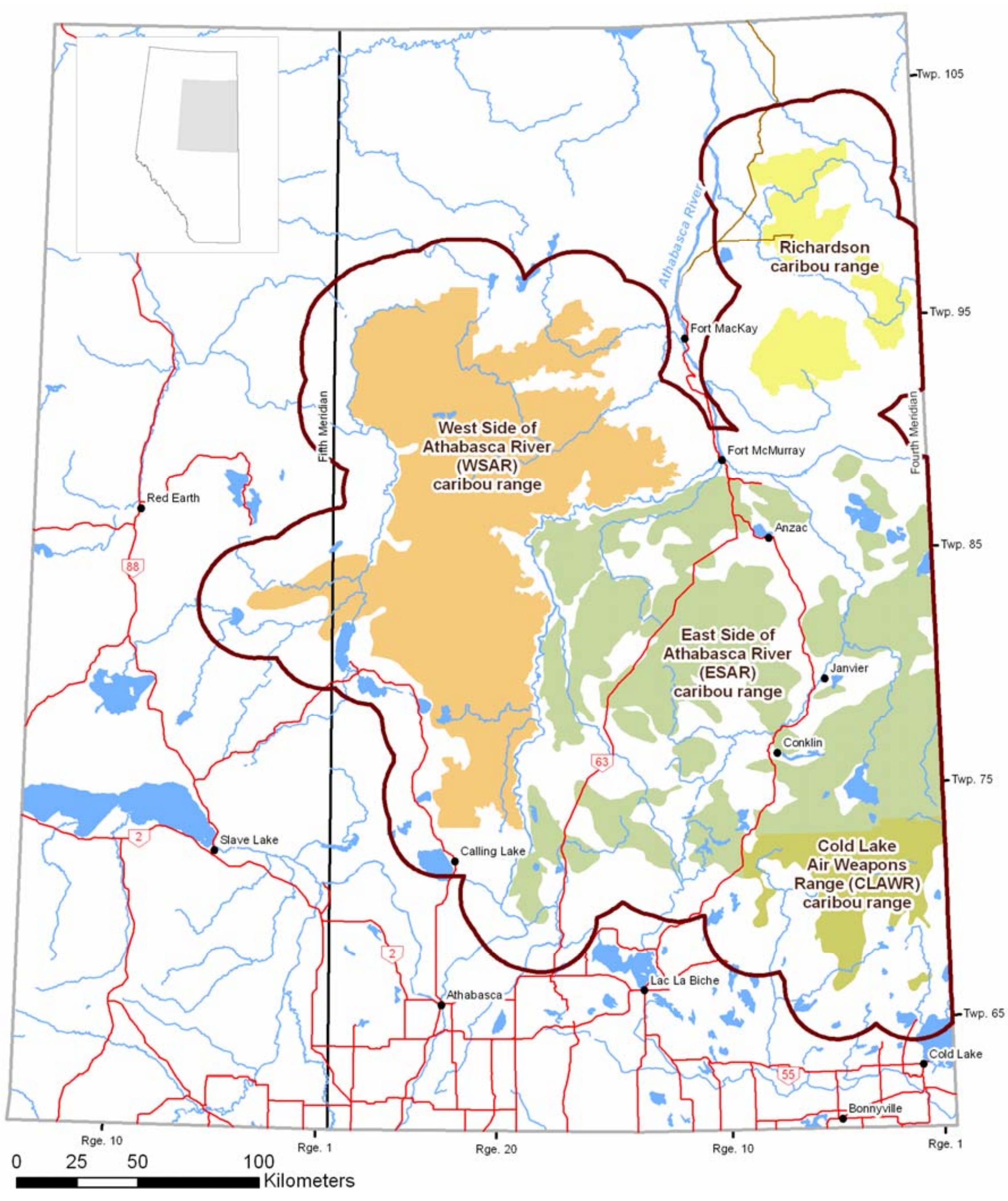
Athabasca Caribou
Landscape Management Options Report



Athabasca Landscape Team
May 2009

EXECUTIVE SUMMARY

Woodland caribou are listed as "threatened" under both Alberta's *Wildlife Act* and the federal *Species at Risk Act*. The Athabasca Landscape Team (ALT) was established in June 2008 by the Alberta Caribou Committee Governance Board (ACCGB) and tasked with developing an Athabasca Caribou Landscape Management Options report for boreal caribou ranges in northeast Alberta (hereafter Athabasca Landscape area). The ALT was asked to develop management options to recover and sustain boreal caribou in all populations in the Athabasca Landscape area, consistent with the provincial woodland caribou Recovery Plan (2004/05 – 2013/14), but not to consider detailed technical, political or economic challenges.

The ALT determined that there is insufficient functional habitat to maintain and increase current caribou distribution and population growth rates within the Athabasca Landscape area. Boreal caribou will not persist for more than two to four decades without immediate and aggressive management intervention. **Tough choices need to be made between the management imperative to recover boreal caribou and plans for ongoing bitumen development and industrial land-use.**

The four Athabasca ranges — Richardson, West Side Athabasca River (WSAR), East Side Athabasca River (ESAR), and Cold Lake Air Weapons Range (CLAWR) — reflect known caribou locations and the presence of suitable peatland habitat. A 20 kilometre (km) buffer was added to these combined ranges to identify ‘planning areas’ that reflect the influence of adjacent habitats and populations of predators and other prey on caribou population dynamics. Available information suggests that there is limited movement between the four ranges or populations. Discrete caribou habitat areas are primarily found in large peatland complexes, but lichen-rich pine forests are also used. These peatlands occur within a matrix of upland mixedwood forest that is avoided by caribou, but provides habitat for other prey species (i.e., moose, white-tailed deer and beaver) that in turn support wolves, black bear, and other potential predators. The selection for peatlands appears to be a spatial separation strategy critical to the survival of boreal caribou.

All monitored caribou populations in the Athabasca Landscape area are currently in decline, and recent trends and simulation modeling results indicate that there is a high risk that the populations will not persist for more than forty years. Current extrapolated caribou abundance in the landscape area (ca. 900 animals) is well below the number that would be expected in the absence of industrial land-use. Predation appears to be the immediate cause of recent declines, and available information indicates that this is directly or indirectly linked to land-use features, including roads, harvest blocks, leases, pipelines and power lines, seismic lines, and agricultural/residential clearings that have led to an increase in moose and deer populations within and around caribou ranges.

The ALT undertook two analyses from which it developed the management options presented in this report. The first was a rating of the relative risk to caribou persistence within each planning area and range based on a series of eight risk criteria. These criteria

included both biological and land-use factors believed to influence short- or long-term persistence and habitat function. Table 2 in this report defines each criterion and summarizes how it was used, along with relevant assumptions and comments. The overall risk rating for each planning area is provided in the Table included at the end of this Executive Summary.

The second analysis conducted for each planning area or range by the ALT involved simulation modeling using ALCES®. Modeling was conducted to forecast likely caribou populations and habitat conditions under three scenarios including Non-Industrial, Business as Usual, and Alternative Futures. Scenarios for Alternative Futures were designed so that multiple simulations would identify the management lever, or combination of levers, that could maintain or increase boreal caribou numbers over the next 50 years.

Land-use footprint, associated with oil sands (bitumen) extraction and forest harvest, is likely to increase throughout the Athabasca Landscape area over the next 50+ years. The highest risk to caribou occurs in areas that are underlain with thick bitumen deposits (which includes portions of all planning areas). Small population size is also associated with higher risk, as in the Richardson and CLAWR areas where both potential and existing populations are considered to be less than 150 individuals. Risk for caribou persistence is lower (but still rated as medium) in the WSAR and the eastern portion of the ESAR planning areas.

The ALT's analyses show that the time for management action in the Athabasca Landscape area is now. Risk of extirpation increases yearly, and further delays in management action implementation will compound the current challenges. ALT analyses demonstrate that an aggressive suite of management options (likely totalling hundreds of millions of dollars) will need to simultaneously focus on reducing predation risk and restoring functional caribou habitat within each planning area. It is important to reiterate that evaluation of political and economic implications of management options was considered outside the scope of the ALT. Likewise, consultation and engagement of parties that would be affected by the recommended management options has not been completed. Nevertheless, the ALT concluded that a suite of management options would be needed to maintain and increase current caribou distribution and population growth rates.

Landscape scale management will be required to successfully sustain caribou in the Athabasca Landscape area. The ALT proposes that this region be managed as two zones. In Zone 1 Areas, described in more detail below, caribou recovery would be the priority designated land use, and all management options identified below would be implemented. Elsewhere within planning areas (Zone 2), all management options excluding future footprint restrictions would be implemented. The exception is portions of the ESAR – Bitumen Fairway sub-planning area underlain by thick bitumen deposits where appropriate best practices would be implemented.

The suite of management options identified by the ALT includes:

- establish large (thousands of square kilometre) Zone 1 Areas in portions of each planning area where recovery of functional habitat (footprint is reduced well below today's levels through aggressive and coordinated reclamation and future industrial footprint is restricted to levels below current conditions); and caribou mortality control (wolves and other prey are controlled for 50+ years) would be the designated and enforceable management priority;
- elsewhere within caribou planning areas (Zone 2 Areas): control wolves and other prey for 100+ years; conduct coordinated reclamation; and implement enhanced best practices; and
- as the viability of cow-calf penning or predator-prey exclosures is uncertain, the Richardson planning area is the most appropriate location to test this option.

The table below provides a summary of the management options that would recover and sustain current caribou abundance and distribution in each Athabasca Landscape planning area. All identified options would need to be implemented as an integrated suite. Simulations showed that successful combinations of management levers were common to all planning areas, although the extent and duration of management actions differed slightly between areas. Simulations and risk ratings demonstrate that larger or more intact planning areas such as WSAR and Richardson have higher probability of success than do smaller, or less intact planning areas such as CLAWR and ESAR in the bitumen fairway.

The ALT concluded that 'Zone 1 Areas' should be established to increase the probability of successfully recovering caribou in each planning area.
Although implementation will require further consultation with stakeholders and consideration of the current land-use policy and regulatory system in the province, the value of Zone 1 Areas is that they would apply a cumulative effects management approach where caribou recovery would be the designated and enforceable land-use priority. From an ecological perspective, Zone 1 Areas need to be of sufficient size (thousands of square kilometres) to recover and sustain an isolated caribou population. In these areas, combined footprint would be reclaimed and future footprint restricted to very low levels (below current conditions) concurrent with continuous predator control until functional habitat is restored. Six candidate areas have been identified in portions of the WSAR, Richardson, ESAR-W, ESAR-E, and CLAWR planning areas. To achieve provincial caribou recovery goals, the ALT boreal caribou management objective, and offset current declines of woodland caribou populations in the Athabasca Landscape area, all planning areas should receive protection through designation and implementation of Zone 1 Areas. Indeed for small planning areas with high relatively high industrial land used and anthropogenic footprint like the CLAWR area, all suitable range should be considered as a Zone 1 Area in order to ensure persistence of caribou. However, if political considerations preclude this approach, the ALT recommends that priority for establishing Zone 1 areas should be in planning areas with greater chance of success for population recovery (i.e., the order listed in the table below). **Ultimately, population size and management effectiveness is related to the amount of functional or intact habitat. If two planning areas are similar in most respects, and choices have to be made between them, the ALT concluded that the area with larger, more continuous, or relatively intact habitat has a greater chance of success.**

A more quantitative evaluation of candidate Zone 1 Areas based on the concepts of risk management and viable populations should be undertaken to understand the relationship between area and extirpation risk and to optimize the location and size of candidate areas.

Mortality management and functional habitat restoration through coordinated reclamation and appropriate best practices are required management options in Zones 1 and 2 of each planning area. Habitat restoration on its own will not achieve success, because unmanaged predation by wolves will cause ongoing decline in caribou numbers in the near term (i.e., several decades minimum), despite restoration efforts. Similarly, mortality management aimed at increasing caribou survival will help caribou persist, but will have to be continued indefinitely if functional habitat is not restored. **These two management strategies – restoration of functional habitat and mortality management – must be applied together.**

It is important to note that the benefits of habitat restoration will not be realized for decades because there is a 30-50 year lag time following reclamation before forest becomes old enough to be considered low quality for other prey, and suitably old to be used by caribou. At minimum, mortality management will need to be continued for this entire lag period. For this reason, **long-term risk will be minimized if both habitat restoration and mortality management begin as soon as possible.**

The suite of successful management options evaluated by the ALT provides new landscape-scale strategies to sustain caribou, but there are also several key challenges:

- establishing legislated boundaries and management guidance for Zone 1 Areas;
- conducting landscape-scale reclamation programs coordinated among multiple stakeholders;
- aggregating decisions for landscape-scale caribou management that are made by individual government departments into a broader integrated cross-government strategy;
- consultation and engagement of stakeholders who would be affected by the recommended management options contained in this report; and
- building awareness of decision-makers, land users, and the general public to maintain social and financial support for required management actions, research, and monitoring over the long term.

The ALT suggests that the current Lower Athabasca Regional Planning initiative under the Alberta Land-Use Framework is an appropriate forum to address these challenges for the Richardson, ESAR, and CLAWR planning areas. The management strategies identified by the ALT will require further leadership and work by the ACC Governance Board and collaboration with others to identify solutions to policy challenges and to develop clear implementation rules and processes that are consistent with existing and proposed legislation.

Table A. Summary of successful management options and considerations for each Athabasca Landscape caribou planning area.

Planning Area	Current Risk Rating[1]	Management Option: Habitat Restoration – Establish Zone 1 Area	Habitat Restoration – Coordinated Reclamation	Habitat Restoration – Best Practices	Mortality Management – Wolf Control	Mortality Management – Other Prey Control	Mortality Management – Cow-Calf Penning	Considerations
West Side Athabasca River (WSAR)	**Med**	√	√	√	√	√		WSAR planning area has the greatest number of long-term management options and highest probability of success if habitat restoration and mortality control are implemented concurrently. Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Candidate Zone 1 Areas in north-central part of planning area connected to Birch Mountains Wildland Park and south-central part of area where caribou telemetry locations are concentrated.
Richardson	**High**	√	√	√	√	√	√	Updated information from winter 2008/2009 field studies indicates that wolf densities are lower than estimated and caribou calf recruitment is higher than projected. Habitat restoration is essential for long-term persistence; mortality management likely required for short-term persistence. Candidate Zone 1 Area northeast of Firebag River adjoining Marguerite River Wildland Park. Land-use and wildlife management in Saskatchewan will influence future conditions.
East Side Athabasca River (ESAR)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Management options were identified for each ESAR planning area; see below (ESAR – West; ESAR – East; ESAR – Bitumen Fairway).
East Side Athabasca River – West (ESAR – W)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Coordinated reclamation and best practices had less benefit for caribou habitat restoration than in the entire ESAR, because there is substantially less bitumen in ESAR-W. Candidate Zone 1 Area in northwest part of planning area incorporating areas of high caribou use between bitumen fairway and Athabasca River.

[1] From Athabasca Landscape Team Current Assessment (2008).

Table A. Summary of successful management options and considerations for each Athabasca Landscape caribou planning area (cont.).

Planning Area	**Current Risk Rating**[1]	Management Option: Habitat Restoration – Establish Zone 1 Area	Habitat Restoration – Coordinated Reclamation	Habitat Restoration – Best Practices	Mortality Management – Wolf Control	Mortality Management – Other Prey Control	Mortality Management – Cow-Calf Penning	**Considerations**
East Side Athabasca River – East (ESAR – E)	**Med**	√	√	√	√	√		Information from winter 2008/2009 field studies indicates that caribou densities are lower than estimated and predator/other prey densities are higher than estimated. Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. ESAR-E has the least amount of footprint associated with in-situ bitumen development; simulations showed no relative benefit of coordinated reclamation and best practices over BAU assumptions at year 50 The most important driver of young forest in this planning area was forestry. Candidate Zone 1 Area east of Christina River in Gipsy Lake Wildland Park area, but further assessment of habitat quality and use by caribou is recommended Option to combine management with CLAWR to increase population size.
ESAR – Bitumen Fairway	**High**			√				Bitumen Fairway has low probability of caribou persistence. Likely future development footprint in Bitumen Fairway forecast to be too high to maintain caribou without footprint restrictions and >100 yr ongoing mortality management.
Cold Lake Air Weapons Range (CLAWR)	**High**	√	√	√	√	√		CLAWR has low probability of caribou persistence. Only option for CLAWR persistence without >100 yr ongoing wolf control is no future development footprint and entire range as Zone 1 Area. Management options limited by access restrictions on air weapons range. Land-use and wildlife management in Saskatchewan will influence future conditions. Initiate discussions with DND and Saskatchewan.

[1] From Athabasca Landscape Team Current Assessment (2008).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure 19. Caribou range areas and 1991-2009 caribou telemetry locations. 53

LIST OF ACRONYMS

ACC	Alberta Caribou Committee
ACCGB	Alberta Caribou Committee Governance Board
ACCRMS	Alberta Caribou Committee Research and Monitoring Subcommittee
ALCES®	A Landscape Cumulative Effects Simulator
Al-Pac	Alberta Pacific Forest Industries Inc.
ALT	Athabasca Landscape Team
ASRD	Alberta Sustainable Resource Development
AVI	Alberta Vegetation Inventory
BAU	Business as Usual scenario
BF	Bitumen Fairway
CEMA – SEWG	Cumulative Environmental Management Association – Sustainable Ecosystems Working Group
CLAWR	Cold Lake Air Weapons Range –Alberta caribou planning area
CRA	Coordinated reclamation of seismic lines, pipelines, and temporary roads
CRS	Coordinated reclamation of seismic lines
DAR	Delineation well access road reclamation simulations
DOE	Alberta Department of Energy
DND	Department of National Defence
ESAR	East Side of Athabasca River caribou planning area
ESAR – BF	East Side of Athabasca River caribou planning area, Bitumen Fairway sub-planning area
ESAR – E	East Side of Athabasca River, east of Bitumen Fairway sub-planning area

ESAR – W	East Side of Athabasca River, west of Bitumen Fairway sub-planning area
FMA	Forest Management Agreement
ILM	Integrated Landscape Management
LARP	Lower Athabasca Regional Plan
WSAR	West Side of Athabasca River caribou planning area

GLOSSARY

Athabasca Landscape: Northeast Alberta boreal caribou ranges plus 20 km buffer defined for Athabasca boreal caribou management and recovery plan.

ACC2 Equation: an equation developed for boreal caribou in Alberta (Sorensen et al. 2008) and subsequently updated by Boutin and Arienti (2008) that relates population growth (lambda) to two factors: percentage of caribou range disturbed by wildfire and forest harvest blocks within the last 30 years (young forest); and linear corridor density (man-made disturbance). Also referred to as Habitat-Based Population Performance.

ALCES®: a landscape simulation model used to forecast the combined influence of natural ecological processes (i.e., fires, insect outbreaks, vegetation succession, predation, and other natural mortality) and industrial land-use (i.e., hydrocarbon exploration and production, forest harvest, and population growth) on boreal caribou habitat and population indicators.

ALT Scenario: a reasonably plausible but structurally different future used for computer simulation modeling.

Best Practices: project-specific measures designed to reduce the area or lifespan of future footprints. Other measures identified in BCC (2001) were not evaluated by the ALT.

Bitumen Fairway: an area in the ESAR planning area defined and delineated by Alberta Energy for use by Cumulative Environmental Management Association – Sustainable Ecosystems Working Group (CEMA – SEWG) as the area where most mineable and steam assisted in-situ bitumen development would occur. Subsequent refinements by Alberta Energy in 2008 significantly changed the boundary of the likely bitumen development areas, but the original planning area provided to the ALT by the ILM laboratory was used.

Buffer or Zone-of-Influence: the distance to which a species is affected by a land use feature, activity, or disturbance.

Caribou habitat: forested peat complexes on level, poorly drained terrain that are used year-round and provide all life history requirements for boreal caribou. Upland lichen-rich pine forest also provides suitable habitat. These habitat types do not necessarily represent 'critical habitat' defined for the federal *Species at Risk Act*.

Coordinated reclamation: a coordinated program to regularly reclaim a fixed percentage of existing and future linear features (seismic lines, pipelines, temporary roads). For Alternative Futures scenario modeling, an area was deemed reclaimed when caribou no longer exhibit reduced use, on or near, a land-use feature (i.e., removal of zone of influence after five or more decades). Reclaimed also assumes that caribou are spatially separated from moose and predators and as such experience natural levels of predator encounter rates. Reclaimed areas within Zone 1 Areas help achieve functional habitat over the long term.

Cow-calf penning: a program to reduce caribou calf mortality during the critical post-birth period by capturing pregnant females immediately prior to calving and keeping them in an enclosure isolated from predators until two to three weeks after calving.

Functional habitat: caribou habitat that is sufficiently old (>50 years in lowlands and >80 years in uplands), has comparatively small areas of young forest (<30 years old) and anthropogenic footprint (i.e., corridors and clearings). Functional habitat provides caribou with sufficient food and opportunities to space away from predators. For scenario simulations, functional habitat was defined as Habitat-Based Population Performance of 1 or higher, calculated using ACC2 equation.

Future footprint minimization levers: management options including reduced future bitumen development, future forest harvest, forest fire suppression, and forest insect outbreak control that result in fewer corridors and clearings compared to Business as Usual assumptions.

Habitat-Based Population Performance: An equation developed for boreal caribou in Alberta (Sorensen et al. 2008) and subsequently updated by Boutin and Arienti (2008) that relates population growth (lambda) to two factors: percentage of caribou range disturbed by wildfire and forest harvest blocks within the last 30 years (young forest); and linear corridor density (man-made disturbance). Also referred to as ACC2 Equation.

Habitat restoration levers: management options including coordinated reclamation of linear corridors and appropriate best practices to reduce the lifespan and size of land-use corridors and clearings compared to Business as Usual assumptions.

Lambda: the finite rate of increase (λ) is the simplest measure of a population's growth rate. A λ value of 1.0 indicates population stability, values less than 1.0 indicate population decline, and values greater than 1.0 indicate population growth. In Alberta, λ is estimated for each caribou population from annual recruitment and mortality of female caribou and summarized for each study period as the geometric mean of annual estimates. Average rate of population change and confidence intervals are calculated using methods described in McLoughlin et al. (2003).

Landscape: an area of tens to hundreds of thousand square kilometres that includes one dominant background ecosystem. Northeast Alberta consists of a number of landscape types including the boreal plain, Canadian Shield, Peace-Athabasca delta, and agricultural landscapes.

Management Lever: a management practice, policy, or procedure intended to restore caribou habitat or populations; specific examples include: land-use restrictions; restoring existing footprints; fire/insect management; predator control; other prey control; caribou cow-calf penning.

Mortality management levers: management options including wolf control, other prey control, cow-calf penning, and predator exclosures that reduce mortality of caribou calves, yearlings, and adults.

Planning Area: a sub-region of the Athabasca Landscape area where one or more caribou conservation and recovery options were evaluated or recommended. Planning areas incorporate ranges (suitable caribou habitat) plus a 20 km buffer around the perimeter to reflect the influence of adjacent habitats and predator- prey populations on woodland caribou. Sub-planning areas were also defined in ESAR to reflect land-use, or biological considerations.

Population: a group of interacting individuals of the same species in a defined area distinguished by a distinct gene pool or distinct physical characteristics.

Population dynamics model: a 4 species (caribou, wolf, moose, deer), 2 gender (male, female), 3 age class (young of year, juvenile, adult) model built in ALCES that projects changes in population of each species based on year-to-year changes in habitat availability, habitat quality, and predation.

Proximate causes of population decline: the immediate factors or symptoms associated with population decline. Predation is the proximate factor for boreal caribou but it is ultimately influenced by habitat availability, quality, and access.

Range: in Alberta, individual caribou within a given range generally have no, or infrequent, interaction with caribou in other ranges (Hervieux et al. 2005). The Athabasca Landscape area is divided into four ranges: Richardson, East Side Athabasca River (ESAR), West Side Athabasca River (WSAR), and Cold Lake Air Weapons Range – Alberta (CLAWR). These were defined using both habitat mapping and telemetry data.

Simulation: a specific model run that uses baseline data and assumptions from a defined ALT Scenario, and forecasts the influence of one or more set of assumptions or management levers on key indicators.

Sub-population: a breeding group or stock with distinct genetic or life history attributes that interact on a regular basis. May also represent a component of a metapopulation or population found in a discrete or isolated area (Hanski et al. 1996).

System shift (regime shift): a change in an ecological system that results from anthropogenic disturbance pushing the system into another state with different structure, function and feedbacks that drive the system's dynamics (Folke et al. 2004). For example, in the boreal plain, increasing land-use footprints and amounts of young forests have caused a system shift from non-industrial conditions where caribou occurred in functional habitat that was spatially separated from moose and wolves, to a system where other prey densities have increased in, and immediately adjacent to, caribou habitat. Since caribou are more vulnerable to wolf predation than other prey species, system shift to a multiple prey and predator system may increase caribou mortality and cause small populations to be extirpated because of increased overlap with higher densities of predators.

Ultimate causes of population decline: the fundamental factors associated with population decline that may be expressed as other symptoms. Changes in habitat availability, quality, and access are the ultimate factors for boreal caribou, although they are normally expressed as changes in mortality.

Zone 1 Area: defined area within a planning area where recovery of functional caribou habitat (footprint is reduced well below today's levels through aggressive and coordinated reclamation and future industrial footprint is restricted to levels below current conditions) and caribou mortality control (wolves and other prey are controlled for 50+ years) would be the designated and enforceable land-use priority.

Zone 2 Area: area within a planning area but outside Zone 1 Area where full suite of management options with the exception of future footprint reduction would be implemented including coordinated reclamation, enhanced best practices, predator control, and other prey control.

1. MANDATE FOR CARIBOU CONSERVATION

Woodland caribou (*Rangifer tarandus caribou*) are listed as Threatened under Alberta's *Wildlife Act* and the federal *Species at Risk Act*. This status reflects continuing declines in caribou population size and distribution, small population size, the dependency of woodland caribou on older forest, and the sensitivity of this species to human activities. Key factors directly or indirectly affecting woodland caribou population size and distribution include habitat change as a result of wildfire or human land-use activities, predation, hunting, poaching, and vehicle collisions (Hervieux et al. 2005).

The Government of Alberta adopted the Alberta Woodland Caribou Recovery Plan 2004/05 – 2013/14 developed by the Alberta Woodland Caribou Recovery Team (Hervieux et al. 2005). This recovery plan outlines a ten-year time line to progressively improve conditions for caribou in Alberta. The recovery plan identified the following two goals and a number of short-term objectives to direct recovery strategies and actions:

1. Achieve self-sustaining woodland caribou populations and maintain the distribution of caribou in Alberta
    a. Stabilize woodland caribou populations and affect a population increase (achieve positive population growth) for populations currently at risk of extirpation.
    b. Achieve stable or positive population growth for populations currently known or believed to be in decline.
    c. Maintain population stability or achieve positive population growth in currently stable woodland caribou populations.
    d. Avoid loss of existing woodland caribou populations.
    e. Determine woodland caribou population trends for populations where population information is lacking.
    f. Determine the feasibility of restoring self-sustaining woodland caribou populations to former range areas.

2. Ensure long-term habitat requirements for woodland caribou are met within Alberta's caribou ranges
    a. Ensure sufficient quality habitat (including type, amount, and distribution) is available at all times to sustain each woodland caribou population and thereby allow range occupation.

A key strategy adopted by the recovery plan was development of Caribou Range (hereafter Landscape) Plans to fine-tune necessary recovery actions and guide the implementation of these actions in individual caribou ranges. Caribou Landscape Plans will be developed by Landscape Teams, with membership composed of technical experts and practitioners, sponsored by the Alberta Caribou Committee Governance Board (ACCGB). Once approved, landscape plans will be submitted to the Deputy Minister of Alberta Sustainable Resource Development (ASRD) as a recommendation for implementation.

The Athabasca Landscape Team (ALT; members listed in Appendix 1) was formally established in June 2008, and tasked with:

1) assessing the current status of the caribou populations and landscape condition within the Athabasca Landscape (ALT 2008); and
2) developing an Athabasca Caribou Landscape Management Options report (hereafter, Athabasca Landscape report).

The Athabasca Landscape report is to include:

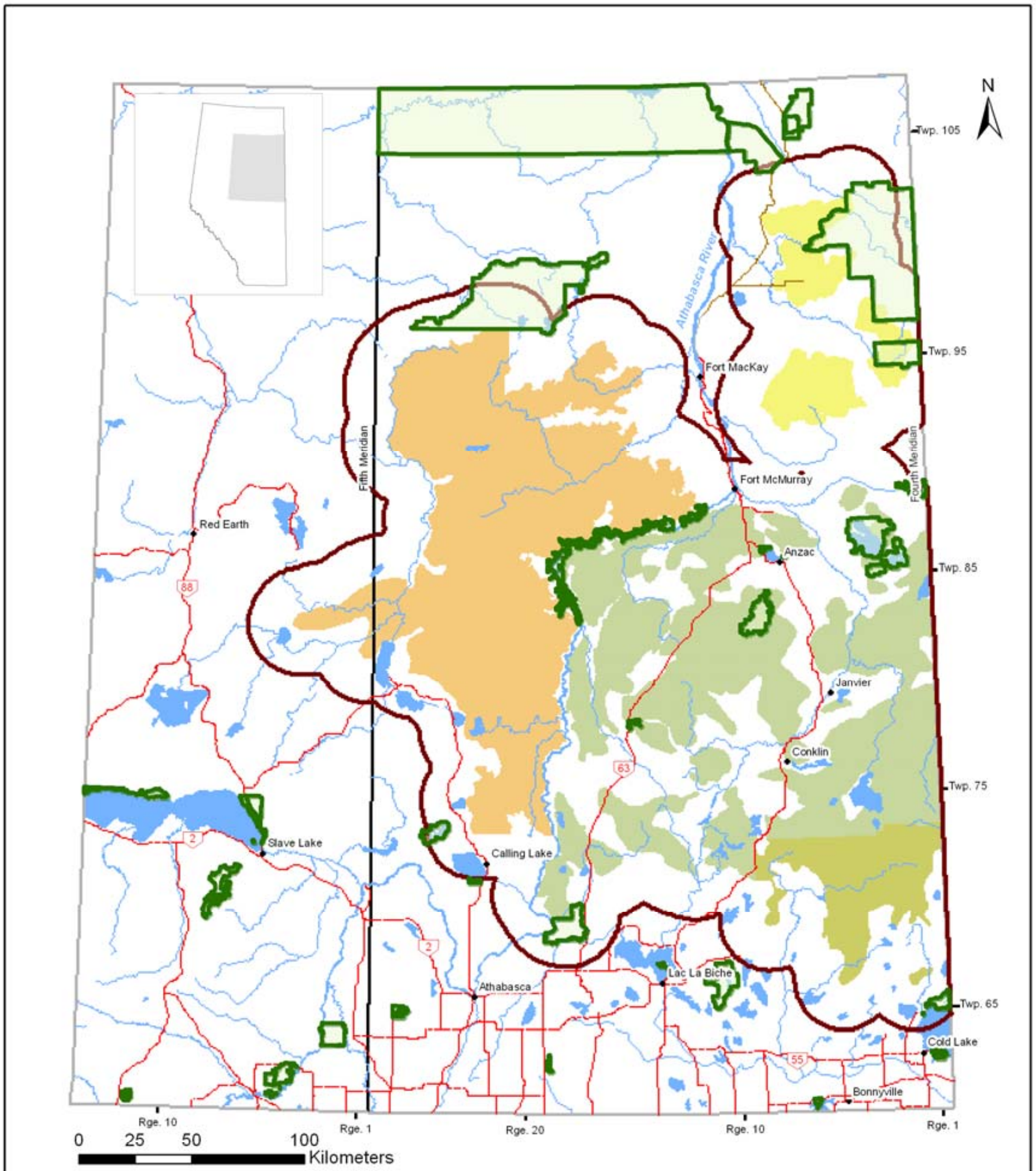
- an assessment of current caribou populations, habitat and other factors (such as levels of predation) as they affect caribou;
- a projection, or projections, of estimated future caribou populations, habitat-based population performance (see Appendix 2 for derivation of this indicator), habitat, and other factors;
- identification of desired future caribou populations, habitat and other factors conducive to caribou conservation and recovery within the planning areas;
- measures to coordinate with other land management policy, direction, and/or plans that may be in place and impacting on the same geographic area; and
- possible management scenarios for the achievement of the desired future conditions within the planning areas.

