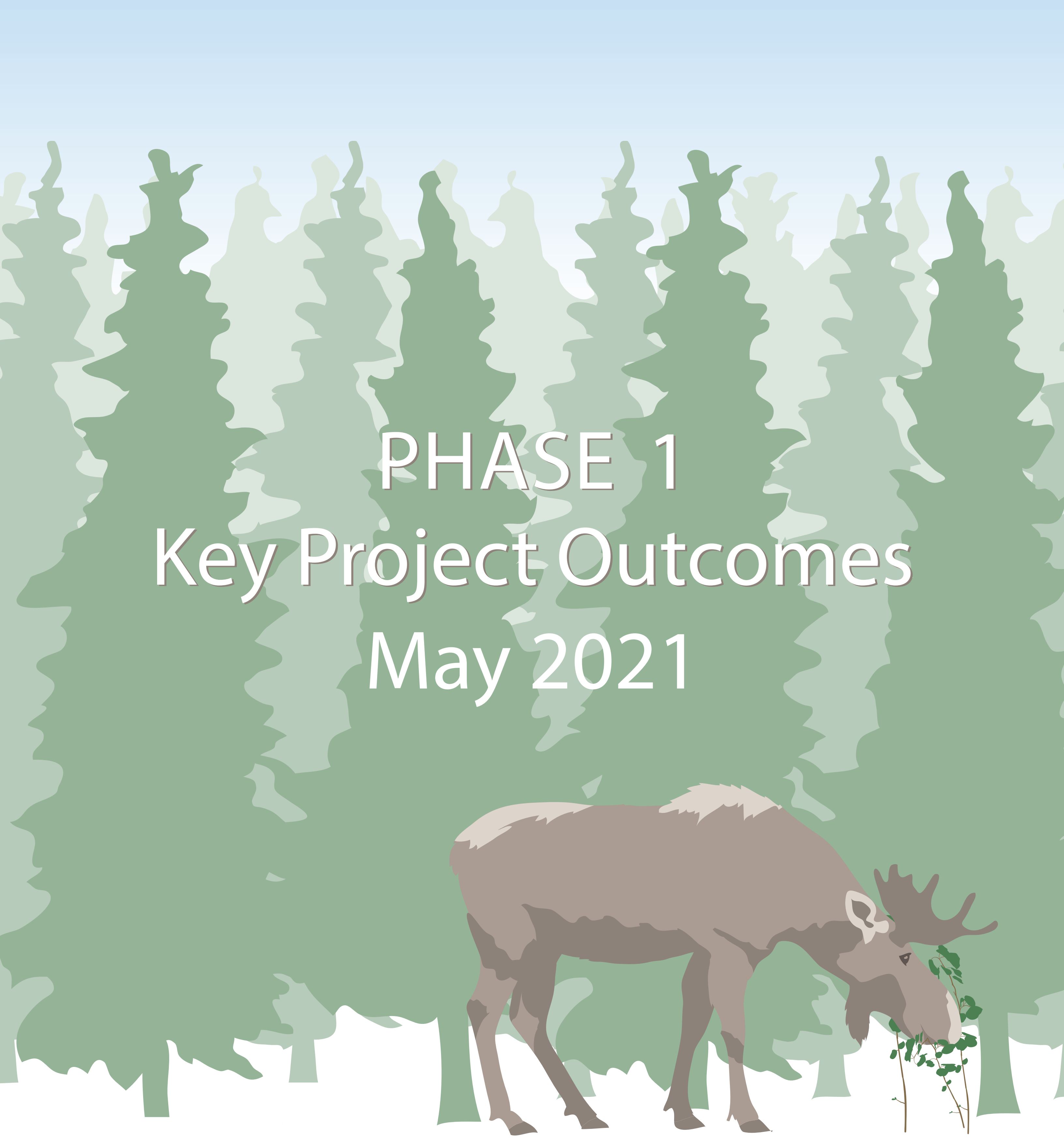


PHASE 1
Key Project Outcomes
May 2021

Boreal Ecosystem Recovery & Assessment

KEY OUTCOME 1

The Forest Line Mapper (FLM) is a powerful, semi-automated tool for delineating and attributing linear disturbances in Alberta forests.

