WOODLAND CARIBOU DEPEND ON A FOOD SOURCE THAT TAKES DECADES TO REGROW

Lichen Transplantation Research Brief

Lichens, despite their vital ecological roles, are often ignored and excluded from reclamation projects. Terrestrial lichens, particularly reindeer lichens (*Cladonia* spp.), are a crucial winter food source for caribou and form the basis of entire northern ecosystems. However, restoring these lichen communities faces significant challenges due to habitat disturbance, their naturally slow growth rates (often just a few millimetres per year), and limited natural dispersal abilities. Recent research indicates that artificial dispersal and transplanting lichen fragments are promising methods for restoration. Still, many obstacles remain, such as the complexity of transplantation, feasibility at large scales, substrate selection, and long-term sustainability. Targeted research and innovative strategies are essential to address these knowledge gaps and effectively incorporate lichen restoration into broader ecological recovery efforts, especially in areas vital for caribou conservation.

Key Takeaways

- Restoring terrestrial lichens through transplantation is more than just experimental—it is effective.
- Most lichens were equally successful on all substrates.
- Broadcasting fragments achieves excellent results by hand or by plane, and hydroseeding has been tested with limited success.
- Spring (April-May) and early fall (August-September) represent the most promising periods for lichen transplant.
- Transplanted reindeer lichens in good sites (dry, nutrient-poor, and open) are still thriving after 24 years.

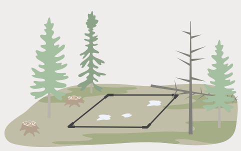
This study aimed to:

- Provide a **comprehensive review of past lichen establishment research**, evaluating their long-term outcomes, methodologies, and lessons for current restoration efforts.
- Investigate how **substrate type and fragment size affect the success of transplanting** familiar boreal terrestrial lichens in a controlled greenhouse environment over 26 months.
- Assess the **influence of terrestrial lichen fragment size on establishment success** across various substrate types in harvested forest areas.
- Examine the potential **effectiveness of hydroseeding lichens** as an innovative strategy to restore harvested forest lands. Hydroseeding helps prevent soil erosion by using a mix of seeds and other materials like fertilizers and tackifiers to stabilize the soil and quickly establish vegetation cover.

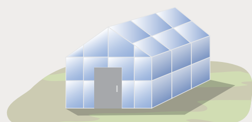
Research Approach and Methodology

Study Design and Data Sources

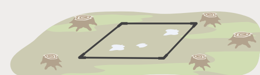
This study integrates data from multiple complementary research approaches:



Historical site reassessments examined lichen transplantation sites established 6-24 years previously, comparing transplanted areas to untreated controls and natural reference sites.



Controlled greenhouse experiments isolated specific variables affecting lichen establishment, including fragment size, substrate type, and species identity.



Field trials tested transplantation under operational conditions under diverse site types, evaluating species-specific survival rates, optimal fragment sizes, and substrate effects in real-world restoration contexts.

Hydroseeding applications assessed the feasibility of mechanized dispersal methods for large-scale implementation, measuring fragment density and survival rates in diverse forestry treatment areas.

Greenhouse Experiments

Assessment Methods and Metrics

- **Lichen health** was assessed using chlorophyll fluorescence, a non-invasive measure of photosynthetic efficiency.
- **Establishment success** was quantified through percentage cover estimates at transplant sites, tracking survival and spread over time. For hydroseeding trials, fragments were counted within quadrats to measure establishment density.
- **Growth** was assessed through fragment length measurements and biomass quantification in greenhouse experiments.

- **Community context** was characterized by determining moisture, nutrient, and other site variables, and recording cover of woody plants, forbs, graminoids, mosses, and lichens, enabling analysis of competitive interactions and site condition effects on establishment.

Geographic and Ecological Context

Research sites spanned boreal forest ecosystems in Alberta and British Columbia, encompassing Upper Foothills and Boreal Forest natural regions. Sites represented diverse disturbance histories (wildfire, harvest), moisture regimes (xeric to mesic), nutrient conditions (poor to medium), and drainage classes (rapid to moderate-well).

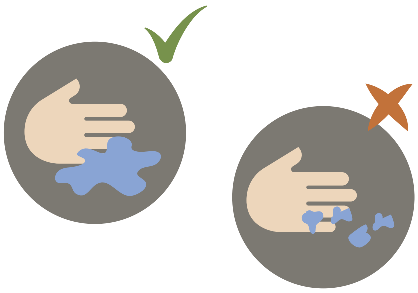
Key Research Questions and Findings

Does terrestrial lichen seeding and/or transplantation have efficacy?

