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Habitat restoration as a key conservation lever for woodland caribou: A review of restoration programs and key learnings from Alberta

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Abstract: The Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population in Canada (EC, 2012), identifies coordinated actions to reclaim woodland caribou habitat as a key step to meeting current and future caribou population objectives. Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in highly fragmented landscapes. Reliance on habitat restoration as a recovery action within the federal recovery strategy is high, considering all Alberta populations have less than 65% undisturbed habitat, which is identified in the recovery strategy as a threshold providing a 60% chance that a local population will be self-sustaining. Alberta's Provincial Woodland Caribou Policy also identifies habitat restoration as a critical component of long-term caribou habitat management. We review and discuss the history of caribou habitat restoration programs in Alberta and present outcomes and highlights of a caribou habitat restoration workshop attended by over 80 representatives from oil and gas, forestry, provincial and federal regulators, academia and consulting who have worked on restoration programs. Restoration initiatives in Alberta began in 2001 and have generally focused on construction methods, revegetation treatments, access control programs, and limiting plant species favourable to alternate prey. Specific treatments include tree planting initiatives, coarse woody debris management along linear features, and efforts for multi-company and multi-stakeholder coordinated habitat restoration on caribou range. Lessons learned from these programs have been incorporated into large scale habitat restoration projects near Grande Prairie, Cold Lake, and Fort McMurray. A key outcome of our review is the opportunity to provide a unified approach for restoration program planning, best practices, key performance indicators, and monitoring considerations for future programs within Canada.

Key words: Alberta; federal recovery strategy; habitat restoration; woodland caribou.

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Introduction

In 2012, the federal Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal Population in Canada was publicly released and it described coordinated actions to reclaim woodland caribou habitat as a key step to meeting caribou population and distribution objectives (EC, 2012). Actions include restoring industrial landscape features such as roads, seismic lines, pipelines, cut-lines, and cleared areas in an effort to reduce landscape fragmentation and the changes in caribou population dynamics associated with changing predator-prey dynamics in fragmented landscapes. The importance of habitat restoration as a recovery action within the federal recovery strategy is high, considering all local Alberta populations have less than 65% undisturbed habitat, which is identified in the strategy as a threshold providing a 60% chance that a local population will be self-sustaining. All local Alberta populations are considered either "not self-sustaining" or as "likely not self-sustaining", with 10 of 14 populations with long-term empirical data known to be in significant decline (Hervieux et al, 2013). Alberta's Provincial Woodland Caribou Policy also identifies habitat restoration as a critical component of long-term caribou habitat management and population recovery (GOA, 2011).

There is on-going economic pressure in Alberta to disturb caribou habitat within "not self-sustaining" local populations, since caribou ranges overlap with oil and gas and bitumen reserves. As a result, the demand to build additional infrastructure to produce and support market delivery of those reserves is also increasing. The challenge is whether continual development of energy sector projects, such as seismic, road and pipeline development is possible within caribou ranges while reducing net residual effects to caribou and caribou habitat. To address this challenge, a number of large-scale and project specific habitat restoration initiatives have been implemented by multi-

Figure 1. Natural regeneration of a typical conventional seismic line in the boreal forest. Photo courtesy of Brian Coupal.

stakeholder groups and individual companies in recent years, including restoration projects near Grande Prairie, Cold Lake, and Fort McMurray. The objectives of these initiatives have been to restore habitat on historical anthropogenic footprint in an attempt to create intact habitat areas for caribou and/or to slow down predation rate as a result of the footprint. Given a lack of formal guidelines on habitat restoration objectives or techniques, as well as a lack of reporting on program learning's, Golder Associates Ltd. (Golder) organized a Restoration Workshop in Edmonton, Alberta, in June 2013. More than 80 participants from industry, government, academia, and consulting attended the one day workshop to discuss caribou restoration efforts in Northern Alberta. The intent of the workshop was to provide an opportunity to improve common understanding from on-the-ground restoration programs in terms of key performance indicators, successes, best practices and outcomes and to link the results of these programs back to provincial guidance on habitat restoration considerations. The workshop balanced learning and discussion with knowledge sharing presentations by government and industry. Breakout groups focused on a series of key questions regarding restoration efforts. Here we outline how lessons learned from past restoration initiatives educate the objectives and techniques for implementation of habitat restoration for current and future restoration projects.

Habitat restoration initiatives

A Caribou Range Restoration Project (CRRP) was first established within Alberta in 2001 (Szkorupa, 2002) in an effort to address growing concerns with the relationship between industrial development and declining local caribou populations. At that time, research from James (James, 1999) suggested wolves were gaining a predation advantage using linear features created by industry, and that indirect habitat loss for boreal caribou was occurring through the avoidance of habitat adjacent to human disturbance (Dyer, 1999; Neufeld, 2006; Oberg, 2001). In addition, seismic lines were reported to have very slow reforestation rates (Revel *et al.,* 1984; Osko and MacFarlane, 2000), with slow tree regeneration attributed to root damage from the original disturbance, compaction of the soil in tire ruts, insufficient light reaching the forest floor, introduction of competitive seed mixes (i.e., plant seed mixes), drainage of sites, and repeated disturbances (e.g., all terrain vehicles) on seismic lines (MacFarlane, 1999 and 2003; Sherrington, 2003). Rehabilitation of existing anthropogenic disturbances within caribou range was expected to reduce the degradation of functional habitat over the long-term, with caribou no longer exhibiting avoidance of the disturbance feature (e.g., Oberg, 2001). The CRRP piloted techniques with the objectives of promoting revegetation of these features, while discouraging access for predator, primary prey, and human use.

