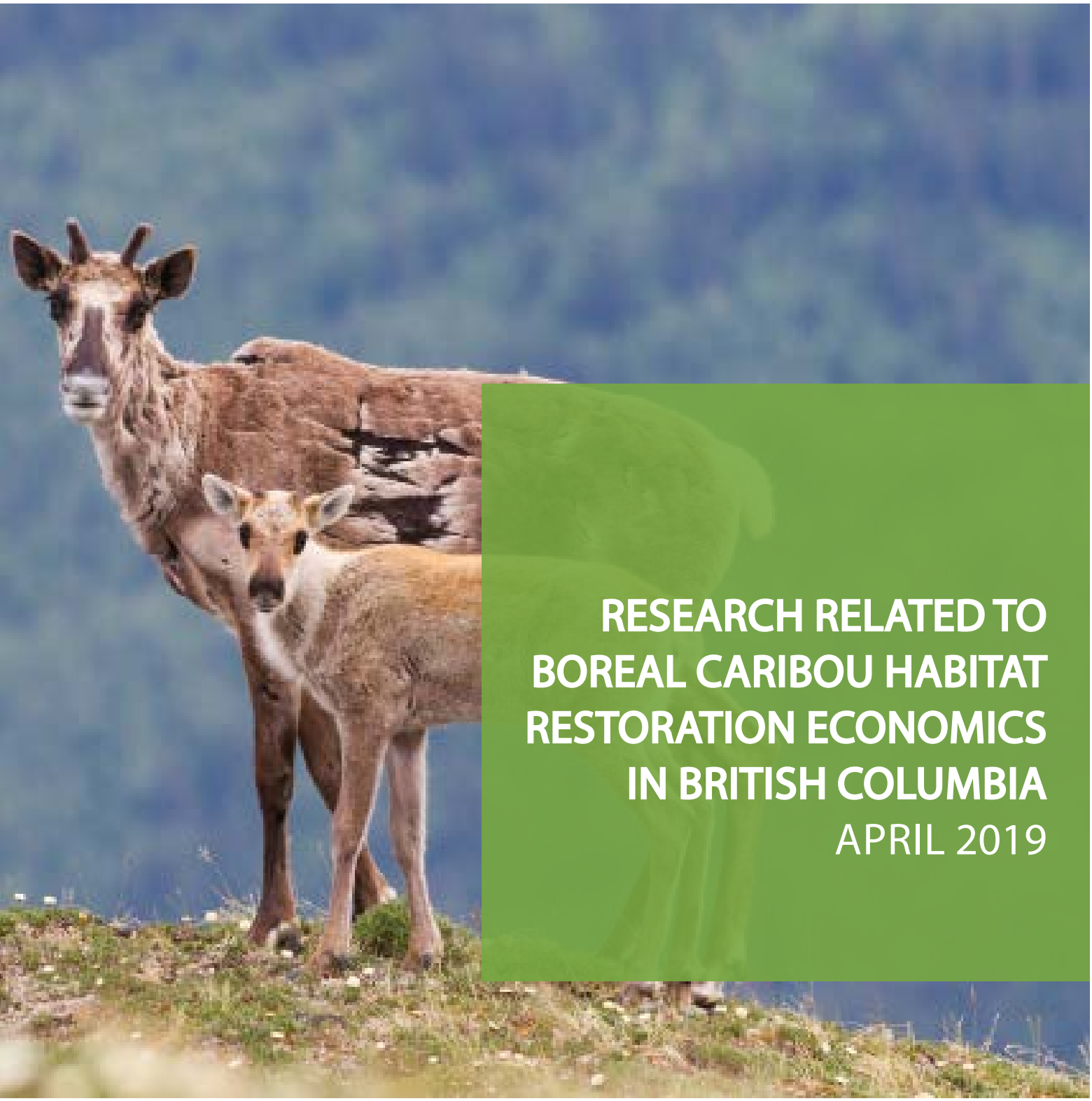

RESEARCH RELATED TO BOREAL CARIBOU HABITAT RESTORATION ECONOMICS IN BRITISH COLUMBIA

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ABOUT THIS STUDY

The David Suzuki Foundation contracted Anielski Management Inc. (Edmonton) to conduct an independent full-cost-benefit accounting and economic analysis of woodland caribou habitat restoration in northeastern British Columbia. Anielski Management Inc. is entirely responsible for the design, analysis and conclusions of its study. Conclusions reached by Anielski Management are its own and not necessarily those of the organizations that commissioned and/or funded this study.

ABOUT THE AUTHOR

Mark Anielski is president and CWO of Anielski Management Inc., based in Edmonton, Alberta. He has over 30 years' experience in natural capital accounting and natural resource economic analysis. He has completed numerous natural capital accounting studies in Canada, including Canada's boreal forest ecosystem and major watersheds (Mackenzie and North Saskatchewan). He is former adjunct professor of corporate social responsibility at the Alberta School of Business. He is schooled in accounting, economics and forest science, with three degrees, including a master of science in forest economics from the University of Alberta.

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EXECUTIVE SUMMARY

Woodland caribou (*Rangifer tarandus caribou*) populations across Canada's boreal forest have been in dramatic decline for decades mainly because of loss and fragmentation of their mature boreal forest ecosystem due to industrial development from oil and gas, mining and forestry development.

Linear disturbance from seismic lines, roads and pipelines has resulted in loss of mature forest habitat and increased exposure of woodland caribou to predators such as wolves. These impacts are now exacerbated by climate change.

In response to their declining populations throughout Canada, the federal government has designated boreal woodland caribou as threatened under the Species at Risk Act. Provinces have a commitment under the Accord for the Protection of Species at Risk, under which each province and territory committed to provide protection for the habitat of threatened and endangered species.

Environment Canada's recovery strategy for the boreal population of woodland caribou for B.C.'s non-self-sustaining herds calls for undertaking "landscape level planning that considers current and future boreal caribou habitat requirements."[1]

The B.C. government has set a caribou range undisturbed ecosystem target of a minimum of 65 per cent, based on the federal government's desired objective for the recovery of caribou populations, which, for many ranges, will require habitat restoration. Of a total 3,199,485 hectares of woodland caribou range areas in the boreal forest regions of northeastern B.C., roughly 76 per cent (1,328,240 hectares) has been disturbed as a result of industrial linear disturbance, including seismic lines, well sites, pipelines, roads and cutblocks. However, according to some recent estimates for Alberta using more advanced geospatial analysis and wall-to-wall human footprint mapping protocols, the Environment Canada linear disturbance estimates may be underestimated between 11 to 23 per cent depending on the respective woodland caribou range in Alberta.[2]

There are 728 boreal woodland caribou remaining in B.C.

The Government of Canada has mandated that a minimum 65 per cent undisturbed boreal habitat be protected to ensure sustainable viable woodland caribou.

To date, the Government of B.C. yet to establish a protocol for caribou habitat restoration zones.

In 2016, there were an estimated 728 boreal woodland caribou remaining across five herd ranges in northeast B.C., as well as the Chinchaga herd range that extends across B.C. and northwestern Alberta. According to Environment Canada, all six B.C. boreal herd populations are considered to be either *very unlikely* or *unlikely* to be self-sustaining.

Reaching the federal government's minimum 65 per cent undisturbed habitat target for boreal caribou restoration would require restoration of an area of at least 1,314,452 hectares of boreal ecosystem in northeastern B.C. To our knowledge, B.C. has not yet established a protocol for caribou habitat restoration zones compared to Alberta, which has begun to prioritize areas (zones) for restoration focused on where optimum habitat restoration gains can be achieved, securing undisturbed habitat and creating a network of priority zones, while focusing efforts on restoring the highest density seismic line areas.

What are the economics and business case for restoring these boreal landscapes to ensure sustainable viable woodland caribou throughout their traditional ranges? Are habitat restoration and future economic benefits from oil and gas and forestry resource development mutually exclusive? Are there win-win economic scenarios for optimizing both economic and ecological values throughout B.C.'s boreal forest ecosystems?

> All six B.C. boreal herd populations are considered to be either very unlikely or unlikely to be self-sustaining.

The B.C. government has drafted a *Recovery Strategy for the Woodland Caribou* (2011) and, more recently, a *Boreal Caribou Recovery Plan* (2017), which has been included in the draft *Boreal Caribou Recovery Implementation Plan* produced by Environment Canada. B.C. is working on revisions following a public comment period that ended May 31, 2017.

While the provincial government and resource industries have undertaken some actions aimed at stabilizing and even increasing caribou herds, the required pace and true cost to reach the desired restoration goals are not clear. A commitment to large-scale land-use planning and modifications to land-use management protocols for oil and gas and forestry will be required throughout the core woodland caribou habitat to ensure long-term, healthy boreal ecosystems that sustain viable populations, as woodland caribou are keystone indicator species of ecological health and integrity.

A commitment to such a forest ecosystem future will take political will, a sustained land-use planning commitment and a forest management regime that will ensure caribou habitat remains resilient. These are among the many challenges with restoring northern boreal forest ecosystems to their original primary forest condition.

Caribou habitat restoration efforts in B.C. and Alberta, including seismic line and well-site restoration, are still at a preliminary stage without tangible verifiable positive impacts on woodland caribou populations. Among ecologists familiar with woodland caribou, there is some debate about what management practices will be necessary to restore healthy boreal forest ecosystems. Certainly, restoration of seismic lines and other linear corridors that facilitate high predator interactions with caribou take priority. Allowing previously mature boreal forest to return to a mature state will take time, even if industrial footprints are reduced immediately. Allowing these forest lands to naturally restore themselves while modifying current resource development practices across large core habitat ranges of northeastern B.C. boreal forest may be another less costly option. Nevertheless, it will take many years of experimentation and practice in restoration to determine which methods are yielding the desired outcomes, namely a healthy, resilient woodland caribou population in B.C.

HOW MUCH AREA NEEDS TO BE RESTORED AND AT WHAT COST?

To reach the minimum of 65 per cent undisturbed habitat target would require restoration of an area of 1,314,452 hectares of boreal ecosystem in northeastern B.C.

Using restoration cost estimates from some of the professionals in the restoration and site remediation industries in B.C. and Alberta, we have derived preliminary restoration cost and benefit estimates to achieve the minimum 65 per cent undisturbed caribou habitat target for northeastern B.C.

Biologists tend to agree that seismic lines constitute the most pervasive and impactful linear disturbance of all forms that are negatively affecting woodland caribou survival throughout northern B.C. and Alberta. Our economic analysis is based on efforts to restore an estimated target of 138,645 kilometres of legacy seismic lines throughout B.C.'s six boreal caribou herd ranges. Using a restoration range from 65 to 100 per cent of this total seismic line restoration target would equate to between 9,012 and 13,865 kilometres of seismic lines restored per annum over a 20-year period. The costs of restoration ($10,000 per kilometre) would be between $901.2 million and $1,386.4 million or between $45.1 million and $69.3 million per year if spread over a 20-year period. Restoration costs could vary from as low as $4,000 per kilometre to $12,500 per kilometre of seismic line with total costs also depending on the width of seismic lines (which can vary from 1.5 to 10.0 metres).

However, whether restoring just the seismic line linear disturbance would result in a sufficient ecological restoration of a majority of 1,314,452 hectares (the 65 per cent undisturbed goal) of disturbed woodland caribou habitat is debatable. In consultation with some restoration experts and practitioners, we found a lack of both experience and verifiable cost estimates to restore the other forms of linear disturbance from well sites, roads and pipelines.

Any commitment to return 1.3 million hectares of caribou range habitat will require a significant pledge to preclude future linear disturbance across existing caribou ranges.

Even if a moratorium on future resource development (oil and gas, forestry and mining) was imposed, it would presumably take these landscapes decades to return to state of ecological integrity suitable for resilient caribou populations.

Placing a moratorium on future resource extraction activities across the entire 1.3 million hectares and allowing the area to return to desired natural ecological state suitable for caribou could be evaluated in terms of the estimated opportunity cost (foregone future resource revenues, royalties, employment, provincial GDP and taxes) to the energy, forestry and other sectors that currently benefit from the use of these landscapes. The opportunity cost estimates have not been estimated in this study, but could be determined.

Not all hectares to be restored would have the same value respecting the relative importance of each caribou herd and range. Moreover, site and range-scale restoration will vary from one area to the next with different restoration protocols and costs. A ranking of the most strategically important areas for restoration would be required.

RESTORATION EMPLOYMENT OPPORTUNITIES

Based on consultation with restoration industry experts, we estimate that caribou habitat restoration on seismic lines alone could seasonally employ between 185 and 284 people per annum with wages ranging from $6.67 million to $10.26 million per year over 20 years.

On a per-unit-of-forest land area basis, restoration employment would generate roughly 0.034 full-time equivalent employment per hectare of restored land, a level of employment per hectare identical to tree planting in southern Ontario. In comparison, in 2017, B.C. forestry and logging employed roughly 0.096 people per hectare of forest lands harvest based on 193,000 hectares of forest land harvested, 18,600 people employed, and wages and salaries of $736.4 million in 2017.

The proposed area of seismic line restoration in B.C.'s woodland caribou ranges would be between 6.7 and 10.2 times larger per annum compared to the average area of reforested forest lands tree in southern Ontario between 2008 and 2018. The Ontario study estimated that tree planting contributes about $12.7 million annually to Ontario's GDP and equates to about $9,381 per hectare of forest land replanted in southern Ontario, based on an average total reforestation cost of $5,315 per hectare. By comparison, our seismic line restoration costs may average $20,000 per hectare given there would likely be higher equipment costs relative to labour.

An important caveat in estimating additional jobs from restoration work is that a "restoration industry" may already exist in the form of labour currently employed to meet forestry and other land-use regulatory standards in B.C. However, we lack evidence of the current size of this subsector of the forestry and oil and gas resource industries.

Not all restoration jobs can be counted as benefits. This is because a more likely scenario is that caribou habitat restoration on forest lands would result in hiring of more unskilled seasonal workers, rather than offsetting employment losses in the forest and oil and gas industries. These industries and the government would be reallocating resources to restoration rather than other operating costs or profits.

These preliminary estimates of the potential economic and employment benefits of caribou habitat restoration suggest this could be a viable economic prospect for northern B.C. that could augment if not complement current forestry employment.

BENEFITS TO INDIGENOUS PEOPLES AND LOCAL COMMUNITIES

FOOD SOURCE

The emergence of a restoration economy in northeastern B.C. would provide considerable economic benefits to small municipalities and Indigenous communities that have a direct cultural interest in woodland caribou, as a food source and as an iconic species that reflects the health of their traditional boreal forest territorial lands. With restoration employment estimates as high as 16,755 workers per year over the next 20 years to achieve the minimum 65 per cent undisturbed habitat goal, such employment and business development prospects would infuse tremendous household and business income and tax revenues into northeastern B.C. communities, adding economic diversity to these northern communities that have traditionally depended on oil and gas and forestry activity.

EMPLOY-MENT

NEW BUSINESS

Several First Nations have already become actively engaged in restoration of well sites and seismic lines given their cultural interest in restoring woodland caribou in their traditional territories. They already see the economic viability of building their own capacity to conduct restoration work, employing community members and generating viable businesses.

IS AN OPTIMIZATION SCENARIO POSSIBLE?

Alberta efforts to engage in integrated land management planning, use of advanced geospatial mapping and zone restoration prioritization and scenario analysis through the Alberta Biodiversity Monitoring Institute and optimization scenario analysis point to signs of hope for what appears to be a daunting challenge in restoring woodland caribou herds in B.C. and Alberta.

A 2018 economic study of woodland caribou habitat restoration in Alberta by economist Tom Power (Power Consulting, Inc.) points to the promise of optimization planning and analysis. In the case of two northwestern Alberta boreal woodland caribou ranges (Bistcho and Yates) "65 per cent or more undisturbed caribou habitat threshold required by the federal government could actually be met with almost no displacement of industrial activity (forestry and oil and natural gas) currently taking place."[3] This would simply require commitment to large portions of existing forest management units to a forest management regime that optimizes ecological health and ecosystem functions to sustain critical caribou habitat while still allowing for forest harvesting and energy resource extraction. The strategy would be to grandfather existing oil and gas licences while precluding standard forest tenures (or allowing a modified forest management regime conducive to caribou habitat resilience) in these caribou ranges. Power's study showed that in the case of these two important woodland caribou ranges connected to B.C. and N.W.T. caribou ranges, development would not require displacement of any existing forestry tenure, while existing oil and natural gas leases could be grandfathered. Moreover, future oil and gas extraction might be done with a smaller land-use footprint.

Whether such a scenario is possible for northeastern B.C. cannot be known without a detailed examination of forest tenures and oil and gas activity throughout northeastern B.C. woodland caribou ranges.

In other boreal forest locations in B.C. and Alberta where the density of oil and gas development is higher, the economic costs of caribou protection (and the opportunity cost to industry) would be expected to be higher. In many cases of legacy seismic areas, tree planting and other site-restoration investments will ultimately have to be made given the poor record of vegetation recovery. (These costs will be examined in the following sections.)

These optimization scenarios can be best determined through a commitment to full-cost-benefit natural capital accounting that reveals the opportunities for optimization of market natural resource values and ecosystem service values. Optimizing models should be used to identify the best land-use choices to realize both habitat and economic goals in caribou ranges.

CONCLUSIONS

Our analysis of potential restoration costs and benefits (employment and wages) suggests there are potentially real and significant benefits from restoration of at least the seismic linear disturbance that compare even more favourably to the current forestry and logging employment in B.C. on a per hectare of land use basis.

This suggests that any losses in economic benefits from continued resource development (as a result of a resource development moratorium) across the estimated 1.3 million hectares of caribou range may more than offset conventional resource sector employment in these areas in northeastern B.C. A proper economic impact modelling would have to be conducted to analyze a spectrum of caribou restoration scenarios that would be deemed satisfactory in the opinion of caribou biologists and ecologists. We have only analyzed one possible restoration scenario of restoring the seismic line linear disturbance which has been extensive across all six woodland caribou ranges. Another option might be to allow the landscape to return to a natural, pre-development ecological state, under conditions of a moratorium on further development. This option could also take decades before a viable population of woodland caribou has been reached and is sustainable.

