ALGAR HABITAT RESTORATION

STUDYING OUTCOMES OF AN ALTERNATIVE TREATMENT TRIAL Phase 2

MONITORING REPORT 2019

EXECUTIVE SUMMARY

The benefits of linear restoration are well understood. Legacy seismic lines remain on the landscape for decades: Many legacy seismic lines require some type of intervention to regrow vegetation and become functional caribou habitat. A major barrier to linear restoration is that it expensive: restoration can cost between $8,000 and $17,000 per kilometre depending on required treatments and the landscape characteristics of the ranges (e.g. remote locations, wet areas, etc.).

During the Algar Caribou Restoration project implementation, a few techniques were tested to boost production rates – helping reduce program costs while striving to achieve restoration outcomes. One technique applied was Leapfrog treatment. Leapfrog methods treated a seismic line for 100 m followed by 100 m of no treatment. The Leapfrog pattern was followed for the entire test treatment area. The concept of less direct ground treatment allows operators to significantly increase restoration production rates by reducing the treatment area by half.

The intent of both forms of linear restoration treatment is to deactivate the line from human, wildlife, and predator use as well as reduce line of sight and establish vegetation cover. Leapfrog treatment goals are the same as full treatment areas but at a higher production rate.

This project's analysis of Leapfrog linear restoration treatment seeks to address key knowledge gaps in the effectiveness of the regular and Leapfrog treatments in achieving restoration goals of caribou habitat restoration, reduced human traffic, and reduced predation risk. This research will benefit both industry and government as they seek innovative and cost-effective solutions for restoring caribou habitat. Both industry and government are embracing linear restoration as a part of caribou range planning. Key questions are:

- How do alternative treatments such as Leapfrog perform in meeting caribou habitat restoration objectives and how do they compare to fully treated lines?
- What is the trajectory of restoration being achieved on Leapfrog lines and in the Algar project area as a whole?
- Can advanced high-resolution imagery from Unmanned Aerial Systems (UAS) be used as an effective tool for efficiently gathering key monitoring data under the Draft Provincial Restoration and Establishment Framework (the Framework) for Legacy Seismic Lines? If so, what kind of imagery data will accomplish monitoring goals?

Overall the indicators assessed in this analysis suggest that the treatments completed in Algar, including an alternative Leapfrog treatment, are progressing towards achieving a positive vegetation response measuring against the Framework. This is an encouraging result that supports further exploration and testing of a Leapfrog approach on other sites as one method to boost the efficiency of implementing linear restoration treatments while achieving the goals and objectives of caribou habitat restoration.

BEST PRACTICES AND PROJECT OUTCOMES

To-date, a number of key learnings have derived from the project outcomes that support further exploration and testing of a Leapfrog approach on a larger scale as one method to boost the efficiency of implementing linear restoration treatments while achieving the goals and objectives of caribou habitat restoration.

Key outcomes in this project to-date (including Phase 1) are:

- Developed monitoring practices using both ground plot surveys and aerial imagery.
- Preliminary results indicate vegetation (trees) closer to the edge of treatment experience more change than untreated portions further away from the edge of treatment.
- Untreated portions of the Leapfrog line appear to experience more vegetation changes than untreated lines.
- Restoration conducted in Algar is on track to meet and sometimes surpass the Draft Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta (the Framework) criteria
- Leapfrog treatments are successfully following similar trends to fully treated lines in meeting monitoring criteria
- Algar treatments are meeting expectations across site types except in rich fens
- High-resolution imagery products from UAS can be used to semi-automatically identify tree species and potentially support monitoring assessments under the Framework.
- A Step in developing more efficient linear restoration programs

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

BACKGROUND

ALGAR CARIBOU HABITAT RESTORATION PROJECT

The Algar Caribou Habitat Restoration Program was initiated in 2011 (Figure 2) by six oil sands companies to improve the quantity and quality of undisturbed caribou habitat by restoring historic linear footprint off-lease and within the East Side Athabasca River caribou range in northeast Alberta. This industry-led imitative was the first large-scale linear restoration program implemented in Alberta. As part of the action plan, approximately 340 km of legacy seismic lines, over a 56,000-hectare area (Map 1), were treated by winter planting and/or natural regeneration protection over the course of four years. Because the region is largely covered by wetlands, winter planting techniques were used to gain access to the area using winter roads. This project was the first to operationalize winter planting on a large scale.

Figure 1 Mounding and winter planting on a legacy seismic line in Algar

As part of an adaptive management approach, vegetation monitoring plots were established on pre-restoration treatment lines to capture pre-and-post-restoration conditions and study the change in conditions as a result of treatments. To-date six years of monitoring data have been collected in the Algar area, spanning several treatment types including winter mounded and planted sites, natural regeneration protection, and no treatment control sites. In addition, a parallel program led by Dr Cole Burton of the University of British Columbia is monitoring the wildlife responses to seismic line restoration using the Algar area to do a camera trap survey. Lastly, Algar has also been used as a case study in an Alberta Innovates funded project examining the potential additional ecosystem ser benefits from linear restoration [1].

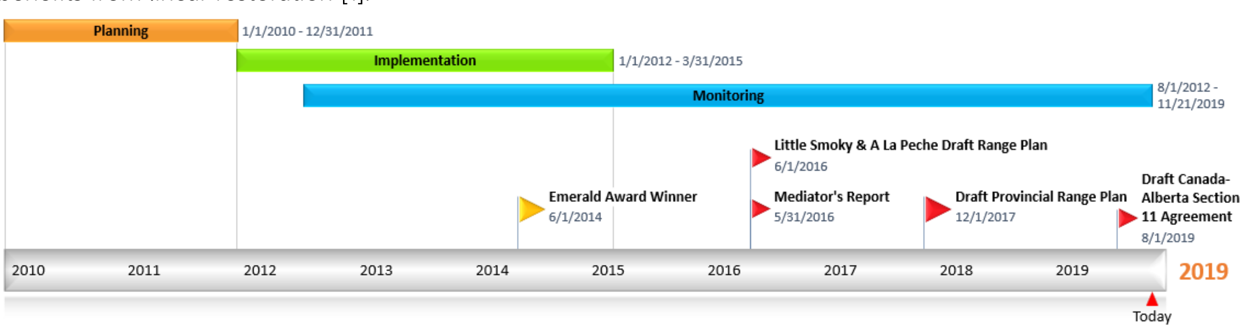
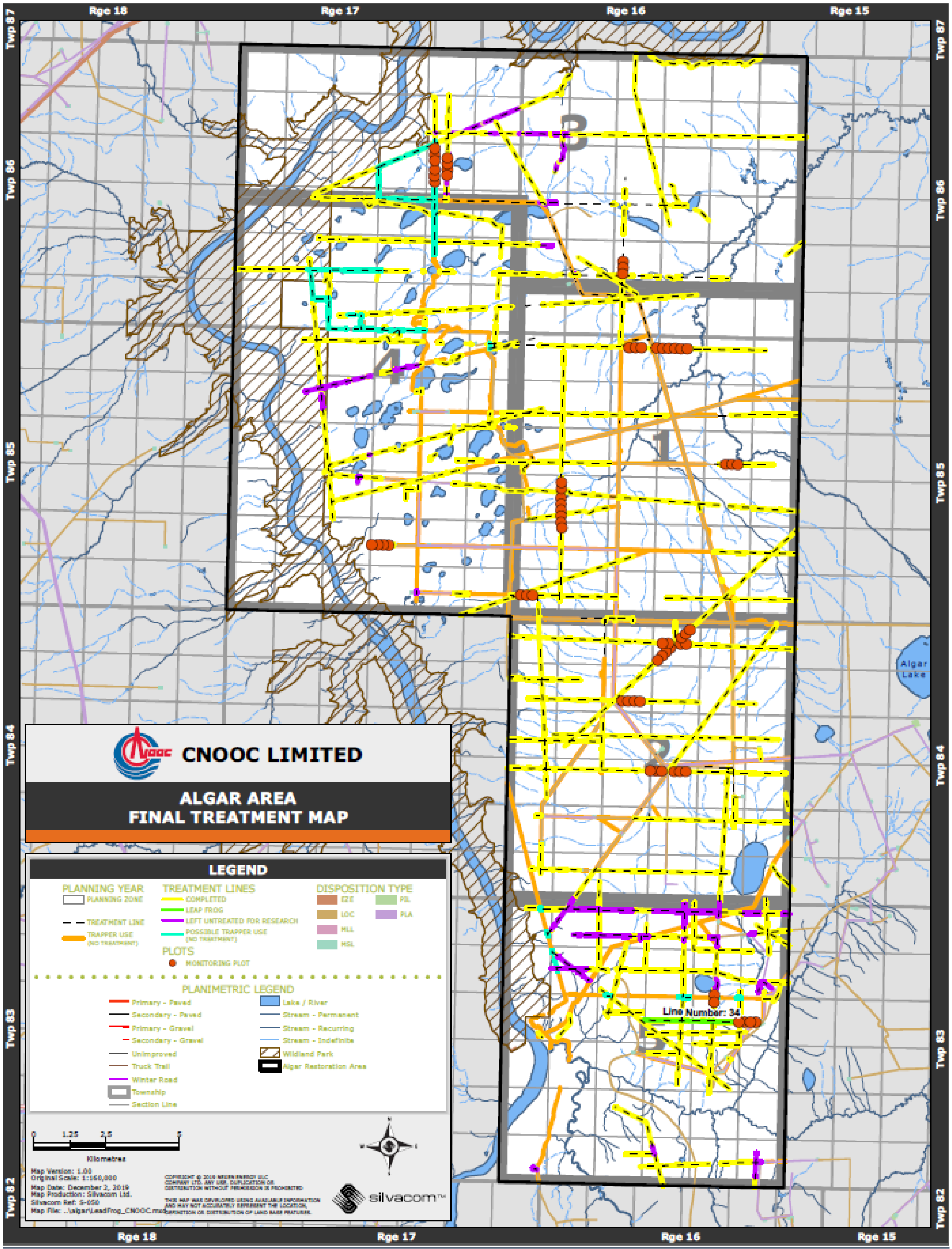


Figure 2 Timeline of Algar habitat restoration program

Map 1 Map of Algar with lines



SCALING UP LINEAR RESTORATION

Woodland caribou (Rangifer tarandus caribou) boreal and southern mountain populations are designated as Threatened under Canada's Species at Risk Act [2] and Alberta's Wildlife Act [3]. In 2012 and 2014, the Government of Canada adopted federal recovery strategies for each population respectively with goals to achieve self-sustaining local populations throughout their current distribution in Canada [4] [5]. Pursuant to the objectives of the federal recovery strategies, the Government of Alberta released a Draft Provincial Woodland Caribou Range Plan (December 2017) [6] outlining key actions and commitments for supporting caribou recovery in Alberta. Among these are a commitment to recover caribou habitat through the restoration of legacy seismic lines and inactive oil & gas infrastructure.

