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ARCKP

Alberta Regional Caribou Knowledge Partnership

PROJECT REPORT

Alternative Silvicultural Systems and Harvesting Techniques for Caribou Habitat

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Alternative Silvicultural Systems & Harvesting Techniques for Caribou Habitat: Summary Version

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The Alberta Regional Caribou Knowledge Partnership (ARCKP)

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This document is a summary of the main report for this project, available from the ARCKP website at https://arckp.friresearch.ca/content/project-reports. Complete citations for the literature review elements of the project are available within the report.

Contents

Tables

Introduction

Urgent action is required to reverse caribou population declines that are occurring throughout Alberta and to meet federal targets for reducing habitat disturbance under the Species at Risk Act. Caribou declines are attributed primarily to anthropogenic habitat alteration, from a range of sources, such as oil and gas development, commercial forestry, and recreation.

Alternative silvicultural systems have potential to allow for a **working landscape** with some level of timber harvest whilst also minimizing negative impacts on caribou. However, widespread adoption of alternative silviculture systems over conventional clearcut forestry remains constrained by knowledge gaps, financial considerations, and policy restrictions. While there are limited caribou-specific trials of alternative systems in Alberta, experience from other jurisdictions and re-purposing of other studies provides guidance in how such systems could be applied.

Forestry in Alberta is a multi-billion-dollar industry and a crucial employer in many rural communities, directly employing 17,500 people and supporting another 23,900 jobs[1].

38% of Alberta's green (forested) zone is within caribou range and over half of Boreal caribou range and nearly all of Southern Mountain winter caribou range is under Forest Management Agreement or other major forestry tenure.

Almost all forestry in Alberta implements an ecosystem-based management approach that makes use of the clearcut harvesting system, supported with retention left within blocks. While this system attempts to emulate the characteristics of natural disturbance, it also causes near-term loss of caribou habitat and often increases apparent competition. This project uses literature review and interviews with subject-matter experts to identify and review alternative silvicultural systems for their potential to reduce negative impacts on caribou while still allowing for timber harvest. Interviews were open-ended, encouraging participants to discuss a range of ideas and identify innovative alternatives.

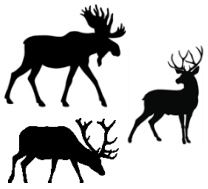
"We tend to have fixed ideas about how we should do silviculture in Alberta, but there's so much more we could be doing, so this may be an opportunity to think about some of the possibilities and not just the current realities."

Impacts were assessed from three main perspectives, considered relative to clearcutting with retention:

- *Minimization of forage availability for other ungulates.* Clearcutting typically results in increased levels of early seral stage vegetation favored as browse by species such as moose, deer, and elk. This habitat supports higher populations of these species, in turn supporting higher populations of predators, which incidentally prey on caribou, causing unsustainable mortality. This mechanism for decline is known as **apparent competition**.
- *Maintenance of caribou biophysical habitat and associated forage resources.* Where harvesting occurs in areas of biophysical habitat, particularly mature and old conifer forest, it results in the near-term loss of that habitat. Since caribou need large, contiguous areas of intact forest and avoid harvested areas, minimizing loss of habitat and/or recovering habitat more rapidly is important.

Other Ungulates

Young stands (<60 years)
Deciduous/Mixedwood
Lush understory
Edge/matrix habitat



Caribou

Old stands (60-80+)
Semi-open coniferous
Sparse understory
Avoids edge, cut areas

[1] https://www.alberta.ca/forest-business-overview.aspx

- *Minimization of the extent and duration of access.* Linear features have been shown to facilitate more efficient access for predators, prey species, and people, ultimately exacerbating predation pressures on caribou. Minimizing access into caribou habitat, particularly for predators such as wolves, is key to reducing predation pressure on caribou.

We consider silviculture as defined by Lieffers *et al.* (2003) as *"the theory and practice of controlling the establishment, composition, growth, and quality of forest stands to achieve the objectives of management"*. A **silviculture system** is a framework, outlining the set of specific treatments, including harvest method, that will be applied in order to achieve a particular set of management objectives. We can think about the term silviculture as referring to the overarching harvest and regeneration systems and/or to the specific treatments applied within a system. **Silvicultural treatments** are specific actions taken within silviculture systems to develop the desired forest structure and composition is achieved of a stand.