In conclusion, despite some shortcomings in data and cost-benefit analysis due to information limitations, our preliminary cost and employment benefit estimates of caribou habitat restoration, when compared to current forestry sector employment for B.C., suggest that the potential benefits of restoration might outweigh the opportunity costs to these traditional resource industries over at least a 20-year restoration period.

ACKNOWLEDGMENTS

The author would like to thank a number of people who were consulted in preparing this report, from a cross-section of sectors and expertise from caribou biologists, plant ecologists, restoration/remediation industry practitioners, resource industry experts, researchers, environmentalists and First Nations. The following people were instrumental in presenting a profile of the potential of a restoration economy in B.C. with respect to restoration of critical caribou habitat impacted by industrial development, especially in the northeastern boreal ecosystems of B.C.:

- Garry Adams, T. Harris Environmental Consultants; expert in linear disturbance remediation, based in Alberta.
- Clayton Apps, Aspen Wildlife Research Inc.,; caribou biologist and restoration expert, based in Calgary, Alberta.
- Regan Boychuk; petroleum royalty and environmental liability expert, Calgary, Alberta.
- Katherine Capot-Blanc, acting lands director, Fort Nelson First Nation.
- Michael R. Clark, Clark Ecoscience and Sustainability Ltd.; plant ecologist and expert in wetland and other linear disturbance restoration, Edmonton, Alberta.
- Bob Demulder, regional vice-president, Nature Conservancy of Canada, Alberta.
- Warren Eng; expert in old growth forest ecosystems, caribou habitat and forest inventory, based in B.C.
- Barry Hochstein, adviser and consultant on First Nations treaty rights and linear disturbance restoration in Alberta and B.C.
- Eric Higgs, professor of environmental studies, University of Victoria; expert in innovative methods of ecological restoration.
- Michael Keefer, Keefer Ecological Services Ltd.; First Nations plant ecologist and consultant on restoration on traditional territorial lands.
- Nancy Newhouse, regional vice-president, Nature Conservancy of Canada, British Columbia.
- Rachel Plotkin, science campaigns manager, David Suzuki Foundation, Toronto, Ontario.
- Matthew Pyper, co-founder, Fuse Consulting Ltd.; expert in caribou habitat site restoration, Alberta.
- Brad Stelfox, wildlife biologist, landscape ecologist and architect of the ALCES (A Landscape Cumulative Effects Simulator) used in Alberta, B.C. and throughout Canada and internationally to assess impacts of cumulative resource development impacts across vast landscapes.
- John Thompson, former senior economist with Stantec, AMEC and the Alberta Natural Resources Conservation Board.
- Sugu Thuraisamy, former chief forester, Little Red River Cree Nation, Alberta.
- Justina C. Ray, president and senior scientist, Wildlife Conservation Society Canada.

CAVEATS, CAUTIONS AND LIMITATIONS

A study such as this comes with a number of caveats and cautions.

A study such as this comes with a number of caveats and cautions. First, the complexity of caribou biology, science and health, along with understanding of the relationship between industrial linear disturbance, climate change and other factors affecting the long-term health and vitality of B.C.'s caribou, should be unequivocally stated. Scientists have agreed since 2008 that disturbance is the key driver of declining woodland caribou herds in Canada's boreal forest.[4] The impacts of climate change are exacerbating these impacts as other ungulate competitors are now encroaching on caribou range and habitat. Industrial disturbance, including seismic lines and cutblocks, have left caribou vulnerable to predators such as wolves and bears.

Second, this report is based on an incomplete portrait of all of the knowledge and actions in B.C. attempting to restore boreal caribou habitat to a minimum 65 per cent undisturbed condition, which is the risk-based management threshold deemed critical to ensure minimum viable populations to avoid extirpation. In the case of boreal caribou, there may be a good understanding of population trends, thanks to effective monitoring. However, the long-term outcomes of habitat restoration efforts remain largely unknown. To accommodate this uncertainty, the province plans to apply adaptive management protocols for boreal caribou by monitoring and adjusting implementation actions as necessary to achieve the population and habitat goals.

Third, while we found geospatial maps showing linear disturbance throughout northeastern B.C .and boreal caribou ranges, we were unable to source any geospatial information on the current state (qualitative conditions) of habitat restoration that would be useful to assess the relative success or failure of on-the-ground habitat restoration on a significant area of linear disturbance. (An estimated 76 per cent of core caribou range among all northeastern B.C. caribou populations has been affected by linear disturbance.) Without a dynamic GIS system to account for the state of caribou habitat restoration that can be easily queried and reported, the ability to monitor and report on a future restoration economy will be difficult.

This study represents a mere snapshot of some of the science, information and experience of professionals (biologists, ecologists, engineers, economists, etc.) engaged in this complex science and adaptive land management. There is always room for more knowledge and lived experience with insights into those best practices effectively securing and restoring caribou range and habitat for viable, healthy B.C. caribou populations.

This study was conducted by a professional ecological economist with a background in forest science and accounting, as well as many years of experience as a senior policy and economic adviser to the Alberta government on public policy, land-use planning and natural capital asset accounting. The combination of these skills and experience is expected to provide a pragmatic framework for decision-making and management of B.C. natural resource assets, including keystone species like caribou, to ensure the optimum economic, ecological and societal values are achieved. A restoration economy that ensures the highest and best use of land to generate healthy economic benefits while ensuring flourishing healthy ecosystems is in B.C.'s best interests.

The aspirations of this research study were ambitious and known at the outset. Even after extensive consultation with land reclamation and restoration industry experts, First Nations, conservation organizations (e.g., Nature Conservancy of Canada) and leading resource industries in land reclamation, and after review of government policies and regulations for industrial land remediation and restoration, it became clear that good information on which to conduct this research study is lacking. The lack of basic information on the ecological conditions or state of large-scale landscapes, including primary caribou habitat ranges in northeastern B.C., the lack of meaningful socio-economic data to assess the "economics" of restoration work, and lack of public sector accounting of natural resources, as assets, and ecological or environmental liabilities in the Province of British

Columbia's public accounts were significant barriers to our ability to conduct meaningful analysis. Most importantly, while there is information on the current state of industrial disturbance (linear disturbance) in key boreal caribou ranges, there is a lack of meaningful publicly reported information on whether any of the disturbed lands have been restored to ensure a viable and healthy woodland caribou population. Restoration efforts have only just begun in some of Alberta's boreal caribou ranges with no results yet of the effectiveness of these efforts and how the Alberta experience might apply to northeastern B.C. caribou ranges. Publicly transparent reporting and verification of the ecological condition of B.C. landscapes and watersheds and reporting on the success of restoration on the ecological health of these lands are paramount to proper public accounting.

Our research was able to understand the current state of industrial activity in terms of physical industrial footprint and the economic benefits (GDP, employment, labour income) of B.C's resource industries (forestry, oil and gas, mining). Data were available on the current level of linear disturbance from these industrial activities as proxies for environmental liabilities and loss of ecosystem service values and functions. From this information, we were able to estimate the annual depreciation costs or losses in ecosystem service values as a result of losses of ecological integrity from linear disturbance of woodland caribou ranges in northeastern B.C. We were able to generate rough estimates of restoration costs for pipelines, well sites and seismic lines in consultation with industry experts and practitioners in industrial land restoration work that would meet current restoration and reclamation standards.[5] The successes or failures of restoration will likely take decades to reveal their impact on caribou populations.

We were able to explore a range of cost estimates for site restoration that might approach a higher "gold" standard for restoration of large-scale ecosystems that would move to more optimum states of ecological integrity and functionality. From these, it is possible to estimate the total investments needed by industry and governments to restore current areas of disturbed landscapes to a desired level of optimum ecological functionality. These estimates are important to identify opportunities for restoration business enterprises that Indigenous Peoples may pursue, particularly those First Nations, Métis and Inuit who have an interest in caribou for their traditional use values.

Using these restoration cost estimates, we were able to derive preliminary estimates of the "unfunded" ecological liabilities that should ultimately be "booked" (but are currently not booked) on provincial, regional, municipal and industry balance sheets as proxies for the investments that should be made and performance restoration bonds that should be posted to restore industrially disturbed ecosystems to a standard sufficient to achieve ecosystem integrity and viable populations of keystone species such as woodland caribou. With these restoration investment cost estimates verified and fully disclosed in both public- and private-sector accounting systems (similar to emerging carbon liability disclosures), it's more likely that the financial service industries — including public pension funds, banks and insurance companies — will be more informed about how ecological liabilities and risk can be assessed to inform lending and investment decisions.

Finally, we were able to determine the current economic benefits (e.g., total output, GDP, employment and labour income) derived from forestry and oil and gas activity in B.C. on a per hectare of land use basis and compare these values with estimates of annual losses in the value of ecosystem service functions that were negatively affected by industrial development. We can compare these respective estimates with the estimated restoration liabilities (estimated restoration costs outstanding) incurred by industry from annual extraction of natural resources across B.C. This would provide decision-makers, especially the B.C. Treasury Board, better information to make the necessary trade-off decisions about how best to optimize economic benefits while ensuring ecological integrity across every hectare of B.C. public lands.

BACK-GROUND

At its core, the "restoration economy" refers to livelihoods and economic actions and activities directly linked to various elements of ecological restoration. Restoration activities can include habitat enhancement, reforestation, water quality improvement, invasive species removal, forest thinning for canopy diversification or any other activity that aims to improve the natural function of an ecosystem.

Contemporary restoration activities are predominantly focused on reaching quantitative indicators of success that, from a socio-ecological perspective, fail to address the reality of nature as a complex, adaptive system. Governments and industry spend billions of dollars annually to reclaim, remediate and/or restore areas affected by oil, gas and/or mineral exploration and extraction. Qualitative elements from real biodiversity, ecosystem interdependence and interconnectivity, trophic cascading and other characteristics that constitute healthy natural systems as a whole are often ignored for the sake of cost efficiency.

There are other factors to be considered, including:

TARGETS

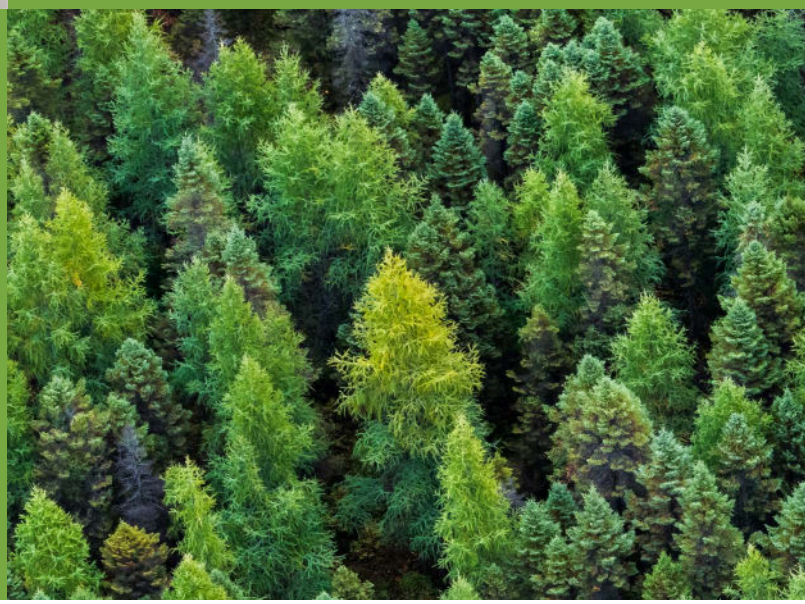
The challenge of meaningful targets for restoration at the site level where proponents are operating, when the ultimate measure of success is the caribou population, which means landscape-level restoration;

SUCCESS

The understandable interest of proponents to demonstrate some kind of success and receive credit at earlier stages of the restoration trajectory — given ultimate success for caribou will take decades and over larger areas than site-based activities; and

REGULATIONS

The unambitious requirements under regulations (reclamation) requiring proponents to simply revegetate the land, rather than truly restore. The shift in land management to a caribou-centric focus is quite recent, since the caribou recovery strategies have been formulated in B.C. and Alberta. This has propelled proponents to focus much more on restoration than ever before.



Another consideration is the importance of Indigenous traditional knowledge with respect to boreal caribou. Contemporary restoration activities fail to recognize, let alone value and apply, local and traditional knowledge. Whereas mainstream science provides valuable building blocks of understanding ecosystems, local and traditional knowledge provide an equally rich context based on deep time and lived experience.

There is now an opportunity to innovate from the quantitative, simplistic and mainstream science-only approaches to nature restoration, to quality-based and nature-centric approaches, inclusive of different ways of knowing. Such innovation will form the basis of a new, nature-based and knowledge-inclusive restoration economy framework that supports sustainable livelihoods and thriving societies.

GOALS OF THIS RESEARCH PAPER

There are two primary research themes and goals of this paper:

Baseline analysis of the current state of play of restoration activities in northeastern B.C.

Exploration of alternative scenarios for innovative, nature-centric restoration economic framework in northeastern B.C.

Research theme 1: Baseline analysis of the current state of play of restoration activities in northeastern B.C. for areas affected by oil, gas and/or mineral exploration and extraction. This component provides a comprehensive assessment of current practices used by private sector, government and communities to restore areas affected by oil, gas and/or mineral extraction, based on expert interviews, review of current literature and new government draft guidelines (B.C. and Alberta) for restoration of habitat for securing healthy boreal caribou populations. (These are referenced later in the report.)

Research theme 2: Exploration of alternative scenarios for innovative, nature-centric restoration economic framework in northeastern B.C. for areas affected by oil, gas and/or mineral exploration and extraction This report examined, through expert interviews, the current state of caribou habitat restoration efforts in six boreal caribou ranges with a view of identifying successful versus unsuccessful restoration efforts as well as estimates of the costs of restoration. This included interviews with First Nations land managers knowledgeable about the on-the-ground experiences of caribou range restoration and what works and does not. We learned that it's far too early to determine which approaches to habitat restoration are succeeding and at what true cost, particularly on a per hectare basis. The report points ultimately to various options for financing a "restoration economy," namely a sector of B.C.'s economy that provides sustainable livelihoods from restoring vast areas of industrial disturbed and damaged lands to an ecological integrity or health standard that could sustain minimum viable boreal caribou populations in the long term. The opportunities for such a restorative economy are likely greatest for rural communities, including Indigenous communities, in B.C.'s boreal and other forest regions. The report suggests funding sources for what will be a significant ecological restoration liability not currently accounted for on B.C.'s balance sheet nor properly treated as environmental liabilities on resource company books.

The study examines new ways of accounting for natural capital assets (and respective environmental liabilities) as part of public sector ac-

countants' long-term commitment to establish proper balance sheets for natural assets for all provinces and Canada. Part of the solution to moving toward a restoration economy is to have a sufficiently robust accounting of the true state of natural assets, ecosystem health and a full costing of both ecological liabilities and restoration investments that are linked to measurable and verifiable net positive impacts on ecosystem conditions and resilience.

In addition, a quantitative and qualitative cost-benefit analysis between the current baseline of economic activity and estimated unfunded (and off-book balance sheet) environmental liabilities are contrasted with the potential ecosystem service benefits and benefits to First Nations' traditional use values that point to a prudent accounting and decision-making system that would attempt to ensure optimum value from land use across a spectrum of economic, ecological and cultural values. Estimates of the potential scale and scope of a restoration economy, properly financed, are provided. This will ultimately result in new employment, better economic opportunities for Indigenous Peoples, improved environmental conditions (i.e., reduced environmental liabilities) and overall improvement in economic resilience for both Indigenous and other communities in northeastern B.C.

METHOGOLOGICAL APPROACH

The primary approach to conducting this study was first to examine and gather all publicly available data to construct a baseline inventory and economic valuation of the state of industrial development, linear disturbance and economic value of industrial activity throughout B.C. but specific to the boreal forest ecosystems of northeastern B.C. where boreal caribou are important keystone indicators of ecosystem health.

Data and information sources included:

- The current state of industrial disturbance (linear disturbance from all industrial activity) across key caribou habitat, particularly in northeastern B.C. as reported by the Government of B.C. These data provided important information on the area of linear disturbance across all caribou ranges in B.C.
- Socio-economic data on total economic output, GDP, employment, labour in-

come data on forestry and oil/gas/mining sector activity in B.C. from Statistics Canada and the B.C. government.

- Interviews and personal communication with a wide range of land restoration industry experts, conservation organizations, First Nations and progressive resource companies about the current state of restoration practices in B.C. and Alberta.
- Review of draft guidelines for boreal caribou habitat restoration for B.C. and Alberta. Alberta's restoration guidelines are more robust and impressive than B.C.'s.
- Review of research literature related to caribou, linear disturbance impacts, ecosystem services.
- Ecological service value estimates as benchmarks for B.C. from previous studies by Anielski et al[6].
- Estimates of the value of traditional use lifestyles, ecosystem service values and economic benefits for First Nations in Alberta (Little Red River Cree Nation, O'Chiese First Nation, Alexis Nakota Sioux Nation) by Mark Anielski.
- Interviews with experts were the primary source of common-sense input to understanding the current state and potential scope of "restoration economies" in B.C. These professionals — involved directly in land management, site remediation and economic development from a variety of sectors, including First Nations — provided important insights into presenting a practical road map for the emergence of a restoration economic system in B.C. These experts provided current cost estimates for reclamation and restoration of oil and gas industrial sites (e.g., well sites, pipeline rights-of-way and seismic lines) in B.C. and Alberta, which is the first step to a proper full-cost accounting.

