

**Appendix 3**  
**ALCES III® Scenario Modeling Report**  
**- Athabasca Landscape Area**

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**May 2009**

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## 1. INTRODUCTION

The Athabasca Landscape Team (ALT) was formally established in June 2008 and tasked with developing an Athabasca Caribou Landscape Management Options report for boreal caribou ranges in northeast Alberta (hereafter Athabasca Landscape area; Figure 1). With respect to caribou recovery and management, the ALT considered the following issues:

- the habitat that caribou require for all aspects of their life history;
- the natural limiting and regulating factors that affect reproduction and survival of caribou at a landscape scale;
- the influence of human land-use on habitat availability, which in turn can affect reproduction and survival of caribou;
- the policies and decision-making processes that determine human land-uses and caribou management strategies; and
- the administrative units in which management actions will be undertaken; and
- the potential influence of climate change, particularly as it may affect distribution and abundance of deer and predator-prey dynamics of multiple species.

In order to evaluate management options that may recover and sustain boreal caribou in the Athabasca Landscape area, the ALT developed scenarios and used simulation modeling to compare and evaluate the influence of different management levers on key indicators for caribou habitat quality or the size and persistence of caribou herds. The ALCES<sup>®</sup> (ver. III) computer model was used to simulate effects of natural and land-use related change on boreal caribou in the Athabasca Landscape area. This model has been independently vetted and was also used by the West Central Alberta Landscape Planning Team. Model customization for the Athabasca Landscape Area, including development of the Population Dynamics module, was completed by Dr. Brad Stelfox, the originator of the ALCES<sup>®</sup> model. Simulations were completed by Terry Antoniuk, John Nishi, Karen Manuel, Mika Sutherland, and Cornel Yarmoloy of the ALCES Group.

This report provides a summary of the modeling approach, key assumptions (Supplementary Data Tables 1-4), and modeling results for the Athabasca Landscape area. Further interpretation of these results is provided in the Athabasca Landscape Area Management Options report (ALT 2009); additional information on the ALCES<sup>®</sup> model is provided at [www.alces.ca](http://www.alces.ca).

### 1.1 OBJECTIVES

The objectives of Athabasca Landscape area scenario modeling were to:

- provide projections of estimated future caribou populations, habitat and other factors for each planning area with different assumptions about natural and land-use changes; and
- help identify management options that sustain boreal caribou populations and distribution in each planning area.

## 1.2 STUDY AREA

The boundaries of the Athabasca Landscape area were established by the Alberta Caribou Committee Governance Board (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 Alberta Vegetation Inventory (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).

As directed by the ACCGB, the modeling area for all ranges included a 20 km buffer to reflect the influence of surrounding landscapes on predator and other prey numbers. The buffer width was selected by the ACCGB based on data that describes typical wolf pack home range size in northeast Alberta (Latham 2009). The buffer did not extend beyond the Alberta-Saskatchewan border (Figure 1).

ALCES<sup>®</sup> models were developed for six sub-regional planning areas within the Athabasca Landscape area for specific consideration by the ALT. Four were consistent with previously defined caribou ranges, incorporating the 20 km buffer (Richardson, WSAR, CLAWR, and ESAR (Figure 1). Two additional ESAR areas (ESAR – West of the Bitumen Fairway (ESAR-W); and ESAR – East of the Bitumen Fairway (ESAR-E)) were delineated based on the strong influence of anticipated bitumen development on future land-use within the ESAR. The Bitumen Fairway was defined by Alberta Energy for the Cumulative Environmental Management Association – Sustainable Ecosystem Working Group (CEMA – SEWG) as the area where most mineable and steam assisted in-situ bitumen development would occur<sup>1</sup>. Only portions of the 20 km buffer defined for ESAR were included for ESAR – E and ESAR – W. Sizes of each range and planning area are 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 buffered planning area.

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<sup>1</sup> 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 Integrated Land Management laboratory (University of Alberta) was used.

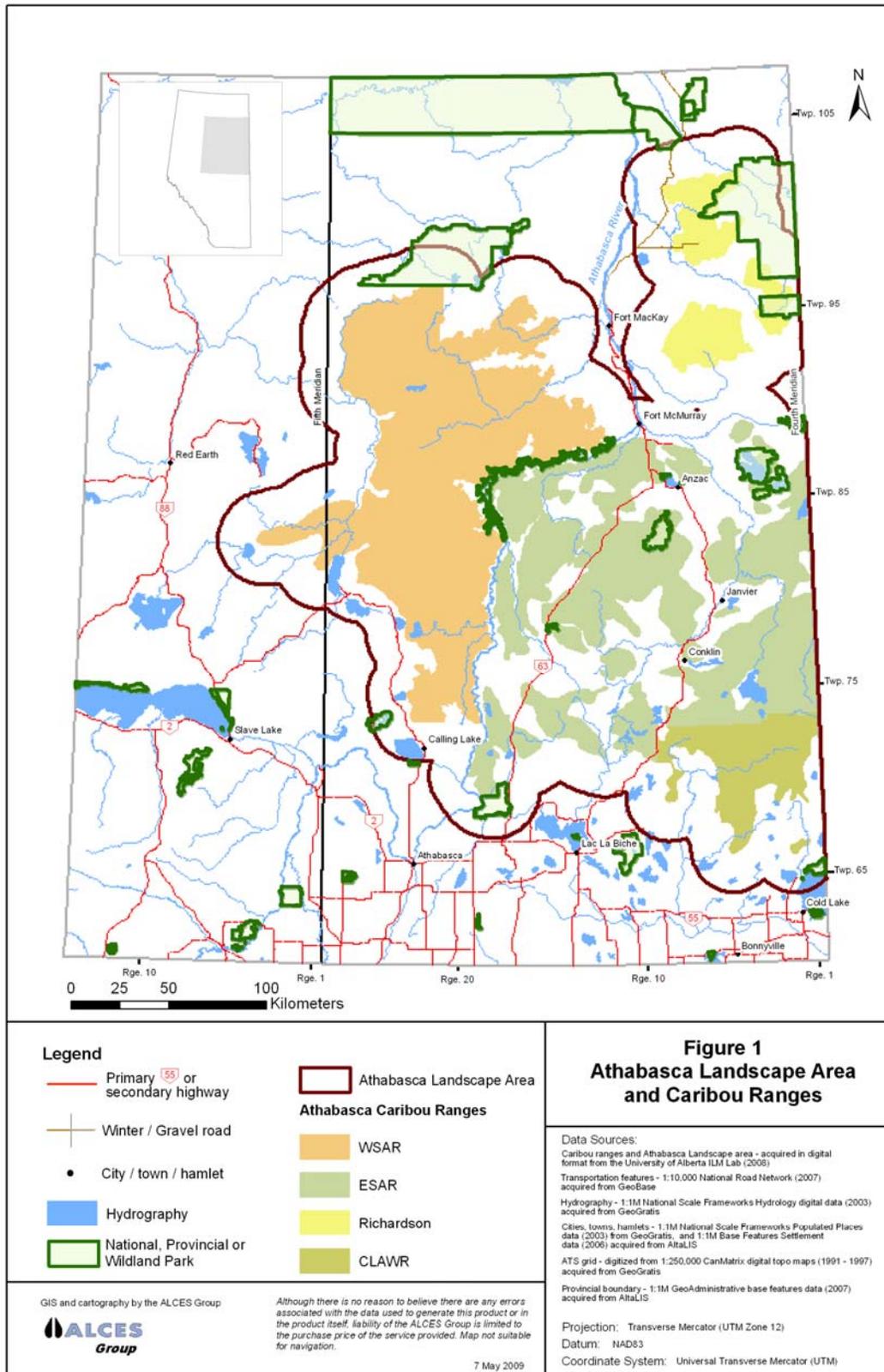


Table 1. Planning area and range areas in Athabasca caribou landscape.

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	267,648	961,564
Landscape Area Total	3,507,018	7,671,443

### 1.3 DEFINITIONS

In the context of range 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. While they do not provide quantitative predictions of conditions in a particular year, 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). The following definitions are relevant to this discussion:

**Scenario 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(s) of assumptions or management levers on key indicators.

**Management lever:** a management practice, policy, or procedure intended to maintain and restore caribou habitat or populations; specific examples include: changing future land-use trajectories; restoring existing footprints; reducing future footprint area or duration; fire/insect management; predator control; other prey control; caribou cow-calf penning.

**Coordinated reclamation:** a coordinated program to regularly reclaim a fixed percentage of unused historic and future linear features (seismic lines, pipelines, and temporary roads).

**Best practices:** project-specific measures designed to reduce the area or lifespan of future footprints.

## 1.4 SCENARIOS

The impacts of specific drivers and management levers can be assessed by developing and evaluating scenarios in which each factor or lever is varied individually or in combination. The following three scenarios were run for each planning area.

1. **Non-Industrial scenario:** This scenario represented the impacts of natural ecological processes (fire, insects, forest succession, predation) on key indicators such as habitat and demographic parameters 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, b) were used for fire and forest succession coefficients. ALT assigned a natural insect infestation rate of 0.5%/yr. Predator/prey coefficients summarized in Supplemental Data Table 1 were derived from regional studies, other scientific literature, and 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, and human population growth) using assumed development trajectories and current footprint sizes and lifespans. 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:** This scenario 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 caribou decline by restoring functional habitat; 2) manage proximate causes of caribou 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 impact 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 5.2.1.1 of main report). 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<sup>®</sup> model concurrently tracked the status of the following six indicators for every year of the simulation period. Indicator status in the last year of a simulation was noted for comparative runs:

1. **Habitat-Based Population Performance:** projected ACC2 value at year 50 based on a regression equation between caribou population growth and the proportion of young forest and linear feature density on the landscape; the analysis and equation are provided in Boutin and Arienti (2008) (Appendix 2 in ALT 2009).
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  $\geq 10$  (arbitrary number assigned by the ALT) in a 50 year simulation.

It is important to note that one of the six indicators described above - Habitat-Based Population Performance (Boutin and Arienti 2008) - is simulated in ALCES<sup>®</sup> based on the dynamic changes in landscape composition (i.e., percent cover of young forests and linear feature density) that are driven by anthropogenic land-use and natural disturbances. The other five indicators are wildlife population metrics that are simulated in the Population Dynamics model of ALCES<sup>®</sup> based on user defined assumptions. The population dynamics module simulates the response of wildlife populations to trophic interactions (i.e., herbivory and predator-prey relationships) through changes in vital rates (i.e., births and deaths) as well as changes in landscape composition that affect habitat availability and quality.

Figure 2 provides an example of an ALCES<sup>®</sup> 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, which in Figure 2 is caribou population size. 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 shown on Non-Industrial simulations represents the projected population range with only natural disturbance and processes; this is used as a reference for Business as Usual and Alternative Futures scenario simulations.

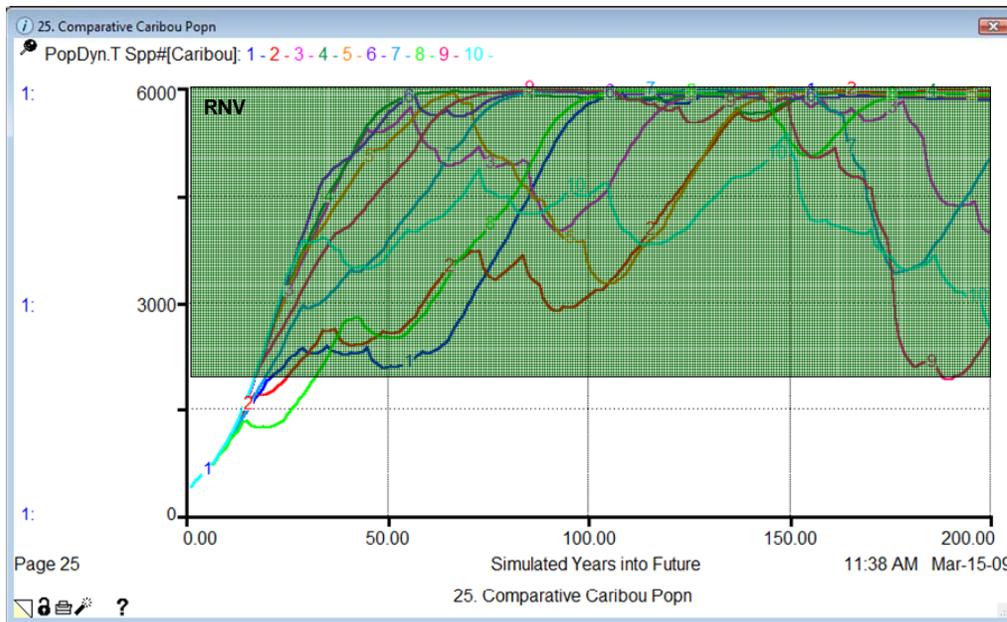


Figure 2. ALCES<sup>®</sup> simulation output graph.

