Project Progress Report

Project Title

Accelerating recovery of boreal caribou habitat via lichen seeding for oil and gas related remediation.

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Project Objectives and Rationale

Boreal caribou represent a culturally imperative food source for Indigenous populations throughout much of the Northwest Territories (NWT); however, habitat degradation, predation, and cascading impacts from climate change have reduced boreal caribou populations across Canada by over 30% in the past 20 years – resulting in their current designation as a Schedule 1 "threatened" species under the Canadian Federal Species At Risk Act. In the NWT there is concern over the cumulative effects of climate warming-related acceleration of disturbances (wildfire and permafrost thaw) coupled with development activities on boreal caribou populations. Successful remediation of sites that have been naturally disturbed by wildfire or associated permafrost decay could, in part, mitigate modern habitat loss, reducing stress on targeted boreal caribou populations. Lichen seeding techniques represent a novel remediation strategy, however, we have limited knowledge of the environmental conditions (i.e., permafrost presence, fire severity, stand age, etc.) that best promote seeded lichen establishment, particularly in discontinuous permafrost systems common to the Northwest Territories.

Objective: We will address this knowledge gap by determining under what landscape conditions caribou habitat recovery can be accelerated by lichen seeding.

Cumulative Project Progress

(1) Synthesis of literature, data and imagery on wildfire and permafrost disturbance interactions in NWT and forage taxa recovery trends

Permafrost and Fire Disturbance Interactions – Permafrost and fire literature and in-hand data were surveyed to identify core knowledge gaps for the southern NWT region and quantify on-going permafrost decay rates at fire impacted sites. This effort resulted in a novel manuscript detailing on-going permafrost thaw rates across southern NWT with relationship to fire history and the implications for organic soils. This synthesis has also been incorporated into an international effort characterizing the relationship between local environmental conditions and ongoing permafrost decay and is expected to significantly contribute to a high impact manuscript detailing the mechanisms advancing boreal region permafrost loss in relation to fire history at the global scale.

Outputs to date:

Dieleman, CM, Day, NJ, Holloway, JE, Baltzer, JL, Douglas, TA, Turetsky, MR. 2022. Carbon and nitrogen cycling dynamics following permafrost thaw in the Northwest Territories, Canada. Science of the Total Environment, accepted with minor revisions.

Dieleman, CM, Day, N, Baltzer, JL, Turetsky, MR. 2020. Carbon and nitrogen co-cycling dynamics following discontinuous permafrost thaw in the Northwest Territories, Canada. AGU Fall Meeting, Virtual.

Forage taxa recovery trends post-disturbance - Using in-hand data we have been developing models of wildlife forage recovery following fire and across a range of environmental and permafrost conditions. This includes two main efforts. The first is the characterization of lichen biomass recovery following fire. This work brought together data from NWT and a related project in Saskatchewan, thereby traversing a broad latitudinal gradient from northern SK to the Sahtú region and a range of permafrost conditions. This study provides a critical baseline for the current work as it established the lichen biomass recovery curves that have informed study site selection and expected recovery rates. The second effort involves modelling the post-fire recovery of forage taxa in the NWT. This focuses on a range of wildlife taxa with a goal of understanding periods of time during which caribou may face biotic pressures due to shared use of an area by other wildlife. This effort formed part of a MSc project that was completed in Sept 2021 and included both a full review of the literature on wildlife forage preferences in boreal Canada and a new manuscript presenting the models described above. This work has been presented at an international conference and forms two manuscripts at different stages of preparation.

Outputs to date:

Gruel, R, Degré- Timmons, G, Baltzer, JL, Johnstone, JF, McIntire, E, Day, NJ, Hart, S, McLoughlin, P, Schmigelow, F, Turetsky, MR, Truchon-Savard, A, van Telgen, M, Cumming, SG. 2021. Predicting patterns of terrestrial lichen biomass recovery following boreal wildfires. Ecosphere, 12(4): e03481.

Jorgenson, A, Alfaro-Sanchez, R, Cumming, S, White, A, Degre-Timmons, GW, Day, NJ, Turetsky, M, Mack, M, Johnstone, J, Walker, X, Baltzer, JL. 2023. The influence of post-fire recovery and environmental conditions on boreal wildlife forage. Ecosphere, accepted.

Jorgensen, A, Biro, J, Hodson, J, Armstrong, T, Schmiegelow, F, Gonet, J, Johnstone, J, Baltzer, J. 2022. Forage and dietary overlap among large ungulates, snowshoe hare, and bears in boreal North America. In revision.

