2024

The Edge

Pushing the Limits of Restoration Research

Boreal Ecosystem Recovery & Assessment

Acknowledgements

The Boreal Ecosystem Recovery and Assessment (BERA) project is a multi-sectoral research partnership of academic institutions, private-sector companies, two public-sector divisions, and a not-for-profit organization. BERA is funded by an Alliance Grant from the Natural Sciences and Engineering Research Council of Canada. Our program is administered by the University of Calgary, and jointly housed at the University of Calgary, University of Waterloo, University of Alberta, and Athabasca University. Thanks to the ongoing support of this diverse partnership, we continue to grow our knowledge of the effects of industrial disturbance and work towards solutions.

University partners:

Private-sector, public-sector, and not-for-profit partners:

About the BERA Program

The central goal of the Boreal Ecosystem Recovery and Assessment (BERA) program is to understand the effects of industrial disturbance on natural ecosystem dynamics, and to develop strategies for restoring disturbed landscapes. BERA's research supports six strategic management goals associated with industrial disturbance:

- Promoting a return to forest cover
- Restoring natural carbon dynamics
- Maintaining wildlife habitat
- Enhancing woodland caribou habitat
- Remote monitoring
- Remote assessement

Practitioners involved in boreal restoration are interested in maximizing effectiveness and efficiency. BERA conducts research on every phase of restoration — planning, implementation, and monitoring — to provide practitioners with the key knowledge, tools, and techniques they need to enhance understanding and improve outcomes of restoration activities.

The 2024 issue of The Edge summarizes the following key findings:

pg.3 Plan

- A better understanding of passive recovery trajectories will help guide restoration planning
- LiDAR is a powerful planning tool
- Seismic lines alter carbon dynamics in boreal peatlands
- Seismic lines create browse subsidies for ungulates in certain ecosites
- Additional disturbances can 'erase' seismic lines in some ecosite types
- Context matters: fragmentation analysis can greatly increase restoration efficiency

pg.9 Implement

- Inverted mounds promote tree growth, but emerging techniques provide opportunities for continual improvement

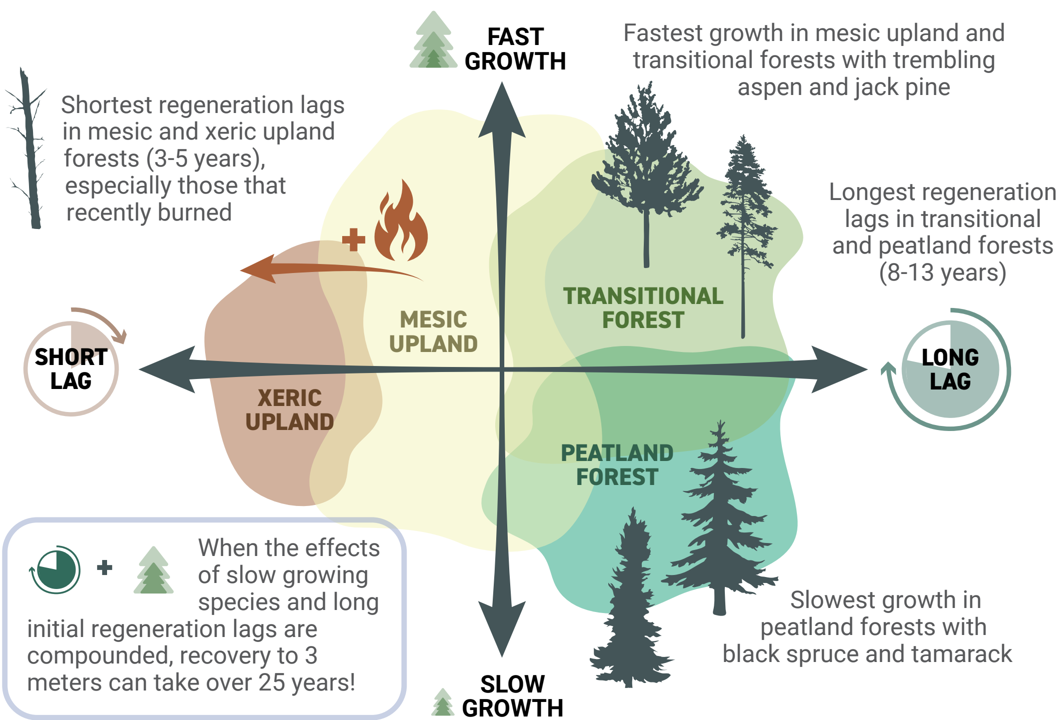
pg.10 Monitor

- Species communities shift as linear feature widths increase
- Some birds adapt their vocalization patterns to deal with industrial noise
- LiDAR and Landsat data together provide a better way to predict bird responses to harvest
- Artificial Intelligence is changing the way we detect and measure seedlings

Plan

A better understanding of passive recovery trajectories will help guide restoration planning

Knowledge: Understanding when and where forests will recover on their own is key to planning restoration initiatives. There are two key variables required to better understand the role of passive recovery: (i) determining the time it takes for trees to start growing after a disturbance (regeneration lag) and (ii) predicting how quickly trees will grow once they are established. Sites with both short lags and tree species that grow quickly will likely be good candidates for passive recovery.