## 1.5 GIS DATA SOURCES

Data documenting current habitat composition and anthropogenic land-use footprints in the six planning areas were provided by the University of Alberta Integrated Land Management laboratory (Arienti 2008) according to the ALCES<sup>®</sup> landscape and footprint classification scheme provided in Table 1.

At the request of the ALT, forest cover types for recent burns were subsequently updated by the ALCES Group with pre-fire Alberta Vegetation Inventory (AVI) data where available, or proportional forest types in each planning area.

Table 2. Landscape Types and Footprint Types used in ALCES® Athabasca Landscape Area models.

No.	ALCES Landscape Type	Description	No.	ALCES Footprint Type	Description
1	HW	Hardwood Forest	1	Maj_Road	Major Road (paved, 40 m wide)
2	MW	Mixedwood Forest	2	Min_Road	Minor Road and Truck Trails (unpaved, 15 m wide)
3	Wh_Sp	White Spruce Forest	3	Rail	Railway
4	Pine	Pine Forest	4	Inbl_Road	Temporary Road
5	Cl BL Sp	Closed Black Spruce Forest	5	Mine	Coal / Other mine
6	Op Bl Spruce Fen	Open Black Spruce Fen	6	Pits	Gravel/aggregate pit or quarry
7	Bog1	Open Bog	7	Peat_Mine	Peat Mine
8	Open Fen	Open Fen	8	Power Line	Transmission or Power line
9	Li Moss	Lichen Moss	9	Rural_Res Camp	Rural Residential/Cabin/ Camp
10	Bl Sp Li Moss	Black Spruce Lichen Moss	10	Town_City	Community
11	Sh Wetl	Shrub Wetland	11	Industrial	Other Industry
12	Nat Herb	Natural Herbaceous	12	Seismic	Seismic Line
13	Lake	Lakes, Ponds, and Standing Water	13	Wellsite	Exploration or Production Well
14	River	Streams, Rivers, and Other Moving Water	14	Pipeline	Pipeline
15	L Shrub	Low Shrub	15	Oilsands Pit	Surface mines and tailing ponds
16	T Shrub	Tall Shrub			
17	Rock	Rock			
18	Beach	Beach			
19	Anthro Herb	Non-native Herbaceous			
20	Unclass	Unclassified			

## 1.6 KEY MODEL ASSUMPTIONS

Key model components and assumptions used by the ALT are summarized below.

### 1.6.1 Natural Disturbance and Processes

CEMA-SEWG coefficients were used for meteorology, fire, and forest succession (Wilson et al. 2008). The ALT assigned a natural insect infestation rate of 0.5%/yr based on Alberta-Pacific Forest Industries Incorporated (Al-Pac) studies in the area.

### 1.6.2 Forest Harvest

Most of the Athabasca Landscape area is within the Al-Pac Forest Management Agreement area. An overview of forest harvest tenures in the area is provided in the Current Assessment report (see Section 3.1.4 of main report).

Forest harvest Softwood (conifer) and hardwood (deciduous) harvest targets for each range and planning area were defined by Al-Pac with a Woodstock-Stanley model (D. Cheyne pers. comm., Supplementary Data Table 4). Forest harvest assumptions were adopted from a recent study completed by CEMA-SEWG for the same geographic area (Wilson et al. 2008).

### 1.6.3 Hydrocarbon Trajectories

Bitumen reserves are the dominant hydrocarbon type in the Athabasca Landscape area. Information on economic reserves and hydrocarbon tenures in the area is provided in the Current Assessment report (ALT 2008).

Energy sector trajectories were defined using a Hubbert-Naill life cycle approach based on economic bitumen reserve volumes and production areas defined by Alberta Energy (J.R. Nichol pers. comm.). Discovery, production, and infrastructure (seismic line, production well, other well) coefficients were developed for multiple formations (Athabasca in-situ; Cold Lake primary; Cold Lake cyclic steam stimulation; Wabasca primary; Wabasca cold waterflood). Combined coefficients for each planning area were derived by area weighting based on the calculated reserve volume within the planning area (Supplemental Data Tables 2 and 3). Athabasca mineable coefficients were adopted from CEMA-SEWG (Wilson et al. 2008).

Energy sector trajectories for natural gas were not provided by Alberta Energy. Natural gas trajectory evaluations done for CEMA-SEWG suggested that comparatively few natural gas wells would be drilled each year (Wilson et al. 2008). This activity level would have negligible influence at the planning area scale, so future natural gas development was not included in Business as Usual or Alternative Futures scenario simulations.

### 1.6.4 Other Industrial Land-use

Potential peat harvesting areas are provided in the current assessment report (ALT 2008). Most dispositions or protective notations are located in the WSAR and ESAR – W planning areas. Data to define active peat harvesting areas were not located, so future peat harvesting was not included in scenario simulations. Other industrial land-uses, including any infrastructure plans by Alberta Transportation, were also not included.

### 1.6.5 Population Dynamics

In July 2008, a predator-prey modeling component in ALCES<sup>®</sup> was requested by the ACCGB to enable an exploration of management scenarios that: a) manipulated predation risk directly through wolf depredation; b) manipulated other prey densities directly through depredation or indirectly through habitat management levers; and c) improved early calf survival through simulating temporary penning of pregnant caribou cows. The intent was to run landscape-level scenarios that allowed the ALT to pull management levers on land-use, habitat reclamation, and wildlife population abundance, and to simultaneously report on wildlife population metrics and track landscape changes in one modeling platform. As a result, a new population dynamics module (population model) was built in ALCES<sup>®2</sup> for this project by Dr. Brad Stelfox. This population model replaced the REMUS model (Weclaw and Hudson 2004) that was used previously by the West Central Alberta Landscape Planning Team in conjunction with ALCES<sup>®</sup> (WCACLPT 2008).

The population model structure was based on an Impact Hypothesis Diagram (IHD; Figure 3) developed initially by the WCACLPT (2008) and further revised by the ALT in conjunction with the Alberta Caribou Committee Research and Monitoring Subcommittee (ACCRMS). The model was designed to simulate a multiple species predator - prey system; it comprised four species (caribou, wolf, moose, deer), two genders (male, female), and three age classes (young of year, subadult, adult) (assumptions in Supplementary Data Table 1). Although bear and beaver are recognized as important players in this multiple species predator-prey system, for simplicity's sake they were not included in this version of the population dynamics model.

During initial development of the model, members of the ACCRMS and ALT suggested that although a direct mechanistic pathway between forage production – ungulate abundance – and wolf predation was a basic requirement of the model, it did not sufficiently explain the relatively high densities of deer and moose currently observed on the Athabasca landscape. The rationale was that on landscapes with high linear feature densities, the proportional increase in young habitat as a result of the direct footprint of linear features could not account for the observed increase in densities of other prey species. Therefore, a recommendation<sup>3</sup> was made for the population model to allow the user to run an alternate pathway that was based on a buffering effect (i.e., zone of influence) associated with linear features that could be positive or negative depending on the species and the landscape type in which the feature occurred. Through this buffering effect of linear features, the model could simulate an increase in available habitat that was greater than the direct footprint and in turn drive a numerical response in a prey species. Similarly, the buffering effect could also increase habitat overlap and influence encounter rates between prey and predator species.

<sup>2</sup> ALCES is a cumulative effects model built using the systems software STELLA<sup>®</sup> (www.iseesystems.com),

<sup>3</sup> ACCRMS and ALT meeting, 10 October 2008, University of Alberta, Edmonton, AB.

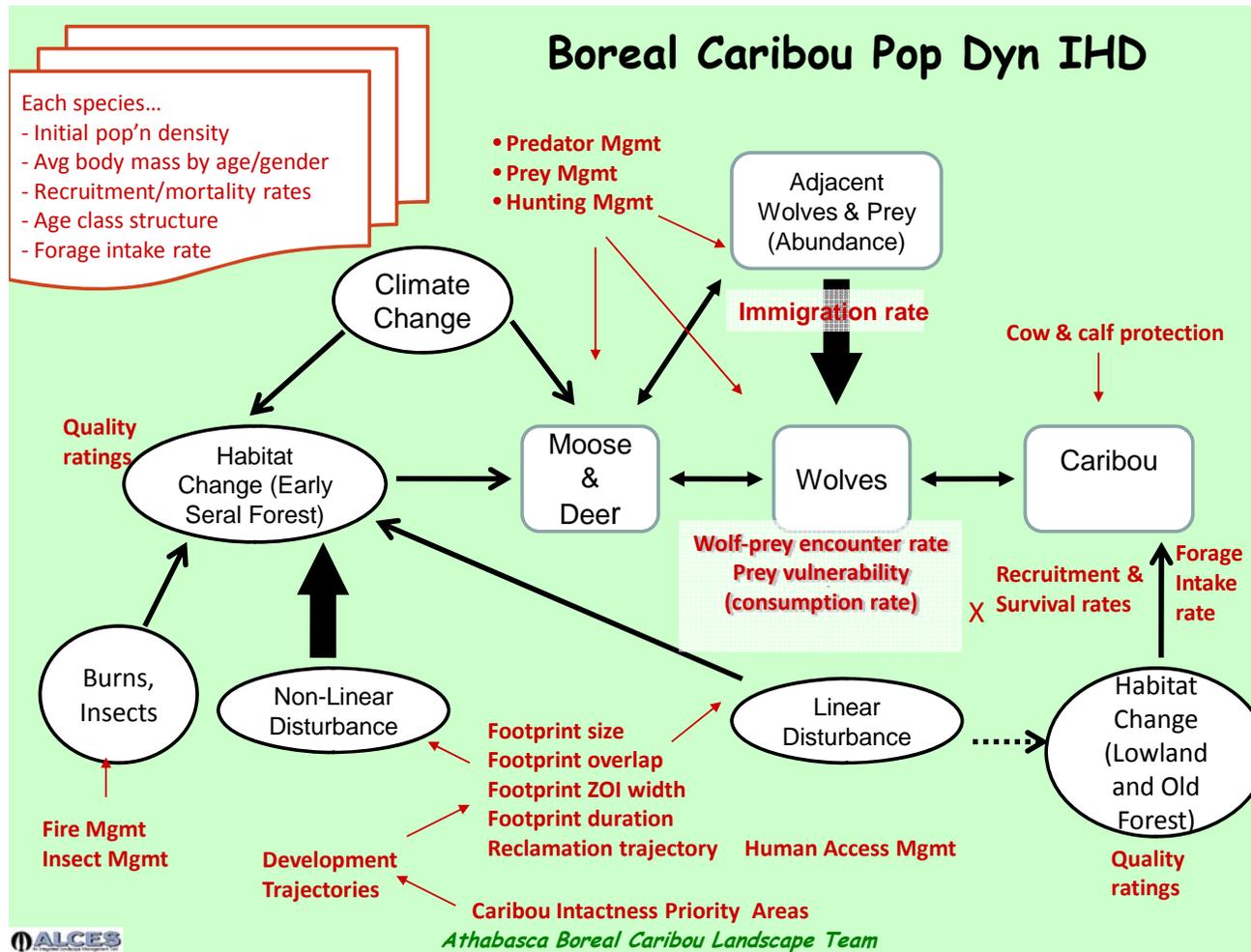


Figure 3. Predator-prey impact hypothesis diagram using to build ALCES® multi-species population dynamics model.

The population model was designed as a landscape-level strategic model and was integrated into the existing architecture and coding of ALCES<sup>®</sup> (Figures 4-8). Since ALCES<sup>®</sup> was built originally to simulate landscape dynamics in response to natural disturbances and anthropogenic land-use, it provided a robust foundation for building interactions between ungulates and forage. This in turn provided a strong basis for modeling landscape-level interactions between predator and prey species. Consequently, the design of the population model in ALCES<sup>®</sup> is best understood broadly in the context of plant-herbivore and predator-prey interactions, which are often referred to as ‘bottom-up’ and ‘top-down’ processes, respectively.

The plant-herbivore interactions were defined at a landscape scale, meaning that relationships between forage availability and population demography of ungulates were considered at a coarse temporal and spatial scale; the model had an annual time step and the study area, which ranged from  $10^5$  –  $10^6$  ha, was stratified into 20 landscape types which were used to calculate habitat availability and available forage biomass. As a strategic model, the ALCES<sup>®</sup> population model was not designed to simulate plant-herbivore dynamics using a highly mechanistic and fine-scaled approach (e.g., Gedir and Hudson 2000); instead it was designed to capture the essential elements of the model system at a broad landscape level. In the ALCES<sup>®</sup> population model, ungulate populations are limited by habitat availability and predation, while wolf populations are limited by prey availability. Prey encounter rate is density dependent, but kill rate can be altered by a ‘vulnerability’ coefficient.