Jorgensen, A, Cumming, S, Day, N, Alfaro-Sanchez, R, White, A, Degré-Timmons, G, Johnstone, J, Turetsky, M, Mack, M, Walker, X, Schmiegelow, F, Baltzer, J. 2021. Plant recovery and wildlife return to the boreal forest after fire. International Boreal Forest Research Association Meeting.

(2) Lichen Seeding Greenhouse Experiment

During the summer of 2022, fragments of the caribou lichen *Cladonia mitis* were collected from four distinct locations representing different environmental conditions: open and forested habitats on both the Taiga Plains and the Taiga Shield. The main questions we were interested in testing were whether these populations responded differently to light and moisture availability. To this end, we established a controlled environment

study in which we grew these fragments in one of four conditions: high light receiving either high or low moisture and low light receiving either high or low moisture. These lichen fragments were exposed to these growing conditions for 4 weeks and their physiological stress measured using chlorophyll fluorometry. This experiment has been completed and we are in the process of analyzing the data.

In the coming summer, we plan to collect more lichen fragments to run a longer-term experiment where growth and productivity of lichen fragments in these treatments would be measured.

Figure 1*. Controlled lichen experiment involving high and low light and moisture conditions and four populations of lichen collected from the Taiga Plains and Taiga Shield in the Northwest Territories, Canada.*

(3) Lichen Seeding Field Experiment

During the 2021 field season we established experimental lichen seeding trials in southern NWT at 51 disturbed sites that vary in terms of 1) permafrost presence or absence, 2) 2014 fire burn severity, and 3) stand age at the time of fire (Figure 2).

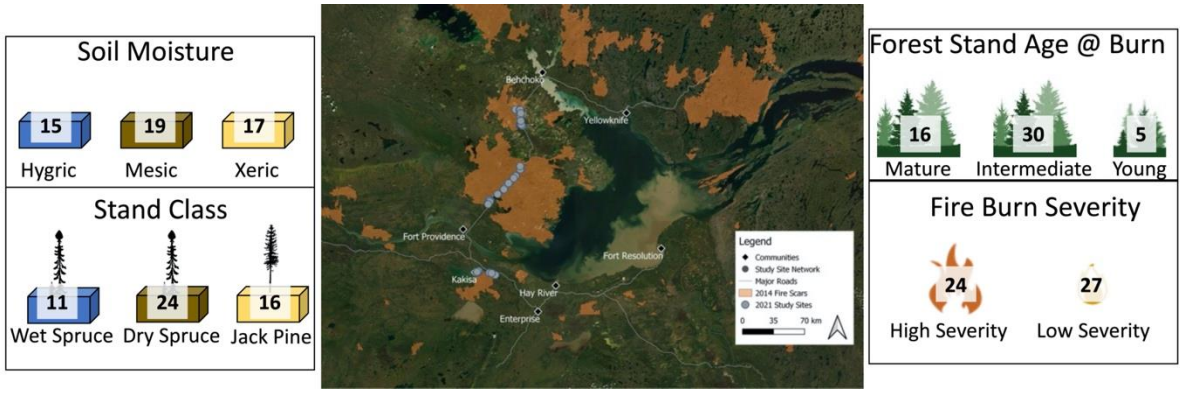

Figure 2. Overview of site selection for our lichen seeding trials in the southern NWT.

For this experiment, we targeted the most common caribou lichen species (*Cladina mitis, C. rangiferina*) to use for seeding. We established eight replicate 1 m × 1 m plots along established 30 m transects previously used to characterize a suite of site characteristics (i.e., soil carbon content, organic layer depth, surface vegetation structure, stand dominance, site drainage). Lichen fragments were applied at high and low densities (3 replicates of each at each site) and two plots were left as unseeded controls (Figure 3).

Figure 3. Left panel: Diagram of experimental design of the lichen seeding experiment. Middle panel: seeded quadrats with high density seeding on the left and low density seeding on the right. Right panel: Catherine Dieleman preparing lichen for experimental application.