Why is it important? Many different variables including initial conditions of the disturbance, the status of recovery, the ecosite type and moisture conditions the disturbance is in, and tree species all affect patterns of passive recovery. Actively treating seismic lines is a huge effort. Restoration strategies that consider how different variables affect passive recovery trajectories will help practitioners better manage limited restoration resources.

What was found? Between 2016 and 2022, BERA researchers sampled naturally regenerating trees on seismic lines across different ecosites. They determined that seismic lines in certain ecosites, like boreal upland forests, can often be left to recover on their own, especially if re-disturbance is limited or regeneration is stimulated by wildfire. In contrast, many peatland and transitional forests are more likely to have both slow growing species and long initial regeneration lags.

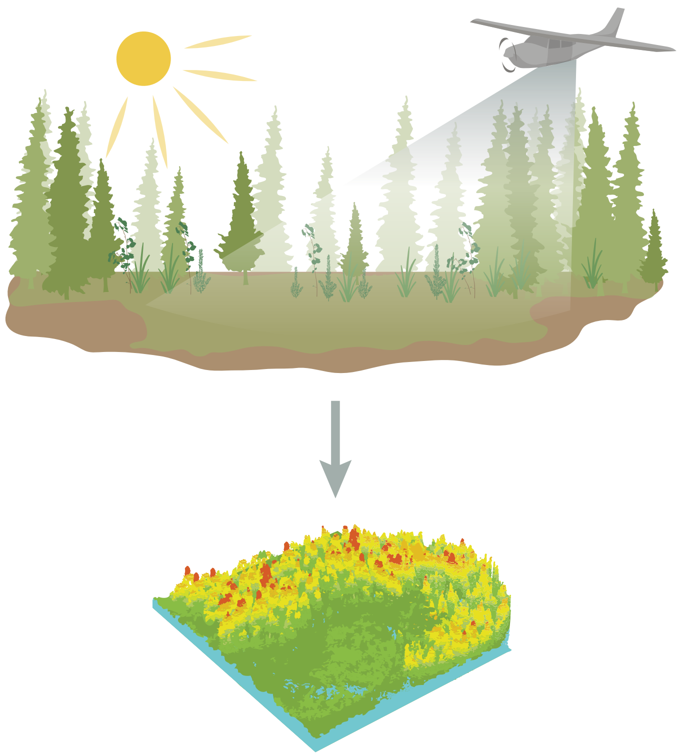
What's next? This work provides the foundational knowledge that will be used to help guide restoration planning. Knowing when to leave disturbances to recovery naturally not only helps prevent wasting resources but is also less invasive to recovering ecosystems. Future research will focus on mapping recovery trajectories across time and space. This will help managers determine where active treatments may be needed.

Relevant Publication: Sutheimer et al., In review

Plan

LiDAR is a powerful planning tool

Tool: LiDAR is a versatile three-dimensional data source that can be used by practitioners for a variety of applications. The power of LiDAR-based tools comes from their ability to reduce the need for costly and labour-intensive field surveys. Recent BERA research shows the utility of LiDAR to create maps of understory vegetation structure, surface microtopography and solar irradiance (light availability).



Why is it important? Accurate information essential for forest management and restoration. Many forest maps are readily available but information on understory vegetation and solar irradiance are rarely included. Understory vegetation plays a key role in forest ecological processes including nutrient cycling, forest succession/regeneration, fire regimes, wildlife movement, and carbon dynamics. Light availability constrains tree growth and can be used to identify if seismic lines have suitable light conditions for specific species. Irradiance maps could help practitioners make restoration plans with a higher probability of seedling survival.

What was found? Tools that map solar irradiance were created using a model that validated LiDAR data against a network of in-situ measurements. Tools for mapping understory vegetation structure were created using a combination of field and LiDAR observations for five understory structural attributes: understory mean height, percent understory cover, understory density, understory complexity, and understory volume.

