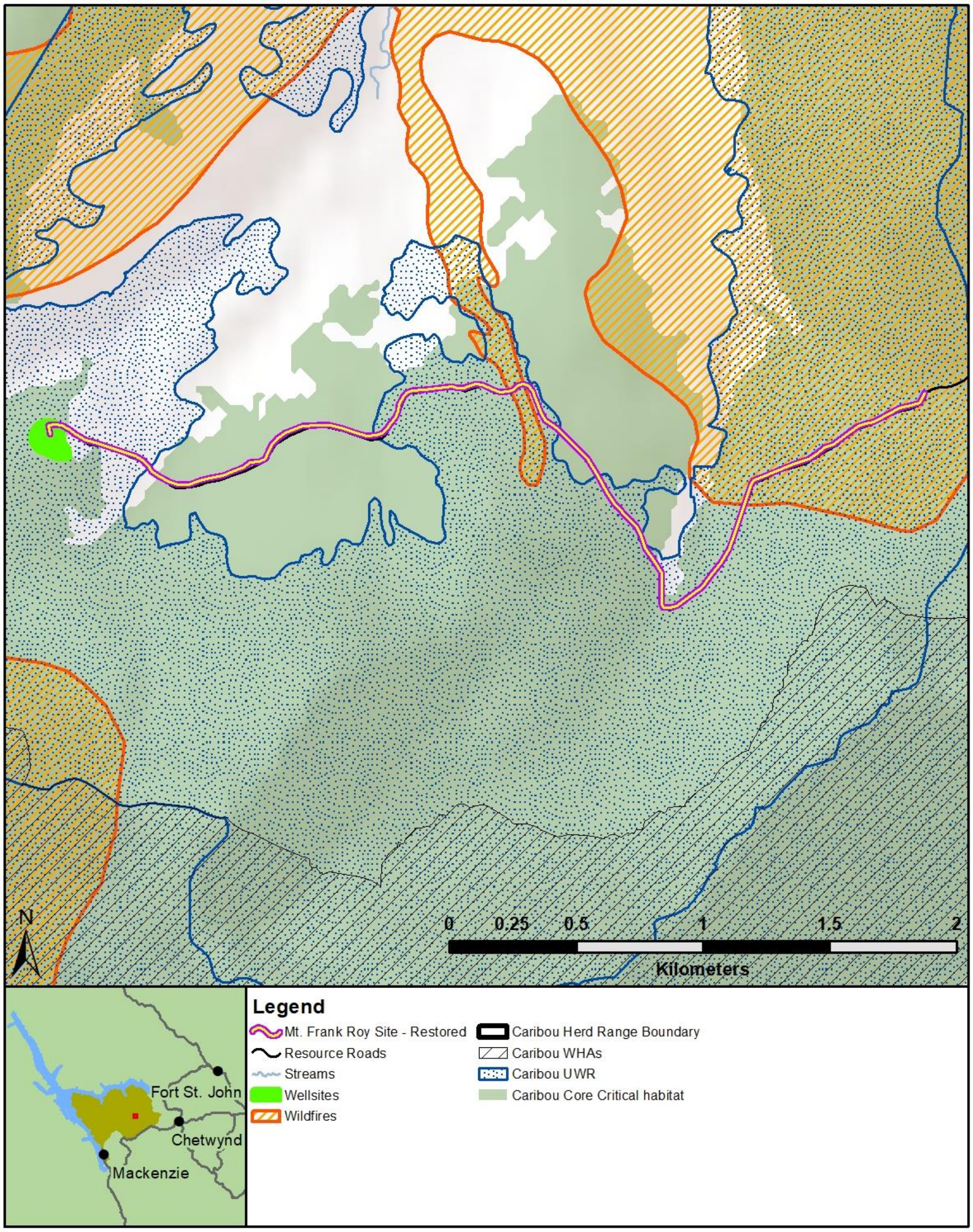

Figure 4. Mt. Frank Roy restoration site, Klinse-Za Caribou Habitat Restoration Program.

RESTORATION PHASES AND STATUS SUMMARY

The general sequence of steps to accomplish restoration objectives of the Klinse-Za caribou habitat restoration program have been:

Phase 1: Pre-treatment Inventory, Planning, and Permitting

1. *Rank priorities*: identify and prioritize potential restoration sites and zones (Woods and McNay 2019).
2. *Classify restoration sites:* in priority zones, confirm priority site classifications[4] through field reconnaissance;
3. *Permitting:* establish collaborative projects with, or seek authorization from, active tenure holder(s), if applicable. For untenured sites, a Special Use Permit (SUP) is necessary to authorize treatments or pursuit of additional permits.

Phase 2: Treatment Implementation

4. *Establish site-level sample units*: at sites selected for restoration, and at comparable control sites, establish sampling units.
5. *Implement restoration activities*: at restoration sites, implement three types of restoration activities singly or in combination: site-preparation, tree-planting, downed wood management (tree-felling/CWD movement).

Phase 3: Monitoring Implementation and Effectiveness

6. *Operational monitoring:* to monitor whether the implemented restoration is/is not maintained/compromised, single camera traps are deployed at selected locations. Post-treatment seedling survival is monitored, and supplementary planting undertaken if necessary.
7. *Effectiveness monitoring:* sample vegetation pre-treatment and monitor camera traps pre- and post-treatment.

Phase 1 – Pre-treatment Inventory, Planning, and Permitting

This phase was completed between 2017 and 2019. The three legacy oil and gas corridors were selected as priority sites because the roads connected low- to high-elevation habitat and facilitated the movement of predators into critical core habitat, including winter and calving range areas. The Amoco Road and Mt. Frank Roy sites were not under active tenure nor were there conflicts with approved industrial development plans. Bickford Mtn.-Fisher Creek FSR was a legal Forest Service Road, actively held by the BC Government.

The permitting process for restoration projects to date has been dynamic and is expected to remain so as a large portion of the Klinse-Za herd area transitions to Provincial Park[5]. Habitat restoration on a large scale is a relatively new practice in the Northeast and Omineca regions, particularly in the interest of threatened caribou. A standardized methodology and workflow for this permitting process has therefore been in continuous development. These developing processes currently fall under existing regulations and permit types, as described below.

4 Classification of priority sites is to confirm the site is: (i) contributing disturbance to caribou range and is therefore requiring intervention, (ii) contributing to disturbance but does not require intervention, or (iii) is not contributing disturbance to caribou range.

5 An outcome of the Partnership Agreement.

At the time of application development in 2019 and 2020, caribou habitat restoration projects on untenured areas were required to have a SUP approved by the BC Government. This permit application included a management plan, site prescription, and any exemption requests if restoration activities were to take place within the boundaries of a Government Actions Regulation (GAR Order) including Old Growth Management Areas (OGMAs), UWRs, and WHAs. A separate application for a Forest and Range Practices Act section 52(1)(b) authorization would also be required if tree felling was included in the prescription. The approval of this package allows us to hold tenure of the area and conduct activities on it according to the provisions set out in the management plan.

Special Use Permits are not covered under a high-level management plan such as a Forest Stewardship Plan (FSP) or Sustainable Forest Management Plan. For a forest licensee, a high-level FSP can be developed and applied to all their operations and can henceforth be referenced in less complex site plans, negating the requirement for detailed Site Plans. Conversely, we are required to provide more detail for SUPs to illustrate how the Crown land will be managed. Section 9 of the Provincial Forest Use Regulation requires the applicant submit a plan that thoroughly describes the use and management of the site in question. This regulation provides statutory decision makers with the discretion to determine if the SUP would impair management and/or conservation of forest resources.

For the Bickford Mtn.-Fisher Creek FSR, as a legal Forest Service Road we had to follow the stream of permitting in which the BC Government was an active tenure holder. For this site we acquired a Forest Planning and Practices Regulation Section 70.1 authorization which provides authority to construct, maintain or deactivate a Forest Service Road.

BC Parks has stated they will honour existing permits for the duration of their term during the transition from industrial to Park status to allow for habitat restoration projects to proceed. We foresee having to apply for amendments to the permits, where deemed necessary to be compliant with BC Parks regulations. In the case of the Bickford Mtn.-Fisher Creek FSR, Amoco Road and Mt. Frank Roy sites, this would include a Park Use Permit for Research Activities, as restoration works have already been completed and ongoing activities is limited to post-treatment monitoring.