The CRRP was a multi-stakeholder group initiated and steered by the provincial government agency Alberta Sustainable Resource Development (ASRD), and the Boreal Caribou Committee (BCC) (Dzus, 2001). Although the CRRP was not extended beyond 2007, the project did incorporate silviculture methods based on knowledge of forestry treatments, focusing on access control treatments and enhancing the vegetation recovery rate of historical seismic lines, pipelines, and lease roads. Based on the outcome of treatments and learnings on linear restoration, the CRRP prepared a Guidance Document (CRRP, 2007a) which included recommended practices for implementing a habitat restoration program, from the planning through to the treatment stages. A monitoring protocol document for revegetation (unpublished) (CRRP, 2007b) was also prepared. Key learnings during the CRRP included recognition that restoring linear development features is not equivalent to replanting a typical mono-

Figure 2. Use of coarse-woody debris on a 4 m wide seismic line. Photo courtesy of Canadian Natural Resources Ltd. Primrose and Wolf Lake Project.

culture or mixed stand forestry cutblock. Linear development features vary with respect to the width and type of initial disturbance, compaction levels, soil types, moisture regimes, and light levels. In addition, restoration objectives often differ, including discouraging predator and human access, and the establishment of vegetation which is not preferred browse for moose or deer.

A number of initiatives and trials established since the CRRP have focused on establishing vegetation and access control treatments on linear development features located within caribou range. Restoration programs have been developed under requirements to meet project approval conditions (provincially through Alberta Environmental Protection and Enhancement Act approval conditions for in-situ projects and federal pipeline approvals through the National Energy Board) as well as voluntary programs. Habitat restoration programs have included implementing treatments to encourage native vegetation establishment such as creating microsites using an excavator, seedling planting (tree and shrub species, frozen seedlings) (e.g., Golder, 2005; DES, 2004; Enbridge, 2010; Golder, 2010; Golder, 2011; Golder, 2012a; OSLI, 2012a), spreading coarse woody debris (Vinge and Pyper, 2012; Pyper and Vinge, 2012) and tree-felling (Cody, 2013; OSLI, 2012a) (Figures 1 to 6).

Lessons learned from these programs have been incorporated into large scale habitat restoration projects focused within caribou areas near Grande Prairie (CRRP, 2007c), Cold Lake (Golder, 2010; Golder, 2012a; Golder, 2015a;

Cody, 2013; Golder, 2015b), and Fort McMurray (COSIA, 2014; OSLI, 2012a), Alberta.

Existing knowledge

Conventional seismic lines, which are generally 6 to 8 m wide, have been reported to have very slow reforestation rates (Revel *et al.,* 1984; Osko and MacFarlane, 2000; Lee and Boutin, 2006). Tree regeneration along seismic lines is influenced by the characteristics of the adjacent forests (e.g., site productivity, tree and shrub species and heights) (Bayne *et al.,* 2011), method of clearing from the original disturbance, compaction of the soil from human use, insufficient light reaching the forest floor, maintenance of apical dominance from surrounding stands, introduction of competitive species such as graminoid dominated seed mixes, naturally poor drainage of sites and repeated disturbances (e.g., all-terrain vehicles, animal browsing, repeated exploration) (Revel *et al.,* 1984; MacFarlane, 1999; 2003; Sherrington, 2003; Lee and Boutin, 2006). The slow pace of recovery of plant communities on seismic lines has been recommended as an area where direct management activities, including access control to reduce repeated disturbance, and silviculture preparations to address site deficiencies, should be applied to set a line on a natural successional trajectory (MacFarlane, 2003).

Positive results for establishing native vegetation on seismic lines and pipeline rights-of-way (ROWs) have been recorded using techniques such as planting tree and shrub seedlings, and creating microsites by methods such as mounding that are conducive to seedling growth and natural vegetation encroachment (DES, 2004; CRRP, 2007b; Golder, 2010; 2011; 2012a; OSLI, 2012a; Macadam and Bedford, 1998; MacIsaac *et al.,* 2004; Roy *et al.,* 1999). Measures such as the use of coarse-woody debris (slash rollback) can address site condition issues including competition from non-target or undesired plant species, erosion, frost, and heat or moisture deficiencies, as well as to create microsites for germination (CRRP, 2007b; Pyper and Vinge, 2012; Vinge and Pyper, 2012).

Transplanting native vegetation has been at-

Figure 3. Alder shrub seedling planting on a pipeline ROW after 1 growing season. Photo courtesy of Enbridge Pipelines (Athabasca).

tempted along seismic lines and pipelines but is challenging to implement on a large scale due to the inconsistent availability of vegetation suitable for transplant, the potential for degradation of neighboring vegetation communities if transplants are sourced from adjacent stands, approval requirements to move vegetation, and less than ideal storage conditions for plant materials due to weather. Other treatments such as seeding and seedling planting have been shown to be more successful and predictable in comparison (Golder, 2012b).

Both natural revegetation and seedling planting initiatives on both seismic lines and pipelines have benefited from minimal disturbance construction during frozen ground conditions that reduce or avoid grubbing and grading and minimize disturbance to the duff layer (e.g., DES, 2004; TERA, 2011; 2012; Enbridge, 2010; TCPL, 2014).

The ability of linear developments to regenerate to native species is affected considerably by human use. Oberg (2001) identified that recovery of conventional seismic lines within the foothills to functioning caribou habitat occurs within 20 years following disturbance in west-central Alberta. Within a boreal caribou area, seismic lines that were allowed to regenerate naturally achieved an average height of 2 m, across all boreal vegetation types, within 20 to 25 years, if the line had not undergone a repeated disturbance (e.g., re-cleared to ground level for winter access or exploration use). The average age of trees on the revegetated seismic lines was only 10 years, suggesting sites that are continually disturbed or re-cleared by seismic exploration or vehicular access take longer to regenerate. Restoration efforts are also negated when human use destroys or damages seedlings after planting (Enbridge, 2010; Golder, 2011; 2012a).