1.1 ATHABASCA LANDSCAPE AREA

The boundaries of the Athabasca Caribou Landscape planning area (hereafter Athabasca Landscape area) were established by the ACCGB based principally from four woodland caribou ranges in northeast Alberta. These caribou ranges were defined from field studies conducted since the early 1990s and habitat mapping (i.e., presence of suitable peatland habitat as defined by Alberta Peatland Inventory and AVI data when available). The four ranges (Figure 1) include:

1. Richardson;
2. West Side of the Athabasca River (WSAR);
3. East side of the Athabasca River (ESAR); and
4. Cold Lake Air Weapons Range – Alberta (CLAWR).

One or more caribou herds may be found within each of these ranges, as shown in Figure 1. These herds are sub-populations or groups of animals that are habitually found within a given area, but interact with other herds within the range. The WSAR, ESAR, and CLAWR range areas were defined using both habitat mapping and telemetry data. Richardson range areas were defined based on presence of suitable peatland habitat only. These range boundaries are continually being updated as more information becomes available.



Legend

- Primary or secondary highway
- Winter / Gravel road
- City / town / hamlet
- Hydrography
- National, Provincial or Wildland Park
- Athabasca Landscape Area

Athabasca Caribou Ranges

- WSAR
- ESAR
- Richardson
- CLAWR

Figure 1
Athabasca Landscape Area and Caribou Ranges

Data Sources:

Caribou ranges and Athabasca Landscape area - acquired in digital format from the University of Alberta ILM Lab (2008)

Transportation features - 1:10,000 National Road Network (2007) acquired from GeoBase

Hydrography - 1:1M National Scale Frameworks Hydrology digital data (2003) acquired from GeoGratis

Cities, towns, hamlets - 1:1M National Scale Frameworks Populated Places data (2003) from GeoGratis, and 1:1M Base Features Settlement data (2006) acquired from AltaLIS

ATS grid - digitized from 1:250,000 CanMatrix digital topo maps (1991 - 1997) acquired from GeoGratis

Provincial boundary - 1:1M GeoAdministrative base features data (2007) acquired from AltaLIS

Projection: Transverse Mercator (UTM Zone 12)

Datum: NAD83

Coordinate System: Universal Transverse Mercator (UTM)

GIS and cartography by the ALCES Group

ALCES Group

Although there is no reason to believe there are any errors associated with the data used to generate this product or in the product itself, liability of the ALCES Group is limited to the purchase price of the service provided. Map not suitable for navigation.

7 May 2009

A 20 km buffer was added to these combined range areas to define the Athabasca Landscape area boundaries (Figure 1). The 20 km buffer was applied to reflect the influence of adjacent habitats and predator-primary prey populations on woodland caribou populations. The buffer distance was selected by the ACCGB based on data that describes typical wolf pack home range size in northeast Alberta (Latham 2009). The total area encompassed by the buffered composite Athabasca Landscape area is 76,714 km^2.

1.2 ATHABASCA LANDSCAPE MANAGEMENT OBJECTIVE

The boreal caribou management objective developed by the ALT for the Athabasca Landscape area was to:

> "sustain stable or increasing boreal caribou populations[1] within the Athabasca Landscape area by maintaining and increasing current caribou range distribution and population growth rates while recovering sufficient functional habitat over the longer term."

1.3 REPORT OUTLINE

This document provides options for recovery and management of boreal caribou in the overall Athabasca Landscape area and four defined planning areas. Challenges to caribou conservation are summarized in Section 2. Section 3 provides a summary of relevant information from the Current Assessment report (ALT 2008), including risk criteria and ratings developed by the ALT to document the current condition of caribou planning areas and ranges. Simulation modelling results for two planning areas are summarized in Section 4 (additional information for these and other planning areas is provided in the modeling report included as Appendix 3). Overall conclusions relevant to the entire Athabasca Landscape area are provided in Section 5, including research and monitoring needs. Section 6 discusses implementation considerations relevant to these conclusions.

[1] The potential size of the combined boreal caribou populations in the Athabasca Landscape area is extrapolated to range from 1,157 to 4,594 animals. This range in potential abundance was calculated as a product of the caribou habitat area of 35,070 km^2 and the average and maximum boreal caribou densities reported for Alberta of 3.3/100 km^2 and 13.1/km^2 respectively (Thomas and Gray 2002). This potential combined population is well below its simulated equivalent with no industrial land use. The current combined abundance guesstimate is <900 animals.

2. CHALLENGES

Strategies for management and recovery of caribou at a landscape scale must consider the:

- habitat that they require for all aspects of their life history;
- natural limiting and regulating factors that affect their reproduction and survival;
- influence of anthropogenic land-use on habitat availability, reproduction and survival;
- policies and decision-making processes that affect land-use decisions;
- administrative units in which management actions will be undertaken; and
- potential influence of climate change, particularly as it may affect distribution and abundance of deer and predator-prey dynamics of multiple species.

If boreal caribou are to be maintained and restored in the Athabasca Landscape area, politically and economically challenging changes to the current management approach will be required. The key issue behind this challenge is that the bitumen deposits within the Athabasca Landscape area are provincially and nationally important to energy production, but their area of occurrence overlaps with ranges of boreal caribou that are listed as threatened provincially and nationally.

2.1 LIFE HISTORY

Because of their life history strategies and low reproductive rate, woodland caribou are more sensitive than most large mammals to landscape-scale conditions that directly or indirectly affect their habitat and predators. A key aspect of this sensitivity is that increased abundance of predator and other prey species in adjacent habitats outside caribou ranges can influence mortality of caribou within caribou habitat. A reasonable explanation for this effect is that industrial land-use and fire within and near caribou habitat increases the amount of young forest and subsequently other prey species, most notably moose and deer, which in turn results in a numerical increase in predators such as wolves. The increased number of prey and predators could then act as a source of immigrants into adjacent caribou habitat. Similarly, within caribou ranges, research suggests that linear features can facilitate invasion and access to preferred caribou habitat by deer, moose and wolves, in effect reducing spatial separation with caribou. At a broader scale, climate change may also be an important external driver that is influencing the northward expansion of deer (Thompson et al. 1998). As spatial separation from wolves is considered an important anti-predator strategy used by caribou (Bergerud et al. 1984; Seip 1992), a reduction in spatial separation is likely to result in increased predation on caribou (James et al. 2004). Therefore, if boreal caribou are to persist or increase in the Athabasca Landscape area, land-use activities and predators that affect caribou must be managed at the landscape scale (100,000 to 1,000,000 hectares (ha)), rather than local or stand scale (100 to 10,000 ha).

2.2 DECISION-MAKING

The complexity created by different mandates of multiple government departments (e.g., Sustainable Resource Development, Energy, Environment, Transportation) and the sometimes competing interests of industry and other stakeholders affects caribou management. Decisions on land and resource uses are frequently made one at a time by multiple decision-makers without reference to overall landscape objectives or by decision-makers whose mandate focuses on a single sector or type of activity (i.e., departmental 'silos'). For example, objectives related to caribou habitat recovery would ultimately be implemented through a multitude of individual decisions about roads, seismic lines, pipeline rights-of-way, electric power transmission lines, facilities, timber harvesting and other land-use disturbances. The need to aggregate individual decisions for landscape-scale caribou management within a broader strategy is intuitively obvious, but difficult to achieve under the present regulatory regime.

The current approach to caribou management and land-use decision-making in defined caribou ranges relies on approval of project- or activity-specific Caribou Protection Plans. The Caribou Protection Plan approach assumes that caribou abundance and distribution can be maintained by applying 'best practices' and mitigation measures at the local scale, i.e., through activity timing restrictions and footprint minimization (BCC 2001). However, this local, project-specific approach has not prevented ongoing decline in caribou numbers (CLMA and FPAC 2007); rather the rate of decline of monitored populations in the Athabasca Landscape area appears to be increasing in spite of considerable effort to mitigate effects.

Another relevant aspect is cross-boundary issues. Independent management actions in Saskatchewan, the federally-administered portion of the CLAWR planning area, Wood Buffalo National Park, and the Red Earth Caribou Landscape area will likely influence caribou within the Athabasca Landscape area. These influences cannot be directly managed, but they must be evaluated as potential risks. Alternatively these external influences may be seen as collaborative opportunities yet to be developed.

2.3 POLICY

There are many policy challenges affecting integrated management of cumulative effects and caribou management more specifically. Two relevant examples are described below.

Existing land-use and resource management policies assume that undesirable or unintended effects on caribou can be avoided or minimized with local, project-by-project mitigation. For this reason, land-use tenures in the Athabasca Landscape area are issued under a competitive bid system without explicitly considering risks to boreal caribou and other non-economic values. Most of the Athabasca Landscape area has existing and often overlapping hydrocarbon, forest harvest, gravel, peat, or miscellaneous industrial tenures.

Tenure holders have defined rights to access their tenures, and will likely seek compensation if these rights change to facilitate caribou management. The economic and political costs of such changes represent a real challenge to caribou management in the region.

Another policy challenge is the prevailing view that public use of untenured linear corridors should be accommodated. Human access is deemed as ‘traditional access’ along seismic lines and other linear corridors if that corridor has been used for travel (e.g., by trappers, First Nations, and recreational users). Traditional access routes are currently difficult to block in Alberta. Repeated use of linear corridors increases the lifespan of these features and their long-term effect on caribou habitat and populations. This policy is a barrier to access control and habitat restoration programs (CLMA and FPAC 2007).

3. CURRENT ASSESSMENT

3.1 SETTING

The Athabasca Landscape area incorporates boreal plain vegetation southeast of Wood Buffalo National Park down to the forest-agriculture transition between the Green and the White areas near the communities of Calling Lake, Lac La Biche, and Cold Lake (Figure 1).

The ACCGB and ALT identified seven sub-regional planning areas within the Athabasca Landscape area for specific consideration.

1. Richardson: the range plus 20 km buffer identified by the ACCGB (Figure 2);
2. West Side Athabasca River (WSAR): the range plus 20 km buffer identified by the ACCGB (Figure 2);
3. Cold Lake Air Weapons Range (Alberta) (CLAWR): the range plus 20 km buffer identified by the ACCGB (Figure 2);
4. East Side Athabasca River (ESAR): the range plus 20 km buffer identified by the ACCGB (Figure 3);
5. ESAR – Bitumen Fairway (ESAR – BF): planning area within ESAR defined and delineated by Alberta Energy for use by CEMA – SEWG as the area where most mineable and steam assisted in-situ bitumen development would occur. Subsequent refinements by Alberta Energy in 2008 significantly changed the boundary of the likely bitumen development areas (Figure 3), but the original planning area provided to the ALT was used;
6. ESAR – East (ESAR - E): planning area within ESAR east of the Bitumen Fairway (Figure 3); and
7. ESAR – West (ESAR – W): planning area within ESAR west of Bitumen Fairway (Figure 3).

The size of each range and planning area is summarized in Table 1. Combined range areas comprise just under half of the Athabasca Landscape area and WSAR planning area. Range areas within the ESAR, Richardson, and CLAWR are much smaller relative to the planning area indicating a more naturally fragmented landscape in these areas.

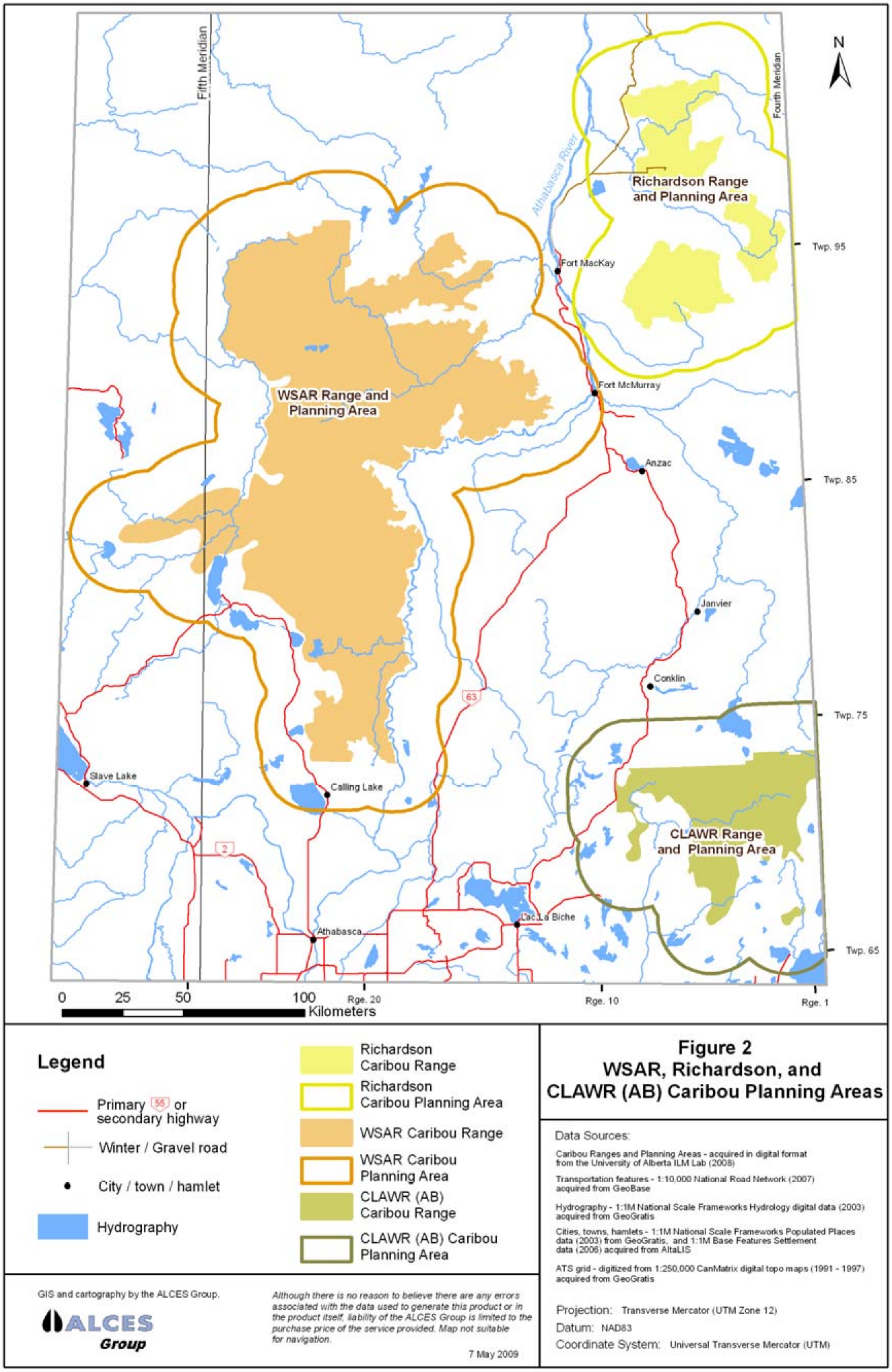
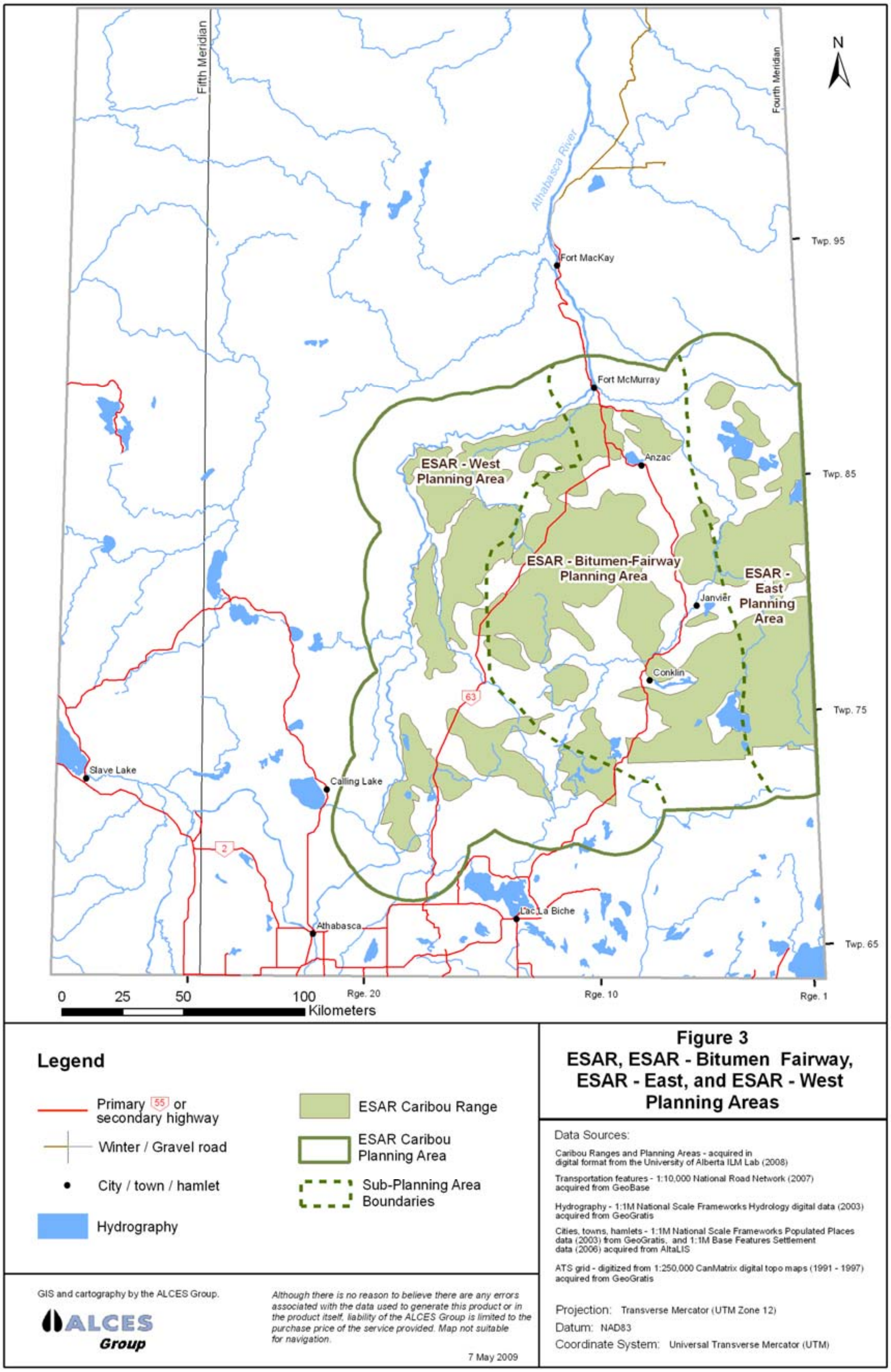


Figure 2
WSAR, Richardson, and CLAWR (AB) Caribou Planning Areas



Fifth Meridian
Fourth Meridian
N
Athabasca River
Fort MacKay
Fort McMurray
Anzac
Janvier
Conklin
Slave Lake
Calling Lake
Athabasca
Lac La Biche
63
2
ESAR - West Planning Area
ESAR - Bitumen-Fairway Planning Area
ESAR - East Planning Area
Twp. 95
Twp. 85
Twp. 75
Twp. 65
Rge. 20
Rge. 10
Rge. 1
0 25 50 100
Kilometers
Legend
Primary 55 or secondary highway
Winter / Gravel road
City / town / hamlet
Hydrography
ESAR Caribou Range
ESAR Caribou Planning Area
Sub-Planning Area Boundaries
Figure 3
ESAR, ESAR - Bitumen Fairway, ESAR - East, and ESAR - West Planning Areas
Data Sources:
Caribou Ranges and Planning Areas - acquired in digital format from the University of Alberta ILM Lab (2008)
Transportation features - 1:10,000 National Road Network (2007) acquired from GeoBase
Hydrography - 1:1M National Scale Frameworks Hydrology digital data (2003) acquired from GeoGratis
Cities, towns, hamlets - 1:1M National Scale Frameworks Populated Places data (2003) from GeoGratis, and 1:1M Base Features Settlement data (2006) acquired from AltaLIS
ATS grid - digitized from 1:250,000 CanMatrix digital topo maps (1991 - 1997) acquired from GeoGratis
GIS and cartography by the ALCES Group.
ALCES Group
Although there is no reason to believe there are any errors associated with the data used to generate this product or in the product itself, liability of the ALCES Group is limited to the purchase price of the service provided. Map not suitable for navigation.
7 May 2009
Projection: Transverse Mercator (UTM Zone 12)
Datum: NAD83
Coordinate System: Universal Transverse Mercator (UTM)

Table 1. Planning areas and ranges in Athabasca Landscape area.

Planning Area	Range area (ha)	Total planning area with 20 km buffer (ha)
WSAR	1,502,268	3,337,806
ESAR	1,468,384	3,624,722
ESAR inside BF	683,762	1,403,913
ESAR outside BF	784,623	2,220,810
East Sub-planning Area	330,956	682,390
West Sub-planning Area	453,666	1,538,420
Richardson	268,717	1,086,734
CLAWR (AB)	267,648	961,564
Landscape Area Total	3,507,018	7,671,443

3.1.1 Boreal Caribou

Boreal caribou in the Athabasca Landscape area select forested peat complexes that develop on level, poorly drained terrain. Upland lichen-rich pine forest also provides suitable habitat (hereafter, caribou habitat; note that this does not necessarily represent 'critical habitat' defined for the federal *Species at Risk Act*). Caribou require large, contiguous tracts of this habitat so that they can maintain low population densities across their range. In part, this behavior is a critically important anti-predator tactic, as predators typically hunt in areas with high prey density or predictability. Caribou also avoid predation by using different habitats than other ungulates (Bergerud et al. 1984, Seip 1992), since predators are drawn to areas where other ungulate species are abundant (Hervieux et al. 2005).

In the Athabasca Landscape area, peatlands are interspersed within a matrix of mixedwood boreal forest on better drained uplands and along riparian corridors. This mixedwood and deciduous forest now provides good habitat for moose and deer, the primary prey base for wolves, but is consistently avoided by caribou. As a result, caribou distribution is naturally patchy within the region.

Boreal caribou are not migratory; most boreal caribou appear to be strongly tied to traditional caribou habitat and ranges, and they do not appear to abandon these areas as a result of disturbance or fire (Tracz 2005; Antoniuk et al. 2007; Dalerum et al. 2007). Little movement between ranges has been documented in telemetry studies (Dzus 2001). At the population level, movements appear to be random within peatland habitat (Stuart-Smith et al. 1997), so management based on caribou habitat appears to be appropriate.

Caribou populations are naturally prone to wide fluctuations in numbers over several decades (Thomas and Gray 2002). Limiting factors that affect year-to-year abundance include predation, winter snow and weather conditions, and insects. The most important source of adult boreal caribou mortality is wolves, followed by predation by bears, and legal and illegal hunting (McLoughlin et al. 2003).

Wolf predation has been concluded to be the proximate cause of recent boreal caribou population declines (Dzus 2001; Thomas and Gray 2002). Caribou are generally taken as incidental prey on an opportunistic basis by wolves whose primary diet is other prey (e.g., moose, deer, and beaver) (Antoniuk et al. 2007, Latham 2009). Calf mortality is highest immediately after calving (Stuart-Smith et al. 1997; Dunford et al. 2003), while adult female mortality can vary seasonally. A cow's ability to avoid predators during the calving and summer period appears to have the greatest effect on both adult and calf survival (Wittmer et al. 2005).

3.1.2 Predators

Caribou within the Athabasca Landscape occur within a multiple-prey, multiple-predator system, with predators primarily supported by moose, white-tailed deer, beaver, and snowshoe hare. Prey numbers appear to have increased in the region as a result of natural and industrial habitat alteration from natural variability, climate change, and land-use. These conditions appear to have created a 'predator pit', with predator numbers maintained at relatively high numbers despite the ongoing decline of an individual prey species such as caribou (Bergerud and Elliot 1986; Seip 1989; Messier 1994).

The gray wolf appears to be the most important caribou predator in the Athabasca Landscape (Stuart-Smith et al. 1997). Other predators that occur within the Athabasca Landscape include black bear, wolverine, lynx, coyote, and to a much lesser extent, cougar. Although Gustine et al. (2006) found wolverines to be the main predator of woodland caribou calves in north-east British Columbia, in the Athabasca Landscape area it is unknown what level of influence these other predators may have on caribou populations, particularly during the calving period. However, woodland caribou are considered to be an incidental prey species for predators and as such caribou do not influence predator populations.

Wolf populations have not been systematically monitored by ASRD in the Athabasca Landscape area, but it is likely that wolves are well established throughout the planning areas, with few if any gaps between territories. This suggests that there is considerable spatial overlap between wolves and caribou.

Average wolf density above 0.65 wolves/100 km^2 is predicted to lead to declining caribou numbers (Bergerud and Elliot 1986; Bergerud 1996). Latham (2009) has recently completed field investigation of wolf and their prey in the southern WSAR and western ESAR area. Deer appear to be the prey base that supports this high density. Wolf density is thought to be inversely related to distance north from the White Area because deer densities are highest in agricultural or highly fragmented landscapes. Latham's work indicates that wolf densities in the south portion of the Athabasca Landscape area are 1.1/100 km^2, but are still thought to exceed 0.65 wolves/100 km^2 to the north (Latham 2009).

3.1.3 Other Prey

Natural disturbance and forest clearing for timber harvesting and other industrial land-use increase the amount and distribution of young forest stands and of various plant species, which may attract and sustain increased numbers of moose, deer, beaver, and/or snowshoe hare. These changes lead to increases in the number of predators, especially wolves, and a subsequent increase in predation threat to caribou (e.g., Seip 1992).

Densities of moose are greater in the southern third of the Athabasca Landscape, likely due to agricultural influences and reduced number of predators in farming areas (Schneider and Wasel 2000). The regional population is generally thought to be stable. Moose tend to concentrate in late winter in riparian zones and old burn areas, with upland spruce and pine being sparsely populated. Agriculture influences moose distribution to the south, and wood lots, riparian areas and alfalfa/hay fields that provide desirable forage strongly affect moose distribution. The Athabasca River valley was surveyed recently and revealed a typical density for the region (ALT 2008).

Agriculture, forestry and cutlines are having a strong influence on deer populations in the Athabasca Landscape area. The expanding network of cutlines and roads is believed to be creating habitat for white-tailed deer (Bayne et al. 2004). White-tailed deer appear to be expanding northward and are now utilizing open muskeg areas for winter feeding activities (Latham 2009). Mule deer in the northeast are generally at low densities, with pockets established around Fort McMurray and disturbed mine areas in reclamation zones. Combined deer populations are thought to be increasing throughout the Athabasca Landscape (Webb and Anderson 2008). Climate change has been suggested as another potential influence affecting deer expansion (see Thompson et al. 1998).

Immediately south of the Athabasca Landscape area, white-tailed deer numbers are stable or increasing, and are well over ASRD population goals. Sport hunting success is generally high in southern WMUs, but hunting mortality does not appear to be sufficient to limit deer population growth (ALT 2008). Latham (2009) estimates that deer densities in WSAR and ESAR - W are twice provincial estimates and that white-tailed deer provided about 40 % of the annual prey biomass available to wolves in this area.

3.1.4 Current Land-use

Industrial land-use has occurred over most of the Athabasca Landscape area. Land-use intensity is highest in agricultural landscapes at the southern edge of the region, and in mineable and in-situ bitumen development areas. Figure 4 depicts areas defined by Alberta Energy where bitumen reservoir thickness exceeds an economically viable minimum (generally 6 m). Representatives of the Canadian Association of Petroleum Producers (CAPP) suggest that this likely underestimates future development areas (P. Koning pers. obs.).

Most of the Athabasca Landscape area is within the Alberta-Pacific Forest Industries Incorporated Forest Management Agreement area (Al-Pac FMA; Figure 5). The current approved Al-Pac FMA Forest Management Plan (Al-Pac 2006) provides a spatial harvest sequence that forecasts 15 years of harvesting activities for all the forest companies, both deciduous (hardwood), and conifer (softwood) operating on the FMA area. The entire Annual Allowable Cut (AAC) is scheduled through the 15 year spatial harvest sequence to all the current forest companies which include: Al-Pac, nine conifer quota holders, and miscellaneous permit holders managed by the Alberta government. The FMA area consists of 5,777,511 ha, of which 1,937,804 ha are currently classified as timber harvesting land base.

Potential peat harvesting areas are located in the WSAR planning area and ESAR – W planning area. Data to define active peat harvesting areas were not located and they were not explicitly considered during scenario modeling. Anticipated future natural gas and provincial transportation infrastructure development were also not considered during scenario modeling.

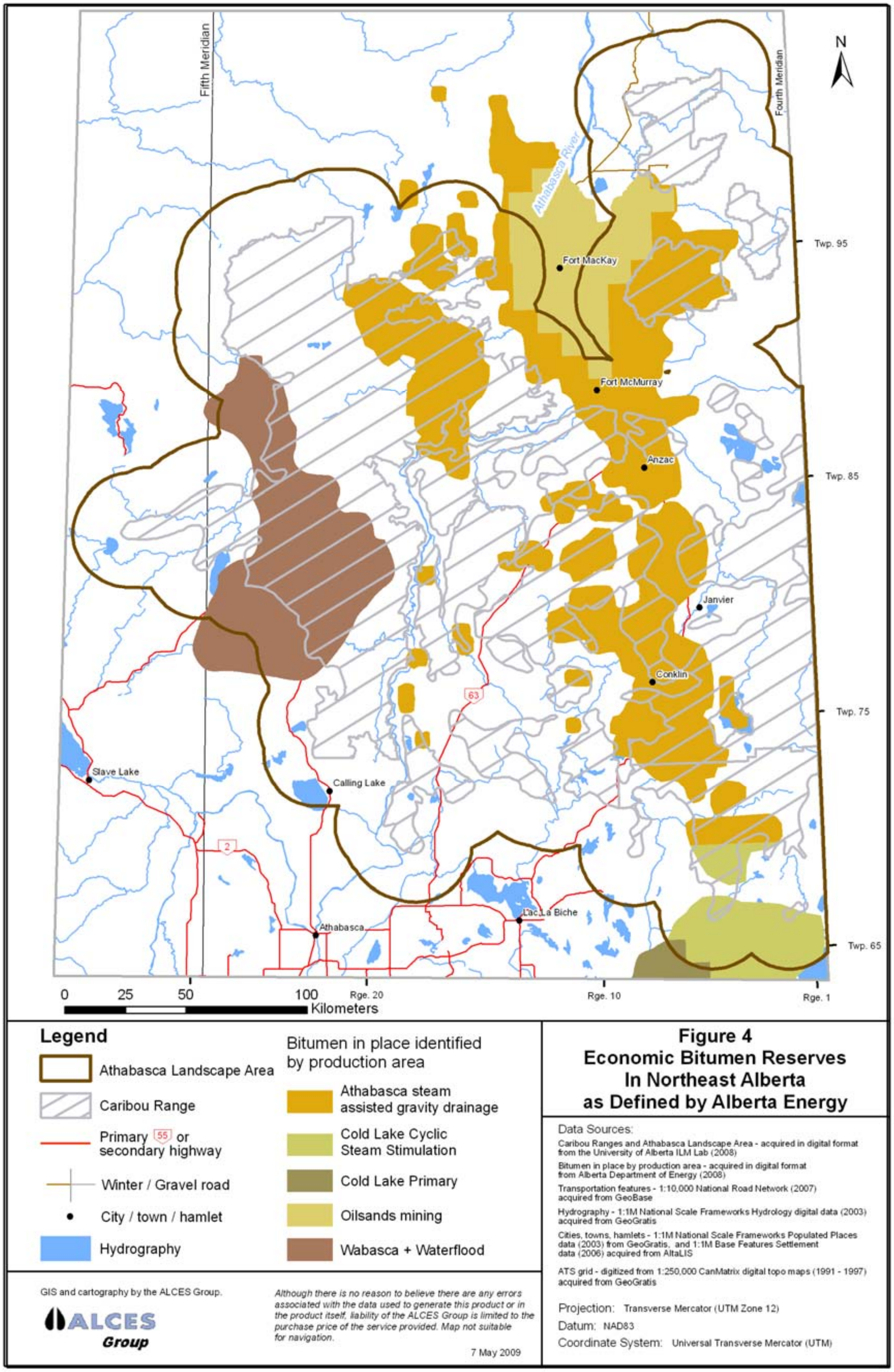


Figure 4
Economic Bitumen Reserves In Northeast Alberta as Defined by Alberta Energy

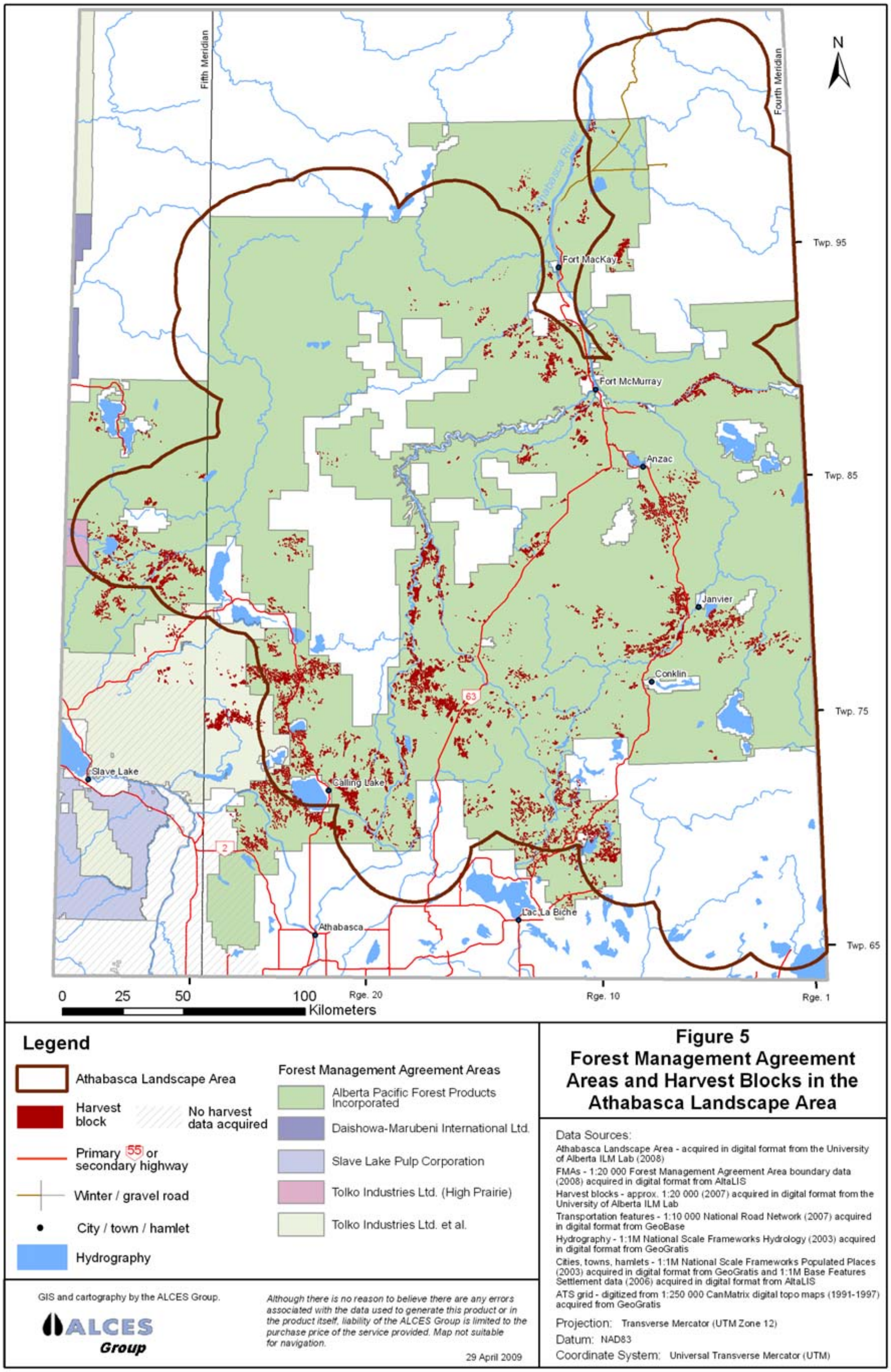


Figure 5
Forest Management Agreement Areas and Harvest Blocks in the Athabasca Landscape Area

3.2 RISK CRITERIA

The ALT developed a series of risk criteria to rate comparative risk to caribou persistence within each range and planning area (ALT 2008). These criteria included both biological and land-use factors believed to influence short- or long-term persistence. Table 2 defines each criterion and summarizes how it was used, along with relevant assumptions or comments. Note that risk ratings applied by the ALT were different than those included in the recent federal critical habitat review (EC 2009).