We used the data collected for effectiveness monitoring prior to restoration treatments to describe the site characteristics prior to field activities. These data, used in conjunction with existing BGC map layers, allowed us to estimate the BGC subzone and competing vegetation species. Site series were confirmed in the field using the criteria defined in Land Management Handbook Number 29 (BC MOF 1994). We collected further information to describe regenerating conifer seedling density and composition, soil substrate and horizons, and rooting depth. We identified factors that could limit effective restoration efforts where present (e.g., vegetation competition, compact soils, erosion hazards, access, frost, etc.).

Phase 2 – Treatment Implementation

This phase was completed in 2017-2018 (Bickford Mtn.-Fisher Creek FSR site) and 2020 (Amoco and Mt. Frank Roy sites) using the methods described below.

Site Preparation

Site preparation, in the context of this program, is the use of heavy machinery to manipulate the soil of a disturbance feature to facilitate additional treatments or create blockages to access. Where features have not been pioneered by native vegetation there are typically two factors contributing to that state: 1) continual access by motorized traffic that suppresses woody plants from establishing and 2) highly compacted soil conditions. Typically, sites are colonized by grasses and forbs; however, the disturbed surface is more conducive to colonization by non-native and/or invasive species preventing the establishment of native species. The compaction is exacerbated by fine-textured silty and clayey soils creating poor water or root penetration. Where disturbance features are wide and compacted, the timeline for natural vegetation ingress can be more than 10 years and is not assured. Mechanical treatment of the compacted soils is often required to increase soil porosity and water penetration, creating a more hospitable growing medium for plantings.

Where access management is challenged due to popularity of recreational use on the site, we have used de-compaction of the soil in conjunction with mounding. We created mounds by using adjacent side cast material or material directly on the site. The creation of mounds reduces the navigability of the site in all seasons except in deep snowpack conditions. The primary drawback we have observed of mounding is the development of microsites that increase in severity the larger the mound (tops of mounds xeric and bottoms of craters hydric).

Site preparation and mounding was only completed on the Bickford Mtn.-Fisher Creek FSR site (Figure 5) (Woods 2020). This site had the highest motorized vehicle use, soil compaction, and was accessible for the use of heavy machinery. Due to the remoteness and previous re-sloping on the Amoco and Mt. Frank Roy sites, site preparation was not conducted on these sites.

Figure 5. Road deactivation and mounding on the Bickford Mtn.-Fisher Creek FSR site, Klinse-Za Caribou Habitat Restoration Program.

Planting

Where natural vegetation ingress has been delayed, and/or if access blocking measures are deemed insufficient, we typically supplement the site by planting trees. Unlike industrial forestry settings, our planting objective is not to grow a stand of commercially valuable species (BCMOFR 2009). Rather, restorative planting activities are designed to impede visibility, mobility and enhance habitat quality along the site. As such, we selected tree planting contractors that understood that planting objectives varied from standard industrial practices, had experienced and specialized crews to select key microsites during planting, and had the ability to work on remote, helicopter-access sites. Without having to adhere to specific spacing requirements, we were able to plant to higher densities and select superior microsites with less consideration to spacing. We have deemed higher density prescriptions a necessity on many sites due to poor planting conditions (e.g., compaction from road construction, vegetation competition), poor access, and logistical or monetary inefficiencies introduced by additional fill-planting treatments. At a greater planting density, a high level of tree mortality can still effectively meet restoration objectives. We conducted cluster planting to mimic naturally regenerating stands and used the flexibility within our prescription to select suitable microsites on the road surface to emulate natural ingress.

In 2018, 12,190 tree seedlings were planted on the Bickford Mtn.-Fisher Creek FSR site, followed by an additional 2,160 seedlings that were fill planted in 2020. In 2020, 41,370 seedlings were planted on the Amoco Road and 7,370 on Mt. Frank Roy. Additionally, 136 juvenile trees (1-2 m tall) were planted on Amoco Road in a theatre-style placement to provide immediate line-of-site blocking (Figure 6).

Figure 6. Juvenile trees planted in theatre-style placement across the Amoco Road restoration site, Klinse-Za Caribou Habitat Restoration Program.

Tree Falling and Bending

The geographic remoteness and lengths of time since the original disturbance of many restoration sites creates problematic access for site preparation, which affects the ability of seedlings to establish and grow to achieve restoration objectives. As an intermediate alternative, we can impede mobility and decrease line-of-sight along the corridor by tree falling and/or tree bending, which also creates microsites to aid seedling establishment.

We used tree falling in remote areas due to the portability of the workers and their equipment. Without accessibility for heavy machinery there is no feasible method for creating barriers to motorized access. Tree falling afforded us the ability to create barriers to mobility and visibility for both animals and motorized traffic.

Selection of trees for felling was conducted while considering other wildlife values and without compromising integrity of the ecosystem. Trees were carefully selected to ensure stick or cavity nests and/or features suitable for furbearer dens are absent. Trees were also felled outside of the breeding bird timing window as to not contravene the Wildlife Act or the Migratory Bird Convention Act. The drawbacks of tree felling include: 1) trees will degrade and shrink over time, b) can be expensive and dangerous to implement, and c) there is the possibility of users re-opening the barrier with chainsaws. Therefore, we typically conducted tree felling in conjunction with a planting treatment to create a barrier that has high likelihood of persisting over time. We create microsites by felling the trees and as degradation begins the established plant community is expected to develop into a long-term barrier.

Tree felling completed on the sites was dependent upon the stipulations within the respective permits authorizing the activity (Woods et al. 2021; Woods et al 2022). We targeted locations with long sight lines, entrances and exits to the sites, and locations that bottleneck animal and human traffic. Concentrations of multiple trees felled in one location was preferred but in the absence of grouped permissible trees, single trees were felled in a more uniform manner over greater distances.

Tree bending is the process of bending juvenile to intermediate age class trees from a vertical orientation to near horizontal without killing them. Conducted in warm temperatures, to limit stem breakage, the trees are winched, pushed, or pulled across the site. The objective is to deform their growth pattern sufficiently that they cannot correct vertically, but not excessively to the point where the tree is uprooted, girdled, or dies. The benefits of this technique are that the bent trees can last much longer than a fallen tree, the branches can continue to thrive and provide additional screening and impediments to movement, and it is less dangerous for personnel when conducted with suitable equipment and safety measures. The primary drawback to bending trees is that it typically requires access for heavy equipment to navigate to the site and may only be suitable on sites where such access is already present. In conjunction with tree planting, tree falling was completed on all three restoration sites identified in this report (Figure 7).

Figure 7. Tree falling across the Bickford Mtn.-Fisher Creek FSR site, Klinse-Za Caribou Habitat Restoration Program.

PHASE 3: METHODS FOR ASSESSING IMPLEMENTATION AND EFFECTIVENESS

Implementation

We assessed implementation progress at the site level using post-implementation surveys to determine consistency with the site prescription (e.g., site preparation objectives, planting density and configuration, tree falling objectives, adherence, etc.), and to determine continued tree survival at suitable densities. We also monitored the state or integrity of the restoration at the site level by placing cameras at strategic locations (i.e., road junctions, or adjacent to key restoration activities). The use of cameras in this way was intended to provide a descriptive warning of potential compromise of the restoration and was not intended for more detailed quantitative analysis. Progress at the meso-watershed levels was based on the difference between pre- and post-implementation proportions of the watershed in an undisturbed state, based on the ECCC (2014) definition of disturbance and assuming our restoration activities were, or will eventually be, effective (see "Effectiveness Monitoring" below), including our reclassification of areas as non-contributing[6] to disturbance according to data collected during the reconnaissance phase of implementation. Restoration implementation progress at the caribou range level was indicated by the relative cumulative number of, size (ha) of, and contiguity of, meso-watersheds having undergone restoration treatment within the Klinse-Za caribou herd area. We characterized these activities to monitor implementation "*operational*" level assessments in contrast to the deeper "*research*" level activities used to assess effectiveness of functional restoration (see "Effectiveness" below).

Effectiveness

Sampling Design

As described in Woods et al. (2021), the overall design for assessing habitat restoration effectiveness was based on Before-After-Control-Impact (BACI)-type sampling designs (see also Stewart-Oaten et al. 1986). We therefore classified samples at each site as:

- Pre-treatment if they were collected "before" restoration treatments;
- Post-treatment if they were collected during and/or "after" restoration treatments,
- Control if they were collected at nearby locations that were untreated (either before, during, or after when treatments were applied to the adjacent sites), and
- Impact if they were collected from the treated sites.