Why it is important: Most existing linear-feature inventories are suitable for cartographic purposes but lack the fine spatial details and multiple attributes required for more demanding analytical applications like restoration assessment. The FLM reliably predicts both the center line (polyline) and footprint (extent polygons) of a variety of linear-feature types including roads, pipelines, seismic lines, and power lines. FLM outputs are consistently more accurate than publicly available datasets produced by human photo-interpreters and can be reliably deployed across large application areas.

Implications: The FLM is open-source and freely available (see http://flm.bera-project.org) and is aimed to assist researchers and land managers working in forested environments everywhere. It requires seed points from lines digitized at approximately 1:20,000 and a LiDAR-derived (light detection and ranging) canopy height model, both of which are widely available in Alberta. The FLM is the first of an envisioned suite of free, open-source tools to support large-area forest-restoration planning and monitoring.

Relevant Publication: Lopez-Queiroz et al., 2020

KEY OUTCOME 2

Airborne remote sensing can detect establishment-aged evergreen seedlings (eight to 10 years old; > 60 cm tall) on seismic lines. Leaf-off imagery and 5 cm pixels are required.

Why it is important: The Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta calls for establishment monitoring two to five years (survivability assessment) and eight to 10 years (establishment survey) after treatment. With many kilometres of seismic lines to be assessed, this work establishes the conditions required for performing remote stocking assessments on an operational basis.

Implications: With existing technology, establishment monitoring of 8-10+ year-old evergreen seedlings is likely feasible on an operational basis, though further testing is required.

Relevant Publication: McDermid et al., in prep

KEY OUTCOME 3

BERA models predict density and growth rates of trees on seismic lines.

Even when trees establish on seismic lines, there is evidence that different characteristics of seismic lines affect their growth rates. Here we predict, in a spatially-explicit manner, the density and growth rates of trees on seismic lines within the Lower Athabasca region using site factors to model tree abundance and recovery dynamics.

Why it is important: This outcome will provide government and industry a set of models, maps, and tools to quickly and easily assess locations in northeastern Alberta where leave-for-natural regeneration strategies are suitable and where reclamation efforts are most needed.

Implications: Trajectory maps and models can be used to prioritize future seismic line restoration efforts.

Relevant Publications: Filicetti and Nielsen, 2020.

KEY OUTCOME 4

Mounding promotes tree regeneration on seismic lines.

Comparisons of treated lines (approximately four years post-mounding and planting) to untreated lines (22 years post-disturbance) in peatlands demonstrated that mounding increased tree densities over untreated lines by a factor of 1.6 times, but there is still high uncertainly in responses to tree survival and growth.

Why it is important: Bog, poor fen, rich fen, and poor mesic peatland had tree regeneration densities on untreated seismic lines averaging (7,680 stems/ha). This suggests that natural regeneration is ongoing at most peatland sites, although tree growth may be limited by site factors and thus ameliorated with mounding. Increased tree densities (12,290 stems/ha) were observed on treated lines in bog, rich fen, and poor mesic sites, but not significantly in poor fens suggesting this ecosite isn't responsive to boosting tree density with current restoration practices. As tree densities on treated lines were much higher than planting densities, the observed increases in tree recruitment can be attributed to structural changes in the line's topography (mounding).

Implications: In peatlands (except poor fens) mounding can increase tree density.

Relevant Publications: Filicetti et al., 2019

KEY OUTCOME 5

Soil disturbance on seismic lines leads to compaction, wetter conditions and organic matter loss.

Seismic line disturbances resulted in a significant increase in bulk density and soil moisture on the line at both ecosites. We found an almost 40% reduction in organic matter on the line compared to natural areas at the poor mesic site, implying changes to carbon cycling, increased mineralization rates and carbon loss from the system. There was also δ13C and δ15N enrichment and narrower C:N ratios on the line, indicating increased decomposition state. We also found evidence of increased decomposition state on the mounds created after restoration at the treed fen.

Why it is important: The large reduction in organic matter found in poor mesic sites has major implications for carbon cycling across these sites, indicating increased rates of mineralization. The mounding technique used for restoration of these lines also causes some disturbance to soil properties through increased decomposition and higher bulk density.