A full-cost-benefit accounting approach was taken in estimating the potential scope of restoration work, investments and economic impacts (including restoration costs and respective labour) using primary socioe-conomic data for B.C. Current economic data on GDP, employment and labour costs for B.C.'s primary resource sectors (oil, gas, mining and forestry) were used in relationship with the current level of industrial use (e.g., timber harvesting, oil and gas production) relative to B.C. public lands allocated to industrial development. From these data, it was possible to derive estimates of the annual (current and historical) GDP, employment and labour income generated per hectare of land area used for economic activity compared to the ecological values of these lands from an ecosystem service valuation perspective. This provides a meaningful method for comparing economic returns per area of land developed for resource extraction to the losses in ecological integrity and ecosystem values (i.e., ecological liabilities). Comparing these respective economic benefits relative to ecological losses or risks should provide B.C. decision-makers with meaningful information to determine long-term economic strategies that would optimize economic returns to B.C. land and resources. The restoration costs to achieve a desired standard of ecological integrity and functionality, including a viable caribou population, can be properly accounted and booked as future restoration work.

WHAT IS RESTORATION ECONOMICS?

The notion of restoration economics has its roots in the mid-1990s in the U.S. with the northern spotted owl habitat crisis in the old growth forests of the Pacific Northwest.

The appearance of the northern spotted owl and some species of salmon on the endangered species list resulted in a significant shift in forest management policies across the Pacific Northwest, leading to drastic decreases in logging and other natural resource extraction activities. The listings also marked a shift toward more environmentally sound land management through forest and watershed restoration, as policy-makers began to realize that environmental restoration work could provide social and economic, in addition to ecological, benefits.

In simple terms, the restoration economy is

the economic activity associated with regenerative land use, such as ecological restoration activities. It stands in contrast to standard economic activities premised on the extraction or depletion of natural resources, measured in standard economic output terms, including GDP, as a measures of success. In contrast, restoration economics considers the impact of resource development activities that result in damages to natural ecosystems and human communities and seeks to repair past damages, restoring natural and human communities at local, regional and national scales.

The "restoration economy" refers to economic activity based on repurposing, renewing and reconnecting the natural, built and socioeconomic environments. The phrase gained popularity with the publication of *The Restoration Economy* by Storm Cunningham in 2002.[7]

In terms of natural resources, "restoration economy" refers to the employment, capital, resources and economic activities that emerge from investments in ecological restoration, or "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." [8] Restoration projects can include habitat enhancement, water quality improvement, invasive species removal, forest thinning for canopy diversification, or any other activity that aims to improve the natural function of an ecosystem. While investments in restoration benefit the environment, restoration projects also require workers, materials and services to implement. The marketplace for these goods and services can create employment, spur business and workforce development, and increase activity in local economies. Activities that use by-products of restoration work are also sometimes considered as part of the restoration economy; for example, the use of small trees and/or shrubs from forest diversification or thinning projects as biomass to produce heat or energy.

Ecological economic analysis protocols as part of a natural capital accounting structure are the primary tools to evaluate and account for the benefits of healthy ecosystems (in terms of ecosystem services or functions) and the costs of damages to natural ecosystem functions and integrity.

From a business perspective, agencies and non-governmental organizations that implement restoration work create employment by

hiring staff and contracting with businesses that hire employees to perform the actual restoration work. This results in contributions to the economy in terms of employment, labour income, taxes and ultimately GDP, while also restoring natural capital assets and ecosystem integrity. As a rule, reclamation work is conducted either by in-house experts or subcontracted to smaller businesses involved in restoration projects. They tend to be small, family-owned businesses subject to large seasonal fluctuations in available work.

Several U.S. studies have examined the economic impacts and activity created by restoration work. These have typically been for individual projects; e.g., a $113 million mine reclamation project in Montana that was estimated to generate a total of 3,563 full-time equivalent positions.[9] A study looking at the economic output of a restoration program across an entire county (Humboldt County, California) determined that the $12.5 million invested in the program in 2002 supported 300 direct jobs that year.[10] A study that looked at investments in restoration projects through federal agencies and non-governmental organizations in Oregon found that restoration investments have similar economic and employment impacts as other public infrastructure projects such as road-building. For every $1 million invested in restoration, 15 to 24 jobs were created, and each invested dollar generated an additional 1.4 to 2.4 dollars in economic multiplier activity as it cycled through the economy, depending on the specific type of project.[11]

To our knowledge, no studies of the economics of restoration projects in Canada have yet been completed or documented. These U.S. studies serve as a baseline to estimate the potential scope of restoration economic development opportunities for critical boreal caribou habitat in northeastern B.C.

WHAT WE KNOW ABOUT THE CURRENT STATE OF CARIBOU IN B.C.

According to B.C. government statistics, the province is home to 54 caribou herds, all of which are of the woodland caribou subspecies (*Rangifer tarandus caribou*), with an estimated total population of 19,000.

B.C.'s caribou population has declined by more than 52 per cent since the early 1900s when there were an estimated 40,000.[12] B.C. has four "designatable units" recognized for their discreteness and evolutionary significance: southern mountain, central mountain, northern mountain and boreal caribou. This study focuses only on boreal caribou located in northeastern B.C.

Figure 1 shows there are six boreal caribou ranges located in northeastern B.C., with one range (Chinchaga) straddling B.C. and Alberta.

Table 1 shows the total estimated B.C. boreal caribou range is roughly 3,199,485 hectares, considering only the B.C. portion of the Chinchaga range.[13] In terms of the area of caribou range disturbed either by anthropogenic impacts (industrial or human disturbance) or fire, an estimated 2,482,329 hectares had been disturbed in 2012 (Table 2). By 2017, the total estimated caribou range disturbed had been reduced slightly by 1.94 per cent to 2,434,272 hectares, according to Environment Canada 2018 estimates.[14] The percentage of total B.C. boreal caribou range disturbed in 2017 averaged 76.1 per cent; from a low of 57.0 per cent for the Parker caribou range to a high of 80 per cent for Chinchaga range.

Figure 1: Boreal caribou ranges and cores in northeastern British Columbia, as defined by the B.C. Boreal Caribou Implementation Plan (2017)

Source: B.C. Ministry of Environment and Ministry of Forests, Lands, and Natural Resource Operations. 2017. Boreal Caribou Recovery Implementation Plan.

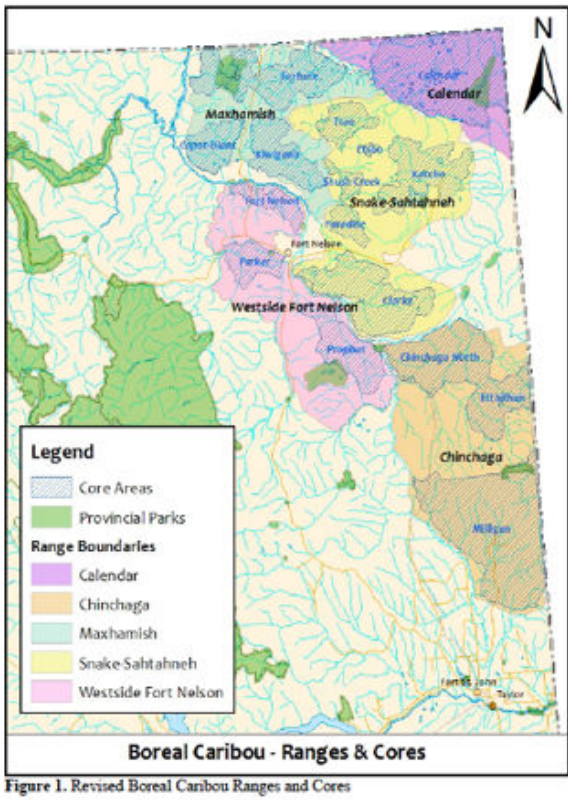


Figure 1. Revised Boreal Caribou Ranges and Cores

Table 1: B.C. boreal caribou populations, range and disturbance in 2012

	Range size (ha)	Population size	Population Trend	Likelihood of self-sustain-ability
Maxhamish	710,105	300	Unknown	Unlikely - not self-sustaining
Calendar	496,400	290	Unknown	Unlikely - not self-sustaining
Snake-Sahtaneh	1,198,752	360	Declining	Very unlikely - not self-sustain-ing
Parker	22.452	40-60	Unknown	Unlikely - not self-sustaining
Prophet	91.581	50-100	Unknown	Very unlikely - not self-sustain-ing
Chinchaga (* B.C. por-tion)	1,390,300*	250**	Declining	Very unlikely - not self-sustain-ing
Total	3,199,485	250**		

Source: Environment Canada, 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada http://publications.gc.ca/collections/collection_2012/ec/En3-4-140-2012-eng.pdf
*estimated area of Chinchaga within B.C. provincial boundary.
** Caribou population in the B.C. and Alberta Chinchaga herd range area.

Table 2: B.C. boreal caribou range disturbance 2012 and 2017, minimal amount of habitat to be restored, 2018

	2012	2017	% of range disturbed	% change since 2012	Minimal amount of habitat to be restored, 2018 (ha)
	Total habitat disturbance (ha)	Total habitat disturbance (ha)			
Maxhamish	404,760	482,871	68.0%	19.30%	234,335
Calendar	302,800	302,804	61.0%	0.00%	129,064
Snake-Sahtaneh	1,042,914	935,027	78.0%	-10.34%	515,463
Parker	7,634	12,798	57.0%	67.64%	4,939
Prophet	72,349	71,433	78.0%	-1.27%	39,380
Chinchaga (* B.C. portion)	1,056,632	1,112,211	80.0%	5.26%	625,606
Total	2,897,747	2,434,272	76.1%	-1.94%	1,314,452

Source: Environment Canada, 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population, in Canada
Source: Environment Canada. 2018. Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (*Rangifer tarandus caribou*), Boreal population in Canada for the Period 2012 to 2017

In terms of caribou populations, Table 3 shows the trends in six B.C. boreal caribou ranges falling from between 1,290-1,360 in 2012 to a low of 678 in 2015 and recovering to 728 in 2016. Environment Canada's 2018 recovery progress report did not provide precise population estimates. According to Environment Canada all B.C. boreal caribou herds are considered to be either likely or very unlikely to be "not self-sustaining" while most herds are either in a state of decline or unknown.

Table 3: B.C. boreal caribou populations, 2012-17

		2012	2013	2014	2015	2016	2017
Range Name							
Maxhamish	BC1	306	132	102	81	100	≥ 100
Calendar	BC2	291	135	79	81	107	≥ 100
Snake-Sahtahneh	BC3	365	321	241	258	280	≥ 100
Parker	BC4	40-60	108	87	69	47	< 100
Prophet	BC5	50-100					< 100
Chinchaga (B.C. and Alberta pop.)	AB1	250**	256	214	189	194	≥ 100
Totals		1290-1,360	952	723	678	728	

Sources:
2012. Source: Environment Canada, 2012. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), boreal population, in Canada. Original source of data is from provincial government ministries.
2013-16 estimates are from B.C. Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations. Draft Boreal Caribou Recovery Implementation Plan, March 2017
2017 estimates are from Environment Canada. 2018. Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (*Rangifer tarandus caribou*), boreal population in Canada for the period 2012-17
https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/recovery-strategies/woodland-caribou-report-2012-2017.html#_app_b_2

Note: Parker and Prophet caribou ranges are part of the Fort Nelson range area so 2013-16 figures from B.C. Ministry of Forests, Lands and Natural Resources combine both sub-ranges.

Figure 2 shows the state of boreal caribou ranges throughout Canada and the likelihood of herds being self-sustaining or not. All B.C. boreal caribou ranges, with the exception of the Maxhamish range, are considered very unlikely to be self-sustaining; Maxhamish is considered to be unlikely to be self-sustaining.

Figure 2: Risk Assessment Map of Boreal Caribou Ranges in Canada, 2017

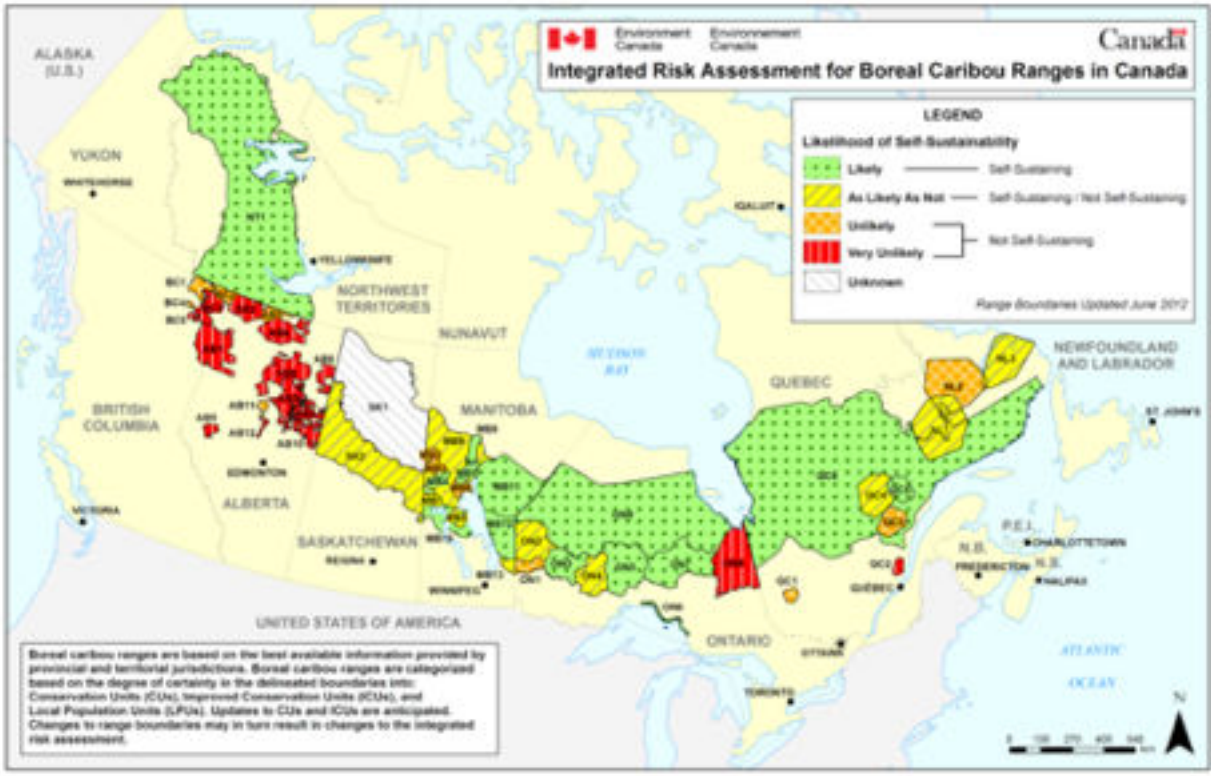


Figure 3. Integrated risk assessment for boreal caribou ranges in Canada, reflecting the capacity of each range to maintain a self-sustaining local population of boreal caribou.

Although declines in B.C. boreal caribou populations have been evident since the 1980s due mostly to industrial linear disturbance, a sharp drop in 2013, according to caribou biologist Kristin Bondo, is due to a sudden catastrophic mortality related to a number of factors, including a significant increase in winter ticks (generally associated with moose) reducing hair cover, which reduced their overall health and resilience. The cause of a sudden increase in winter tick populations is not clear, although some believe this may be the impact of climate change.[15] Bondo attributes the dramatic die-off to substantial hair loss (72-86 per cent) from winter tick infestation, which may be related to winter ticks expanding northward along with moose, which are carriers. This may be related to climate change impacts.[16]

The overall declining health conditions and resilience of B.C. boreal caribou are due to the cumulative biological, environmental and socio-economic pressures or effects on individuals and populations of caribou, most importantly anthropogenic disturbance impacts from industrial activity. Currently there are number of co-morbidity drivers of woodland caribou extirpation with the primary cause being industrial linear disturbance of their habitat exacerbated by climate change.

THE STATE OF HABITAT DISTURBANCE

Caribou habitat has been affected by a combination of natural disturbance (e.g., fires) and anthropogenic disturbance (industrial linear disturbance).

Environment Canada's most recent assessment of caribou recovery estimates the degree of disturbance in B.C.'s boreal caribou ranges in 2017 (Table 4). Anthropogenic disturbances from linear disturbance has had the greatest impact with fire having less significant impacts. As the figures show the extent of linear disturbance from seismic lines, well sites, roads, pipelines and forestry cutblocks are significant, ranging from 53 per cent range area disturbance in the Calendar range to 79 per cent disturbance in the Chinchaga range.

Table 4: B.C. boreal caribou habitat range and disturbance by impact, 2017

Boreal Caribou Range, B.C.	Percentage of range disturbed	Percentrage of range burned (fire)	Percentage impacted by anthropogenic disturbance
Maxhamish	68	2	67
Calendar	61	16	53
Snake-Sahtaneh	78	5	77
Parker	57	3	57
Prophet	78	10	78
Chinchaga (B.C. only)	80	9	79

Source: Environment Canada. 2018. Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (*Rangifer tarandus caribou*), boreal population in Canada.

Data on the relative area of disturbance by type of linear disturbance type were not available from either the B.C. government or Environment Canada reports. We found only one earlier draft 2011 report (Recovery Strategy for the Woodland Caribou) by Environment Canada that included figures of linear disturbance maps for the six B.C. boreal caribou ranges without any accompanying data that provided information on the area of linear disturbance. In other words, we could not verify without geospatial human/industrial footprint analysis (such as completed by ABMI for Alberta) the exact area of linear disturbance industrial footprint type, whether seismic, well-sites, roads and/or cutblocks. More detailed GIS mapping and analysis is critical for conducting any further analysis of the potential restoration economics of a restoration scenario. An ILM long-range restoration plan common in Alberta, is critical. That would map out a restoration scenario that would achieve the federal government's restoration target of 65 per cent or more undisturbed caribou habitat threshold habitat and bring the respective five to six caribou herds back to a self-sustaining condition.

What we do know is that that total area of accumulated caribou range disturbed as of 2017 amounted to 2,434,272 hectares across all five caribou ranges representing 76.1 per cent of the total caribou ranges in northeastern B.C. (Table 5).[17] We also know that a minimum of 1,314,452 hectares of the current caribou

range area (or 41.1 per cent of total range area of 3,199,485 hectares) would have to be restored to an undisturbed state; or in other words, 54.0 per cent of the total area disturbed (2,434,272 hectares) would have be restored to meet the 65 per cent undisturbed habitat threshold set by the federal government in the recovery strategy.