Table 2. Risk criteria developed for the Athabasca Caribou Landscape area.

Risk Criteria	Definition	How it was used	Comments; Assumptions
Lambda	Population growth rate calculated from telemetry data.	Indicator of current population status: declining growth rate puts population at risk. If growth rate is consistently <1, population will not survive without intervention	Latest values and long term geometric means were provided for each population/range by ACCRMS and ASRD. Risk ratings: Low risk: ≥0.99; Moderate risk: 0.95-0.99; High risk: <0.95.
Potential Population Size	Potential population based on area of suitable caribou habitat within range or planning area	Potential population size is related to the amount of functional habitat. If 2 populations are equal in all respects, preference would be given to maintaining the population with larger, more continuous, or less fragmented habitat, if choices have to be made	Potential population size calculated using caribou habitat area and average Alberta caribou density (3.3/100 km^2). Risk assigned using average density values to extrapolate potential population size based on suitable habitat area; same ratings as population size.
Current Population Estimate	Number of animals in the range/ planning area/ population	Larger populations have higher probability of persistence. If 2 populations are equal in most respects and if choices have to be made between them, then preference should be given to maintaining the larger population.	Accurate population estimates for populations or ranges do not currently exist; best guesstimates from ASRD and Draft National Recovery Plan (2007) were used. Risk ratings: Low risk: >500; Moderate risk: 150-500 High risk: <150.
Linear corridor density (km/km^2)	Amount of linear disturbance per km^2 of landscape	Primary land-use driver in the ACC Habitat Potential equation; Provides information on current habitat fragmentation at within range (i.e., township) scale ILM township data used to calculate average values for each range and planning area.	ALT agreed that excluding seismic lines from linear corridor density was not appropriate. Risk ratings based on Antoniuk (2006); High: > 1.2 km/km^2, Moderate 1.2 - 0.6 km/km^2; Low: <0.6 km/km^2.

Table 2. Risk criteria developed for the Athabasca Caribou Landscape area (cont.).

Risk Criteria	Definition	How it was used	Comments; Assumptions
Young forest in caribou habitat area	Amount of young forest (<30 years old) in designated caribou population area or suitable habitat	Assumed to be an indirect measure of primary prey availability (moose and deer assuming that highest quality habitat is <30 years old) and predator numbers. Age class distribution provides information on how long early seral forest will persist (in absence of fire and land-use)	Based on township information provided by ILM Lab and ALCES runs. Over time, this is influenced by fire as well as energy and forest trajectories. Risk ratings: Low ≤10%; Moderate 10-30%; High ≥30%.
Young forest in range or planning area	Amount of young forest (<30 years old) outside the caribou population area	Assumed to be an indirect measure of primary prey availability (moose, deer) and predator numbers. Age class distribution provides information on how long early seral forest will persist (in absence of fire and land-use)	Key assumption is the size of the area outside suitable caribou habitat that influences predator numbers (e.g., how far away does a predator source area have to be before it has no influence?) 20 km buffer zone defined by ACCRMS was used.
Energy sector trajectory	Predictions of amount, type, duration, and ultimate reclamation strategy of impact of energy developments on the land	Provides measure of long-term risk from land-use. Bitumen thickness map developed by Alberta Energy was applied to determine probability of future development. Development probability: Low <6 m; High >15 m.	Determine separately for: – mineable bitumen; in-situ bitumen; conventional oil; conventional gas, and oil shale. CEMA results directly applicable to mineable and in-situ bitumen. No reliable trajectories for oil shale which is considered speculative. CEMA-SEWG work suggested that the gas trajectory would be insignificant.
Forest harvest trajectory	Predictions of amount, type and duration of forest harvest on the land	Provides measure of long-term risk from land-use. Al-Pac provided planned harvest locations and volumes for each planning area, and range in Al-Pac's FMA area.	Track hardwood and softwood separately. Planned harvest in CLAWR and Saskatchewan could affect young forest within buffer.

3.2.1 Risk Criteria Ratings

Risk criteria ratings for Athabasca Landscape planning areas and ranges are summarized in Table 3. As described previously in Section 2.1: **planning areas** include ranges plus a 20 km buffer as defined by the ACCGB, or portions of planning areas (sub-planning areas). **Ranges** were provided by the ACCGB based on ASRD field studies conducted since the early 1990s and habitat mapping.

The overall risk ratings for each planning area, sub-planning area and range were assigned using the following rationale:

- High risk where current/potential population is less than 75 animals, or more than one of the following conditions applied: current linear corridor density is high; lambda is below 0.95; current/potential population is 75-150 animals; average bitumen thickness is ≥15 m; amount of young forest is high; or forest harvest is comparatively high.

- Moderate risk where current/potential population is greater than 250 animals or more than one of the following conditions applied: current linear corridor density is low-moderate; lambda is 0.95-0.99; current/potential population is 150-250 animals; average bitumen thickness is <6 m; amount of young forest is low-moderate; or forest harvest is comparatively limited.

- Low risk where one or more of the following factors applied: current/potential population is greater than 500 animals; current linear corridor density is low; lambda is above 0.99; average bitumen thickness is <6 m; amount of young forest is low-moderate; or forest harvest is comparatively limited.

Table 3. Caribou persistence risk ratings for planning areas and ranges in the Athabasca Landscape area (see Table 2 for definitions and assumptions; Green = Low Risk; Yellow = Moderate Risk; Red = High Risk of caribou decline).

Planning Area or Range	Risk Criteria Used for Ratings								
	Overall Risk Rating	Lambda (long term avg from monitoring)	Potential Population Size (habitat-based)	Current Population Estimate	Linear corridor density - All (current)	Young Forest (current)	Energy Sector Trajectory (future bitumen)	Forest Harvest Trajectory (future hardwood AAC)	Forest Harvest Trajectory (future softwood AAC)
		λ	no.	no.	km/km^2	Avg (%)	Avg thickness (m)	m3	m3
Richardson Planning Area		?	-	< 100	0.75	23.9	14.0	48,909	85,649
Overall Planning Area		?	81		0.82	21.3	15.7	limited	limited
Audet Range		?	35		0.38	19.0	5.9	limited	limited
Firebag Range		?	15		0.38	34.5	14.0	limited	limited
Steepbank Range		?	31		1.63	17.0	29.5	limited	limited
ESAR Planning Area		0.940 ± 0.041	-	200 - 250	1.85	11.7	9.8	866,461	650,490
ESAR Range		0.940 ± 0.041	445		1.90	12.6	11.1	-	-
BF Sub-planning Area		?	207		2.16	14.2	17.8	351,201	201,201
West BF Sub-planning Area		?	100		0.96	13.1	2.9	182,135	124,141
East BF Sub-planning Area		?	137		1.94	9.9	5.4	331,469	323,413
WSAR Planning Area		0.975 ± 0.034	-	< 400	1.69	6.8	6.5	1,110,975	621,797
WSAR Range		0.975 ± 0.034	455		1.38	4.7	6.3	limited	limited
North Sub-planning Area		?	256		1.30	6.7	9.6	?	?
South Sub-planning Area		?	199		2.09	6.5	2.9	?	?
CLAWR (AB) Planning Area		0.919 ± 0.065	-	100 - 150	2.03	17.1	7.5	74,525	44,404
CLAWR Range		0.919 ± 0.065	81		0.80	21.9	8.9	limited	limited

- Low risk for caribou persistence
- Moderate risk for caribou persistence
- High Risk for caribou persistence

3.3 RELATIVE INTACTNESS

The ACCRMS (McCutchen et al. 2009) elaborated on the concept of habitat intactness incorporated in the West Central Alberta Caribou Landscape Plan recommendations (ACCGB 2008). Intactness of caribou habitat is reduced by human-caused habitat change and fire, so managing for intactness is an important component of any caribou recovery strategy. The ALT was directed to develop a map of relative intactness for the Athabasca Landscape area based on the following factors described by McCutchen et al. (2009) at a township scale:

POSITIVE FACTORS (areas having more of these features will receive a relatively high ranking):

- **Woodland caribou habitat.** Total area (ha per township) of >50 year old forested peatlands (closed and open black spruce) and > 80 year old upland pine forest.

NEGATIVE FACTORS (areas having more of these features will receive a relatively low ranking)

- **Young forest** (% of township <30 years old natural disturbance)
- **Forest harvest blocks** (% of township <30 years old)
- **Well sites** (total area (ha) per township)
- **Linear features which includes all roads, pipelines, power lines, and seismic lines** included in the GIS dataset developed by the ILM laboratory (average km/km^2; calculated as total kilometres of all features in township divided by township area)
- **Mines (**total ha per township of all mine types including oil sands, coal, peat, gravel)
- **Facilities** (total area (ha) per township)
- **Human settlements** (total area (ha) per township)

Relative intactness for the Athabasca Landscape area (Figure 6) was calculated based on a GIS procedure outlined by McCutchen et al. (2009). Calculated values for each factor were binned into ten equal classes bounded by lowest and highest values in the Athabasca Landscape area. Each township was then assigned a ranking score of 1-10 based on the bin in which it fell, with grid-cells containing high positive or low negative intactness factors receiving higher ranks. An overall intactness score was calculated for each township by combining the rating for each positive and negative factor. Note that this score is relative to other townships in the Athabasca Landscape area, and does not provide an absolute measure of intactness.

The intactness scale on Figure 6 is graded with green representing comparatively high intactness, yellow representing intermediate intactness, and red representing comparatively low intactness. According to McCutchen et al. (2009) areas that are ranked as relatively intact (i.e., light to dark green in Figure 6) should be managed as Intactness Priority Areas in order to retain and improve that intactness; 2) factors that negatively affect intactness in Intactness Priority Areas should be reduced (human-caused habitat change in particular); and 3) attempts should be made to increase the size of Intactness Priority Areas by taking management actions that improve the level of intactness in areas that surround them.

Ultimately, caribou population size and management effectiveness is related to the amount of functional or intact habitat. If two planning areas are similar in most respects, and choices have to be made between them, the ALT concluded that the area with larger, more continuous, or relatively intact habitat has a greater chance of success.

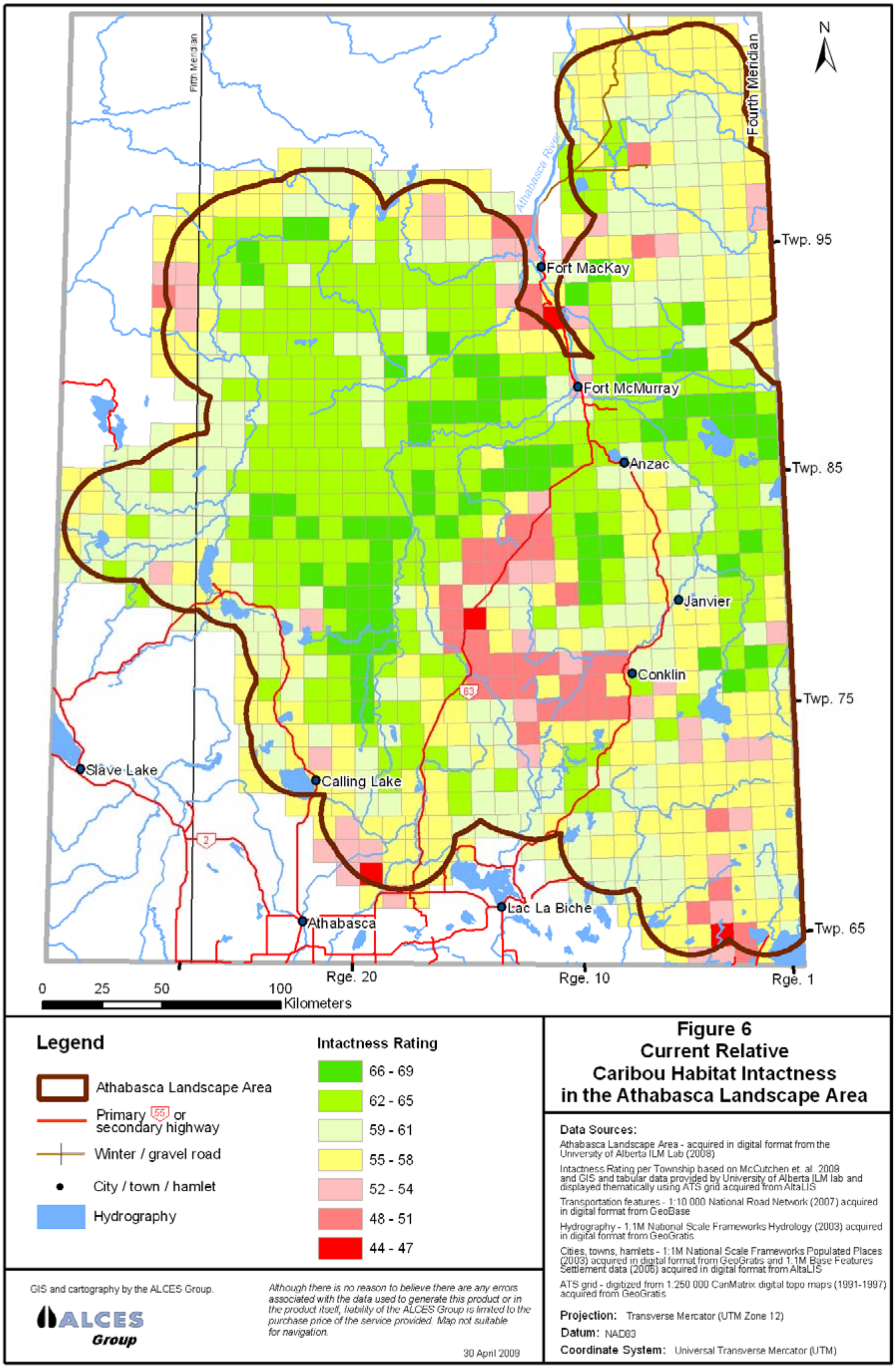


Figure 6
Current Relative Caribou Habitat Intactness in the Athabasca Landscape Area

4. ALTERNATIVE FUTURES

4.1 SCENARIO MODELING

The ALCES III® computer model was used to simulate effects of natural and land-use related change on boreal caribou in the Athabasca Landscape area. An earlier version of this model was also used by the West Central Alberta Landscape Planning Team (WCACLPT 2008). A description of the model and modeling assumptions is included in Appendix 3; additional information is provided at www.alces.ca .

In the context of landscape planning, a scenario can be defined as a reasonably plausible, but structurally different future. Scenarios are stories about alternative futures that describe how the future might unfold. The influence of specific footprints and management levers were assessed by developing and evaluating scenario simulations in which each factor or lever was varied individually or in combination.

The following three scenarios were simulated with ALCES for each planning area:

1. **Non-Industrial Scenario:** This scenario represented the influence of natural ecological processes (fire, insects, forest succession, and predation) on key indicators such as habitat and demographics of predator and prey species in the absence of past, current, and future land-use. The non-industrial scenario was used to simulate range of natural variability for indicators and provided a baseline reference for comparing other scenarios. In this scenario, caribou, wolves, and moose were present, but deer were absent in the Athabasca Landscape area. Assumptions from work done by the CEMA-SEWG (See Wilson and Stelfox 2008, Wilson et al. 2008a, Wilson et al. 2008b) were used for fire and forest succession coefficients; ALT assigned a natural insect infestation rate of 0.5%/yr. Predator/prey coefficients were derived from regional studies, other scientific literature, systematic model refinements and were reviewed and accepted by the ALT. Influence of climate change was not considered. Non-Industrial scenario simulations were run for 200 years.

2. **Business as Usual Scenario:** This scenario represented future land-use trends without changing management practises. It described the combined effects of natural ecological processes and land-use (bitumen development, forestry, human population growth) using assumed development trajectories and current footprint sizes and lifespan. Subsistence, hunter, and trapper harvest of all four species was not incorporated in simulations, nor was influence of climate change. Business as Usual scenario simulations were run for 50 years.

3. **Alternative Futures Scenario:** These scenarios examined combinations of management levers intended to maintain and restore caribou populations and habitat in the Athabasca Landscape. They included management levers intended to: 1) manage ultimate causes of decline by restoring functional habitat; 2) manage proximate causes of decline by reducing predation rates; and 3) combined management of both ultimate and proximate causes. While some of these levers may

have spatial components, their influence can be assessed at the planning area scale. One example of a lever with a spatial aspect is: restoration of habitat in Zone 1 Areas where this would be the designated land-use priority (see Section 5). Alternative Futures scenario simulations were generally run for 50 years, but some 100 and 200 year long sensitivity simulations were completed to evaluate the influence of key variables and assumptions.

The outcomes of alternative regional management lever simulations were compared to caribou persistence and habitat objectives to determine which strategies are likely to contribute to improved outcomes for caribou. Potential influences of future climate change or different industrial land-use trajectories were not evaluated with scenario modeling.

For each scenario, the ALCES model concurrently tracked the status of six indicators over a 50 year simulation period:

1. **Habitat-Based Population Performance:** projected ACC2 value at year 50 based on the young forest and linear land-use equation provided in Boutin and Arienti (2008) (see Appendix 2).
2. **Caribou Population Size:** projected number of caribou in the planning area at
year 50.
3. **Wolf Population Size:** projected number of wolves in the planning area at year 50.
4. **Moose Population Size:** projected number of moose in the planning area at year 50.
5. **Deer Population Size:** projected number of deer in the planning area at year 50.
6. **Caribou Persistence**: projected number of years where caribou population in the planning area is ≥10 in a 50 year simulation.

4.1.1 Assumptions and Uncertainty

Computer scenario simulations do not provide quantitative predictions of conditions in a particular year, but they can be compared to assess the influence of specific assumptions or management approaches, and represent a defensible and useful way to explore key uncertainties (Duinker and Greig 2007). Although detailed assumptions and uncertainties relevant to ALCES caribou modeling are discussed in Appendix 3, we briefly discuss some aspects of uncertainty and robustness in our simulation modeling.

There is considerable uncertainty regarding the reversibility of the system shift linked to higher deer abundance in and adjacent to caribou habitat. Specifically, it is uncertain whether deer will persist in an industrial landscape that is restored back to a state that approximates mature functional habitat for caribou. Modeling simulations described in Appendix 3 suggest that functional habitat recovery may not be sufficient to restore spatial separation of wolves and caribou because of the density and persistence of deer in the system, and that there may be a time lag in the order of multiple decades. In all Business as Usual and Alternative Futures scenario simulations, deer populations grew to the habitat carrying capacity (well above current densities) regardless of whether they used lowland caribou habitat or were restricted to upland habitats. Further research will be required to address this uncertainty.

Wildlife managers have low confidence in current Athabasca Landscape population estimates and predator / prey dynamic assumptions. Under the direction of the ALT, numerous sensitivity analyses were conducted for one or more planning areas. This was done by running multiple 50-year simulations where key coefficients were systematically varied. These analyses demonstrated that future caribou population trends were relatively insensitive to initial predator and prey population size and relative prey vulnerability. **Therefore, our conclusions on management options are robust despite the uncertainty around population and vulnerability estimates.**

4.1.2 Management Lever 'Optimization'

ALCES was used to systematically identify the best practice levers that make the greatest contribution to habitat recovery over a 50 year simulation. Best practices considered were:

a) overlap between new and existing land-use features;
b) number of in-situ wells per wellpad;
c) proportion of pipeline right-of-way reclaimed immediately following construction;
d) oilsand mine lifespan;
e) seismic line lifespan; and
f) regular, coordinated reclamation of a proportion of pipelines, temporary roads, and seismic lines.

4.1.3 Scenario Modeling Results

Figure 7 provides an example of an ALCES simulation output graph. The X-axis reflects time, beginning with present landscape conditions (year 0) to the end of the simulation period (here 200 years). The Y-axis represents the modeled indicator, here caribou population, as noted in the blue bar above the graph. Each coloured line is the result of an individual simulation, here showing how the caribou population changes each year over the 200 year simulation period in response to random fire and insect outbreaks and forest succession. The shaded green area represents the simulated population range under natural (i.e., no industrial land-use) conditions; this range in natural variability (RNV) is used as a reference for Business as Usual and Alternative Futures scenario simulations.

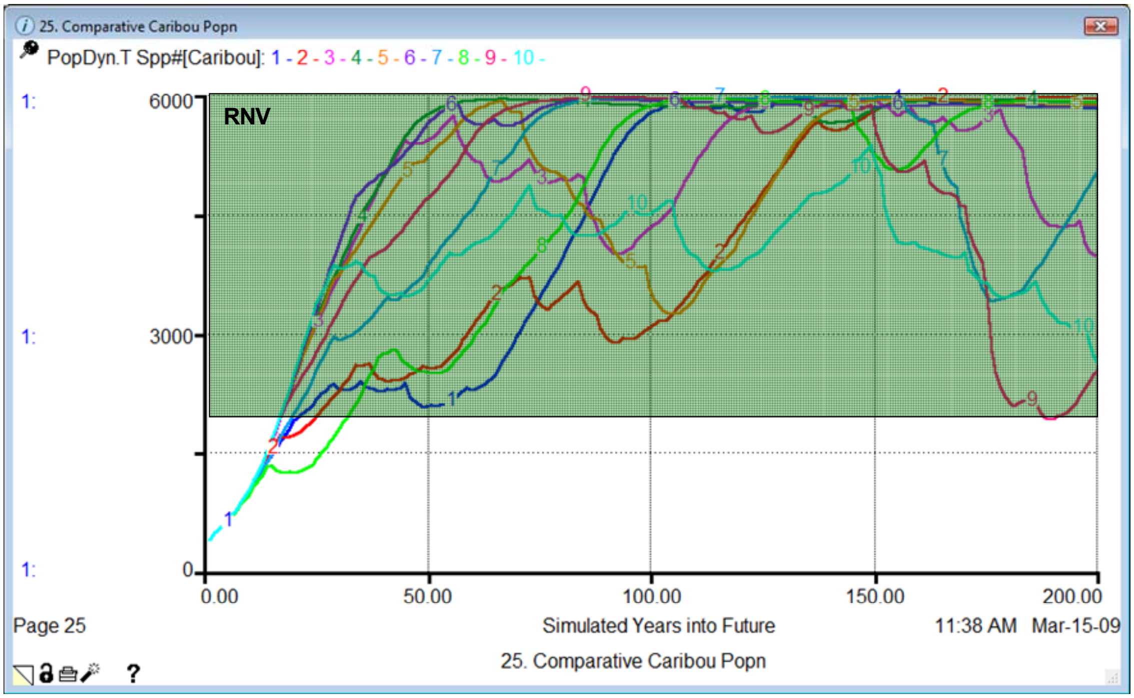


Figure 7. Example of an ALCES simulation output graph. Simulation year on the X axis, and modeled indicator (here caribou population) on the Y axis. Each coloured line is an individual simulation with random disturbance assumptions. Shaded green area represents the simulated population range under 'natural' conditions.

Scenario modeling conclusions were similar for all planning areas. Overviews of scenario modeling results and conclusions for the West Side Athabasca River and Richardson planning areas are provided below in Sections 4.2 and 4.3 respectively as examples. Readers interested in results for other planning areas or more information on model assumptions should review the more detailed information included in Appendix 3.

4.2 WEST SIDE ATHABASCA RIVER PLANNING AREA (WSAR)

The 3,337,806 ha WSAR comprises the entire Athabasca Landscape area west of the Athabasca River (Figure 2). The planning area includes large peatland complexes east and northeast of Wabasca lakes at the boundary between the Peace and Athabasca river drainages. To the south and north, smaller peatlands occur within a mixedwood matrix. The range polygon shown on Figure 2 was defined based on 15 years of telemetry data and incorporates small patches of upland mixedwood habitat. This suitable habitat represents a total area of 1,502,268 ha, or 45% of the planning area (Table 1) and unlike other planning areas, consists of a large, relatively contiguous polygon.

WSAR caribou habitat is relatively intact compared to other Athabasca Landscape planning areas (Figure 8). Approximately 7% of the WSAR was classified as young forest (<30 years old); young forest is most common in the buffer outside the caribou habitat area. Total current land-use footprint is 107,241 ha, or 3.2% of the planning area. Forest harvest blocks under thirty years old contribute just over half of this footprint and are located primarily in the 20 km buffer. Seismic lines and hydrocarbon development comprise most of the remaining footprint. Linear corridor density is currently much lower in the northern half of the planning area (ALT 2008).

Caribou in the southern WSAR planning area have been monitored for 15 years; this population is estimated to include fewer than 400 animals as of April 2008, although confidence in this extrapolation is low. Wolf density is currently very high in at least the southern half of the WSAR and this appears to have resulted in population declines. White-tailed deer have been observed in the lowland caribou habitats in the area, often several kilometres from uplands. Beaver and white-tailed deer appear to provide sufficient biomass to support increased wolf numbers (Latham 2009).

The latest (2007/2008) lambda calculation for the WSAR planning area is 0.91. Growth rate was relatively stable from 1992/1993 through 2001/2002, but has declined since that time and as a result, the average lambda calculated over the fifteen year monitoring period (0.975 +/- 0.034), is much higher than current values (ALT 2008).

The WSAR has the lowest risk rating of all Athabasca Landscape planning areas and the highest relative habitat intactness. Areas of caribou habitat are frequently large in extent and have a comparatively small edge: interior ratio, giving them lower sensitivity to the influence of the surrounding buffer. However, while this planning area has fewer existing energy tenures than other areas, long-term development risk is rated as high due to anticipated in-situ bitumen, forestry activities, and possibly oil shale development.

4.2.1 WSAR Non-Industrial Scenario

Non-industrial scenario simulations for caribou and moose in the WSAR planning area showed that caribou and moose numbers fluctuate naturally in response to the combined effects of random fire and insect disturbance, forest succession, and predation. The wolf population also varies between years in relation to available prey biomass but wolf abundance is more stable because of the relative abundance of total prey biomass.

Based on ten random model simulations, 2,500 to 6,000 caribou and 4,300 to 5,400 moose could be supported in the WSAR planning area with no land-use footprints and wolves present. Current estimated caribou abundance (<400) is substantially lower than their simulated natural population range while the estimated moose population (5,000) is within their simulated population range. These results are consistent with our current understanding that boreal caribou, but not moose, are below their expected range of natural variability in the Athabasca Landscape area.

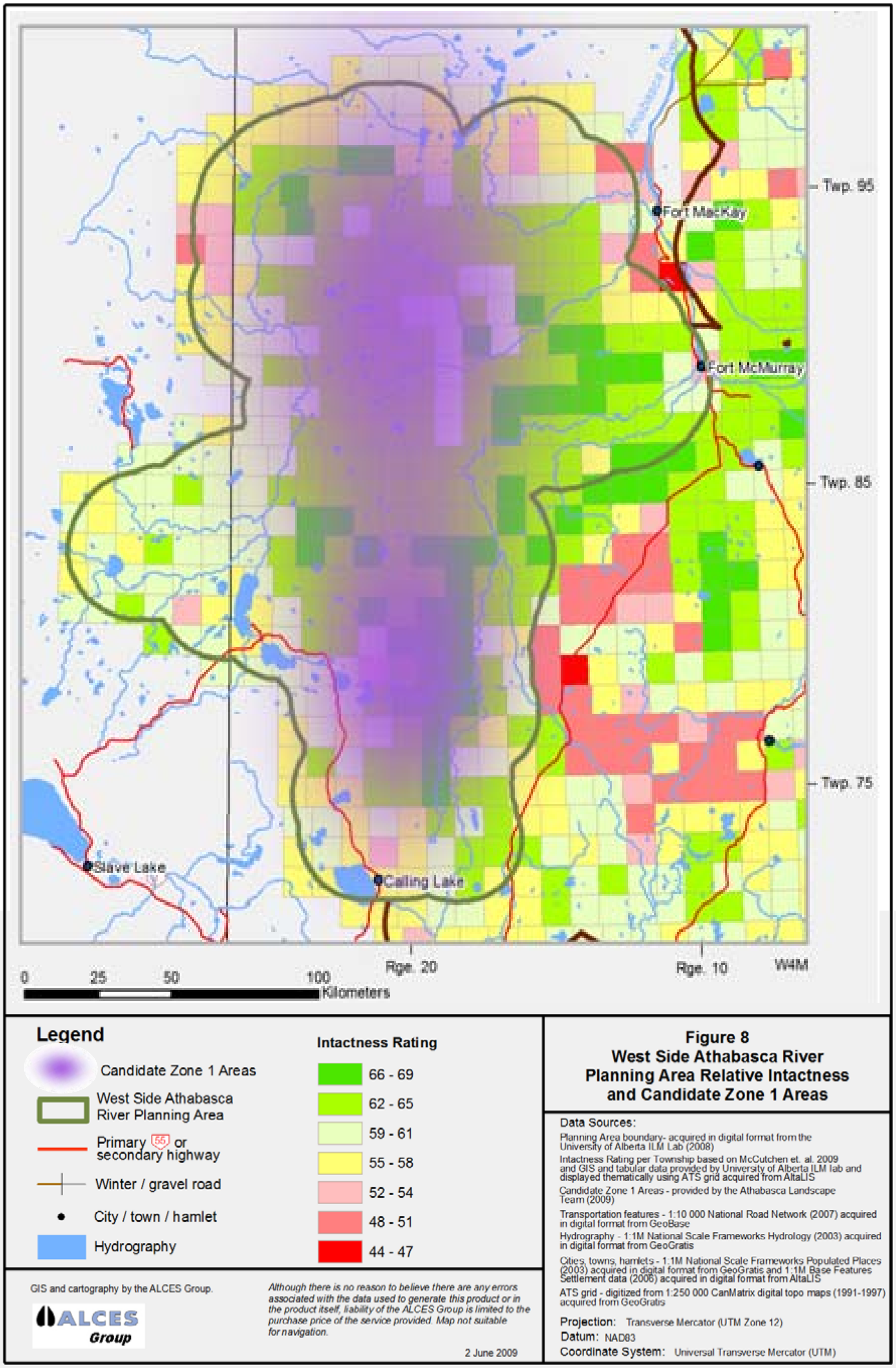


Figure 8
West Side Athabasca River Planning Area Relative Intactness and Candidate Zone 1 Areas

4.2.2 WSAR Business as Usual Scenario

Business as Usual (BAU) scenario simulations suggest that boreal caribou in the WSAR planning area will be extirpated within the next three decades as footprint increases, Habitat-Based Population Performance gradually decline from 0.97 to 0.89, and as shown in Figure 9, deer numbers rapidly increase to a density of 65/100 km^2, wolves increase to a density of 1.4/100 km^2, and moose increase slowly to a density of 20/100 km^2.