We conducted two years of pre-treatment effectiveness monitoring to characterize vegetation state and wildlife/human use at each of the three restoration sites. In Phase 3, we completed the pre-treatment monitoring and collected information from the first portion of post-treatment monitoring. Currently, the Bickford Mtn.-Fisher Creek FSR site

[6] Non-contributing or "not contributing to disturbance of caribou range" is, at this early stage of restoration development, based on the judgement of Subject Matter Experts and usually can be characterized by linear features with advanced vegetation regeneration or by short (< 500 m) spur roads at elevations < 1000 m, both conditions which we assume provide predators and humans no significant advantage in accessing caribou range.

is the only site that has a true “control”, represented by the untreated section of the Fisher Creek FSR leading up to the restoration site. Pre-treatment monitoring of the Amoco Road and Mt. Frank Roy has been ongoing since 2018, and, after completion of the restoration treatments in 2020, one-year post-treatment monitoring occurred in Summer 2021.

At sites where sampling to assess effectiveness occurred, the layout included an array-grid-plot design, where plots were nested within grids, nested within an array (Figure 8). An array occurred at 500 m intervals along the linear feature. Each array consisted of three 30 x 30 m grids, which were spaced 250 m apart (Figure 8). At each grid, we placed nine 10 x 10 m vegetation plots (see Vegetation plots below) and one camera (see Camera traps below). Three of the nine vegetation plots were located along the road surface and the remaining six plots where adjacent to the road surface (Figure 8).

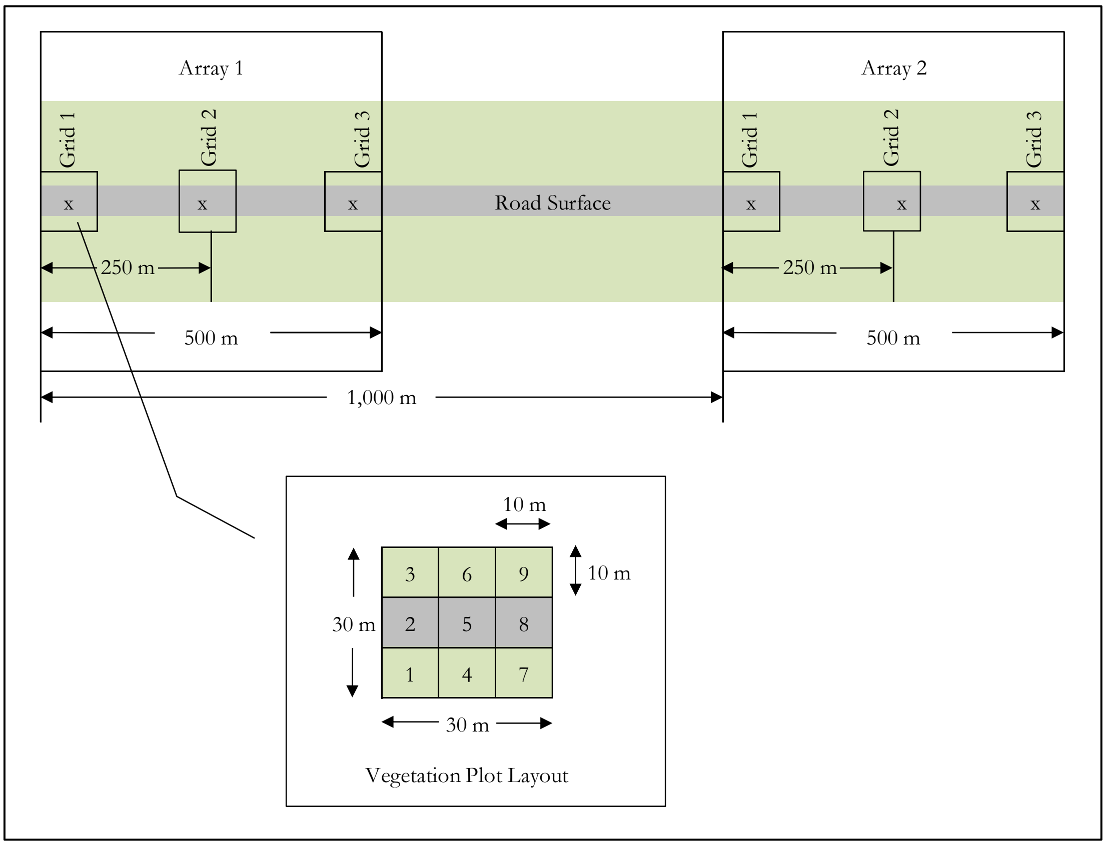

Figure 8. Array, grid, and plot method established for camera traps (marked with ‘x’) and vegetation plots to measure treatment effectiveness along the road surface (grey shaded) and adjacent areas (green shaded), Klinse-Za Caribou Habitat Restoration Program.

Vegetation Plots

Vegetation characteristics, cover and tree regeneration were measured at the plot-level. In the first two project years, we sampled all three road plots (plot numbers 2, 5, and 8) and three randomly selected adjacent plots. We anticipated that a high level of sampling effort would be necessary to address the expected variation in site and vegetation conditions along the lengthy restoration corridors (e.g., 10 to 15 km), which are often characterized by significant changes in elevation (e.g., ± 500 m). We considered that biophysical characteristics (aspect, elevation, slope and BGC zone) would be important covariates for vegetation response to treatment and therefore characterised each monitoring station accordingly with spatial data from DataBC[7] collected using ArcMap (ESRI Corp., Redlands, CA). We measured vegetation characteristics following methods described in the *Procedures for Environmental Monitoring in Range and Wildlife Habitat Management* (Habitat Monitoring Committee 1996). At each grid, we sampled surface substrate (percent cover of decaying wood, bedrock, cobbles-stones, mineral soil, organic matter, and water), moisture regime, and coarse woody debris (CWD). We defined CWD as any woody vegetation (>10 cm in diameter) that had fallen and was on the ground or suspended above the ground and assigned a CWD class (high, moderate, low) based on the impediment (i.e., number of pieces, their sizes, and positioning) posed to the usability by wildlife.

At each plot, we measured percent cover and spatial distribution of each plant species and vegetation type (tree, shrub, herb, grass, lichen, moss). We divided tree and shrub cover into three height classes (<2 m, 2 to 10 m, or >10 m) and identified all trees, shrubs and herbs to species but did not identify grasses, lichens, and mosses to the species level. Each species was categorized into one of nine classes describing its spatial dispersion across the plot, from a single occurrence of the plant to a continuous, dense distribution (Habitat Monitoring Committee 1996). At the center of each plot, using a modified Robel pole (Robel et al. 1970), horizontal cover (a measure of line-of-sight) was quantified as the height (cm) at which more than 40% of the Robel pole was obstructed from a distance of 4 m in each cardinal direction to represent visual obscurity along the corridor.

Camera Traps

A camera trap was installed at each grid to sample use by humans and wildlife. Cameras were positioned to capture a field of view perpendicular to the corridor and to maximize the detection area along and across the corridor (Dickie et al. 2021). The use of the array design for camera traps is known to improve detection probability of wildlife (O'Connor et al. 2017). We set the motion-activated cameras (Reconyx UltraFire Professional Covert Camera Trap™) to take two photo images per triggering event (1 second between triggers). We collected the photo data twice annually (spring and fall). Collected camera data were entered into Timelapse2[8] and we visually classified the contents of each photo in the first years and used MegaDetector (Beery et. al 2019) to classify content from photos collected in 2022. MegaDetector is software that can identify the presence of an object (i.e., human, vehicle or wildlife) and filter out the images that are empty due to false triggers of the camera traps. "Empty" photos were those where a photo was taken but no objects appear, or the camera was triggered by moving vegetation or movement of the tree the camera is mounted on. The software has shown substantial gains in efficiency, and accuracy comparable to exclusively human classification from previous tests (Fennel et al. 2022) but we have not yet fully assessed the rate of false negatives for this project area. For example, after having used MegaDetector, human classifiers could then re-classify the empty photos to determine a

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[7] See https://data.gov.bc.ca/ (accessed July 01, 2017)

[8] http://saul.cpsc.ucalgary.ca/timelapse/

false negative error rate which presumably could be modeled based on factors including random (e.g., camera id) and fixed (e.g., night/day, winter/summer, object type) effects. Multiple photos of the same person, animal or vehicle were considered “duplicates” when the detections occurred <1 hour apart. Empty and duplicate photos were removed from further analysis. We defined a detection as occurring if an object (wildlife or anthropogenic) was visible in the photo. Detections were considered independent when they were >1 hour apart (Harris et al. 2015, Dickie et al. 2021). Each detection was categorized as a vehicle, person, or wildlife. A person was defined as people on foot or using non-motorized transportation (e.g., horses, bicycles). We classified motorized vehicles as quads, side-by-sides, trucks, snowmobiles, and dirt bikes. We classified wildlife by species, sex, and age, where discernable. We noted collars and ear tags on caribou, moose, and wolves. We classified photos into seasons: caribou calving (May-June), summer (July-August), fall (September-October), early winter (November-December) and late winter (January-April), comparable to those defined by Dickie et al. (2021).