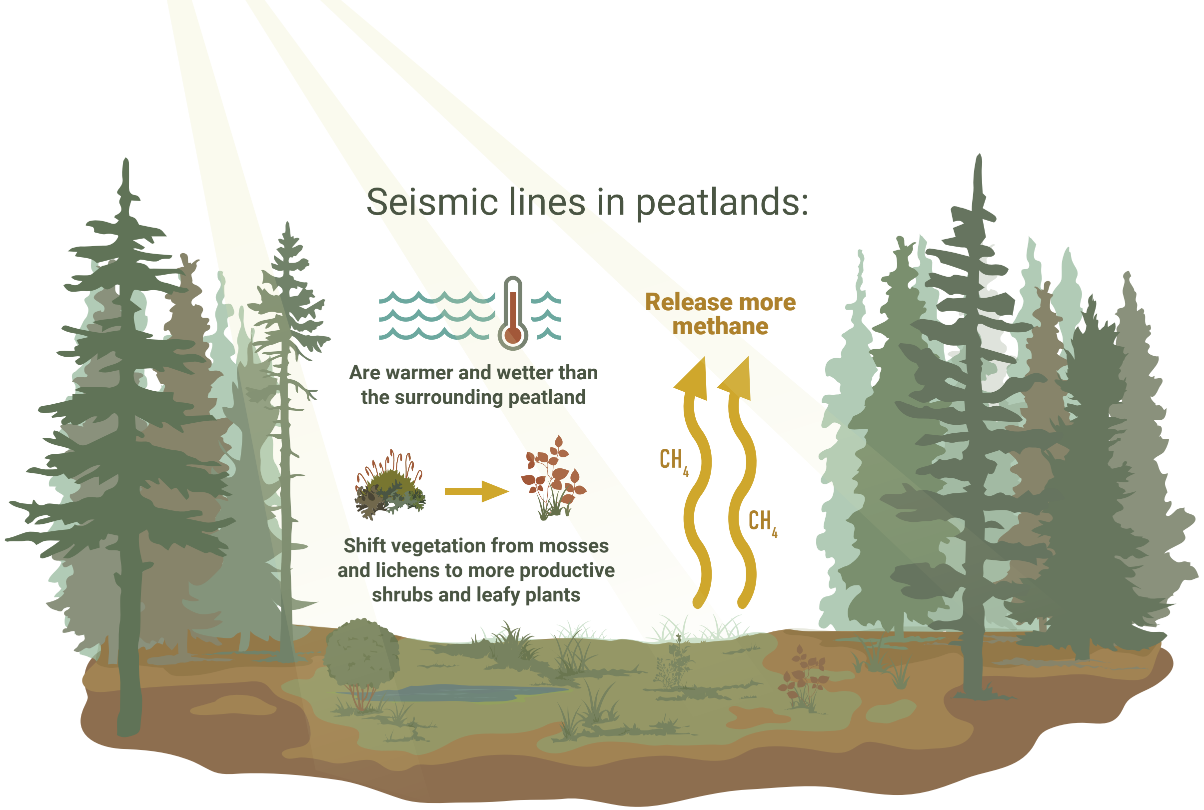
What's next? These workflows are in the first stages of research and development and require further refinement before being made available to practitioners. Currently, the solar irradiance model maps detailed patterns of light availability based on forest structure and seismic lines but still needs to be transformed into software. LiDAR-derived measures of forest understory structure are largely ready for operational deployment under many boreal conditions but need to account for minor biases present between LiDAR and ground truth measurements. Both methods still need to be tested and proven across various ecosystem types.

Relevant Publications: Losada, 2021 (M.Sc. Thesis); Hegels et al., In prep

Plan

Seismic lines alter carbon dynamics in boreal peatlands

Knowledge: In some boreal peatlands, seismic line disturbances can compress the soil and cause wetter conditions, limit tree recovery, shift vegetation communities, and alter microclimatic conditions. These changes increase CH_4 emissions, alter potential peat accumulation rates, and influence long-term carbon storage.



Why is it important? Peatlands store about one third of the world's soil carbon and play a key role in the regulation of greenhouse gases. Peatlands also account for 5-10% of global methane emissions, which are produced when organic matter decomposes without oxygen. Additionally, altered soil properties and local hydrological conditions drive wetter conditions on lines, which enhances methane release. The management of peatlands has been highlighted as an important nature-based climate solution.

What was found? Researchers found that seismic lines in boreal peatlands show an increase in methane release, a shift to warmer and wetter conditions, including greater snow accumulation and a shift in vegetation communities from mosses and lichens to shrubs and leafy plants. These changes are altering peat accumulation rates and long-term carbon storage in boreal peatlands. In addition to altering carbon cycling, the loss of microsites, altered soil properties and saturated conditions can limit the return to forest cover.

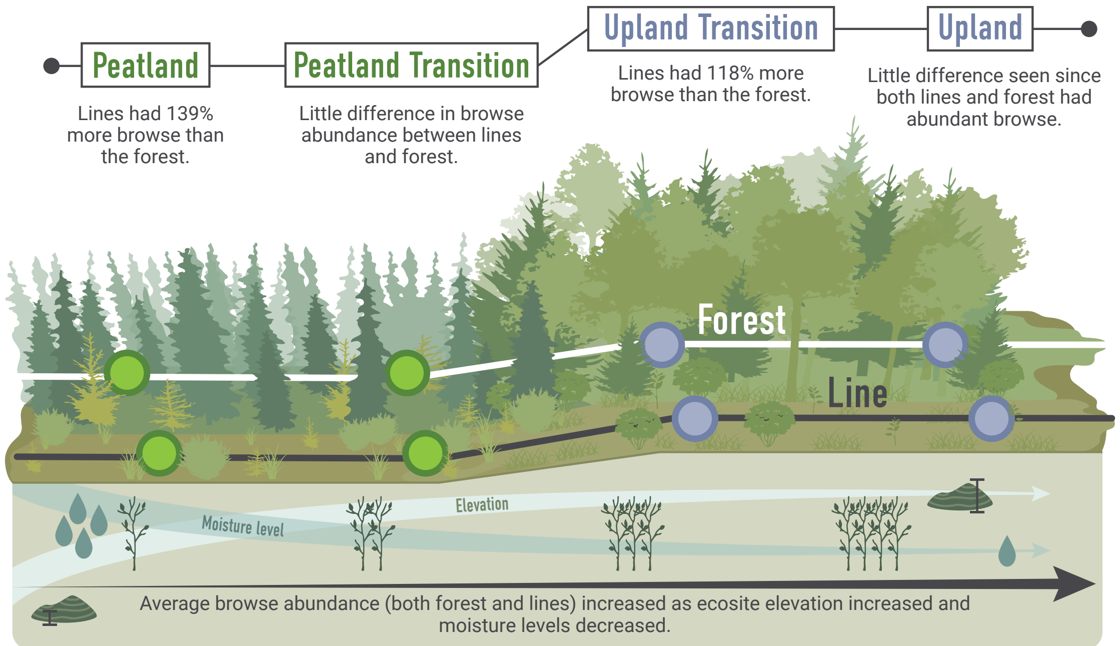
What's next? Understanding how disturbances affect the carbon balance and hydrologic conditions within peatlands is foundational to improving future land management policies related to disturbance and restoration of peatlands. This knowledge will contribute to accurate greenhouse gas (GHG) reporting for disturbances in boreal peatlands and provide a foundation for designing and setting better restoration targets in boreal peatlands. Since peat accumulation is such a complex and long-term process, future studies need to be conducted over longer time scales.