Key Systems & Treatments

Clearcut System: Even-aged system in which all or most trees are removed from the stand in a single cut at planned intervals (rotation). It is the dominant system in Alberta because the majority of Alberta forests are fire origin and clearcutting mimics the open forest conditions that occur post-wildfire, allowing for rapid and efficient reforestation of fire-adapted species that regenerate well in full light conditions.

Shelterwood System: Removal of mature trees in a series of patch or strip cuts over a short period (e.g. 20-30 years), in order to regenerate an even-aged stand under the shelter of existing canopy. The term shelterwood is often also used in a more general context for some forms of partial harvest. Irregular shelterwood results in irregular (multi-cohort) structure.

Understory Protection System: Even-aged system in which the deciduous canopy in aspen stands is removed to encourage recruitment of white spruce found in the understory. In Alberta, used in aspen stands with a white spruce (or sometimes balsam fir) understory. Could be used to minimize understory browse species response.

Selection Systems: Uneven-aged system in which mature timber is removed in small groups or single trees at short intervals (e.g. 10-25 years), maintaining an uneven-aged stand. Could be used to retain biophysical habitat and minimize understory response.

Intensive Silviculture: Intensive silviculture refers to the application of a higher intensity and/or number of treatments to a stand in order to maximize timber output, often to the detriment of other forest values. Intensive management is not widely applied in Alberta but other jurisdictions such as Québec have adopted some elements as part of a zoning or TRIAD approach to forestry. Not strictly a silviculture system but could be used to mitigate timber volume reductions from areas where alternative systems are applied.

Commercial Thinning Treatment: A silviculture treatment used in immature stands that have reached merchantable size. It allows for some timber volume to be extracted earlier than in a traditional clearcut system where the stand would be left until maturity, while also improving the growth and quality of remaining trees.

Herbicide Treatment: Herbicide treatments are an effective method for managing competing vegetation to ensure successful seedling establishment and are effective at reducing elk, moose, and deer forage availability in the short-term.

Site Preparation Treatment: Site preparation commonly refers to the mechanical modification of soils in preparation for planting of seedlings. It is most often used in a clearcut system but can also be used in other systems. Typically used to improve planting sites but could also be used to control browse species and deter movement.

Stocking Density Treatment: High stocking densities can increase the rate at which a stand regenerates to be above the browse line and to shade out understory browse species.

Artificial Seeding Treatment: Alternative to planting, typically using aerial dispersion. Can result in dense stands.

Results

A number of relevant case studies from Alberta, British Columbia, and Quebec were selected and reviewed. Some studies are explicitly focused on how to use alternative systems to promote caribou habitat or minimize apparent competition, while others are primarily focused on other aspects of forestry but still have relevance to these questions.

- In coniferous stands, partial harvest systems with varying levels of removal and spatial layout can maintain old forest characteristics and associated terrestrial and/or arboreal lichens that caribou rely upon. Such systems have been extensively trialed in other jurisdictions. However, accompanying caribou population monitoring is often unavailable, making it difficult to know if favorable forest structure outcomes translate to continued caribou use.

- For apparent competition, the outcomes are mixed. In some cases the maintenance of canopy cover can prevent a significant response from the understory. However, in other cases, such as in highly productive sites, partial harvest systems can lead to a major "flush" of highly palatable early seral stage growth, creating excellent habitat for other ungulates.
- Single-tree selection systems show potential, for example, through the use of commercial thinning treatments. These result in a more open stand structure, which can favour lichen growth, while providing timber volume. To be favorable to caribou in the long-term, a clearcut could be replaced with a commercial thinning treatment and perhaps a series of thinnings over time if the access limitations can be addressed.
- Deciduous and mixedwood forests in or near to caribou habitat are important because harvest in these areas using standard practices increases early seral stage habitat availability and therefore apparent competition.