Subjective expert ratings suggest that effectiveness of access control measures such as gates, berms, mounding, slash rollback, and visual screening vary considerably between negligible and high effectiveness in controlling human access within caribou ranges (CLMA and FPAC, 2007). Effectiveness of access control measures are dependent on suitable placement (e.g., placed to prevent detouring around access control point), enforcement, and public education of the intent of the access control, which facilitates respect of the control measures (AXYS, 1995). Excavator mounding is a well-researched and popular site preparation technique in the silviculture industry (Macadam and Bedford, 1998; Roy *et al.,* 1999; MacIsaac *et al.,* 2004). Mounding has been found to discourage human access such as off road vehicular use and also creates microsites that improve vegetation establishment (CLMA and FPAC, 2007). Physical access control measures provide short-term solutions to manage access and allow for natural regeneration (Golder, 2009). It has been suggested that once linear features have regenerated to a pole sapling or young forest structural stage, they no longer facilitate vehicular access (Sherrington, 2003).

A number of the techniques used to block human access use of regenerating industrially disturbed features also contribute to initiatives to block line–of–sight. Short-term management for access and line-of-sight blocking is understood to lead to long-term access control by providing the necessary conditions for the disturbance to regenerate to natural vegetation conditions (CLMA and FPAC, 2007). Expediting growth of visual barriers along linear features can be achieved by concentrating reclamation efforts on productive upland habitats, since tree and shrub (e.g., alder which is less palatable for prey species) species grow more quickly on these sites compared to lowland sites. On deciduous and mixedwood upland sites, encouraging deciduous tree species and shrub growth is important to quickly establish visual and physical barriers in the short-term. Tree-felling has recently been applied through the Cenovus Energy Linear Deactivation (LiDEA) project in northeastern Alberta and early results suggest it is effective in providing an immediate access control through remote camera monitoring (Cenovus, 2014). Although regeneration of conifer species is the endpoint for caribou habitat use and minimizes habitat creation for other prey species, conifer species growth rates are slower than the growth rates of deciduous species. Faster growth rates provide for access control and line-of-sight barriers more quickly (DES, 2004). Recent field trials suggest that planting shrubs along with conifer tree species may allow trees to grow healthier, faster and with less competition for nutrients and water from fast-growing grasses than when planted without shrubs (OSLI, 2012a). Planting shrubs may also provide important habitat benefits for wildlife, compared to only planting tree seedlings, by providing hiding cover (Bayne *et al.,* 2011).

The OSLI program (now COSIA) includes on-going studies to determine what the most efficient vegetation introduction techniques are for peatland areas, such as planting frozen seedlings in the winter instead of summer planting, and whether to use seed or seedlings, dependent on site conditions and other variables. The OSLI/COSIA program also involves voluntary restoration of legacy footprint within caribou critical habitat in an effort to restore large, late seral stage patches of caribou habitat to increase habitat intactness and discourage corridor use (OSLI, 2012a).

The Government of Alberta has not provided a manual for reclamation that can be utilized for developing silvicultural prescriptions for large scale habitat restoration programs. However, a revegetation matrix was developed by Alberta Environment and Parks and published within the Cumulative Effects Management Association (CEMA) document ‘Stony Mountain 800 Linear Footprint Management Plan’ (CEMA, 2012). The revegetation matrix examined vegetation trajectories associated with the natural recovery of linear features over time. The values provided in CEMA (2012) are based on practitioner opinion as well as estimates based on ecosite and tree species growth potential. The revegetation matrix can be used to simulate how vegetation height may change over time (CEMA, 2012).

While there has been some effort to assess wildlife use of regenerating seismic lines (e.g., Bayne *et al.,* 2011) and reclaimed areas (e.g., Hawkes, 2011), few researchers have documented the relationship between natural habitat recovery and wildlife responses to recovery with respect to caribou. A pilot study to measure the effects of revegetating linear disturbances on wildlife use and mobility collected data for a group of predators (i.e., cougar, wolf, coyote, lynx, grizzly and black bears) and prey (i.e., moose, deer and caribou) (Golder, 2009). Results indicated that revegetated seismic lines with a minimum of 1.5 m of consistent vegetation regrowth were preferred by both predator and prey species (including caribou) compared to open, low (< 1.5 m vegetation) vegetation control lines. The line-of-sight measured on the revegetating lines was typically less than 50 m. In general, control lines were used primarily for travel by both predators and prey species. Human use was primarily limited to the control lines. Golder (Golder, 2009) suggested that moose and deer may have been attracted to the revegetated lines for forage availability and perceived cover protection. The preference for regenerating seismic lines by wolves may be explained as a response to increased prey use of these lines. More recently, pre-treatment (Dickie, 2015) and post-treatment wolf movement data is being gathered through the University of Alberta to look at the effectiveness of line-blocking within the Cold Lake region of Alberta. Wolves selected conventional seismic, pipelines, railway, roads, trails, and transmission lines, but did not select low-impact seis-