Relevant Publications:
Bayatvarkeshi et al., Submitted; Korsah et al., In prep; Weiland et al., In prep

Plan

Seismic lines create browse subsidies for ungulates in certain ecosites

Knowledge: Seismic lines can create browse subsidies (increased food abundance) for moose and deer in some ecosites. BERA researchers showed that the amount of browse did not differ between seismic lines and adjacent upland forests but doubled in peatland forests and in transitional upland-peatland sites. Researchers found evidence for browse subsidies in peatland interior, peatland transition, and upland transition sites, with 139%, 127%, and 118% increases in browse abundance, respectively.



Why is it important? Forest disturbances like seismic lines remove mature trees and promote the growth of deciduous shrubs. Moose and deer rely on shrub species (browse vegetation) for food, particularly in the winter. High populations of deer and moose negatively affect at-risk woodland caribou populations, so it is important to know if seismic lines are changing the amount of food available for moose and deer and whether this alters their browsing habits.

What was found? Differences in winter browse abundance between seismic lines and the adjacent forest were compared for different ecosites. Generally, both browse availability and use were higher on seismic lines. Although moose and deer seemed to select seismic lines more often for browsing, the increase in browse use remained proportional to the increase in abundance. In addition, average browse abundance (both forest and lines) increased as ecosite elevation increased and moisture levels decreased.

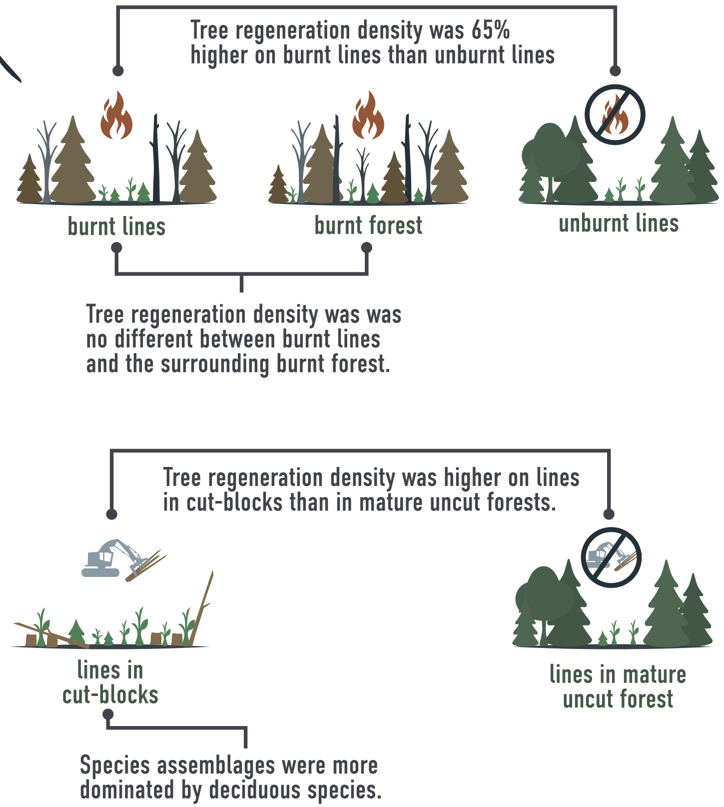
What's next? Managing deer and moose distribution and behaviour is a conservation challenge that has implications for caribou habitat and recovery. Practitioners can use this knowledge to inform seismic line restoration planning and prioritize caribou recovery actions where browse subsidies are strongest.

Relevant Publication: Quayle and Nielsen, In prep

Plan

Additional disturbances can ‘erase’ seismic lines in some ecosite types

Knowledge: Seismic lines are one of the largest contributors to forest fragmentation in the boreal and negatively affect caribou populations. When wildfire and forest harvest blocks are layered on top of seismic lines, the initial disturbances are largely ‘erased’, being replaced by the most recent disturbance.