Analytical Approach

The portion of the analysis framework for assessing effectiveness of functional restoration primarily uses two data sources from the sampling (above): 1) captures (detections) made by wildlife cameras and 2) sampled vegetation data collected in the grid design. Because the present stage of development, the framework is focussed on assessing effectiveness of functional restoration rather than ecological restoration, the vegetation component is primarily used as additional descriptive information about sites and for interpretive purposes only. Eventually, extension of the framework to assess long-term ecological restoration will involve more quantitative use of vegetation data.

Sample Units

We consider the finest spatial level of data collection to be the “sampling unit” (individual camera, or vegetation plot). Specifically, for our focus our primary sampling unit was therefore individual wildlife cameras. Data from each sampling unit is (or can be) summarized and aggregated at increasingly larger scales of aggregation (e.g., Sample Unit (camera-> array) -> Site -> Meso-watershed -> Project -> Range), depending on the monitoring questions of interest.

A varying number of remote wildlife camera traps were deployed at each site depending on the monitoring purpose (Table 1). Camera trap locations (individual or array) are intended to remain at the same location and actively collecting data from year to year, however other considerations (vulnerability to loss, camera failure, cost, etc.) sometimes means that cameras are lost, or become otherwise inactive. If not replaced, these locations become inactive.

Restoration Treatment Types and Characterization

Over the length of each restoration site, the type of restoration activity (hereafter called “treatment”) that has so far been undertaken on the site (Table 2), year and month each activity occurred and the spatial location (segment) of the feature receiving each treatment event was recorded. These form the segment-specific “treatment history” for

Table 1. Annual deployments of wildlife cameras for the three study sites over the period 2014-2022, Klinse-Za Caribou Habitat Restoration Program.

Shown are the numbers of cameras (number of arrays). Note that single operational cameras are not part of a camera array. For Research sites, lack of gray shading indicates whether cameras (arrays) were collecting data in untreated (Control) or Pre-treatment conditions; data collected after restoration was initiated is shaded. In years when treatments are first initiated, data may be either Pre-treatment or Post-Treatment, hence the use of lighter shading.

Design	Site	Type	2014	2015	2016	2017	2018	2019	2020[1]	2021	2022
Operational	Bickford Mtn.		1 (-)	1 (-)	1 (-)	1 (-)	5 (-)	7 (-)	7 (-)	7 (-)	7 (-)
Research	Amoco Rd.	Control					3 (1)	3 (1)	3 (1)	3 (1)	3 (1)
		Treatment					30 (13)	36 (13)	36 (13)	36 (13)	35 (13)
	Mt. Frank Roy	Control					24 (8)	24 (8)	24 (8)	24 (8)	24[2] (8)
		Treatment					12 (5)	15 (5)	15 (5)	15 (5)	15 (5)
Total (Research)							69 (26)	78 (26)	78 (26)	77 (26)	75[1] (26)
Total							74 (26)	85 (26)	85 (26)	84 (26)	82[1] (26)

[1] For research sites, application of restoration treatments began in mid-2020 in both Research sites. For arrays and cameras designated as "Treatment", data collected prior to the mid-month time the first treatment was initiated is considered "Pre-treatment", while subsequent data is considered "Post-treatment".

[2] In fall 2022, the number of Control camera arrays was reduced to 4.

Table 2. Classes of individual restoration activities (treatments) currently defined in the analysis framework, Klinse-Za Caribou Habitat Restoration Program.

Restoration activity[1]	Label	Description
None	None	No treatment has yet been applied.
Leave for natural	LFN	Natural regeneration is considered advanced enough to impede access.
Site preparation	SiPr	Use of heavy machinery to manipulate the soil of a disturbance feature to facilitate additional restoration treatments or create blockages that limit access to, or use of, the feature.
Seedling planting	SePl	Seedling trees are planted to defined stocking densities if natural vegetation ingress has been delayed, and/or access blocking measures are deemed insufficient.
Juvenile tree planting	JTrPl	Container-grown ~5-year-old trees (1-2 m tall) planted in groups to expedite barriers to line-of-sight.
Tree falling	TrFa	Tree falling and/or tree bending is used to decrease lines-of-sight and impede mobility along linear features, while also creating microsites to aid with planting and natural seedling establishment.
CWD spreading	CWD	Redistribution of downed wood available at the site to impede movement along the feature
Mounding	Mnd	Mounds are created by using adjacent side cast material or material directly on the site to reduce the navigability of the site, especially in summer.

[1] Because different treatment classes may be applied at a given location (or the same class applied multiple times), over several years, each line segment may be assigned a sequence of several activities (e.g., "SePl-SePl-TrFa") defining its "treatment history" from the beginning of the treatment period to the date of the analysis.

each linear feature. As different treatments may only partially overlap, the segments can gradually become more finely divided as years and treatments progress.

See Appendix B for a complete list of spatial data sources used in this study.

Statistical Analyses

Prior to analysis, we attributed each valid detection (see "Camera traps" above) with treatment status and biophysical contextual information. To further characterize the treatment status and context of the sampling unit, each was attributed with its distance from the origin point of the linear feature, the treatment history applicable to the immediately adjacent segment of the feature, and the cumulative record of the treatments applied from the origin point of the site to that segment. We also classified detections by season as summer (May 1-Oct 31) or winter (Nov. 1-Apr. 30), its phase of the treatment cycle (Control sites: untreated; treatment sites: pre-treatment, post-treatment), and a four-class *a priori* classification of its expected vehicle and wildlife use comprised of a Low or High classification of each type of use. Identified wildlife species were classified into three types: predators (wolves, all bear species, lynx), moose, caribou, and human (vehicle or person). Each sampling location was attributed with its BEC subzone, elevation, aspect, and slope for biophysical characterization. Finally, each sample unit was also attributed with landscape context information, including site identifier, meso-watershed identifier, and administrative boundaries (project and range identifiers) for aggregation (roll-up) and reporting purposes.

To control for unequal sampling efforts between sites (i.e., varying number of cameras deployed), we report camera data as a detection rate: the total number of detections per camera trap day (including days of no detections) for each species type. Total detections were the sum of individual detections on the same day or counts of multiple individuals (groups) of the same species. To help control for the effects of spatial autocorrelation between sampling units arranged linearly along the site, the mean distance between each sample unit and its immediately adjacent unit on either side was calculated and used as a covariate in modelling.

We evaluated the effects of cumulative distance along the linear feature to each sampling unit that had been treated to date, season, site, and type of sampling unit (control or treatment) on the detection rates observed for each species type. We included the mean distance between adjacent sampling units as one way to reduce the effects of spatial autocorrelation between sites. We modelled all predictors as fixed effects in a general linear model using a hurdle-model approach based on the truncated-Poisson distribution with a log-link function (Brooks et al., 2017), We did not include 'year' in these analyses as exploratory analysis indicated that 'year' was seldom a significant predictor in model fitting. This approach separately evaluates if there was a detection or not (i.e., the probability of being absent versus present, expressed by the model as the probability of 0) and if there were detections, their frequency (i.e. the frequency of use when present). We note that while we are modelling whether the species is detected compared to not detected, we interpret this as presence or absence assuming perfect detection. The interpretation of the probability of absence, i.e. the zero-component of the hurdle model, can inversely be considered as the probability of presence.

Significance is defined if 95% confidence intervals for estimated coefficients do not overlap zero. All analyses and modelling presented in this report were conducted in R (R Core Team 2022), using the *glmmTHB* (Brooks et al. 2017) package.

PHASE 3: ASSESSMENT OF IMPLEMENTATION AND EFFECTIVENESS

Implementation

Site Level

Two years after seedlings were planted on the three sites, surveys were completed on the natural and planted seedlings present (Table 3). Amoco Road (1,617 stems/ha) and Bickford Mtn.-Fisher Creek FSR (2,028 stems/ha) sites surpassed the prescribed density for well-spaced density, while Mt. Frank Roy (987 stems/ha) failed to meet the density that was prescribed. Gross density of stems for each of the three sites was considerably higher, lending to clumped distribution of seedlings. Of the 136 juvenile trees planted on the Amoco Road site, 7% were dead, and 14% had experienced stem breakage due to the heavy snowpack conditions.

Table 3. Site level restoration implementation summary, Klinse-Za Caribou Habitat Restoration Program.