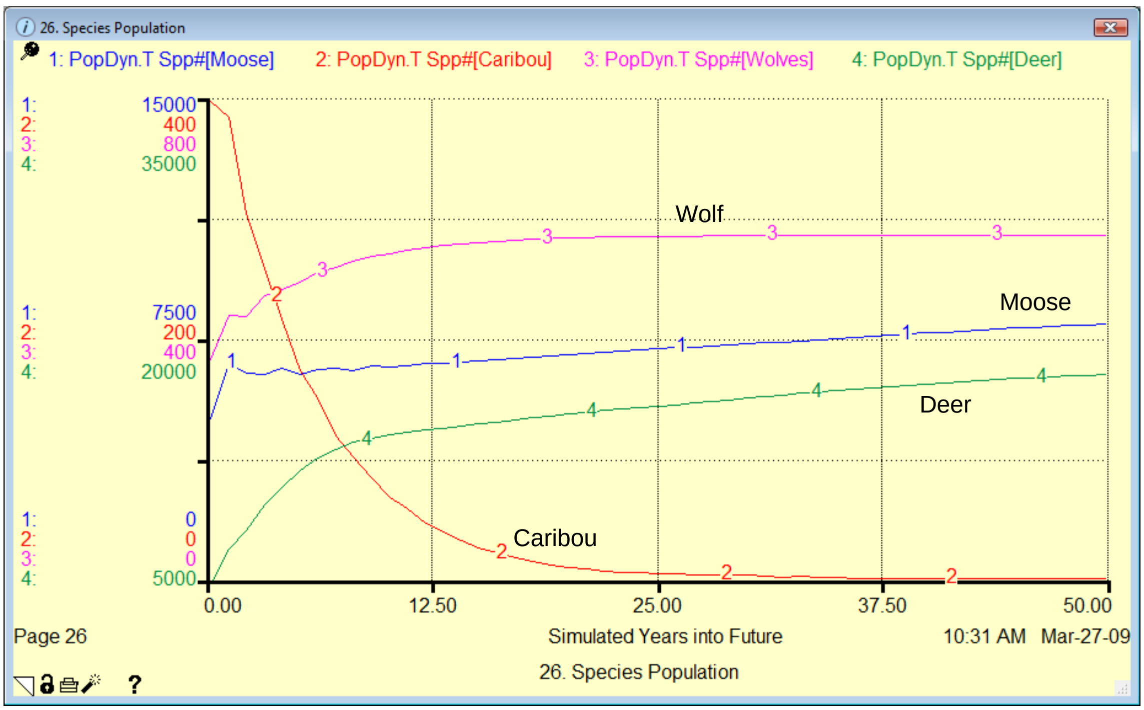


Figure 9. Forecast Business as Usual caribou, moose, wolf, and deer population size in WSAR planning area (assumes constant rate of disturbance, all species at current numbers; standard prey vulnerability and buffers assumptions; forecasted land-use; 50 year simulation period).

4.2.3 WSAR Alternative Futures Scenario

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 4.2.3.1, 4.2.3.2, and 4.2.3.3, respectively.

4.2.3.1 WSAR Habitat Restoration Levers

Two types of habitat restoration levers were evaluated for WSAR and other planning areas: 1) minimizing future footprint and young forest by reducing future in-situ bitumen development rate, annual forest harvest target, or fire and insect disturbance rates; and 2) applying coordinated reclamation to recover a defined proportion of current and future land-use footprints and applying appropriate best practices on a project-by-project basis to reduce future land-use footprint size or lifespan.

WSAR Future Footprint Minimization

Figure 10 summarizes the influence of future footprint minimization levers on Habitat-Based Population Performance at year 50. The BAU scenario simulation is provided for reference as the furthest left bar; in all cases, the higher the bar, the better the success of that management lever or combination. These results show that none of the individual levers or combinations considered here is sufficient to restore functional caribou habitat (defined as Habitat-Based Population Performance of 1 or higher).

Figure 10 indicates that in WSAR (and all other planning areas), the most effective option is to reduce the future footprint of all industrial sectors and simultaneously increase the fire return interval through better fire suppression. Results show that future in-situ (IS) development has the greatest effect on habitat function; simulations that reduce this footprint by reducing future bitumen production rates have the largest single influence on habitat recovery (IS simulations in Figure 10; number after IS refers to development rate relative to BAU assumptions). The influence of the forestry footprint (F) is smaller, but reducing the future softwood (SW) and hardwood (HW) harvest footprint would measurably improve habitat potential (F, SW, and HW simulations in Figure 10; numbers after acronyms refers to annual harvest targets relative to BAU assumptions). Reducing the fire return interval through fire suppression would also improve habitat function, but manipulating insect outbreak rates would have a comparatively small effect on Habitat-Based Population Performance (Fire and Ins simulations; number after refers to rate relative to BAU assumptions).

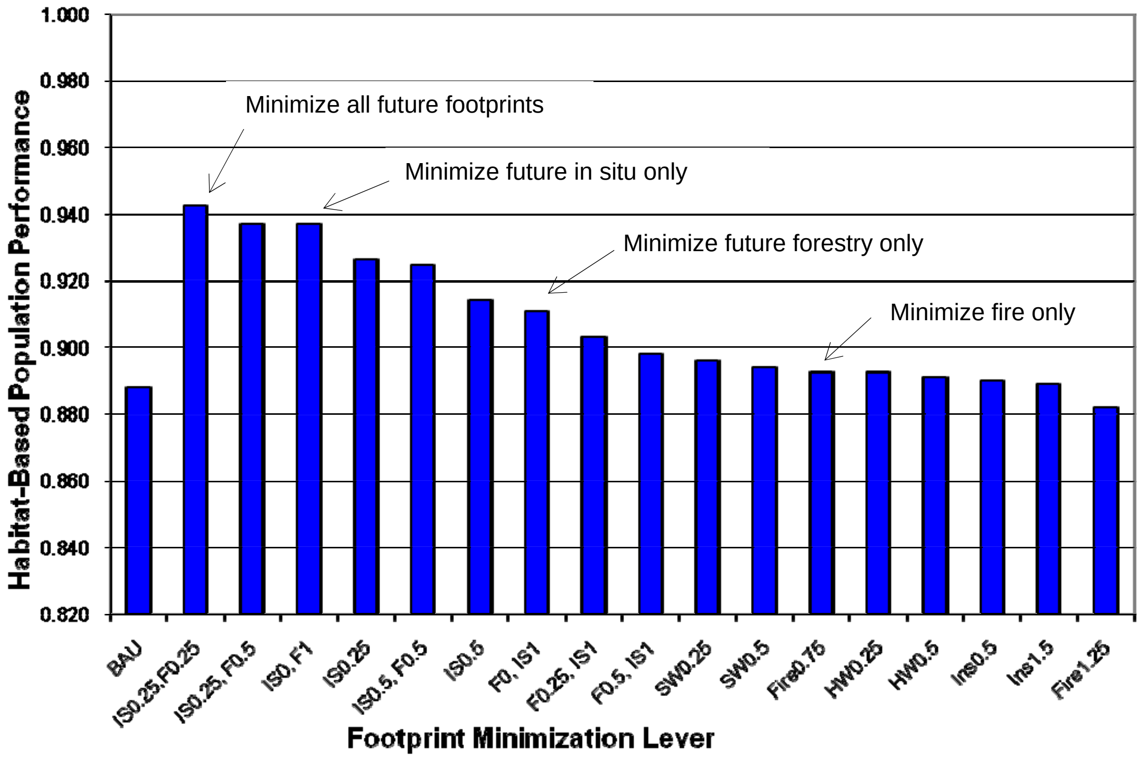


Figure 10. Influence of footprint minimization levers in the WSAR planning area (BAU = Business As Usual assumptions; IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions. For example IS0.25,F0.25 [second bar] means that in-situ and foresty footprint were both reduced to 25% of BAU projections. Similarly, F0.25,IS1 [ninth bar] indicates that the simulation was run with forestry at 25% and in-situ development was run at 100% of BAU assumptions.)

WSAR Coordinated Reclamation and Best Practices

Figure 11 summarizes the influence of coordinated reclamation and best practice levers on Habitat-Based Population Performance at year 50 when conducted independently. Note that these management levers have less overall effect than the footprint reduction levers summarized in Figure 10 (restoration of Habitat-Based Population Performance to 0.92 vs. 0.94 respectively).

Coordinated reclamation of seismic lines, pipelines, and temporary roads has a much larger incremental effect on functional habitat restoration than seismic lines alone or any single best practice (CRA simulations in Figure 11, first number after reflects the proportion reclaimed each period, second number reflects the interval between each reclamation period). Optimization simulations also indicate that the influence of coordinated reclamation diminishes after 10-15 years when most historic footprint has been reclaimed. Shortening delineation well access road (DAR) lifespan by using minimum ground disturbance construction methods and rapid reforestation has the next largest effect (DAR simulations in Figure 11, number after represents lifespan in years, compared to BAU assumption of 35 years). Conducting coordinated seismic line reclamation (CRS), increasing the number of production wells per pad (WPP) and reducing seismic line lifespan (SL) also have a beneficial effect on future Habitat-Based Population Potential, but their incremental effect is comparatively small relative to other levers considered (in Figure 11, first number after CRS reflects the proportion reclaimed each period, second number reflects the interval between each reclamation period; number after WPP simulations represents number of wells/pad relative to BAU assumption of 10/pad; number after SL represents lifespan relative to BAU assumption of 10 years).

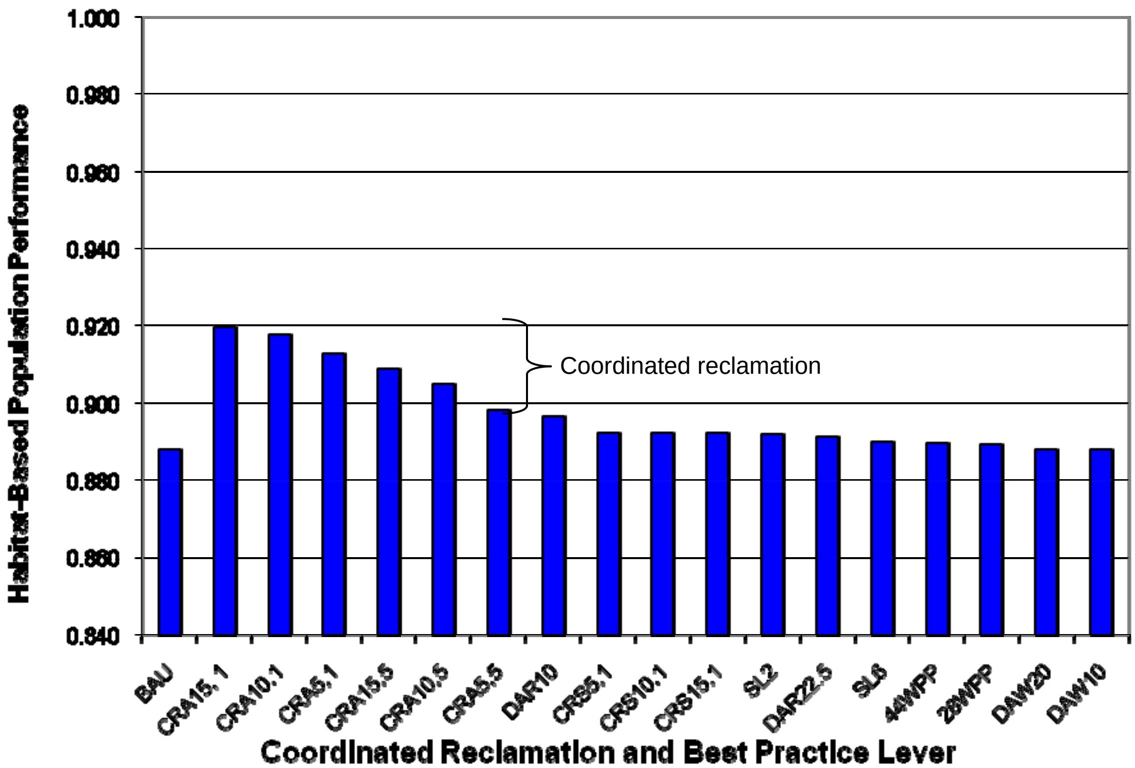


Figure 11. Influence of coordinated reclamation and best practices levers in the WSAR planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; DAW = delineation wellpad lifespan; CRA and CRS numbers represent percent reclaimed per year and interval; number for other levers are proportional change from BAU assumptions. For example CRA15,1 [second bar] means that coordinated reclamation was occurring for 15% of all seismic lines, pipelines and temporary roads every year). Similarly, CRS5,1 [ninth bar] indicates that the simulation was run with coordinated reclamation on seismic lines 5% on an annual interval.)

4.2.3.2 WSAR Mortality Management Levers

ALCES simulations of WSAR with habitat restoration levers improved Habitat-Based Population Potential but did not improve caribou persistence relative to Business as Usual simulations. In all cases, wolf abundance continued to increase from current high levels as deer and moose populations increased with expansion of land-use footprints and young forest. This indicates that high caribou predation will continue for decades, regardless of whether or not habitat restoration is implemented in the short-term. Simulation results for WSAR indicate that some form of mortality control (wolf control, with or without other prey control; or cow-calf penning) is needed to prevent caribou extirpation within two to four decades. Figure 12 presents results of comparative wolf control simulations. The BAU scenario simulation (i.e., caribou are extirpated) is provided for reference in the left-hand side of the figure; in all cases, the longer the bar, the better the success of that predator control option. The numbers on the X axis provided for each option represent percent of wolves removed / assumed wolf immigration rate / control interval.

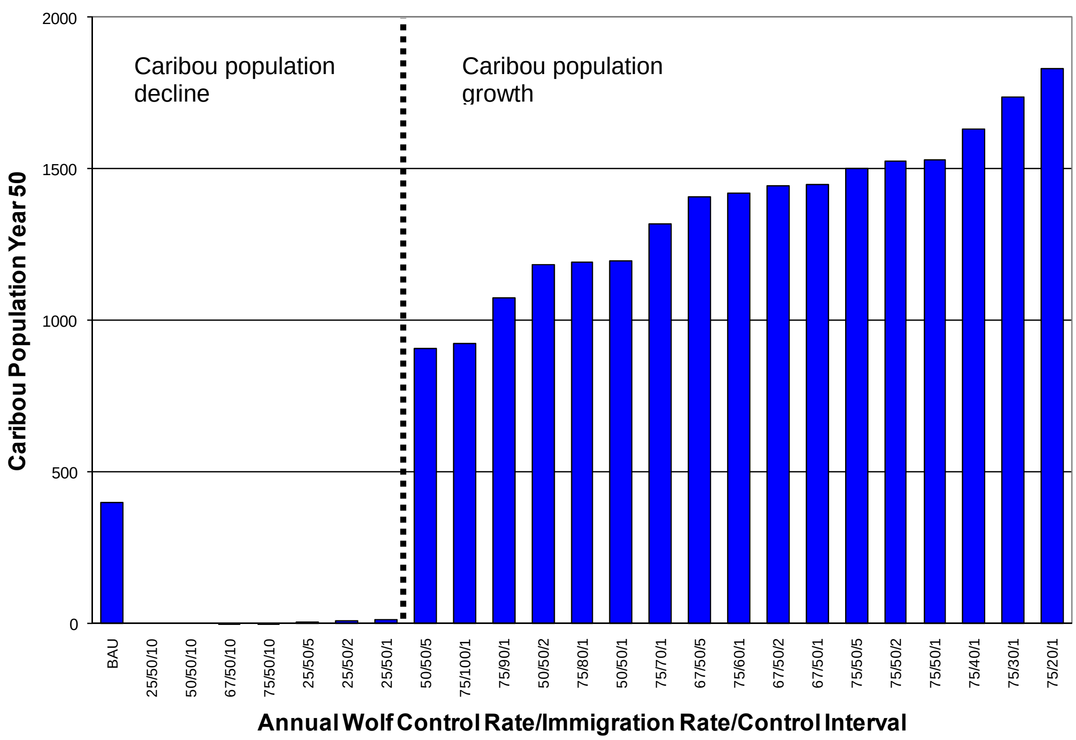


Figure 12. Interaction between wolf control and wolf immigration rates on simulated caribou population in the WSAR planning area (Numbers on x-axis reflect assumed annual wolf control rate/wolf immigration rate/control interval in years for that simulation. For example 50/50/5 [ninth bar from the left] means that the wolf control rate was 50%, there were 50 new wolf migrants per year, and wolf control was conducted at five year intervals during the 50 year simulation. For example 25/50/10 [location of second bar] means that annual wolf control rate was set at 25%, the rate of wolf immigrations was set at 50 wolves per year, and the the wolf control interval was 10 years. Similarly, 50/50/5 [ninth bar] indicates that the simulation was run with wolf a 50% wolf control rate, immigration was 50 wolves per year, and that wolf control was conducted at 5 year intervals.)

As anticipated, the simulated success of predator control was highly dependent on assumptions regarding control rate, control interval, and wolf immigration rate (Figure 12). Sensitivity simulations for the WSAR planning area suggest that with the standard immigration rate of 50 wolves/year (see Appendix 3), wolf control should occur at least every 5 years, with removal of at least half of the wolves in the planning area (current estimate is 367 wolves). Likelihood of success is directly related to control rate and inversely related to immigration rate and control interval. In other words, risk to caribou is minimized if a higher wolf control rate is applied each year and if the immigration rate is much lower than the removal rate.

Simulations indicated that cow-calf penning to increase calf survival would not sustain the WSAR caribou population over a 50 year period.

Results of other prey control simulations are less straightforward because removal of other prey can increase short-term predation on caribou in the absence of simultaneous wolf control. Highest probability of success occurs when aggressive wolf control is combined with less aggressive control of other prey. Further discussion is included with the Richardson planning area overview below.

4.2.3.3 WSAR Combined Management Levers

Landscape scale management will be required to successfully sustain caribou in the Athabasca Landscape area. **Simultaneous application of a full suite of management options will be required to recover and sustain caribou in the WSAR planning area as no single management lever is sufficient.** This includes: habitat restoration, future footprint reduction, and continuous mortality management until functional habitat is restored.

As described more fully in Section 5, ALT proposes that WSAR and other planning areas be managed as two zones to minimize the risk of caribou extirpation. In Zone 1 Areas, caribou recovery would be the priority designated land use, and all management options identified below would be implemented. Elsewhere within planning areas (Zone 2), all management options excluding future footprint restrictions would be implemented.

Two candidate Zone 1 areas were identified in the north-central and south-central parts of the WSAR planning area (Figure 8). In these areas, restoration of functional caribou habitat and caribou mortality management would be the designated and enforceable land-use priority. Each Zone 1 Area would need to include thousands of square kilometres to sustain caribou over the next 50+ years. The two candidates identified by the ALT incorporate relatively intact habitat with large contiguous areas of old lowland / peatland habitat and lichen-rich jack pine stands that are currently used by caribou.

The shaded polygons shown on Figure 8 identify the general areas discussed by the ALT. The ALT did not define specific boundaries for candidate areas because further evaluations will be required to optimize their size and location (see Section 5.2.1.1 for a more complete discussion).

The area between the Athabasca River and Wabasca lakes was identified because it:

- includes suitable lowland habitat (Figure 2) that has been heavily used by collared caribou over the last fifteen years;
- is relatively intact compared to other areas in WSAR and the Athabasca Landscape area (Figure 8);
- has areas with no currently economic bitumen reserves or plans for timber harvest in the next 15 years (Figures 4 and 5); and
- can be linked to candidate Zone 1 Areas in north WSAR (and possibly ESAR – W) to create a landscape-scale movement corridor.

The area south of Birch Mountains Wildland Provincial Park was identified because it:

- includes suitable lowland habitat (Figure 2) that is currently used by caribou based on winter 2008/2009 surveys (T. Powell pers. obs.);
- has comparatively low numbers of moose, deer, and wolves relative to the southern part of the planning area based on winter 2008/2009 surveys (T. Powell, pers. obs.);
- is relatively intact compared to other areas in WSAR and the Athabasca Landscape area (Figure 8);
- has areas with no currently economic bitumen reserves or plans for timber harvest in the next 15 years (Figures 4 and 5);
- can be linked to the existing wildland park to the north (Figure 1) and caribou range within the Red Earth Landscape area and Wood Buffalo National Park to facilitate implementation and create a landscape-scale movement corridor; and
- is further north and potentially less influenced by direct and indirect effects of climate change.

Simulations indicate that to restore habitat inside a Zone 1 Area, the combined management priorities would be:

- no new footprint;
- coordinated reclamation of all existing footprints; and
- combined wolf and other prey control for at least 50 years.

To sustain caribou and increase their distribution in Zone 2 Areas within the WSAR planning area but outside Zone 1 Areas (or in the absence of such areas), necessary combined management levers would include:

- ongoing wolf control (ideally combined with other prey control) for at least 100 years;
- coordinated reclamation of existing seismic lines, temporary roads and pipelines; and
- implementation of appropriate best practices considered by the ALT.

Simulations indicate that in addition to the combined management levers listed above for areas outside the Zone 1 Area, a reduction in future land-use footprint would also be required in order to restore functional habitat in the WSAR planning area within 50 years.

4.3 RICHARDSON PLANNING AREA

The 1,086,734 ha Richardson planning area is located northeast of Fort McMurray, bounded to the east by the Alberta-Saskatchewan border, to the west by the Athabasca River, to the north by the Canadian Shield, and to the south by the Clearwater River (Figure 2). The planning area consists of isolated peatlands in a mixedwood landscape. Small to medium-sized watercourses drain uplands along its eastern border.

The Richardson caribou population is poorly understood and few data exist for the 3 potential ranges identified in the planning area (Audet, Firebag, and Steepbank). The total number of caribou in this area is estimated to be less than 100 by ASRD. During winter 2008/2009 surveys, a minimum of 91 caribou were observed; most were in the Audet range area northeast of the Firebag River (T. Powell pers. obs.). The comparatively small population size suggests that Richardson caribou are highly vulnerable to extirpation in the absence of immigration from other nearby populations in the Athabasca landscape or Saskatchewan.

Range polygons shown on Figure 2 were described in the early 1990's with wetland/peatland data (% polygons) and expert opinion (Halsey and Vitt, Rippin and Gunderson, ASRD). These discrete caribou habitat areas comprise a total area of 268,717 ha, or 24% of the planning area (ALT 2008). Because these caribou habitats are isolated within a mixedwood matrix, they are assumed to be highly susceptible to indirect effects of land-use and predator-prey dynamics in the surrounding buffer.

Approximately 25% of the Richardson planning area was classified as young forest (<30 years old) and this, plus localized land-use footprints, has reduced relative intactness (Figure 13). Young forest is most common in the northern and eastern portions of the area, including the Firebag range polygon (35% young forest). Unlike other planning areas, white-tailed deer are not widely distributed in the Richardson area, and snow depth and habitat may limit abundance of deer and moose. Wolf and other prey numbers were observed to be low in the Audet range during winter 2008/2009 (T. Powell pers. obs.).

Seismic lines are the most common linear corridors in the planning area, and linear feature density is highest in the Steepbank caribou habitat polygon. Commercial bitumen reserves and anticipated development activities are found in the southwest portion of the planning area (Figure 4), but forest harvest is projected to have comparatively limited effect on habitat in this planning area (Figure 5).

Two protected areas overlap this planning area: the Marguerite River Wildland Provincial Park (two parts) in the Firebag and Audet ranges; and Richardson River Dunes Wildland Provincial Park at the northern edge of the planning area. The Maybelle River Wildland Provincial Park is just north of the northern boundary of the Richardson planning area.

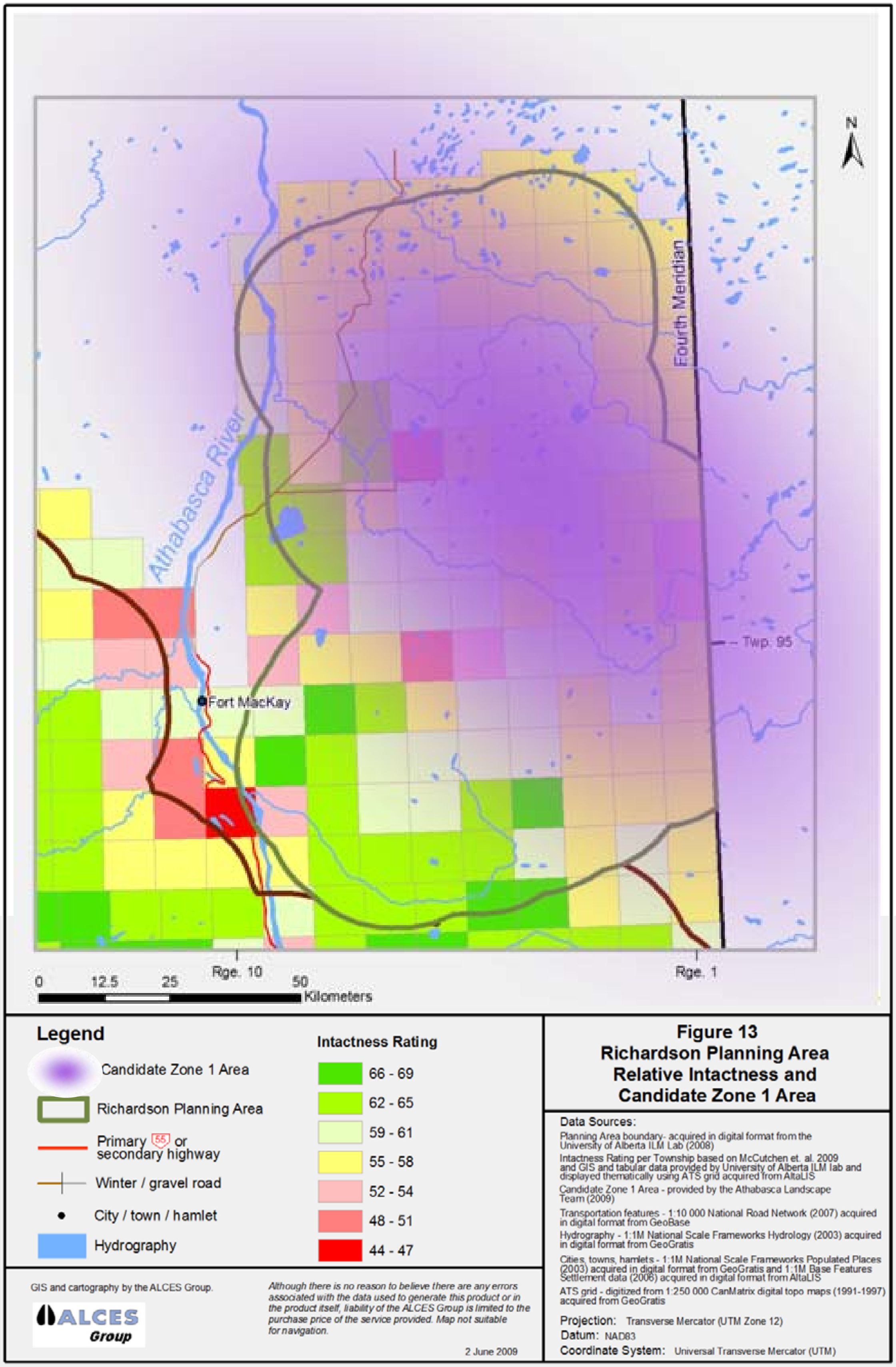


Figure 13
Richardson Planning Area Relative Intactness and Candidate Zone 1 Area

Although the Richardson planning area is moderately intact relative to other Athabasca Landscape areas, risk to boreal caribou is considered high because: 1) existing and potential caribou numbers (<100) are relatively small; 2) caribou habitat areas are isolated and highly sensitive to the influence of the surrounding buffer; and 3) young forest is relatively common (Table 2). Long term development risk for the Steepbank range is high because economic bitumen deposits occur over much of it (Figure 4).

4.3.1 Richardson Business as Usual Scenario

The current estimated size of the Richardson boreal caribou population (<100) is substantially lower than the simulated Non-industrial population of 700-900 individuals. The Business as Usual simulation suggests that boreal caribou in the Richardson planning area will be extirpated within the next three decades as: 1) footprint and young forest increase; 2) the Habitat-Based Population Performance indicator declines from 0.98 to 0.90; and 3) as shown in Figure 14, deer numbers increase to an average density of 40/100 km^2, wolves increase to a density of 1.8/100 km^2, and moose increase slowly to a density of 17/100 km^2.

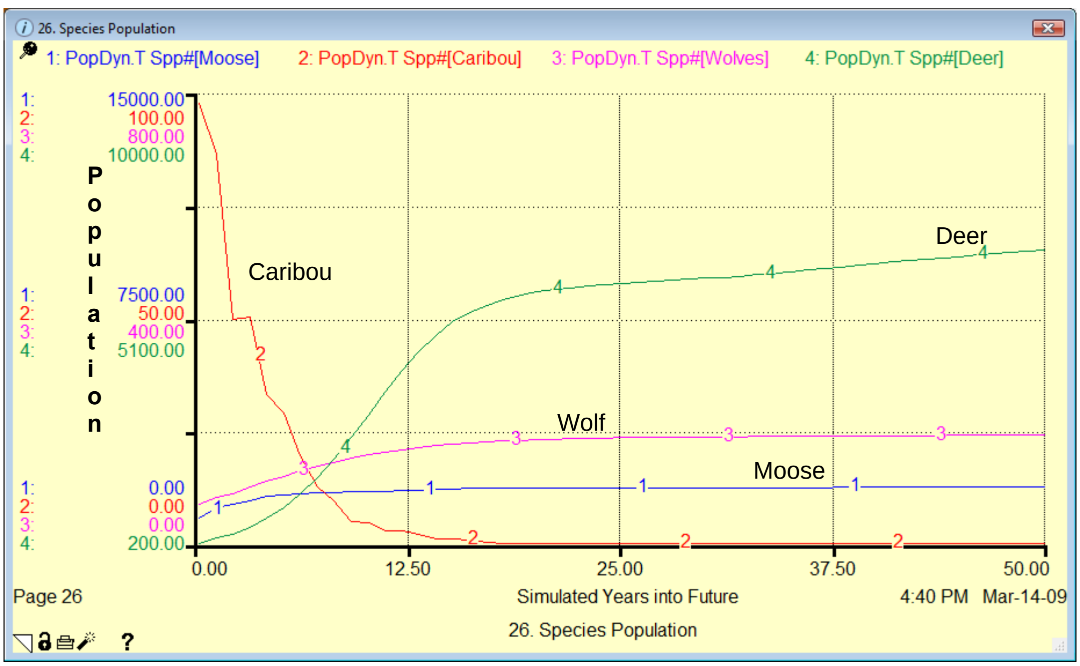


Figure 14. Simulation forecast of caribou, moose, wolf, and deer populations in Richardson planning area with Business as Usual assumptions and constant disturbance.