Why is it important? Understanding that disturbances tend to ‘erase’ each other in some ecosite types rather than accumulate is important. Different disturbance types have different landscape effects, and some types are easier to restore than others. For example, trees regenerate more quickly within cut-blocks or burned areas than they do on seismic lines. Moreover, controlling recreational access can become easier in these other disturbance types, further accelerating restoration.

What was found? Over multiple projects, BERA researchers have investigated two disturbance types — wildfire and forest harvest — overlaid onto seismic lines in the mesic upland forest ecosite. They determined that wildfires improve natural tree regrowth on seismic lines (the same results found for treed peatlands and jack pine forests in previous studies). Tree regeneration density on burnt seismic lines was 65% higher than unburnt lines for mesic upland forests, no different than the surrounding burnt forests. Tree regeneration data for legacy seismic lines located within cut-blocks showed 95% of the lines within cut-blocks reached Provincial density targets compared to only 65% of lines in the mature uncut forest. Although harvesting practices effectively ‘erased’ the seismic lines, the species assemblage became more dominated by deciduous species suggesting a greater reset of succession.

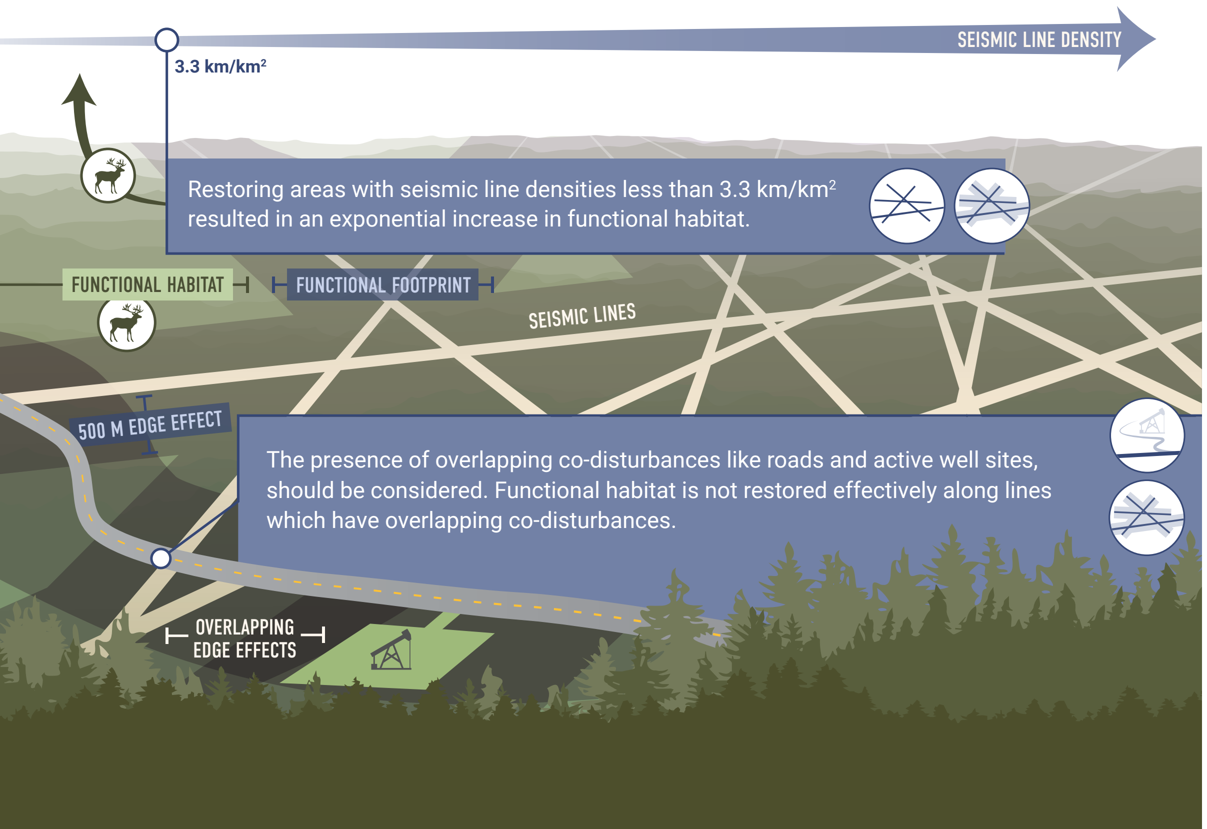
What’s next? Although re-disturbing the landscape with the intent to restore should not be a primary tactic, this knowledge can help practitioners better allocate restoration resources. Landscapes that will be harvested or those with a high wildfire risk can be deprioritized, allowing restoration efforts to be concentrated where they will have the largest effect.

Relevant Publications: Filicetti and Nielsen, 2022; Viliani and Nielsen, In prep

Plan

Context matters: analysis of changes to fragmentation can greatly increase restoration efficiency

Knowledge: Not all seismic line restoration efforts influence recovering caribou habitat to the same extent. Prioritizing the right sites for restoration can maximize positive effects for caribou and other wildlife while also maximizing cost-effectiveness.