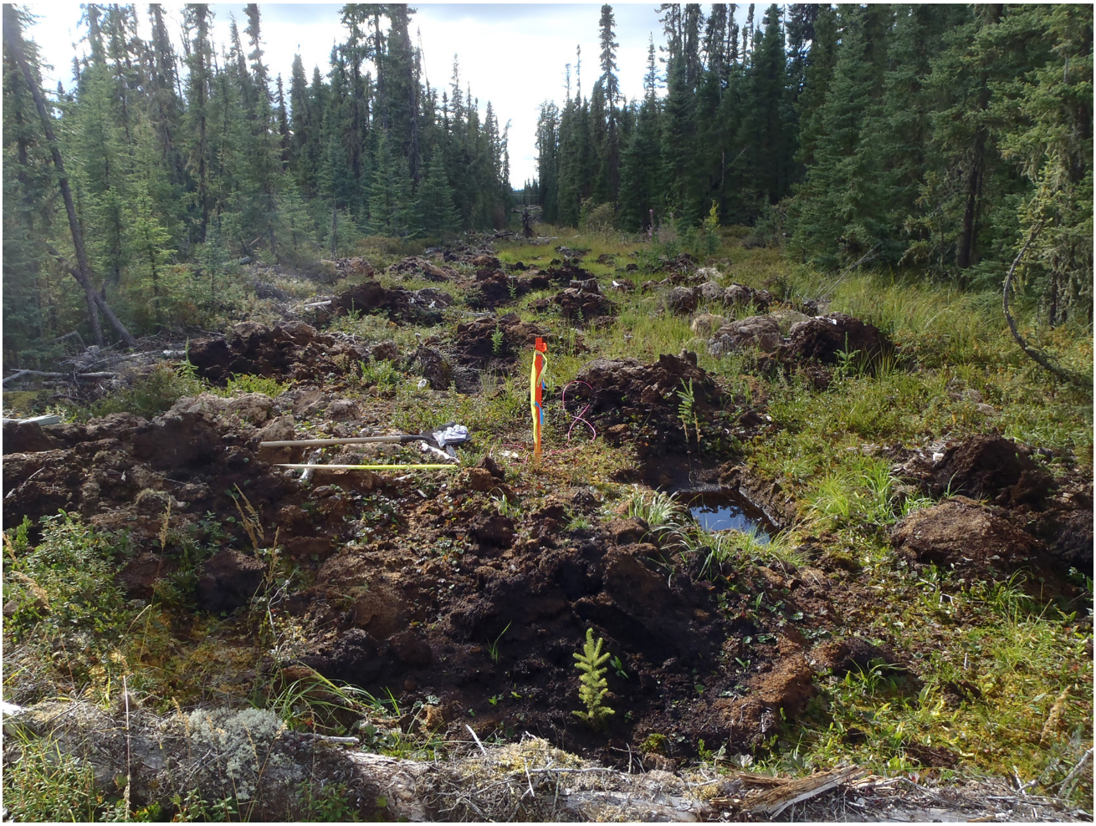

Figure 4. Mounding and seedling transplanting treatment location. Photo courtesy of Canadian Natural Resources Ltd. Primrose and Wolf Lake Project.

mic in summer (Dickie, 2015). Wolves selected all linear disturbance footprints in winter with the exception of trails (Dickie, 2015). Wolves moved faster on linear disturbance footprints as compared to surrounding forest, with the exception of low-impact seismic in both summer (30% reduction in travel speed) and winter (53% slower on low-impact seismic lines than in surrounding forest) (Dickie, 2015). While using linear features, wolves selected for shorter vegetation, changing their movement on linear features with increasing vegetation height, with a breakpoint of 1m in summer and 2.7m in winter. When travelling on linear features, wolf travelling speed decreased by 20% after linear features reached a height of 1m in summer, and travelling speed decreased by 26% after lines reached 2.7m in winter (Dickie, 2015).

The focus of habitat restoration initiatives has been on revegetation and access control, and limiting plant species that are favourable to wolves' primary prey, with the goals of creating line-of-sight breaks, directly restoring habitat with transplanted vegetation, planting shrub and conifer tree seedlings, sowing native shrub and tree seed, and controlling human access to reclaimed areas to allow undisturbed vegetation growth. Vegetation recovery in the medium and long-term following the creation of linear disturbances has not been extensively documented, however, the attributes of naturally revegetated linear features have been documented by the CRRP (CRRP, 2007b), the Foothills Research Institute (FRI, 2014), and van Rensen *et al.,* (2015). Natural regeneration does occur, with linear development features in mesic sites, the most likely to regenerate naturally without treatement, whereas a linear development feature in a bog or fen is least likely to regenerate naturally; and a narrow (<3m) line has improved regeneration over a wider line (van Rensen *et al.,* 2015). Natural regeneration to 3 m vegetation height is inversely related to terrain wetness, line width, proximity to roads as a proxy for human use of lines, and lowland ecosites (fens, bogs) (van Rensen *et al.,* 2015). Areas adjacent to major rivers illustrate high probability of regeneration. Overall, terrain wetness and the presence of fens has the stongest negative effect on natural regeneration (van Rensen *et al.,* 2015). Lack of time sequence recording for regenerating seismic lines and other linear developments reduces the ability to estimate natural rates and types of vegetation recovery, however predictive models do exist (e.g., van Rensen *et al.,* 2015).

Workshop results

Although the federal Recovery Strategy (EC, 2012) for boreal caribou describes the requirement for habitat restoration, it is not clear what defines successful habitat restoration. During the workshop participants discussed a proposed definition of habitat restoration: Restored (decades) - disturbed caribou range is returned to functional habitat that can support self-sustaining caribou population without ongoing intervention (e.g., predator control). Participants identified that habitat restoration needs to consider spatial and temporal scales, trajectories, as well as predator/prey dynamics.

During the restoration workshop, a number of the presentations discussed key elements of program planning, including authorization to implement restoration measures. Government of Alberta representatives acknowledged that an approval process needs to be developed that provides a consistent approach to authorize implementation of restoration treatments on historical seismic lines, and that development of the process is under discussion. As well, Alberta Environment and Parks presented draft restoration priority areas mapping, available upon request, to help direct where restoration efforts should be focused (D. Hervieux pers. comm., 2013).