Seismic lines represent a significant contribution to the disturbance footprint in caribou habitat and because they are so prevalent, successfully re-establishing tree cover could increase undisturbed habitat more than other management tools [6]. Without intervention, legacy seismic lines can remain on the landscape for decades for a variety of reasons including terrain wetness, continued human use and clearing size [7]. It is estimated that 150,000 km of legacy seismic footprint requires varying levels of intervention to re-establish vegetation and encourage restoration within caribou ranges in the province [6]. The challenge is that linear restoration is expensive. Restoration costs can range between $8,000 and $17,000 per kilometre depending on the required treatments and the landscape characteristics of the ranges (e.g. remote locations, wet areas, etc.) [8].

Restoration at the scale achieved in Algar is a significant investment and has helped highlight many tactical challenges and opportunities for delivering an effective and efficient program at both the range and provincial level. There are many important considerations when designing and sequencing a restoration program to fit into broader caribou objectives and opportunities [9]. These may include but not limited to relevance to woodland caribou, accessibility, existing natural regeneration, forest harvest plans, future oil & gas development, current use of lines, etc.

During the Algar project implementation, a few techniques were tested in an attempt to boost production rates helping reduce program costs while striving to achieve restoration outcomes. One technique was termed Leapfrog treatment, where a seismic line was treated for 100m followed by 100m of no treatment. This pattern was followed for an entire test treatment line. Figure 3 and Figure 4 illustrate a comparison of a fully treated line with a Leapfrog approach.

This concept allows operators to increase production rates significantly by reducing the treatment area by half. The intent is for this treatment to still deactivate the line from human, wildlife and predator use as well as reduce line of sight and establish vegetation cover. If Leapfrog techniques are proven to be effective at restoring functional caribou habitat, it may reduce future restoration treatment costs significantly and become part of the restoration toolbox to help achieve provincial range plan objectives.

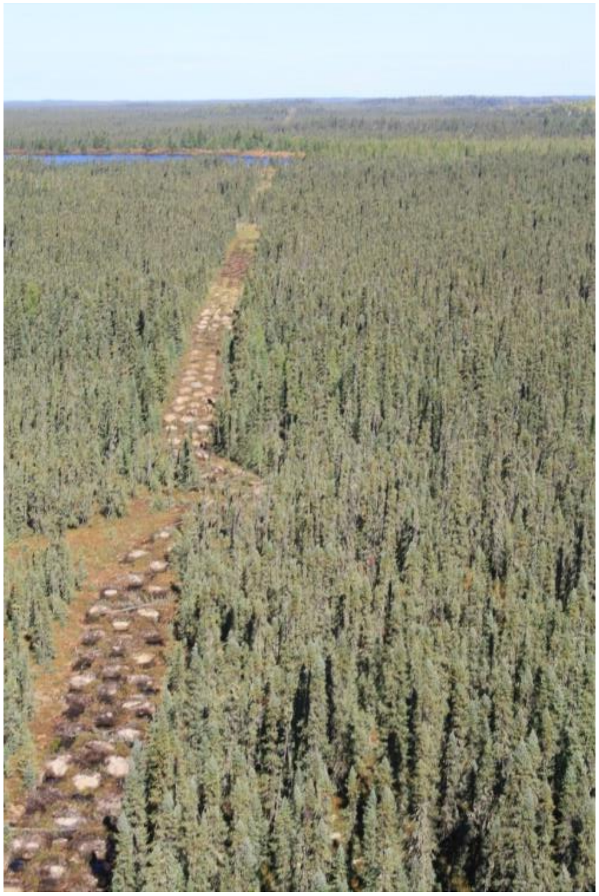


Figure 3 Fully treated line

Figure 4 Leapfrog treated line

STUDYING OUTCOMES OF THE LEAPFROG TRIAL

This project seeks to address key knowledge gaps in the effectiveness of the Leapfrog linear restoration treatments (Figure 5) in achieving restoration goals of caribou habitat restoration and reduced predation risk. This research will benefit both industry and government (who is embracing linear restoration as part of caribou range planning), as they seek innovative and cost-effective solutions for restoring caribou habitat.

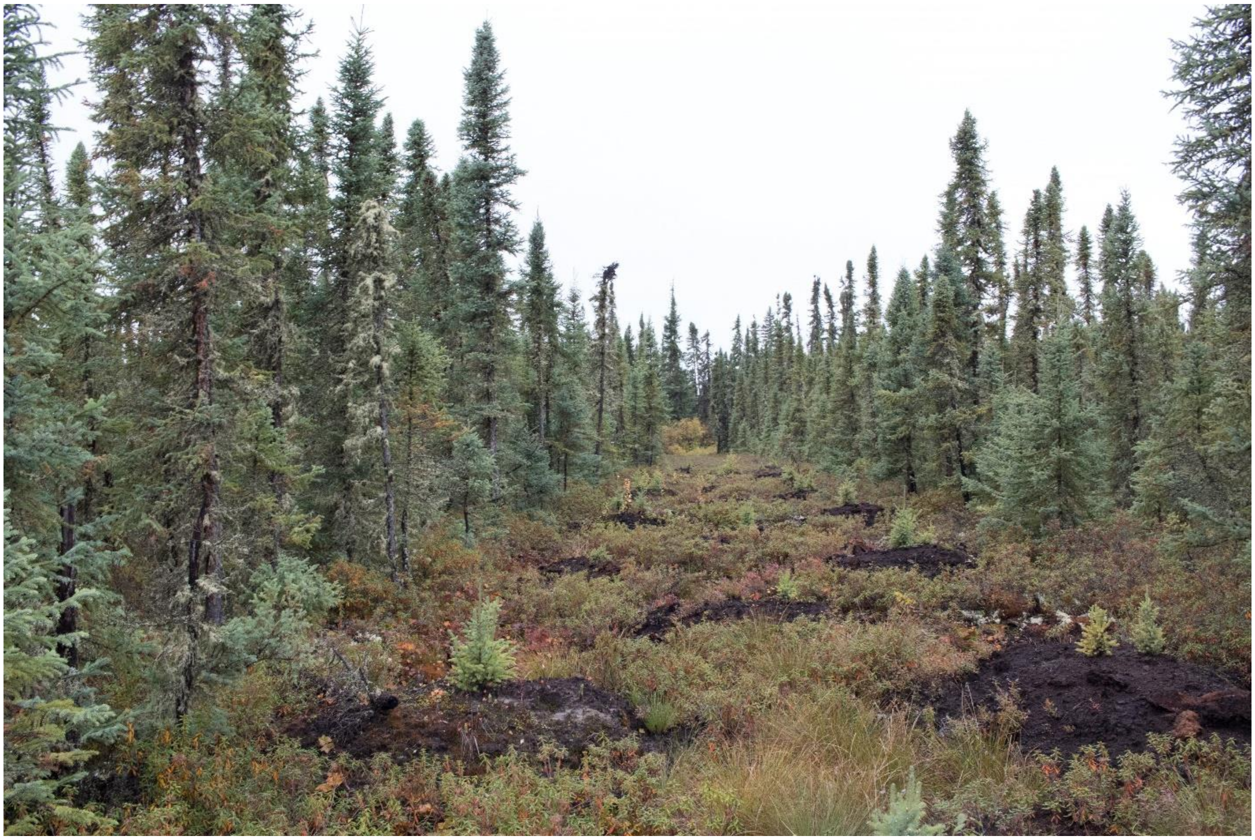


Figure 5 Leapfrog treated line showing successful tree growth on mounds 3 years post-treatment

SUMMARY OF PHASE 1 RESULTS

Despite a portion of the Leapfrog being untreated, there is a potential edge effect from the treated segment that may influence conditions for the neighbouring untreated segment. Seismic lines themselves create edge effects with surrounding forests influencing microclimatic conditions [10] [11] [12] and therefore it may be possible for a vegetation response from the edge of the Leapfrog treatment.

Phase 1 focused on two key questions that were analyzed through fieldwork involving ground plots and a UAS survey with analysis:

- Is there a vegetation response on the untreated portions of Leapfrog lines and how does it compare to non-treated/control lines?
- Is vegetation response different between untreated and treated segments of the Leapfrog line and is there reduction in the response further from the treatment edge?

Results from last year's monitoring of Leapfrog suggests that the treatment may accomplish restoration goals similarly to regular treatment. Preliminary results indicate vegetation (trees) closer to the edge of treatment experience more change than untreated portions further away from the edge of treatment. Furthermore untreated portions of the Leapfrog line appear to experience more vegetation changes than untreated lines.

Figure 6 illustrates what the Leapfrog treatment line looks like from above. Surveys were taken in both treated and untreated portions of the lines.

Figure 6. Imagery of a Leapfrog line

PHASE 2 OBJECTIVES

Building on the results of the Phase 1 study and leveraging the UAS data collected, Phase 2 focuses on examining the survey results of the Leapfrog treatment in comparison to fully treated lines elsewhere in Algar. Specifically:

- How do alternative treatments such as Leapfrog perform in meeting caribou habitat restoration objectives and how do they compare to fully-treated lines?
- What is the trajectory of restoration being achieved on Leapfrog lines and in the Algar project area as a whole?
- Can advanced high-resolution imagery from UAS be used as an effective tool for efficiently gathering key monitoring data under the Framework? If so, what kind of imagery data will accomplish monitoring goals?