During the summer of 2022, we revisited all plots to evaluate lichen establishment. We used metrics of physical establishment, vigor, and biomass. Specifically, we mapped the distribution of lichen fragments within the plots and in a 1m buffer around the plot to understand whether fragment displacement is an issue and if so, whether this varies by ground surface type (Figure 4). We determined that lichen displacement was not an issue as very few lichen fragments were found in the buffer zones of the experimental plots (Figures 4 and 5). We measured the vigor of seeded fragments in three ways. First, we visually assessed the health of a subset of fragments in each plot using existing protocols (Duncan 2011). Second, we used measures of chlorophyll fluorescence to determine the physiological status of fragments (i.e., were the fragments experiencing physiological stress; Figure 6). Third, we took microscopic images of a subset of fragments to quantify establishment features including apothecia (reproductive structures) and hapters (attachment features) (Figure 7). The data from this field season is entered and being analyzed. MSc Brown-Dussault will revisit these sites during summer 2023 to remeasure the physiological stress and establishment features in the experimental plots.

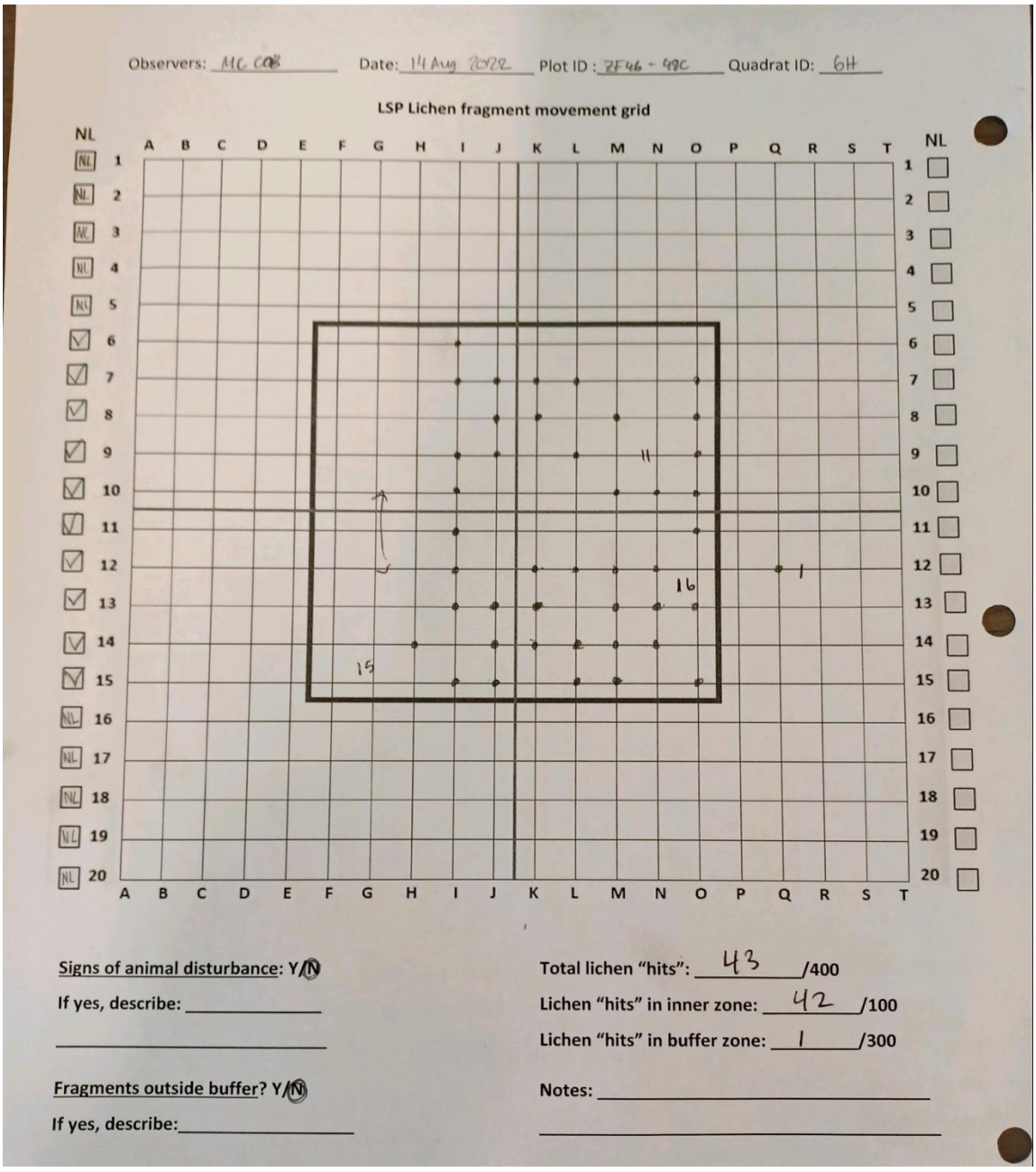

Figure 4. Example datasheet for lichen mapping measurements. The black square indicates the 1 x 1m quadrat and the remainder of the grid shows the mapped buffer zone. Each dot represents an individual lichen fragment. In this example, a single lichen fragment had been displaced outside of the original quadrat.