Learnings from existing restoration programs were presented and included an awareness that not all linear disturbances are equal and that restoration on linear disturbances differs from silviculture prescriptions applied to cutblocks, given the higher variability in site conditions. As a result, the toolbox for restoration treatments needs to consider a number of variables, in particular the lack of a seed bed and mineral layer for plant growth and compaction.

It was discussed, based on previous initiatives, that prior to applying treatments on the ground, linear feature (and polygon) inventories of the existing footprint are the first steps in designing a restoration program. Collecting inventories help ensure an efficient allocation of resources committed to habitat restoration. For example, a pilot habitat restoration program in west-central Alberta approximately four townships in size and another pilot northwest of Cold Lake, approximately eight townships in size, reported that approximately 85% of linear features observed were already on a natural recovery trajectory and revegetation treatments were not recommended (CRRP, 2007c; Golder, 2010) (Fig. 1). Inventories are gathered using remote sensing to spatially map linear disturbances and the level of natural regrowth (e.g., van Rensen *et al.,* 2015). In addition to the amount of natural regrowth, field truthing of candidate treatment sites is completed to document detailed ground conditions. Data is collected on classifying the type(s) of disturbance (roads are considered severe disturbance whereas a cutline is often minimal disturbance), level of human (e.g., all-terrain vehicle) and wildlife (game trails) use, width and orientation of a line (impacts light penetration and moisture level), compaction level (impacted from construction practices), soil mineral layer (nutrients) and microsite availability, adjacent ecosite phase / forest attributes (very wet to very dry, upland/transitional/lowland), coarse woody debris level/availability/fuel loading considerations from a fire management perspective, and historical seeding practices which often results in high levels of competing vegetation to conifer seedlings (Vinge, 2013; CRRP, 2007c).

During the remote sensing and ground truthing of site conditions, treatment sites and prescriptions are finalized and often located into priority areas for restoration and to areas where human access control treatments will prevent repeated use. This ensures that the 'right lines for restoration' are selected. For large scale restoration programs, future development plans in the area (e.g., forestry harvest plans, lease areas, development footprints, pay depth to bitumen, etc.) (ALT, 2009), provincial priority areas, as well as a focused plan to create large, contiguous intact habitat areas should be considered. Restoration program development considers not only a planning scale, but a tactical scale with efficiency of operational implementation considerations. For example, the OSLI/COSIA program used a modelling approach called Landscape Ecological Assessment and Planning (LEAP) to enhance efficiency in bringing landscape data sources together to assess and develop restoration scenarios, strategic to tactical implementation plans, and monitoring plans (OSLI, 2012a).

Restoration toolbox

The objectives of past and current habitat restoration programs for caribou have been to restore habitat on existing anthropogenic footprint to create large contiguous habitat patches that can support self-sustaining caribou populations with historical predator-prey encounter rates. This objective implies that habitat restoration must address revegetation, predator and primary prey access, predator efficiency, and forage for primary prey species. Although the federal recovery strategy and analyses to set caribou recovery management measures indicate that habitat restoration is linked to improving caribou population projections, the feasibility (cost, large scale application, rate of restoration as compared to rate of ongoing development pressure) and predicted outcomes of restoration activities remain highly uncertain (ALT, 2009; Wilson *et al.,* 2010). This uncertainty includes the time lag required to recover disturbed areas to effective habitat to support self-sustaining caribou populations.

Based on monitoring of revegetation of existing disturbances, it is expected that vegetation recovery of disturbed areas will take decades, with or without intervention. To address the time lag associated with natural revegetation of linear features (Fig. 1), industries and governments have built a toolbox of habitat restoration treatment best practices, focused on establishing vegetation similar to adjacent forest communities, creating line-of-sight breaks, and discouraging human, predator and primary prey usage of linear features. The treatment best practices, including their objectives and recommended specifications, are summarized in Table 1. Inclusion of a reference in Table 1 was based on if the results of implemented treatments were successful, for the objective outlined (e.g., if a treatment met the objective of establishing vegetation along a segment of linear feature where vegetation did not exist prior to the treatment). Specifications and considerations for each treatment are also provided, based on positive evidence of success.

The treatments designed to promote revegetation of linear features are intended to address micro-site deficiencies, and are well recognized silvicultural practices modified for linear feature application. When implemented properly, these practices will meet their objective of establishing vegetation. Additional monitoring on site preparation treatments such as mounding and spreading woody debris are currently being researched in NE Alberta to determine their efficacy in achieving the goal of discouraging predator and primary prey usage of linear features. Although long-term results are not yet available, preliminary results indicate these methods are achieving this objective (Cenovus, 2014).

Implementing practices to reduce a new project's impacts at the construction phase will reduce the need for, and the amount of, habitat restoration required following construction. Construction practices which enhance the ability of a site to restore naturally will reduce the level of effort and cost of site preparation (e.g., mounding) and tree/shrub planting over the entire project. For example, three practices that can be implemented during or immediately following the construction phase of a project are minimizing line width (e.g., low impact seismic <3m width; Dickie, 2015), minimal disturbance vegetation removal (e.g., DES, 2004), and controlling off road vehicle access (Revel *et al.,* 1984).

Since the ability of cleared areas to quickly regenerate to native species following construction is affected considerably by human use, applying human access control measures, with effectiveness monitoring, along linear features should occur immediately following construction. Woody debris treatments, excavator mounding, berms, tree-felling and steel gates are treatment types that are effective immediately and can be considered; but require monitoring. The type of control can be determined by the amount of expected human use at the location, width of the linear feature, ecosite phase, and topography. For example, a seismic line seldom used by humans, crossing a newly constructed pipeline ROW, may be treated with excavator mounding and planted seedlings (e.g, Fig. 4), while a pipeline crossing of a winter access road, well-used by humans, may be treated with a greater density of excavator mounding, planted seedlings, along with a steel gate.