Although the population model was designed with an integrated approach to herbivore and vegetation dynamics, the ALT was advised to simulate ungulate carrying capacities deterministically based on expected maximum densities, rather than attempt to develop an additional set of coefficients to define positive and negative feedback loops for each ungulate species and forage type and simulate carrying capacity (K) as a dynamic equilibrium (K. Smith pers. comm.)<sup>4</sup>. Consequently, carrying capacity for each ungulate species was based on user-defined input density estimates (Figure 4b). This approach is consistent with the current understanding that predation is the most important proximate factor limiting woodland caribou (Bergerud and Elliot 1986, Wittmer et al. 2005, Latham 2009, but see Brown et al. 2007 for a discussion on the importance of understanding bottom-up processes related to forage and nutrition).

Figure 4a) shows the basic logic and structure for defining a buffering effect on linear features. The key input variables are: 1) an estimated buffer width for each combination of species x landscape type (‘Spp x FT Buffer x LT’); and 2) whether the buffer receives increased or reduced use by animals (‘Buffer Use Index 0 or 1’). Two key outputs from this submodel are the change in area of habitat associated with attraction to or avoidance of buffers (‘Spp Habitat ha x LT’), and the change in area of overlap between prey species and wolves (‘Prey x Wolf Overlap ha’); the former can increase available habitat to a species and contribute to a numerical increase, whereas the latter is an important variable for determining kill rates by wolves on prey species (Figure 6).

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<sup>4</sup> Kirby Smith, Senior Wildlife Biologist, Alberta Sustainable Resource Development. Edson, AB. Personal Communication, 10 October 2008.

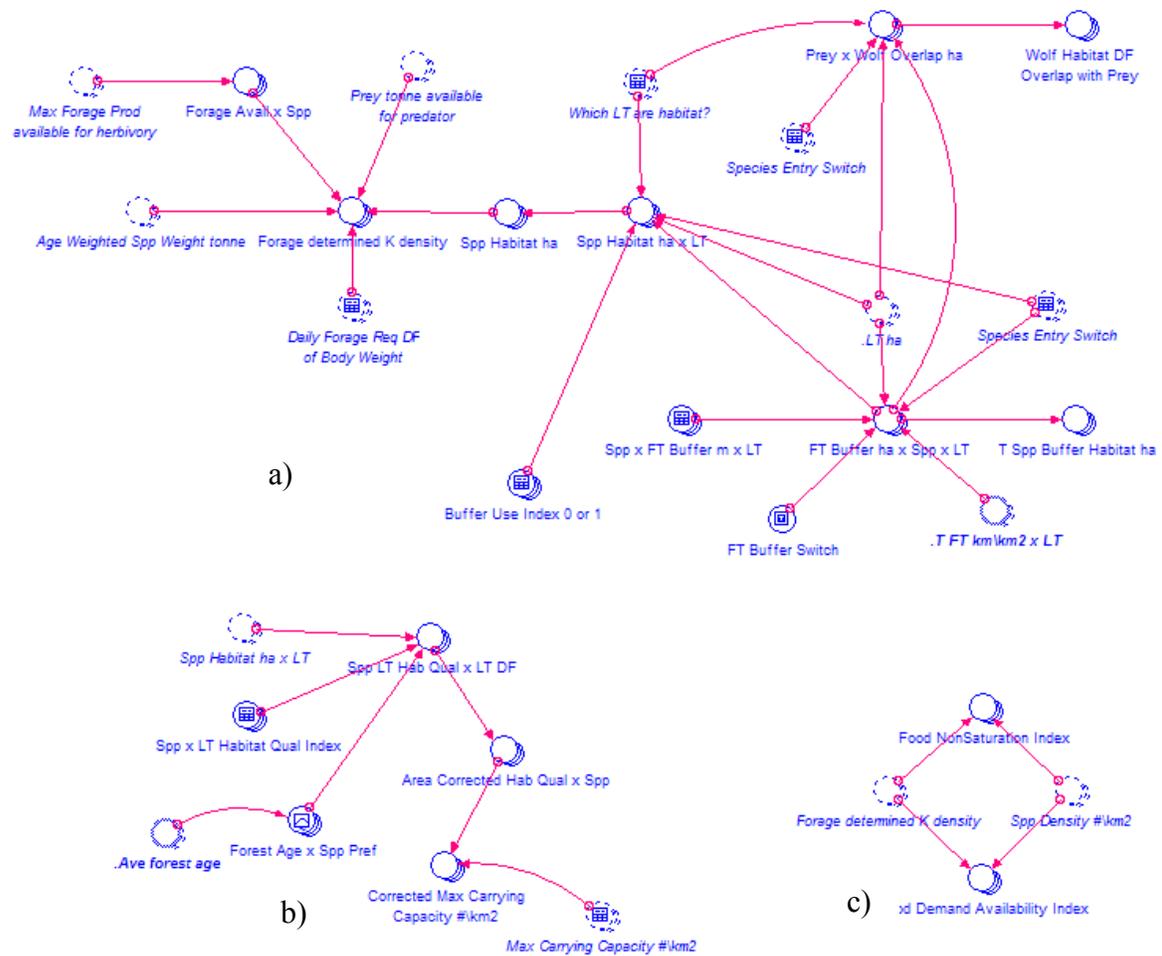


Figure 4. A STELLA® map of carrying capacity in the ALCES® population model. Diagram a) displays forage-based carrying capacity (K) calculated as an array for each species; it also shows linkages of buffers to linear features and the way in which buffers may increase available habitat and affect overlap between predator and prey species; b) illustrates the linkage between habitat quantity and quality and the general logic for deriving a corrected K value for each species based on user-defined inputs for maximum carrying capacity; and c) shows the parameters used to define the negative feedback loop between food determined K and animal density, as density approaches K.

Figure 5 shows the submodel structure for the calculation of birth rates in the model. An important switch is the user-defined input that determines whether reproduction is to be constrained by food availability, density (relative to user inputted K), or both ('Food 1 Density 2 Both 3 for Repro Constraint'). Depending on this assumption, the model calculates birth rates as a product of user input fecundity rates (Fecundity Rate) and an index tied to either density ('Density NonSaturation Index') or food availability ('Food NonSaturation Index'), or both. In this project, the density setting was used for ungulates and the food setting was used for wolves.

Predation rate in the ALCES<sup>®</sup> population model (Figure 6) is primarily driven by two factors. The first is encounter rate ('Encounter Rate') which is a density dependent variable based on abundance of predator and prey species in the portion of the landscape in which they overlap ('Wolf Habitat DF Overlap with Prey'). The second factor is a user-defined prey vulnerability coefficient ('Relative Prey Vulnerability') which can be turned on or off with a switch ('Prey Vulnerability Switch') (see Section 1.6.5.3 below). The total number of prey (by species and age class) killed by predators ('Prey # Killed by Predators') in an annual time step is calculated by dividing the abundance of relative prey biomass required ('Prey Biomass Required/Avail by Predator') by the average body mass of prey (Ave Spp Body Mass tonne') (Figure 6).

Other important components shown in the predation submodel (Figure 6) are the four user-defined switches and input devices that define how cow and calf penning are linked to the stock of available prey biomass for predators. The switch titled 'Cow Calf Penning Switch' simply informs the model whether this management lever is turned on or off. If the switch is turned on, then the user also needs to indicate: 1) the proportion of cows in the population that will be penned ('Cow Female DF Penned?'); 2) the reduction in calf mortality that will be simulated ('Calf Predation Mortality Reduction from Penning'); and 3) the number of years between cow penning events ('Cow Calf Penning Interval'). It is evident from Figure 6 that when the 'Cow Calf Penning Switch' is turned on and associated inputs assumptions are defined by the user, the number of penned cows and calves are temporarily removed from the potential stock of available prey.

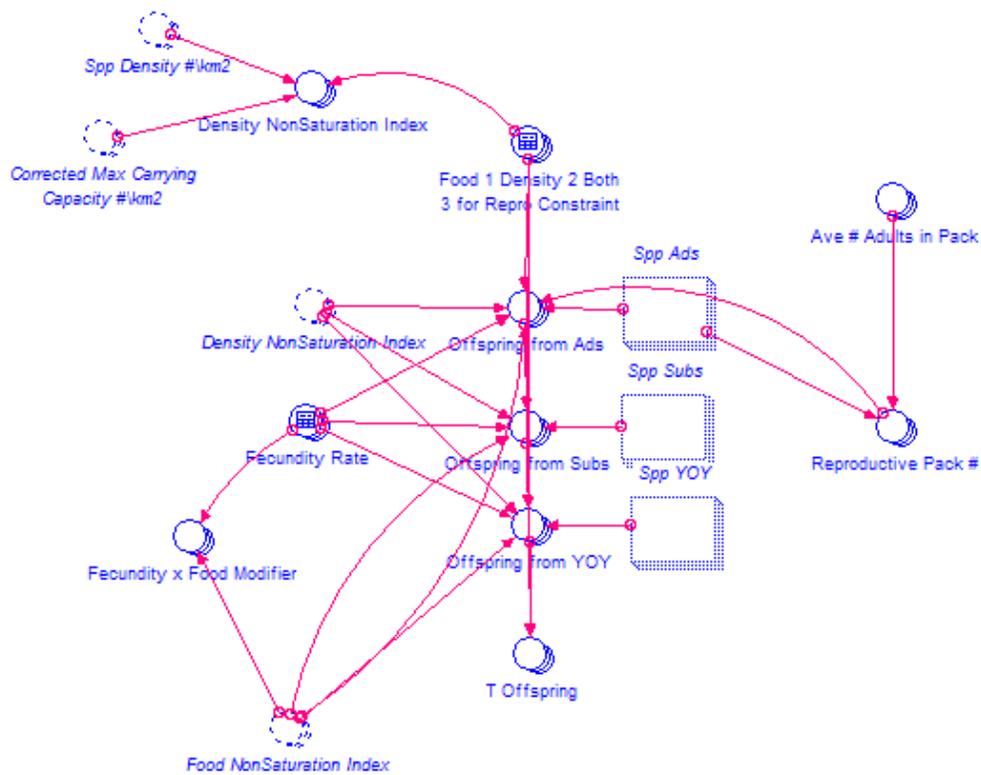


Figure 5. A STELLA<sup>®</sup> map of reproduction in the ALCES<sup>®</sup> population model. Reproductive rates for each of the three cohorts across the array of species ('Spp Ads', 'Spp Subs', and 'Spp YOY') was calculated based on user-defined fecundity rates ('Fecundity Rate') and a coefficient linked to carrying capacity, which was expressed as either a function of density ('Density NonSaturation Index'), available food ('Food NonSaturation Index'), or both. The selection of the carrying capacity coefficient was determined by the user through a switch ('Food 1 Density 2 Both 3 for Repro Constraint'). At each annual time step, fecundity rates were multiplied by the current stock of animals (arrayed by sex and species) to calculate offspring.