Why is it important? Fragmented habitats are negatively impacting caribou populations. Seismic line restoration can help restore these habitats but is expensive and time consuming. A restoration-planning approach that prioritizes restoring seismic lines where caribou habitat will be most efficiently defragmented can help ensure that resources have the greatest positive effect.

What was found? BERA researchers compared caribou habitat change in unrestored and fully restored landscapes in a model environment to demonstrate the most efficient restoration approach for maximizing caribou habitat recovery. Edge effects, line density, line configuration, and overlapping disturbances are key landscape factors that should be taken into consideration when choosing sites to restore. This approach can improve the cost-effectiveness of restoration efforts by 25-fold.

What's next? Seismic line configuration and the spatial context of other disturbances in the surrounding landscape should be considered in restoration planning and management plans. Using this initial framework, BERA researchers will be able to develop simple visual tools that will show where future conservation actions will be most cost-effective.

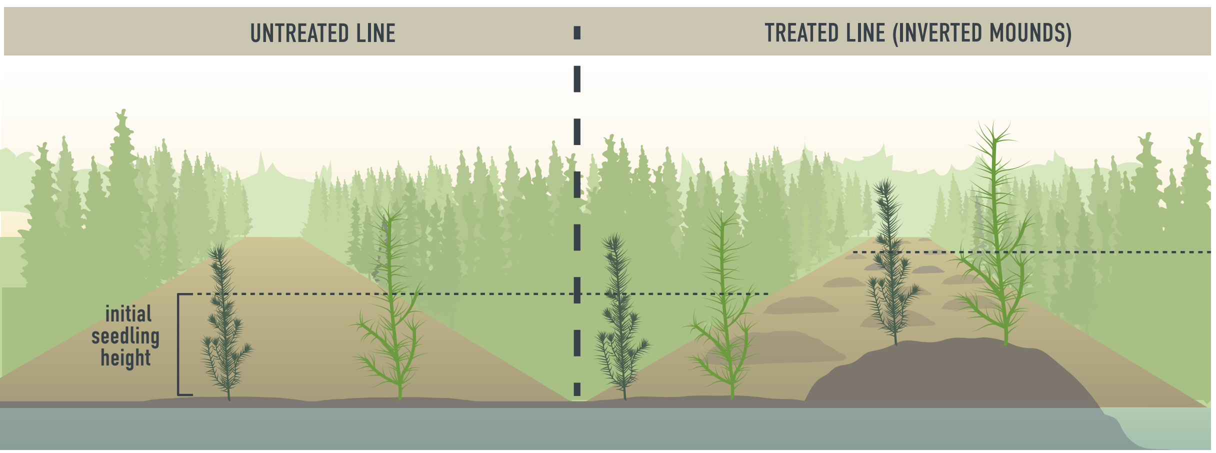
Relevant Publication: Viliani et al., In review

Implement

Inverted mounds promote tree growth, but emerging techniques provide opportunities for continual improvement

Knowledge: Selecting which mounding techniques work best in peatlands depends on the goals of restoration. Currently, inverted mounding treatments are supported by the most comprehensive research regarding tree growth, but emerging research into other novel mounding techniques may provide opportunities for continual improvement that better preserve natural peatland functions.

Overall, **inverted mounding and tree planting improved early seedling growth** for black spruce and tamarack in fens.



Why is it important? Many different mounding techniques can be used to create the microsites trees need to grow but not all these methods have been rigorously tested. A key BERA study tested the effectiveness of inverted mounding on seedling growth — a necessity for habitat restoration and caribou recovery. However, it is important to keep in mind that inverted mounds have both positive and negative effects, and influence complex ecosystem components like plant communities, soil function, and hydrology. Our understanding of different mounding techniques on these components and the trade-offs involved is still evolving.

What was found? In fens, inverted mounding and tree planting can accelerate the growth of seedlings like black spruce and tamarack. Seedling growth depended on species, ecosite, initial seedling size, and light availability. Therefore, site-specific prioritization of mounding may prove more efficient than generic restoration plans. Current restoration objectives are largely focused on tree recovery to address the immediate caribou habitat threats, but the importance of other peatland functions should not be overlooked. Since inverted mounding flips the peat layers, it can set back recovery of bryophyte communities among other impacts. If restoring peatland function is a main goal of restoration, other mounding techniques may be able to provide the same benefits as inverted mounding while limiting disturbance.

What's next? The ideal mounding technique would promote tree growth while also limiting disturbance to other peatland functions. BERA researchers will continue to investigate and compare inverted and non-traditional mounding techniques to find the most effective recovery methods for practitioners.

Relevant Publications: Shellian et al, 2024; Echiverri et al., 2020; Echiverri et al., 2023; Fliesser, 2023 (M.Sc. Thesis); Goud et al., In prep

Monitor

Species communities shift as linear feature widths increase

Knowledge: The width of linear features is a key variable that alters communities of birds and small mammals. Many species are tolerant of linear disturbances up to a certain width threshold. Above this threshold, species communities start to shift, attracting birds who prefer shrub-based and early seral habitats.