4.3.2 Richardson Alternative Futures Scenario

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 4.3.2.1, 4.3.2.2, and 4.3.2.3, respectively. Management levers and assumptions for the Richardson planning area were identical to those for the WSAR planning area, with the exception that wolf immigration rate was reduced for Richardson area wolf control simulations to better reflect its smaller area (the buffered Richardson planning area is 1/3 the area of the buffered WSAR area) and smaller wolf population (the guesstimated number of wolves in the Richardson planning area was 71 compared to 367 in the WSAR Range; Supplemental Data Table 1 in Appendix 3).

4.3.2.1 Richardson Habitat Restoration Levers

Richardson Footprint Minimization

The graph provided in Figure 15 summarizes the influence of future footprint minimization levers on Habitat-Based Population Performance at year 50. The BAU scenario simulation is provided for reference as the furthest left bar; in all cases, the higher the bar, the better the success of that management lever or combination.

Results are similar to those provided earlier for the WSAR planning area. None of the individual levers or combinations considered here is sufficient to restore functional caribou habitat (defined as Habitat-Based Population Performance of 1 or higher). Future in-situ development has the greatest effect on habitat function while the influence of the forestry footprint is smaller. Other management levers have no effect on Habitat-Based Population Performance.

Richardson Coordinated Reclamation and Best Practices

Figure 16 summarizes the influence of coordinated reclamation and best practice levers on Habitat-Based Population Performance at year 50 when conducted independently. Note that these management levers have less overall effect than the footprint reduction levers summarized in Figure 15 (restoration of Habitat-Based Population Performance to 0.93 vs. 0.96 respectively).

Richardson results were the same as WSAR and all other planning areas: coordinated reclamation of seismic lines, pipelines, and temporary roads (CRA simulations in Figure 16) has the largest incremental effect on functional habitat restoration, followed by feature overlap (not shown in Figure 16), shortening delineation well access road lifespan (DAR simulations in Figure 16), and shortening seismic line lifespan (SL simulations in Figure 16).

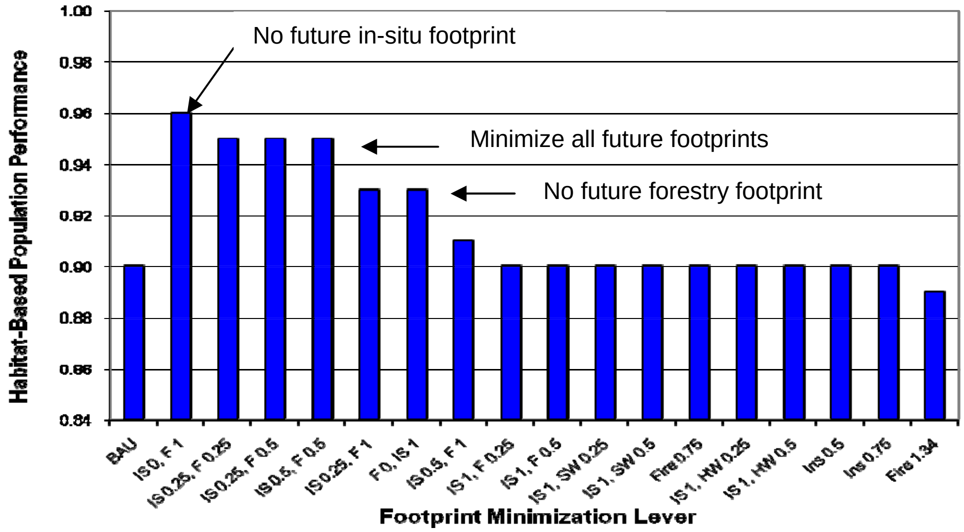


Figure 15. Influence of footprint minimization levers in the Richardson planning area (IS = in situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions. For example IS0,F1 [second bar] means that the simulation was run with no in-situ footprint and with forestry operating at 100% of BAU projections. Similarly, IS1,F0.5 [ninth bar] indicates that the simulation was run with in-situ at 100% and forestry at 50% of BAU assumptions).

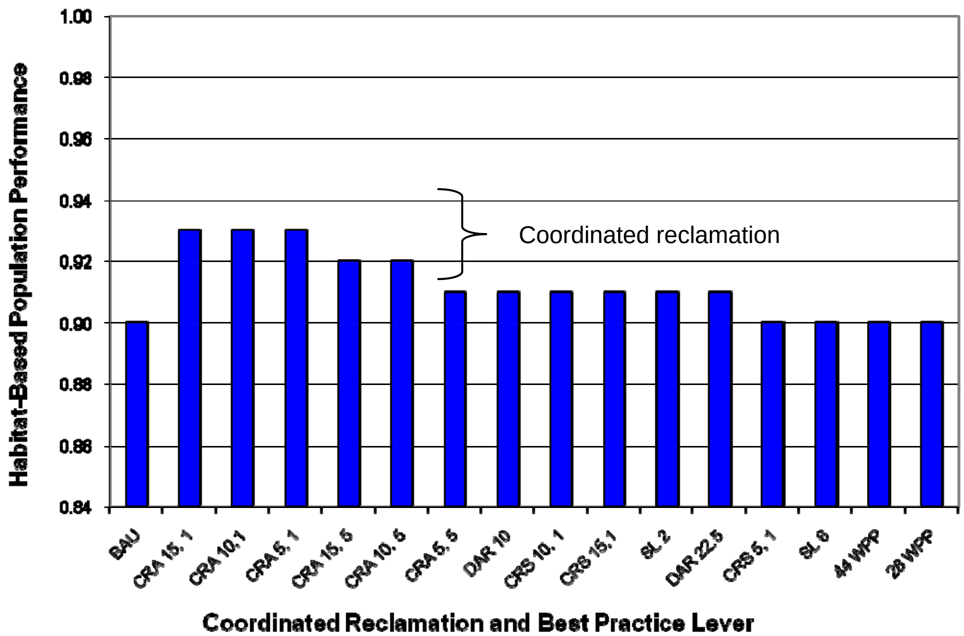


Figure 16. Influence of coordinated reclamation and best practices levers in the Richardson planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; DAR = delineation well access lifespan; CRA and CRS numbers represent percent reclaimed per year and interval; number for other levers are proportional change from BAU assumptions. For example CRA15,1 [second bar] means that coordinated reclamation of seismic lines, pipelines and temporary roads was conducted at 15% of the existing footprint every year. Similarly, CRS10,1 [ninth bar] indicates that the simulation was run with coordinated reclamation of 10% of the seismic lines at an annual interval).

4.3.2.2 Richardson Mortality Management Levers

ALCES simulations with habitat restoration levers in the Richardson planning area improved Habitat-Based Population Potential but did not improve caribou persistence relative to Business as Usual simulations. As in the WSAR planning area, some form of mortality control (wolf control, with or without other prey control; or cow-calf penning) is needed to prevent caribou extirpation within two to four decades. Simulations indicated that wolf control of at least 67% per year would be required to sustain a stable caribou population in the Richardson planning area. This outcome was sensitive to assumed wolf immigration rates: for example, changing assumed wolf immigration rate from 25 to 30 per year resulted in caribou growth to decline.

Simulations indicated that cow-calf penning would sustain the Richardson caribou population only if every cow was penned each year of the 50 year period.

Figure 17 presents results of a representative control simulation of other prey species, i.e., moose and deer. Control of other prey alone (i.e., without wolf control) substantially reduces wolf and other prey populations in the Richardson planning area but does not sustain caribou because of prey switching by wolves. Note that simulations assume no immigration of caribou or other prey, so once they are extirpated, they do not return. Simulations suggest that the most successful strategy is to control deer less frequently and at low levels (i.e., 15% control every 10 years) to reduce the likelihood of prey switching by wolves. Winter 2008/2009 surveys suggest that deer and moose numbers are lower than previously estimated in the Richardson planning area (T. Powell pers. obs.), so deer control might be able to reduce future deer abundance and distribution, with associated benefits for caribou in this area.

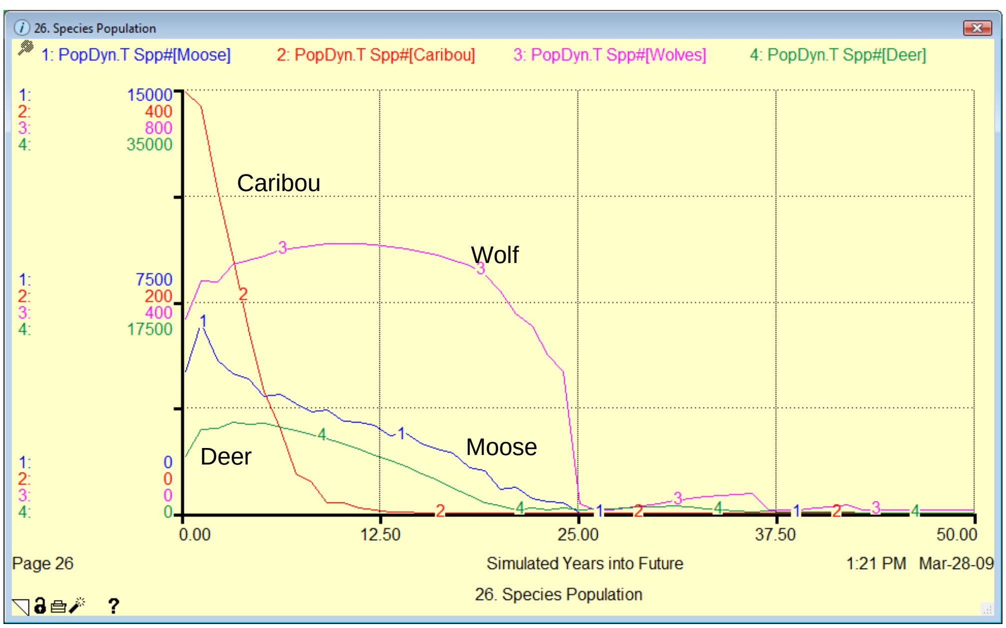


Figure 17. Influence of annual control of 15% moose and 15% deer on predator and prey populations in the Richardson planning area.

4.3.2.3 Richardson Combined Management Levers

Simultaneous application of full suite of management options will be required to recover and sustain caribou in the Richardson planning area as no single management lever is sufficient. This includes: functional habitat restoration, future footprint reduction, and continuous mortality management until functional habitat is restored.

Simulations suggest that Richardson is the only planning area where continuous cow-calf penning would be sufficient to offset mortality over a 50 year period. However, simulations indicated that cow-calf penning would sustain the Richardson caribou population only if every cow was penned each year of the 50 year period. The technical, economic, and political viability of this approach could be evaluated for this area. Another speculative alternative discussed by the ALT was constructing and maintaining a barrier to impede deer and predator movement into the area northeast of the Firebag River.

The lowest risk management approach for the Richardson planning area identified by the ALT would be to establish a large Zone 1 Area northeast of the Firebag River, including Marguerite River Wildland Park (Figure 13). In this area, restoration of functional caribou habitat and caribou mortality management would be the designated land-use priority. This Zone 1 Area would need to include thousands of square kilometres to sustain caribou over the next 50+ years. It should incorporate relatively intact habitat with large contiguous areas of old lowland or upland pine habitats that are currently used by caribou.

The shaded polygon shown on Figure 13 identifies the general area discussed by the ALT. The ALT did not define specific boundaries for candidate areas because further evaluations will be required to optimize their size and location (see Section 5.2.1.1 for a more complete discussion). A 5,000 to 6,000 km^2 polygon in the northeast portion of the planning area was identified as the most suitable candidate because it:

- includes suitable lowland and pine habitat (Figure 2) that is currently used by caribou based on winter 2008/2009 surveys and recent telemetry data;
- has comparatively low numbers of moose, deer, and wolves based on winter 2008/2009 surveys (T. Powell, pers. obs.);
- is relatively intact compared to other areas in Richardson and the Athabasca Landscape area (Figure 6);
- has areas with no currently economic bitumen reserves or immediate planned timber harvest (Figures 4 and 5);
- can be linked to the existing wildland parks to the east and north to facilitate implementation and create a landscape scale movement corridor; and
- is further north and potentially less influenced by direct and indirect effects of climate change.

Simulations indicate that to restore habitat inside a Zone 1 Area, the combined management priorities would be: no new footprint; coordinated reclamation of all existing footprints; and combined wolf and other prey control for at least 50 years.

To sustain caribou and increase their distribution in the Zone 2 Area within the planning area but outside the Zone 1 Area (or in the absence of such areas), necessary combined management levers would include: ongoing wolf control (ideally combined with other prey control) for 100 years; coordinated reclamation of existing seismic lines, temporary roads and pipelines; and implementation of appropriate best practices considered by the ALT. **Simulations indicate that this would not be sufficient to restore functional habitat in the Richardson planning area within 50 years without reducing future land-use footprint.**

5. OPTIONS FOR CARIBOU CONSERVATION ON THE ATHABASCA LANDSCAPE

The present distribution of boreal caribou in the Athabasca Landscape is discontinuous and strongly associated with poorly drained treed peatlands that provide year-round habitat; there has been limited movement between the four ranges. These discrete caribou habitat areas are found within a matrix of upland mixedwood forest that is avoided by caribou, but provides habitat for other prey species that in turn support wolves, black bear, and other potential predators. Upland lichen-rich pine forest also provides suitable habitat.

The Relative Intactness map provided as Figure 6 describes current habitat 'quality' for boreal caribou within the Athabasca Landscape area. This map is based on criteria developed by the ACCRMS (McCutchen et al. 2009) and identifies areas that currently have highest relative habitat value for caribou in the Athabasca Landscape area.

5.1 BUSINESS AS USUAL SCENARIO

The ALT determined that there is insufficient functional habitat to maintain and increase current caribou distribution and population growth rates within the Athabasca Landscape area. Caribou will not persist for more than two to four decades without immediate and aggressive management intervention. Tough choices need to be made between the management imperative to recover caribou and plans for ongoing bitumen development, industrial land-use and forest harvesting.

While abundance of caribou and other species fluctuate naturally in response to landscape-level changes, simulation modeling suggests that current caribou abundance is well below the range expected under natural conditions. Current caribou population estimates in all ranges and the overall Athabasca Landscape area are substantially below those simulated for the Non-Industrial Scenario using 'natural' assumptions (i.e., no past, current, or future land-use, but with a suite of natural ecological processes including random fire and insect outbreaks, forest succession, and predation). In contrast, current moose population estimates are within their simulated non-industrial population range, while current wolf and deer populations are above their simulated non-industrial population range.

Wildlife managers have low confidence in current caribou, wolf and prey population estimates because monitoring programs have been designed to track population trends rather than obtain accurate and precise population estimates (Dzus 2001). Sensitivity simulations summarized in Appendix 3 show that differences between actual and estimated populations will affect the duration of caribou persistence, but not change the trend of ongoing decline. **Therefore, our conclusions on management options are relatively robust despite the uncertainty around population estimates, relative prey vulnerability, and future development trajectories.**

Predation appears to be the proximate cause of recent declines in the Athabasca Landscape area. Available information suggests that increasing land-use footprints (corridors and clearings) and young forest have caused a system shift from non-industrial conditions where caribou are present in functional habitat that is spatially separated from moose and wolves, to one where other prey densities have increased in, and immediately adjacent to, caribou habitat. Caribou mortality is higher than expected based on their comparative density because caribou are more vulnerable to wolf predation than other prey species. Because of this system shift, immediate and aggressive intervention is required to reduce caribou mortality and restore functional habitat.

The highest future risk to caribou occurs in areas underlain by thick bitumen deposits in the ESAR – BF, and Richardson planning areas, and in smaller planning areas (Richardson, CLAWR, and ESAR – E) where both potential and existing populations are less than 150 individuals. Risk for caribou persistence is lower (but still rated as medium) in the WSAR planning area, largely due to the proportion of the area that is underlain by bitumen deposits.

The current approach to caribou management and land-use decision-making in the Athabasca Landscape area assumes that caribou abundance and distribution can be maintained by applying 'best practices' and mitigation measures at the local scale (e.g., through activity timing restrictions and footprint minimization). **However, empirical data on observed rates of decline in caribou populations and results from ALCES® simulations indicate that continued implementation of current 'best practices' will not maintain and restore caribou.**

5.2 ALTERNATIVE FUTURES SCENARIO

Politically and economically challenging conservation and recovery measures will be required in both the short- and long-term to sustain the Athabasca Landscape boreal caribou population and maintain or increase current caribou distribution as directed by the provincial recovery plan.

Landscape scale management will be required to successfully sustain caribou in the Athabasca Landscape area. The ALT proposes that this region be managed as two zones. In Zone 1 Areas, described in more detail below, caribou recovery would be the priority designated land use, and all management options identified below would be implemented. Elsewhere within planning areas (Zone 2), all management options excluding future footprint restrictions would be implemented. The exception is portions of the ESAR – Bitumen Fairway sub-planning area underlain by thick bitumen deposits where appropriate best practices would be implemented.

Simulation modeling using ALCES® was conducted for each planning area to identify successful management options. A full suite of management options was considered, including combinations of two or more of the following management levers:

- Zone 1 Areas: defining areas where caribou recovery and maintenance is the designated land-use priority and is supported by appropriate legislation;
- Implementing a coordinated reclamation program to reclaim existing and future footprints in Zones 1 and 2 of caribou planning areas;
- Implementing appropriate best practices in Zones 1 and 2 to minimize the incremental size and lifespan of future land-use footprints;
- Managing caribou mortality in Zones 1 and 2 by reducing numbers of predators and other prey; and
- Managing caribou mortality in Zones 1 and 2 by penning caribou cows during the calving period.

Table 4 identifies some practical considerations of the most successful management levers evaluated by the ALT.

5.2.1 Functional Caribou Habitat Restoration

The most effective approach to restore functional caribou habitat is to increase the size of currently intact areas by 'recruiting' adjacent areas through future footprint reduction, coordinated reclamation, and best practices.

Because the amount of existing footprint is high in many parts of the Athabasca Landscape area, restoration efforts of individual land users and land managers should be coordinated in previously defined areas that have highest short- and long-term value for boreal caribou recovery. Ultimately, population size and management effectiveness is related to the amount of functional or intact habitat that can be maintained or restored in the next 15 to 20 years. If two populations are equal in all respects, and choices have to be made, the ALT's recommendation would be to maintain the population with larger, more continuous, or relatively intact habitat.

It is important to note that the benefits of habitat restoration will not be realized for decades because there is a 30-50 year lag time following reclamation before forest becomes old enough to be considered low quality for other prey, and suitably old to be used by caribou. At minimum, mortality management will need to be continued for this entire lag period. For this reason, long-term risk will be minimized if habitat restoration begins as soon as possible.

Table 4. Implementation considerations for Athabasca Landscape area management levers.

Strategy	Management Lever	Implementation Considerations
Habitat Re0storation	Zone 1 Areas	- Formal evaluation of optimum candidate area size and location is most appropriately conducted as part of the Lower Athabasca Regional Planning initiative. - Need to define legal boundaries and associated decision-making and administrative procedures. Wildland Provincial Park, Forest Land Use Zones, or new legislated options under the proposed Alberta Land Stewardship Act are options that should be evaluated. Given the landscape-scale focus of this management option, it is most appropriately evaluated as part of the recently initiated Lower Athabasca Regional Planning process to ensure that the full suite of stakeholder views are acknowledged and considered - This approach will have associated costs related to foregone resource development opportunities and compensation to existing tenure holders. In-situ development has the greatest incremental influence on future habitat function, followed by forestry, and oilsand mining.
	Coordinated Reclamation	- An annual coordinated program is required to regularly reclaim a portion (5%, 10%, or 15%) of seismic lines, pipelines, and temporary roads. Table 5 in Appendix 3 shows initial lengths of linear features that would need to be reclaimed at 5%, 10% and 15% for pulsed reclamation. Incremental benefit declines after 10-15 years when most historical footprint has been reclaimed. - Cooperative industry or industry/ government program will be required in pre-defined area (ideally Zone 1 Area). Conservation offset program or equivalent would allow developers to restore habitat in Zone 1 Areas in return for new footprint 'credits'. - Centralized body will likely be needed to develop inventory, define objectives of reclamation and appropriate methods for upland and lowland areas that achieve simulated future outcomes, and track amount of reclamation that actually occurs. - Ownership constraints may restrict the actual amount that can be reclaimed each interval. - Opportunity for adaptive management to compare results from different treatments in different planning areas.
	Best Practice – Feature Overlap	- Feature overlap refers to increasing overlap of linear features onto existing footprints during construction from 15% to 22.5% or 30%. - This will require agreement of decision-makers that overlap on partially reclaimed features is preferable to new corridors. - Reserve delineation regulations may not allow in-situ exploration footprint to be minimized. - Opportunity for adaptive management to compare results from different treatments in different planning areas.
	Best Practice – Delineation Well Access Lifespan	- Use minimal ground disturbance techniques and reforestation to reduce wellpad and access road lifespan from 35 years to 20 or 10 years. - Definition of 'reclaimed' required for functional caribou habitat. - Difficulty restricting traditional access on public lands is a barrier to implementation.

Table 4. Implementation considerations for Athabasca Landscape area management levers (cont.).

Habitat Restoration (cont.)	Best Practice – Seismic Line Lifespan	- Reduce lifespan of seismic lines from 10 to 6 to 2 years through narrower lines or post-program reclamation. - Uncertainty about whether future seismic has been underestimated if 4D programs become routine. - In simulations, this best practice had a comparatively minor influence at the planning area scale over 50 years.
Mortality Management	Wolf control	- Annual or biannual control of 50%-75% of current wolf population throughout planning areas; this is near or at a technically feasible level. - Model simulations were sensitive to assumptions on the relative rates of control and immigration rates between control periods. - Consider advantages of sterilizing alpha pair to reduce wolf immigration rate in Richardson planning area; in other areas, this may not be possible because pack structure becomes dynamic following control. - Because of ongoing wolf immigration and increasing populations of other prey, continuous control will be needed and interruption for social/political reasons will lead a rebound in wolf numbers that will jeopardize long term success. - Ongoing (50 year +) social support for this lever considered unlikely based on past experience (see National Research Council 1997); support would likely be more certain if implemented in Wildland Parks as part of Caribou Conservation Areas. - Monitoring will be required to document wolf and other predator densities before and after control activities.
	Other Prey Control (moose and deer)	-Annual or biannual control of deer and moose populations in range plus buffer. - Must be conducted in conjunction with wolf control. Simulations suggest that removing other prey alone will increase short-term predation on caribou and increase rate of decline. - Benefit to caribou sensitive to other prey/wolf control ratio. - Increasing sport harvest and beaver trapping is an indirect method to achieve this. - Social support for ongoing moose and deer control in this region is unknown. - Monitoring will be required to document other prey densities before and after control activities.
	Cow-calf Penning	- Capture, pen, and feed pregnant cows until 2-3 weeks post-calving when calf predation risk decreases. - Past success has been variable (Smith and Pittaway 2008). - Ongoing penning will be required. - Stress on individual animals may be cumulative; concerns about this issue caused Chisana program to stop within 5 years (T. Jung, pers. comm., Wildlife Biologist, Yukon Government). - Ongoing (50 year +) social support for this lever considered unlikely based on past experience. - Monitoring will be required to document other prey and predator densities before and after penning activities.
	Predator / Other Prey Exclusion	- Construct and maintain a barrier to reduce predator and other prey movement into caribou habitat. - Speculative approach that has not been applied or tested in this manner; maintenance and monitoring would be required. - Opportunity for adaptive research / monitoring program to evaluate viability of these levers.

5.2.1.1 Zone 1 Areas

The ALT has concluded that designating ‘Zone 1 Areas’ is the management option most likely to achieve provincial caribou recovery plan goals at the scale of both individual planning areas and the Athabasca Landscape area more generally. The economic implications of doing so have not been evaluated. Zone 1 Areas apply a cumulative effects management approach where caribou recovery would be the designated and enforceable land-use priority. These need to be of sufficient size (thousands of square kilometres) to recover and sustain a caribou sub-population. In these areas, combined footprint would be restored and future footprint restricted to very low levels (below current conditions) concurrent with continuous predator control until functional habitat is restored. To be most effective, short-term caribou habitat restoration activities should be focused in Zone 1 Areas where function is currently less compromised.

The ALT adopted the following criteria for defining Zone 1 Areas within each planning area:

Primary

- Defined as woodland caribou habitat by ASRD.
- ASRD / ACCRMS / other monitoring confirms current caribou use of the area.

Secondary

- Moderate to High relative intactness (Figure 6) based on methods of McCutchen et al. (2009).
- Comparatively low future development potential based on information provided to the ALT from DOE and Al-Pac.
- Comparatively low predator and other prey densities.
- Other biodiversity benefits (connectivity with other existing or proposed protected areas).
- Further north to minimize potential direct and indirect influence of climate change.

The ALT did not define specific boundaries for Zone 1 Areas but Figure 18 shows the general areas identified as candidates by the ALT. Caribou telemetry locations are also shown on this figure for reference. Note that telemetry monitoring effort has been lower in north WSAR, Richardson, and ESAR – E planning areas, so absence of locations in these areas does not necessarily indicate that they are not currently used by caribou.

Of the six candidate Zone 1 Areas identified by the ALT, the WSAR and Richardson planning area candidates were considered to have the greatest potential to minimize long-term risk to caribou:

1. North WSAR: area of suitable habitat south of Birch Mountain Wildland Park in the north half of the WSAR planning area. Limited telemetry data are available for this area, but use of suitable lowland habitat by two collared animals has been documented (Figure 19); use of this area was also observed

in winter 2008/2009. Moderately intact (Figure 20), but predator / other prey densities and future development potential (Figure 21) are thought to be lower than the southern half of WSAR. This Zone 1 candidate can be linked to suitable habitat in the Red Earth Landscape and Wood Buffalo National Park to the north to create a landscape scale movement corridor.

2. South WSAR: large lowland area between Wabasca lakes and the Athabasca River that has been heavily used by collared caribou over the last fifteen years (Figure 19). Area is comparatively intact (Figure 20) and part is outside economic bitumen area defined by Energy (Figure 21). High predator / other prey densities. This Zone 1 candidate could be linked to North WSAR (and potentially ESAR – W) candidate areas to create a landscape scale movement corridor.
3. Richardson: northeast portion of the Richardson planning area near the Firebag River incorporating Marguerite River Wildland Park. Telemetry was only begun recently in this area (Figure 19), but use of suitable habitat in the candidate Zone 1 Area was confirmed in winter 2008/2009. Future development potential (Figure 21) and predator / other prey densities are comparatively low relative to other parts of the Athabasca Landscape area. This Zone 1 candidate can be linked to existing protected areas to the east and north to create a landscape scale movement corridor.
4. ESAR – W: isolated areas of suitable lowland habitat in northwest portion of sub-planning area between Bitumen Fairway and Athabasca River (Algar, House, and Horse drainages) that have been heavily used by collared caribou over the last fifteen years (Figure 19). Some comparatively intact areas remain (Figure 20) and much of this candidate is outside economic bitumen area defined by Energy (Figure 21). High predator / other prey densities in Athabasca River valley. This Zone 1 candidate could be linked to North and South WSAR (and potentially ESAR – W) candidate areas to create a landscape scale movement corridor.
5. ESAR – E: patches of suitable habitat in eastern portion of sub-planning area between the Christina River and Saskatchewan border. There are limited data for this area (Figure 19), however, winter 2008/2009 field investigations indicated that this area has comparatively poor caribou habitat and limited evidence of current use was observed (T. Powell pers. obs.); further monitoring is warranted to validate actual use and population trends. Comparatively intact habitat (Figure 20) with limited future development potential (Figure 21) but high predator / other prey densities.
6. CLAWR: entire range excluding buffer area south of suitable habitat. Heavily used habitat (Figure 19) with low comparative intactness (Figure 20), high future development potential (Figure 21) and high predator / other prey densities. Simulations suggest that significant management intervention would be required to sustain this population. Dialogue with Department of National Defence and the Government of Saskatchewan will be required for co-management of this population.