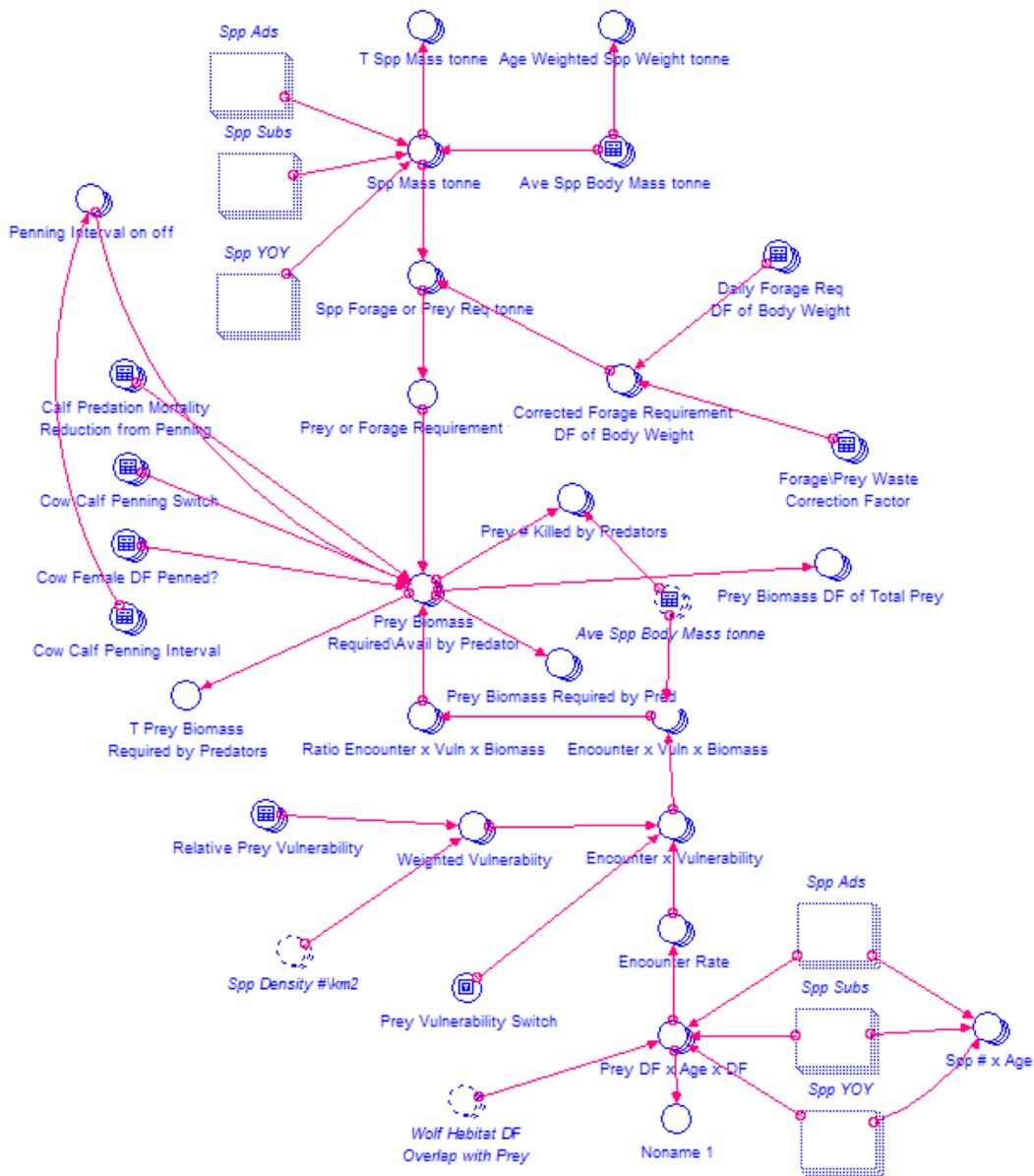


Figure 6. A STELLA® map of predation in the ALCES® population model. The main part of the predation submodel is shown in a) which demonstrates how encounter rate ('Encounter Rate') and prey vulnerability ('Relative Prey Vulnerability') are main factors that drive total predation rate by wolves on prey species. The product of encounter rate and vulnerability is used to convert the total prey biomass required by predators in to the numbers of prey killed (by species and age class). Total prey biomass required by predators ('Prey of Forage Requirement') is based on the numerical abundance of predators and their individual forage requirements (expressed as proportion of their body weight ('Daily Forage Req DF of Body Weight')).

Figure 7 shows the accounting structure for sources of mortality in the population model, which includes hunting, depredation (population reduction by wildlife managers), and natural mortality. Hunting by sport hunters and aboriginals, and depredation can be simulated and defined in the model, and are defined similarly by three user inputs – switches, rates, and intervals. In short, the switch informs the model on the additional human-caused mortality that will be included. The amount of hunting or depredation is user-defined as a rate or a decimal fraction of the animal population according to species and age. The third user-input is the interval (in years) between hunting and/or depredation events. For the ALT project, we did not run hunting scenarios, and only applied depredation to wolves and other prey species. Natural mortality also has a user-defined natural mortality switch and two user input tables for minimum food mortality rate (expected rate of mortality during food shortages) and maximum food mortality rate (expected rate of mortality when food is abundant).

The importance of the ‘population structure’ submodel (Figure 8) is that it integrates demographic rates from other submodels, i.e., reproduction and mortality, and ‘grows’ the various wildlife populations (arrayed across species) through a linear hierarchy of stocks and flows. At first glance the modeling structure in Figure 8 appears to be dauntingly complex, but that is primarily due to connections between various components of the submodel and the user-defined switch and input table on minimum viable populations; these components assist with data output and are not important to the overall working design. The most important patterns and processes to understand in Figure 8 are threefold: 1) the stocks (rectangular boxes) represent each of the three age classes as a dynamic pool that is affected by rates of inflow and outflow; 2) the main inflows that run from left to right are fecundity (i.e., births add to the abundance of young of the year – YOY), recruitment of yearlings to subadults, and recruitment of subadults to adults; and 3) the main outflow from the bottom of the stocks is age-class specific mortality. This figure includes parameters from previously described submodels (Figures 4-7) and depicts the overall population structure and dynamic of inflows and outflows to and from each of the age classes. An additional inflow into the stock of subadults is immigration. Immigration is controlled firstly by a switch (‘Immigration Switch’), and then refined by user-defined input assumptions on rate of immigration (i.e., the number of new immigrants into the subadult stock) and the interval (in years) between immigration events.

The baseline assumption for wolf immigration was two wolves per year. This low rate of immigration is based on an assumption that territorial behaviour acts as a social control that minimizes successful immigration of subadult wolves. In this model, immigration of subadult wolves was an important parameter that could influence likelihood of success for increasing caribou abundance during simulations of wolf depredation. For simulations with wolf depredation, the immigration rate of wolves into an area was initially assumed to be 50 immigrants per year due to breakdown in territorial behaviour and social control on immigrants. The coarse assumption of 50 wolves per year was based on the estimated number of subadults in each planning area, as summarized in the Current Assessment (ALT 2008).

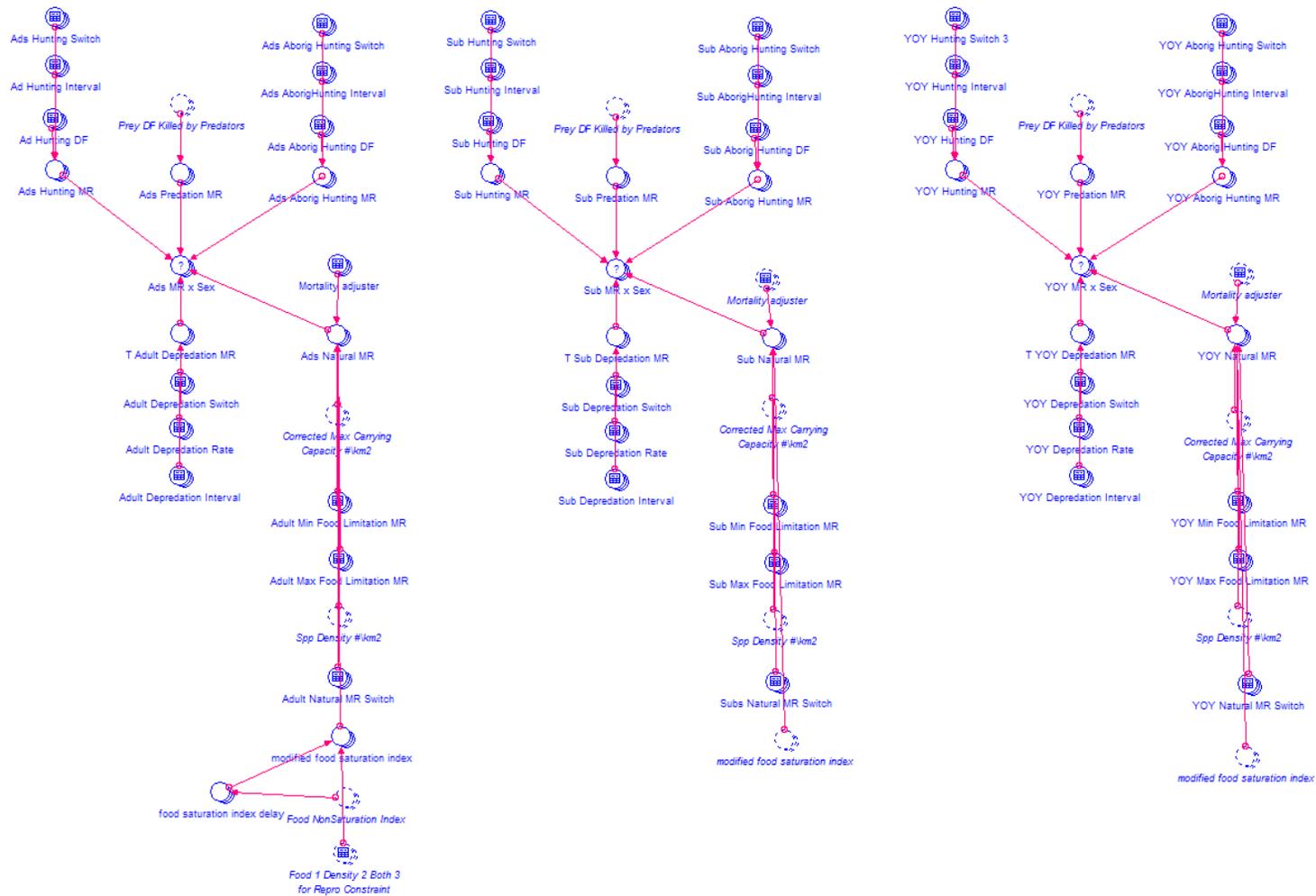


Figure 7. A STELLA map of mortality in the ALCES<sup>®</sup> population model. This diagram shows the structure for accounting several direct and indirect sources of mortality. Each discrete arrangement of icons is associated with an age class that is arrayed for all species. Examples of mortality include hunting, depredation and natural mortality.

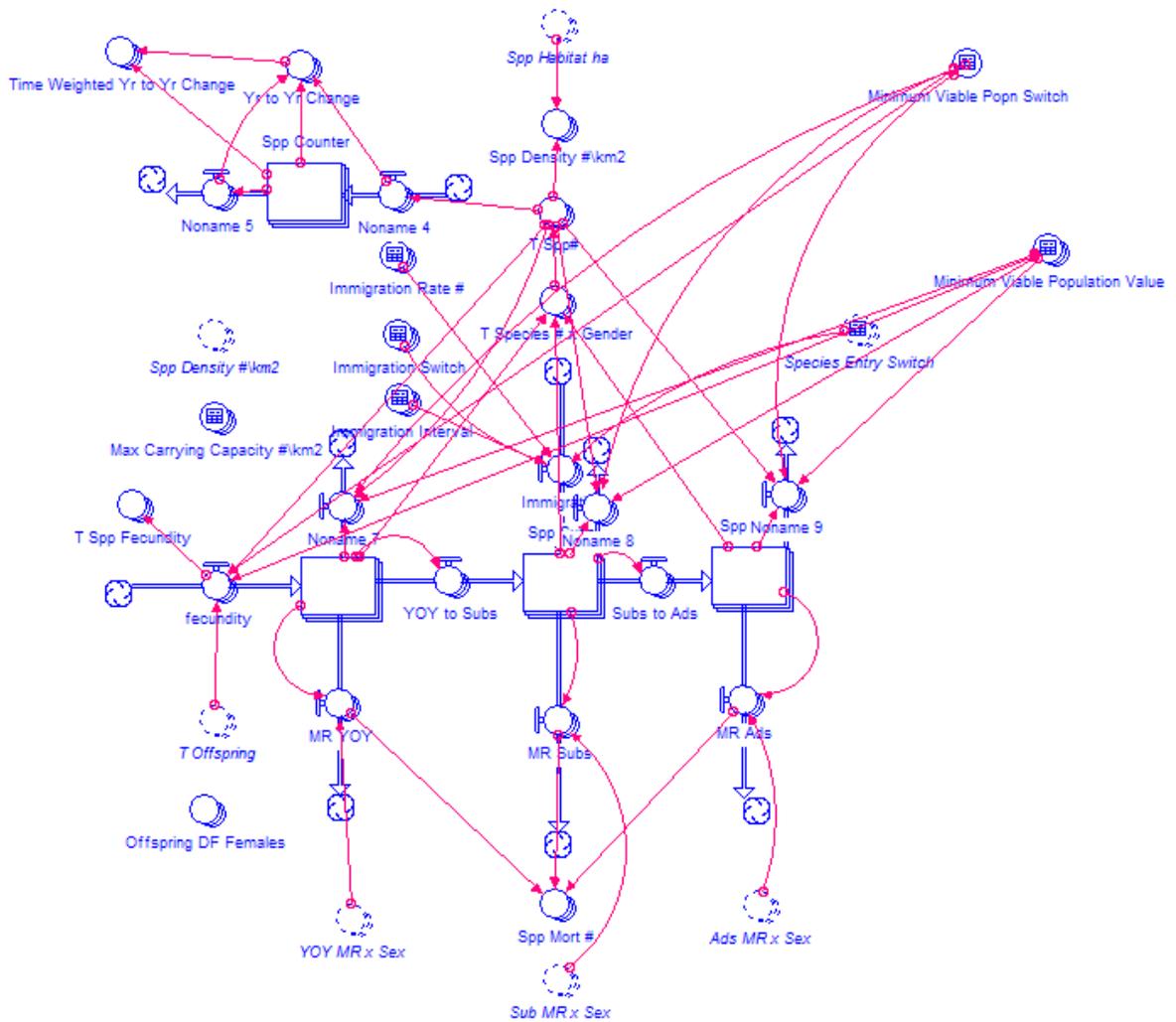


Figure 8. A STELLA map of population structure in the ALCES<sup>®</sup> population model. The main structure of this sub model is illustrated by stocks for each age-class (represented by the 3 rectangular icons in the middle), and their respective inflows (births, recruitment, and immigration) and outflows (mortality).