- Understory protection is sometimes used in deciduous stands to remove mature deciduous overstory while protecting and releasing the regenerating coniferous understory. Under the right conditions, such as when the coniferous understory is well stocked, it may be effective at suppressing aspen suckering and the growth of other browse species, creating an opportunity to harvest timber whilst minimizing habitat quality for other ungulates. This system also accelerates development of conifer, which may result in return to or creation of caribou biophysical habitat sooner than under natural conditions. Understory planting could also be used when natural coniferous regeneration is unevenly distributed.
- Partial harvest systems in deciduous or mixedwood stands may also be an option in some cases for reducing understory browse species response by maintaining canopy cover.

Key Trade-Offs

Access requirements are an Achilles heel for many alternative systems. Increased access can bring more predators, other ungulates, and people into caribou habitat. In some cases, the negative effects of additional access may outweigh the benefits of adopting alternative systems, although there is much uncertainty in quantifying this. Aggregated harvest utilizing partial harvest systems with a single entry may be one option but will have significant timber volume and financial costs.

Alternative systems, particularly low removal partial harvest and single-tree selection systems, involve additional costs and/or lower timber volume removals per unit area, increasing harvest costs and reducing Annual Allowable Cuts. In addition, if we assume mill requirements remain constant, adoption of partial harvest systems risks spreading disturbances across caribou habitat.

Table 1. Summary of case studies and their key characteristics.

Case Study	Alternative System(s)	Location	Forest Type(s)	Scale	Study Focus	Measurement(s)	Takeaway(s)
EMEND	Variable retention (aggregated & clump)	Northwest Alberta	Coniferous, Mixedwood, and Deciduous.	Extensive replicated long-term trial	Overstory and understory vegetation. Also, caribou and other ungulate use.	Understory response (vascular plants, lichen, bryophytes, graminoids), wildlife response (including caribou, moose, and deer via camera traps / pellet transects), soil, productivity.	Caribou didn't use stands with <20% retention, use increased with level of retention. Moose / deer showed no response. Higher retention resulted in less understory cover with evidence for a threshold between 10-20% retention. Understory response differences absent 17 years post-harvest though composition altered. Opportunity to use data to examine understory response in context of moose / deer habitat quality.
Commercial Thinning in West-Central Alberta	Single-tree selection via commercial thinning	West-central Alberta	Coniferous (lodgepole pine dominant)	Local trial	Terrestrial lichen abundance and understory vegetation.	Lichen and bryophyte abundance, vascular plants.	Commercial thinning treatments maintained (but did not increase) terrestrial lichen abundance. Understory vascular plant abundance similar to controls in this system.
Hotchkiss River Mixedwood Management Demonstration Area	Understory Protection	Northwest Alberta	Mixedwood	Long-term replicated trial	Understory protection techniques, including minimizing wind damage and encouraging regeneration.	Understory spruce response, windthrow risk, regeneration.	Data may be useful to investigate how understory protection could be used to minimize understory response in mixedwood stands in or near to caribou ranges.
Itcha-Ilgachuz	Group selection, variable retention, irregular group shelterwood	West-central British Columbia	Coniferous (lodgepole pine dominant)	Replicated long-term trial	Forage lichens.	Lichen response, windthrow risk, regeneration.	Arboreal lichen maintained with 30% group selection system and terrestrial lichens maintained with 50% shelterwood system. Rate of lichen recovery varied by treatment. Minimal understory vegetation response in this system.
Quesnel Highland	Group selection	East-central British Columbia	Coniferous (Engelmann spruce & subalpine fir dominant)	Replicated long-term trial	Arboreal lichen.	Arboreal lichen response to harvest.	Arboreal lichen maintained sufficiently at 30% retention.