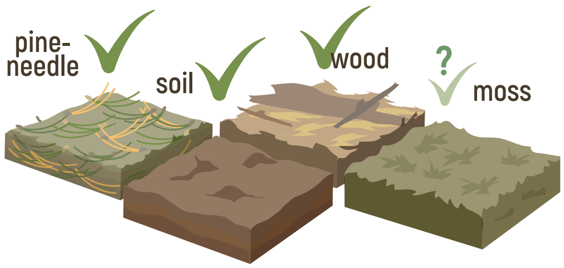
Terrestrial lichen restoration through seeding and transplantation shows measurable success across diverse ecological contexts, although success rates vary with species choice, fragment size, substrate type, and application method.

Long-term monitoring offers strong support for the viability of transplants. A 24-year study in Alberta revealed that hand-transplanted and broadcast reindeer lichens maintained about 30% cover over twenty years, while control plots showed minimal natural growth. An 8-year post-wildfire study in British Columbia found transplanted lichens maintained healthy photosynthetic capacity with a 3.5-4% average cover, whereas control areas mainly remained barren.

Controlled experiments identified key factors for success:



Larger fragments (4-6 cm) had significantly higher survival rates, especially for *C. rangiferina*.



Lichens overall performed well regardless of substrate, easing operational complexity. Higher covers of feather moss, forbs, and dense trees, as well as low, wet areas, reduced success.

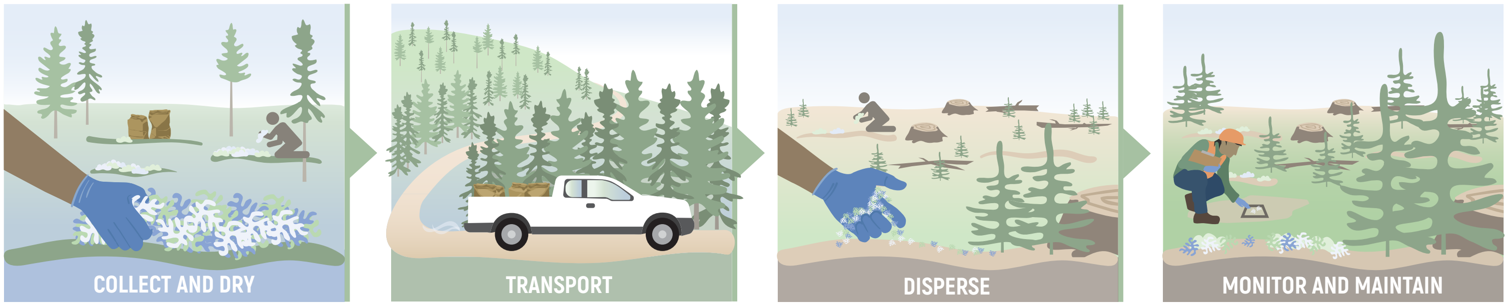
Alberta field trials confirmed practical viability:

- Three-year survival rates ranged from 65% to 70% overall, with species-specific variations from 55.2% to 98.3%.
- Medium-sized fragments (2-4 cm) achieved the highest cover levels (21.9%).
- Hydroseeding was effective at dispersing lichen fragments, and may be an option for large-scale work due to its operational efficiency ($8,500-$10,000 CAD per hectare), but future refinement is recommended to increase lichen survival rates.

What is required to achieve successful lichen growth from seeding or transplantation?

Successful lichen restoration depends on careful management of source material, site conditions, application techniques, and long-term care:

- **Source Material and Site Conditions:** Collect healthy, diverse lichen material from ecologically similar donor sites, using medium- to large-sized fragments (2-6 cm). Select sites with open canopy, good drainage, xeric to mesic moisture regimes, and poor to medium nutrient status where vascular plant competition is minimal. Wood, mineral soil, and pine needle duff are the best substrates, and moss is only slightly less effective.
- **Application and Species Selection:** Apply lichen evenly at up to 14 g/m² during moderate weather with adequate moisture. Prioritize species with proven establishment success: *Cladonia arbuscula* ssp. *mitis, C. rangiferina, C. uncialis*, *C. stellaris*, and *Stereocaulon tomentosum*. Avoid *Cladonia stygia* due to poor transplantation rates.
- **Management and Expectations:** Plant and maintain lower tree densities to allow adequate space and light, and minimize additional site disturbances. Results are immediately seen, but will be more successful on some microsites than others.
- **Appropriate source material:** Healthy, diverse lichen collections from ecologically similar sites, properly stored and processed.