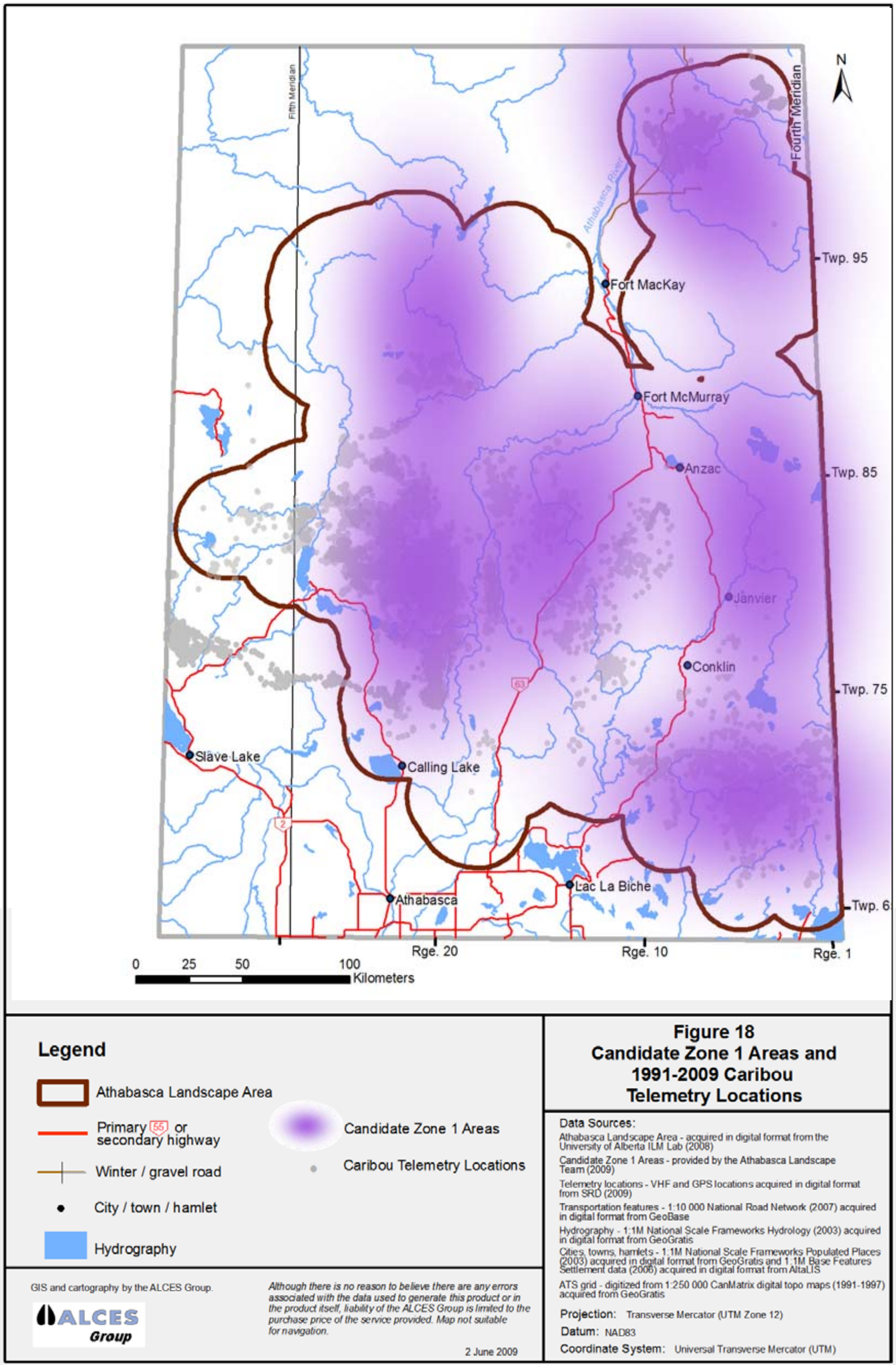


Figure 18
Candidate Zone 1 Areas and 1991-2009 Caribou Telemetry Locations

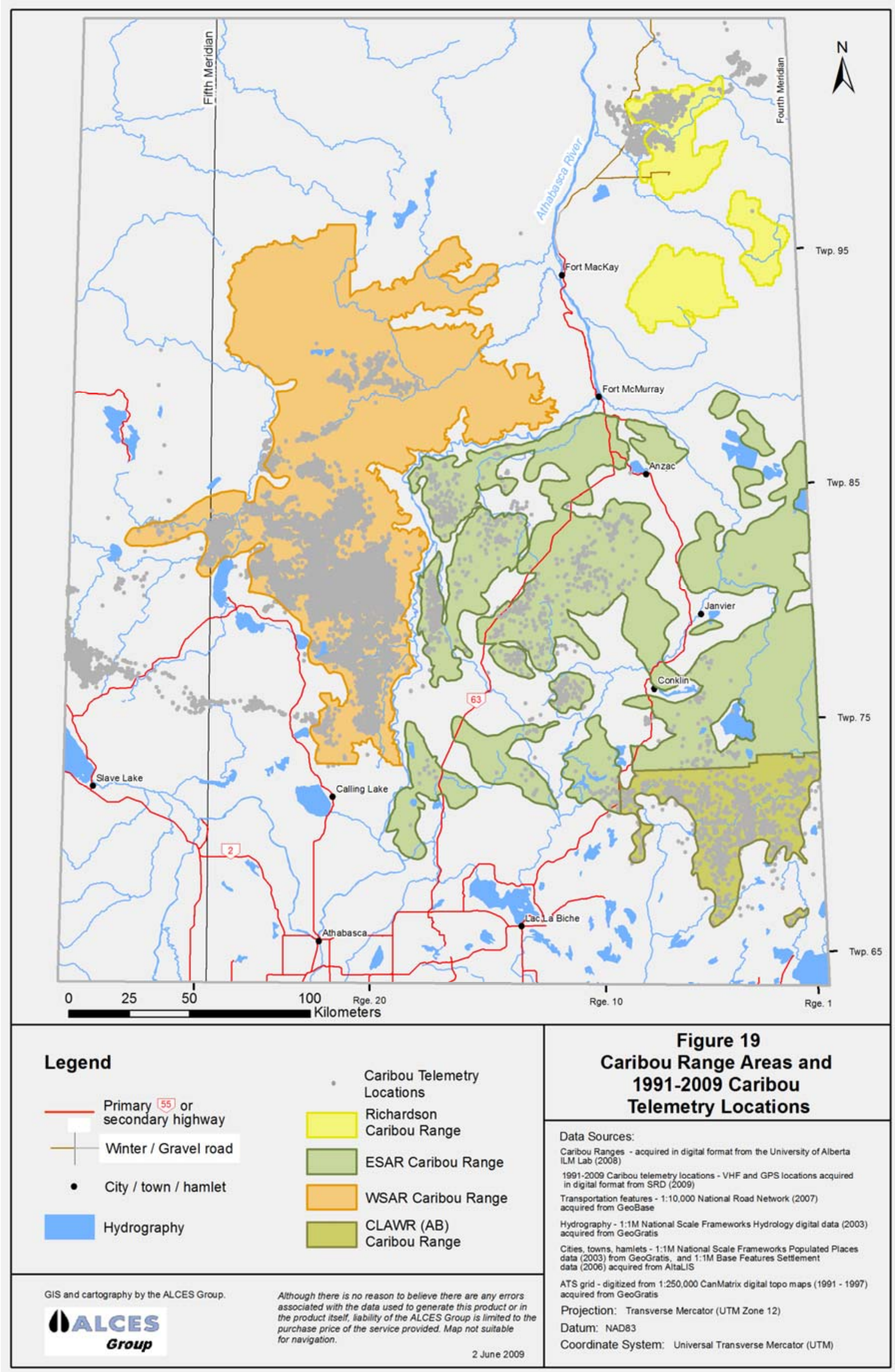
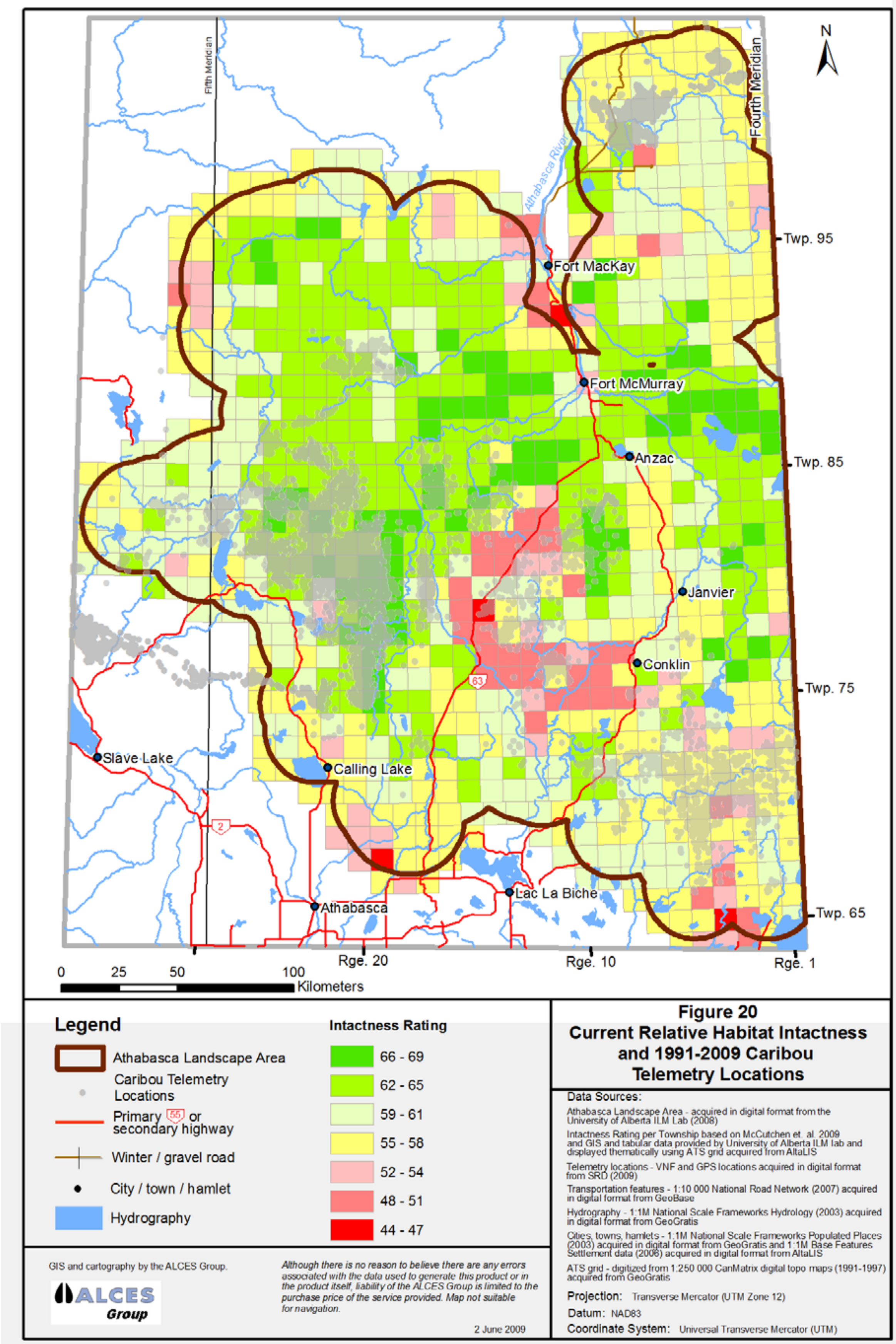


Figure 19
Caribou Range Areas and 1991-2009 Caribou Telemetry Locations


N
Fifth Meridian
Fourth Meridian
Athabasca River
Twp. 95
Twp. 85
Twp. 75
Twp. 65
Fort MacKay
Fort McMurray
Anzac
Janvier
Conklin
Slave Lake
Calling Lake
Athabasca
Lac La Biche
63
2
Rge. 20
Rge. 10
Rge. 1
0 25 50 100
Kilometers
Legend
Athabasca Landscape Area
Caribou Telemetry Locations
Primary 55 or secondary highway
Winter / gravel road
City / town / hamlet
Hydrography
Intactness Rating
66 - 69
62 - 65
59 - 61
55 - 58
52 - 54
48 - 51
44 - 47
Figure 20
Current Relative Habitat Intactness and 1991-2009 Caribou Telemetry Locations
Data Sources:
Athabasca Landscape Area - acquired in digital format from the University of Alberta ILM Lab (2008)
Intactness Rating per Township based on McCutchen et. al. 2009 and GIS and tabular data provided by University of Alberta ILM lab and displayed thematically using ATS grid acquired from AltaLIS
Telemetry locations - VNF and GPS locations acquired in digital format from SRD (2009)
Transportation features - 1:10 000 National Road Network (2007) acquired in digital format from GeoBase
Hydrography - 1:1M National Scale Frameworks Hydrology (2003) acquired in digital format from GeoGratis
Cities, towns, hamlets - 1:1M National Scale Frameworks Populated Places (2003) acquired in digital format from GeoGratis and 1:1M Base Features Settlement data (2006) acquired in digital format from AltaLIS
ATS grid - digitized from 1:250 000 CanMatrix digital topo maps (1991-1997) acquired from GeoGratis
Projection: Transverse Mercator (UTM Zone 12)
Datum: NAD83
Coordinate System: Universal Transverse Mercator (UTM)
GIS and cartography by the ALCES Group.
ALCES Group
Although there is no reason to believe there are any errors associated with the data used to generate this product or in the product itself, liability of the ALCES Group is limited to the purchase price of the service provided. Map not suitable for navigation.
2 June 2009

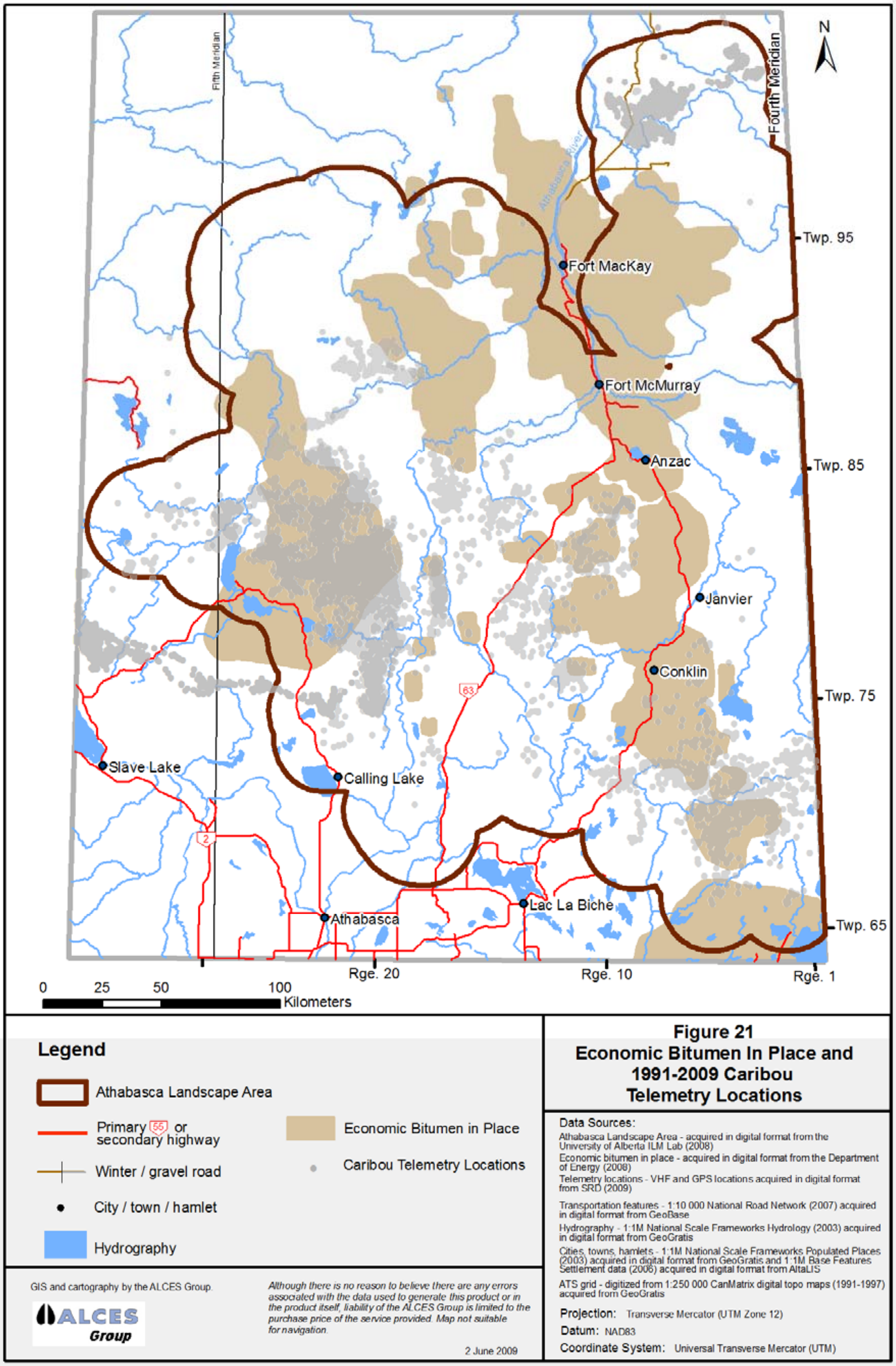


Figure 21
Economic Bitumen In Place and 1991-2009 Caribou Telemetry Locations

A key question for caribou management in the Athabasca Landscape area is the appropriate size of Zone 1 Areas. Given the ALT's mandate to provide recommendations for the recovery of all populations, the entire Athabasca Landscape area should be managed as a Zone 1 Area to minimize risk to caribou. The ALT acknowledges that this would require economic trade-offs with regional, provincial, and national implications. Because of this, the team considered options to more defensibly define the size of conservation areas. The question of minimum size could not be directly simulated with ALCES given the overriding influence of mortality on population persistence. However, results of Richardson, CLAWR, and ESAR-E simulations indicate that populations in these smaller planning areas (<11,000 km^2) were more sensitive to random natural processes and predation assumptions than were larger planning areas such as WSAR or ESAR. Schneider (2001) concluded that protected areas in the order of 5,000 km^2 were more likely to have a stable fire regime and habitat dynamics than areas less than 1,000 km^2.

A density-based extrapolation was also applied. Using the reported Alberta mean boreal caribou density of 3.3/100 km^2 (range 1.7 to 13.1; Thomas and Gray 2002), if a minimum population of 150 is desired within each planning area to maintain a medium extirpation risk (Table 2), the caribou habitat required in each Zone 1 Area would be 4,500 km^2 (range 1,145km^2 to 14,800 km^2). This extrapolation based on mean caribou density represents approximately 15% of ESAR and WSAR; 30% of ESAR-W; 40-50% of Richardson and CLAWR; and 67% of ESAR-E. Reduced or higher extirpation risk would be present if respectively, larger or smaller Zone 1 Areas are defined.

Based on these lines of evidence, Zone 1 Areas should be thousands of square kilometres in size to minimize risk of caribou extirpation over the next 50 years. The ALT recommends that further work be done to complete a more quantitative evaluation of candidate Zone 1 Areas based on the concepts of risk management and viable populations to understand the relationship between area and extirpation risk and to optimize the location and size of candidate areas.

The primary goal for delineating and implementing Zone 1 Areas is to ensure that there is an adequate land base of an appropriate size in which to restore and protect enough functional habitat to support and manage a viable caribou population(s). Selection of policy tools for implementing Zone 1 Areas should reflect this primary goal. Successful integration of Zone 1 Areas in the Athabasca Landscape area will be related to the legislative authority that the land management agency has over the lands in question. The ALT considered two existing land management options: Wildland Provincial Park and Forest Land Use Zone.

If the legal right to manage access, both to recreational users as well as industrial ones, along with the mandate to conserve and manage flora and fauna are required, then the Provincial Parks Act and accompanying regulations would appear to provide a useful option. The Provincial Parks Act would be particularly relevant if Zone 1 Areas were to be classified as Wildland Provincial Parks. This approach would align with the Alberta Biodiversity Strategy Implementation Plan, which has recommended that Alberta Parks become the lead agency to manage lands considered “high value conservation lands”.

A possible alternative to Wildland Provincial Parks is the designation of a Forest Land Use Zone (FLUZ), which is an area of public land to which legislative controls apply under authority of the Forests Act and Forest Recreation Regulation, to assist in the management of industrial, commercial and recreational land uses and resources. The Alberta Government has established limitations on recreational use in certain environmentally sensitive areas in the Province; these areas have been designated as forest land-use zones, under the authority of the Forests Act. FLUZs can be used to ‘protect areas containing sensitive resources such as wildlife and their habitats, vegetation, soils and watersheds as well as to separate or control conflicting recreational activities’ (ASRD 2008).

The ALT suggests that Wildland Provincial Park designation appears to be an appropriate legislated land management regime for Zone 1 areas. Further evaluation of existing and proposed legislation[2] and policy tools for Zone 1 Areas is recommended. Given the landscape-scale focus of this management option, it is most appropriately evaluated as part of the recently initiated Lower Athabasca Regional Planning process to ensure that the full suite of stakeholder views are acknowledged and considered.

5.2.1.2 Coordinated Reclamation

Athabasca Landscape area simulation results indicate that **coordinated reclamation should be the foundation of caribou habitat restoration in both Zones 1 and 2 in all planning areas because it has the greatest influence on functional habitat recovery**.

Comparative simulations from the ESAR planning area and ESAR-E and ESAR-W sub-planning areas demonstrate that the amount of existing and likely future footprint affects the projected influence of coordinated reclamation over the next five decades. Coordinated reclamation of seismic lines, pipelines, and temporary roads is the best habitat restoration lever in areas such as the overall ESAR planning area that have many corridors and large economic bitumen reserve volumes. In areas such as ESAR-E and ESAR-W, economic bitumen reserve volumes and existing footprint are lower, and forest harvest is the major influence on future footprint and the Habitat-Based Population Performance indicator (e.g., Figures 47 and 48 in Appendix 3 modeling report). Coordinated reclamation of linear corridors in ESAR-E was projected to have no measurable benefit at year fifty (Figure 51 in Appendix 3), because most existing corridors would have reclaimed naturally, and few new corridors have been constructed (based on Business as Usual assumptions). Nonetheless, in these sub-planning areas coordinated reclamation would restore functional habitat more quickly over the next one to two decades. Therefore, at the scale of both the Athabasca Landscape area and the four

[2] On April 27, 2009, the Alberta Government tabled Bill 36, the Alberta Land Stewardship Act (http://www.assembly.ab.ca/bills/2009/pdf/bill-036.pdf), which is intended to amend and align more than 25 existing laws and to support regional planning in the province through Alberta’s Land-use Framework. The proposed amendments provide administrative tools to enable the government to direct planning requirements and processes for the province, and facilitate the implementation of a cumulative effects approach for managing activities through regional land-use plans.

planning areas, coordinated reclamation is the most influential option to effectively restore caribou habitat.

Coordinated reclamation must aim to achieve the following four end points to be consistent with simulation assumptions.

1. Control undesirable / non-native vegetation along historical lines where it exists (e.g., grass and legume species that are palatable for deer and black bears).
2. Restore native vegetation compatible with adjacent areas (refer to Section 3.2.6 of CLMA and FPAC (2007) for summary on piloted techniques).
3. Impede predator / prey movement into peatland areas (i.e., blocking within upland/lowland transitional sites).
4. Impede human access into areas undergoing recovery treatment.

5.2.1.3 Best Practices

ALT evaluations reveal that best practices to minimize the incremental area and duration of future footprints have real, but lower magnitude benefits for habitat restoration than coordinated reclamation or future footprint reduction. Simulations in each planning area determined that the most influential best practices are:

- increasing the overlap between new footprints and existing footprints;
- reducing the lifespan of delineation well access trails through minimum ground disturbance and rapid reforestation; and
- decreasing the total amount of all-weather road access to in-situ production pads by increasing the number of production wells per pad.

Simulations indicate that appropriate best practices will need to be implemented throughout the Athabasca Landscape area (both Zones 1 and 2) to minimize risk of caribou extirpation in the next fifty years.

5.2.2 Caribou Mortality Management

ALCES simulations suggest that wolf abundance will continue to increase in all planning areas as deer and moose populations expand on land-use footprints and young forest. This will increase incidental predation on caribou. Given actual monitored declines of caribou populations and modeling results, **immediate mortality management (wolf and other prey control or cow-calf penning) is needed to prevent caribou extirpation within two to four decades while habitat function is being restored.**

Ongoing mortality management will be required until sometime after: 1) net development footprint begins to decline; 2) functional habitat is recovered in an area of sufficient size to sustain a viable caribou population; and 3) spatial separation of wolves and caribou is restored. There is considerable uncertainty regarding condition number 3. Modeling simulations suggest that functional habitat recovery may not be sufficient to restore spatial separation of wolves and caribou. In all future simulations deer populations grew well above current densities regardless of whether they used lowland caribou habitat or were restricted to upland habitats. Long-term research will be required to confirm whether functional caribou habitat can be restored when deer are present.

5.2.2.1 Wolf Control

Compared to control of other prey species and cow penning, ongoing wolf control was identified through simulation modeling as the most effective caribou mortality reduction strategy in all planning areas. High control rates (generally >67% of wolves present) applied annually appear to be needed, but this simulation result was also dependent on assumptions about the immigration rate of wolves in to the area. Evidence from other wolf control programs suggests that a control rate approaching 67% will be at or near the practically achievable level (T. Powell pers. comm.), and actual results will depend on the number of wolves that move into the control area prior to the next control effort.

A key concern of ALT members is that continuous social license and political support for wolf control as a viable management option is unlikely over a 50 to 100 year period (National Research Council 1997). Because of ongoing wolf immigration and increased populations of other prey species, continuous control will be needed and interruption for social/political reasons is likely to cause a numerical increase in wolf abundance that will jeopardize long term success. Figure 22 compares two simulations of caribou abundance in the Richardson planning area with 67% annual wolf control; the blue line represents caribou trend under ongoing wolf control and the red line represents caribou abundance after wolf control is stopped at year 30.

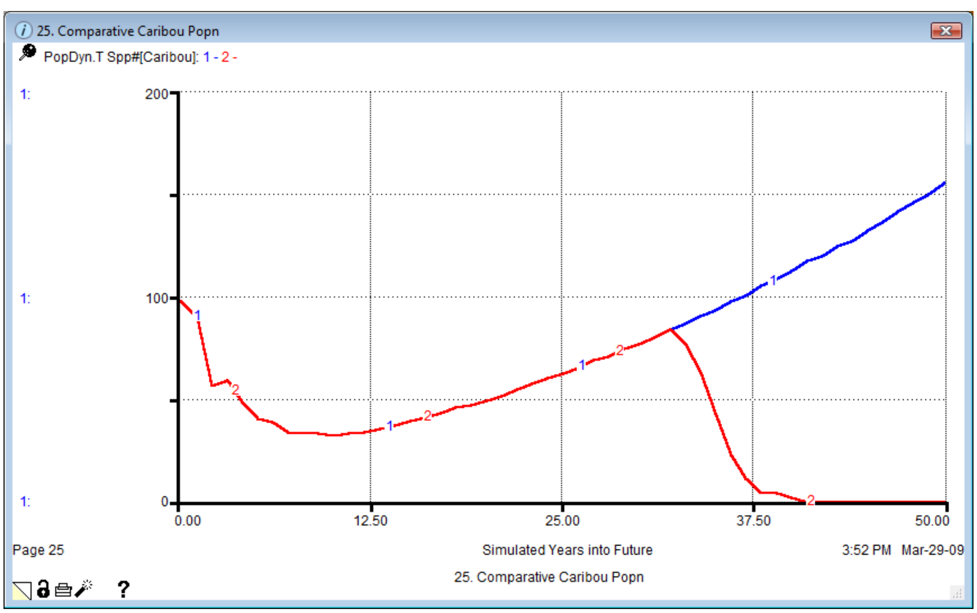


Figure 22. Effect of stopping wolf control on caribou population size. Red line shows wolf control stopped at year 30. Blue line shows continuous wolf control.

Non-lethal methods of wolf control such as surgical sterilization (i.e., fertility control) of dominant breeding pairs combined with removal of subordinate animals in targeted packs has been implemented in interior Alaska and southern Yukon as a means of reducing and maintaining low wolf densities in a specific area and to improve survival of caribou (ADF&G 2007). Dominant pairs of sterile wolves had smaller territories, generally lived longer than non-sterile wolves, retained territories for several years and did not readily accept other wolves into their territories, thus maintaining relatively low wolf densities in a targeted area (Boertje et al. 2008). However, the ALT considered that this non-lethal approach to wolf control is unlikely to be successful in the boreal forest where pack structure can be seasonally dynamic (Culling et al. 2006; Latham 2009) and therefore dominant animals are less likely to defend their territories from new migrants.

5.2.2.2 Cow-calf Penning and Exclosures

Cow-calf penning is only a realistic management option in small planning areas such as Richardson and ESAR – E where most females can be captured. This option would also need to be applied annually for 50+ years. This management option has been previously applied to only two populations, Chisana population in east central Alaska and southwest Yukon (Yukon Government 2009) and Little Smoky population in west central Alberta (Smith and Pittaway 2008); and there is evidence that continuous social support for this management option is unlikely over a 50 to 100 year period. Managers are also concerned about cumulative stress on individual animals (T. Jung, pers. comm.).

A speculative alternative discussed by the ALT was constructing and maintaining a barrier to impede deer and predator movement into the areas where densities are currently low. The Richardson planning area would be the most appropriate area to test the viability of this mortality management approach.

5.2.3 Successful Management Options

ALCES simulations demonstrated that **simultaneous habitat restoration and mortality management are required in Zones 1 and 2 to recover and maintain caribou in the Athabasca Landscape area.** This is depicted graphically in Figure 23. As described in Section 4 for WSAR and Richardson examples, Habitat-Based Population Potential in all planning areas is forecast to decline to levels well below 1 over the next 50 years and caribou are unlikely to persist at sustainable numbers for more than two to four decades (Business as Usual oval in Figure 23). Under natural conditions, Habitat-Based Population Potential should be near 1, and caribou would persist for 50 years; this is assumed to define success ('natural' oval in upper right-hand portion of Figure 23).

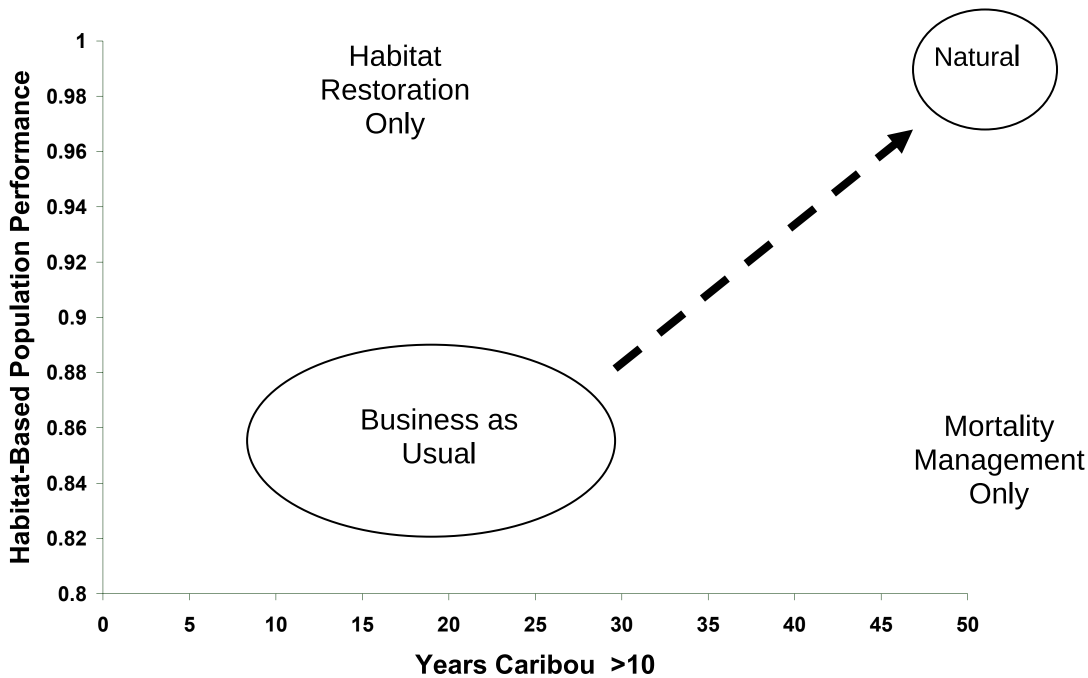


Figure 23. Successful caribou management options must include both mortality management and habitat restoration.

Habitat restoration on its own will not achieve success, because unmanaged predation will cause ongoing decline in caribou numbers. Similarly, mortality management will help caribou persist, but will have to be continued forever if functional habitat is not restored to a condition where caribou can reduce their risk to predation by avoiding wolves in the landscape. As depicted in Figure 23, these two management options must be applied together. For simulations in this report, successful management options were defined as those where caribou persisted for the entire 50 year simulation period with stable to increasing population size and where Habitat-Based Population Performance (defined by Boutin and Arienti (2008) in the ACC2 equation, see Appendix 2) was restored to 1 in 50 years.

Simulations identified several successful combinations of management levers that are common to all planning areas, although some details differ between areas. Table 5 provides a summary of the management options that would maintain or increase current caribou population abundance and distribution in each Athabasca Landscape planning area.

Table 5. Summary of successful management options and considerations for each Athabasca Landscape area caribou planning area.

Planning Area	Current Risk Rating[1]	Management Option: Habitat Restoration – Establish Zone 1 Area	Management Option: Habitat Restoration – Coordinated Reclamation	Management Option: Habitat Restoration – Best Practices	Management Option: Mortality Management – Wolf Control	Management Option: Mortality Management – Other Prey Control	Management Option: Mortality Management – Cow-Calf Penning	Considerations
West Side Athabasca River (WSAR)	**Med**	√	√	√	√	√		WSAR planning area has the greatest number of long-term management options and highest probability of success if habitat restoration and mortality control are implemented concurrently. Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Candidate Zone 1 Areas in north-central part of range connected to Birch Mountains Wildland Park and south-central part of range where caribou telemetry locations are concentrated.
Richardson	**High**	√	√	√	√	√	√	Updated information from winter 2008/2009 field studies indicates that wolf densities are lower than estimated and caribou calf recruitment is higher than projected. Habitat restoration is essential for long-term persistence; mortality management likely required for short-term persistence. Candidate Zone 1 Area northeast of Firebag River adjoining Marguerite River Wildland Park. Land-use and wildlife management in Saskatchewan will influence future conditions.
East Side Athabasca River (ESAR)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Management options were identified for each ESAR planning area; see below (ESAR – West; ESAR – East; ESAR – Bitumen Fairway).
East Side Athabasca River – West (ESAR – W)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Coordinated reclamation and best practices had less benefit for caribou habitat restoration than in the entire ESAR, because there is substantially less bitumen in ESAR-W. Candidate Zone 1 Area in northwest part of range incorporating areas of high caribou use between bitumen fairway and Athabasca River.

[1] From Athabasca Landscape Team Current Assessment (2008). **Planning Area**	**Current Risk Rating[1]**	Management Option						**Considerations**
		Habitat Restoration			Mortality Management			
		Establish Zone 1 Area	Coordinated Reclamation	Best Practices	Wolf Control	Other Prey Control	Cow-Calf Penning	
West Side Athabasca River (WSAR)	**Med**	√	√	√	√	√		WSAR planning area has the greatest number of long-term management options and highest probability of success if habitat restoration and mortality control are implemented concurrently. Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Candidate Zone 1 Areas in north-central part of planning area connected to Birch Mountains Wildland Park and south-central part of area where historical caribou telemetry locations are concentrated.
Richardson	**High**	√	√	√	√	√	√	Updated information from winter 2008/2009 field studies indicates that wolf densities are lower than estimated and caribou calf recruitment is higher than projected. Habitat restoration is essential for long-term persistence; mortality management likely required for short-term persistence. Candidate Zone 1 Area northeast of Firebag River adjoining Marguerite River Wildland Park. Land-use and wildlife management in Saskatchewan will influence future conditions.
East Side Athabasca River (ESAR)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Management options were identified for each ESAR sub-planning area; see below (ESAR – West; ESAR – East; ESAR – Bitumen Fairway).
East Side Athabasca River – West (ESAR – W)	**High**	√	√	√	√	√		Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. Coordinated reclamation and best practices had less benefit for caribou habitat restoration than in the entire ESAR, because there is substantially less bitumen in ESAR-W. Candidate Zone 1 Area in northwest part of planning area incorporating areas of high caribou use between bitumen fairway and Athabasca River.

[1] From Athabasca Landscape Team Current Assessment (2008).

Table 5. Summary of successful management options and considerations for each Athabasca Landscape area caribou planning area (cont.).