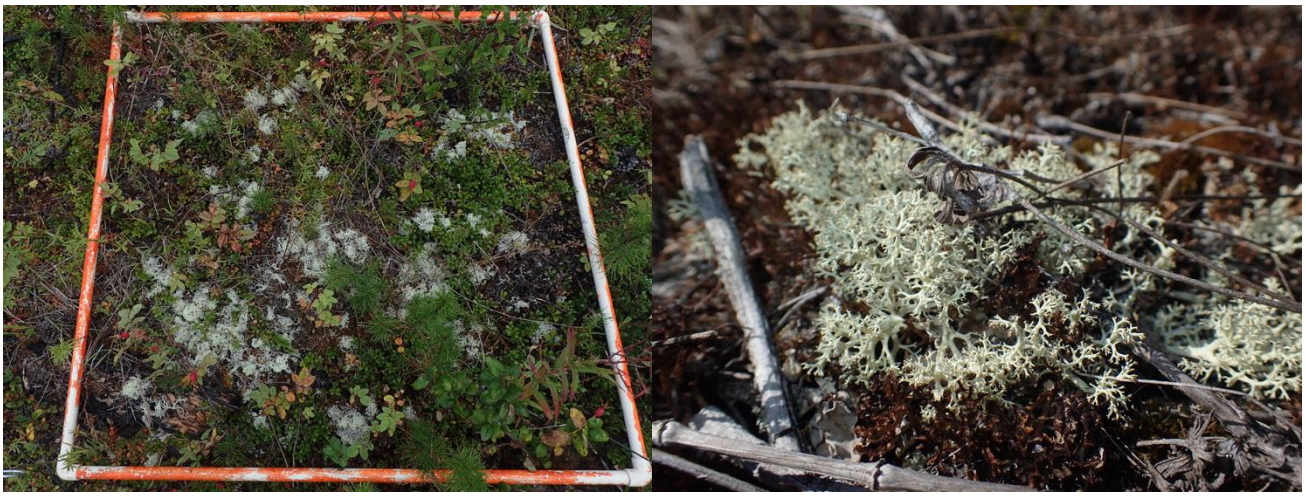

Figure 5. Left: An above-plot photo of a seeded lichen plot showing the persistence of lichen fragments in the plot. Right: a healthy lichen fragment in an experimental plot.

Figure 6. Field measurements of chlorophyll fluorescence by MSc Elise Brown Dussault during summer 2022.