### 1.6.5.1 Habitat Quality

Moose and deer habitat quality ratings were adopted from CEMA – SEWG assumptions (Wilson et al. 2008) and caribou habitat use and quality ratings from Bradshaw et al. (1995), Culling et al. (2006), and input from the ALT. Wolf habitat quality was assumed to be 1 (high) in all upland habitat types and medium (0.6) in all lowland habitat types to reflect density of prey rather than habitat per se (see Table 3).

In the model, wolf, moose, and deer are able to access unused lowland habitat types on land-use footprints, thereby expanding their population size and distribution on the landscape over time. Although the exact mechanisms of this expansion are unknown, it is consistent with monitored response (see Section 1.6.5.4 below). This assumption is critical for modeling results, because it suggests that deer populations will ultimately expand to the habitat carrying capacity once they are introduced into a landscape area.

Table 3. Habitat use and quality ratings for ALCES<sup>®</sup> landscape types in the Athabasca Landscape area.

ALCES Landscape Type	Moose		Caribou		Deer		Wolf	
	Use <sup>1</sup>	Quality <sup>2</sup>	Use	Quality	Use	Quality	Use	Quality
HW	1	0.9	0	0	1	0.9	1	1
MW	1	0.7	0	0	1	0.7	1	1
Wh_Sp	1	0.6	0	0	1	0.6	1	1
Pine	1	0.4	1	0.3	1	0.4	1	1
Cl BL Sp	1	0.4	1	0.6	1	0.2	1	0.6
Op Bl Spruce Fen	1	0.2	1	1	0	0.1	0	0.6
Bog1	1	0.2	1	0.3	0	0.1	0	0.6
Open Fen	1	0.2	1	0.1	0	0.1	0	0.6
Li Moss	1	0.1	1	0.6	0	0.1	0	0.6
Bl Sp Li Moss	1	0.2	1	1	0	0.1	0	0.6
Sh Wetl	1	0.9	1	0.1	0	0.6	1	1
Nat Herb	1	0.5	0	0	1	0.9	1	1
Lake	1	0	1	0.1	0	0	1	1
River	1	0.3	0	0	0	0	1	1
L Shrub	1	0.7	0	0	1	0.4	1	1
T Shrub	1	0.9	0	0	1	0.4	1	1
Rock	0	0	0	0	0	0	1	1
Beach	0	0	0	0	0	0	1	1
Anthro Herb	1	0.5	0	0	1	0.9	1	1
Unclass	1	0.5	0	0	1	0.5	1	1

<sup>1</sup> 1 = used; 0 = not used

<sup>2</sup> Continuous scale between 0 and 1 where 0 = no quality and 1 = highest possible quality.

### 1.6.5.2 Population Size

Wildlife managers have low confidence in current Athabasca Landscape population estimates because monitoring programs have been designed to track population trends rather than obtain accurate and precise population estimates. Winter 2008/2009 surveys suggest that the Current Assessment (ALT 2008) moose and deer population estimates in northern parts of the Athabasca Landscape area may have been too high (T. Powell. pers. comm.).

To evaluate the influence of initial population size using the population dynamics module in ALCES<sup>®</sup>, we ran multiple 50-year simulations for the ESAR planning area to assess the sensitivity of caribou population trend with respect to five different initial population sizes for each species. All model sensitivity simulations comprised interacting populations of caribou, moose, deer, and wolves in the ESAR planning area under Business as Usual scenario assumptions, which included: i) constant rates of natural disturbance, ii) initial landscape composition with energy and forestry land-use trajectories, iii) relative prey vulnerability (see Section 1.6.5.3) and footprint buffer switches (see Section 1.6.5.4) turned on, and iv) wolf immigration set at 2 immigrants per year.

We did not conduct a fully factorial simulation experiment to assess the effects of initial population sizes of all species on caribou trend because the full combination of initial values (5) and species (4) would have required 625 simulations (*i.e.*, 5 levels x 4 factors =  $5^4 = 625$ ). Instead we ran a compilation of six simulations (Figures 9 to 14) where we changed the initial population sizes of species either singly or in combination, and at five levels, *i.e.*, 0.25, 0.5, 1.0, 1.5, and 2.0 times the current population sizes.

Figure 9 shows that despite a large range in initial caribou population size, caribou are extirpated within 25 years. Figure 10 shows caribou populations starting off from the same level but with varying initial population sizes of wolves. When initial wolf numbers are set at half or a quarter of current guesstimates, the caribou population is able to grow initially and persist for a longer period of time, but ultimately caribou are extirpated once the wolf population grows to reflect the available prey base.

Figures 11, 12, and 13 show the sensitivity of caribou population trend relative to initial population sizes of other prey (moose, deer, and both moose and deer respectively). The trends for these figures are very similar, and show an accelerated rate of decline for caribou when initial populations of moose and deer are lower than the current estimate. This is caused by comparatively higher initial predation rates on caribou because: the initial population of wolves is high relative to total prey biomass; caribou represent a larger proportion of the prey base; and caribou have higher (assumed) vulnerability to predation. Despite marked differences in caribou trend for the first 10 years of the simulation period, overall trends are similar and caribou are extirpated within 30 years in all cases.

Figure 14 shows that caribou population trend is insensitive to initial numbers of moose, deer and wolves because they are extirpated at the end of the 50 year simulation period regardless of initial population values.

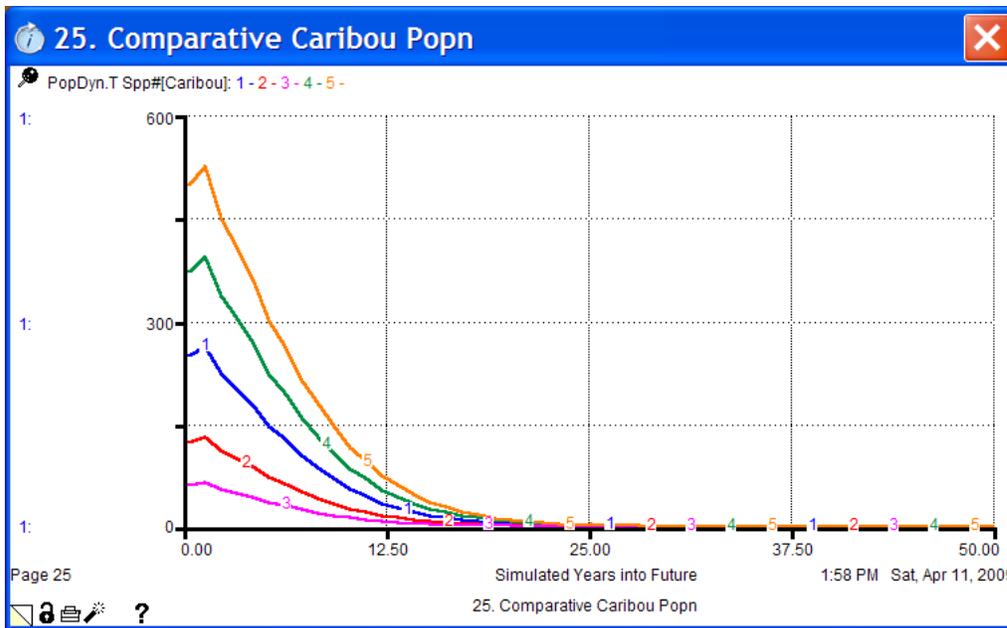


Figure 9. Influence of initial caribou population size on caribou trend in ESAR. Run #1 is based on current population size. Runs #2 (red line) and #3 (pink line) represent simulations with initial caribou population sizes that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial caribou population sizes that were 1.5 and 2.0 times the current population size.

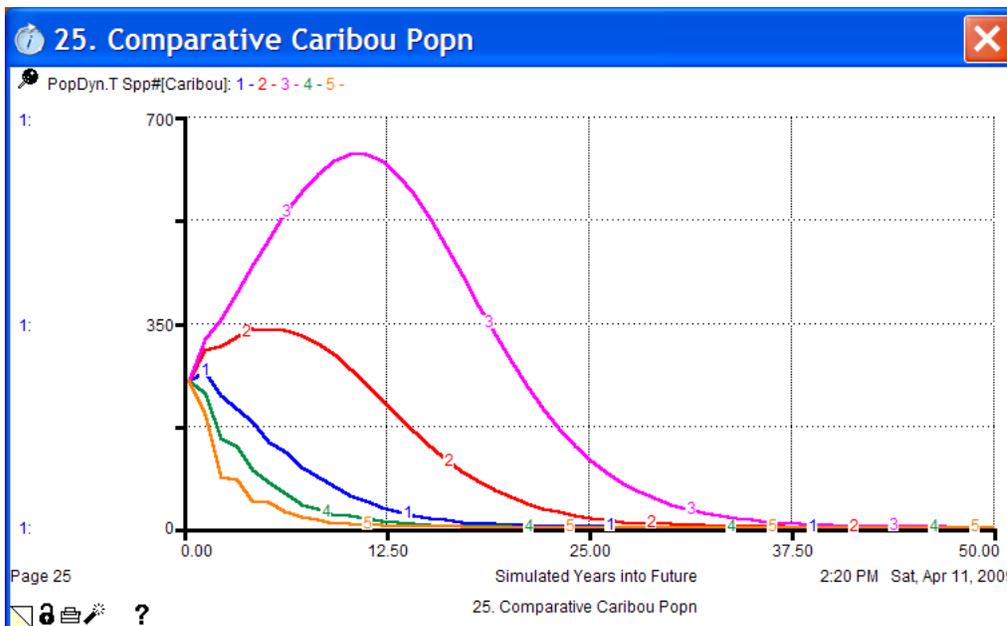


Figure 10. Influence of initial wolf population size on caribou trend in ESAR. Run #1 is based on current population size of wolves. Runs #2 (red line) and #3 (pink line) represent simulations with initial wolf population sizes that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial wolf population sizes that were 1.5 and 2.0 times the current population size.

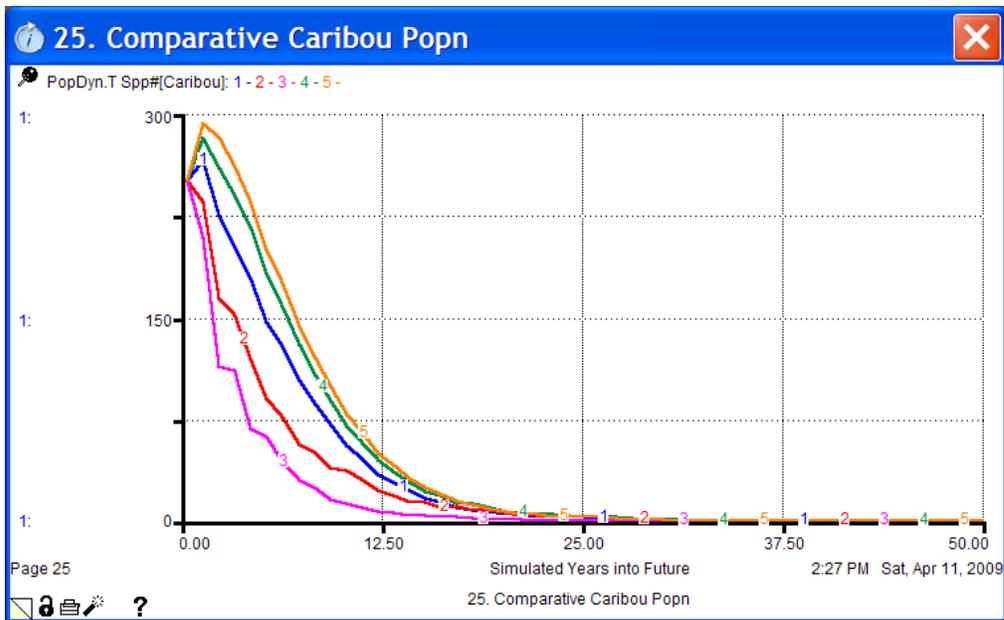


Figure 11. Influence of initial moose population size on caribou trend in ESAR. Run #1 is based on current population size of moose. Runs #2 (red line) and #3 (pink line) represent simulations with initial moose population sizes that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial moose population sizes that were 1.5 and 2.0 times the current population size.