Table 5: Woodland caribou habitat range and disturbance by impact, 2017

Boreal Caribou range	Total range disturbance (ha) 2017 (1)	% of range disturbed	Seismic line disturbance (km) (2)	Minimal amount of habitat to be restored, 2018 (ha)	Minimal amount of habitat to be restored, 2018 (ha)
Maxhamish	482,871	68.0%	24,517	234,335	234,335
Calendar	302,804	61.0%	7,902	129,064	129,064
Snake-Sahtaneh	935,027	78.0%	46,164	515,463	515,463
Parker	12,798	57.0%	1,119	4,939	4,939
Prophet	71,433	78.0%	5,403	39,380	39,380
Chinchaga (B.C. only)	1,112,211	80.0%	53,541	625,606	625,606
Total	2,434,272	76.1%	138,645	1,314,452	1,314,452

Sources:
1. Environment Canada. 2018. *Report on the Progress of Recovery Strategy Implementation for the Woodland Caribou (Rangifer tarandus caribou), Boreal population in Canada for the Period 2012 to 2017.*
2. Estimated by Anielski Management Inc., February 4, 2018 based on Golder and Associates (2016). Natural Recovery on Low Impact Seismic Lines in Northeast British Columbia, BCIP 2016-18, Report 1654243. December 2016.[18]

The Environment Canada disturbance estimates may underestimate the full extent of linear disturbance in B.C. and Alberta boreal woodland caribou ranges. According to a study prepared by the ABMI for the Canada's Oil Sands Innovation Alliance in 2017, Environment Canada significantly underestimated human disturbance across Alberta woodland caribou ranges as much as between 11 and 23 per cent compared to ABMI's Wall-to-Wall Human Footprint Inventory mapping and analysis.[19] ABMI uses fine-scale SPOT satellite imagery. It's highly probable that Environment Canada's estimates of the human disturbance footprint across B.C.'s boreal woodland caribou ranges are also underestimated.

Figure 3 shows the most recent assessment of seismic, roads and pipeline linear disturbance across the entire B.C. northeastern caribou ranges proportionally to the expected reduction in wolf use of seismic lines.[20] The map displays the abundance of seismic lines compared to other linear features across the landscape within caribou range in northeast B.C. This map was used to conduct restoration scenario simulations, one where all seismic lines were restored, and the second where all linear features were restored.

Figure 3: Seismic lines, roads and pipeline linear disturbance in northeastern B.C.

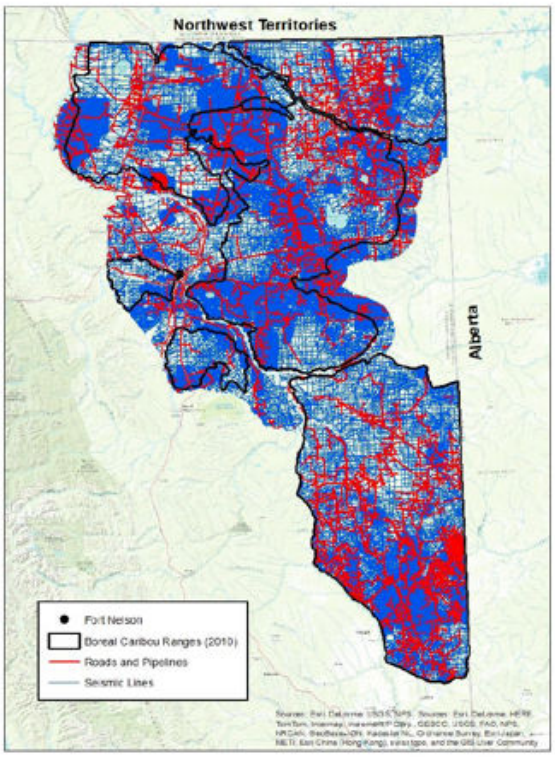
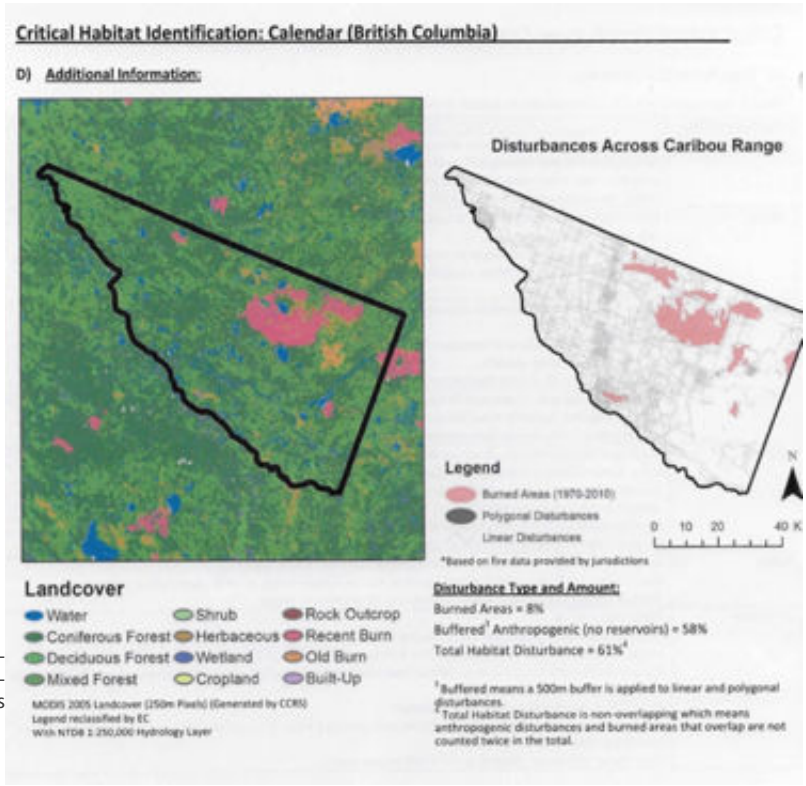


Figure 1: Map displaying the abundance of seismic lines compared to other linear features across the landscape within caribou range in northeast British Columbia. Two scenarios were simulated, one where all seismic lines were restored, and the second where all linear features were restored.

Source: Serrouya, Robert, Melanie Dickie, Craig DeMars, and Stan Boutin. 2016. Predicting the effects of restoring linear features on woodland caribou populations. Prepared for British Columbia Oil and Gas Research and Innovation Society

At an individual caribou range scale, Figure 4 shows the linear disturbance and fire impacts in 2011 across the Calendar caribou range as of 2010.[21] The map shows linear disturbances (seismic lines, well sites, roads and other linear disturbance), polygonal disturbances (e.g., forestry cutblocks) and burned areas. The GIS map shows eight per cent of the Calendar range had been affected by fire while 58 per cent had been affected by linear anthropogenic disturbance (using buffering protocols around the linear disturbance). The extent of linear disturbance is significant. As noted, there were an estimated 107 boreal woodland caribou in the Calendar range in 2016, one of the "least worst-off" caribou ranges.

Figure 4: Linear disturbance map of CalendarB.C. boreal caribou range, 2010



Source: Environment Canada, 2011. Recovery Strategy for the Woodland Caribou (*Rangifer tarandus caribou*), boreal population, in Canada. Draft report 2011.

Linear disturbance from seismic line activity by the oil and gas sector has had significant negative impacts on caribou populations. Restoring seismic lines has been highlighted as a key factor to tackle in boreal caribou population recovery .[22] In addition to the cumulative early seral habitat created by these disturbances, seismic lines facilitate the movement of wolves which has been considered to be one of the most significant forces driving caribou decline.[23]

According to the Power Consulting report (2018), "a major reason for the persistent disturbance of these habitats by seismic lines is that once the vegetation has been removed in creating the seismic line, the water intake on that line decreases. This leaves the water to pool, which in turn compacts the relatively limited soil. As persistent linear features, they provide vegetation to feed deer and moose, and they are used as travel corridors for deer, moose, wolves and people (including on motorized vehicles). The increased presence of moose and deer gives the wolves more animals to prey on than they otherwise would have, and wolf numbers have increased in the caribou ranges. Because their numbers and travel routes through the forest have increased, wolves prey on caribou more now than in the past. As well, access of motorized vehicles contributes to harassment of caribou and the displacement of them from prime range as well as poaching."[24]

The Power Consulting study of woodland caribou restoration in northwestern Alberta drew from studies that found that tree regrowth without specific planting programs is often nonexistent;[25] after 35 years, more than 60 per cent of the seismic lines in a landscape-scale study "showed little or no recovery back to a forested state."[26] Many of these legacy seismic lines remain unvegetated decades after they were cut.

According to Golder and Associates' 2014 study, estimated linear disturbance by seismic line development throughout the three major boreal woodland caribou core areas of northeastern B.C. (Calendar, Maxhamish and Snake-Sahtaneh, which represent 53 per cent of all woodland caribou core ranges), has increased significantly between 2000 and 2014.[27] Between 2000 and 2004, seismic line linear disturbance totalled 19,235 kilometres across all three major core areas, or an average of 4,809 hectares per year. Note: Chinchaga (1,390,300 hectares) and Westside Fort Nelson (866,400 hectares) were not assessed by Golder and Associates. Between 2005 and 2014, a total of 50,154 kilometres of new seismic line was cut, an average of 5,573 kilometres per year; this was during a transition to more narrow "low-impact" seismic lines. The accumulated total of seismic line cut between 2000 and 2014 was 60,527 kilometres. Based on the average cut between 2005 and 2014, we project that the total seismic line cut by the end of 2018 will be 80,589 kilometres. However, without verified seismic line activity data that supports our Table 6 estimates from the B.C. government, we cannot verify whether this estimated accumulated linear disturbance area is accurate.

Using the three caribou ranges for which seismic line cutting data are available, we estimated the relative seismic line activity in the Chinchaga, Parker and Prophet core areas (which constitute 47 per cent of the total core caribou areas in northeastern B.C.). This was done in the absence of publicly available GIS data on estimates of actual seismic and other linear disturbance in these three ranges.

We have estimated a total of 138,645 kilometres of seismic lines were cut between 2000 and 2018, or the equivalent of roughly 85,960 hectares of seismic line area (Table 6). This estimated seismic line linear disturbance would represent a small fraction (approximately four per cent in terms of estimated area in hectares of seismic disturbance, without buffering) of the total estimated anthropogenic linear disturbance. If buffering protocols of roughly 500 meters were applied to the 138,645 kilometers of legacy seismic lines on either side of a 5-8 metre seismic line, the total industrial footprint spatial area would be much larger. Estimates of the total area (hectares) of the seismic line spatial footprint depends on the respective width of each seismic line, which could range from as small as 1.5 metres with Low Impact Seismic (LIS) lines to 10 meters for older legacy seismic lines. This will also impact the restoration cost estimates for restoring legacy seismic lines.

Our estimate for B.C. seems reasonable compared to Alberta government estimates that there are at least 250,000 kilometres of seismic lines across woodland caribou ranges in that province. This B.C. estimate would constitute the total potential restoration area of seismic lines alone in B.C.'s boreal caribou habitat areas.

Table 6: Seismic line cut area through northeastern B.C. boreal caribou core areas

Boreal caribou ranges northeastern B.C.	Seismic line area cut, 2000-04 (kms)	Seismic line area cut, 2005-14 (kms)	Seismic line area cut, 2015-18 est. (kms)	Accumulated seismic line cut (2018) (kms)
Maxhamish	1,456	16,472	6,589	24,517
Calendar	654	5,177	2,071	7,902
Snake-Sahtaneh	13,278	23,490	9,396	46,164
Parker	n.a.	n.a.	n.a.	1,119
Prophet	n.a.	n.a.	n.a.	5,403
Chinchaga	n.a.	n.a.	n.a.	53,541
Totals	15,388	45,139	18,056	138,645

Source: Golder and Associates. 2016. Natural Recovery on Low Impact Seismic Lines in Northeast British Columbia, BCIP 2016-18, Report 1654243 December 2016. Italicized figures are estimates of seismic line development in the B.C. portion of the Chinchaga range that extends into Alberta.

The amount of anthropogenic disturbance area that includes forestry cutblocks, roads, well sites, pipelines and other industrial disturbance would have to be estimated using geospatial mapping and analysis, which were not available to us at the time of our analysis.

B.C.'S BOREAL CARIBOU RECOVERY PLAN

The B.C. government's Draft Boreal Caribou Recovery Implementation Plan[28] outlines various strategies for restoring caribou habitat throughout the northeastern portion of the province, proposing to reduce the amount of early seral habitat in order to move progressively towards achieving the minimum 65 per cent undisturbed management threshold established by Environment Canada.

The plan focuses on management of the primary factors that affect boreal caribou habitat in B.C.: early seral habitat resulting from forestry activities and wildfire, and linear features associated with oil and gas development.

The Draft Boreal Caribou Recovery Implementation Plan[29] established the following population and habitat goals that will guide implementation of the plan within the province, to stabilize and achieve self-sustaining populations across each boreal caribou range:

FORESTRY:

1. Establish an early seral habitat objective of initially less than six per cent across each boreal caribou range;
2. Prohibit forest harvesting and road-building in 15 of the 16 core areas. For the Milligan core, the current management practices regarding forest harvesting and road-building will be maintained; and
3. Prohibit the creation of new early seral forest in core ranges unless an exception is granted.

PETROLEUM AND NATURAL GAS DEEVLOPMENT

1. Require a net decrease in the density of linear features within core areas by applying habitat offsets (initially 4:1) for future development impacts across ranges, leading to a positive habitat trend in each range over time; and
2. As a short-term solution, replace existing Resource Review Areas with better-aligned RRAs over untenured portions of caribou core areas, until incremental habitat protections and population management actions are finalized.

SPECIES MANAGEMENT AND WILDFIRE:

1. Determine if and where other non-habitat-related management actions such as predator management and caribou population management (i.e., predator fencing) are required, feasible and supported by First Nations. Align predator management with the provincial Wolf Management Plan; and
2. Manage wildfires in each boreal caribou range to minimize the creation of natural early seral habitat.

The goals, objectives and actions of the revised plan are tailored to each boreal caribou range, and consider the population and habitat status, as well as socio-economic priorities of each. An individual plan for each range is provided, including information on recommended monitoring and research priorities. An important component of this revised Boreal Caribou Implementation Plan is the use of adaptive management, which enables the province to amend the actions used to best achieve the goals.

According to the B.C. Caribou Recovery Plan, "the Province has committed to developing a methodology for mapping and classifying disturbances not just for Boreal Caribou, but for other ecotypes of caribou and other wildlife species. As of March 2017, the Province is evaluating the suitability of disturbance data collated by the B.C. Oil and Gas Commission for use in the Area-Based Analysis, as well as the suitability of disturbance data used in the Cumulative Effects assessment. Once the Province has developed a methodology, existing disturbance metrics will be summarized (Appendix F) for each range."[30]

As evident in the recovery plan, restoration poses some risks to caribou. The implications of increased early seral habitat on boreal caribou are increased apparent competition.[31] Another study found that wolves did not select for caribou habitat, and suggested that predation risk for caribou was more strongly related to the occurrence of other prey species, such as moose and deer.[32] Creation of early seral habitat can stimulate an increasing moose population that results in higher wolf abundance and changed wolf distribution. This cascade is called apparent competition and has been shown to have adverse impacts on some caribou populations.[33]

Environment Canada defines disturbed habitat as all burned areas ≤ 40 years and all anthropogenic disturbance visible on Landsat imagery at a scale of 1:50,000 plus a 500-metre buffer. The province is currently defining early seral habitat as young forest ≤ 35 years for burns and ≤ 25 years for cutblocks.[34]

Caribou biologist Ray provides some cautionary notes about definitions of seral habitat.

"If 'early seral' is equivalent to 'disturbance,' it is a hugely different definition of disturbance from ECCC. Lowering the bar for early seral forest may mean that they assume caribou habitat constitutes burned forest > 35 years and cutblocks > 25 years, and there is little evidence for this. More importantly than the list of restoration targets is an explanation of how B.C. plans to use such targets that will add up to the overall goal of achieving the 65% undisturbed threshold."[35]

The development of potential alternative approaches using forest attributes to assess habitat condition is underway. In recognition of Environment Canada's approach to calculating disturbance, the province will apply a 500-metre buffer (representing a zone of disturbance) to cutblocks and all anthropogenic disturbances.[36] However, the province suggests the application of a single buffer size (e.g., 500 metres) to all disturbances increases uncertainty in the results, since caribou respond differently to varying types of disturbances.[37] [38]

The B.C. Boreal Caribou Recovery Plan has several complex components with respect to caribou; for example, the tension between regeneration and rates of predation, as regenerating areas attract more ungulates, which in turn attract more predators, and the determination of an appropriate buffer around disturbance used to calculate the negative impacts on caribou. As such, different protocols are used by different planners.

With respect to standards for linear feature disturbances in habitat ranges, the province will determine progress in achieving habitat targets using early seral data without a 500-metre buffer. A similar approach will be followed with linear features, where progress relative to targets is measured 1) with a 500-metre buffer applied to all linear features except low impact seismic lines; and 2) without a 500-metre buffer (i.e., linear features that do not significantly contribute to early seral/disturbed habitat).

The province proposes to reduce the amount of early seral habitat[39] primarily by identifying an early seral threshold. The mechanism to reduce disturbance is to restrict the creation of future disturbance to levels that are compatible with boreal caribou recovery. The province has identified an early seral threshold of six per cent of each range, excluding burns (i.e., less than six per cent of each range must be in an early seral condition as a result of timber harvesting). What is not known is whether the province has in fact implemented this threshold standard or how it plans to enforce such a standard with industry. The early seral threshold is based on results of a model (Wilson, unpublished report) using predator-prey data and landscape characteristics such as linear feature density and proportion of early seral habitat. The early seral threshold represents an additional six per cent over naturally occurring disturbance; in the event of a catastrophic wildfire, the province would re-evaluate the management levers used in that range.