Case Study	Alternative System(s)	Location	Forest Type(s)	Scale	Study Focus	Measurement(s)	Takeaway(s)
Mount Tom	Group and single tree selection	East-central British Columbia	Coniferous (Engelmann spruce & subalpine fir dominant)	Replicated ongoing trial	Habitat attributes, caribou use, alternative prey & predator use.	Lichen response, wildlife response (caribou, mule deer, moose), understory vegetation.	Arboreal lichen maintained in residual forest. Caribou avoiding group selection blocks while use by moose has increased.
Northeastern Quebec	Diameter-limit cutting (CPPTM), single tree selection	Northeastern Quebec	Coniferous (black spruce dominant)	Small-scale trial	Habitat attributes, wildlife use (did not include caribou).	Old growth forest attributes, tree mortality, wildlife response (did not include caribou).	CPPTM negatively impacted closed-habitat wildlife species. Selection cutting with 65% retention recommended to preserve old-growth forest attributes.
North Shore	Aggregated diameter-limit cutting	Northeastern Quebec	Mixedwood (balsam fir, white spruce, black spruce, birch)	50,800 ha trial area	Aggregation and caribou use.	Caribou occurrence, vegetation surveys.	Couldn't determine a preference between harvest techniques. Caribou avoided cutblocks and adjacent protected areas. Patches 55-182 km^2 too small to maintain populations long-term. Larger protected areas & better connectivity recommended.
Western Quebec	Partial harvest systems	Western Quebec	Coniferous (black spruce dominant)	Small-scale trial	Terrestrial lichen response to partial harvest.	Terrestrial lichen abundance, lichen transplants	Partial harvest maintained higher abundance of terrestrial lichens than clearcutting. Understory response in more determined by soil disturbance than the level of overstory removal.
Gaspé Peninsula	Gaspé Peninsula, Quebec	Diameter-limit cutting, seed tree, commercial thinning, single tree and group selection, shelterwood.	Mixedwood (balsam fir, white spruce, black spruce, white birch, yellow birch)	Large-scale retrospective analysis.	Arboreal lichen response to alternative silvicultural systems. Caribou habitat attributes and understory response.	Arboreal lichen abundance, Overstory and understory response (number of sapling and fruit-bearing shrubs, vegetation cover, lichen).	Commercial thinning (67-70% retention) and shelterwood (50-70% retention) maintained some suitable caribou habitat characteristics and minimized understory response; selection and partial harvest treatments with 60-75% retention intermediate. CPRS (clearcut), diameter-limit cutting, and seed tree removed most arboreal lichens and favored predators.

Table 2. Summary of selected harvest systems and treatments and their possible impacts on caribou habitat, other ungulate habitat, costs, and access requirements. Entries are colour coded (reds = negative, greens = positive, grey = not applicable or unknown).

Silviculture System	**Caribou Habitat:** *Old-growth forest characteristics + lichen/forage availability.*	**Other Ungulate Habitat:** *Early-seral forest + herbaceous forage availability.*	**Economics:** *Costs of harvest, regeneration etc.*	**Access:** *Requirements for additional infrastructure & length of time roads must remain open.*	**Notes:** *Additional considerations and research needs.*
Clearcut	Old forest characteristics and associated lichen resources are lost.	Early seral stage habitats are created, favouring other ungulates.	Efficient and cost-effective system for harvesting and regeneration.	Access and disturbance can be minimized by using a single-entry and aggregated harvesting.	Herbicide treatments, site preparation, and increased stocking density may be able to mitigate the increase in habitat quality for other ungulates by minimizing early seral stage vegetation and maximizing rate of forest re-growth.
Seed Tree					Seed tree systems unlikely to benefit caribou and not well suited to Alberta's tree species.
Shelterwood	Can be used to maintain forest structure and terrestrial lichens in some circumstances.	Could be used to minimize understory response in some circumstances.	Harvesting in patches or strips more cost-effective & efficient than single tree removal. Additional pre-planning costs.	Access requirements vary by number of entries. In-block roads/skid trails can be temporary or permanent.	Shelterwood may prevent a flush of understory vegetation depending on the size and spatial pattern of removal. High levels of retention likely required to maintain caribou habitat; varies by productivity of the system. Windthrow is a significant concern.
Understory Protection	Accelerates the succession of deciduous stands to coniferous stands which may lead to the development of caribou habitat earlier than what would have occurred naturally.	If coniferous understory is well developed, it may effectively shade out aspen suckering and other browse species.	Harvesting in patches or strips more cost-effective & efficient than single tree and group selection removal. Additional pre-planning and monitoring costs but can accelerate conifer development resulting in increased AAC at forest level.	Final entry eventually required when understory matures. If natural regeneration is successful, roads can potentially be deactivated between entries.	A well-developed coniferous understory that is released may hinder deciduous vegetation growth. Can also provide economic and ecological benefits as conifer volume growth is accelerated without the use of site preparation, planting or tending with herbicides.