To answer the key questions, the objectives of this project are to:

- Measure Algar and Leapfrog restoration trajectories relative to the Framework's suggested standards of stocking, survival, and establishment targets,
- Assess the usefulness of imagery data in accomplishing the monitoring requirements of the Framework,
- Provide best practice recommendations for continued linear restoration and monitoring in the Algar region, and
- Display the progress of the linear restoration in the Algar project area.

This phase will also support a third phase that will refine UAS survey data collection and analyze change over two growing seasons (both between aerial survey and ground survey) to further examine the effectiveness of Leapfrog treatments.

Table 1 Studying Outcomes of An Alternative Treatment Project Activity List

Project Year	Activity	Expected Completion	Complete
Phase 1 2018 PTAC 18-ERCP-08	Desktop analysis - site condition stratification	June 2018	✔
	Imagery acquisition	July 2018	✔

Project Year	Activity	Expected Completion	Complete
	Remote sensing preliminary assessment	August 2018	✔
	Ground survey sample design and protocols	September 2018	✔
	Ground survey data collection	October 2018	✔
	2018 Interim data analysis & reporting	November-December 2018	✔
2019 PTAC 19-ERCP-02	Further analysis using advanced imagery products and assess the ability to use UAS imagery products to conduct Survival Assessments	July 2019	✔
	Comparative analysis of key trends in vegetation ingress and growth from existing data	August 2019	✔
	2019 Interim report	September 2019 – Draft Complete October 2019	✔
2020	2020 UAS re-measurement survey and ground data collection	Q3 2020	
	2020 Interim data analysis & reporting	Q4 2020	
	2020 Final program results, conclusions and recommendations report	Q4 2020	

DATA AND METHODOLOGIES

APPROACH

Building off of the work completed in 2018 this portion of the project was designed to complete further data analysis in assessing the outcomes of the Leapfrog alternative treatment trial using ground-based and aerial-based survey data. Specific questions examined include:

- How do alternative treatments such as Leapfrog perform in meeting caribou habitat restoration objectives and how do they compare to fully-treated lines?
- What is the trajectory of restoration being achieved on Leapfrog lines and in the Algar project area as a whole?
- Can advanced high-resolution imagery from UAS be used as an effective tool for efficiently gathering key monitoring data under the Framework? If so, what kind of imagery data will accomplish monitoring goals?

The following actions were taken to address the specific questions:

- Comparative analysis of the multiple years of ground plot information collected at Algar across Areas,
- Comparative analysis of the Leapfrog and regular treatments in accomplishing the goals of caribou habitat restoration on seismic lines relative to the Framework standards,
- Analysis using advanced imagery products to classify imaged lines in ways which supported the goals of the Framework, and
- Lessons learned and best practices for the use of UAS imagery products to conduct Survival Assessments and Establishment Surveys as described by the Framework.

The analysis of high-resolution imagery products provides an opportunity to further assess the effectiveness of restoration treatments. The focus of this portion of the project is:

- The outcomes of alternative treatments using advanced imagery products, and
- How UAS imagery products may help to efficiently conduct Framework assessments

DATA SOURCES

Table 2 summarizes the data sources that were used to complete the analysis in this phase of the project.

Table 2 Data sources for this project

Data Source	Collection Year	Description
Algar Monitoring Program	2011-2018	Algar vegetation monitoring plot data (ongoing regular treatment line observation and fixed plot locations)
Algar Habitat Restoration: Studying Outcomes of An Alternative Treatment Trial Phase 1 Ground Survey Data	2018	Leapfrog vegetation monitoring plot data
Algar Habitat Restoration: Studying Outcomes of An Alternative Treatment Trial Phase 1 UAS Imagery Derived Datasets	2018	Elevation Data (25 cm) Vegetation Height Model (25 cm) RGB Imagery (4 cm) Multispectral (NIR) (12 cm) Multispectral (NDVI) (12 cm)

ALGAR MONITORING PROGRAM DATA

Linear restoration treatments were implemented in Algar between 2011 and 2015. Sixty-four monitoring plots were established at fixed locations within each operational area. Plot measurements were taken prior to treatment and subsequently re-measured biennially following treatment. To date, there are 339 observations with the earliest plots having seven growing seasons.

The number of growing seasons allowed Silvacom to compare a greater number of plots across all Areas. For example, all plots which have been measured at three growing seasons past establishment can be compared.

Each monitoring plot is composed of:

- A transect photo,
- A panoramic photo,
- A 1.78 m radius plot vegetation survey, and
- A 10 m coarse woody material transect.

Line of Sight Photographs

A line of sight photo series was completed at each plot. A photo reference marker was placed at distances of 10m, 50m, and 100m from the plot centre in both directions of the seismic line. The midpoint on the photo reference marker was 1.2m off the ground which represents the approximate height of a mature caribou. Table 3 demonstrates transect photography and Table 4 shows a 360° panoramic photo.

Table 3 Line of sight photograph examples from the Algar monitoring projects

Photo 1	Photo 2	Photo 3
		
The photo reference point is set so that the middle is 1.2m off the ground. The camera lens height is also 1.2m. The photo reference point is 10m away from the plot centre and camera.	Photo reference is moved to 50m from plot centre	Photo reference is moved to 100m from the plot centre. The process is repeated in the opposite direction of the seismic line for photos 4-6.

<u>Panoramic Photographs</u>

A 360° panoramic captures the general condition of the line.

Table 4 Panoramic photograph example from the Algar monitoring projects

360° PANORAMIC PHOTO


Vegetation Survey

Vegetation plots used a 1.78m fixed radius plot, established at the plot centre, (a circle with a radius of 1.78m is ~ 1/1000th of a hectare). Trees that were located within the plot were distinguished by species and tallied according to a defined height class. Shrubs were tallied by height class. Only trees above the minimum height of 15 cm and shrubs above 50 cm were tallied.

Coarse Woody Material Survey

A 10m transect from the monitoring plot centre was directed down the centre of the seismic line for the coarse woody material (CWM) surveys. Any woody material intersecting the transect was measured for decay class and diameter at the point of intersection. Only CWM over 8 cm that was not self-supporting and within 2m of the ground at the point of intersection was recorded.

LEAPFROG ALTERNATIVE TREATMENT TRIAL GROUND SURVEY MEASUREMENTS

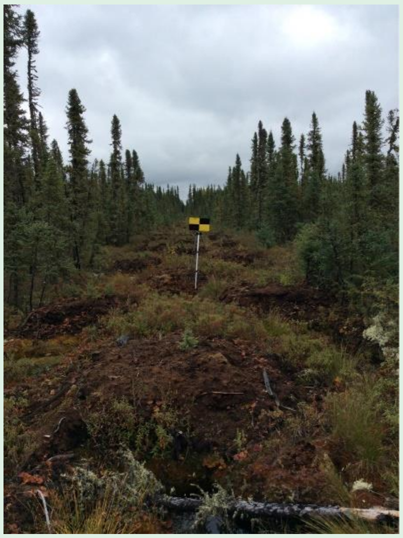
Leapfrog ground surveys were established in 2018. All Leapfrog implementation had three growing seasons at the time they were measured. The results of the surveys were reported in the document "Algar Habitat Restoration: Studying Outcomes of an Alternative Treatment Trial" in 2018. Each ground survey included three components:

- Transect photos,
- A 10m transect vegetation survey, and
- A 1.78 m radius plot vegetation survey.

Transect Photographs

To help visualize the differences in the treatments and make multi-year comparisons, photos were taken at each plot in the same direction as the transect. Table 5 shows a comparison of each treatment type with transect photos and a Mosaic RGB photo from the UAS. Monitoring of the control plots was done after the other plots because snowfall, wind, and rain limited the ability of the UAV and helicopter to fly. As a result, conditions were visibly different, not only because of the site-type differences but because of the significant changes in weather. Photos were taken of a marker that was positioned at 1.2 m above the ground and 10 m from the plot centre in the direction of each transect.

Table 5 Leapfrog Plot Comparisons of Treated, Untreated, and Control (No Treatment) sites

Leapfrog Treated	Leapfrog Untreated	Control
		
		

Vegetation Survey

Vegetation surveys had up to four 10 m rectangular transects: two in each direction. In each direction, one would be within 0-25 m from the edge of treatment, and the other would be 25-50 m from the edge of the treatment. On the edge of each rectangular transect on the side closest to the plot centre, was a 1.78 m radius plot. In the circular plots, the tally of each moss, lichen, forb, grass, shrub, and tree species was taken, as well as the percent of ground cover.

LEAPFROG ALTERNATIVE TREATMENT TRIAL UNMANNED AERIAL SYSTEM SURVEY

Silvacom enlisted Ventus Geospatial Inc. (Ventus) to acquire the imagery. The lines were surveyed in with ground control points first, then Ventus surveyed the lines with their Unmanned Aerial System (UAS). First, the lines were flown with the Unmanned Aerial Vehicle (UAV) using an RGB sensor followed by a flight with a multispectral sensor. The UAS surveys produced RGB Visual Imagery, Multispectral Imagery, Normalized Difference Vegetation Index (NDVI), Digital Terrain Models, a Vegetation Height Model, Drawing Sets for Vegetation Height, and a

Flythrough Video for the project to aid in analysis and visualization. Figure 7 shows some of the equipment used to collect the imagery for this project.

Figure 7 Image of Unmanned Aerial Vehicle (UAV) and other imagery acquisition equipment

Imagery and the associated analysis provide information about the amount of vegetation and the heights of that vegetation for the area flown. Using geospatial analysis, vegetation counts and heights along the survey lines were analyzed from the imagery outputs.

ANALYSIS METHODS

COMPARATIVE ANALYSIS OF THE LEAPFROG AND REGULAR TREATMENTS IN ACCOMPLISHING THE GOALS OF CARIBOU RECOVERY

The Framework developed by the provincial government is intended to aid in the quality, efficiency, and effectiveness of linear restoration monitoring projects. Government-sponsored projects are expected to follow the

Framework's proposed monitoring techniques; however, private linear restoration projects are only recommended to follow the Framework's design in order to have cohesion throughout the province when projects are compared and discussed. Algar was planned and implemented prior to the Framework's development – so was the monitoring program. For this analysis, we chose to align the Algar and Leapfrog monitoring data to the Framework's measurement targets so that the findings could be described on a broader scale and offer some learnings to future projects which may use the Framework to guide restoration.