B.C. has also developed a framework for restoration and associated monitoring for seismic lines within woodland caribou habitat and are in the process of testing alternative restoration techniques, such as snow fences to reduce predator (wolf) movement.

CHALLENGES OF RESTORATION

The B.C. government has set a caribou range undisturbed threshold of a minimum of 65 per cent, based on the federal government's directed minimum objective for restoration.

To reach this target would require restoration of at least 1,314,452 hectares of linearly disturbed habitat of a total disturbed area of 2,434,272 hectares.

How B.C. plans to implement and enforce its Boreal Caribou Recovery Plan and move from the 2017 assessed state of boreal woodland caribou range disturbed by Environment Canada (76.1 per cent disturbed) to a goal of 65 per cent undisturbed condition is not clear. The B.C. Government has not established an ILM system as Alberta has initiated, nor has the government initiated any form of scenario analysis or modelling that would examine various options and trade-offs for achieving the 65 per cent undisturbed habitat area target while mitigating potential opportunity costs to oil, gas and forestry future activities.

The Government of Alberta is using their ILM strategic planned approach to restore, manage and reduce the human footprint on the landscape that can balance values, benefits, risks and trade-offs. The Alberta Land-use Framework[40] [41] and the Biodiversity Management Framework have emphasized restoration of legacy seismic lines and committed to an ambitious restoration program restoring 6,000 kilometres of seismic lines within five years as part of the draft plan for the Little Smoky and A La Peche caribou ranges.[42] These initiatives are only now being implemented; results are not yet forthcoming. These initiatives hold some promise and possibility for land use policy changes that could result in positive restoration efforts in B.C. and Alberta.

One of the strengths of the Alberta government's ILM and ABMI systems is the capability to do scenario analysis and look at different accommodations between caribou recovery and the continuation of extractive natural resource

industry activity in Alberta's caribou ranges. Alberta's woodland caribou restoration strategy of 2017 shows that to date, an estimated 2,455,338 hectares (24.4 per cent) of an estimated 10,062,536 hectares of woodland caribou range has already been protected in the form of parks, wilderness areas and natural areas. As economist Power points in his study of caribou restoration economics for Alberta's Bistcho and Yates boreal caribou ranges, if the "Bistcho and Yates ranges are to be returned to at least 65 per cent undisturbed habitat, there will have to be large areas that are protected from commercial extractive activity."[43] He points to the potential for using the Patchworks optimization model[44] to conduct what-if optimization scenarios while achieving the 65 per cent undisturbed habitat targets.

Power hypothesizes that in Alberta restoration of boreal caribou habitat across the two specific ranges may occur by grandfathering existing oil and gas extraction activities across the necessary (minimum) 65 per cent of caribou range habitat while halting all future seismic, well site and forestry activities on the same habitat range while still allowing 35 per cent of the range to be used for resource extraction activities. He suggests that a caribou land management plan might entail connectivity of islands of range across all respective caribou herd ranges. He also points out that the opportunity cost to the oil, gas and forest industries from such a scenario of grandfathering existing resource industry activities might actually result in rather minimal opportunity costs to these industries. At the same time, restoration of legacy linear disturbances such as seismic lines could lead to positive economic impacts from labour-intensive site restoration such as tree planting that could offset any potential economic losses to business-as-usual resource industry activities. A pilot project by the Government of Alberta to restore approximately 10,000 kilometres of legacy seismic lines in cooperation with the energy sector companies in the Little Smoky and A La Peche boreal caribou ranges is currently underway with results being closely monitored and assessed. This is part of Alberta's May 2017 newly released *Provincial Restoration and Establishment Framework for Legacy Seismic Lines in Alberta*. Once these results become public, they should provide important insights into what may be viable for seismic line restoration across the five to six B.C. boreal caribou herd ranges.

What has been learned in the case of Alberta's efforts is that a combination of "habitat restoration" (vegetative restoration on legacy seismic lines) and "functional restoration" (creating barriers to limit access on legacy seismic lines by predators, other competitor ungulates such as moose and deer, and human recreation) will both be required for restoration efforts to succeed. Natural Resources Canada caribou biologist Anna Dabros (Dabros, et.al, 2018) has concluded that "to be successful, restoration treatments must clearly document site-limiting factors, and address these factors through creation of microsites, facilitation of natural regeneration, mechanical site preparation, and (or) tree planting…Prioritization of seismic restoration efforts will be inevitable… priority must be established as to which areas need to be restored first, based on their ecological value in terms of supporting biodiversity and (or) vulnerable species, and provision of economic and ecosystem services."[45]

Restoring 1,314,452 hectares of B.C.'s woodland caribou forest ecosystem in northeastern B.C. will take decades, if not a century, for the forest ecosystems to return to the mature forest habitat required by boreal caribou. A commitment to such a forest ecosystem future will take political will and sustained commitment in terms of land-use planning and a forest management regime that will ensure caribou habitat can be effectively restored. It will also require some economic restraint and some intensive management (e.g., wolf control) to keep the caribou alive while restoration and protection is occurring. A huge challenge, as outlined in Ray's paper, is that industry would like to receive credit for restoration activities they undertake before such sites qualify as habitat, so industry can undertake new activities, which may undermine any habitat restoration. These are among the many challenges with restoring northern boreal forest ecosystems to their original primary forest condition. While B.C. has drafted a Boreal Caribou Recovery Plan, it's not clear at what pace restoration could take place to reach the restoration goal or even if the goal can be achieved with the plan. Nor is it clear whether there is a real political or policy commitment (e.g., land-use planning and management guidelines) to lead to such a restoration aspiration.

A review of the literature and consultation with caribou biologists found many apparent challenges and uncertainty as to what the best ap-

proach should be to restoring woodland caribou habitat and a stable woodland caribou population throughout the northeast boreal forest ecosystem.

Biologists are of mixed opinion on what might be the best approach to habitat restoration in caribou habitat already significantly affected by linear disturbance; whether a macro-ecosystem approach or microsite-level restoration, or a combination of both. Dealing with the emerging risks of climate warming on caribou health (e.g., winter ticks and hair loss) adds another layer of complexity to a practical restoration strategy.

Caribou scientist Ray spells out the caribou habitat restoration challenges (site-specific and range-level) for achieving self-sustaining caribou herds. In her 2014 discussion paper, Ray points out the following challenges:

"The extent of habitat loss that is ongoing in large parts of the species' distribution is exacerbated by a legacy of inadequate attention to reclamation following development and associated linear features. The Recovery Strategy for boreal caribou under the federal Species at Risk Act, released in 2012, provides a framework for setting restoration priorities for boreal caribou, based on a well-established relationship between habitat disturbance and population condition. The reference state for boreal caribou habitat restoration efforts is defined as the relative amount of "undisturbed habitat" as a key part of Recovery Strategy's critical habitat definition, relative to the recovery goal of achieving self-sustaining local populations in all boreal caribou ranges throughout their current distribution in Canada, to the extent possible.

The practice of ecological restoration tends to be dominated by local-scale efforts, yet effective restoration for boreal caribou will require explicit linkages between site-specific restoration actions and corresponding range-level effectiveness evaluations. Site-scale efforts directed towards restoring features (e.g., well pads, cutblocks, linear features, etc.) are necessary to set a course for success, where work is defined on the basis of local (e.g., eco-site) conditions to establish the best potential areas, likely trajectories, and the end points of active efforts. And while it would be appropriate to credit restoration efforts in some fashion for work that has achieved interim success (i.e., establishment on a trajectory), this does not itself indicate that sufficient restoration has occurred to trigger permitting of disturbance elsewhere in a population range if it has not achieved self-sustaining status.

Where required, habitat restoration at the range scale should prioritize areas for restoration effort, undertake strategic coordination of restoration activities, build large blocks of restored features with high connectivity, and monitor progress of range-scale restoration. Range plans, mandated by the Recovery Strategy, will provide a useful platform for guiding restoration efforts at appropriate scales and monitoring the success of all recovery efforts. Locally variable conditions and a lack of a true ecological threshold makes it necessary to adopt a cautious approach with deploying the management threshold of 65% "undisturbed habitat" as a restoration target, and heightens the importance of monitoring of population trends to test whether local populations are responding positively to restoration efforts."

Ray provides a framework for establishing criteria for measuring progress toward the restoration goal and objectives, with each criterion designed to be implemented at either the feature or range scales, which should be considered in tandem.

Some ecologists have pointed to the challenge of site-specific restoration such as linear disturbance from seismic lines. Functional restoration while restricting predator corridor travel has shown limited ability to recover forest habitat vegetation.[46] What is important is the distinction between functional restoration treatments (which limits predator movement) and habitat restoration methods.

Anna Dabros et. al. point out the following challenges with seismic lines:

"Seismic lines represent site conditions that provide additional challenges to restoration efforts, such as high shading, cold soils, high water tables, or in some cases compacted soils. To be successful, restoration treatments must therefore clearly

document site limiting factors and address these factors through creation of microsites, facilitation of natural regeneration, mechanical site preparation, and (or) tree planting. The costs, labour, and logistical constrains necessary for restoration of all currently present seismic lines may be a daunting and unrealistic undertaking. Given the scale of this challenge, prioritization of seismic restoration efforts will be inevitable. As such, priority must be established as to which areas need to be restored first, based on their ecological value in terms of supporting biodiversity and (or) vulnerable species, and provision of economic and ecosystem services. One possibility could be the use of active restoration within woodland caribou ranges, and outside them, use approaches to "erase" seismic lines through forest harvesting or prescribed burning, which may provide a more efficient means of achieving restoration objectives."

On a range-scale they note:

"Preventative measures should also be taken to minimize future disturbances through integrated land management and mitigation practices [large range-scale planning], which may reduce the overall footprint of cumulative disturbances, including linear disturbances such as seismic lines. To facilitate more rapid recovery of LIS lines, approaches should be tested which better create the necessary microsite conditions upon which natural recovery may occur rapidly following the initial disturbance."[47]

These recommendations are worth considering from a proper full-cost accounting perspective, i.e., the estimated restoration costs be on a per-hectare, site-specific basis of linear disturbance under various restoration options including:

1. Facilitating natural regeneration;
2. Creation of microsites (e.g., islands of native plant species as the source regeneration of seismic lines, pipelines and well sites);
3. Mechanical site preparation;
4. Tree-planting; and
5. Prescribed burning of already extensively disturbed sites to "erase" seismic lines, as one option for establishing an ecological "reset" to move more quickly to a new primary forest ecosystem.[48]

Biologist David Polster (Polster Environmental Services Ltd.) noted that "burning re-sets the clock ecologically, but the impact on caribou where winter food is arboreal lichens could be significant if large areas were burned. However, burning is what these forests used to do before human industrial development came along so I would assume that caribou found a way to cope with forest fire cycles."[49]

Burning will not be effective if there are adjacent undisturbed areas to supply food that are also put at risk. What is certain is that the combined, cumulative effects of logging, seismic line, well site and pipeline development and natural disturbance (fire) have affected caribou negatively.

In a 2018 study of restoration economics for Alberta's woodland caribou, Power points to another possible scenario that might be applied to northeastern B.C. boreal caribou ranges. He suggests an optimization approach that prioritizes the areas in each caribou range that have the best chance to return the legacy seismic lines to undisturbed status, while keeping in mind the costs of restoration in each different area. This type of optimization analysis is made possible with different conservation planning software tools that allow land managers to achieve the minimum of 65 per cent undisturbed goals with various range plans. His study shows that in some Alberta ranges, "historically 'disturbed' lands can be converted to 'undisturbed' status in order to meet the minimum 65 per cent 'undisturbed' target, thus reducing the extent to which current industrial activity might otherwise have to be reduced to meet that target. In that sense, the out-of-pocket cost of such restoration activities can be seen as an opportunity cost incurred to allow higher levels of industrial activity on caribou ranges while meeting the 'undisturbed' target."

According to the Alberta government's Woodland Caribou Plan, 150,000 kilometres of legacy seismic lines "in their current state, are not fully capable of natural woody vegetation re-establishment, and therefore need some treatment(s) to encourage restoration."[50] According to the same document, an additional 100,000 kilometres of legacy seismic lines "do not need intervention due to a combination of factors, such as:

1. Areas have sufficiently regenerated or

are on their way towards natural regeneration;

2. Historical and near-term approved future timber harvest areas overlap legacy seismic lines, which will be reforested as a best management practice;
3. Areas are not practical to restore due to environmental conditions — potential for further ecosystem degradation, poor accessibility, muskeg or bog areas that don't support significant tree cover naturally; and
4. Historical wildfire areas, where natural regeneration has been initiated through natural processes."[51]

However, there remains evidence in Alberta that "legacy seismic lines will not return themselves to undisturbed status" as after 35 years, more than 60 per cent of the seismic lines in Alberta "showed little or no recovery back to a forested state."[52] In Alberta's northern Bistcho[53] and Yates boreal woodland caribou ranges, Power Consulting used this evidence to estimate there were "about 43,000 km of the total 67,000 km of seismic lines that need to be restored before the minimum 65 per cent undisturbed threshold can be met, or about 65 per cent of the legacy seismic lines that exist on the two ranges."[54]

WHAT MIGHT WORK FOR HABITAT RESTORATION?

Nagy (2011) noted that all B.C. boreal woodland caribou populations were considered non-self-sustaining because more than 45 per cent of the habitat was disturbed and/or because population numbers were low.[55] The 2012 Environment Canada study Recovery Strategy for the Woodland Caribou showed that all B.C. boreal caribou ranges were either unlikely or very unlikely to be not self-sustaining.[56]

Connectivity of habitat both within a range and between ranges is essential for boreal caribou persistence on the landscape.[57] However, more recent studies by Environment Canada (2012) shows that the overall disturbance level is a more important driver. In other words, if the disturbance is high, it does not really matter how connected the habitat is. Within a range, habitat connectivity allows for seasonal movement among habitat with the different resources needed by boreal caribou to satisfy their life history requirements, and for boreal caribou to use different areas as they respond to disturbance or as disturbed habitat recovers.

"Studies have demonstrated that isolation of local populations as a result of disturbance to the landscape (i.e. any form of anthropogenic or natural habitat alteration), can result in a significant reduction in genetic diversity (Courtois et al., 2003; Weckworth et al., 2012). Connectivity between ranges also maintains recovery or rescue effects between boreal caribou ranges. Finally, connectivity within and between boreal caribou ranges will allow for movement in response to changing environmental conditions (e.g. climate change) (Racey and Armstrong, 2000; Courtois et al., 2003; McLoughlin et al., 2004; Pither et al., 2006; Boreal Caribou ATK Reports, 2010-2011)."[58]

Given that climate change is resulting in environmental changes that allow increased populations of insects like pine-bark beetle and higher temperatures, the incidence of fire is increasing. Given current caribou habitat conditions and the potential increase in fire affecting northern landscapes,

the only factors we can control to try to stabilize or increase populations of woodland caribou in northern B.C. are levels of human-made disturbances, by avoiding the disturbance of areas of remaining habitat (which has implications for forestry, oil, gas, mining and other human activities) and/or measures to restore disturbed habitat. For low caribou populations, interim population management will be critical to keep them alive.

Restoration activities are problematic because one cannot just plant an old growth forest; there is a significant time delay between action and outcome. Short-term activities should focus on restoration activities on linear disturbances that would at least reduce potential effects of predation and hunting, even though habitat recovery may take a long time.

Without some sort of human intervention, B.C. woodland caribou populations are likely to continue to be non-self-sustaining and conditions will worsen as a result of ongoing human activities and an increased probability of fire. Intervention needs to involve ceasing human activities in remaining areas of undisturbed caribou habitat as a first priority and undertaking restoration activities in selected areas as a second priority. We can undertake restoration of linear disturbances but unless there are large adjacent areas of undisturbed habitat, these activities may not actually benefit caribou populations. While planning is important at the microsite level, it's equally if not more important at the range scale. This is an important consideration in selecting areas for restoration activities (optimization).

As Dabro et al. (2018) note: "To be successful, restoration treatments must therefore clearly document site limiting factors and address these factors through creation of microsites, facilitation of natural regeneration, mechanical site preparation, and (or) tree planting. The costs, labour, and logistical constraints necessary for restoration of all currently present seismic lines may be a daunting and unrealistic undertaking. Given the scale of this challenge, prioritization of seismic restoration efforts will be inevitable (van Rensen et al. 2015).

As such, priority must be established as to which areas need to be restored first, based on their ecological value in terms of supporting biodiversity and (or) vulnerable species, and provision of economic and ecosystem services." The ultimate measure of success is to keep an eye on the population and range conditions.

COULD BOREAL CARIBOU RESTORATION IN SOME OF B.C.'S KEY CRITICAL HABITAT RANGES BE ACHIEVED WITHOUT ANY DISPLACEMENT OF FORESTRY OR OIL/GAS INDUSTRIES?

Power's 2018 economic study of woodland caribou habitat restoration in Alberta noted that, in the case of two northwestern Alberta boreal woodland caribou ranges (Bistcho and Yates), "65 per cent or more undisturbed caribou habitat threshold required by the federal government could actually be met with almost no displacement of industrial activity (forestry and oil and natural gas) currently taking place."[59] Denhoff, a mediator facilitating the conversation about caribou restoration strategies in Alberta concluded "that committing two Forest Managements Unites (FMUs) to caribou conservation: will achieve permanent protection of…61% of the Bistcho range, 72% of the Caribou Mountains range and 72% of the Yates range--immediately. It does not require displacement of any existing forestry tenure and existing oil and natural gas leases can be grandfathered in." It should be noted that grandfathering does not constitute protection of habitat, per se.

Power's report supports the use of optimizing models, such as the Patchworks Spatial Planning System, to identify the best choices to realize habitat and economic goals in caribou ranges using a combination of both functional restoration (i.e., physical landscape efforts to block access along legacy seismic lines) and habitat restoration (i.e., vegetative remediation, planting, etc.) on legacy oil, gas and forest activity land throughout northeastern B.C. woodland caribou ranges.