Implications: it has to be questioned whether mounding these lines is a trade-off between disturbing the landscape to encourage tree regeneration and enhancing organic matter decomposition leading to increased carbon losses from the system, at least in the short term. As mounding has been successfully used to improve tree regeneration in other ecosite types, future work should involve investigating alternative mounding techniques to ensure both tree recovery and minimal impact to the ground layer vegetation in wetland systems.

Relevant Publications: Davidson et al., 2020.

KEY OUTCOME 6

Mounding alters physical and chemical properties in soils that may affect long-term tree establishment.

The objective of mounding is to change soil physical and chemical properties to improve tree growth. Although mounds may serve to create drier microsites for trees, current mounding technique – inverting the soil profile – may decrease soil quality by exposing older, more decomposed peat.

Why it is important: It is important to understand the implications of restoration to better adapt restoration methods to promote tree growth over other species. Without proper establishment of black spruce and other tree species, mounding will not be fully successful in restoring seismic lines.

Implications: Although mounding is already tailored to the recovery of trees, changes may be needed to support long-term tree establishment and survival. Further research will be required to fully understand how local soil property change caused by mounding treatments affect growth of key species, especially to identify situations when tree planting is necessary.

Relevant Publications: Kleinke et al., 2021.

KEY OUTCOME 7

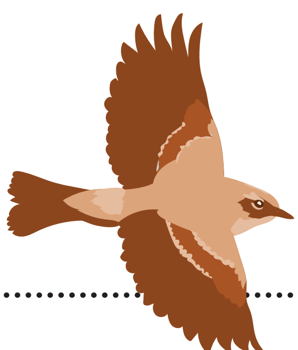
Fire promotes tree regeneration in lowlands and uplands.

Wildfires facilitate and speed tree recovery on seismic lines across both lowland and upland ecosites with most ecosites averaging tree regeneration densities of at least twice the rate of unburned lines.

Why it is important: Since the fire return interval in Alberta's boreal forest is quite high, seismic lines that haven't burned will burn at some point in the next number of decades. Natural recovery (passive restoration) is expected post-fire.

Implications: Active restoration practices may not be needed for places that do not require immediate conservation actions (e.g., caribou recovery), although existing inhibitory factors, such as loss of microtopography, may affect other traits like tree height and growth.

Relevant Publications: Filicetti and Nielsen, 2018; Filicetti and Nielsen, 2020; Filicetti and Nielsen, 2021.



KEY OUTCOME 8

Multi-source remote sensing improves bird-habitat models.

We evaluated different types of spatial data (AVI, satellite imagery, LiDAR) as well as drone imagery influence our ability predict bird use and bird abundance on disturbed sites in the boreal forest. For most analyzed species, composite models drawing on multi-source data worked better. Drone imagery provides an excellent way to provide the high-resolution vegetation imagery to link to high resolution bird use data.

Why it is important: There are pros and cons to every type of spatial data set out there, and researchers and managers constantly question their relative values. More accurate habitat model allows us to make much better predictions on the size of bird populations and more detailed understanding of their behavior near energy footprints. Our work shows all three types of data to be complementary, with LiDAR being perhaps the most important. Drone imagery was also very effective at showing why birds used some wellpads more than others.

Implications: To effectively assess the overall state of the oilsands region for birds, a regular and standardized collection of LiDAR is needed. Drone imagery can be very useful complement in some situations.

Relevant Publications: Wilson et al. 2020; Leston et al., in prep.

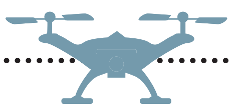
KEY OUTCOME 9

Autonomous Recording Units (ARUs) decrease costs of determining if wildlife view energy disturbances as recovered.

Why it is important: To understand how wildlife respond to natural regeneration and reclamation of energy sector footprint requires we measure where individuals spend time and accurately estimate density. Autonomous Recording Units allow a non-invasive and much more precise measurement of density and habitat use by birds than what was previously possible. The digital record provided by ARUs and our data management system WildTrax mean that data can be shared among agencies to facilitate better environmental decision making through data sharing.