Why is it important? This knowledge will help practitioners determine which line widths have the lowest effect on wildlife communities and better predict the response curves of animal communities across space. It will also help identify which line widths should be prioritized for restoration and which could be left to regenerate naturally. In addition, small mammals can alter forest regeneration patters through seed and seedling predation. Knowing the conditions these species prefer can help practitioners anticipate risks and plan accordingly.

What was found? Camera trap data revealed small mammal communities change as linear features get wider. Forest habitat species, like the southern red-backed vole or the red squirrel, tolerate narrow linear features up to 10 meters and progressively abandon lines as they become wider. These species are almost entirely absent for lines > 100 m wide. Species adapted to more open habitats, such as the eastern meadow vole and the western jumping mouse, become predominant when linear features are > 80 m wide.

Autonomous recording units are used to monitor bird communities. Data from linear features has shown that these disturbances alter the composition of bird communities, increasing species richness and diversity. Wider linear features attract more shrub-associated and early seral birds.

What's next? It is important to determine which species are positively or negatively affected by different linear feature widths. Since line width is a key variable for predicting wildlife response, restoration activities should categorize linear features by width rather than function. In addition, converting wide linear features into narrow ones could help limit impacts to wildlife for lines that are still being used.

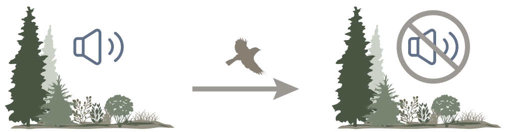
Relevant Publications: Kalukapuge and Bayne, In press; Franceschini and Bayne, In prep

Monitor

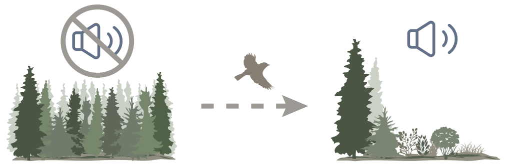
Some birds adapt their vocalization patterns to deal with industrial noise

Knowledge: Some birds, like the Lincoln's sparrow prefer the more open habitats created by industrial activities. To live in these noisy areas, though, they need to change the ways they communicate.

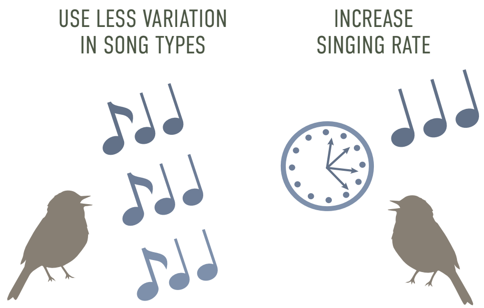
In areas with similar levels of vegetation disturbance, Lincoln's sparrows were less likely to occupy those with greater noise.



Lincoln's Sparrows prefers to breed in open areas with small shrubs and are likely to tolerate living in areas with certain levels of noise if the habitat vegetation conditions are ideal.



The chronic noise generated by compressor stations affected the vocal features of Lincoln's Sparrow songs. Males breeding in noisy areas were found to:



Why is it important? Industry disturbances alter vegetation communities, which are known to shift bird-species compositions. However, many industrial disturbances involve other components such as light or noise pollution that should be investigated as well. It is important to consider the full range of habitat requirements of a species when determining how they are affected because they can create additional edge effects.

What was done? Noise from industrial disturbances is altering songbird communities in the boreal. Research into the Lincoln's sparrow has shown that this bird prefers the open and edge habitats often created by industrial activities. The sparrow is more likely to occupy quiet areas with open vegetation rather than noisy ones with similar levels of vegetation disturbance. However, they are likely to tolerate living in areas with certain levels of noise if the habitat vegetation conditions are ideal. But to live in these noisy areas, the birds need to adapt the ways they communicate. The chronic noise generated by compressor stations affected the vocal features of Lincoln's sparrow songs. Males breeding in noisy areas were found to sing a more consistent song type and increase their singing rate.

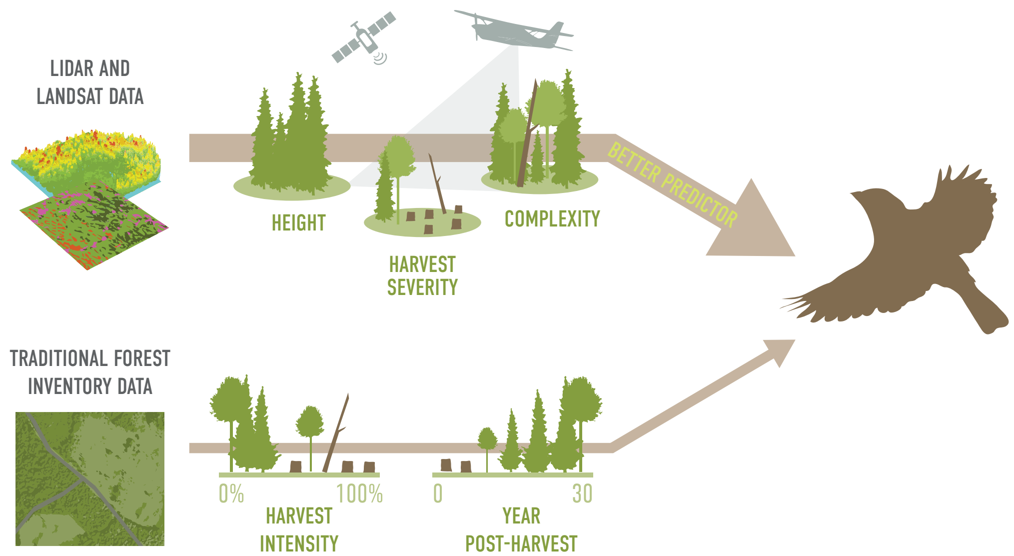
What's next? Singing more frequently requires more energy and may only be effective over short distances. Since long distance communication is needed to attract females, sparrows in noisy areas may need to move around more. This could lead to greater exposure to predators and less time spent foraging. Further investigation is required to understand the full effects of noise on Lincoln's sparrow populations. BERA is currently evaluating other sources of noise like OHV, traffic, and industrial equipment impact birds.