Figure 8 shows timelines for conducting Survival Assessments and Establishment Survey monitoring based on the type of restoration conducted. This report outlines the analysis conducted using these timeframes as baselines for comparisons.

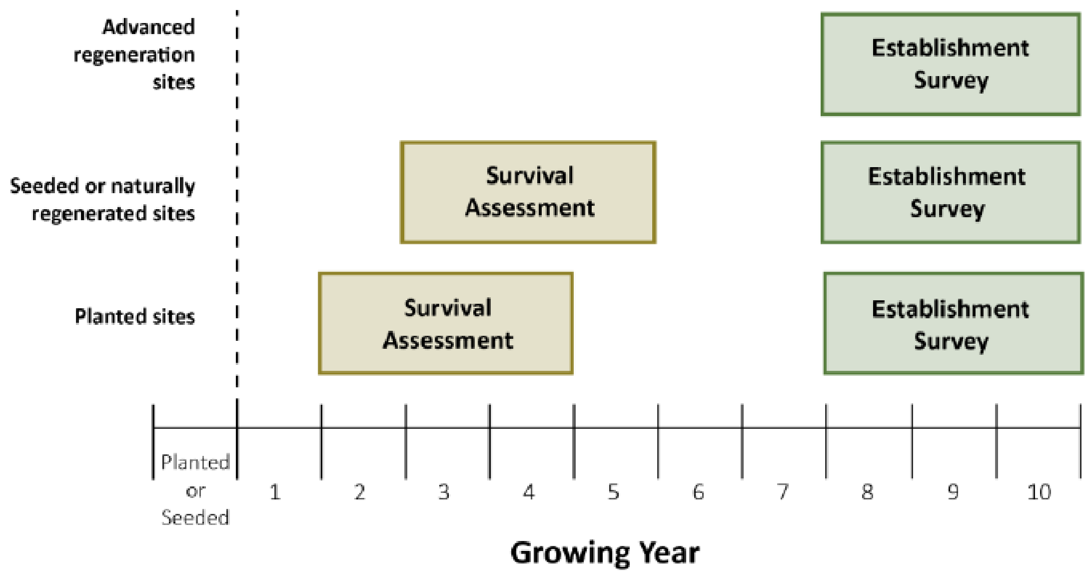


Figure 8 Acceptable survey windows for Survival Assessments and Establishment Surveys based on seedling origin on a restored site.

<u>Survival Assessment</u>

Survival Assessment targets describe the status of plots as in "passing" or "failing" with minimum acceptable heights of 15 cm and 30 cm for conifer and deciduous regeneration, respectively. Survival Assessments according to the Framework are completed between two and five years since restoration. The Framework provides survival targets depending on whether a site was treated or not and based on the site type. Targets for survival are summarized in Table 6. For the purposes of this analysis, the regeneration target densities (combined total of natural and planted regeneration) by site type from the Framework were used as the benchmark for survival. The Algar monitoring plots do not specifically distinguish between planted and natural regeneration making an estimate on percent survival difficult to ascertain.

Table 6 Targets used for evaluation of survival[1]

Site Type	Treatment	Target
Upland Transitional Lowland Treed	Treated Area	75% survival of winter-planted trees[2]
		80% survival of summer-planted trees
		4,000 – 5,000 stems per hectare (sph) of trees
	Advanced Regeneration Area	N/A
Upland Dry Lowland Low-Density Treed	Treated Area	75% survival of winter-planted trees[2]
		80% survival of summer-planted trees
		2,500 – 4,000 stems per hectare (sph) of trees
	Advanced Regeneration	N/A

In the Algar and Leapfrog projects, the acceptable species are the same as those identified in the Framework. Those species which are present in the Algar region and acceptable as per the Framework are found in Table 7.

Table 7 Acceptable tree species and species codes[3]

Latin Name	Common Name	Species Code
Picea glauca	White spruce	SW
Picea mariana	Black spruce	SB
Pinus banksiana	Jack pine	PJ
Larix laricina	Tamarack larch	LT
Abies balsamea	Balsam fir	FB
Populus balsamifera	Balsam poplar	PB

[1] Adapted from Table 4 of the Framework.
[2] All Algar and Leapfrog seedlings were planted in the winter.
[3] Adapted from Table 6 of the Framework.

Latin Name	Common Name	Species Code
Populus tremuloides	Trembling aspen	AW
Betula papyrifera	White birch	BW

All the tree species in Table 7 may be found in Algar and Leapfrog plots; however, only White spruce and Black spruce were planted. Black spruce was the predominant tree in Algar and the most common seedling type used in linear restoration in the area.

Plots were assessed based on the site type targets as outlined in Table 6 and acceptable species as outlined in Table 7. Key metrics analyzed include stem density and maximum conifer height. Ecosite was an additional variable that was analyzed.

There are four plot categories which are summarized in Table 8.

Table 8 Summary of the categories of seismic lines included in this analysis

Plot Category	Description	Plot Count
Leapfrog – 100 m Treated	These plots are on Leapfrog-treated lines and are located on the portion of the line which experienced site preparation, coarse woody material application, and mounding. The segments of line on which these plots are located alternate every 100 m with the Leapfrog – 100 m Untreated segments.	11
Leapfrog – 100 m Untreated	These plots are on Leapfrog-treated lines and are located on the portion of the line which did not experience site preparation, coarse woody material application, or mounding. The segments of line on which these plots are located alternate every 100 m with the Leapfrog – 100 m Treated segments.	15
Full Treatment	These plots are in the area of Algar which received total-line treatment. Treatment included site preparation, coarse woody material application, and mounding.	180
Control (No Treatment)	These plots were identified as requiring total-line treatment for restoration but were not treated at all. They are monitored and serve as research plots – identifying how the restored	34

Plot Category	Description	Plot Count
	lines could have continued if they had not received treatment at all.	

Algar plots are measured biennially so some plots have been measured in their growing seasons of even increments (i.e. measurements at two and four growing seasons) and others have been measured in their growing seasons of odd increments (i.e. one and three growing seasons and so on). All Leapfrog plot data was collected following three growing seasons. To compare Leapfrog results of survival passing rates, stem density, and maximum conifer heights to full treatment plots in Algar and control plots, the results are reported in the third growing season. Algar plots which were measured in the fourth growing season are also included since the range for Survival Assessments is between two- and five-years post-implementation.

The number of growing seasons a plot has experienced is determined by keeping track of how many summers have been completed since implementation at the time of re-measurement in the monitoring program. Seedlings were winter-planted, and measurements have occurred in several seasons, so a measurement of the count of growing seasons rather than years since implementation presents a more accurate picture of progress in the early stages of the development of the restoration.

ADVANCED IMAGERY ANALYSIS

In September 2018, Leapfrog plots were measured and photographed. UAS imagery was collected on Leapfrog lines as well. For this analysis, the field crew team helped the GIS analysts to identify the location of a few plot centres on aerial imagery and classify the plant cover based on the transect photography done on the ground. The visual roadmap was used to apply a classification scheme to the RGB imagery. Vegetation type classifications resulted from the RGB analysis.

RGB-based vegetation classes included the following types:

- Seedlings
- Dead trees
- Deciduous shrubs
- Grass
- Labrador tea
- Mound
- New Seedling
- Peat Moss
- Reindeer Lichen
- Tree

The GIS analyst prepared a supervised classification algorithm to select breaks between vegetation types. In order to run the supervised classification, the GIS analyst selected a set of pixel values representing each type. When the algorithm ran on the imagery, polygons that were defined by the specific values were classified in the various vegetation types. The results of the image processing were analyzed for suitability and alignment with the identified plot photos.

LiDAR point data was used to determine the height and height classes of seedlings and features in the imagery; however, the LiDAR point data was at a resolution too low to draw conclusive evidence of these metrics.

RESULTS

ANALYSIS USING GROUND PLOT DATA

SURVIVAL ASSESSMENT

Preliminary analysis using all plot data from Algar revealed that treatments were performing relatively consistent across different site types except for rich fens. In these cases, plots were performing well below average. The extent of rich fens in Algar is limited and is not present in the Leapfrog line thus it was decided to remove these plots from the analysis for comparison purposes. There could be a number of contributing factors for performance on rich fen sites including competition from grasses and other shrubs, excessive moisture, moving water that destabilizes mounds, etc. that require further investigation.

As discussed in the methodology, for the purposes of this analysis, stem density targets from the Framework are being used as the primary indicator in the Survival Assessment. Overall, stem density is higher in both the Leapfrog and full treatment plots compared to the control plots. Full treatment plots have a higher average density than the Leapfrog plots however there are both on average above the stems per hectare targets outlined in the Framework (

Figure 9).