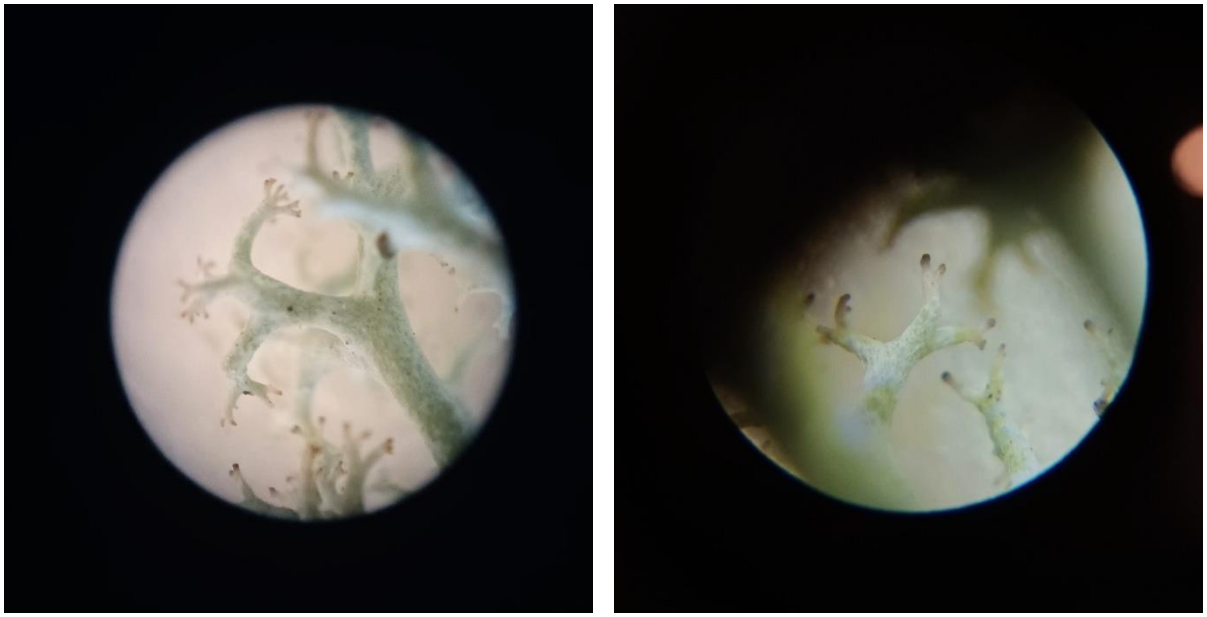

Figure 7. Pictures of *Cladonia rangiferina* taken with a 20x-60x field microscope.

Outputs to date:

Brown-Dussault, E. Lichen It: Refining post-fire winter caribou habitat restoration. 2022 Cold Regions Research Centre Student Conference. *Elise's 3-minute thesis presentation was awarded first place at this student conference.

Brown-Dussault, E, Baltzer, J, and Dieleman, C. 2023. Lichen It: Refining post-fire winter caribou habitat restoration. Joint North American Caribou Workshop and Arctic Ungulate Meeting. Anchorage, Alaska, May 2023.

It is noteworthy that for the coming year (2023-24) MSc Elise Brown-Dussault has been the recipient of two competitive scholarships: NSERC CGS-M and Weston Family Fellowship in Northern Research, which will support her salary for the year in addition to university funding contributions. Brown-Dussault also received funding to support community outreach in the NWT through the Weston Family Boreal Research Fellowship.

(4) Communication of Results to Date

The results of the aforementioned permafrost and fire synthesis were presented at the international American Geophysical Union meeting, with very positive reception from the academic community and government representatives from USA and Canada. The manuscript itself was published in the high impact journal Science of the Total Environment in 2022. The aforementioned lichen biomass recovery manuscript was published in 2021 in the journal Ecosphere and has generated tremendous interest including several invited talks by the

lead authors and have also been presented at a range of Territorial and National meetings focused on caribou management. The wildlife forage recovery work has just been accepted in the peer-reviewed journal Ecosphere and its contents are being translated into a SpaDES ecological forecasting module. This work was presented at the International Boreal Forest Research Association Meeting in August 2021. The review paper on fire impacts on wildlife forage was submitted to the Journal of Wildlife Management, reviewed and rejected. We are currently revising the manuscript for resubmission. Finally, preliminary analyses from the lichen seeding experiment were presented in May 2022 at the joint meeting of the North American Caribou Workshop and the Arctic Ungulate Conference.

(5) Community engagement and Knowledge Sharing

Leading up to the 2021 field season, there was substantial engagement of the Tłı̨chǫ government about this project. This included zoom meetings and presentations to share our plans and hear about research the community is doing to understand the impacts of the Tłı̨chǫ All Season Road to Whatì. During summer 2021, we hired Jody Zoe, a youth from Behchokǫ̀, as part of this project. Jody lived and worked with our team, learning methods and contributing to data collection. Our team also spent considerable time in the community of Kakisa, living in the community and contributing to community events. We created a video that includes an overview of this project at the request of and funded by CIMP: https://www.youtube.com/watch?v=AqdseK1u4lA

During summer 2022, there was substantial engagement with the Ka'a'gee Tu First Nation as Brown-Dussault and her assistants were living in Kakisa for much of the summer, providing the opportunity to share informally their results with the community. They also contributed to community events including a community garden day. Elise participated in the week-long Dehcho Youth Ecology Camp in Fort Providence in September 2022, where she organized activities focused on lichens and their importance. Informal meetings to update the Tlicho government on this research were held in July 2022.

For the coming summer, Elise has received funding through the Weston Family Boreal Research Fellowship to support community outreach and engagement. Over the last year, we have discussed our lichen seeding efforts with a representative for the Deninu Kų́ę́ First Nation (Marc D'Entremont), who are similarly evaluating the potential for lichen seeding to help recover caribou habitat. We are meeting in the coming week to discuss land-based knowledge sharing about these two complementary projects being carried out in different regions. Elise is also attending a community meeting in Ka'a'gee Tu First Nation in June 2023, and we are evaluating possibilities for other outreach toward the end of the summer.