Implications: In aspen forest, ARUs have been used to show that forest specialists are starting to use energy footprints as vegetation recovers. Such information is crucial for being able to ensure the functional habitat quality is maintained for species and is pivotal when assessing if threshold levels of quality habitat remain available as development proceeds.

Relevant Publications: Wilson and Bayne, 2018; Wilson and Bayne, 2019; Hedley et al., 2020.



KEY OUTCOME 10

Drones have emerged as a powerful complement to traditional field work and can be trusted to perform a variety of vegetation-mensuration tasks.

Why it is important: If the vegetation target is large enough (approximately 30 cm seems to be the lower limit) and distinct enough (we prefer the shoulder seasons where living targets stand out on senesced backgrounds) then significant efficiencies and cost-savings can be achieved. Environmental conditions and Transport Canada regulations remain the largest considerations for drone operations.

Implications: Drones can reduce (not replace) the need for field surveys of vegetation, leading to cheaper/faster ground operations. Detection, count, and measurement of trees, saplings, and larger seedlings are currently feasible and can likely proceed under operational conditions.

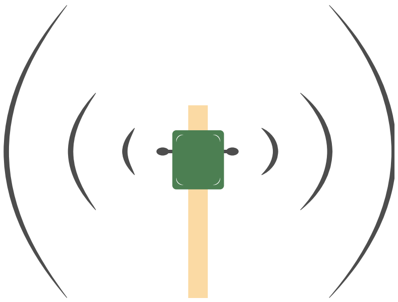
Relevant Publications: Ahmed et al., 2017; Chen et al., 2017; Franklin et al., 2017; Franklin et al., 2017; Hird et al., 2017; Williams et al., 2017; Feduck et al., 2018; Franklin et al., 2018; Castilla et al., 2020

KEY OUTCOME 11

ARUs, industrial, noise and bird response

While there is often focus on how energy footprint influences wildlife, there is also evidence that noise, light, and human activity at energy sites may cause functional habitat change (i.e. create edge effects). A key challenge has been finding cost-effective ways to measure noise pollution and the magnitude of its effects on birds.

Why it is important: If the habitat around noisy sites is reduced in quality the effect of energy sector may be considerably larger than we expect. Noise can travel many kilometres into the forest in some situations. Past work on this



topic did not accurately estimate noise level and our new approach provides a repeatable and consistent way of measuring noise level.

Implications: As we develop more effective ways of measuring noise levels we can create noise thresholds that have an impact on birds. With this information we can assess the level of investment in noise suppression technologies or design that may be used to improve habitat quality for birds.

Relevant Publications: Sanchez and Bayne, in prep.: Hedley and Bayne, in prep.