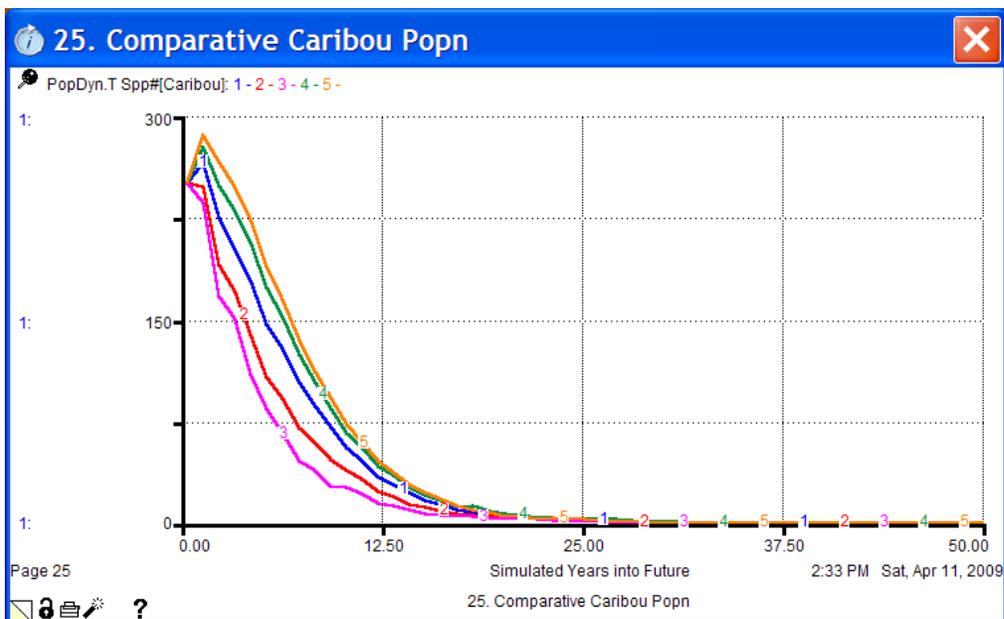


Figure 12. Influence of initial white-tailed deer population size on caribou trend in ESAR. Run #1 is based on current population size of deer. Runs #2 (red line) and #3 (pink line) represent simulations with initial deer population sizes that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial deer population sizes that were 1.5 and 2.0 times the current population size.

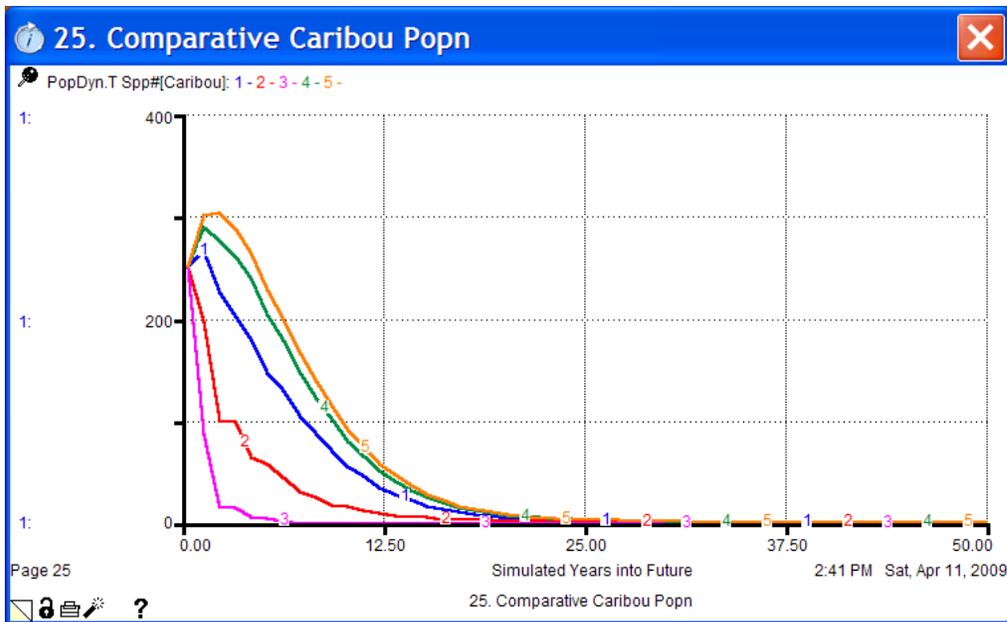


Figure 13. Influence of initial moose and white-tailed deer population size on caribou trend in ESAR. Run #1 is based on current population size of moose and deer. Runs #2 (red line) and #3 (pink line) represent simulations with initial moose and deer sizes that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial moose and deer populations that were 1.5 and 2.0 times the current population size.

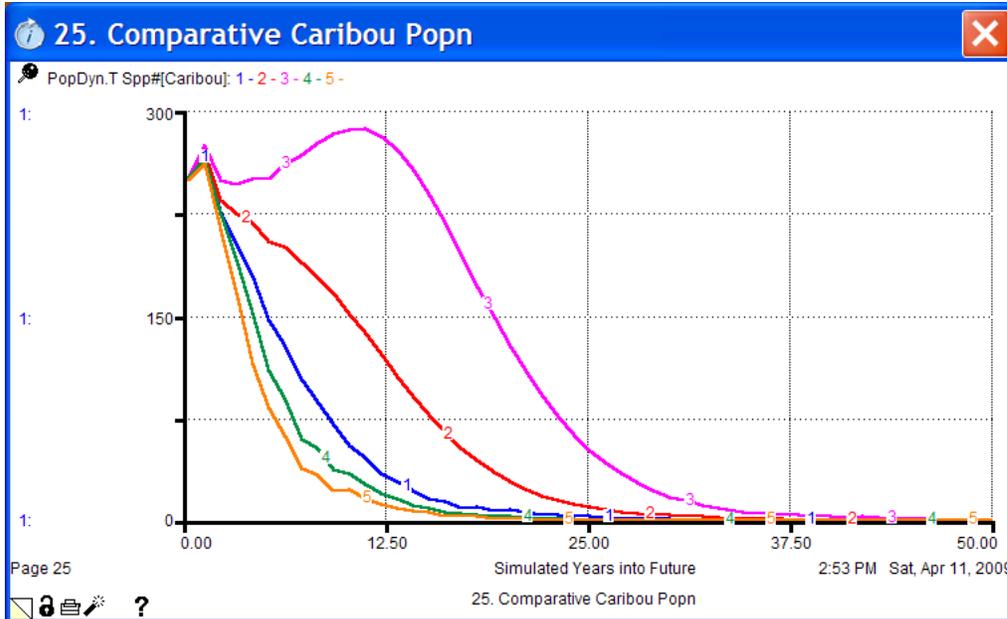


Figure 14. Influence of initial moose, white-tailed deer and wolf population size on caribou trend in ESAR. Run #1 is based on current population size of moose, deer, and wolves. Runs #2 (red line) and #3 (pink line) represent simulations with initial moose, deer, and wolf populations that were 0.5 and 0.25 times the current population size. Runs #4 (green line) and #5 (orange line) represent simulations with initial moose, deer, and wolf populations that were 1.5 and 2.0 times the current population size.

In summary, our sensitivity analyses in the ESAR planning area showed that caribou trend was relatively insensitive to initial sizes of other prey and predator populations because caribou were extirpated within 50 years regardless of initial conditions. This indicates that assumptions regarding birth and death rates are more important than initial population size for longer term dynamics and persistence of populations in the ALCES® population dynamics model.

These sensitivity analyses do indicate that wolf population estimates and trends have the greatest single influence on caribou populations because of the overriding influence of wolf predation on caribou persistence. This influence becomes particularly important when considering wolf depredation strategies in each planning area.

### 1.6.5.3 Vulnerability

The rate at which caribou, moose, and deer encounter wolves is density dependent in the population dynamics model, but subsequent mortality rate for each prey species can be altered with a ‘vulnerability’ coefficient. This coefficient is intended to reflect several interrelated factors including prey cryptic behaviour or encounter response, and wolf preference (e.g., caribou calves are more likely to be killed when encountered than are moose calves because unlike caribou, moose cows defend their calves). In the ALCES® population dynamics module, a switch allows the user to specify whether user-defined prey vulnerability coefficients will be multiplied by the density dependant encounter rate between predator and prey in order to simulate total annual mortality from predation.

Vulnerability coefficients were initially defined based on professional judgement, and systematically refined using sensitivity runs to be consistent with comparative prey consumption reported by Latham (2009) and discussions with ALT members about anticipated future population trends of caribou, moose, wolf, and deer in a multi-species system. The base case vulnerability coefficient (caribou are three times as likely to be killed as deer and six times as likely to be killed as moose) generated caribou decline rates consistent with those extrapolated from lambda calculated from monitoring data.

At the request of the ALT, we ran multiple 50 year simulations to systematically assess the sensitivity of caribou population trend to different vulnerability assumptions. All model simulations comprised interacting populations of caribou, moose, wolf and deer in the WSAR planning area with Business as Usual scenario assumptions.

Figure 15 shows the influence of changing the caribou vulnerability coefficient on caribou population size. Overall trends do not change until caribou vulnerability approaches that of deer (simulation run # 4); this supports observations that caribou predation is not density-dependent, and that caribou are much more vulnerable than deer and moose. Increasing caribou vulnerability (simulation runs #5 through #7) simply increases the rate at which caribou decline and decreases forecast population persistence.

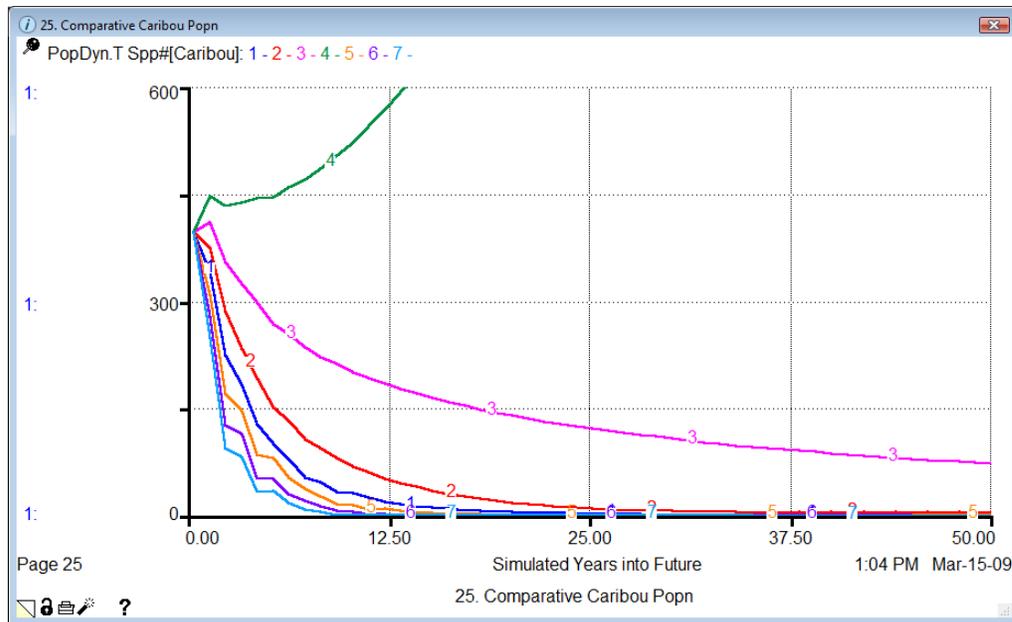


Figure 15. Comparative WSAR runs showing effect of changing caribou vulnerability relative to moose and deer. Scenario run #1 is based on base case values (0.25 for caribou, 0.08 for deer, and 0.04 for moose. Runs #2 (red line) and #3 (pink line) represent simulations with lower caribou vulnerabilities of 0.2 and 0.15. Run #4 (green line) is caribou vulnerability of 0.1 (equivalent to that of deer). Runs #5 (orange line) # 6 (purple line) and #7 (light blue line) represent simulations with higher caribou vulnerabilities of 0.3, 0.35, and 0.4.

#### 1.6.5.4 Spatial Separation of Caribou, Wolves, and Other Prey

Based on ACCRMS input, caribou are assumed to be only partially separated from wolves and other prey. Caribou use mainly lowland habitats (and older low productivity upland pine stands), while moose, deer and wolves mainly use mixedwood uplands. Caribou naturally overlap with other species in the upland pine landscape type (Table 3).

As suggested by the ACCRMS, moose, deer and wolves are able to use previously unselected lowland habitat on clearings and linear corridors, and within a specified Zone of Influence or Buffer (e.g., 100 m) from these footprints. Conversely, we assumed that caribou avoided areas within a specified Zone of Influence or Buffer (e.g., 100 m) from clearings and linear corridors in suitable habitat. In the ALCES<sup>®</sup> population dynamics module, this is achieved by applying buffers with a switch. The user then specifies whether the buffer adds to habitat (i.e., attraction) or reduces habitat (i.e., avoidance). A generalized zone of influence of 100 m of total exclusion or total use was assumed for all Business as Usual and Alternative Future scenario simulations.