Planning Area	Current Risk Rating[1]	Management Option						Considerations
		Habitat Restoration			Mortality Management			
		Establish Zone 1 Area	Coordinated Reclamation	Best Practices	Wolf Control	Other Prey Control	Cow-Calf Penning	
East Side Athabasca River – East (ESAR – E)	**Med**	√	√	√	√	√		Information from winter 2008/2009 field studies indicates that caribou densities are lower than estimated and predator/other prey densities are higher than estimated. Habitat restoration is essential for long-term persistence; >50 year mortality management is essential for short-term persistence. ESAR-E has the least amount of footprint associated with in-situ bitumen development; simulations showed no relative benefit of coordinated reclamation and best practices over BAU assumptions. The most important driver of young forest in this range area was forestry. Candidate Zone 1 Area east of Christina River in Gipsy Lake Wildland Park area, but further assessment of habitat quality and use by caribou is recommended Option to combine management with CLAWR to increase population size.
ESAR – Bitumen Fairway	**High**			√				Bitumen Fairway has low probability of caribou persistence. Likely future development footprint in Bitumen Fairway forecast to be too high to maintain caribou without footprint restrictions and >100 yr ongoing mortality management.
Cold Lake Air Weapons Range (CLAWR)	**High**	√	√	√	√	√		CLAWR has low probability of caribou persistence. Only option for CLAWR persistence without >100 yr ongoing wolf control is no future development footprint and entire range as Zone 1 Area. Management options limited by access restrictions on air weapons range. Land-use and wildlife management in Saskatchewan will influence future conditions. Initiate discussions with DND and Saskatchewan.

[1] From Athabasca Landscape Team Current Assessment (2008).

Simulations and risk ratings demonstrate that larger or more intact planning areas such as WSAR and Richardson have more management options than do smaller or less intact areas such as ESAR – BF and CLAWR. To achieve provincial caribou recovery goals and the ALT boreal caribou management objective and offset current declines of woodland caribou populations in the Athabasca Landscape area, all planning areas should receive protection through designation and implementation of Zone 1 Areas. Indeed for small planning areas with high relatively high industrial land used and anthropogenic footprint like CLAWR, the entire range or planning area should be considered as a Zone 1 Area in order to ensure persistence of caribou. However, if political considerations preclude this approach, the ALT recommends that priority for establishing conservation areas should be in planning areas with greater chance of success for population recovery (i.e., the order listed in Table 5 above).

Immediate mortality management will be required in all planning areas to ensure caribou persistence until functional habitat is restored. **The ALT suggests that the magnitude and duration of mortality management required (particularly wolf control and cow-calf penning) is unlikely to obtain social and political support without concomitant effort to address habitat requirements, i.e., Zone 1 Areas and coordinated reclamation.**

Future footprint reduction and coordinated reclamation are the habitat restoration levers with greatest incremental benefit (Figures 10, 11, 15, 16). The long-term benefit of these measures will be greatest if they can be focused on areas with comparatively high value for caribou. The ALT has concluded that the lowest risk strategy to achieve provincial recovery plan objectives would be to define large Zone 1 Areas (thousands of square kilometers) where combined footprint is actively restored or restricted to very low levels that do not impair habitat function. Given current and projected land-use patterns, this low risk approach can be applied only in portions of WSAR, Richardson, and ESAR planning areas unless future development trajectories are substantially reduced.

Figure 24 provides a simplified schematic of combined management options that will be required to recover and sustain caribou in the Athabasca Landscape area.

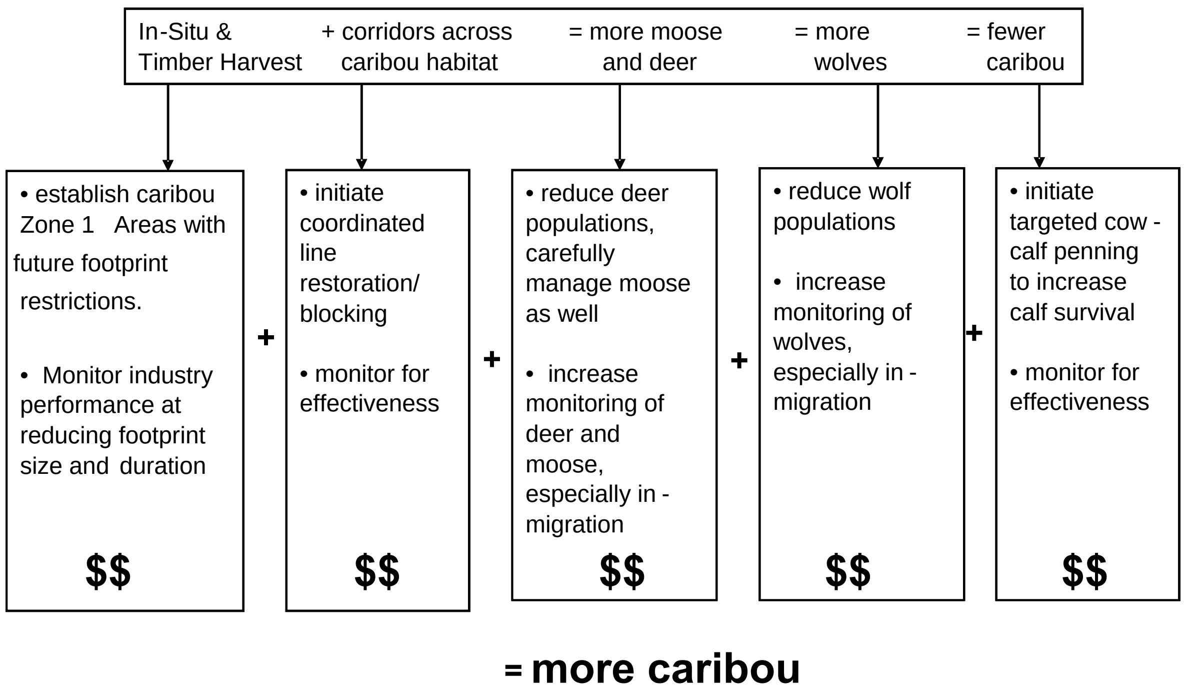


Figure 24. Simplified schematic and rationale behind management options to increase caribou. The top horizontal bar represents the concept that industrial land-uses such as in-situ bitumen development and forest harvesting are important drivers that increase the number of linear features and young forest in caribou habitat. These two factors also improve habitat conditions for other prey species which in turn supports higher numbers of wolves which leads to fewer caribou. The five columns below shows examples of combined management options and monitoring activities that would be used to reduce industrial land-uses and to improve conditions for each of the subsequent indicators, and to ultimately increase caribou numbers.

5.3 RESEARCH AND MONITORING

Several of the proposed management options are based on impact hypotheses that will be influenced by actual (as opposed to modeled) conditions when implemented. For example, actual wolf immigration rates will need to be assessed to evaluate and predict effectiveness of wolf control measures. Consequently, the ALT proposes the following points for consideration by the ACC Governance Board and ACC Research and Monitoring Subcommittee:

- A key uncertainty is future deer and wolf response in restored habitat areas and whether spatial separation between caribou and wolves can be restored when deer are present. Climate change has been suggested as another potential influence affecting deer expansion (Thompson et al. 1998) and predator-prey dynamics (Bergerud et al. 2008). A research and monitoring program should be developed and implemented by ACCRMS to define cause-effect pathways as candidate hypotheses which can subsequently be modeled and tested through adaptive management and monitoring.
- Concurrent with taking management action, predator and other prey density should be monitored prior to, during, and following mortality management in all areas where it is conducted and results should be incorporated in subsequent program design by the ACCRMS.
- Caribou population dynamics (age structure, maternal condition, survival, recruitment) should be monitored continuously in all planning areas, with particular emphasis on candidate or defined Zone 1 Areas, and areas with no or limited existing data (i.e., north portion of West Side Athabasca River; Richardson, east side of ESAR).
- Consider a rigorous adaptive management approach testing different management options / conservation area sizes / management treatments in different planning areas.
- Consolidate and analyze existing project-specific baseline and regional wildlife monitoring data to generate better estimates of predator and prey density. Require the use of consistent data collection and monitoring protocols for site-specific monitoring where appropriate. Maximize the use of project-specific monitoring programs through submission of geospatially-referenced data to a centralized group.
- The Richardson planning area is concluded to be the most suitable area to evaluate the viability of cow-calf penning and predator / prey exclosures.

6. IMPLEMENTATION

The suite of successful management levers evaluated by the ALT provides new landscape-scale strategies to sustain caribou. In particular, candidate Zone 1 Areas are seen as the nucleus of management efforts to maintain caribou populations in the Athabasca Landscape Area. Key challenges identified by the ALT include:

- establishing legislated boundaries for Zone 1 Areas;
- conducting landscape-scale reclamation programs coordinated among multiple stakeholders;
- aggregating decisions for landscape-scale caribou management that are made by individual government departments into a broader integrated cross-government strategy;
- consultation and engagement of stakeholders who would be affected by the recommended management options contained in this report; and
- building awareness of decision-makers, land users, and the general public to maintain social and financial support for required management actions, research, and monitoring over the long term.

The current Lower Athabasca Regional Planning initiative under the Alberta Land-Use Framework (www.landuse.alberta.ca) appears to be an appropriate forum to address these challenges.

Management strategies identified by the ALT will require further leadership and work by the ACC Governance Board and others to identify solutions to the policy challenges that were introduced in Section 2 and to develop clear implementation rules and processes. **The ALT strongly proposes the following measures for consideration by the ACC Governance Board.**

- Management action is needed NOW. This will require a plan to marshal substantial resources and make difficult trade-offs between competing land uses.
- Implementation of mortality management and coordinated reclamation should begin immediately to reduce risk of caribou extirpation within the next two to four decades.
- Further work will be required to design optimum predator and other prey control programs. Alternative approaches should be rigorously evaluated in different planning areas or at different times, where feasible.
- The social and economic implications of caribou management options should be evaluated as part of the Lower Athabasca Regional Planning initiative. Potentially affected stakeholders should be given the opportunity to participate and comment on this evaluation.
- The advantages and disadvantages of the candidate Zone 1 Areas and any other areas identified by the Governance Board should be evaluated as part of the Lower Athabasca Regional Planning initiative. Wildland Provincial Park status appears to

be an appropriate legislative authority for Zone 1 Areas because it would allow the entire suite of management options; including restricting motorized recreational access, and allows for surface footprint to be managed. A formal evaluation of the advantages and disadvantages of this and other existing and proposed regulatory options (e.g., Forest Land Use Zones and proposed Alberta Land Stewardship Act) should be undertaken as part of the Lower Athabasca Regional Planning initiative.

- A more quantitative evaluation of candidate Zone 1 Areas based on the concepts of risk management and viable populations should be undertaken to understand the relationship between area and extirpation risk and to optimize the location and size of candidate areas.
- The merits of legislated access control, in addition to physical access control, should be evaluated both within and outside Zone 1 Areas.
- A provincial action plan to reclaim industrial footprints within the Lower Athabasca Regional Plan should be developed. This plan would need to address the policy and government 'silo' issues identified within Section 2 and be consistent with the proposed Alberta Land Stewardship Act. For example, human access will need to be prevented into areas that are being reclaimed. This plan will also need to address how to deal with specific land-use dispositions (e.g., oilsand exploration cutlines without a Licence of Occupation). The ALT suggests that the Lower Athabasca Regional Planning initiative look to other jurisdictions working to build an implementation plan (e.g., the Foothills Landscape Management Forum that is currently developing an implementation plan in west central Alberta; W. Thorp pers. comm.)[3].
- Create a Coordinated Reclamation Organization to deliver the reclamation program. This organization would be solely responsible for an initial natural recovery inventory and mapping, planning, implementation, method development, monitoring and tracking spatial and temporal success of coordinated reclamation as a management lever. An initial milestone would be the completion of a linear feature natural recovery inventory within the candidate Caribou Conservation Areas identified by the ALT. The Coordinated Reclamation Organization should work with the RMS to develop a rigorous research and monitoring program to document revegetation success (CRRP 2006) and wildlife use (e.g., Golder 2009).
- A pre-defined provincially regulated conservation offset approach (Dyer et al. 2008; also referenced in the proposed Alberta Land Stewardship Act) should be applied and evaluated as part of the Lower Athabasca Regional Planning initiative. For example, offsets would be triggered through new development applications and directed into the priority intactness areas through the established organization (examples include 4 to 1 no net loss wetlands policy, and a 2:1 no net loss policy on a National Energy Board pipeline). This should include regional restoration banking and protocols for linking project-specific mitigation with coordinated planning area reclamation programs.

[3] Wayne Thorp, Managing Director of Foothills Landscape Management Forum. Personal Communication with Paula Bentham (Senior Biologist, Golder Associates) on April 9, 2009.

- Given the value of reclamation and the lag time required for restoration of functional caribou habitat, individual companies should be encouraged to implement reclamation within their lease areas immediately, if they have not already started. Wherever possible, individual companies should encourage regrowth of native vegetation on existing used footprints such as pipeline rights-of-way.
- Reclamation requirements should become directly tied to all linear and polygonal land-use dispositions approved within the Athabasca Landscape area (designated caribou ranges plus the 20 km buffer defined by the ACCGB).
- The primary focus for coordinated reclamation in the short-term should be within Zone 1 Areas, ideally within 3 to 4 years. To meet this timeline, natural recovery inventory and execution plans should be developed in year 1 (e.g., seedlings ordered, access into remote areas determined, hiring of subcontractors, coordination with land users) to allow program execution in years 2 and 3.
- The benefits of footprint re-use must be considered on a project-by-project basis relative to long-term functional habitat restoration. Spatial and temporal intactness areas should be considered prior to approving re-use of development footprints.

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Appendix 1

Athabasca Caribou Landscape Team Members

Athabasca Landscape Team (ALT)

Members

Role	Name	Agency / Organization
Team Lead and Modeling Lead	Terry Antoniuk	ALCES Group
Technical Expert (mitigation / reclamation)	Paula Bentham	Canadian Association of Petroleum Producers (Golder Associates)
Technical Expert (forest development)	Dave Cheyne	Alberta-Pacific Forest Industries
Project Manager	Melanie Duhaime	Sierra Systems
Technical Expert (energy development)	Peter Koning	Canadian Association of Petroleum Producers (Conoco-Phillips)
Technical Expert (caribou & wildlife biology)	Todd Powell	Alberta Sustainable Resource Development, Fish and Wildlife Division
Technical Expert (parks and protected areas)	Rick Schneider	Integrated Landscape Management Lab, University of Alberta

Advisors

Role	Name	Agency/Organization
Technical Expert (caribou biology)	Nicole McCutchen	Alberta Caribou Committee – Research and Monitoring Subcommittee
Technical Support (modeling) and alternate to Team Lead	John Nishi	ALCES Group
Technical Expert (parks and protected areas)	Norbert Raffael	Alberta Tourism, Parks and Recreation
Technical Expert (energy development)	Kevin Williams	Alberta Department of Energy
Technical Expert (energy development)	J. Bob Nichols	Consultant to Alberta Department of Energy

APPENDIX 2

ACC2 Equation Methodology
(Boutin and Arienti 2008)

BCC equation reanalysis – Final Report

Stan Boutin
Cecilia Arienti
November 26, 2008

Key Recommendation

Given the current data available:

Lambda = 1.0184 - 0.0234 * Linear feature density - 0.0021 * % Young habitat (<30 years old, Burn plus Cut)

provides a reasonable description of the relationship between caribou population growth and two factors (linear features and young habitat). We add the following additional comments:

1. ***Our certainly about the numerical values of the actual coefficients is not high given the sample size but we have reasonable certainty that the effects are negative.***
2. ***The model can be incorporated into land use models such as ALCES to capture the relationship between linear feature density, young habitat, and population growth of caribou populations.***
3. ***The model should not be used to establish targets of activity to achieve stable caribou population growth.***
4. ***This analysis does not directly test causation.***

Our final report consists of two components: the text provided below and an Excel file containing three worksheets:

1. Original data-contains all of the data for each herd for every variable considered in the analysis.
2. Pearson's correlations-contains a cross-correlation table. Coloured values represent correlations greater than 0.7 (Values of 0.7 or higher should not be included in the same statistical model).
3. Model analysis- contains the AIC comparisons for the models considered in the model selection analysis..

This document contains a detailed description of the methods used to calculate the dependent and independent variables plus the step-by-step process we followed to perform the analyses. The main points are captured as 9 Key Outcomes and they are listed in bold. These outcomes can serve as an executive summary but Outcome #9 captures the major conclusion.

The objectives were:

1. To examine potential statistical relationships between woodland caribou population performance (calf survival as measured by calf/cow ratios, adult female survival, lambda) and various disturbance variables (fires and human-caused). Selected variables are meant to assess the proposed relationship between human activities and the creation of primary prey habitat (young forest) and improved predator access (linear features).
2. To determine if there was statistical support for a model that could be incorporated into ALCES.

Herds included in the analyses

1- WSAR
2- ESAR
3- Cold Lake Air weapons range Alberta side
4- Chinchaga
5- Red Earth
6- Caribou Mountains
7- Little Smoky
8- Slave Lake
9- Red Rock Prairie Creek
10- A La Peche

Methods

The range shapefiles used for each herd were obtained from the ACC website. These were combined into 1 shapefile. A 20 km buffer was applied to each range as well, and all the buffered ranges were combined into 1 shapefile. Some of the buffered ranges crossed over to Saskatchewan and BC. In order to avoid this and because we did not have any data for either of these provinces, the buffered ranges were clipped to the boundary of Alberta.

All explanatory variables described below were calculated at the range and (range + 20 km buffer) levels.

Dependent Variables

The dependent variables used in this analysis are:

1- Calf recruitment as measured by Calves/100 Adult Females in Feb or March
2- Adult female survival May through April
3- Annual lambda

For each herd, the geometrical mean and geometrical variance for each of these population parameters were determined using the methods in McLoughlin et al. (2003) over the period 1993-2006. For the Little Smoky herd, geometrical mean and variance were calculated over the period 1993-2005, discarding the population data from years after wolf control and calf penning were implemented.

Explanatory variables

The Base Features 2006 dataset was used as a source for all linear feature information. This dataset comes organized into individual NTS sheets, so each of the sheets overlapping the study area ranges were merged together.

1- Linear feature density: Road, Pipeline and Seismic line polyline shapefiles were intersected with the range and buffered range in order to obtain the total length, in km, of each type of linear feature per range or buffered range. The total length was then divided by the area of the range or buffered range, in km^2, to obtain densities of roads, pipelines and seismic lines in km/km^2. These were also summed to provide the total density of all linear features.

2- Linear feature area (ha): The Road, Pipeline and Seismic line polyline shapefiles were used to recreate the actual, on the ground, area of each feature. Pipelines widths were 15 m to each side of the line, with flat ends, and then completely dissolved in order to remove any overlaps. Seismic line widths were 2.5 m to each side of the line, with flat ends, and then completely dissolved in order to remove any overlaps. Road widths were given a variety of sizes (Table 1), with flat ends, and then completely dissolved in order to remove any overlaps.

Table 1: Buffer sizes applied to each type of road.

Road Type	Width (to one side)	Total width size
Truck trail	5 m	10 m
Ford winter crossing	5 m	10 m
Road unclassified	10 m	20 m
Road unimproved	10 m	20 m
Road winter road	10 m	20 m
Interchange ramp	15 m	30 m
Road Gravel 1 lane	15 m	30 m
Road Gravel 2 lanes	15 m	30 m
Road paved divided	15 m	30 m
Road paved undivided 1 lane	15 m	30 m
Road paved undivided 2 lanes	15 m	30 m

Each linear feature type was intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, of each type of linear feature. These were also summed to provide the total area of all linear features.

3- Linear feature area (ha) + zone of influence: The Road, Pipeline and Seismic line polygonal shapefiles described above (where each polyline was buffered to represent their actual on-the-ground area) were each buffered by applying a 25 m buffer to each side (50 m buffer in total), with flat ends, and then completely dissolved in order to remove any overlaps. Buffer sizes of 100 m (50 m to each side) and 200 m (100 m to each side) were also applied. These three buffered polygons represent the total zone of influence of each linear feature type. Once buffered, each linear feature type was intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, of each type of linear features plus its zone of influence.

4- Young Burns: Fire polygons were obtained from the provincial fire database. All fires that occurred between 01/01/1976 and 01/01/2006 were included in the analysis (i.e. fires less than 30 yrs old). Polygons with burncode = I (unburnt islands) were discarded, however, polygons with burncode = PB (partial burns) were retained. All fire polygons were dissolved together in order to remove any overlap. The fire shapefile was then intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, and the percent area of burns less than 30 yrs old.

Note: Sorensen et al. (2008) only included class E fires in their analysis; however, we included all classes of fires.

5- Young Cutblocks: Because we couldn't get Cutblock shapefiles for all of the ranges, we had to fall back and use tabular data (from ARIS database, provided by the SRD Forest Branch) containing information of forestry cutblocks (area and harvesting date among other things) that were harvested between 01/01/1976 to 01/01/2006. Many of the cutblock records in the tabular database had information on the township, range, meridian and section (TTRRMMSS) in which the cutblock is located; however, some of the records only had information on township, range, meridian (TTRRMM) so this was the only spatial reference that could be used. Each TTRRMMSS and TTRRMM was intersected with the range and buffered range shapefiles, and the proportion of each one of these cells falling within each range/buffered range was calculated. Once this was known, each cutblock was matched to a range or buffered range based on the TTRRMMSS or TTRRMM where it is located. For those TTRRMMSS/TTRRMM that fell only partially within a certain range or buffered range, the known area of the cutblock was multiplied by the proportion of the corresponding TTRRMMSS or TTRRMM that fell within the range or buffered range. We did this to avoid counting the totality of a large cutblock for a certain range if only part of the corresponding TTRRMMSS/TTRRMM fell within the range/buffered range. Once each cutblock was matched to a range/buffered range and its area within the range/buffered range proportionally adjusted, we added them in order to obtain the total area as well as the percent area of cutblocks less than 30 yrs old.

6- Well sites: We used well point shapefiles from the IHS dataset. From this shapefile, we selected all wells that had a SPUD date < 01/01/06 (86,175 wells). There were some records that didn't have SPUD date information (2,087 records). From these, we discarded 1367 wells that had STATUS Date > 31/12/05 and STATUS = NEW LICENSE, because it was assumed that those wells would have been constructed well into the year 2006. The remaining wells were given a 1 ha square area, and then completely dissolved in order to remove any overlaps. The well shapefile was intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, of wells.

7- Well sites (ha) + zone of influence: The well site polygonal shapefile described above (where each well point was buffered to represent their actual on-the-ground area) was buffered by applying a 50 m buffer around each well site, and then completely dissolved in order to remove any overlaps. These buffered polygons represent the total zone of influence of each well site. Once buffered, the well site shapefile was intersected with the range and buffered range shapefiles in order to obtain the total area, in ha, of wells plus their zone of influence.

8- Proportion of range <30 yrs old: This variable was calculated by adding the area of young burns and young cutblocks and then dividing this by the total area of the range or the buffered range. Additionally, we calculated the proportion of the range or buffered range that has been disturbed; this variable included the area of young burns, young cutblocks, well sites (1 ha each), roads (widths as outlined in Table 1) pipelines (30m width) and seismic lines (5m width).

Statistical Analysis

We calculated the Pearson correlation coefficient for each pair of independent variables, at the range and buffered range levels.

To conduct regression analysis, we followed the methods used by Sorensen et al. (2008) and used a weighted least squares linear regression. The inverse of the geometric variance for each of the three dependent variables for each herd was used to weight the data. Because of the low sample size (n = 10) and the large number of dependent variables, we were only able to fit univariate models. Models were compared using small sample AIC (AICc).

Results

Table 2: Population parameters for 10 herds calculated over the period 1993-2006.

HERD	Calves/100 Adult Females in February or March		Adult Female Survival May through April		Annual Lambda		Number of years monitored
	Geometric Mean	s^2	Geometric Mean	s^2	Geometric Mean	s^2	
WSAR	22.0	1.674	87.6	1.118	0.975	1.147	13
ESAR	16.4	2.243	86.6	1.131	0.945	1.170	12
Red Earth	15.0	2.645	84.8	1.245	0.922	1.286	11
Caribou Mtn.	13.5	2.336	83.5	1.287	0.898	1.299	11
CLAWR	11.8	2.433	87.7	1.207	0.933	1.210	7
Chinchaga	16.3	2.363	86.6	1.210	0.926	1.211	4
Slave Lake	23.9	6.720	90.1	1.165	1.012	1.108	3
Little Smoky	10.6	2.467	85.9	1.125	0.908	1.163	6
Red Rock	21.7	2.706	86.1	1.361	0.960	1.413	8
A La Peche	21.3	2.844	91.6	1.107	1.023	1.091	8

Variable Definitions: **A number of variables are expressed as % of the range or as proportion of the range. Any variable expressed as % of the range can be converted to proportion of the range by dividing by 100 and vice versa.**

Code	Description
TAREAhaH	Area, in ha, of the caribou range
RoDensH	Road density, in km/km2, per caribou range
PiDensH	Pipeline density, in km/km2, per caribou range
SeDensH	Seismic density, in km/km2, per caribou range
LFdensH	Linear Feature density (roads+pipelines+seismic lines) in km/km2
RoHAH	Area of roads (in hectares)
PiHAH	Area of pipelines (in hectares)
SeHAH	Area of seismic lines (in hectares)
LFHAH	Linear feature area (road area+pipeline area+seismic area), in hectares
RoHAPH	Percent area of roads
PiHAPH	Percent area of pipelines (in hectares)
SeHAPH	Percent area of seismic lines (in hectares)
Ro50mBH	Area of roads + 50 m buffer (in hectares)
Pi50mBH	Area of pipelines + 50 m buffer (in hectares)
Se50mBH	Area of seismic lines + 50 m buffer (in hectares)
Ro50mBPH	Percent area of roads + 50 m buffer (in hectares)
Pi50mBPH	Percent area of pipelines + 50 m buffer (in hectares)
Se50mBPH	Percent area of seismic lines + 50 m buffer (in hectares)
Ro100mBH	Area of roads + 100 m buffer (in hectares)
Pi100mBH	Area of pipelines + 100 m buffer (in hectares)
Se100mBH	Area of seismic lines + 100 m buffer (in hectares)
Ro100mBPH	Percent area of roads + 100 m buffer (in hectares)
Pi100mBPH	Percent area of pipelines + 100 m buffer (in hectares)
Se100mBPH	Percent area of seismic lines + 100 m buffer

Ro200mBH	Area of roads + 200 m buffer
Pi200mBH	Area of pipelines + 200 m buffer
Se200mBH	Area of seismic lines + 200 m buffer
Ro200mBPH	Percent area of roads + 200 m buffer
Pi200mBPH	Percent area of pipelines + 200 m buffer
Se200mBPH	Percent area of seismic lines + 200 m buffer
FireHAH	Area of burns (<30 yrs old
FirePERH	% of burns (<30 yrs old)
CCsHAH	Area of CCs (<30 yrs old)
CCsPERH	% of CCs (<30 yrs old)
CCswoWFHAH	Area of CCs
CCswoWFPERH	% of CCs within each caribou range
WeHAH	Area of wells
We50mBH	Area of wells + 50 m buffer
PYngHabH	Proportion of range in young habitat (CCs+ burns) / Total area
PYngHabALLH	Proportion of range in young habitat (CCs, burns, wells, roads, pipelines,seismic lines) / Total area

All subsequent variables as above but calculated for the range plus 20 km buffer
TAREAhaB
RoDensB
PiDensB
SeDensB
LFdensB
RoHAB
PiHAB
SeHAB
LFHAB
RoHAPB
PiHAPB
SeHAPB
Ro50mBB
Pi50mBB
Se50mBB
Ro50mBPB
Pi50mBPB
Se50mBPB
Ro100mBB
Pi100mBB
Se100mBB
Ro100mBPB
Pi100mBPB
Se100mBPB
Ro200mBB
Pi200mBB
Se200mBB
Ro200mBPB
Pi200mBPB
Se200mBPB
FireHAB
FirePERB

CCsHAB
CCsPERB
CCswoWFHAB
CCswoWFPERB
WeHABB
We50mBB
PYngHabB
PYngHabALLB

Independent Variable reduction due to correlation

Given that we produced roughly 90 different variables (see above) it was necessary to reduce this number down to a manageable level. This was done on the basis of a high degree of correlation between certain variables and our interest in linear features, cutblocks, burns, and overall young habitat.

Key Outcome #1. Linear feature density and the % of range within buffers are highly correlated.

1.1 The Pearson correlation table (excel file) shows that seismic density is very highly correlated with overall linear feature density.
1.2 Further, buffering of various features to produce a proportion of the range within a buffer (100 m of seismic for example) was highly correlated with the linear feature density. An example of this appears in Fig. 1 but the same holds for any linear feature and any buffer width.

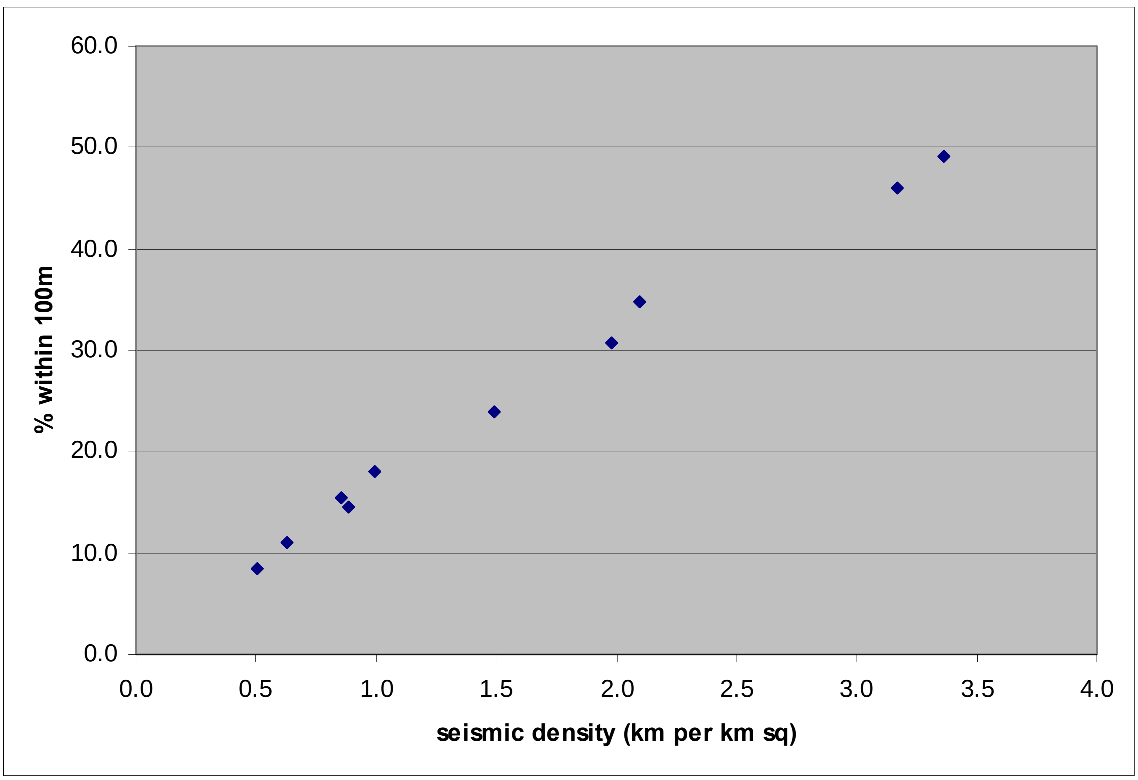


Figure. 1. The relationship between seismic line density in a given range and the proportion of the range within 100m of a seismic line. The Pearson correlation coefficient is 0.99.

Conclusion: Given the high degree of correlation between these variables it is impossible to determine whether one buffer size is more relevant than another. Each and every one should show similar relationships to caribou demographic variables because of their high inter-correlation. **As a consequence, we used overall linear density (km/km^2) as a surrogate for linear features for further analyses**. Even though we would like to determine the relative importance of potential different buffer widths it is not possible to do so with a dataset that has such strong inter-correlation. However, we can be confident that selection of any one variable (linear feature density) can act as a reasonable surrogate for any of the other highly correlated variables. Consequently there is no need to run the analyses on each and every linear feature variable.

Key Outcome #2. Linear feature density is not correlated with the % of range cut or the % of range burned.

Linear features are not correlated with the proportion of the range that has been cut in the last 30 years (r= 0.472, Fig. 2) nor are they correlated with % burn (r= -0.186).