Silviculture System	**Caribou Habitat:** *Old-growth forest characteristics + lichen/forage availability.*	**Other Ungulate Habitat:** *Early-seral forest + herbaceous forage availability.*	**Economics:** *Costs of harvest, regeneration etc.*	**Access:** *Requirements for additional infrastructure & length of time roads must remain open.*	**Notes:** *Additional considerations and research needs.*
Group Selection	Can effectively maintain old-growth forest characteristics and associated arboreal lichens.	Can promote ideal habitat for other ungulates through early seral stage response and edge habitat availability, but results depend on site conditions.	Harvesting in patches or strips more cost-effective & efficient than single tree removal. Additional pre-planning costs. Re-entry to stands required for subsequent harvests.	Access requirements higher but vary by number of entries. In-block roads/skid trails can be temporary or permanent.	Group selection using small openings has been used to maintain arboreal lichens in British Columbia, but also led to increased habitat use by moose. This might be less of an issue in lower productivity systems. System could be adjusted in terms of patch size and layout.
Single-tree Selection	Can effectively maintain old-growth forest characteristics.	With low removal level and suitable site conditions a large understory response favouring other ungulates can be avoided.	Additional planning, marking, site supervision, and specialized skills and machinery typically required.	Extensive road network typically required. Access may be required indefinitely for repeated entries.	Single-tree selection or thinning treatments may accelerate development of old-growth stands and maintain or even promote lichen. Should also avoid major understory response if removal level is low enough relative to site productivity.
Diameter-limit Cutting	Removing the largest trees causes loss of arboreal lichen but unclear impacts on terrestrial lichens.	May result in increased other ungulate habitat desirability.	Additional planning, marking, site supervision, and specialized skills and machinery typically required. Light removals typically made on short (e.g. 15-20 year) cycles.	Extensive road network typically required. Access may be required indefinitely for continuous cover forestry.	Used primarily in Quebec and Ontario. Some indication that CPPTM cutblocks are avoided by caribou but frequented by moose. The removal of large, mature trees removes arboreal lichens and increases forage for other ungulates.

Silviculture Treatment	Caribou Habitat: *Old-growth forest characteristics + lichen/forage availability.*	**Other Ungulate Habitat:** *Early-seral forest + herbaceous forage availability.*	**Economics:** *Costs of harvest, regeneration etc.*	Access: *Requirements for additional infrastructure & length of time roads must remain open.*	**Notes:** *Additional considerations and research needs.*
Commercial Thinning	Can be used to maintain forest structure and terrestrial lichens.	Can minimize understory response but dependent on site conditions and level of removal.	Provides flexibility in wood supply and can be used to produce larger diameter timber more quickly.	Expectation that access remains available to allow for multiple entries.	Existing research shows this treatment can effectively maintain terrestrial lichen availability, but it is unclear if caribou continue to use treated areas.
Herbicide	Mixed/inconclusive evidence on response of terrestrial lichens.	Arguably the most effective silvicultural treatment available to control competing vegetation.	Cost-effective treatment used to improve seedling survival.	No additional access requirements unless ground application is utilized.	Significant societal push-back against use, particularly aerial spraying. Banned on crown lands in some provinces.
Stocking Density		High stocking densities decrease time for overstory to shade out understory browse species.	Additional planting costs incurred to increase stocking density.	No additional access requirements.	Growth rate of stands will decrease following stand closure which would impact the rotation age and potentially the AAC for the forest .
Artificial Seeding		Typically results in high-density stands and so may decrease time for overstory to shade out understory browse species.	Relatively cheap treatment but not effective for all species, variable success rates.	No additional access requirements.	