What is the best time to do lichen transplantation?

Optimal timing for lichen transplantation in boreal Alberta and British Columbia balances lichen physiology with practical constraints. While existing studies do not explicitly compare seasons, our analysis suggests spring (April-May) and early fall (August-September) are the most promising.

Spring offers key advantages: lichens emerge from dormancy as temperatures moderate (5-15°C), snowmelt provides establishment moisture, and minimal plant competition maximizes the growing season. However, wet conditions may limit site access.

Early fall (late August-September) is equally compelling: moderate temperatures reduce heat stress, late-summer precipitation provides moisture, declining plant competition aids establishment, and site access is excellent. The 24-year Alberta study's September-October establishment demonstrated exceptional long-term success.

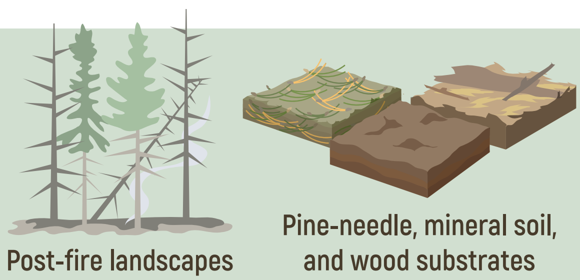
Early to mid-summer (June-July) is more challenging. The hydroseeding study's June application resulted in 72% fragment mortality, though multiple factors contributed. Summer heat, drought stress, and established plant competition create less favorable conditions, though traditional methods achieved good survival, suggesting that the application method may matter more than season.

Winter application is not recommended due to lichen dormancy, logistical challenges, and high fragment loss risk during spring snowmelt.

Recommendation: Prioritize spring (April-May) or early fall (August-September), with fall potentially offering the best combination of physiological conditions and logistical practicality.

Which locations would be most successful for transplantation?

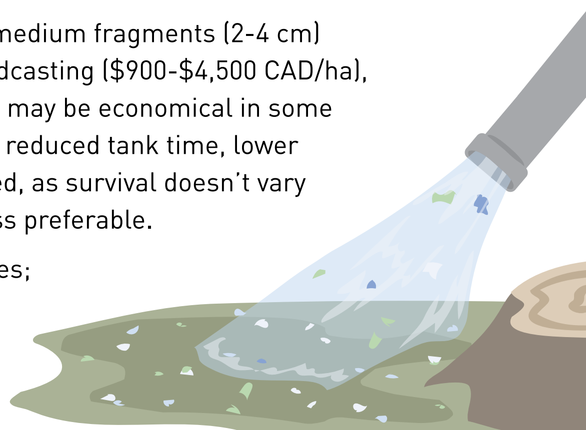
Post-fire landscapes offer superior conditions compared to harvested areas, due to reduced vascular plant competition, favorable substrate exposure, and altered nutrient dynamics. Optimal sites exhibit rapid to moderate-well drainage with xeric to mesic moisture regimes, poor to medium nutrient availability, and gentle topography (0-20% slope). Success correlates positively with canopy openness and negatively with dense moss, forb abundance, and thick tree regeneration. Wood, mineral soil and pine-needle substrates provide the most favorable surfaces, whereas water-pooling areas should be avoided. These findings apply directly to woodland caribou habitat restoration, where reindeer lichen recovery is critical for species conservation. Site selection must prioritize conditions that minimize competitive pressures while providing adequate moisture and light for these slow-growing organisms.



How can these techniques be implemented economically?

Fragment-based approaches prove more economical than intact mats, with medium fragments (2-4 cm) balancing survival and coverage. Three methods are evaluated: manual broadcasting ($900-$4,500 CAD/ha), hydroseeding ($8,500-$10,000 CAD/ha), and aerial application. Hydroseeding may be economical in some situations, but the technique requires optimization looking at factors such as reduced tank time, lower pressures, and indirect spray angles. Minimal substrate preparation is needed, as survival doesn't vary significantly across wood, soil, and pine needles, and moss is only slightly less preferable.

The most economical strategy: collect diverse species from high-density sites; disperse medium to large fragments either manually (for smaller sites) or aerially; and distribute up to 14 g dry weight/m^2 across burn sites with appropriate moisture.



Is there potential to explore historical lichen-transplantation locations to assess efficacy?