Site	Total Disturbance Footprint Length (km)	Net Buffered[2] Disturbance Footprint Area (ha)	Net Buffered Footprint of Direct or Indirect[3] Treatments (ha)	% Buffered Footprint Reduction	Planted Length (km)	Prescribed Density (Stems /ha)	Well-Spaced Density[1] (Stems /ha)	Gross Stem Density (Stems /ha)	Tree Falling Length (km)	Site Prep. Length (km)
Mt. Frank Roy	13.7	758	275	36	4.6	1,200	987	6,600	0.1	0
Amoco Rd.	15.0	707	647	92	11.1	1,200	1,617	12,717	4.3	0
Bickford Mtn.-Fisher Creek FSR	8.5	531	531	100	2.3	1,200	2,029	4,200	2.6	2.6

[1]Distance between trees is greater than or equal to 1.6 meters.
[2]Includes 500 m buffer on both sides of the linear feature.
[3]Removing motorized access as a result of arterial treatments.

Access management treatments on each of the three sites reflected their respective levels of vehicle use (Table 4). Bickford Mtn.-Fisher Creek FSR experienced the most vehicle use pre-treatment; the intensity of the access management treatments was effective at increasing the difficulty of wheeled-vehicle and snowmobiles access from low to high. Amoco Road and Mt. Frank Roy sites experienced low vehicle use pre-treatment, access management treatments were not emphasized and they did not experience changes in difficulty for both access types.

Table 4. Qualitative motorized access management pre- and post-treatment, Klinse-Za Caribou Habitat Restoration Program.

Site	Treatment Combination	Vehicle Use Pre-Treatment	Wheeled-Vehicle Access Difficulty Pre-Treatment	Wheeled-Vehicle Access Difficulty Post-Treatment	Snowmobile Obstruction Access Difficulty Pre-Treatment	Snowmobile Obstruction Access Difficulty Post-Treatment
Bickford Mtn.-Fisher Creek FSR	Site Preparation + Tree Falling	High	Low	High	Low	High
Amoco Rd.	Tree Falling	Low	High	High	High	High
Mt. Frank Roy	Tree Falling	Low	Moderate	Moderate	Low	Low

Meso-watershed Level

To date, restoration activities in the three sites have reduced the percent disturbance of the meso-watersheds they overlap by varying amounts (range: 0%-23.9%) (Table 5). Weighted average reductions by site are Bickford Mtn.-Fisher Creek FSR: -5.6%; Amoco Road: - 8.7%; Mt. Frank Roy: -1.6%.

Range Level

The total un-buffered length of linear disturbance features in the Klinse-Za herd areas is 5,607 km (Woods et al. 2018). Once buffered by 500 m on both sides, the total footprint of linear disturbance features is 238,687 ha (44% of the herd area; Table 6). Treatments applied to Amoco Road, Bickford Mtn.-Fisher Creek FSR, and Mt. Frank Roy, have resulted in the reduction by 24.2 km unbuffered, or 1,453 ha buffered (0.61% of herd area). The remaining restoration sites in the Klinse-Za restoration program account for a reduction of unbuffered 115.1 km, or 4,529 ha buffered (1.9% of herd area). The Klinse-Za restoration program as a whole, has resulted in the reduction of 139.3 km unbuffered, or 5,982 ha buffered (2.5% of herd area), bringing the total herd level disturbance area to 41.5%.

Effectiveness

We collected camera data from 1 camera/year from 2014- 2017 (operational design), and 74 cameras (26 arrays)/year from 2018-2022 (operational and research designs combined) across the three study sites (Table 1). A total of 20,506 true detections were recorded at the three sites between Aug. 3, 2014 and Oct. 13, 2022 after false detections and duplicate photos were removed (Table 7). Of these, there were a total of 1,526 detections (mean: 0.010 ± 0.065/camera-day) of people on foot or on non-motorized forms of transportation, while there were 6,659 (mean: 0.047 ± 0.068/camera-day) detections of predators, 280 (mean: 0.002 ± 0.009/camera-day) of caribou, 6,592 (mean: 0.047 ± 0.007/camera-day) of moose and 5,440 (mean: 0.039 ± 0.054/camera-day) of other wildlife species respectively. Detections of all species types were considerably higher in summer than in winter.

Patterns of detections/camera-day by species type varied among sites, and years (Figure 9). Detections of human use at the Bickford site continue to occur through time and at a higher level than any other species, especially in winter. However, at the Research sites, human use appears to decline over time, while there are few clear patterns indicating systematic changes in use of sites by the other species.

Analyses of changes in detection rates for each species type (human, predator, caribou, and moose) in relation to factors related to restoration (treated or not), location (cumulative distance from origin) and distance between sampling units, assessed in the context of seasonal site factors revealed among species differences in both the use of sites (frequency) when detections occurred and the chance that detections at sampling unit would not occur (Table 8). Humans were significantly less likely to be detected at cameras if treatment had occurred, but more likely the further from the origin the sampling unit was located, while the opposite appears to be true for predators. As well, for both humans and predators, frequency of detections where detected was not significant for almost all factors. Response patterns to each of these factors was also

Table 5. Meso-watershed scale effect of restoration activities undertaken to date. Shown are the meso-watersheds in which sites are located, and the pre-and post-treatment changes in the % disturbance estimate for the meso-watershed, Klinse-Za Caribou Habitat Restoration Program.

Design	Site	Meso-watershed Id	Meso-watershed area (ha)	Pre-treatment Meso-watershed disturbance (%)	Post-treatment Meso-watershed disturbance (%)	Net % of Meso-watershed influenced by treatment
Operational	Bickford Mtn	18970[1]	2,747	40.3	16.3	23.9
		18987	8,730	60.9	59.2	1.6
		13286	4,508	87.6	85.4	2.2
Research	Amoco Rd.	18988	3,417	37.8	37.6	0.2
		18970[1]	2,747	40.3	16.3	23.9
		18971	2,057	35.7	30.6	5.1
		18972	2,582	23.0	16.5	6.5
	Mt. Frank Roy	19045	9,642	87.4	87.4	0.0
		18968	2,680	65.3	65.3	0.0
		13087	5,330	32.3	27.2	5.2

[1]This meso-watershed is shared among 2 sites therefore its treatment activities and designations appear in calculations for both sites.

Table 6. Herd level reduction in linear disturbance features, Klinse-Za Caribou Habitat Restoration Program.

	Buffered[1]		Unbuffered
	Area (Ha)	Area (%)	Length (km)
Total Linear Disturbance Features Pre-2018	238,687	44.0	5,607.0
Restoration sites this study	1,453	0.6	24.2
Other Restoration Sites[3]	4,529	1.9	115.1
Remaining Untreated Linear Disturbance Features[2]	232,705	41.5	5,467.7

[1]Includes 500 m buffer on both sides of the linear feature.
[2]Does not account for potential restoration treatments completed by other parties.
[3]Includes features directly and indirectly treated.

Table 7. Summary metrics of the detections/camera-day at the three study sites. Klinse-Za Caribou Habitat Restoration Program.

Design	Site	Season	Metric	Human	Predator	Caribou	Moose	Other
Operational	**Bickford**	**Summer**	**Mean**	0.123	0.067	0.012	0.067	0.086
			SD	0.288	0.047	0.027	0.086	0.089
			Median	0.033	0.060	0.000	0.033	0.060
			N	702	380	66	384	492
		Winter	**Mean**	0.066	0.004	0.002	0.006	0.004
			SD	0.094	0.006	0.008	0.011	0.010
			Median	0.019	0.000	0.000	0.000	0.000
			N	283	16	7	25	18
Total (Operational)			**Mean**	0.098	0.039	0.007	0.040	0.050
			SD	0.225	0.047	0.021	0.072	0.078
			Median	0.033	0.016	0.000	0.006	0.011
			N	985	396	73	409	510
Research	**Amoco**	**Summer**	**Mean**	0.001	0.103	0.005	0.042	0.040
			SD	0.003	0.089	0.013	0.047	0.045
			Median	0.000	0.071	0.000	0.027	0.027
			N	21	3921	189	1604	1518
		Winter	**Mean**	0.004	0.001	0.001	0.004	0.012
			SD	0.013	0.004	0.005	0.007	0.014
			Median	0.000	0.000	0.000	0.000	0.006
			N	101	22	15	100	277
	Frank Roy	**Summer**	**Mean**	0.008	0.056	0.000	0.101	0.073
			SD	0.016	0.051	0.001	0.093	0.067
			Median	0.000	0.043	0.000	0.087	0.054
			N	310	2213	3	4013	2888
		Winter	**Mean**	0.004	0.004	0.000	0.016	0.009
			SD	0.009	0.007	0.000	0.033	0.010
			Median	0.000	0.000	0.000	0.006	0.006
			N	109	107	0	466	256
Total (Research)			**Mean**	0.004	0.048	0.002	0.047	0.038
			SD	0.011	0.070	0.007	0.070	0.052
			Median	0.000	0.016	0.000	0.016	0.016
			N	541	6263	207	6183	4939
Total			**Mean**	0.011	0.047	0.002	0.047	0.039
			SD	0.065	0.068	0.009	0.070	0.054
			Median	0.000	0.016	0.000	0.016	0.016
			N	1526	6659	280	6592	5449