Relevant Publication: Sánchez et al., 2022a

Monitor

LiDAR and Landsat data together provide a better way to predict bird responses to harvest

Technique: Using a combination of LiDAR and Landsat data rather than relying only on traditional forest inventory data helps improve predictions of bird responses to forest harvest.



Why is it important? To conserve federally listed species, wildlife managers need to understand when habitat conditions are contributing to species declines. Although the most accurate methods of predicting bird response to harvest involve detailed ground-based surveys, these are difficult and costly to implement over large areas. Using remote sensing technology makes it easier to get this information, but often comes at the cost of accuracy. Traditional forest inventory data obtained through aerial photography does not capture all the habitat features that are important for determining bird responses to harvest.

What was done? BERA researchers compared how well traditional forest inventory data, airborne LiDAR, and Landsat imagery predict bird responses to harvest patterns in boreal forests. They determined that the height, complexity, and that harvest severity measures obtained from LiDAR and Landsat data together improved predictions compared to traditional forest inventory data.

What's next? This technique is being refined. Since LiDAR data and bird surveys are rarely taken at the exact same time, vegetation can change during this time difference. Finding ways to determine the effect of these temporal misalignments is important to maximize predictive power and ensure that models are robust. Novel remote sensing products, cloud-based computing platforms like Google Earth Engine, and long-term bird monitoring data will continue to provide opportunities to improve models of species-habitat relationships and apply them over large areas.

Relevant Publications: Casey and Bayne, 2024, In review

Monitor

Artificial Intelligence is changing the way we detect and measure seedlings

Tool: AI interpretation of LiDAR and optical imagery obtained from drones is transforming the way we detect and monitor seedlings on industrial disturbances. Preliminary results from a variety of studies are showing promising that may pave the way for performing remote establishment surveys.

Why is it important? Boots-on-the-ground field surveys to count seedlings and perform stocking assessments are costly and labour intensive. Many different tools and technologies are being tested to determine the best way to detect and measure seedlings remotely. BERA researchers are prioritizing accuracy, feasibility, and affordability in their exploration of new tool to bring to practitioners.

What was done? AI based strategies for detecting seedling and measuring their properties show promising results. Accuracy tends to vary based on tree species, seasonal conditions (leaf-on or leaf-off), and vegetation density or overlap.

- Currently, deep learning models can detect 90% of visible seedlings, with the best accuracy for seedlings over 90 cm. For this technique, conifer detection is best in leaf-off conditions, but tamarack seedlings are more difficult to detect.
- High-density point clouds from LiDAR or photogrammetry can measure individual tree heights with reasonable accuracy. For conifers, leaf-on vs leaf-off conditions does not greatly affect accuracy, but leaf-on conditions are best for deciduous species.
- AI models have a 10% error rate for the detection of 90+ cm saplings. Accuracy is influenced by the biases in human visual interpretation used to train models, image quality, and the presence of dense or overlapping vegetation.

What's next? AI tools are still being developed and tested across diverse ecosystems. Various biases are being worked out and a deeper understanding of the conditions the tools work best under is being developed. Exploration into lower resolution imagery and data is being explored to make it easier to deploy these tools to operational scales.

Relevant Publications: Shellian et al., In prep; Terenteva et al., In prep

BERA — What's next?

Over the past several years, the BERA team of researchers have worked to better understand ecosystem dynamics in Canada's boreal forests and how industrial disturbances can be effectively restored. Thanks to close relationships with on-the-ground practitioners, BERA has contributed several key advancements to support restoration in boreal landscapes. These key findings include:

- **How to maximize cost-efficiency when allocating resources for restoration planning.**
- **Best practices for implementing restoration in peatlands.**
- **The latest tools being used to for establishment monitoring.**

As a multi-sectoral research partnership, BERA will continue to make more tools and features available to practitioners through the continued support from academic, private, public, and non-profit organizations. Many BERA projects are still in the initial stages of acquiring knowledge. As the program matures, this knowledge will be used to develop BERA Tools available to practitioners. For more information on the tools, techniques, and knowledge under development, visit the beraproject.org for contact information and relevant BERA publications.

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