Because of constraints within STELLA<sup>®</sup> - the modeling software that ALCES<sup>®</sup> runs in - the model does not currently reflect potential for a reduction in predation risk near linear and polygonal footprints if caribou avoid the linear features while wolves select them. Following release of a new Stella version in 2009, this enhancement could be incorporated for future landscape planning projects if desired.

## **1.7 BEST PRACTICE OPTIMIZATION**

ALCES<sup>®</sup> was used to run a factorial simulation experiment that varied best practice levers across three levels: current, intermediate, and best. Multiple regression was applied to the simulation results to model the relationship between best practice implementation and caribou Habitat-Based Population Performance at year 50. The explanatory variables were % implementation of each best practice lever, where 0.0 is the “current” level for a best practice lever and 1.0 is the “best case” level of a best practice lever. The best practice strategies are presented in Table 4.

In order to evaluate the potential reclamation effort (and associated costs) of coordinated reclamation, we summarized current length of three linear features (seismic lines, temporary roads, and pipelines) within the Athabasca Landscape planning areas. Table 5 shows the current cumulative lengths of each linear footprint type within each of the planning areas, and provides an estimate of reclamation effort required during the first year for the current (5%/year), intermediate (10%/year) and best case (15%/year) scenarios for pulsed reclamation.

Table 4. Best practices management levers used in optimization simulations for the Athabasca Landscape area.

Management Lever	Footprint Type	ALCES Variable	Current	Intermediate Case	Best Case
Feature overlap	Minor roads	Overlap modifier[Min Road]	15%	22.5% (required that minor road be changed from 20% to 22.5%)	30% (required that minor road be changed from 25% to 30%)
	In block road	Overlap modifier[Inbl Rd]			
	Delineation (i.e. exploratory) well access roads	Overlap modifier[Min Road]			
Wells per pad	In-situ production wells	Wells/Pad Modifier[In-situ]	10 wells/pad	28 wells/pad	44 wells/pad
Immediate reclamation of pipeline post construction	Minor Pipeline	Imm Reclaimed modifier[pipeline]	25%	37.5%	50%
Well and road lifespan	Delineation well access	Well Rd Lifespan Modifier[DryExpl]	35 years	20 years (required that temporary forestry roads be changed from 22.5 to 20 years)	10 years
	Delineation well	Wellpad Life Modifier[DryExpl]			
	Temporary road (forestry)	FT Lifespan Modifier[Inbl Rd]			
Oilsand mine lifespan	Mine	FT Lifespan Modifier[Oilsands pit]	100 years	50 years	25 years
Seismic lifespan	Seismic	FT Lifespan Modifier[Seismic]	10 years	6 years	2 years
Coordinated reclamation	Seismic lines	Pulse Reclamation interval[Seismic]	5% per year	10% per year	15% per year
	Temporary roads	Pulse Reclamation interval (Temp Roads)			
	Pipelines	Pulse Reclamation interval[Pipeline]			

Table 5. Current length of linear features within Athabasca Landscape planning areas and associated length of features to be reclaimed in the first year of a pulse reclamation simulation at three levels of reclamation effort. Reclamation lengths will vary in subsequent years depending on assumptions for growing and reclaiming linear features in each of the planning areas.

Athabasca Landscape range planning area	Current Total Length (km)	Pulse Reclamation Rate		
		5% (km)	10% (km)	15% (km)
<b>CLAWR</b>				
Temporary Roads	2,586	129	259	388
Seismic lines	9,537	477	954	1,430
Pipelines	4,215	211	422	632
<b>ESAR</b>				
Temporary Roads	10,181	509	1,018	1,527
Seismic lines	39,873	1,994	3,987	5,981
Pipelines	11,297	565	1,130	1,694
<b>ESAR inside BF</b>				
Temporary Roads	4,068	203	407	610
Seismic lines	18,989	949	1,899	2,848
Pipelines	6,088	304	609	913
<b>ESAR outside BF</b>				
Temporary Roads	6,113	306	611	917
Seismic lines	20,884	1,044	2,088	3,133
Pipelines	5,209	260	521	781
<b>ESAR - East</b>				
Temporary Roads	1,096	55	110	164
Seismic lines	4,424	221	442	664
Pipelines	260	13	26	39
<b>ESAR - West</b>				
Temporary Roads	5,016	251	502	752
Seismic lines	16,460	823	1,646	2,469
Pipelines	4,949	247	495	742
<b>Richardson</b>				
Temporary Roads	2,467	123	247	370
Seismic lines	4,960	248	496	744
Pipelines	236	12	24	35
<b>WSAR</b>				
Temporary Roads	8,371	419	837	1,256
Seismic lines	34,754	1,738	3,475	5,213
Pipelines	6,631	332	663	995

## 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 16). 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 caribou range polygon shown on Figure 16 was defined based on 15 years of telemetry data and incorporates small patches of upland mixedwood habitat. Defined habitat represents a total area of 1,502,268 ha, or 45% of the planning area (Table 1) and unlike other ranges and planning areas, consists of a large, relatively contiguous polygon.

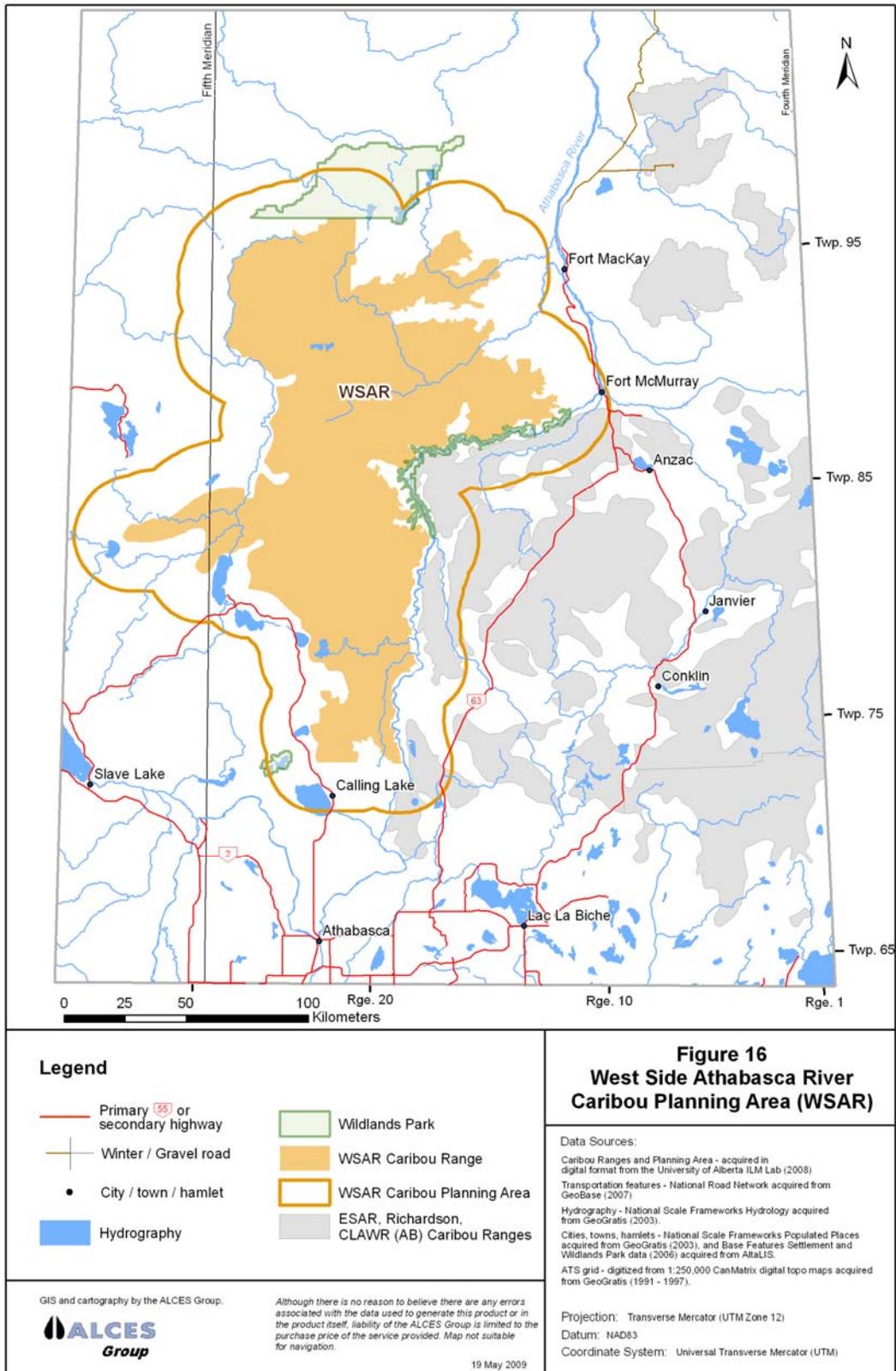
WSAR caribou habitat is relatively intact compared to other planning areas in the Athabasca Landscape area, and the ALT proposed two candidate Zone 1 areas in the northern and southern parts of the planning area (Figure 17). Approximately 7% of the WSAR was classified as young forest (<30 years old); young forest is most common in the buffer outside defined caribou range. Total current land-use footprint is 107,241 ha, or 3.2% of the planning area. Harvest blocks contribute just over half of this footprint. Seismic lines and hydrocarbon development comprise most of the remaining footprint. Linear corridor density is currently much lower in the north half of the planning area (ALT 2008).

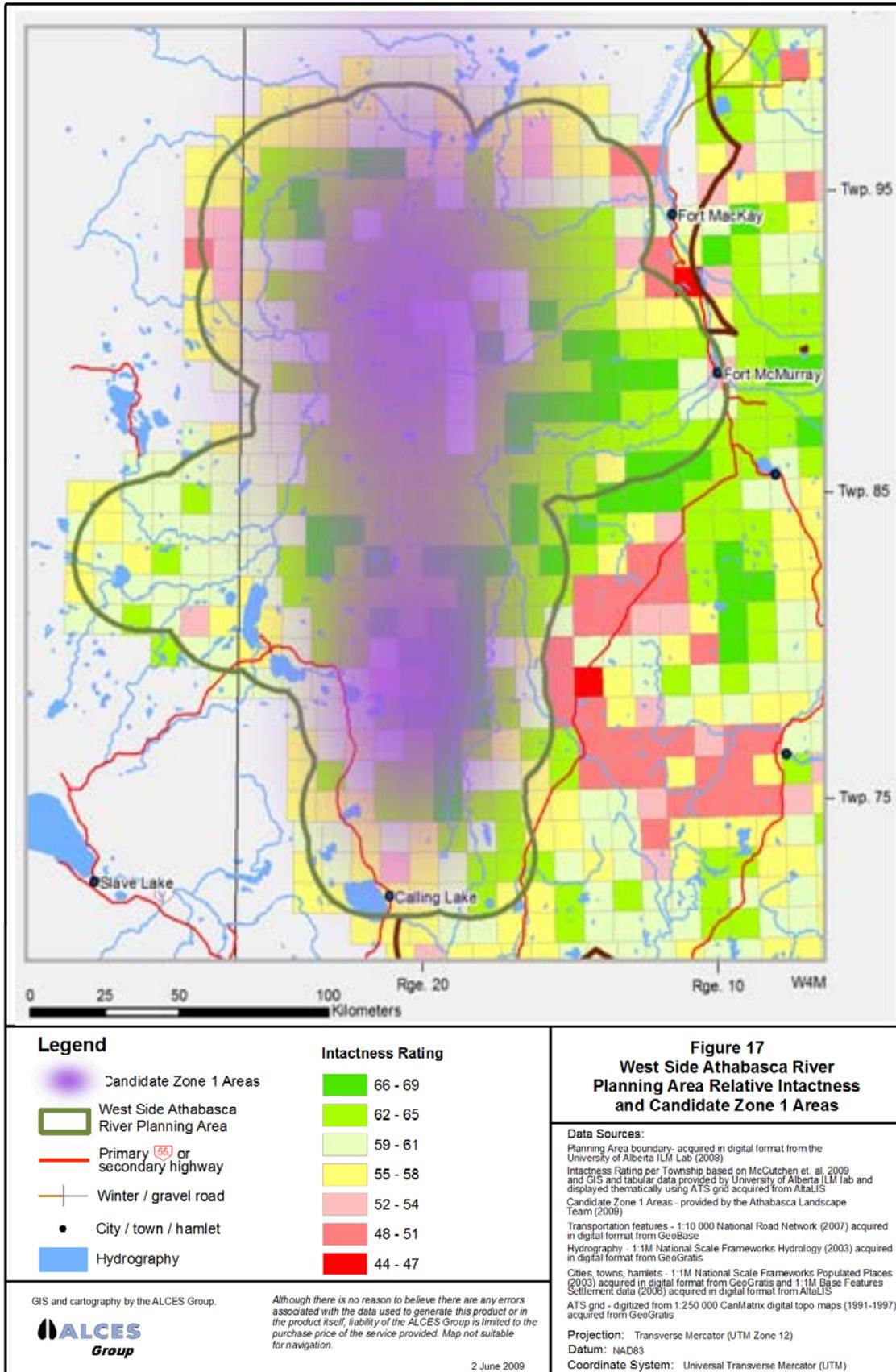
Caribou in the southern WSAR planning area have been monitored for 15 years; this sub-population is guesstimated to include fewer than 400 animals as of April 2008. Wolf density is currently very high in at least the southern half of the WSAR and this appears to have resulted in sub-population declines. White-tailed deer have been observed in the lowland caribou habitats in the planning area, often several kilometres from upland areas. 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 for the last ten years (0.975 +/- 0.034), is much higher than current values (ALT 2008).