Historical assessments indicate a strong potential to explore past lichen-transplant sites to evaluate long-term restoration success. Reassessing three historical locations in Alberta and British Columbia, ranging from 6 to 24 years after establishment, provides essential insights that short-term studies cannot offer:

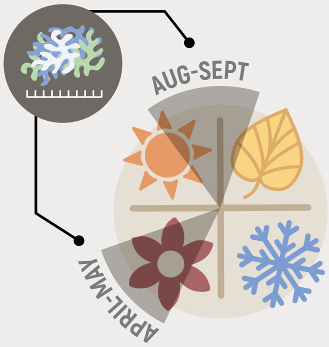
- **Sustained viability:** reindeer lichens maintained approximately 30% cover in treatment plots versus 1-3% in controls after 24 years, demonstrating persistent restoration effects well beyond typical monitoring periods.
- **Species-specific responses:** *Cladonia arbuscula* ssp. *mitis* showed greater natural re-establishment capacity on its own than other reindeer lichens.
- **Limited natural dispersal:** even after 24 years, lichen spread remained confined to areas immediately adjacent to transplanted plots, confirming the necessity of active restoration and dispersal.
- **Site condition influences:** transplants succeeded across diverse drainage, moisture, and nutrient regimes, though shaded and wet microsites performed more poorly.
- **Burn versus harvest environments:** post-fire sites showed virtually no natural lichen recovery, suggesting these environments are particularly suitable for transplantation.

Practical Implications

Lichen transplantation is a practical, cost-effective method for boosting lichen recovery, yet it must be implemented strategically.

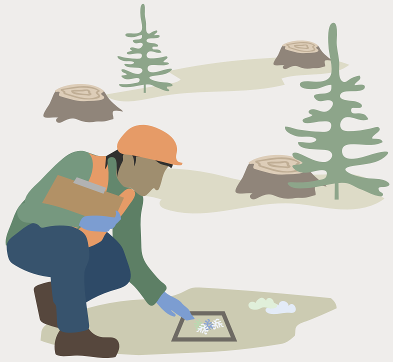
Integrate lichen restoration into post-disturbance planning. Forest management plans should identify lichen restoration opportunities during planning, not as an afterthought. Post-fire sites offer exceptional conditions due to reduced competition and exposed mineral soil. Where salvage logging occurs, managers should prioritize lichen collection from areas scheduled for harvest, using a "rescue and relocate" approach to capture material that would otherwise be lost.

Operational-scale dispersal can be done many ways. Both manual and aerial broadcasting are effective, but correct techniques are required to prevent clumping.



Collect and Preserve Carefully. Prioritize *Cladonia arbuscula* ssp. *mitis, C. rangiferina, C. uncialis*, *C. stellaris*, and *Stereocaulon tomentosum*, which demonstrated 73-98% survival rates. Keep fragments larger for better survival, or fragment to 2-4 cm segments for higher coverage. Be sure to quickly dry lichens well for storage and minimize storage time. Application rates should not exceed 14 g/m^2. Time applications for spring (April-May) or early fall (August-September).

Select sites based on ecological suitability. Prioritize post-fire landscapes with rapid-to-moderate well-drained drainage, xeric-to-mesic moisture regimes, poor-to-medium nutrient status, and open-canopy conditions. Avoid areas with dense moss cover, high forb abundance, thick tree regeneration, or lower, wetter areas.



Commit to long-term monitoring and communicate realistic expectations. Incorporate monitoring protocols extending 10-20 years post-application. Lichen restoration complements, but does not substitute for, disturbance reduction, predator management, and protection of existing habitat.

RECOMMENDED READING

Coxson, D. S., & Marsh, J. (2001). Lichen chronosequence (postfire and postharvest) in lodgepole pine (Pinus contorta) forests of northern interior British Columbia. Canadian Journal of Botany, 79(12), 1449-1464. https://doi.org/10.1139/b01-127

Haughian, S. R., & Frego, K. A. (2016). Short-term effects of three commercial thinning treatments on diversity of non-vascular plants in white spruce plantations of northern New Brunswick. Forest Ecology and Management, 370, 45-55. https://doi.org/10.1016/j.foreco.2016.03.055

Roturier. S., Jensen J., Nutti L., Barbillon P., Ollier S. (2024). Assessing the restoration and the dispersal of reindeer lichen after forest fire in northern Sweden: Results after eleven growing seasons. Ecological Engineering, 209: 107415. https://doi.org/10.1016/j.ecoleng.2024.107415

Photo credits: Northern Alberta Institute of Technology

This research was led by the NAIT Boreal Research Institute and Portage College, and funded by the ARCKP. To read the full report, see other research notes, and learn more about the ARCKP's funding partners, visit arckp.ca.