Discussion

While the investigation of alternative silviculture systems demonstrated that silviculture can be an effective method to alter vegetation to favour components of caribou habitat with a reasonable degree of confidence, there is insufficient information to assess the costs and benefits of different silvicultural prescriptions and if the result is a net positive for caribou. However, we can surmise that given the large spatial scales required for self-sustaining caribou populations, if alternative silviculture systems are utilized, they would need to be applied throughout ranges and on a sustained basis to affect caribou population trends.

We caution that results from the reviewed systems will be highly dependent on forest type, site productivity, and extent of required access. There is the potential for some systems to have negative impacts if applied in the wrong situation. As such, it is vital that any alternative system is carefully evaluated in the context of local conditions.

The impacts of alternative systems must be considered in the context of:

- Caribou habitat attributes
- Apparent competition
- Access requirements

The interplay between these components, local site conditions, and the details of how a system is implemented is crucial to success. The relative importance of each component is likely to vary depending on location. For example, in much of the boreal less than 50% of the land under forestry tenure is managed for timber production, leaving large areas of caribou biophysical habitat always unharvested. Addressing apparent competition is likely to be more important in these systems than maintaining lichen availability in harvested areas. In some areas, such as the foothills, a much larger proportion of tenured area is actively managed for timber production (e.g. 70%+), meaning that the relative importance of apparent competition and maintaining forest structures is different and both must be addressed.

Interviews: *What we Heard*

Apparent competition is an important driver of caribou declines and the key focus for any attempt to use alternative systems to improve outcomes for caribou.

It is also crucial to avoid the loss of high-quality caribou habitat itself, particularly in areas with a heavier disturbance footprint.

While we should be cautious about applying findings from other jurisdictions within Alberta's ecosystems, we cannot wait for perfect knowledge to act.

Management objectives and target stand conditions should be identified and more clearly defined.

New harvest systems or techniques need controls and quantitative monitoring to assess outcomes.

Intensive silviculture, perhaps through a zonation approach, could be an opportunity to increase harvested timber volumes in less ecologically sensitive areas and create space to reduce pressure in caribou ranges (e.g. through using alternative systems with lower levels of removal).

Cross-discipline collaboration between silviculturists, wildlife biologists, and foresters should be improved.

Both provincial legislation/standards & the existing forestry status quo in Alberta are significant barriers to adoption of alternative systems.

The lack of information on caribou responses to alternative systems is an unknown and a risk.

Understanding where a system could be adopted effectively and how it should be adapted to local conditions is a challenge. A framework using light conditions and site productivity to identify expected understory responses could be beneficial in this context. We also still have relatively little data on caribou responses to alternative systems, especially at the landscape scale, which is a major knowledge gap. Large-scale monitoring of caribou, other ungulates, and predators must be a part of future initiatives if we are to make progress in this regard.

Widespread adoption of alternative systems over conventional clearcut forestry therefore remains constrained by knowledge gaps, financial considerations, and policy restrictions. Nevertheless, given the urgency of caribou declines in Alberta we recommend that large-scale attempts be made to trial, operationalize, and monitor alternative silvicultural systems. The literature review and interviews show the complexity, intricacies, and uncertainty in attempting to apply alternative systems to manage for caribou habitat and maintain a working landscape.

Pilot Planning Study

We recommend that the information assembled in our review on the role of alternative silviculture systems be applied in a strategic planning exercise designed to better assess the cumulative trade-offs for a large component of a caribou range. This approach will allow for an efficient investigation of the costs and benefits of the integration of alternative silviculture systems in terms of caribou habitat, but also in terms of impacts on other forest values. A detailed planning approach is required as alternative (non-clearcut) silviculture systems can only be successfully applied to a limited range of stand conditions whereas clearcutting can be applied to any stand condition with merchantable timber. The limitations on practical application and extent of alternative silviculture systems will have impacts on their ability to influence caribou habitat. Detailed local knowledge will be required to develop plausible plans.

We recommend assembling a multidisciplinary team of forestry professionals, biologists, and government representatives with the necessary expertise in strategic planning, ecological dynamics, caribou biology, and silviculture. Collaboration of this group of experts will help to ensure success in the determination of a comprehensive understanding of the opportunities that exist at the stand- and forest-levels and identify requirements for implementation of an effective but practical strategy.