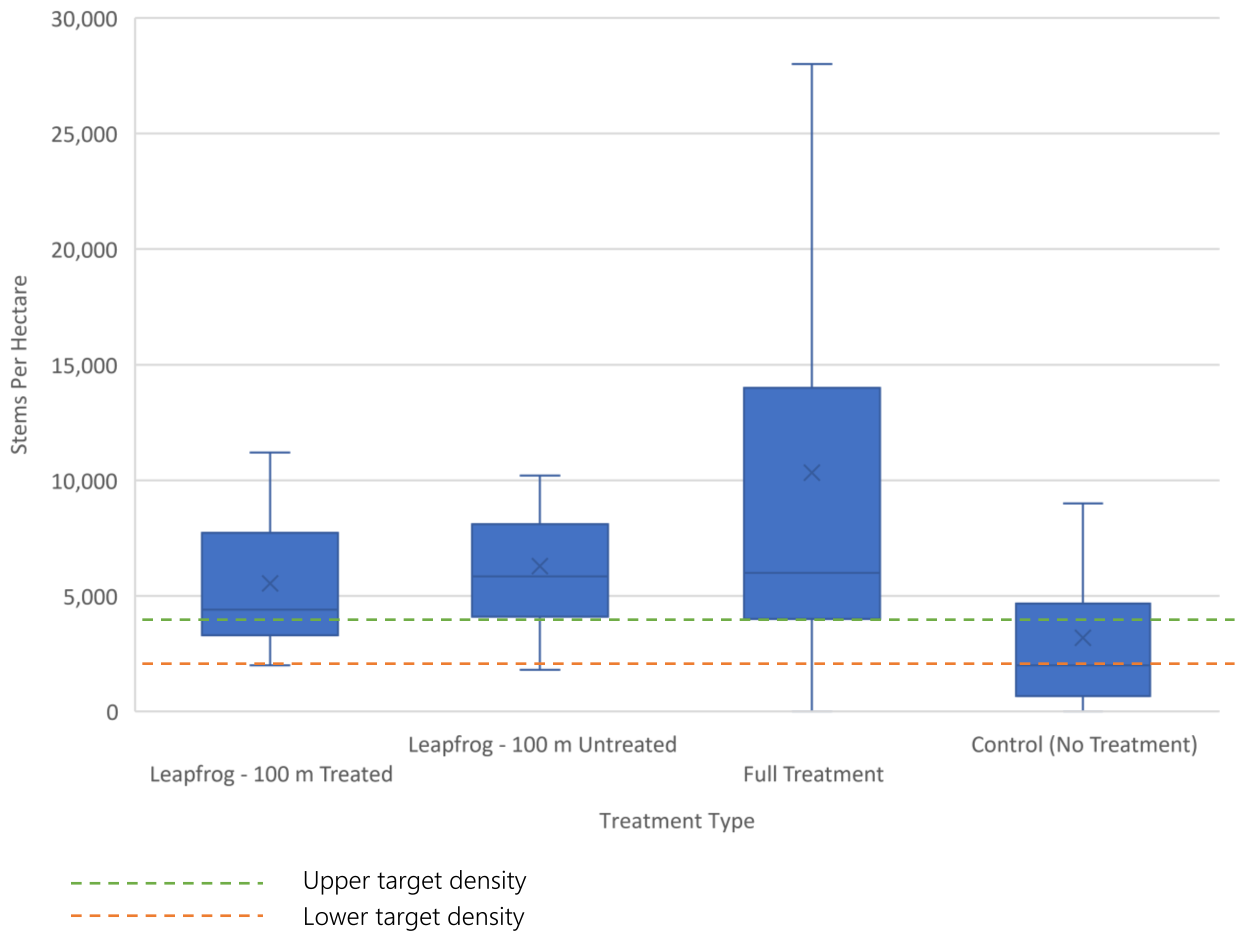


Figure 9 Stem density at three and four growing seasons, excluding rich fens[4]

[4] Outliers were removed from Figure 7 for scale visibility of the data.

Based on the stem density results, Leapfrog (including untreated segments) is performing consistently with full treatment in terms of percentage meeting survival criteria 3-4 growing seasons following treatment (Figure 10).

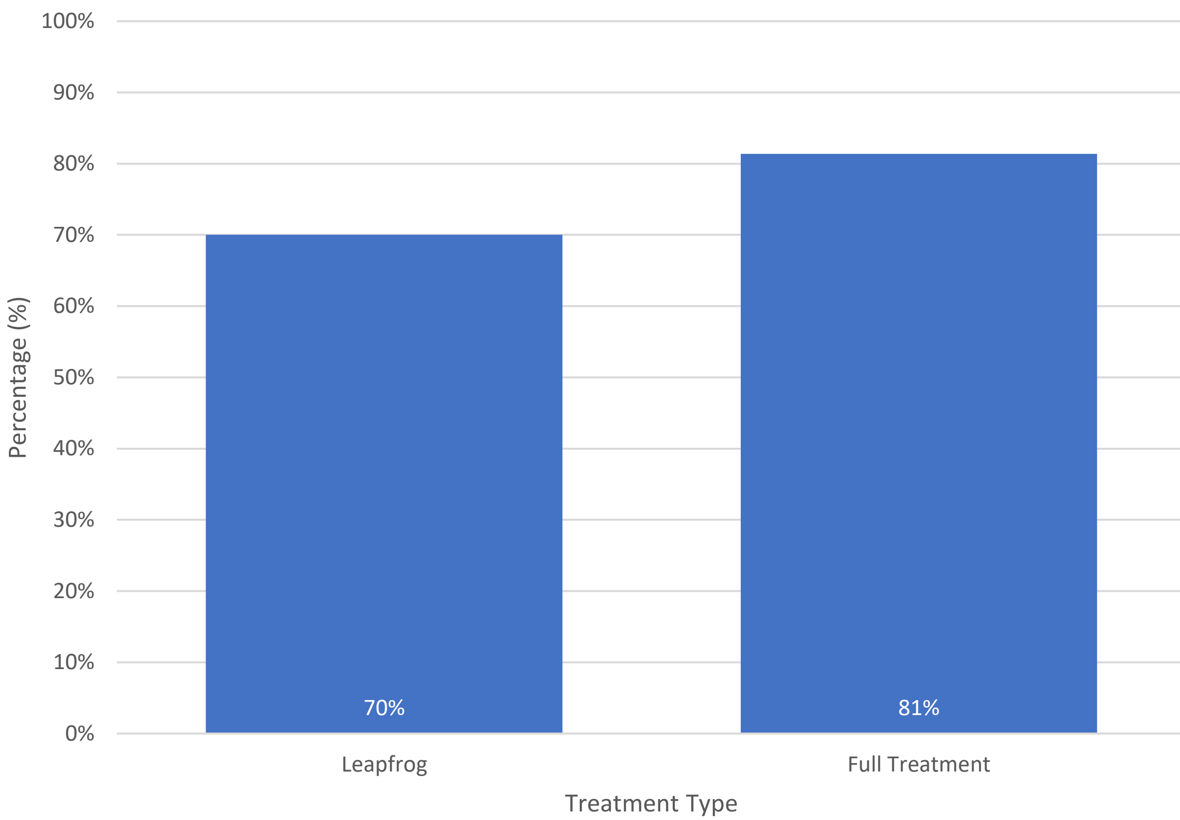


Figure 10 Percentage of treated plots passing Survival Assessments at three to four growing seasons by treatment type

ESTABLISHMENT SURVEY

Establishment Survey data could not be derived directly from Algar or Leapfrog data because Establishment Surveys require a minimum of eight growing seasons. Future Algar monitoring projects will be able to supply this information. However looking at the data we currently have, we can exam trends of key characteristics for meeting establishment targets.

Height is one factor in stocking criteria that forms the basis of the Establishment Survey. While this is not a specific indicator for Survival Assessments or establishment on its own, it does provide some additional insight into the performance and trends towards meeting establishment criteria 8-10 years following treatment. Height requirements for conifer stocking range from 40cm to 70cm depending on site type. All four plot treatment types had a representation of maximum conifer heights – meaning that there were conifers measured in at least some of the plots of each treatment type and are on average near or to height thresholds (Figure 11). Control plots had a higher mean height, and the outliers were more extreme than the three types of plots that experienced treatment (Figure 11). Full treatment plots also had outliers above the average, but they were much tighter to the boxplot (Figure 11). The Leapfrog plots had similar results and were slightly shorter mean maximum conifer heights than the full treatment average (Figure 11).

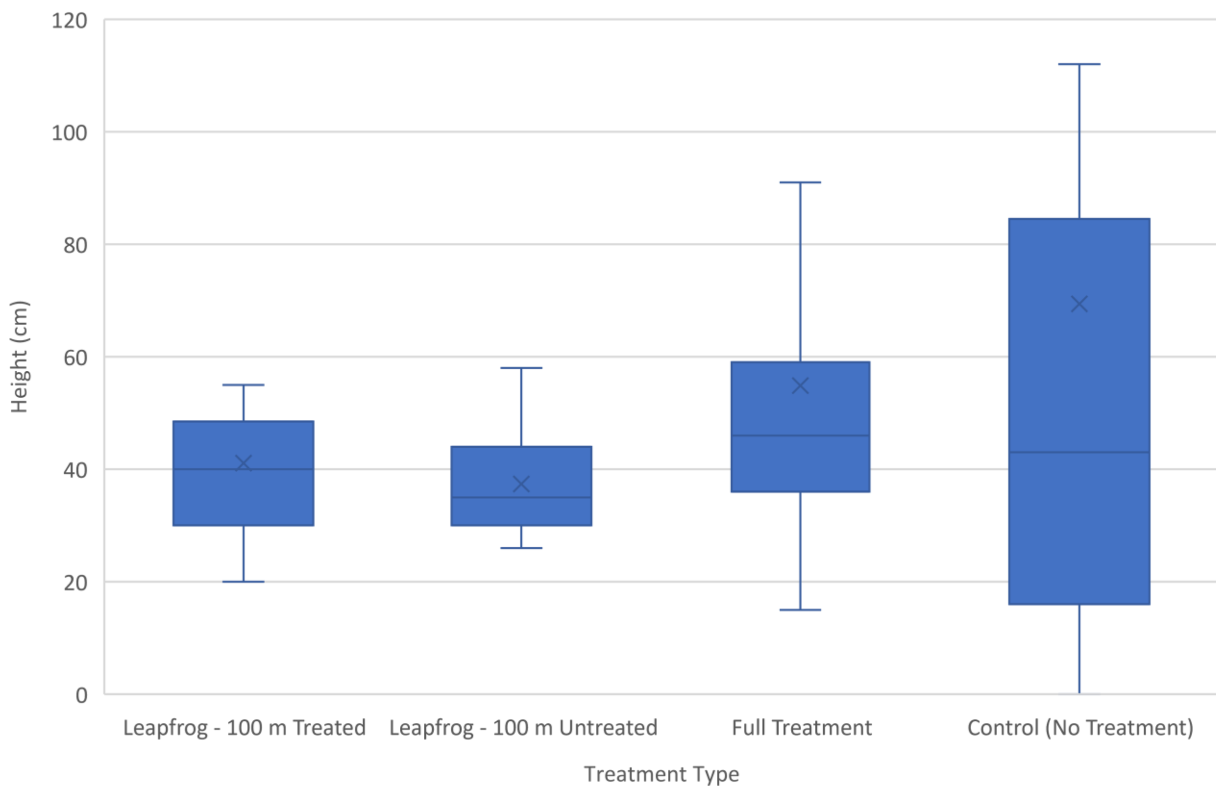


Figure 11 Maximum conifer height at three and four growing seasons, excluding rich fens[5]

[5] Outliers were removed from Figure 11 for scale visibility of the data.