Power's 2018 study on restoration economic potential for Alberta points to the possibility of optimizing for conservation and commercial economic values, and pursuing the best land-use choices to support both goals in caribou ranges.

RESTORATION COST ESTIMATES

A logical question is: What would it cost to test any one or more of the above restoration options on a per hectare basis of disturbed habitat?

Restoration and reclamation practitioners offer insufficient full-cost evidence about restoration costs if applied to a specific caribou ranges or the entire estimated 1,314,452 hectares of northeastern B.C. boreal forest caribou habitat that would have to be restored to achieve the minimum 65 per cent undisturbed goal. As Power points that while there is a tremendous amount of research focused on seismic line regeneration in support of caribou, "there is a decided lack of specific costs associated with that seismic line restoration."[60] A full-cost accounting (including capital, operating and labour costs) of these options will ultimately be necessary to estimate the economic benefits potentially available to B.C. from ecological restoration of these landscapes for caribou recovery.

A number of biologists and site restoration consultants and practitioners were interviewed to assess the current state of restoration activity in B.C. and Alberta that could provide insights into the estimated cost of restoring seismic lines, pipeline rights-of-way, well sites and other oil and gas development footprints in the boreal forest. Cost estimates vary depending on the type of treatment of a site. Treatment of seismic lines will have a different cost structure than treatment of well sites. Currently, no prescribed treatment is deemed effective at restoring caribou habitat to an ecological functional level. At best we can learn from the successes and failures of current site restoration practices.

We cannot say how much restoration effort will be required over what specific habitat zones across a total of over 2.4 million hectares of caribou range affected by anthropogenic disturbance will be required to achieve the 65 per cent undisturbed habitat goal (an area of 1.314 million hectares) and self-sustaining caribou herds. It may be that investments in seismic line restoration may have the greatest return on investment in terms of caribou restoration effectiveness, which would constitute a smaller land area of restoration 138,645 kilometres of seismic lines) across the disturbed caribou habitat. Also, it may be that some caribou habitat restoration may occur across some forest landscapes simply through natural restoration of the forest ecosystem, requiring little or no human effort. We cannot say for sure.

To date the evidence of historical site remediation efforts on mine sites, seismic lines and well sites suggests that caribou habitat restoration has been less than satisfactory if the aspiration was to return the land back to its historical ecological conditions, such as a primary forest.

SEISMIC LINE RESTORATION COSTS

Seismic lines are by far the most pervasive linear disturbance in oil and gas areas in the B.C. and Alberta northern boreal forest region[61] and the most important factor affecting the amount of landscape fragmentation and disturbed boreal woodland caribou habitat, compared with other forms of linear disturbance such as cutblocks, trails, well pads, pipelines, transmission lines, industrial sites, roads and mine sites.[62]

Given the extent of seismic line development and large spatial footprint throughout B.C. and Alberta boreal woodland caribou habitat ranges, large restoration programs will be required to facilitate recovery of woodland caribou communities back to natural disturbance conditions.[63]

Efforts at restoring legacy seismic lines in

both B.C. and Alberta are only now beginning to be made with no public reporting of the effectiveness of these efforts nor a full-cost-benefit accounting of these efforts. This limits our ability to provide a reasonable estimate of the potential economic impacts of restoring these seismic lines to functional habitat for B.C. and Alberta woodland caribou.

The Alberta government is conducting a pilot project to restore approximately 6,000-10,000 kilometres of legacy seismic lines (to achieve the minimum 65 per cent undisturbed habitat goal) in co-operation with energy sector companies in the west central Little Smoky range (98 per cent legacy seismic line disturbance) and the adjacent A La Peche caribou winter range (84 per cent seismic linear disturbance). This project is a joint partnership between the Alberta government and Alberta's energy industry, which has volunteered to pay for the project.

Power Consulting's report on Alberta's seismic line restoration efforts could provide reasonable proxies or benchmarks for assessing the potential economics of B.C. caribou habitat restoration. Power believes the Alberta pilot project could potentially be a road map for seismic line restoration across the different Alberta caribou ranges . Whether the project will be effective in restoring legacy seismic line areas that will also secure a healthy woodland caribou population across these two caribou ranges has yet to be verified. The cost details and results of this pilot are not currently available to the public.

More recently, findings were published about the economics of restoring trees on seismic lines in treed peatlands in Alberta woodland caribou ranges.[64] They found that methods of reforesting seismic lines in northeastern Alberta are expensive, averaging $12,500 per kilometre (average $25,000 per hectare assuming a five metre average width) with seismic lines averaging between three to eight metres in width. The high costs are due to narrow (three to eight metres) and long (kilometers long) linear shapes and remoteness (difficulties in accessibility for equipment and labour). Their study points to the uncertainty as to which types of seismic lines need which treatments. It concluded that "seismic lines in treed in treed peatlands are not recovering following disturbance, with some staying unforested for many decades. Trees that do establish on seismic lines often have difficulty in growth and survival due to simplification in microtopography and a lower water table depth. Restoration treatments increased tree density when compared to the untreated lines, despite averaging 3.8-years since treatment application (vs. untreated lines averaging 22 years). Mechanical Site Preparation (MSP) on seismic lines show promise in restoring caribou habitat (treed peatlands), but further studies with a longer time horizon are required."

Power's 2018 economic study for caribou restoration provides meaningful, relevant restoration cost estimates that could be applicable to B.C. caribou range restoration efforts, notwithstanding the lack of full disclosure of a breakdown of the costs and labour of restoring legacy seismic lines in Alberta's A La Peche and Bistcho caribou ranges. He points to B.C.'s Boreal Caribou Habitat Restoration Operational Toolkit[65] and COSIA[66] and Cenovus[67], which are actively restoring small sections of different caribou ranges in Alberta. Firms like Silvacom (Alberta) are actively promoting and selling fully integrated restoration of seismic lines from modelling to implementation.[68]

Craig DeMars and Kendal Benesh, with support from the BC Oil and Gas Research and Innovation Society, in co-ordination with the University of Alberta and the ABMI, produced a report called Testing Functional Restoration of Linear Features within Boreal Caribou Range.[69] This study looked at the costs associated with functional restoration, which only aims to create barriers to animal travel on the legacy seismic lines, whether wolf (predominately), moose, deer or human. The authors found that:

Cost effectiveness and logistical feasibility were key components of our overall objective. In terms of cost, the techniques suggested here are well under costs associated with current ecological restoration initiatives (mounding and tree planting) on a per km basis (i.e. ≤ $6,200 vs.> $10,000).[7071]

Power Consulting examined these costs more closely and found they could be in the lower range of $4,000 per kilometre for functional restoration of seismic lines, meaning that trees are used to block the seismic lines in place of fences and that helicopters are not needed for transportation of equip-

ment, materials and personnel (because of easier accessibility). This cost estimate is about 40 per cent of the cost typically cited by the Alberta government. The lower-bound estimate of $4,000 per kilometre is based on the recent experience by Eric Auger and Sons, an Indigenous-owned seismic line restoration contractor in Alberta that worked on remediation of seismic lines in Alberta's A La Peche woodland mountain caribou range (still in a 72 per cent undisturbed condition). The project entailed restoration of 59 kilometres of seismic lines by planting more than 80,000 trees, and protecting 11 kilometres of advanced regrowth. Seismic line restoration involved restoring human-made linear features to a forested condition and has been identified as a critical component in the effort to create and maintain self-sustaining caribou populations in Alberta.[72]

Power adopted a restoration cost estimate of $10,000 per kilometre[73] (or about $20,000 per hectare assuming an average five-metre width) to estimate a combined functional and habitat restoration cost of legacy seismic lines in the Bistcho and A La Peche caribou ranges, noting "it appears to be the most common assumption, even though a specific breakdown of that cost per km into its component parts is elusive…no one has a detailed breakdown of the specific costs associated with legacy seismic restoration."[74]

In contrast to seismic line restoration, costs of restoring pipeline rights-of-way are roughly $60,000 per kilometer of pipeline right-of-way over a five-year period, according to Alberta-based restoration consultant Garry Adams. A pipeline right-of-way is generally 50 metres wide, compared to a five-metre wide, low-impact seismic line. On an equivalent area basis, Adams' cost estimate applied to a typical seismic line would equate to $6,000 per kilometre of seismic line restoration over five years.

Power's $10,000 per kilometre cost estimate is drawn from the 2017 study by Craig DeMars and Kendal Benesh on functional restoration. We can estimate the amount of labour and effort required to restore legacy seismic lines and apply these to B.C. They estimate teams of four people can collectively treat one kilometre per day with an estimated five people per kilometre assumed to be necessary to plant trees and cut, and run the machine that creates the mounds, but who can only work for one-third of the year while the ground is frozen. Assuming that there would only be 122 seasonal working days in a year to do the work, Power estimates it would take 20 five-person teams working for 18 years to restored 65 per cent of the linear disturbances in each of Yates (552,244 hectares)[75] and Bistcho (1,435,801 hectares) caribou ranges in Alberta. This would equate to an annual cost of between $9.75 million (using the lower bound $4,000/kilometre cost estimate) to $24.37 million per year (using the $10,000/kilometre cost estimate), for a total undiscounted cost of about $434 million over 18 years.

Their estimates do not reveal how much of this total is labour versus equipment and other expenses. Notwithstanding the value of restoration, employment would be significant for the caribou range area totaling nearly two-million hectares. This restoration activity would result in direct employment and money that could flow back into local communities in wages and salaries as well as diesel fuel purchases, equipment rental and other costs. This would be seasonal work similar to all timber harvest and tree-planting work.

We will use Power's $10,000 per kilometer cost estimate for both functional and habitat restoration of legacy seismic lines in B.C.'s boreal caribou ranges (Table 9). These cost estimates can be applied to a potential spectrum of seismic line restoration from, e.g., 65 per cent of the estimated 138,645 kilometres of legacy seismic lines to 100 per cent of these seismic lines; this depends on how much seismic line restoration that would also encompass buffer area would be necessary to achieve the 65 per cent undisturbed habitat range area. Power used the 65 per cent of seismic lines in his estimate for restoration economics for the Bistcho and Yates ranges in Alberta.

Table 7: Seismic line restoration cost estimates

Estimated seismic line restoration costs	Lower limit	Seismic line area cut, 2005-14 (kms)
(65% of total)	Upper limit	138,645 km
Seismic line (km) restoration target (total) across all six caribou ranges over 20 year restoration period	90,119 km	138,645 km
Seismic line (km) restoration per annum over 20 yrs.	4,506 km	6,932 km
Seismic line area (hectares) of annual restoration over 20 yrs.	9,012 ha	13,865 ha
Cost per km	$10,000	$10,000
Total restoration costs	$901,192,500	$1,386,450,000
Annual restoration costs for restoration (over 20 yrs.)	$45,059,625	$69,322,500
Labour/wages		
Seismic line kilometers restored per day over a 122 day work season	36.9	56.8
# of workers required per year/season to restore the linear disturbance in 20 yrs.	185	284
Estimated total wages (@$37.00/hour and eight-hour days)	$6,668,825	$10,259,730
Assumptions		
Seasonal working days per year	122	122

If this work were spread out over a 20-year restoration period, the average annual restoration would be between $45.1 million to $69.3 million per year.

We estimate total annual employment of between 185 and 284 seasonal workers over a 20-year period to restore only the kilometres of seismic lines. The labour estimates are based on Power Consulting estimates that about five workers are required to restore each kilometre of seismic line, working seasonally, which is roughly 122 days per year. The wages generated by this amount of employment would be significant considering that average hourly wages in B.C.'s forestry, fishing, mining, quarrying and oil and gas industries averaged $37.00 per hour in 2018.[76] If we used the same $37.00 per hour wage rate applied to the estimated 185 to 284 seasonal workers per year working eight-hour days 122 seasonal days per year restoring legacy seismic lines alone, the total wages could range from $6.67 million to $10.26 million per year over 20 years.

By comparison, in 2017, 18,600 people were employed in B.C.'s forestry and logging with activities sector in 2017.[77] Total wages and salaries in B.C.'s forestry and logging industries in 2016 was $736,427,000, according to Statistics Canada.[78]

If restoration work was expressed on a per

hectare of land use basis, restoration would employ an estimated 0.034 people per hectare of restored lands compared to 0.096 people per hectare of forest lands harvested in B.C. in 2017.[79] This is based on a ratio of 18,600 employed in forest harvesting to 193,000 hectares of forest land harvested each year in B.C. in 2017.[80]

Another relevant benchmark to seismic line restoration economics is the cost and economics of tree planting on forest lands. A recent study of the economic benefits of tree planting in southern Ontario by Green Analytics (2019) shows the following comparative economic impacts:

- Average cost of tree planting per hectare = $5,315 per hectare
- Employment (FTEs) per hectare of reforested forest lands = 0.077
- Seasonal employment per hectare of reforested forest lands = 0.230
- GDP benefits per hectare of reforested forest land = $9,381
- Ecological goods and services value per hectare of forest land reforested = $61,084
- Average of 1,353 hectares of forest land replanted per year between 2008-2018
- Average of 2,221,080 trees planted per annum between 2008-2018

By comparison, the proposed area of seismic line restoration in B.C.'s woodland caribou ranges would be between 6.7 and 10.2 times larger of an area per annum compared to the average area of reforested forest lands tree in southern Ontario between 2008 and 2018.

Our estimates are likely conservative since we have only considered functional and habitat restoration on legacy seismic lines. The total spatial area of linear disturbance could be more than 20 per cent higher than Environment Canada estimates if using more advanced geospatial analytics such as the ABMI has conducted for Alberta caribou ranges. A more complete cost estimate should also include effective restoration of well sites, roads and forestry cutblocks, which are included in the estimated 2,434,272 hectares of caribou range affected by anthropogenic linear disturbance. It's difficult to determine just how much restoration would be actually be sufficient and effective across this large landscape area without testing the veracity of restoration protocols.

Our seismic line restoration employment estimates come with caveats. New restoration employment or jobs would not necessarily be created; rather, marginal incremental employment of either unemployed or underemployed workers with the suitable skill sets would occur. Some site restoration work is already ongoing in fulfilment of B.C. regulatory standards (e.g., oil and gas sector standards), and these employment numbers are found within Statistics Canada industry employment figures for forestry and mining sector statistics. Exact restoration figures are unknown.

There would be additional monitoring costs to ensure successful restoration occurs, whether the restoration is functional or habitat. These cost estimates have not been determined for this study.

These restoration scenarios and cost estimates should be considered as a preliminary at-best set, as Power notes in his economic analysis. Real costs and results of caribou habitat restoration have not yet been proven or verified. Power points out that, in Alberta, it's unclear if functional restoration alone will allow a recovery of caribou on their ranges with "some 150,000 km of legacy seismic lines that have not grown back on their own….It should be kept in mind that this low cost 'restoration treatment' may not qualify as turning the seismic lines into undisturbed caribou range that can contribute to reaching the federal government's mandate of at least 65 per cent undisturbed habitat."[81]

These preliminary economic benefit estimates have not considered a full-cost-benefit accounting of a full suite of values, including a range of ecosystem service value benefits that are often considerable yet unpriced in economic impact analysis.

We concur with Dabros et.al. (2018) that, given the scale of this challenge, prioritization of seismic line restoration efforts will be inevitable; priority must be established as to which areas need to restored first, based on their ecological value in terms of supporting vulnerable species like woodland caribou, and provision for economic and ecological services.[82] Preventative measures must be taken to minimize future disturbances using ILM and mitigation practices that will reduce the overall footprint of cumulative disturbances, and potentially target intensive management to make sure the caribou population will not go under while all restorative work is undertaken.

PIPELINE RESTORATION COSTS

According to OGC, the province had 44,552 kilometres of pipelines, of which 80 per cent were natural gas.

This represents and estimated total spatial area of 222,760 hectares (assuming a 50-metre width).[83] Using pipeline restoration estimates by T. Harris Environmental Management based in Alberta, restoration costs can be as high as $30,000 per kilometre in year one of restoration, followed by declining annual costs of $10,000 per kilometre (year two), $9,000 per kilometre (year three), $7,000 (year four) and $5,000 (year five) for a total of $12,200 per kilometre of pipeline.[84] The amount of additional work required in subsequent years depends on the success of site restoration. Applied to B.C.'s total pipeline footprint, the estimated restoration costs for remediating all pipeline kilometres would be roughly $2.717 billion. How much of this pipeline restoration liability can be attributed to the northeastern B.C. woodland caribou range could not be determined.

Michael Clark of Clark Ecoscience and Sustainability Ltd. estimates restoration costs of roughly $5,000 per island (microsites) for a typical right-of-way on Alberta pipelines. Clark prefers to restore sites to a more biodiverse range of plant and herb species than single grass monocultures even though it's costlier per hectare of right-of-way. He recommends creating a number of islands on pipeline and seismic rights-of-way; e.g., roughly five mid-sized islands on a one-kilometre stretch. He estimates each microsite island would cost $5,000 to establish or $30,000 for a one-kilometre pipeline and 80-metre right-of-way width. This would equate to roughly $3,750 per hectare of linear disturbance area in the first year of restoration. The cost of annual site care, including monitoring and watering, will depend on various ecological conditions, including drought.

WELLSITE RESTORATION COSTS

The most recent reporting (November 2014) shows there were 6,978 abandoned wells and 2,945 suspended wells in B.C., a total of 9,923.