Reclamation criteria and guidelines for forested areas should be consulted prior to determining specifications and design of a tree and shrub seedling planting program. For example, the Government of Alberta guidelines for forest reclamation in the oil sands region (AENV, 2010) specify ranges of seedling planting densities that vary by the site type and species planted. These guidelines are not specific to caribou habitat restoration, and may need to be modified with consideration to measureable objectives for caribou habitat restoration. The Science and Community Environmental Knowledge branch of the Government of British Columbia has recently commissioned the creation of a Boreal Caribou Habitat Restoration Operational Toolkit for British Columbia that contains reclamation recommendations specific to caribou ranges, focusing on linear feature restoration (Golder, 2015a). Considerations for determining species, planting density and locations of planting should include site type (dry, moist/poor, moist/rich, wet rich), surrounding vegetation community, disturbance level (high with no LFH layer, low with LFH layer intact), coarse woody debris level, and site preparation (Vinge, 2013).

A critical component of a successful habitat restoration program is protection of the treatment locations from disturbance. Sites that have been developed using methods that promote speedy natural revegetation or planted to enhance revegetation, line-of-sight break locations, or access control treatments should be clearly marked in the field and protected with physical barriers if necessary. For example, seedlings planted on an upland graded site can be damaged or destroyed from human use of the ROW unless they are protected by a sufficient layer of coarse woody material.

Monitoring

Monitoring of construction practices, the success of treatments to establish vegetation, lines undergoing natural revegetation trajectories and the effectiveness of access control methods

Figure 5. Lease road prior to treatment with mounding, tree-felling, tree-bending, and tree transplanting. Photo courtesy of MEG Energy.

Figure 6. Lease road after treatment with mounding, tree-felling, tree-bending, and tree transplanting. Photo courtesy of MEG Energy.

is necessary for any habitat restoration program. Monitoring programs should be linked to restoration objectives and measureable targets for the program to determine success or opportunities for adaptive management measures within restoration priority areas. During the workshop participants discussed monitoring programs and the overall consensus was that there is a need for consistent design in what's being measured, that there should be near term variables measured to determine if a site is on trajectory (with consideration of revised reclamation certificate criteria); successional trajectories or milestones should be determined and monitored against; and there is a disconnect between the end goal of caribou population lambda and the desire to consider habitat restored as early as possible. Adaptive management on restoration programs will need to be implemented by adjusting and/or supplementing restoration measures, where warranted, to achieve the objectives of the habitat restoration initiatives. Monitoring programs will need to consider a number of response metrics including the wildlife response to restoration (multi-species including caribou population trends, wolf movement and behavior, and primary prey population response) and the site level response both short-term and long-term with successional trajectories or milestones developed (Cody, 2013). Given the relatively short time period since large scale habitat restoration programs have begun to be implemented, field results are currently in the early stages of reporting regarding the success of caribou habitat restoration methods meeting their objectives. Monitoring outcomes will inform adaptive management, allowing for modification of unsuccessful measures to continuously improve, and are an important means of addressing uncertainty.

Discussion

At the national scale, Alberta's woodland caribou are among the least viable in Canada (EC, 2011). Under the *Species At Risk Act*, in 2012 the federal government released its recovery strategy for woodland caribou, with a clearly outlined habitat threshold to meet critical habitat levels (EC, 2012). In four caribou ranges in northeastern Alberta underlain by oil sands deposits, on average only 24% of caribou habitat remains undisturbed, far below the recovery plan target of 65% undisturbed habitat (Pembina Institute, 2012). For any new project planned or project expansion within a caribou range in northeast Alberta, under the SARA, the new project footprint could be deemed destruction of critical habitat for the species. As such, planning for approved future development projects within caribou ranges will need to consider the entire mitigation hierarchy: avoidance of caribou range; minimizing impacts through project planning, utilizing the least footprint necessary, overlapping land uses (e.g., coordinated access planning, integrated land use management planning); planning out a comprehensive habitat restoration plan; and include off-sets to address residual project effects due to the time lag and uncertainty around habitat restoration success to caribou recovery.

Habitat restoration has been highlighted within the federal recovery strategy, as well as within the Alberta Caribou Policy (GOA, 2011) as a critical component of long-term caribou habitat management. Given the current range condition for caribou in Canada, recent National Energy Board and Federal Joint Review Panel conditions for pipeline ROW occurring within caribou ranges have included preparing, implementing and monitoring Caribou Habitat Restoration Plans (e.g., NGTL, 2014a; 2014b). These Caribou Habitat Restoration Plans provide details on the objectives of restoration plans, the criteria used to identify potential habitat restoration sites, the process to identify restoration actions to be used at different types of sites, quantifiable targets and performance measures that will be used to evaluate the effectiveness of restoration measures to offset impacts to habitat, as well as a follow-up monitoring program (NEB, 2013). Long-term vegetation removal and the time-lag associated with vegetation re-establishment to suitable caribou habitat are considered residual effects and are to be addressed with habitat offset measures for caribou (NEB, 2013).