Again this does not fully satisfy establishment criteria on its own but gives an indication that tree growth is progressing towards establishment targets.

As another proxy for Establishment Survey data, a basic analysis was completed on the seventh growing season with the subset of plots that have reached that stage since implementation (lines that were treated in the first year of implementation). Results indicate that positive Establishment Survey outcomes can be anticipated – even in plots that may not have passed Survival Assessments. Of the thirteen plots with seven growing seasons, 92% would meet Establishment Survey targets – a full growing season ahead of the eight years defined in the Establishment Survey. Further discussion on future Establishment Surveys can be found in the Discussion and Conclusions and Recommendations sections of this report.

PROJECTING RESULTS

Since the Leapfrog and Algar responses are similar in the third growing season, Algar's response to treatment over time can provide informed expectations for Leapfrog's future state. Algar plots have been measured over multiple growing seasons and looking at the trends over successive growing seasons we can hypothesize as to the potential results of a survey in Phase 3 of this project next year.

Over time, Figure 12 demonstrates that full treatment plots experience increasing success in meeting the Framework's Survival Assessment requirements. After two growing seasons, full treatment plots had a reasonably high success rate of meeting Survival Assessment standards as outlined in the Framework (Figure 12). It seems likely that there is a plateau of success rate on full treatment lines: perhaps after five- to six- growing seasons.

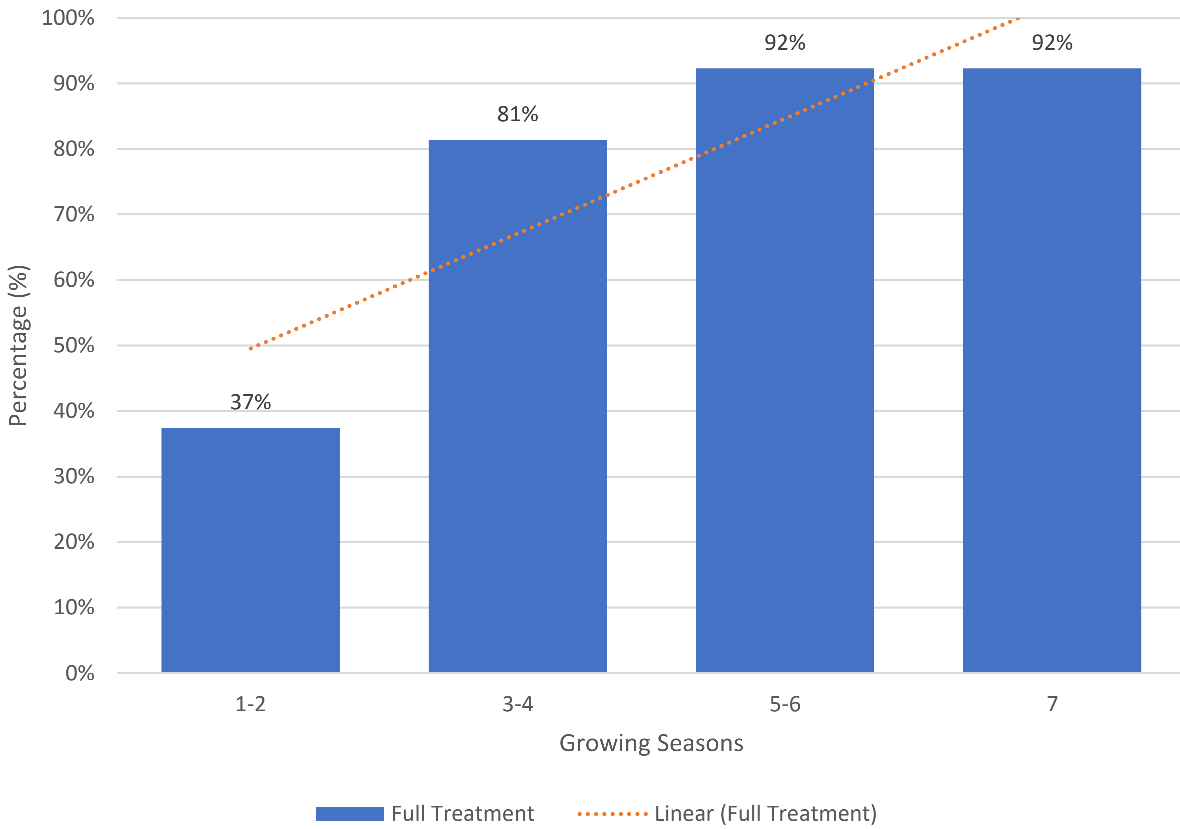


Figure 12 The survival passing rate of Algar plots, excluding rich fens

ANALYSIS USING UNMANNED AERIAL SYSTEM

The first step in achieving the objectives of this project with respect to the UAS was to determine which imagery source provides the best and most accurate results. In order to achieve this goal, GIS analysts ran several algorithms that were applied to all imagery – ISO data, K-means and Fuzzy K-means. To further test the objectives, an image segmentation algorithm was also applied. The results of these analyses determined that the RGB imagery produced the most accurate results for both classification and segmentation algorithms.

Figure 13 shows what the original imagery from the RGB data looked like. This was the best data to use for this area of interest and with the objectives of the project in mind.

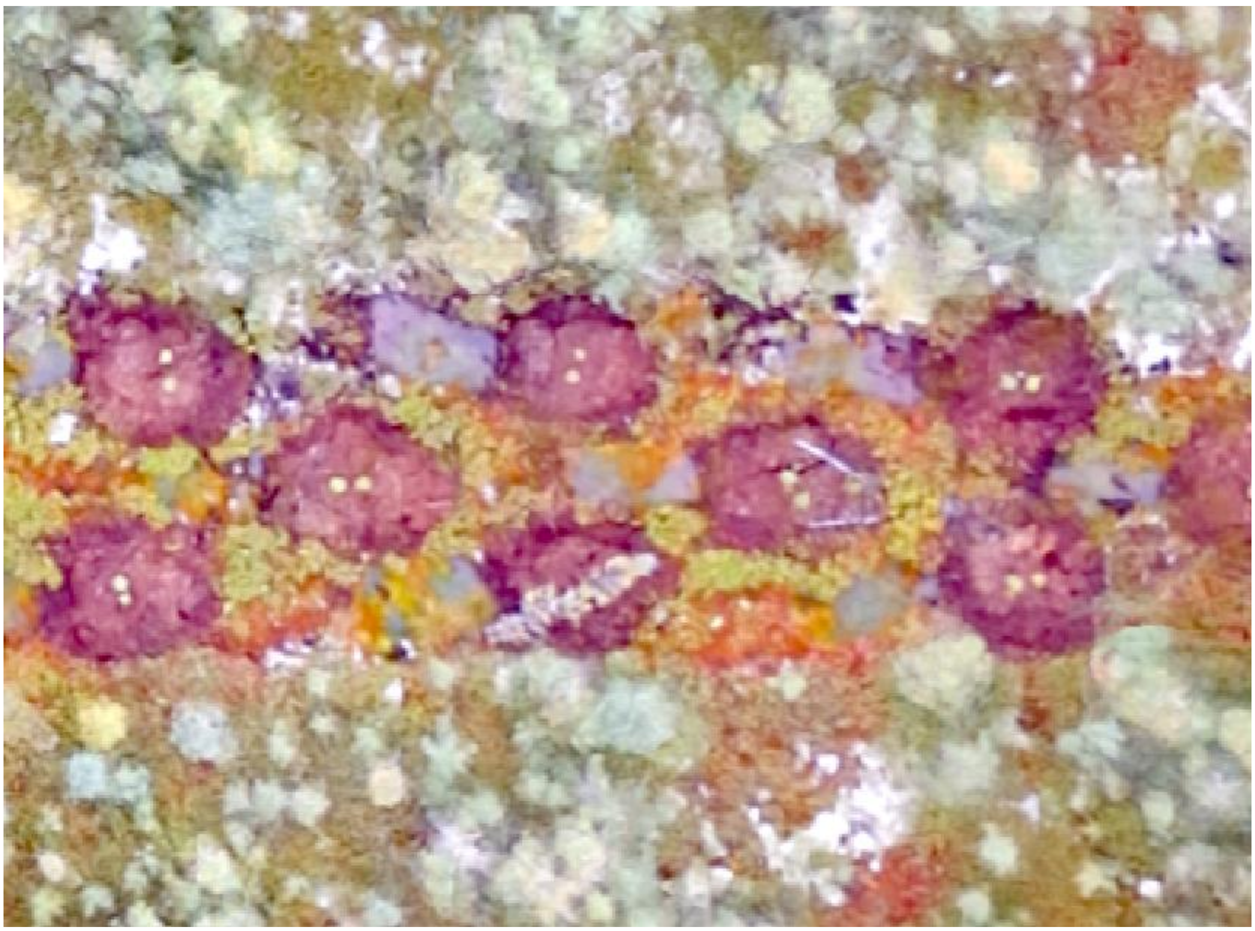


Figure 13 RGB imagery of a sample area

Using the algorithms built by the GIS analyst, seedlings were identified as well as several vegetation classes. The vegetation class detection was over 85% accurate. Vegetation classes defined and detected included:

- Seedlings
- Dead trees
- Deciduous shrubs
- Grass

- Labrador tea
- Mound
- New Seedling
- Peat Moss
- Reindeer Lichen
- Tree

The algorithm was not able to identify dead seedlings against alive seedlings as the dead seedlings were either not present, or the algorithms could not confidently select them as an individual class. Figure 14 shows the same area as in Figure 13 but is illustrating the results of the analysis conducted by the GIS technician. Using baseline information from photos taken by the field team, it was possible to build the algorithm to identify seedlings, identify mounds, and find different vegetation classes.