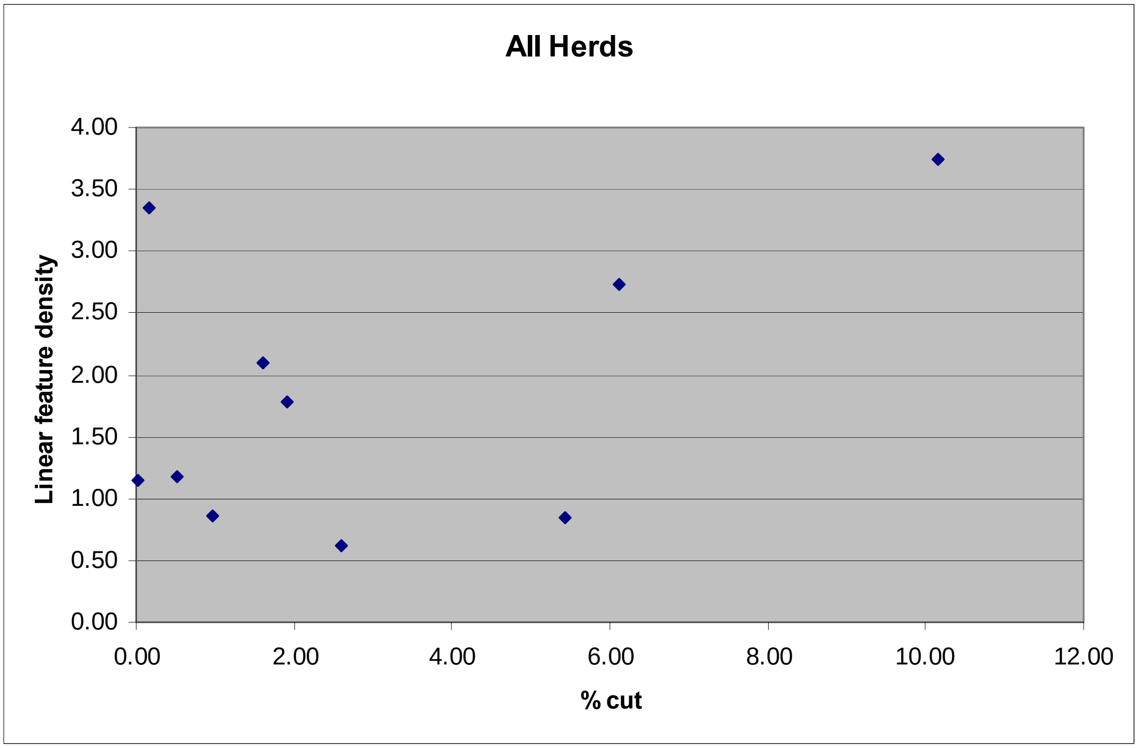


Figure 2. Percentage of the range that has been cut versus linear feature density (km/km^2).

Conclusion: Given the low correlation it is acceptable to include both linear feature density and % cut or % burn in the analyses.

Key Outcome #3: The % of range burned is not correlated with the % of range that has been cut.

The two variables are negatively correlated (r-=-0.508) but this relationship is driven by the Little Smoky Herd which has no burning and high cutting (10%) in its range (Fig. 3).

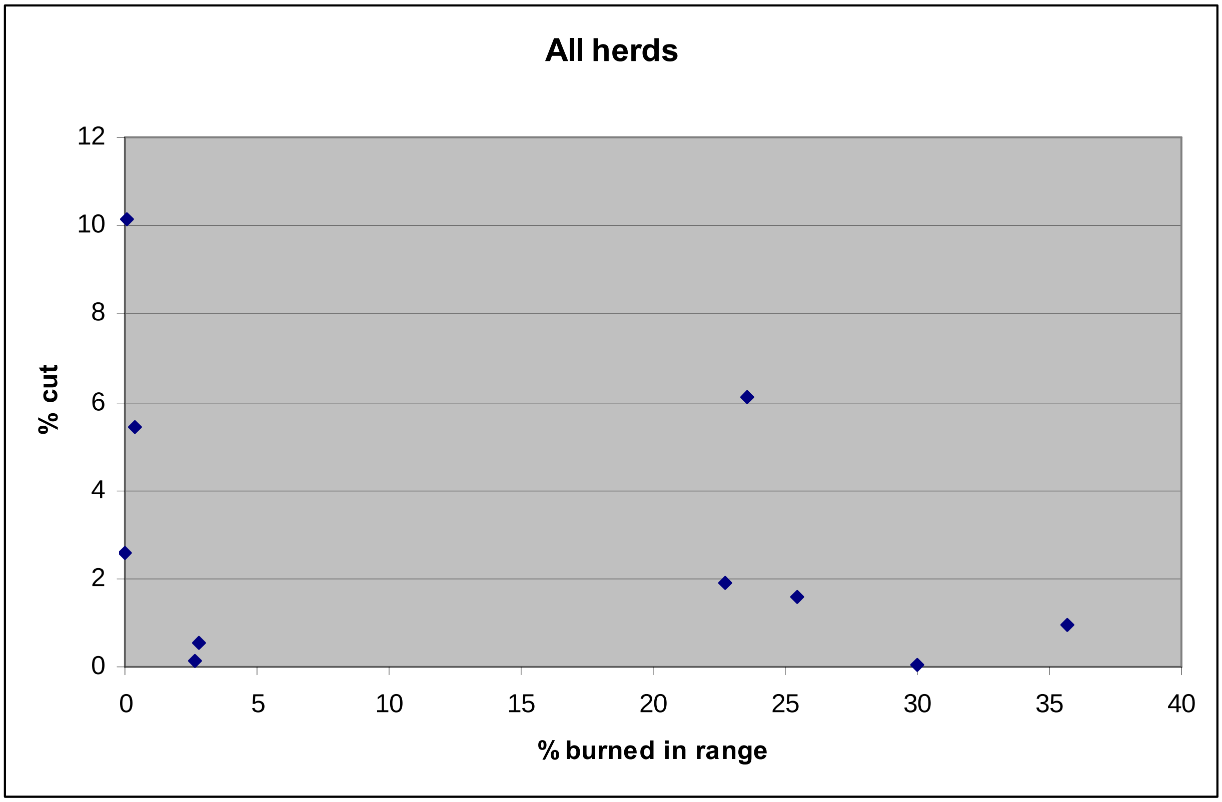


Figure 3. % Burned versus % Cut in each range.

Conclusion: Given the low correlation it is acceptable to include both % Cut and % Burned in the analyses.

Key Outcome #4. % Young habitat is highly correlated with % Burned but it is not correlated with % Cut or linear feature density.

% Young habitat is highly correlated with % Burn (r=0.964) but it is not correlated with % Cut (r = -0.108), nor with linear feature density (r = -0.022). This means that contrary to our initial premise, forest cutting has relatively little influence on the overall amount of young forest on caribou range which for the most part, is driven by fire.

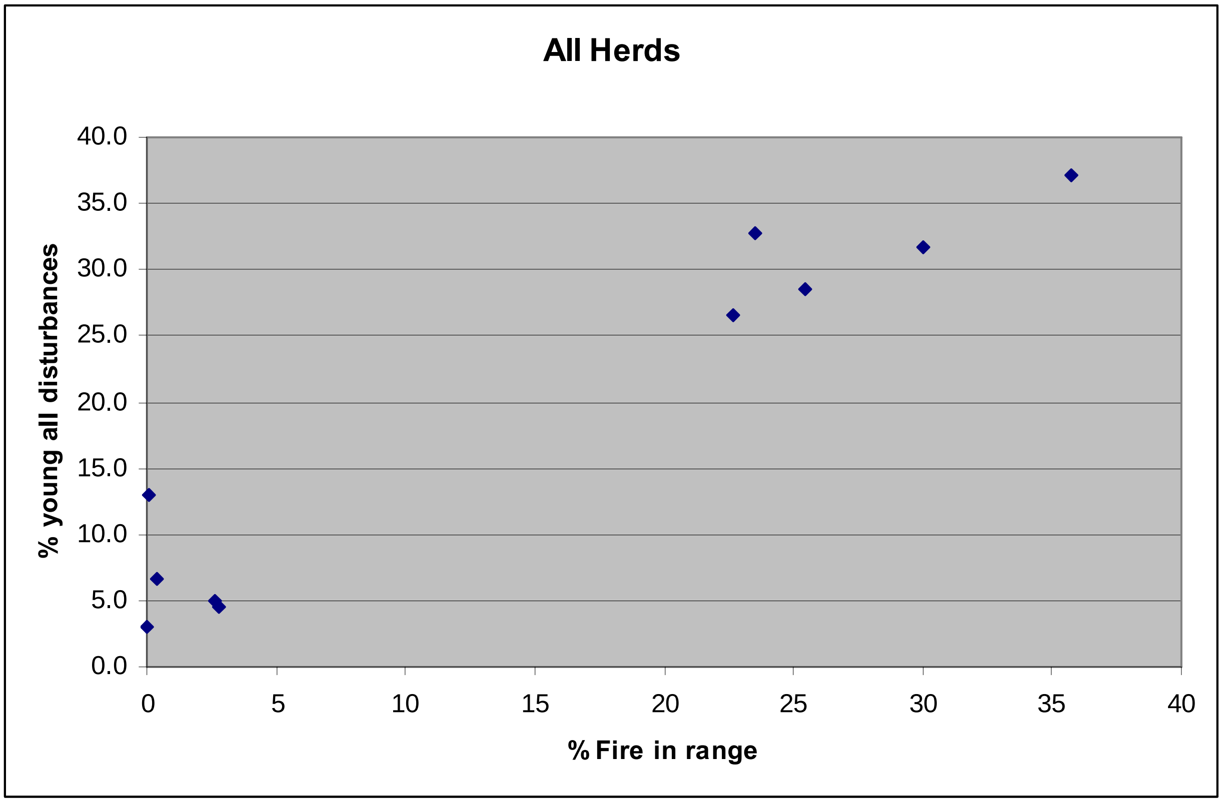


Figure 4. % Burned versus % Young forest resulting from all disturbances.

Conclusion: We used both % Burned and % Cut as variables for analysis rather than % Young forest to allow us to explore the relative contribution of each to the statistical models. However, after discussion within the working group it was agreed that area cut and area burned should affect caribou habitat in a similar fashion. Consequently they were combined to produce area of young habitat (expressed as proportion of range) which was also included in the AIC model analysis. Linear features create very little young forest (0.4-3.2% of the range) and as a consequence, do not affect the amount of area considered young habitat.

Key Outcome #5. Activities within a range are highly correlated to activities in the 20 km buffer.

Our primary concern was that forest cutting may be relatively low inside caribou range but rather higher outside of the range and this could lead to the potential for newly created ungulate habitat going undetected. Figure 5 shows that the two are highly correlated and although the buffer tends to have higher cut levels than in the range on average, what you see in the range is indicative of what you see in the buffer as well. The same held for linear features and % Burned.

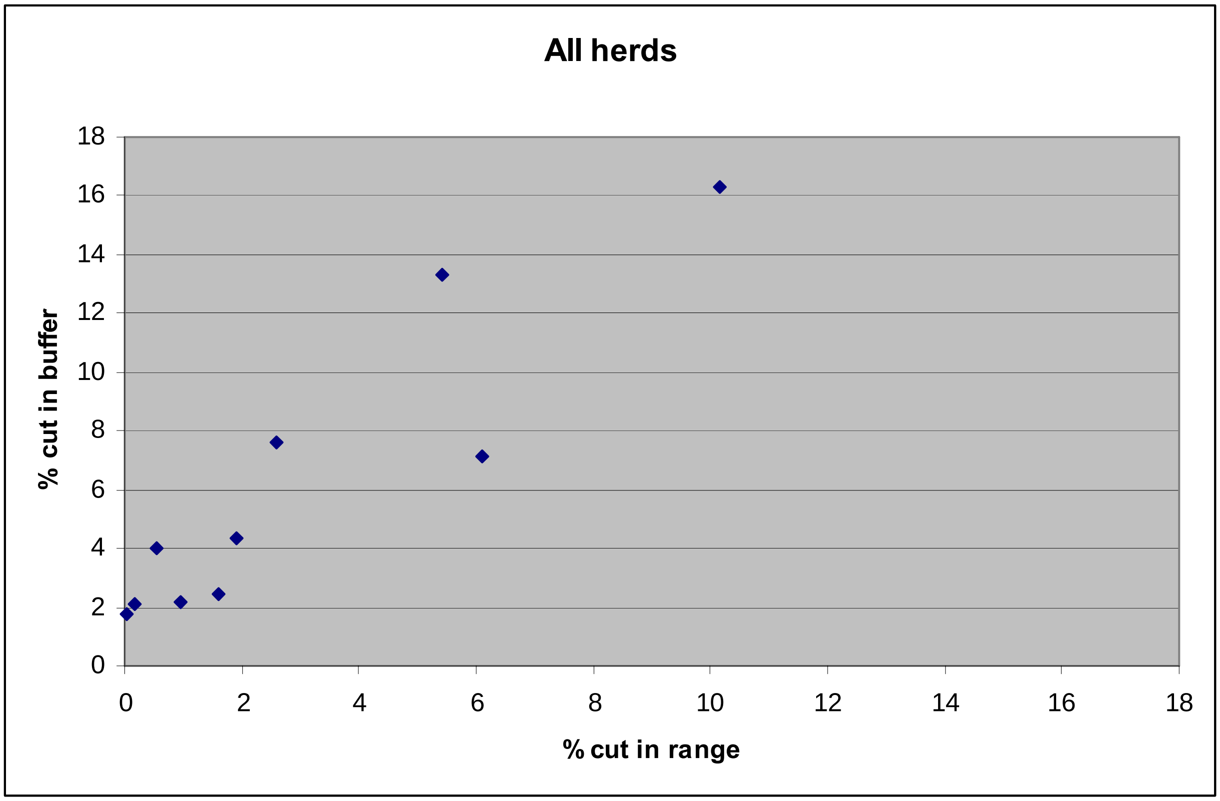


Figure 5. % Cut in Range was highly correlated with % Cut in the surrounding 20 km Buffer.

Conclusion: We performed all of our analyses using variables calculated for the range only.

Statistical analyses

Given the results of the cross-correlational analyses (key outcomes given above) we analyzed three independent variables:
Linear feature density
% Cut
% Burned
% Young (% Cut + % Burned)

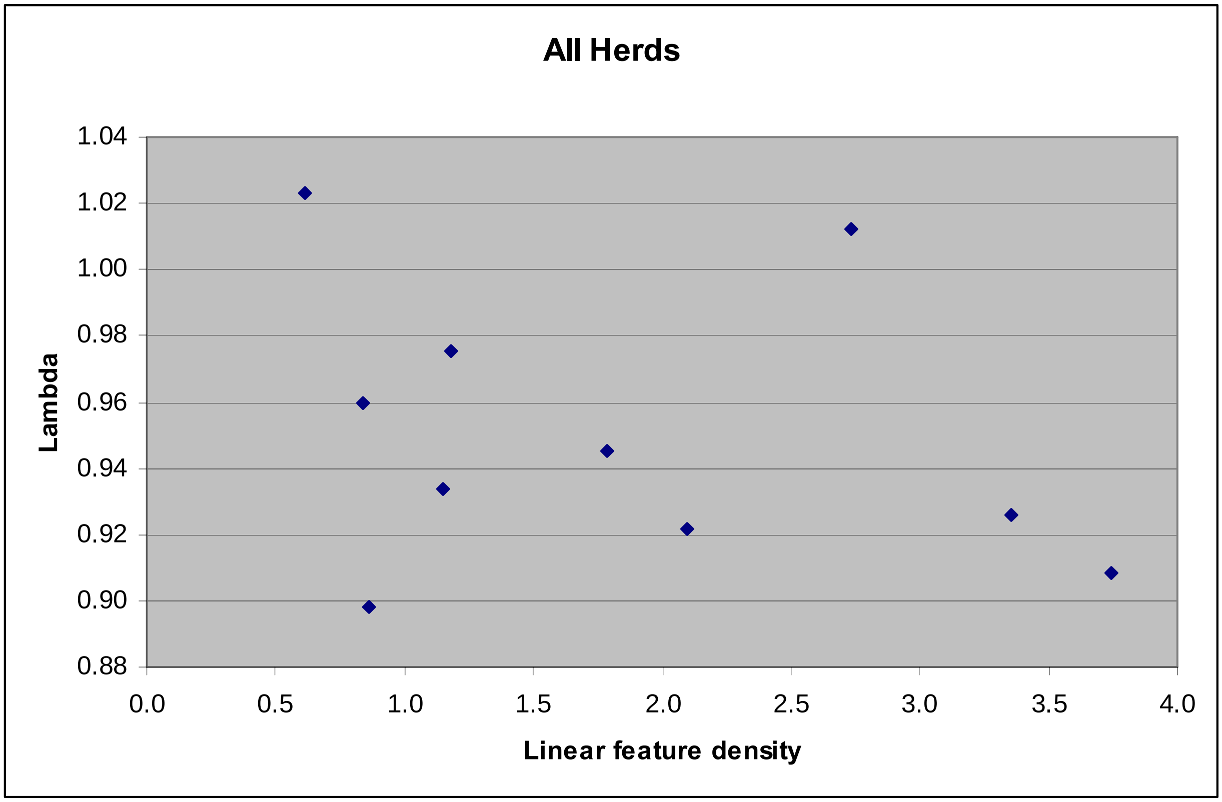
All independent variables were calculated for the range only.

We discuss results using Lambda as the dependent variable. Results for calf recruitment and adult survival are qualitatively similar and the correlation coefficients can be found in Spreadsheet "Pearson correlations".

Univariate analyses

We begin with simple univariate plots of each independent variable versus lambda using all herds.

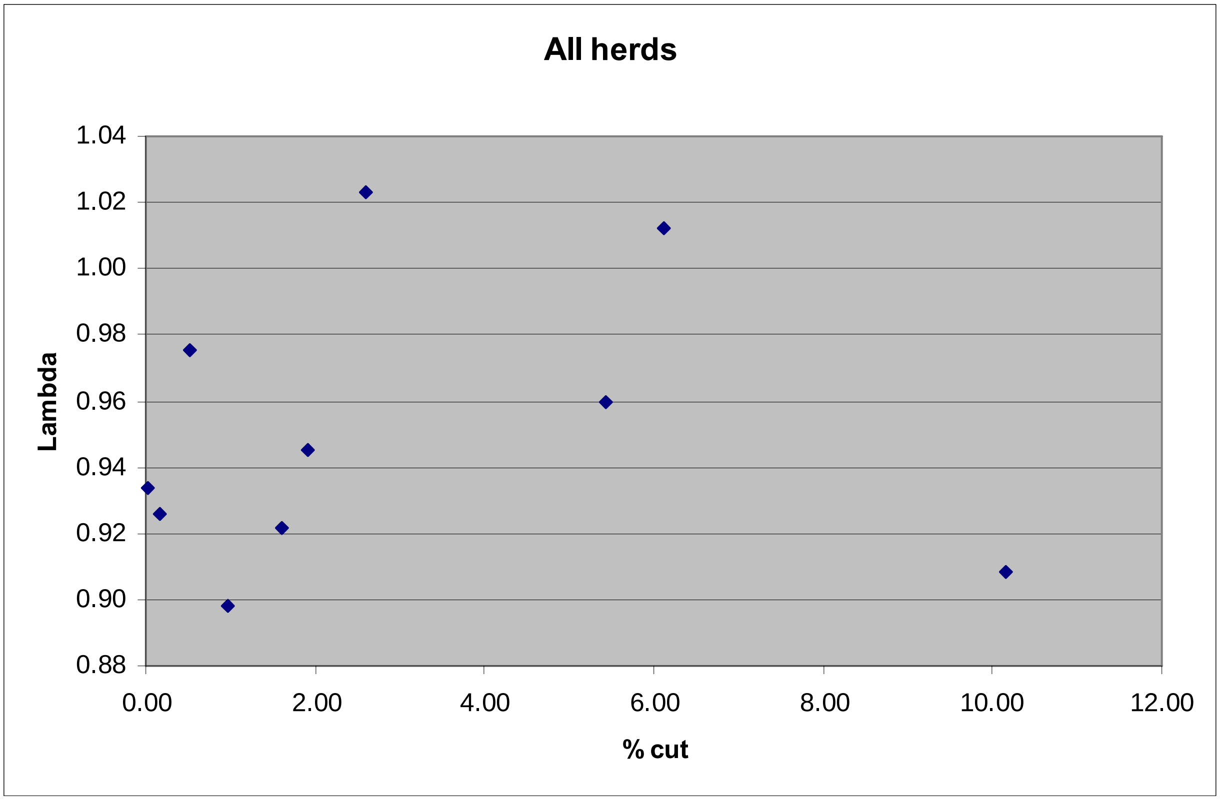
There is a weak negative relationship between linear feature density and lambda (Figure 6). There are two anomalous herds, CM which has a low linear feature density but low lambda, and Slave Lake which has a high linear feature density and high lambda.



HERD	LFdensH	Lambda2
ALP	0.61167	1.02324
CM	0.86488	0.89807
CH	3.35678	0.92613
CL	1.15176	0.93344
ESAR	1.78366	0.94522
LS	3.74757	0.90841
RE	2.09729	0.92158
RRPC	0.84141	0.95995
SL	2.73737	1.01249
WSAR	1.17901	0.97512

Figure 6. Linear feature density versus lambda.

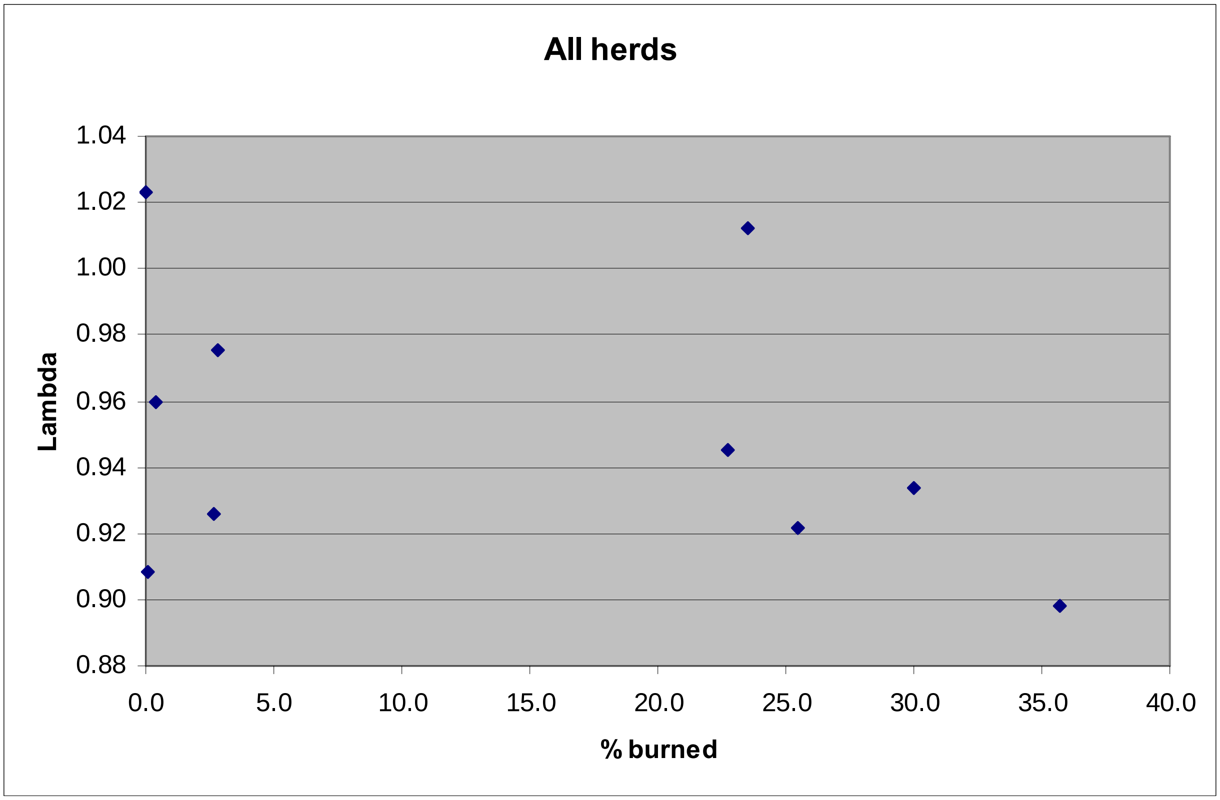
There is no strong relationship between % Cut and Lambda (Fig. 7). If LS is removed, the relationship becomes positive.



HERD	CCsPERH	Lambda2
ALP	2.60203	1.02324
CM	0.96317	0.89807
CH	0.15569	0.92613
CL	0.02938	0.93344
ESAR	1.91660	0.94522
LS	10.16583	0.90841
RE	1.60477	0.92158
RRPC	5.42790	0.95995
SL	6.11301	1.01249
WSAR	0.53021	0.97512

Figure 7. There is no relationship between lambda and % Cut.

There is a weak negative relationship between %Burned and Lambda (Fig. 8). Slave Lake stands out as an outlier again. However, LS and CM are influential as well. LS has no fire but low Lambda while CM makes the correlation negative because of the high area burned and the very poor Lambda value.



HERD	FirePERH	Lambda2
ALP	0.00154	1.02324
CM	35.71134	0.89807
CH	2.63241	0.92613
CL	30.02471	0.93344
ESAR	22.70601	0.94522
LS	0.09608	0.90841
RE	25.48671	0.92158
RRPC	0.38400	0.95995
SL	23.53818	1.01249
WSAR	2.78638	0.97512

Figure 8. % Burned is negatively related to lambda (r = -0.322).

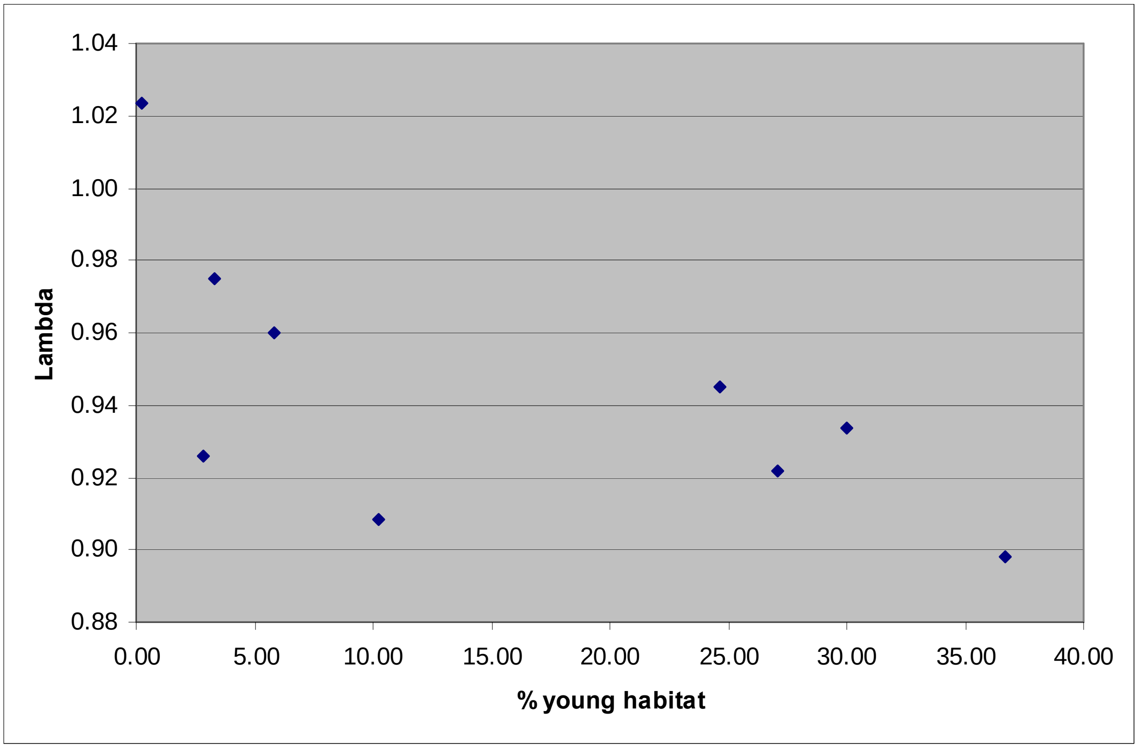


Figure 9. % Young habitat versus lambda. LS Herd not included.

If % Young is used instead of % Burned, the results are similar. The correlation is negative and the value is -0.323.

Model comparisons using an Information Theoretic Approach (AIC)

The AIC approach is a statistical technique that allows one to compare the relative level of support for a series of candidate models that have been developed before the analysis has been carried out. The models are ranked based on AIC values (lowest value is the best). AIC weights can be produced as well and the ratio of two AIC weights gives the relative likelihood of one model over another. We used this approach with the following caveats.
We were uncomfortable with the information for the Slave Lake Herd for a number of reasons. The demographic data cover only 3 years and there appears to be some justification for splitting the data into two components (Nipisi and Slave Lake). As a consequence, we have not included Slave Lake in the model analysis.

We conducted model analyses on two datasets; a boreal herd only dataset which excluded RRPC and ALP and an "All herds" dataset (minus Slave Lake). Results differ little for the two datasets.

We produced the following set of candidate models for comparison.

lambda=linear density + % cut + % burned (this is the Global model because all variables are included)

= Linear density
=% Burn
=% Cut
=Linear density + % Burn
=Linear density + % Cut
=% Cut + % Burn
=% Young
=Linear density + % Young

Note that a model including both % Burn and % Young was not part of the candidate set because these two variables were highly correlated and therefore, should not be included in the same model.

Results of this analysis can be found in Worksheet AIC analyses. Using all herds (except Little Smoky) the model receiving greatest support was:

In the case of the Lambda, the model receiving the greatest support was:

Lambda=linear density + % Burn.

However, the model

Lambda=linear density + %Young

ranked second and it had similar support. The model including only % Young was ranked fourth and it was 18 times less likely than the top-ranked model. The adjusted r^2 on the best model was 0.69 and coefficients for linear feature density and % Burn were negative and statistically significant.

The adjusted r^2 for Lambda=linear density + % Young was 0.74 and coefficients for linear feature density and % Young were negative and statistically significant. This means that either model could be used to provide a reasonable description of the data. There was little support for any univariate models.

Conclusions are similar if A La Peche and RRPC herds are excluded from the analyses. The top model was:

Lambda=linear density + % Burn

but the model Lambda= % Young ranked second.

Key Outcome #7. The overall model selection exercise gives the following models:

Lambda=1.0139-0.0253*Linear feature density-0.00191*% Burned

or

Lambda=1.0184-0.0234*Linear feature density-0.0021*% Young

Both models have reasonable statistical properties (AIC support, coefficients significantly different from 0). As a consequence, it would be acceptable to use either in a model such as ALCES as an empirical representation of how lambda will change as the linear feature density changes and/or the amount of a of range burns or is converted into young habitat (burned + cut).

Key Outcome #8. Our analysis produced results that were similar to those arrived at by Sorensen et al. (2008).

For comparison, The Sorensen et al. (2008) model was

Lambda=1.192-0.00315* (% within 250m of Industrial features)-0.0029(%Burned)

This is not surprising given the finding that linear feature density is highly correlated with the percentage of range within a given distance from industrial features (dominated by seismic lines). There is reasonable evidence to support the contention that linear features have some relation to caribou population growth. The linear feature variable can be expressed as seismic density, total linear density, or proportion of the range within a certain buffer (as used by Sorensen). All of these variables are highly correlated so it is not possible to determine the relative "importance" of components of linear features given our data.

As with Sorensen et al. (2008), there is good evidence to support inclusion of % Burned or % Young in the model. Proportion of the range burned is the primary driver of the proportion of the range in young habitat.

Key Outcome #9. Given that we still have relatively few data points to work with, we need to be conservative in our interpretation of these results. However, given the current data we recommend that:

Lambda = 1.0184 - 0.0234 * Linear feature density - 0.0021 * % Young habitat (<30 years old, Burn plus Cut)

provides a reasonable description of the relationship between caribou population growth and two factors (linear features and young habitat). We add the following additional comments:

5. ***Our certainly about the numerical values of the actual coefficients is not high given the sample size but we have reasonable certainty that the effects are negative.***
6. ***The model can be incorporated into land use models such as ALCES to capture the relationship between linear feature density, young habitat, and population growth of caribou populations.***
7. ***The model should not be used to establish targets of activity to achieve stable caribou population growth.***
8. ***This analysis does not directly test causation.***

APPENDIX 3

ALCES Scenario Modeling Report