Although habitat restoration activities have moved from pilot projects beginning in 2001 to large scale project implementation since the release of the recovery strategy, some cautionary details need to be considered. First, there is currently no direct link to indicate that implemented restoration treatments are having a positive effect on caribou populations. Although modelling scenarios of management options for caribou indicate that restoration of habitat should have benefits in the long-term by contributing to the restoration of large contiguous habitat patches that are preferred by caribou (e.g., ALT, 2009), additional management measures must be applied by governments to address the proximate cause of caribou declines. Specifically, governments must look to implement immediate population management of predators with effective habitat conservation measures (Hervieux *et al.,* 2014) and primary prey (CAPP, 2012). It has been noted that industry actions and planning around minimizing and eliminating project footprints will be of no value if caribou populations are not stabilized through aggressive wildlife (i.e., predator and alternate prey) management and long-term habitat conservation. It is recognized that the full benefits of habitat recovery will not be realized for decades because there is a 30 to 50 year lag time following reclamation before re-establishing vegetation becomes old enough to be considered low quality for other prey, and suitably old to be used by caribou (ALT, 2009). At a minimum, predator management through wildlife control will need to be continued for this entire lag period (ALT, 2009). Intuitively, extirpation risk of local herds will be reduced if habitat restoration begins as soon as possible (CAPP, 2012). Lastly, there is not a clear understanding of the desired objectives provided by regulators regarding landscape level habitat restoration programs. With no official framework, legislation or best practices within the provincial jurisdiction, it is difficult to implement consistent caribou habitat restoration and monitoring programs (Golder, 2013).

The driver to implement large-scale habitat restoration programs has been to lower the anthropogenic footprint within caribou ranges, and to address how caribou, wolves and primary prey species utilize habitat within restored areas. Although we have identified the planning and physical measures that can be implemented for a restoration program to begin restoring caribou habitat following construction or along historical linear features, it is unreasonable to directly associate local caribou population trends with these programs due to the time lag to grow vegetation; as well as the other factors contributing to these population trends, specifically the effects of apparent competitioninduced mortality on secondary prey such as boreal caribou (DeCesare *et al.,* 2010; Hervieux *et al.,* 2014), and the current rate of development. Monitoring and adaptive management of the restoration toolkit measures, and the wildlife response to these measures, will be a critical element of industry led habitat restoration programs.

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Table 1. Caribou habitat restoration treatment best practices.

Treatment	Objective(s)	Specifications	Positive Experiences with this Technique	Considerations to take into account	Ideal Timing for Treatment	References
Mechanical site preparation: Mounding and/or ripping using an excavator (Figures 4 and 6)	• Create microsites in areas where it is deemed to be effective for increasing survival and growth rates of planted seed and seedlings, and natural regrowth of woody species • Access control	• For access control purposes, mounds should be created using an excavator. The holes left behind by the mounds should generally be approximately 0.75 m deep, if feasible. The excavated material is positioned right beside the hole, creating the mounds. • Ripping should focus on upland sites where excessive moisture is not a concern. • Troughs created by ripping should be positioned to reduce erosion potential. • Target density of mounding for access control and/or microsite creation purposes can vary from 600 to 2,000 mounds/hectare (ha), depending on the size of the hole and mound. • When completing in synergy with seedling planting, seedlings are generally planted near the hinge of the mound: • Slightly higher up from the hinge for lowland and transitional sites • At or slightly lower than the hinge for upland sites	• For the purposes of creating microsites for planted seedlings, mounding is a well-researched site preparation technique in the silviculture industry. It is commonly used in wetter, low-lying areas to create elevated, welldrained microsites for seedlings • Mounding treed fen and bog areas can enhance a site to promote natural revegetation over time, as higher, drier spots are created that seed can eventually settle into and germinate • Mounding has been used as an access control measure on decommissioned roads, seismic lines, and pipelines to discourage off-road vehicle activity. It is effective immediately following implementation • Ripping is a standard forestry site preparation method that has been modified in this case for tighter workspaces	• Sufficient frost is required to access sites in the winter when crossing lowland areas: This varies from winter to winter • Research regarding machines that can operate in lowlands during non-frozen conditions is underway in NE Alberta	• Winter (frozen-ground conditions)	Macadam & Bedford, 1998 Roy *et al.*, 1999 MacIsaac *et al.*, 2004 Golder, 2010 OSLI 2012a, 2012b Nexen, 2013 CRRP, 2007b Archuleta & Baxter, 2008 USDA, 2009 BC MFR, 2014 BCFS, 1998 BC MOF, 2000 BC MFR, 1998

Table 1 continued.

Treatment	Objective(s)	Specifications	Positive Experiences with this Technique	Considerations to take into account	Ideal Timing for Treatment	References
Tree/shrub seedling planting (Figures 3 and 4)	• access control • erosion control • reduce line-of-sight • restore habitat	• Tree/shrub species are determined based on site conditions, the adjacent forest stand and restoration objectives (e.g., low palatability for ungulates). Coniferous tree species (Spruce sp., Pine sp.) are recommended to meet caribou habitat needs. Considerations for the use of shrubs: • Alder is generally planted because it forms an effective access control and line of sight break in a relatively quick period of time • Alder has a similar palatability rating for ungulates as conifer species (CRRP 2007b) • Willow is avoided due to the high palatability rating for ungulates (CRRP 2007b) • Shrub and tree seedlings are often planted together, depending on site conditions and anticipated natural revegetation of both species	• Seedling planting is considered a long-term restoration treatment due to the length of time it takes to establish effective hiding cover and access deterrents • Seedlings should ideally be sourced at least six months prior to planned planting dates • Seedlings and/or seed for growing seedlings may not be available for every species prescribed and therefore seed may need to be collected and grown in the nursery • Seedling planting during winter is generally restricted to lowland and transitional sites with organic soil that have been treated with mechanical site preparation immediately prior to planting • Seedling planting density for reclamation purposes has generally been based on adjacent site type and quickly providing hiding cover; it can range from 2,000 to 2,500 stems/hectare	• Use of frozen seedlings need to consider preparation of nursery stock, storage, planting temperature, and use of snow packing following planting to avoid winter freeze/thaw seedling mortality	• Seedlings can be planted on frozen sites in the winter (OSLI, 2012a; MEG, 2014; Cenovus, 2013) • Non-frozen stock are generally planted as summer stock in consideration of the Least Risk Timing Windows (BC) or Restricted Activity Period (AB) for caribou	AENV, 2010, 2011 BC MFR, 1998 Cenovus, 2013 CRRP, 2007b DES, 2004 Golder 2005, 2010, 2011, 2012b, 2012c MEG, 2014 OSLI 2012a, 2012b Nexen, 2013 NEIPC, 2010

Table 1 continued.