Well sites vary in size from the historically typical well site area of 1.440 hectares (3.558 acres) with one well to larger sites that may contain multiple wells where the size may range between 1.62 to 10.12 hectares (four and 25 acres). Using average well site size of 1.440 hectares, the total spatial footprint of B.C. well sites would be roughly 14,294 hectares. At the end of the 2016-17 fiscal year, unsold Terra Energy Corp. sites (wells, facilities and pipelines) were designated orphan sites, bringing the total count of orphan sites to 220 in B.C. This is significantly lower than the nearly 10,000 abandoned or suspended wells in B.C.[85]

Precisely how many well sites are located within the two-million-hectare northeastern woodland caribou ranges is not known; we do not know how many wells are orphaned, abandoned or suspended that require remediation and restoration for caribou habitat purposes.
Total oil and gas levies from the fiscal year were $1.5 million. At the end of the fiscal year, the orphan well fund balance consisted of $5.3 million in current assets. However, the full decommissioning and restoration costs for the orphan sites was estimated to be in the range of $40 to $60 million or between $181,818 to $272,727 per well site restoration cost liabilities.[86] This suggests there is a significant shortfall of between $34 and $55 million; that is the difference between the estimated future restoration cost liabilities ($40 to $60 million) and the current balance of restoration levies collected from industry.

According to research conducted by John Werring, David Suzuki Foundation senior science and policy adviser, B.C. has grossly underestimated the cost of cleaning up abandoned and suspended well sites, which he estimates to be around $700 million (assuming an average cost of around $70,000 per well for an estimated 10,000 well sites). At an upper-bound remediation cost of around $200,000 per well site, that liability could be as high as $2.706 billion in 2017 dollars. Whether the abandoned well site restoration would be sufficient for caribou habitat restoration is subject to further inquiry and research.

If the B.C. government had the foresight to apply a reasonable levy on industry to help pay for the cleanup cost of each well drilled, there would have been ample funds available to ensure restoration of these disturbed sites.

Governments have the power to hold industry accountable for posting sufficient environmental performance or restoration levies or bonds. Given the significant shortfall in expected future restoration costs and levies collected, it's clear that the B.C. government has not enforced its rights to secure the necessary restoration funds from industry or hold them liable for paying future restoration costs. These costs are passed on to the public and future generations, particularly if resource companies become insolvent and unable to pay them. If setting aside money into a restoration fund for the actual costs of well-site restoration to a suitable ecological standard were mandatory, these funds would become the basis of a viable, flourishing restoration economy in B.C.

Alberta, by comparison, had 330,000 orphaned and abandoned well sites with a booked orphan well-site fund liability by the Alberta Energy Regulator of $30.2 billion, or $91,515 per well site. However, recent revelations as of November 1, 2018, by the Alberta Environmental Regulator estimate Alberta's oil and gas facilities (well sites and other facilities) cleanup liability at $100 billion, which would amount to $303,000 per well site. This is closer to B.C.'s estimated upper-end well-site cleanup cost of $272,727 per site. However, similar to B.C., Alberta faces a massive shortfall in funds collected (only $.2 billion) from industry remediation levies compared to the estimated $100 billion in cleanup liabilities.

Our argument is that the funds to pay for site re-

mediation and restoration of all industrial lands (including caribou range habitat) should come from reclamation funds that resource companies are expected to contribute as a form of a performance bond or environmental liability provision and that most provinces have established. In B.C., the Orphan Site Reclamation Fund is intended to pay for future well site cleanup costs.

OPTIMIZATION ECONOMICS OF RESTORATION

In his study of the restoration economics of caribou habitat restoration, Power points out that ensuring caribou survival and recovery through habitat restoration needs a commitment to optimized economic solutions by industry.

He notes, "Whether that value is caribou habitat or biodiversity generally, priorities must be established as to which areas will be restored first. This type of optimization is precisely what the different conservation planning software tools allow land managers to do."[87]

This is the economic point we are making in this paper. The goal is to achieve a minimum of 65 per cent undisturbed caribou habitat threshold with the least amount of effort and limited costs, while attempting to ensure long-term market economic benefits from future resource development that optimizes caribou habitat. This will require determining the areas in each caribou range that have the best chance to return legacy seismic lines and pipelines to undisturbed status and orphaned well sites to integral ecological conditions, while keeping the costs of restoration in each different area in mind. There will be circumstances where current industrial activities may have to be reduced or modified to meet caribou range restoration targets. These opportunity costs can be determined in the short and medium term and contrasted with the economic benefits of a restoration regime over the next 20 years or more.

Our study supports the use of optimization and scenario modelling along with full-cost-benefit accounting protocols to identify the best choices to realize both habitat and economic goals in caribou ranges. Our preliminary full-cost-benefit accounting provides preliminary estimates of the costs of restoration under different scenarios and can contrast these with current economic benefits and employment from extractive industries (forestry, oil and gas) expressed on a per hectare land use basis. This information can be used to evaluate future opportunity costs and trade-offs to existing industries and to find optimization scenarios. The goal is to find the right balance whereby optimization of economic benefits (GDP, employment, taxes) for every hectare of land use can be achieved in harmony with ecological objectives, including viable, healthy woodland caribou herds. As Power identified in the case of two Alberta caribou ranges, these trade-offs and opportunity costs to industry may be somewhat easier to accommodate, particularly where forest resources have not yet been allocated and existing oil and gas industry operations can be grandfathered out under a management regime that results in a smaller, less-impactful industrial footprint in caribou habitat.

ASSESSING RESOURCE DEVELOPMENT IMPACTS ON INDIGENOUS PEOPLES

Indigenous Peoples have inherent rights to economic, ecological and cultural values from natural resources, including the value of keystone species like woodland caribou, within their traditional territories.

In principle, Indigenous Peoples can define the terms and nature of land and resource management in B.C. and other provinces. In turn, they can seek and receive fair compensation for losses to their traditional lifestyle from the impact of industrial use of their traditional lands. Often, development proceeds without sufficient consultation with First Nations and/or in the absence of Indigenous consent. But there are also instances wherein Mutual Benefit Agreements have been negotiated between Indigenous Peoples and the federal and provincial governments in union with resource industries that are given legal licence to harvest or extract natural capital assets from the land.

Indigenous Peoples have been shortchanged their fair share of resource extraction benefits from provincial governments and have not been compensated for losses in traditional use damages sustained as a result of resource development.

The determination of fair compensation — royalties, employment, shared revenue agreements and equity partnerships — for the losses sustained by First Nations communities from disturbance of traditional lands has been a challenge for many. How should fair compensation value be determined? Or estimated economic losses respecting a traditional-use lifestyle to a typical household? Losses of a portion of the market benefits or government royalties/taxes derived from oil, gas, mineral and timber extraction by industry? Compensation in lieu of the losses in ecosystem service values due to damages to ecosystem functions from linear and other ecosystem disturbance?

Indigenous Peoples could benefit from participating in a restoration economy — the restoration of an estimated 455,004 hectares of disturbed lands in B.C. with a potential economic value of $6.7 billion to B.C. and First Nations in the form of a restoration economy that would manage and reduce the cumulative impact of well sites, seismic lines and pipelines. The benefits would be multiple, including restoring healthy and sustainable caribou populations in key ranges.

Resource companies have an opportunity to consult and employ Indigenous Peoples, including traditional use elders, in restoration of disturbed landscapes to generate high traditional-use values per hectare of land use than what would otherwise be the case with lower-cost remediation to less diverse plant species. Total economic, ecological and cultural values per hectare of land use could be further optimized. Such an approach to restoration of linear-disturbed landscapes would constitute a win-win fair strategy where higher values are realized at marginal costs that seem both reasonable and economical, given industry revenues from resource extraction.

The mutual benefits to both resource industries and First Nations are clear. Resource companies would strengthen their social licence to operate on Crown land by building a stronger, mutually beneficial working relationship with the First Nation. Land stewardship practices that optimize both economic and traditional use benefits from the land (plants, medicines and other traditional materials) could be a win-win fair scenario for many First Nations. Members of the First Nation, particularly elders and youth, could be employed to plan, restore and manage linear disturbance areas, ensuring long-term ecological health of the lands and important species like boreal caribou. This would bring long-term employment opportunities at what would likely be a relatively small marginal cost to resource companies on a per hectare area basis. Corporate balance sheets would be strengthened with social capital improved and environmental liabilities properly accounted for and managed. Such a win-win fair relationship may set a new precedent in relationships with Indigenous Peoples and strengthen the value and importance of traditional wisdom and traditional uses to long-term ecological and economic sustainability.

Who and how would First Nations be compensated for their restoration works? We have already noted that if B.C.'s restoration fund was properly structured, effective site restoration costs estimated that achieve verified impacts on goals such as caribou restoration, and industry contributed responsibly to the restoration fund through regular levies based on full-cost accounting estimates of restoration costs, then a potentially large pool of financial capital (as much as $6.7 billion) could be available for restoration of linear-disturbed landscapes in B.C. with a net positive impact to traditional territories of First Nations, Inuit and Métis communities. These estimated historical, cumulative liabilities should be treated as retroactive, forward-looking payments by resource companies.

B.C. FIRST NATIONS RESTORATION ECONOMIC OPPORTUNITIES

Several First Nations in northeastern B.C. are either interested or actively engaged in attempts to restore boreal forest ecosystems and specifically industrial sites (e.g., well sites) for caribou habitat restoration.

These include the Fort Nelson, Blueberry River, West Moberly and Saulteau First Nations.

We examined the Fort Nelson First Nation in northeastern B.C. as a case study into how some First Nations in the boreal see economic and cultural opportunities in woodland caribou range restoration. FNFN is already actively engaged in restoration activities on well sites and other industrial disturbance areas in its traditional territory. FNFN is involved in the following key restoration activities related to boreal caribou habitat restoration in their traditional territory:

- Partnership with OGC to restore Crown land that was once used for oil and gas activities (campsites, water-loading stations and borrow pits were the focus this year). This involved three sites, two where mechanical treatment was conducted and one where topsoil has been laid. All three sites will be planted by FNFN field techs in the spring using genetically native plant plugs grown in Fort Nelson.
- Contract with the Ministry of Forests Lands and Natural Resources Operations: This project was a functional restoration project where FNFN used tree-hinging methods to visually and physically block old seismic lines. This was done to aid boreal caribou populations.
- Orphan wells (OGC): FNFN will be piloting restoration techniques to see if the base level currently acceptable for restoration can be changed to ensure old well sites return to functional habitat rather than just grass/non-native species.

FNFN has been experimenting with planting of indigenous plants (medicines) that may be higher per unit cost but will generate higher cultural and health value to their community than conventional site treatments.

Katherine Capot-Blanc, acting director of the FNFN Department of Lands and Resources, sees enormous opportunities for her nation to participate in the emerging restoration economy within their traditional territory in northeastern B.C.[88]

Use of traditional knowledge is guiding FNFN restoration practices e.g., traditional plant species such as goldenrod, yarrow and mint are important herbs and medicines. Traditional knowledge of the benefits of plants and medicines is being combined with western science to help guide restoration of riparian areas.

FNFN is currently working with the OGC on a pilot study looking at costs to do this restoration. They have not yet calculated the full costs of restoration but know that initial costs will be higher than conventional restoration methods. They expect to get more cultural and health benefits in the long term.

Capot-Blanc noted that while companies are paying $80,000 to $100,000 per season to spray for vegetation control, millions could be saved in the long term, including restoring ecological health conditions, with a more traditional-use approach to site restoration. She noted that while it will cost energy companies more up front to restore to a higher ecological standard, experience shows that current conventional reclamation of oil and gas sites rarely results in the landscape reverting back to its original forest ecosystem, but remains a grassland monoculture. FNFN believes that traditional knowledge of boreal ecosystems will help ensure restoration of industrial lands to a healthy, sustainable boreal forest ecosystem.

Industry, she notes, is interested in the marginal cost of restoration to a higher ecological standard than what they are accustomed to and willing to invest in and experiment with. Based on current site restoration experiments, FNFN expects to have better information on relative successes and challenges after the 2018-19 winter on well sites relative to the full costs of restoration on a per hectare basis. One of the challenges is determining how best to scale up site-specific

successes to a much larger spatial area of impact that industry needs to understand better.

Capot-Blanc noted that the boreal woodland caribou issue is one of the most important to solve for FNFN and is at the heart of its well site restoration work. They have noticed that caribou are currently using certain parts of restored well sites. Further study is necessary to understand what attributes of site restoration are attracting caribou in summer and winter. It's not yet clear how and why caribou are behaving as they are.

The issue of scale needed is an important consideration in effective restoration. How to restore large-scale caribou ranges and core areas remains a challenge. Restoring previous old growth (200-year) black spruce forest ecosystems will take decades. Yet small steps can be taken. Soil health is a key factor in attracting and retaining caribou. Caribou avoid contaminated soils on oil and gas sites, yet are accessing native vegetation repopulating hundreds of hectares of disturbed areas.[89]

According to FNFN, the local oil, gas and forestry industries have been receptive to and supportive of restoration economics. They have experienced many good industry players going above and beyond the reclamation or restoration standards set by the B.C. government. Downturns in the energy economy with energy price fluctuations could affect the level of sustained commitment by industry to progressive restoration efforts. FNFN has created an economic development company that can do well site reclamation, site preparation, ground work and seed collection and planting. They see a role for elders in site monitoring and verification of site restoration to a traditional-use standard. FNFN has conducted a number of traditional-use studies, which are verified with the elders.

FNFN has been working with a local nursery that grows native species such as shrubs at roughly $4.50 per plant; a seemingly high cost yet with greater long-term health and well-being benefits. Investment in FNFN's own greenhouse is being explored.

It's too early to determine the actual full costs of FNFN's efforts and levels of restoration success; those results are forthcoming over the next year. They expect better restoration results from their more traditional approach compared to larger remediation firms. It's clear to FNFN that restoration needs to be done by local people who are indigenous to the local ecosystem.

The key question FNFN is asking is who will pay for these restoration efforts and experiments with so little left in the B.C. orphan well fund?

Lessons learned from FNFN:

- They know there is a business case for restoration of industrial lands.
- They have seen many reclamation firms underperform in terms of restoration, whether it's planting the minimum viable species versus higher value plants and species.
- Effective restoration of caribou habitat will take decades, requiring an analysis framework that recognizes initial costs for site restoration will be higher while long-term benefits will only be seen in the distant future.
- Restoration of well sites has been instructive when it comes to learning what caribou like and don't. The key is that any toxic soils are properly reclaimed. As such they still don't know why caribou respond the way they do.
- They see a role for elders to play a long-term verification function that periodically assesses and reassess ecological health.
- They have not yet done any true full-cost-benefit accounting on restoration efforts to compare the costs of current standards of site reclamation to an ecologically/cultural ideal level in terms of assessing the marginal costs. It's too early.
- Some industry players are progressive and committed to going beyond the current B.C. reclamation standards and would like to do more; current economic conditions and markets have led to budget constraints and depletions of orphan well site reclamation funds.
- The bottom line is that B.C. should take a proper full-cost accounting approach to restoration economics that evaluates the short- and long-term costs (and benefits) of restoration using proper full-cost accounting protocols to make the business case. Industry would likely invest and participate vis-a-vis First Nations enterprises if they were more fully aware of the economics of alternative options. Some of the existing restoration firms might be replaced with First Nations full-service contracts, including their own greenhouse operations to grow (from seed) native species of importance to the nation.

UNFUNDED SITE RESTORATION COSTS AS PROVINCIAL LIABILITIES

Who should pay for the $900 million to $1.39 billion in caribou habitat restoration costs and where will the money come from?

Were oil, gas, mining and forestry companies required to post a "restoration performance bond" equivalent to the discount future cost of habitat restoration, a provincial caribou restoration fund could be established similar to the Orphan Site Reclamation Fund that pays for cleanup costs for orphaned or abandoned well sites.

Caribou restoration liability is not currently booked on the Province of British Columbia or resource companies' balance sheets. If it were, each hectare of future land and resource development would require posting or setting aside sufficient funds for restoration of all linear disturbance; e.g., for each hectare of new seismic activity in northeastern B.C., the resource company would be required to post a restoration deposit or bond for each kilometre of seismic linear disturbance or hectare of caribou habitat disturbance, depending on a full-cost accounting of effective habitat restoration.

In principle, the booked future restoration costs for well site, pipeline and other industrial remediation can be the basis of shadow pricing the costs of restoration of linear disturbance. This is because companies are technically required to book environmental restoration costs on their balance sheets as liabilities (future restoration or cleanup costs).

From an accounting perspective, no actual funds have been set aside for restoration expenditures either by resource companies or the provincial government regulator. This is a peculiar aspect of accounting whereby assets such as buildings and equipment may be depreciated based on a capital cost allowance or depreciation schedule on the balance sheet, yet no actual funds are set aside for replacement or maintenance of these assets. This is the same situation with respect to natural capital assets prohibited from being accounted for as assets in public sector accounting. This longstanding prohibition of accounting for the value of natural resources on provincial and national government balance sheets is a peculiar anomaly in public sector accounting, let alone business enterprise accounting standards. The CPA body in Toronto is addressing changes to public sector protocols to include a proper accounting of at least the market value of natural resources or assets through a proposed revision to national public sector accounting standards. The importance of this prohibition of natural asset accounting in public sector accounting and proper accounting of future environmental cleanup liabilities cannot be overstated.

WHO SHOULD PAY?

The fundamental question remains: Who should pay for restoring caribou habitat?

According to resource economist John Thompson, "There are only two possible ways, each has its pros and cons. The first approach would be to change the regulatory regime so that private companies (forestry, oil and gas, mining) would be obliged to restore any linear disturbances in core habitat on Crown land. This would force industry to increase its operating costs, resulting either in higher costs to consumers (assuming industries could charge higher prices in a competitive global economy) or reducing its operating surplus (resulting in lower profits, lower provincial and federal corporate income tax payments, and reduced income to shareholders). If the oil and gas and mining industries were to be responsible for the entire costs of restoration, then the effective provincial

royalty rate (including recovery costs), using 2018 as a base year, would have to increase by 3% to 8% to cover annual costs of $8 million to $19 million per year at a time when oil and gas prices are quite low." Many restoration liabilities would rest with companies that no longer exist (orphan wells and seismic lines), so it would be necessary to make the entire industry pay these costs. Based on these two issues, this option would be challenging to implement, especially when the B.C. government is encouraging LNG exports.[90]

Thompson goes on to suggest:

"Another alternative would be to have government pay for all restoration costs through full subsidies to industry or through funding a restoration program. This would mean that all B.C. taxpayers would be paying for the costs of restoration. The [estimated] $8 million to $19 million per year needed for restoration in core areas would represent a minor part of a provincial budget that has annual operating expenses in excess of $55 billion." This could be seen as a subsidy to industry (which could affect foreign trade negotiations), and may not be politically palatable at a time when the government's focus is on reducing the tax load on individuals.