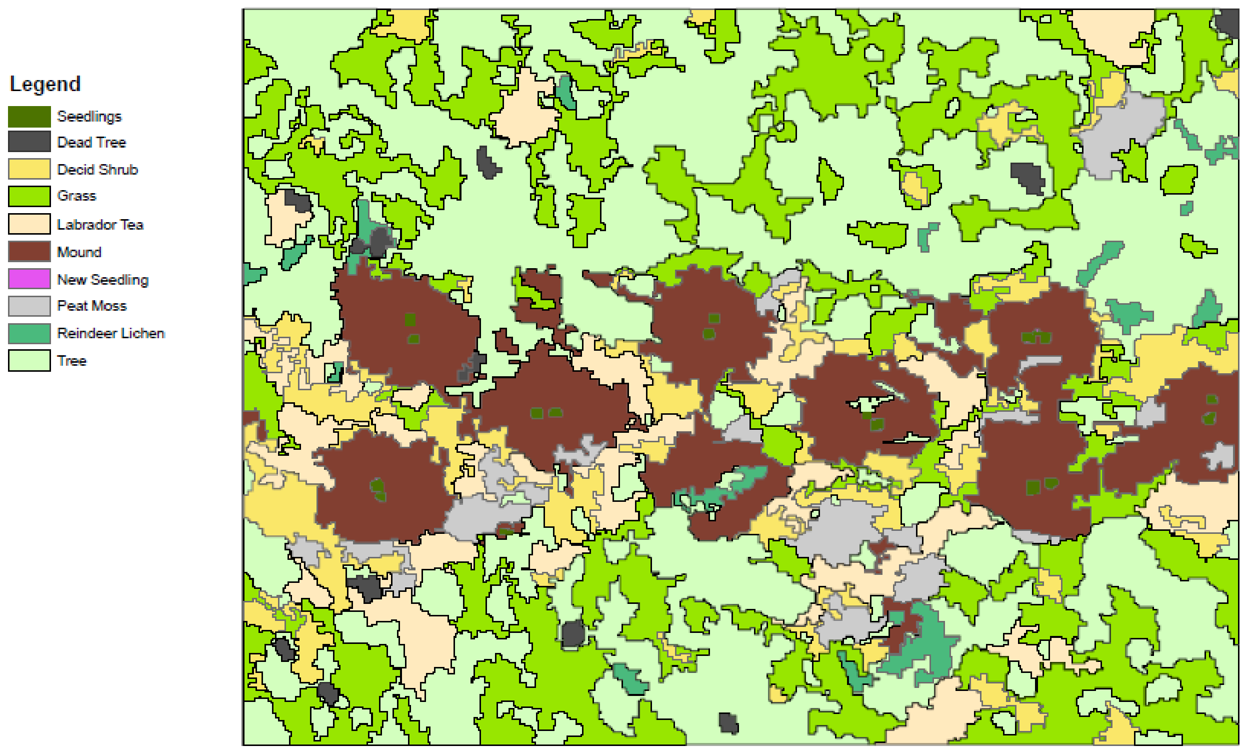


Figure 14 Vegetation type classification of a sample area

Another objective was to determine the capacity of the UAS to identify tree height classes of the seedlings planted on the lines as well as any naturally regenerated seedlings that followed treatment and planting. Figure 15 shows the accuracy and precision of the LiDAR data. Although the imagery is high-resolution it is not adequate to be able to determine the height of the seedlings with high confidence. The blue dots are the LiDAR data points the red circles are pairs of seedlings. There are no accurate readings of seedlings, and as a result, seedling heights could not be determined confidently. The LiDAR point cloud would need to land directly on top of the seedlings for height to be accurately determined. However, a rough idea of the general height (highest tree, lowest vegetation) and height classes could be determined.

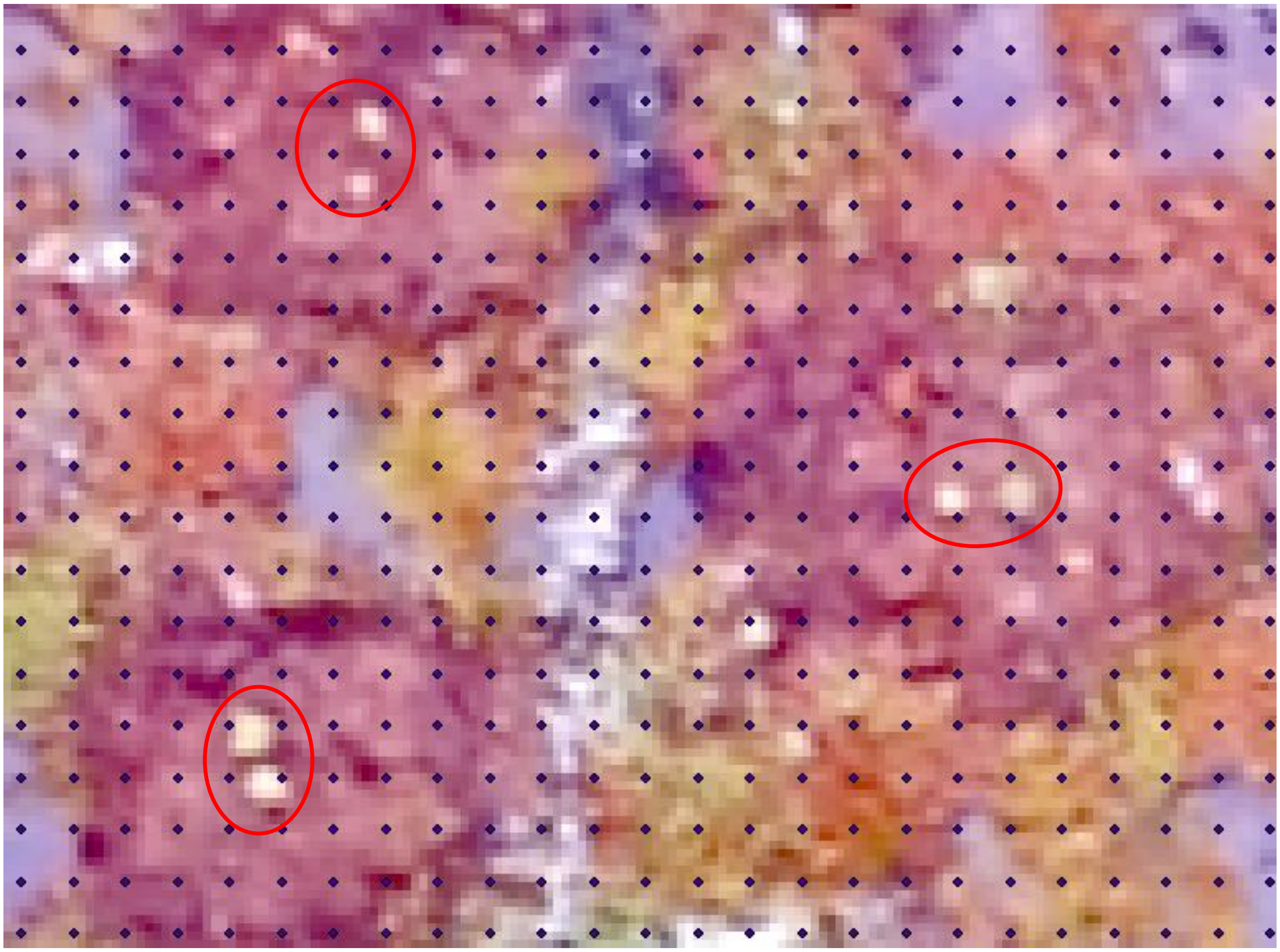


Figure 15 Point cloud data with RGB imagery

DISCUSSION

Overall the indicators assessed in this analysis suggest that the treatments completed in Algar, including an alternative Leapfrog treatment, are progressing towards achieving a positive vegetation response measuring against the Framework criteria. This is an encouraging result that supports further exploration and testing of a Leapfrog approach on other sites as one method to boost the efficiency of implementing linear restoration treatments while achieving the goals and objectives of caribou habitat restoration.

It is worth noting the success of Algar as a whole: it is progressing towards meeting the Establishment Survey criteria. The results were consistent across site types except in rich fen sites where the measurements indicate the treatments are performing below expectations. This is a key learning and contributing factors may include excess moisture, moving water that destabilizes mounds and competition from grasses and other low shrub vegetation. Overall this makes up a small component of the Algar area and thus further analysis and monitoring would be required to examine this closer. Rich fens are not present on the current Leapfrog treatment and therefore were excluded in further analysis in this study for comparison purposes.

The following subsections discuss in more detail observations and results of the analysis completed in this Phase.

SURVIVAL ASSESSMENT

At the third- and fourth- growing seasons, the results indicate that treatment has a positive effect on a plot's ability to meet Survival Assessment targets. Control plots occasionally passed Survival Assessments; however, plots of the three other plots types – Leapfrog – 100 m, Leapfrog – 100 m Untreated, and Full Treatment – all passed Survival Assessments more frequently. Treatment does appear to have a positive impact on meeting restoration goals, even as early as three growing seasons post-implementation.

In Figure 12, it is apparent that the ability of a plot to pass the Survival Assessment standards increases with the number of growing seasons – as one would expect, the more time post-treatment a plot is assessed, the more stems and the taller those stems will be. It is anticipated that plots measured in Leapfrog after the fifth growing in Phase 3 will continue to perform at even a higher rate based on results in the rest of Algar. The fifth growing season is currently the maximum time allotted for the performance of Survival Assessments in the Framework.

When stem densities are compared, Leapfrog plots of both types averaged near 6,000 sph compared to the full treatment plots which were over 10,000 sph in the same time frame. This could be due to the same reason that Survival Assessment s are slightly higher for full treatment plots – the full treatment plot measurement includes plots with four growing seasons. An additional year of growth may allow a higher overall stem density.

Of the few plots which have reached seven growing seasons and were analyzed as a proxy for the eight- to ten-growing season Establishment Surveys, several plots which had not passed the Survival Assessment in their early years passed the Establishment Surveys.