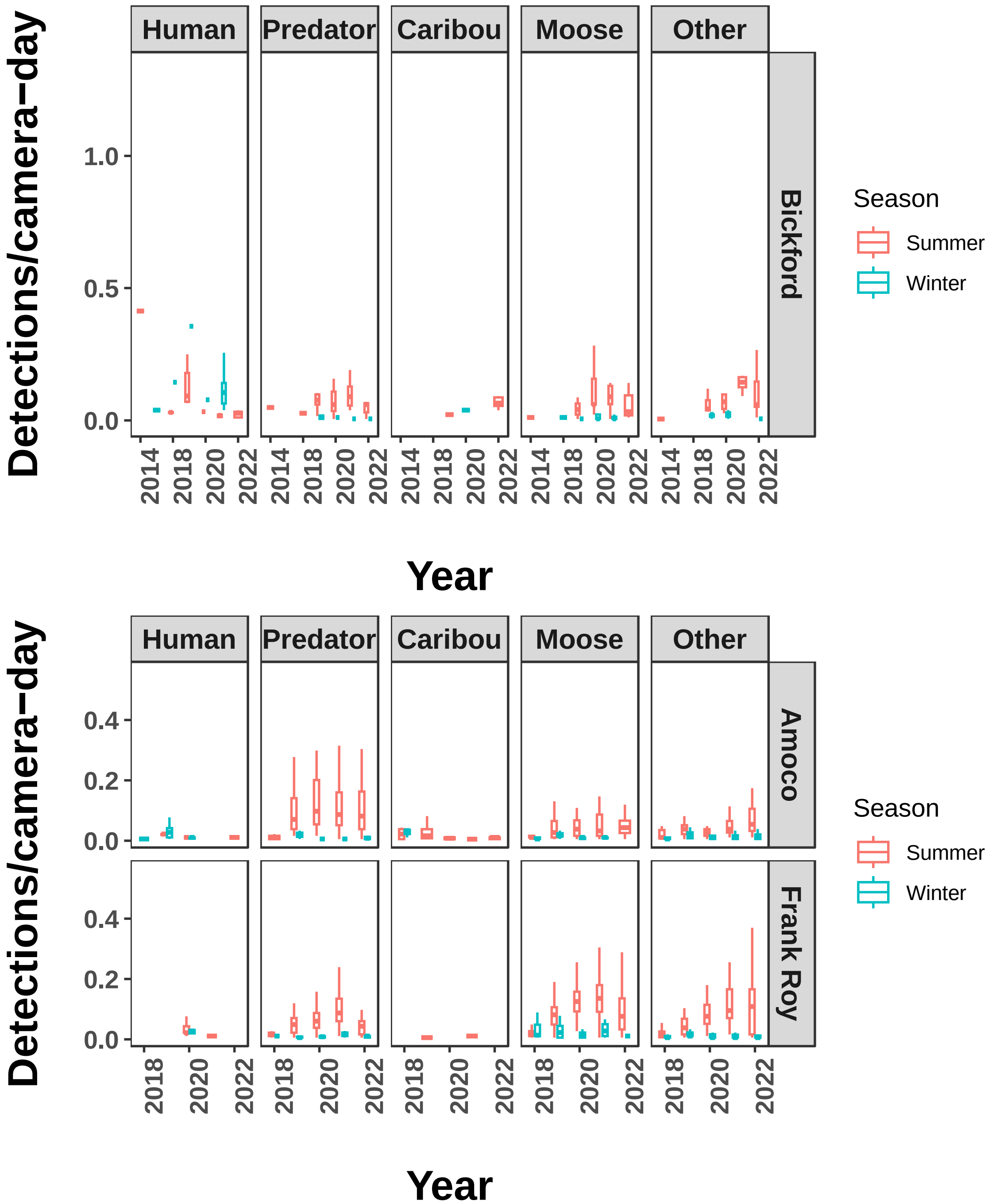

Figure 9. Annual and seasonal patterns of detections per camera-day for the different species groups at the Operational (top panel) and Research (bottom panel) sites included in the case study. Shown are the data (points) for each sample unit (camera location), overlaid with a boxplot of the distribution of values. Bold horizontal lines indicate median values, box hinges represent 25% and 75% percentiles, and each individual in-season value is displayed. Note the different y-axis scales between the Operational and Research panels. Klinse-Za Caribou Habitat Restoration Program.

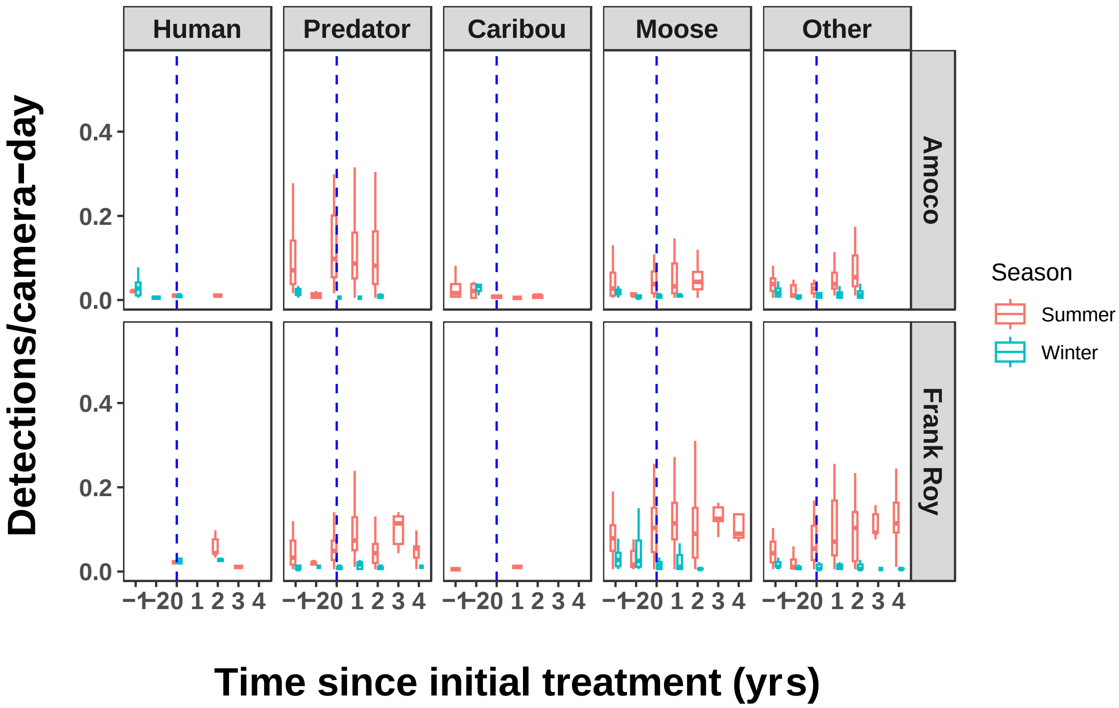

Figure 10. Annual and seasonal patterns of detections per camera-day for the different species groups at the two Research sites relative to time since restoration treatments began at each site. Years prior to the application of the first treatment are negative, years after are positive and the year in which restoration treatments began is 0 (vertical blue dashed line). See Figure 9 caption for interpreting the data values. Klinse-Za Caribou Habitat Restoration Program.

different for moose and caribou. Site was a significant covariate for all species types, as was season (except for humans) and type of sampling unit (i.e., whether it was "treatment" or "control"). The distance between sampling units was significant only for predators but not other species type. Note that the wide confidence limits for several of the coefficients for caribou may be related to small number of detections.

Table 8. The effects of different factors on the probability of absence (presence/absence), and frequency of use given presence (frequency), at sampling units located on linear features in two research sites being restored by type of species. Reference conditions were season (summer), close to the origin, no treatment, SU type = control, and site = Amoco A random intercept was included for each camera and array. Bold signifies significance, defined as 95% confidence intervals (1.96 * standard error) non-overlapping zero.