Thompson concludes: "The most probable way of finding the money to pay for restoration costs is likely through some combination of industry and government funding."

ACCOUNTING ERRORS AND CHALLENGES

The importance of understanding accounting protocols is critical to understanding how a restorative economic model might emerge.

Current public sector standards prohibit an accounting of natural resources on the books of federal, provincial and municipal governments, although they do allow resource companies to account for their natural resource stocks, at least in physical if not market value. The CPA Canada Public Sector Accounting Handbook currently limits the consideration of natural assets within public sector financial statements. The PSACC

that guides public sector accountants prohibits recognizing inherited natural resources, arguing that "the costs, benefits and economic value of such items cannot be reasonably and verifiably quantified using existing methods."

The prohibition means that no public sector entity can place natural assets on its balance sheets. Not placing natural assets on balance sheets is a de facto statement that they have no inherent value and make no economic contribution. This runs counter to all accumulated evidence on natural capital and on the growing municipal experience in Canada, and means that provincial and local governments have limited incentive and no direction to inventory or value their natural assets.

The preclusion of natural assets in public sector accounting is a significant barrier to the sustainable management of natural resources as assets since these assets and their depreciation or degradation are completely ignored by policy-makers and in government budgets. Without a proper accounting of natural assets similar to built-infrastructure assets (with depreciation cost accounting), the environmental liabilities and damages to ecosystems that result from resource extraction activities go unaccounted for, providing no signals to either governments or the private sector to behave in a manner that would make restoration of ecosystems following resource extraction a common practice.

We see the results of this accounting anomaly in the significant shortfall in restoration funds collected from industry against an estimated restoration cost liability. Since no restoration liability is required to be posted either by governments or industry, it's not surprising that resource companies can avoid restoring damaged ecosystems while governments (the public) are ultimately left with cleaning up the environmental damages.

The costs to restore ecosystems to a desired ecological standard can be accounted for and legitimately booked as liabilities and levies collected and saved commensurate with the estimated future cost of restoration. The estimated depreciation cost of losses in ecosystem services or functions can also be measured and accounted for in the same way as depreciation costs for buildings, equipment and machinery.

The logic behind this longstanding historical exclusion of natural resources as assets on provincial government balance sheets is unclear. It may relate to historical treatment of Canada's resources when it was a colony of Great Britain. This exclusion is now being addressed and hopefully rectified by a group of natural capital accounting experts, comprising professional accountants, governments, financial institutions (TD Financial) and conservation organizations (e.g., Ducks Unlimited Canada and the Nature Conservancy of Canada). The Ontario Ministry of Natural Resources began establishing the province's first forest natural capital accounts in 2016. A natural capital accounting working group, with the Canadian Accounting Standards Board in Toronto, has been developing new accounting standards for proper treatment of natural capital assets and environmental liabilities.

Another serious flaw in the way resource companies report and account for environmental cleanup cost liabilities is that they tend to use highly inflated discount rates applied to long-term future restoration expenditures rather than lower "social" discount rates that reflect the true value of natural resources and ecosystems as societal assets. Using discount rates in the five to seven per cent range versus a societal discount rate of two per cent artificially reduces the total unfunded liability on the company's balance sheet. This is likely what has happened in Alberta with the previous estimate of $60 billion in environmental liabilities recorded by resource companies and the Alberta Energy Regulator now restated at $260 billion in future environmental cleanup cost estimates. This massive difference reveals that resource companies were taking $200 billion in environmental liabilities off their balance sheets using artificially high discount rates. The result is that these future off-balance sheet liabilities would ultimately be passed on to Albertans. Yet, even if these accounting irregularities were rectified, no money ($260 billion) has actually been set aside for future restoration work. Until the provincial regulators enforce their legal right to collect restoration cost levies, proper site restoration will remain underfunded or unfunded. Restoration by industry can now only be funded out of current operations. Given the inherent risk to energy market irregularities industry faces it's difficult to believe the B.C. government won't be left paying for current and future restoration costs.

Resource companies should be required to book their future environmental liabilities at

the more appropriate societal discount rates and in turn set aside the appropriate estimated restoration costs as a performance bond or levy into a provincial restoration fund. This would constitute corporate societal responsibility.

We can only speculate and imagine a scenario in which B.C.'s oil and gas industry had paid the restoration levy of over $272,000 for each of the roughly 10,000 abandoned or suspended wells. A restoration fund of $2.7 billion would be available today for effective site restoration. Instead, a mere $5.3 million in levies is in B.C.'s orphan well remediation fund.

Another key caveat in our analysis involves the differences between accounting for private sector costs, which are included in provincial and national accounts, and public or social costs, which don't necessarily show up in any accounts. What may be considered public and private costs could be altered by changing the regulatory regime so that private operators would have to pay more to meet restoration requirements (and increase booked costs). This would reduce public restoration liability (unbooked costs). Since achievement of restoration objectives will likely require some sort of regulatory and/or policy changes that will lead to more money being spent on these activities, we would need to understand the existing baseline (under current the regulatory regime) to correctly quantify the potential incremental economic effects associated with the proposed change. Since we do not have a baseline data account, our analysis should be considered preliminary and would need verification with each incremental restoration work.

FUTURE RESEARCH NEEDS

These key research needs relate to seismic line restoration throughout B.C. and Alberta boreal woodland caribou ranges:

1. More on landscape level implications (responses of understory vegetation) of LIS development; while LIS has significantly reduced the footprint of individual seismic lines, the relative number, density and cumulative disturbance has increased dramatically.
2. Understanding the magnitude and extent of edge effects caused by seismic lines, particularly the short- and long-term effects of cumulative disturbances across the landscape.
3. More on the effectiveness of prescribed burning, natural wildfire and targeted harvesting, particularly in dense seismic line development, to potentially reset ecosystems to early successional stages, "erasing" cumulative seismic lines. The use of fire and targeted harvesting is becoming increasingly relevant to discussions of seismic line restoration and is the subject of research by ecologists at the Canadian Forest Service and the University of Alberta.
4. Projecting future recovery probability based on current ecological conditions; recovery trajectories could emulate the growth-and-yield curves used by the forest industry to model and predict forest stand growth over time.[91]

There are many other areas of research that will be required to better understand the effectiveness of caribou range restoration efforts as these practices begin to emerge.

CONCLUSIONS

This study examined the economics and business case for the restoration of woodland caribou ranges in northeastern B.C. using a natural capital accounting approach to full-cost-benefit accounting.

Preliminary analysis of the restoration economic impacts of boreal caribou range restoration points to the potential value of adding a restoration component to the natural resource economic base of northwestern British Columbia with potentially limited negative impacts to existing extractive industries under various land stewardship scenarios.

To reach the minimum 65 per cent undisturbed habitat target established by the federal government (Environment Canada) would require restoration of an area of at least 1,314,452 hectares of boreal ecosystem in northeastern B.C. of a total of 2.4 million hectares of disturbed habitat.

Pilot seismic line restoration projects (seismic lines having perhaps the most significant impact on woodland caribou populations) in Alberta and B.C. are still at an early stage of pilot testing with no publicly reported results of either success or failure.

Some cost estimates from some restoration professionals from these preliminary efforts were available for 2018 and 2019. These should be treated with considerable caution and caveats in our attempts to estimate preliminary restoration cost and benefit estimates to achieve the minimum 65 per cent undisturbed caribou habitat target for northeastern B.C.

To restore just the legacy seismic line anthropogenic disturbance between 65 and 100 per cent of the estimated 138,645 kilometres of estimated accumulated legacy seismic lines as of 2018 throughout the core areas of northeastern B.C.'s woodland caribou habitat could cost between $901 and $1,386 million. If this work (restoring between 9,012 to 13,865 kilometers of seismic lines per annum) were spread out over a 20-year period, the average annual restoration would be between $45 million and $69.3 million per year and employ between 185 and 284 seasonal workers per year. These estimates are based on restoration costs of $10,000 per kilometer of legacy seismic lines. These costs may range from between $4,000 to $12,500 per kilometre of seismic line, depending on the type of seismic line restoration, whether functional or habitat restoration or a combination. Costs may also vary depending on the width of each seismic line being restored (width can vary from 1.5 to 10 metres) as well as the total cumulative spatial area of seismic line linear disturbance being restored.

Restoration would employ an estimated 0.066 people per hectare of restored lands on a seasonal basis (working 122 days) or 0.034 full-time equivalent jobs per hectare. These estimates are comparable with a recent study of the economics of tree planting on forested lands in southern Ontario, with roughly 0.034 full-time equivalent tree-planting-jobs per hectare of reforested land at an average cost of $5,315 per hectare. Tree planting contributes about $12.7 million per annum to Ontario's economy or an average of $5,315 per hectare of reforested land. Our estimates of legacy seismic line restoration across B.C.'s northeastern woodland caribou ranges over the next 20 years would amount to an area of annual reforested lands in southern Ontario between 6.7 and 10.2 times larger.

By comparison, B.C.'s forestry sector employed 18,600 people in logging in 2017 and, based on an average of 193,000 hectares of B.C.'s forest

land harvested, would equate to employment of 0.096 people per hectare of forest lands harvested in 2017. Total wages and salaries from forest harvesting was about $736,427,000 in 2016.

If the caribou range restoration target were the full 1,314,352 hectares of habitat spread over 20 years, this would entail an annual average restoration area of 65,723 hectares per annum, roughly 34 per cent of the total annual forest lands harvested throughout all B.C. in 2017. Caribou herd restoration could take as long as 40 years following effective habitat restoration.

These restoration employment estimates come with caveats and cautions. They don't take into account that B.C.'s resource industries are already spending money on site restoration and/or avoidance of negative impacts as a result of the current regulatory regime. We could not find an accounting of these employment statistics. We have only estimated the restoration costs of legacy seismic lines for which some cost estimates were available from Alberta; restoration of other linear disturbances including well sites, roads, pipelines and forestry cutblocks should be conducted. We have not accounted for how conservation efforts for caribou to restore boreal forest ecosystems might support potential increases in tourism, nature-based recreation, enhanced ecosystem services and traditional use values to Indigenous People.

From an orthodox economic analysis perspective, none of the estimated 185 to 284 seasonal jobs in caribou range restoration can be counted as benefits, because offsetting (or even greater employment effects) could be created if government chose to spend the same amount of funds on other program areas or if the same money was left in the hands of taxpayers who then spent it on consumer goods and services. Not all restoration jobs can or should be counted as benefits in economic impact analysis; the more likely scenario is that the hiring of more unskilled seasonal workers will more than offset employment losses as a result of industries and the government reallocating resources to restoration rather than other operating costs or profits.

We have only considered the potential costs and benefits of restoring seismic lines throughout the six core boreal caribou ranges, and were unable to estimate the additional costs and benefits of restoring well sites, cutblocks, roads and other linear disturbance that would need to be restored across the full 1,314,452 hectares of disturbed woodland caribou habitat (the amount of habitat to be restored to meet the minimum 65 per cent undisturbed area goal). The actual costs and benefits of restoring this disturbed land base could be larger.

It's critical that to have a properly informed discussion about the true benefits and costs of caribou habitat restoration, a forensic full-cost-benefit accounting of realistic restoration scenarios will be necessary. This is beyond the scope of our preliminary analysis. Pilot restoration projects and restoration of legacy seismic lines in woodland caribou ranges, whether in Alberta or B.C., are only now underway, with results not yet publicly available nor analyzed in terms of economics.

Using preliminary restoration cost estimates from a few pilot studies suggests a strong case for a viable environmental restoration sector that could generate positive employment opportunities and economic benefits in B.C.'s northwestern communities. The potential negative economic impacts on conventional oil, gas and forest sectors may be much lower than some may expect, particularly under new ILM regimes.

Any attempt to avoid the extirpation of the remaining 728 (or fewer) woodland caribou in the six core ranges in northeastern B.C. will likely require an immediate moratorium on any future resource development and extraction activities across at least the minimum 1,314,452 hectares of their core range. Allowing this entire landscape to return to a natural pre-development ecological state, under conditions of a moratorium on further development, may take decades even without any formal restoration efforts on linear disturbance areas.

The grandfathering of existing resource industry activities, the potential displacement of existing oil and natural gas leases and forestry tenures, and a moratorium on future development would need to be examined under various scenario analyses. Scenario and optimization modelling is possible, as is being done in Alberta. Power notes that, in the case of restoration economic analysis for two boreal caribou herd ranges (Bistcho and Yates), grandfathering existing oil, gas and forestry tenures could be met with almost no displacement of

industrial activity currently in these ranges. Power notes that achieving the minimum 65 per cent undisturbed caribou habitat target, caribou range protection and restoration will not cause a stark economic decline in economic value of the conventional resource sectors. Each of the six B.C. boreal caribou ranges could be examined using the same scenario and optimization land-use planning lens that have been applied to these two Alberta caribou herds and ranges.

The use of optimization and scenario land-use and caribou management modelling along with forensic full-cost-benefit accounting protocols would be beneficial to identify the best choices and scenarios to achieve the minimum target for habitat restoration. Alberta is currently testing ILM scenario analysis pertaining to caribou restoration; when made public, results should be useful for informing decisions in B.C. A prudent strategic approach to caribou land management scenario planning would benefit from taking an economic view of the landscape, finding the least cost land-use allocations and assigning high conservation value for caribou habitat that have high value to extractive industries. Restoration of caribou ranges on lands no longer important for current commercial extractive activities should be a priority. Changes in forestry and energy land-use practices to reduce their ecological footprint and reclamation of previously disturbed lands such as legacy seismic lines will also be prudent.

Our preliminary analysis of the restoration economic impacts of boreal caribou range restoration points to the potential value of adding a restoration component to the natural resource economic base of northwestern British Columbia with potentially limited negative impacts to existing extractive industries under various land stewardship scenarios. Further scenario and optimization analysis, integrated land-use planning to achieve the minimum 65 per cent undisturbed habitat target and full-cost-benefit analysis would be prudent in determining the best path forward for B.C.

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76 B.C. Stats. Industrial average hourly wage rates; https://www2.gov.bc.ca/gov/content/data/statistics/people-population-community/income/wage-rate-info.
77 B.C. Labour Force statistics. https://www.workbc.ca/Labour-Market-Information/Industry-Information/Industry-Profiles/Forestry-and-Logging-with-Support-Activities .
78 Statistics Canada. CANSIM table 281-0024: Survey of Employment, Payrolls and Hours (SEPH), employment by type of employee and detailed North American Industry Classification System (NAICS). (accessed April 20, 2018).
79 According to B.C. Labour Force Survey statistics, there were 18,600 people in forestry and logging with activities in 2017. With an average of 193,000 hectares of B.C.’s forest lands harvested each year, the employment per hectare harvested yields a ratio of 0.096 persons employed in the sector for every hectare of forest harvested in a year.
80 https://www.for.gov.bc.ca/hfd/pubs/docs/mr/mr113/harvest.htm .
81 The Economic Impact of Restoring Woodland Caribou Habitat in the Bistcho and Yates Ranges in Northwestern Alberta. 2018. Power Consulting Inc. October 2018.
82 Dabros, Anna, Matthew Pyper, and Guillermo Castilla . 2018. Seismic lines in the boreal and arctic ecosystems of North America: environmental impacts, challenges, and opportunities. NRC Research Paper. Environ. Rev. 26: 214–229 (2018) dx.doi.org/10.1139/er-2017-0080.
83 https://www.bcogc.ca/node/11470/download.
84 Personal communication with Garry Adams of T. Harris Environmental Management.
85 Suspended wells: Often a well is suspended because it is not considered to be economically viable at the time, but it could be in the future. In most cases, companies choose to wait for improved technology, infrastructure, or commodity pricing before continuing production. Before a well is considered suspended, it must first pass through an inactive phase. An inactive well is one that hasn’t produced oil, gas or injected fluids, or disposed of waste for six or 12 months, depending on the type of well and its potential risks to the public or environment.
Abandoned wells: When a company no longer needs a well to support its oil and gas development, the well must be permanently sealed and taken out of service. This part of the closure process is known as abandonment. When energy infrastructure has been suspended and is no longer needed, the company that owns it must permanently dismantle it. Even after a company has successfully abandoned its infrastructure, it remains permanently responsible for maintaining it in accordance with provincial regulatory requirements.
Orphaned wells: In the upstream oil and gas industry, an orphan is a well, pipeline, facility or associated site which has been investigated and confirmed as not having any legally responsible and/or financially able party to deal with its abandonment and reclamation responsibilities.
Source: https://www.aer.ca/regulating-development/project-closure/suspension-and-abandonment.
86 https://www.bcogc.ca/node/14849/download.
87 Power Consulting Inc. 2018. P. 23
88 Personal communication, October 24, 2018
89 For example, Katherine Capot-Blanc noted that from their experience they have noticed that willow is not the only species of importance to caribou; that they go after smaller plant species. Fort Nelson restoration efforts are trying to develop a mosaic of plants on the existing industrial sites. They have observed that caribou seem to be selective of various soil types and respective vegetation and are trying to mimic or replicate these preferences in terms of site restoration practices and plantings. It is difficult to restore some well sites back to muskeg as they are built on clay. How to restore these well sites to upland range ecological conditions is the main challenge.
90 Based on personal conversation with John Thompson January 14, 2019.
91 Dabros, Anna, Matthew Pyper, and Guillermo Castilla . 2018. Seismic lines in the boreal and arctic ecosystems of North America: environmental impacts, challenges, and opportunities. NRC Research Paper. Environ. Rev. 26: 214–229 (2018) dx.doi.org/10.1139/er-2017-0080.


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