STEM DENSITY

The stem density analysis at three- and four- growing seasons compared both regular Algar and Leapfrog plots. There are four plot types in the stem density analysis: Leapfrog – 100 m Treated, Leapfrog – 100 m Untreated, Full Treatment, and Control (No Treatment). Stem density in control plots was less than any other treatment type. Leapfrog – 100 m Treated and Leapfrog – 100 m Untreated plots were similar, suggesting that they react similarly to treatment. Full treatment plots averaging more than other plot types might suggest that although Leapfrog treatments do have a positive impact on the trajectory of the seismic line to caribou habitat restoration, the full treatment offers a larger positive impact on the metric of stem density. In terms of stem density, it is evident that any type of treatment contributes to the goals of caribou habitat restoration.

MAXIMUM CONIFER HEIGHT

Maximum conifer height may have been most variable in the control plots because if conifers are present in the plots at all, they could have been established at any time in the lifespan of the seismic line and grown any height over that time. The three treatment plot types would most likely have been reset when the seismic line was placed on a new restoration trajectory with site preparation and planting. On the treated lines, the odd natural regeneration conifer stem that may have been present, but not in quantities high enough for satisfactory stem density, may have been removed, damaged, or set back in comparison to the control plots.

The three types of plots which experienced treatment and/or traffic during treatment are similar in average maximum conifer height to plots on lines that were not reset on restoration trajectories. Such results suggest that stems in areas that were treated experience faster growth rates for seedlings which lead growth in the plots. Perhaps the seedling in treated areas benefit from the site preparation and planting boost so much so that the reset back to a beginning stage of growth is not as detrimental as growing indefinitely in a site with limiting factors. For example, a seedling in a control bog may exist and even reach 120 cm eventually, but it may reach a point where it can no longer support vertical growth. In contrast, a seedling planted on a mound has a stronger ground base, is above the point of excess moisture, and has other advantages of site preparation such as soil nutrients. A planted seedling also has a significant advantage of growth compared to a seed. Such a planted seedling may begin shorter than an already-established seedling; however, it has advantages that may provide an opportunity for it to surpass the older seedling in growth rate and height. The higher Survival Assessment success rates of treated plots combined with the early three- and four-growing season maximum conifer heights suggests that if monitoring continues, this pattern may be seen eventually.

ESTABLISHMENT SURVEYS

Establishment Surveys are to be done from eight- to ten-years post-implementation. None of the plots in Algar or Leapfrog projects have reached eight growing seasons, but by using plots from Algar with seven growing seasons as an example, it was found that Establishment Survey outcomes were positive and ahead of schedule. The thirteen plots which passed the Establishment Survey also passed the Survival Assessment. Since Leapfrog plots have demonstrated a similar Survival Assessment passing rate to the full treatment plots (Figure 10), it is reasonable to expect that Leapfrog will also see positive Establishment Survey results when the time arrives to perform those assessments. Currently, the Leapfrog plots have experienced three growing seasons.

The only Establishment Survey criteria that could be assessed with the current monitoring data collection was the stocking of acceptable tree species. The current monitoring methods for Algar and Leapfrog lines do not allow for the assessment of the plot species suitability compared to the neighbouring stands or the presence of human access[6].

All the plots which have reached seven growing seasons are full treatment plots. That these plots which have reached seven growing seasons have almost all met establishment targets prior to the timeline in which they should be measured to meet the establishment targets suggests that the establishment targets given in the Framework are achievable and realistic. The establishment targets may also be realistic and achievable in correlation to the Survival Assessment requirements as most of the plots with seven growing seasons also passed the Survival Assessments. These results are promising; however, with only thirteen plots to demonstrate the results of a potential Establishment Survey, there is some uncertainty. More plots at the same stage post-implementation would increase the confidence of these preliminary findings – for both full treatment and Leapfrog treatments.

UNMANNED AERIAL SYSTEM

RGB imagery was chosen as the best imagery to work with for the purpose of creating an automatic vegetation type cover. The imagery was segmented and classified into relevant cover classes as demonstrated in Figure 14. RGB imagery was analyzed using an algorithm to identify species and cover types. Overall, it can be stated that using the available imagery, the area of interest could be monitored for vegetation classification. Being able to identify vegetation classes with a UAS could help to describe to change over time of a treated line towards habitat represented on either side of the line. Using the proportions and distributions of cover types to identify a segment's similarity and difference from other segments could help describe larger areas of seismic lines in a landscape and plant community-based approach. The limitation of analysis by vegetation class is that specific species and individual stems are not differentiated as well: Instead of a density approach, it would be a proportion approach. A rough representation of the different height classes and tree heights was possible, but detailed information about height and height classes was not possible. The benefit of height class proportion is similar to the benefit of vegetation class distribution: the comparison of general height distributed across the line can be compared to neighbouring stands to determine whether the line is reaching goals of matching forest structure. Drawbacks of measuring height class by the general distribution of heights on a seismic line include an inability to definitely tell what item (i.e. mound, seedling, shrub) is meeting height requirements and species are not differentiable so information for the planning of future restoration is limited based off of such data.

For the area of interest, some imagery sources – such as NDVI and MS – did not produce functional results. If the vegetation distribution of the area of interest is similar to that of Leapfrog in future projects, it is expected that RGB imagery would produce more accurate results than other imagery types. In the future, it is recommended to use RGB imagery for these types of monitoring projects. If vegetation types differ dramatically from Algar and Leapfrog, re-evaluation of the variety of imagery sources would be prudent.

[6] Reference Table 4 of the Framework.

For future monitoring of the same area, RGB imagery (3 and 4 band) is likely to be the best option. LiDAR data could be extremely useful; however, it is imperative to have higher resolution LiDAR data for an effective contribution to data collected through imagery analysis.

CONCLUSIONS AND RECOMMENDATIONS

The Algar Habitat Restoration Program pioneered linear restoration on an operational scale in Alberta. The monitoring programs to-date in Algar have provided key learnings on the vegetation and wildlife response to treatments that support an adaptive management approach to linear restoration. The focus of this study has been the outcomes of an alternative treatment trial, called Leapfrog which used an alternating pattern of 100 m treatment segments (mounding and tree planting) followed by 100 m segments with no treatment. This approach has the potential to significantly increase operational productivity and reduce linear restoration program costs. This study has been examining the outcomes in terms of its effectiveness in achieving caribou habitat restoration goals.

Phase 1 results completed in 2018 project indicate vegetative response on untreated portions of the Leapfrog line and that response appears to diminish as you move away from the edge of treatment. Furthermore, untreated portions of the Leapfrog line exhibit promising vegetation responses relative to lines left entirely untreated. The Leapfrog treatment technique appears to help return the legacy seismic lines to a trajectory in line with the surrounding forest.

Phase 2 focused on comparing the outcomes of vegetation response relative to other fully treated lines in Algar using the Framework's monitoring criteria. Under the Survival Assessment criteria (2-4 years post-treatment) the Leapfrog lines (treated and untreated segments combined) and the fully treated lines in the rest of Algar met the stem density targets 70% and 81% of the time respectively. The similarity in the success of both treatments is encouraging for the program as a whole and the potential use of alternative treatments to increase efficiency. The Leapfrog treatment line itself is currently too young to assess against the Establishment Survey criteria (8-10 years post-treatment) however examinations of stocking and height response from plots in the earlier areas of Algar show a trend towards achieving establishment criteria. This is also a positive signal for Leapfrog treatments if it continues to trend with the other fully treated areas in Algar. It should be noted that the vegetation response is one component of the Establishment Survey criteria which also considers line use and coverage, etc.. The Algar monitoring plot design was established prior to the Framework and does not capture all of the items identified however assessing key indicators like density and stocking provide critical insight into the success of treatments. An additional learning through the analysis was that treatments in rich fen ecosites tended to perform below expectations. Contributing factors may include excess moisture, moving water that destabilizes mounds and competition from grasses and other low shrub vegetation. Further analysis and monitoring would be required to examine this closer.

In addition to examining ground plot data, this phase also completed further analysis of the UAS imagery data gathered in Phase 1. Examining the different products more closely (RGB, Vegetation Height Model, Multispectral NIR, Multispectral NIR), it was determined that the RGB imagery produced the best results in species identification and delineation. The Vegetation Height Model provides insight at a macro level on line-height profile however use at the tree level (an important consideration for completing monitoring) was limited due to the resolution. Overall with the 4cm RGB imagery and a higher resolution Vegetation Height Model, the technical approach could be utilized to help assess the monitoring criteria in the Framework.

It is recommended that a third phase of this study be completed which would include the re-measurement of ground plots and UAS survey to measure change since the last measurement which will help refine projections towards meeting the Establishment Survey criteria and further assessing the effectiveness of alternative treatments.

Beyond this study, continuing to pilot the Leapfrog treatment in other projects would help increase understanding of how it achieves habitat restoration objectives under different site conditions and also testing impacts of different treatment segment lengths (50 m, 100 m, 200 m, etc.).

Continued monitoring of long-term restoration projects like Algar contributes to the ability of industry and government to finesse and align linear restoration techniques and targets for efficiency and effectiveness. Private- and government-funded linear restoration projects will benefit from increased knowledge and efficiency about the abilities of treatments to meet targets for the simple reasons that budgeted funds will be able to be distributed more broadly for more kilometres of restored legacy seismic lines. Continued monitoring will create confidence in various treatment techniques and long-term trajectories which can be expected when future restoration projects are planned. UAS imagery provides an opportunity to scale up the monitoring processes deemed necessary through the Framework. Combining ground plots, transect photography, and aerial imagery analysis would provide robust and extensive evidence of the progress of linear treatments towards caribou habitat restoration.

APPLICATION

In future linear restoration projects, the learnings of Algar and Leapfrog could significantly contribute to the effectiveness and efficiency of treatment. Depending on the site's attributes, using a combination of regular and Leapfrog treatments could increase the cost-efficiency of linear restoration projects while maintaining the effectiveness of treatment. UAS monitoring strategies combined with ground surveys could increase the cost efficiency of monitoring programs. Changes to the UAS monitoring strategies employed in Leapfrog could allow for the completion of Survival Assessments and Establishment Surveys by a variety of means. The UAS strategies outlined in this document could allow for more monitoring programs at larger scales.

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