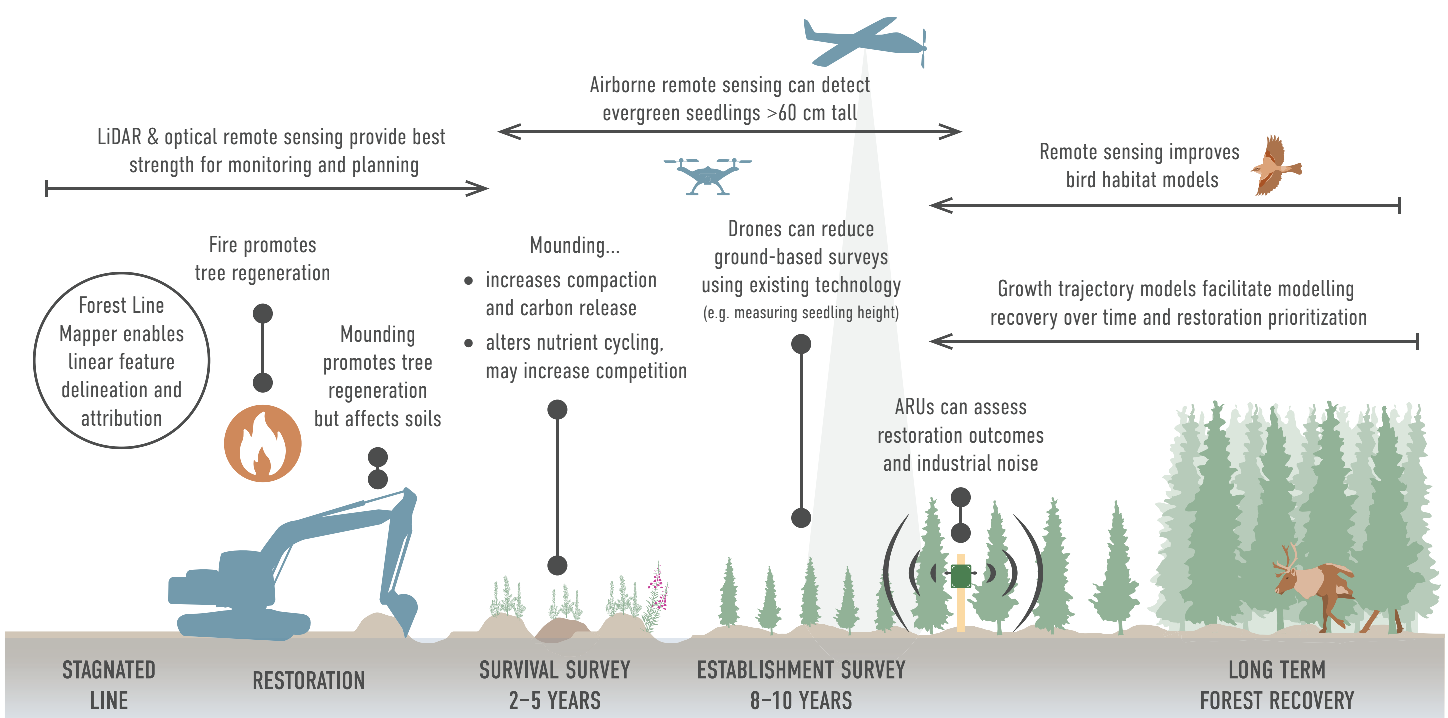
KEY OUTCOME 12

LiDAR and optical remote sensing are essential and complementary datasets for forest monitoring and restoration.

Why it is important: Light detection and ranging (LiDAR) is the de-facto standard for measuring three-dimensional (3D) terrain and forest structure, but digital aerial photogrammetry (DAP) from optical data has emerged as a viable and economical alternative. Our assessments show that the two technologies remain complementary. Optical data are the best source for land-cover mapping and change detection, but DAP's sensitivity to occlusions and mismatched tie points make it a poor alternative to LiDAR for most detailed 3D mapping.

Implications: Accurate characterization of vegetation and surface terrain are necessary for a host of workflows associated with forest monitoring and restoration planning. LiDAR and optical datasets are complementary and essential, even in a cost-constrained environment. We recommend continued investment in both.

Relevant Publications: Rahman et al., 2017; Dietmaier et al., 2019; Lopez-Queiroz et al., 2019; Lopez-Queiroz et al., 2020; Losada, in prep.



BERA 2: Deepening the focus on topics of relevance to restoration and ecosystem recovery

Following the successful completion of BERA 1 in 2021, our partners and research team have created BERA 2. This second phase will provide an additional five years of research funding, enabling us to continue our work building knowledge and planning tools to assist restoration efforts in the boreal forest.

Our central goal is to understand the effects of industrial disturbance on natural ecosystem dynamics, and to develop strategies for restoring disturbed landscapes in a system that is under pressure from climate change. Our work is driven by four strategic management goals associated with seismic lines and other types of industrial disturbance:

1. Promoting a return to forest cover
2. Restoring natural carbon dynamics
3. Maintaining wildlife habitat
4. Enhancing woodland caribou habitat

The research is designed to provide knowledge and planning tools for researchers and resource managers engaged in boreal restoration, and to train the next generation of highly qualified personnel working in this space.

While our work is conducted in the context of Alberta's boreal forest, the findings and deliverables are anticipated to be transferable to other ecosystems in Canada and beyond.

BERA Strategic Goals:

- ✔ Promote return to forest cover
- ✔ Restore natural carbon dynamics
- ✔ Maintain wildlife habitat
- ✔ Enhance caribou habitat