We propose the following steps:

1. Select a large-scale component of an Alberta caribou range where harvesting is permissible. One opportunity could be to make use of Harvest Timing Units (HTUs) that have been or are being developed by Alberta forestry companies for the purpose of aggregated harvest planning. It is assumed that these HTUs will be clearcut harvested, but for this study a selection of HTUs could instead be re-planned with a focus on alternative harvest systems. Other HTUs scheduled for clearcut and HTUs with no near-term harvest plans would make effective controls. However, at this scale it may be difficult to assess impacts to timber harvest volumes (AAC) and to better address this, planning at an FMU scale could be more appropriate. Ultimately the scale and location of the study area would need to be discussed and defined by the participants in the process.
2. Consider the application of treatments that are possible with the existing forest structure to achieve the stand level objectives (varies by range). Evaluate the present stratification for the forest and enhance it where necessary to align with the proposed silviculture alternatives.
3. Develop a matrix of scenarios to test.
4. Develop stand-level vegetation objectives that are positive for caribou and negative for other ungulates, to direct silviculture prescriptions.
5. Develop silviculture treatments to either maintain or speed up the development of desirable vegetation, considering practical operational limitations but without restrictions on the use of existing equipment or costs.

6. Develop growth and yield models and transitional yield curves that would be representative of alternative silviculture treatments. Include yield curves for lichen abundance if possible. Identify costs for operational planning, access requirements, etc.
7. Quantify the costs, timber extracted, and rates of production from each treatment and assign scores for caribou habitat or other prey, perhaps with qualitative rankings by experts for some attributes.
8. Field visits will be required to determine practicable applications and plausible vegetation trajectories, including to areas with existing trials or implementation of alternative systems.
9. Integrate alternative silviculture, including estimated growth and yield projections, access requirements, and costs into a spatial modeling framework to evaluate management scenarios.
10. Compare and contrast scenarios for caribou and other ungulate habitat values considering access impacts along with timber production and costs.
11. Detail how monitoring of vegetation, caribou, other ungulate, and predator responses would be achieved and the associated costs. Without an effective monitoring component, it will not be possible to evaluate success or failure.
12. If the pilot planning study indicates that positive outcomes could be achieved, move to an implementation phase.

Additional Recommendations

Knowledge Exchange: Organized workshops to facilitate knowledge exchange between silviculture experts, professional private-sector foresters, and wildlife biologists. This could be incorporated into the pilot planning study. A project to provide a practical, visual guide to the forest characteristics of high-quality caribou habitat in different parts of the province, perhaps driven by existing telemetry data and on-the-ground data and image collection. This would help to facilitate discussions between silviculture specialists and caribou biologists.

Utilizing Existing & Planned Trials: EMEND has a wealth of data on understory response to different levels of retention as well as post-harvest terrestrial lichen data that has not yet been analyzed. The Hotchkiss River Mixedwood Management Area and other understory protection trials could inform if and when understory protection systems could be used to reduce habitat quality for other ungulates. Long-term partial harvest trials in British Columbia and Quebec have a wealth of information available that could be used to help identify specific partial harvest systems that might be used in caribou ranges.

There are opportunities to "piggyback" on future trials with a caribou-focused component (e.g. large-scale planned trials for commercial thinning by FGrOW). By incorporating an understory monitoring component in these trials, important insights could be gained at relatively low cost.

Research: The review presented in this report, as well as the feedback from subject-matter experts, makes it clear that the impacts of any alternative silvicultural system or harvesting technique are highly dependent on the specifics of the system and the local forest and ecosystem. There is significant risk with many systems because under some conditions, outcomes for caribou might be worse than clearcutting. In the context of apparent competition, we expect there to be a range of understory responses that can be quantified based on light levels (amount of canopy removal) and site conditions (productivity). A research goal should be to define the boundaries of these axes and identify if there are "sweet spots" where minimal understory response and maintenance of caribou habitat can be achieved (e.g. using forage availability, ecosite types and site index, canopy cover and structure using LiDAR, and light models).

"I think that conversation is at the interface of objective setting and implementation. I think the biggest part of this is we need ecosystem management professionals to sit together and talk these things through. To date […] we're not really having that conversation on objective setting."