Species	Covariate	Absence[1]			Frequency[2]		
		Estimate	-CI	+CI	Estimate	-CI	+CI
Human 541 detections	Intercept	**8.184**	**7.417**	**8.951**	-0.071	-1.267	0.984
	Km from origin	**-0.932**	**-1.004**	**-0.816**	0.143	-0.426	0.140
	Treated (Y)	**0.933**	**0.435**	**1.432**	0.014	-1.038	1.065
	Season (W)	1.661	1.176	2.145	0.082	-0.728	0.892
	Site	**2.979**	**1.879**	**4.078**	0.405	--0.610	1.421
	SU Type (Trmt)	**-2.387**	**-3.215**	**-1.558**	-0.446	-1.524	0.633
	Dist. between SUs	-0.087	-0.630	0.455	0.184	-0.411	0.779
Predator 6,263 detections	Intercept	**2.706**	**2.56**	**2.85**	-0.805	-1.254	-0.355
	Km from origin	**0.058**	**0.045**	**0.070**	-0.095	-0.131	-0.059
	Treated (Y)	**-0.491**	**-0.575**	**-0.406**	-0.220	-0.456	0.016
	Season (W)	**3.211**	**3.020**	**3.402**	-0.766	-1.651	0.120
	Site	**0.237**	**0.132**	**0.343**	-0.259	-0.627	0.110
	SU Type (Trmt)	**-0.211**	**-0.356**	**-0.065**	0.458	-0.032	0.948
	Dist. between SUs	**-0.120**	**-0.228**	**-0.011**	**-0.468**	**-0.818**	**-0.119**
Caribou 207 captures	Intercept	**6.557**	**4.078**	**9.035**	-0.588	-31583	31582
	Km from origin	**-0.108**	**-0.168**	**-0.048**	**-0.104**	**-0.198**	**-0.009**
	Treated (Y)	**1.650**	**1.162**	**2.138**	-0.372	-1.048	0.304
	Season (W)	**3.564**	**2.414**	**4.716**	**1.272**	**0.673**	**1.871**
	Site	**2.623**	**1.215**	**4.030**	-16.513	-8100	8067
	SU Type (Trmt)	-0.737	-3.167	1.693	2.523	-31580	31584
	Dist. between SUs	0.437	-0.790	1.665	-2.018	-5.120	1.083
Moose 6,183 captures	Intercept	**3.425**	**3.281**	**3.568**	**-1.692**	**-2.139**	**-1.246**
	Km from origin	**0.028**	**0.014**	**0.042**	**0.091**	**0.055**	**0.127**
	Treated (Y)	**-0.306**	**-0.388**	**-0.223**	-0.130	-0.341	0.080
	Season (W)	**2.107**	**1.990**	**2.225**	**0.518**	**0.259**	**0.778**
	Site	**-0.933**	**-1.034**	**-0.831**	**0.490**	**0.235**	**0.744**
	SU Type (Trmt)	-0.091	-0.225	0.043	**-0.619**	**-0.954**	**-0.284**
	Dist. between SUs	-0.056	-0.212	-0.099	-0.361	-1.101	0.379

[1] Estimates are logit values. Positive values indicate increasing probability of absence from sites per day (i.e. decreasing use of sites)
[2] Estimates are log values. Positive values indicate increasing # predicted detections per day.

DISCUSSION

Restoration of caribou range is a relatively new domain in applied science with much uncertainty around policy, practice, and short and long-term consequences. Assessing effectiveness of habitat restoration is therefore challenging and the assessment questions could be broader and deeper than those we posed here. Ultimately, the goal of caribou habitat restoration is a demographic one: to create conditions for recovering populations of caribou that lead to self-sustainability. Ideally, the findings from an analytical framework would be linked to long-term changes in caribou demography within the range. For example, using more intricate research designs to assess and understand the deeper mechanistic implications of changes in use of linear features by predators (encounter rates and kill rates) requires efforts beyond our scope. Also, in this report we only address effectiveness at the level of individual linear features but, as with our assessment of implementation, restoration effectiveness could also address questions at multiple nested levels of a geographic scale including: at individual linear features, among linear features nested within meso-watersheds (or other spatial units), among meso-watersheds within a project area (if/when appropriate to do so), and/or among meso-watersheds (or projects) within the caribou range. This nested hierarchy of assessment would enable measures of effectiveness to be aggregated in different ways to explore the consequences of restoration through time.

This broad range of monitoring metrics that span implementation progress through effectiveness at multiple levels of geographic scale is necessary to assist in prioritizing restoration activities in space and time. This is necessary because of logistical limitations in how much restoration can be untaken at any one time. As well, while the ultimate goal of restoration is to move habitats toward a condition that assists in demographic recovery of caribou populations, gaining near-term insights about the likelihood that restoration can reduce use of linear features by human and predators (functional restoration) is important in targeting continued restoration effort.

Our monitoring approach is evolving. Results to date derived from analyses of the functional effectiveness of the types of restoration applied on two sites with 3-4 years of data suggest that restoration could be contributing to (currently) small decreases in detections of predator and humans along legacy features. However, sample sizes of detections are small, geographically dispersed, and involve types of species (humans, predators, ungulates) with wide differences in behaviour and patterns of use of linear features, challenging interpretations of effects and separating out confounding spatial effects (spatial influences of elevation, distances of entry points to the lines from layout of treatments (which are also spatial). Nonetheless, as effects of restoration are expected to strengthen over time via tree growth and ingress, monitoring of the sampling unit -> site scales may yield stronger statistical results. We note that presently, temporal imprecision in camera timestamps has prevented us from calculating movements speeds as a supporting metric. This is planned as a future exploration.

In addition to functional effectiveness as explored here largely at the finer-scaled portions of the hierarchy (sample unit->site), we show that metrics of implementation success at the meso-watershed scale suggest that restoration efforts spatially appear to be beginning to reduce aggregate measure of area disturbed, although these changes are still relatively small. Linking measures of functional effectiveness to these metrics of implementation success is an active area of development of the analytical framework.

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APPENDIX A. KLINSE-ZA CARIBOU HERD AREA DESCRIPTION

The Klinse-Za caribou population extends across 550,151 ha of land from ~15 km west of Moberly Lake to the eastern shore of Parsnip Arm of the Williston Reservoir, and from Highway 97 to the southern shore of the Peace Arm of the Williston Reservoir (Figure 11)[9]. The core of the area includes Klinse-Za Park and the Twin Sisters Special Resource Management Zone (hereafter, RMZ)[10]. This core area has profound spiritual significance and traditional use value for First Nations and contains numerous cultural sites including old cabins, heritage campsites, some burial sites, and many historic trails. These cultural values are the management priority for the RMZ, and management of other values is conducted with a high degree of sensitivity to those values.

The area is characterized by mountainous terrain and rolling hills, with peaks rising to 2,100 meters. Most of the plan area is made up of higher elevation Engelmann Spruce-Subalpine Fir (ESSF) and Boreal Altai Fescue Alpine (BAFA) biogeoclimatic zones (BGC; DeLong et al. 1994; Figure 11). The Sub-boreal Spruce (SBS) zone occurs at lower elevations below approximately 1,000 m and the Boreal White and Black Spruce (BWBS) zone is found below the SBS in the eastern portion of the area (Delong 2003, 2004, DeLong et al. 1990). Forest cover in the ESSF is mostly composed of subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanni*) and hybrid white spruce (*Picea glacua* x *engelmanni*). The SBS is dominated by hybrid white spruce with some lodgepole pine (*Pinus contorta*) occurring on drier sites. Tree cover in the BWBS primarily consists of trembling aspen (*Populus tremuloides*) due to disturbance by fires, with spruce occurring in wetter areas (DeLong et al. 1990). Fire disturbance is rare or infrequent in most of the study area, except for in the eastern portion where fires recur every 100-150 years on average (Delong 2002). Other natural disturbances in the area include the relatively recent and widespread outbreak of mountain pine beetle (*Dendroctonus ponderosae*), which was classed as moderate to severe in the eastern portion of the plan area in 2010 (Westfall and Ebata 2010). Recent forest health inventories and analyses have indicated an increased prevalence of the spruce bark beetle in British Columbia[11] (*Dendroctonus rufipennis*). Seventy-two percent of the herd area is classified as coniferous forest, with mixedwood forest (8%) and shrub cover (5%) as the next most abundant cover types.

The western side of the plan area is wetter and has more snow than the eastern side. Alpine slopes in the eastern portion of the area tend to be windswept and have less snow than alpine slopes in the western portion of the area. Other large mammals that live in the area include grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*), wolves, wolverine (*Gulo gulo*), moose (*Alces americanus*), elk (*Cervus canadensis)*, mule and white-tailed deer (*Odocoileus hemionus*, *O. virginianus*), mountain goats (*Oreamnos americanus*) and, historically, Stone's sheep (*Ovis dalli stonei*).