Treatment	Objective(s)	Specifications	Positive Experiences with this Technique	Considerations to take into account	Ideal Timing for Treatment	References
Spreading of woody material (Figure 2)	• control of human access during snow free periods • erosion control • protect planted seedlings from extreme weather, wildlife trampling, and damage from ATVs • provide site nutrients when the wood decomposes • provide microsites for natural seed ingress	• Spread woody material evenly across the entire corridor or polygon feature • Ensure woody material is consistently dense enough on the ground to discourage ATV and wildlife use • The Guide to Fuel Hazard Assessment and Abatement in British Columbia (2012) recommends woody loads do not exceed 99 tonnes/ha (~175 m^3/ha). An exemption may be allowed for larger volumes from the local fire centre under Section 25 or 26 of the Wildfire Regulation. • Vinge and Pyper recommend applying between 60 to 100 m^3/ha of woody material to reclaimed sites to mimic the natural range of variability for woody material in the forest • Implement at sites left for natural recovery when woody material is available as well as sites that are planted with seedlings	• The length of a treated segment is dependent on sufficient quantities of woody material available. Longer segments are a more effective treatment at controlling human access since ATV riders will be less inclined to attempt to travel through the woody material or traverse around it in adjacent forest stands if the woody material continues for an extended distance • Woody material can also conserve soil moisture, moderate soil temperatures, provide nutrients after it decomposes, prevent soil erosion, provide a source of seed for natural revegetation, provide microsites for seed germination and protection for introduced tree seedlings, and protect seedlings from wildlife trampling and browsing • Spreading of woody material is effective as an access control immediately following implementation • Woody material can be brought to a site from another location that has identical tree species	• Potential for fuel loading is a concern. The BC MFLNRO specifies acceptable levels of woody material while considering fire management objectives. Consultation with the local fire regulations recommended prior to treatment • Storage and use of woody materials may be compromised if bark beetle is a concern in the area and would be discussed with the local forest officer • Storage of woody material for extended periods without increasing fire hazard can be challenging and should be discussed with district fire managers as part of the planning process when using woody materials	• Winter (frozen-ground conditions)	CRRP, 2007b Enbridge, 2010 Osko & Glasgow, 2010 Golder, 2010, 2011 Government of Alberta, 2013 OSLI 2012a, 2012b BC MFLNRO, 2012 Pyper & Vinge, 2012 Vinge & Pyper, 2012

Table 1 continued.

Treatment	Objective(s)	Specifications	Positive Experiences with this Technique	Considerations to take into account	Ideal Timing for Treatment	References
Tree-felling/ Tree Bending (Figures 5 and 6)	• access control • reduce line-of-sight • reduce shade effect	• Bend (hinge) mature trees partially across the line with an excavator while treating the features for mounding purposes or spreading woody material • Fell mature trees across the line on upland and transitional sites (e.g., white spruce, pine, aspen, and black spruce) • An excavator is preferred for felling trees by pushing them over, if site conditions are suitable for excavator access • Trees can be felled with a chain saw if site access is suitable to address safety concerns • Trees are to be felled perpendicular to the line. Trees are not to be felled parallel to the line to reduce a fire hazard • Treatment locations to occur approximately every 20 m on lowland and upland sites • At each treatment location, 2 or more trees to be felled, from opposite sides of the line, to create an access control and line of sight break • Treatment locations should occur where sufficient sized timber is present. • Treatment locations should be as frequent as possible to discourage wildlife use, understanding that locations will be variable depending on forest stand adjacent to line • More trees to be felled near access points and intersections to restrict access and predator movement. Additional trees can be felled along identified lines where the adjacent trees are of suitable height (depends on width of line, need to cover across entire corridor)	• Tree-felling and tree bending across the line is mimicking natural processes that occur in the forest. • Tree-felling from the adjacent eco-site can reduce the shade effect on the corridor, leading to more sunlight and warmer soils, creating an enhanced environment for plant growth	• Tree-felling will result in tree mortality. Tree bending may keep trees alive with longer term needle cover • Potential for fuel loading is a concern. The BC MFLNRO specifies acceptable levels of woody material while considering fire management objectives. Consultation with the local fire centre is recommended prior to treatment. • Felling and bending is difficult to implement using hand fallers due to difficulties with access, and safety considerations. Mechanical equipment and site safety supervision should be considered • A permit may be required to fall trees that are outside the restoration site	• Winter (frozen-ground conditions	Cody, 2013 Cenovus, 2013 CRRP, 2007b MEG, 2014 Keim *et al.*, 2014

Table 1 continued.

Treatment	Objective(s)	Specifications	Positive Experiences with this Technique	Considerations to take into account	Ideal Timing for Treatment	References
Installing fences	• access control	• Fences can be installed at intersections with linear corridors and/or along a corridor where predator/human access control and line-of-sight breaks are required • Where natural topography or bends in the corridor do not break the line-of-sight, fences can be placed to limit access and sight lines • Wooden panels should be pre-constructed off-site, fastening the panels together at the treatment site to create a fence	• Fences could also be established using poles and geotextile or similar style decomposable matting • Gates can be installed on fences if desired to allow some operational access	• Fences are logistically challenging to establish in areas without pick-up access. • Used infrequently in the past and unknown efficacy • Installing fences during summer may be difficult to implement due to access availability	• Winter (frozen-ground conditions)	CRRP, 2007a