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[9] In the future, the geographic scope of interest for habitat restoration and recovery of caribou in the area is likely to extend to a much larger area: into other herd areas, and to range where caribou occurred historically but are no longer present (WMFN 2014).

[10] Dawson Creek LRMP: https://www.for.gov.bc.ca/tasb/slrp/plan27.html

[11] BC MFLNRORD 2018. Spruce Beetles in British Columbia. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/bark-beetles/5782_sprucebeetles_factsheet_flnro_web.pdf

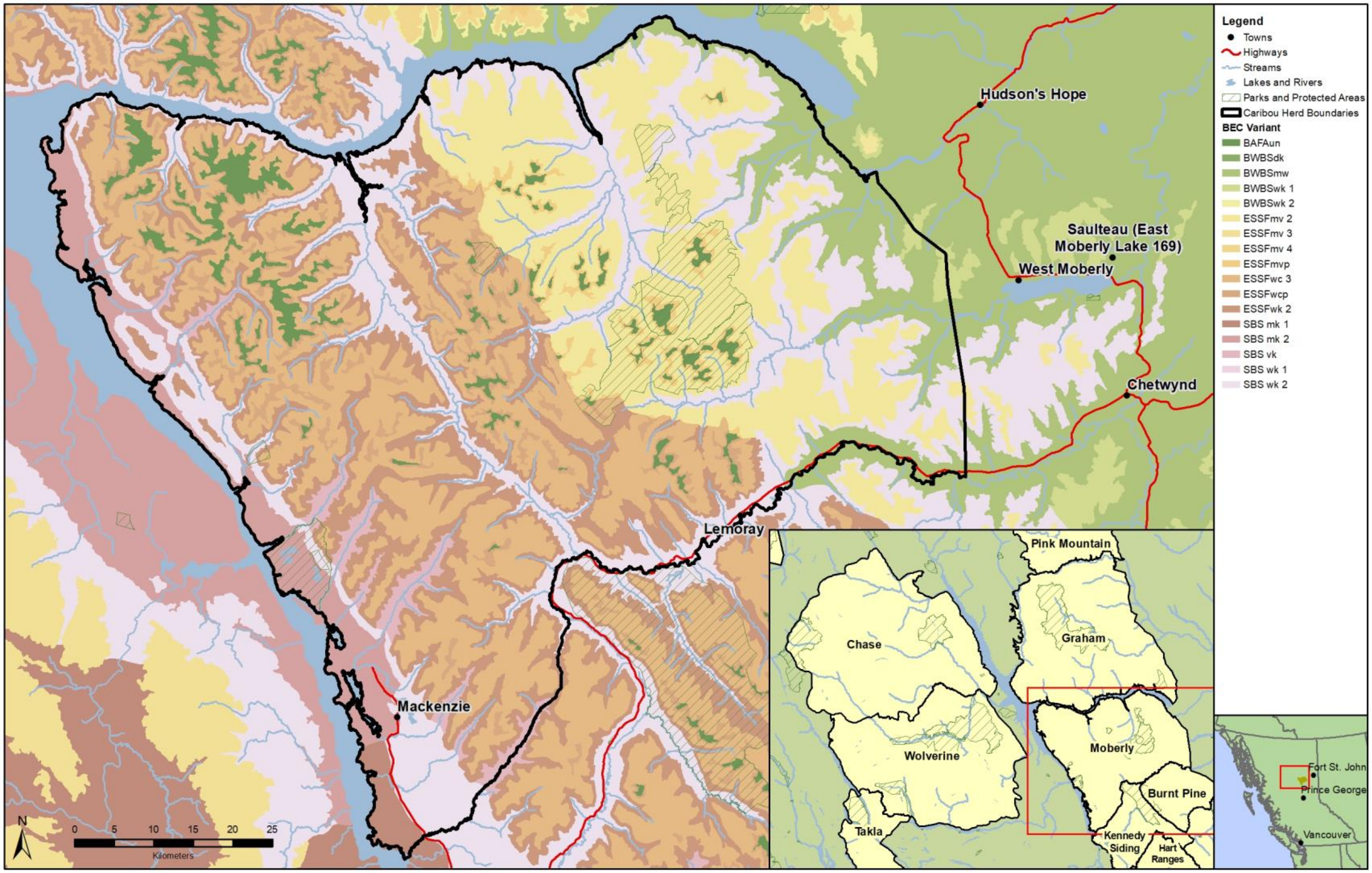

Figure 11. Location and Biogeoclimatic Zones of the Klinse-Za caribou range in northern British Columbia, Klinse-Za Caribou Habitat Restoration Program.

Habitats in the Klinse-Za caribou range have been altered by a wide spectrum of existing natural disturbances (wildfire and forest pest infestation) and existing and proposed anthropogenic disturbances. These latter disturbances include a combination of linear features (roads, seismic lines, transmission lines, pipelines, and railway lines) and polygonal features (forest harvesting cutblocks, oil and gas facilities, wind farms, urban/private land, and mineral developments). When the footprint is buffered by 500 m, total disturbance from linear features is approximately 238,000 ha or 43% of the herd area.

In Spring 2020, an Intergovernmental Caribou Partnership Agreement (hereafter, the Partnership Agreement) between West Moberly First Nations, Saulteau First Nations, the BC Government, and the Federal Government was signed for the purpose of supporting caribou recovery in the Central Group of Southern Mountain Caribou. Within the agreement, land use priorities are identified in seven zones that include sustainable resource activity zones, conservation and restoration areas, interim moratoriums on new industrial development, new protected area, and areas of First Nations interest.

APPENDIX B. SPATIAL DATA SOURCES USED IN THIS STUDY

Table 9. Description and sources of the different types of spatial data used in this study. Klinse-Za Caribou Habitat Restoration Program.

Spatial Input	Description	Data Source	Vintage
Mesoscale Assessment Watersheds	Assessment Watersheds are based on groupings of fundamental watersheds using FWA watershed code and local code, with a target size of between 2,000 ha and 10,000 ha.	https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-assessment-watersheds	2009
Caribou Range Boundaries	Current caribou subpopulation (herd) boundaries.	https://catalogue.data.gov.bc.ca/dataset/caribou-herd-locations-for-bc	2021
Biogeoclimatic Subzones	Biogeoclimatic Ecosystem Classification (BEC) Zone/Subzone/Variant/Phase map (version 12).	https://catalogue.data.gov.bc.ca/dataset/bec-map	2021
Digital Elevation Model (25m)	Federally distributed 25 m digital elevation model	ftp.geogratis.gc.ca/pub/nrcan_rncan/archive/elevation/geobase_cded_dnec/50k_dem	2010
Camera Locations	Point locations of all trail cameras including those which are presently deployed and those which have since been moved/removed.	N/A	2022

Spatial Input	Description	Data Source	Vintage
Path Origins	User-generated point locations representing the 'start' or 'entry' points into a restoration site. These points may be located ahead of any restoration treatments at that site and are the point from which distances to cameras are calculated.	N/A	2022
Optimal Path Barriers	User-generated linear features representing hard barriers when generating paths between origin points and cameral locations. These barriers were necessary for path generation when there were multiple potential ways to access a given cameras. The barriers are simple linear features that cross the features of the linear disturbance feature network that allow multiple access points to the cameras.	N/A	2022

Spatial Input	Description	Data Source	Vintage
Linear Disturbance Database	Assembled database of linear disturbance features in the study area. This database is composed of features from the Digital Road Atlas, Forest Tenure Road Segments, National Railway Network, electrical transmission lines and Oil & Gas Commission layers (roads, pipelines, and seismic line). Some features are also collected by field crews using GPS. All features bear tracking information identifying treatment history in the study area.	https://catalogue.data.gov.bc.ca/dataset/digital-road-atlas-dra-master-partially-attributed-roads https://catalogue.data.gov.bc.ca/dataset/forest-tenure-road-segment-lines http://ftp.geogratis.gc.ca/pub/nrcan_rncan/vector/geobase_nrwn_rfn/bc/ https://catalogue.data.gov.bc.ca/dataset/bc-transmission-lines/resource/6aa63176-7e73-4ff6-8126-04fa748a6622#edc-pow https://data-bcogc.opendata.arcgis.com/search?collection=Dataset&tags=OD_Roads https://data-bcogc.opendata.arcgis.com/search?collection=Dataset&tags=od_pipeline https://data-bcogc.opendata.arcgis.com/search?collection=Dataset&tags=seismic	2021 2021 2013 2020 2021 2021 2021