Three protected areas overlap this planning area: Birch Mountain, Grand Rapids, and Otter-Orloff Lakes Wildland Park.

The WSAR has the lowest risk rating of all Athabasca Landscape area 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 tenures than other areas, long-term development risk is rated as high because much of it is tenured for in-situ bitumen and forestry activities.





## 2.1 NON-INDUSTRIAL SCENARIO

Non-industrial scenario simulations for caribou and moose in the WSAR planning area show that caribou and moose numbers fluctuate naturally in response to the combined effects of random fire and insect disturbance, forest succession, and predation (Figures 18 and 19).

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 or deer present. Current estimated caribou abundance (<400) is substantially lower than their simulated natural population range while the estimated moose population (5,000) is within the simulated range. These results are consistent with our current understanding that boreal caribou are lower than their expected range of natural variability in the Athabasca Landscape area, and that moose are generally closer their natural range.

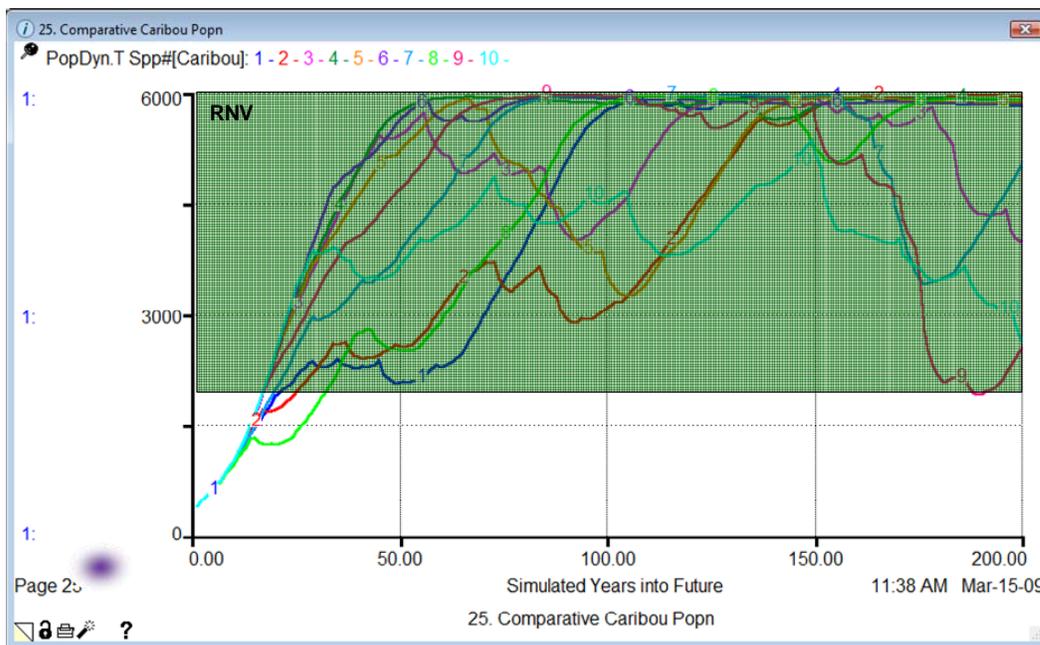


Figure 18. Forecast non-industrial caribou population in WSAR planning area (assumes random disturbance, wolves and moose present at current numbers; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

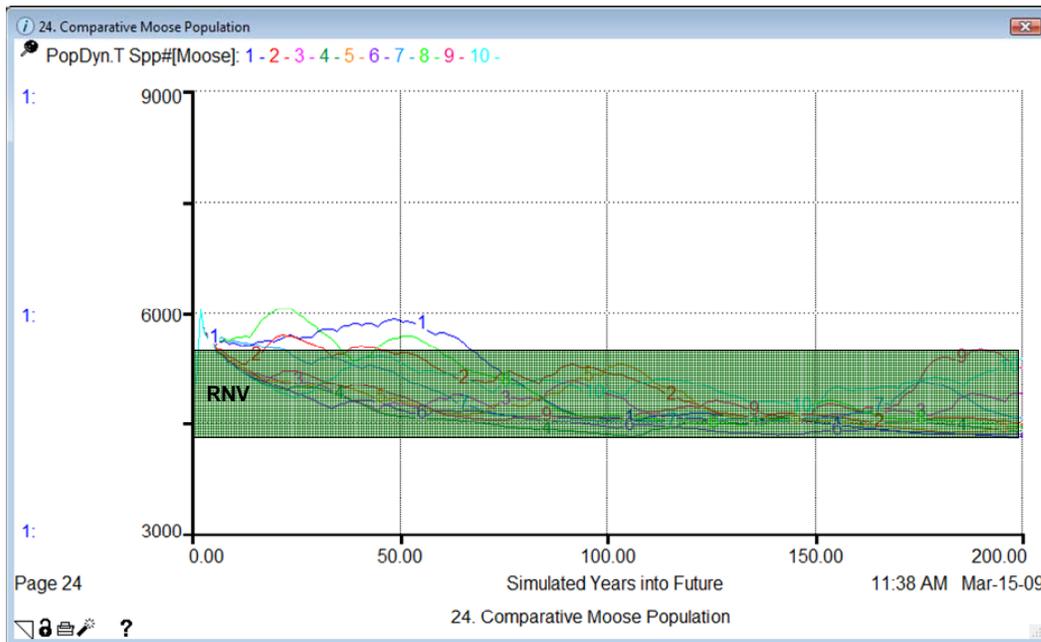


Figure 19. Forecast non-industrial moose population in WSAR planning area (assumes random disturbance, wolves and moose present at current numbers; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

## 2.2 BUSINESS AS USUAL SCENARIO

Business as Usual 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 20, deer numbers rapidly increase to a density of 65/100 km<sup>2</sup>, wolves increase to a density of 1.4/100 km<sup>2</sup>, and moose increase slowly to a density of 20/100 km<sup>2</sup>.

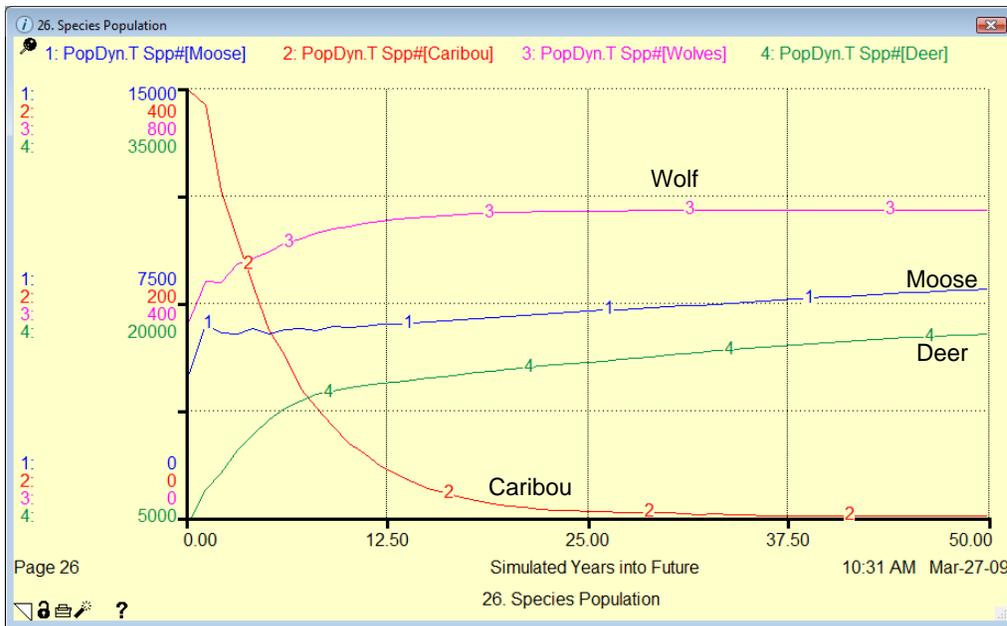


Figure 20. Forecast Business as Usual caribou, moose, wolf, and deer population size in WSAR planning area (assumes constant disturbance, all species at current numbers; standard vulnerability and buffers assumptions; forecast land-use; 50 year simulation period).

## 2.3 ALTERNATIVE FUTURES SCENARIO

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 2.3.1, 2.3.2, and 2.3.3, respectively.

### 2.3.1 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 best practices on a project-by-project basis to reduce future land-use footprint size or lifespan.

#### 2.3.1.1 Future Footprint Minimization

Figure 21 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 21 shows that in WSAR, the most effective option is to reduce the future footprint of all industrial sectors and simultaneously increase the fire return interval through fire suppression. Results show that future in-situ development has the greatest effect on habitat function. Therefore simulations that reduce this footprint by reducing future bitumen production rates have the largest single influence on habitat recovery (IS in Figure 21). The influence of the forestry footprint is smaller, but reducing the future softwood and hardwood harvest footprint would measurably improve habitat potential (F, HW, and SW simulations in Figure 21). 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 in Figure 21).

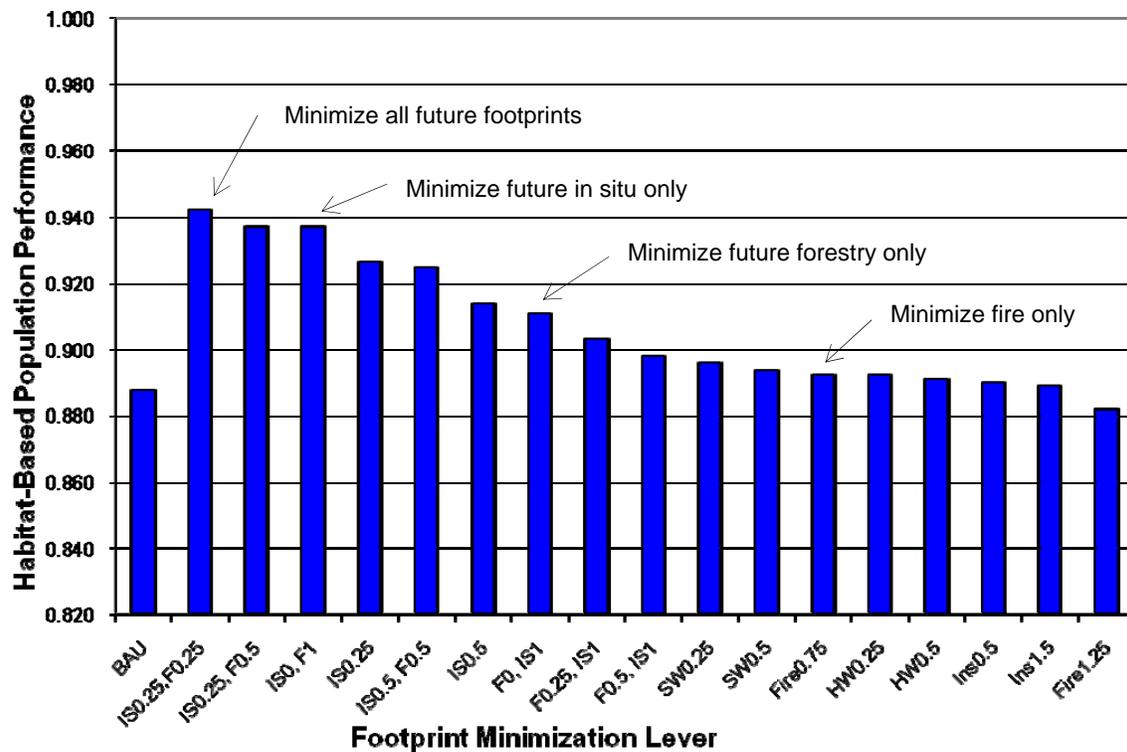


Figure 21. Influence of footprint minimization levers in the WSAR planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers following footprint codes represent proportional change from BAU assumptions. For example "IS0.25,F0.25" [2<sup>nd</sup> bar] means that in-situ and forestry footprint were both reduced to 25% of BAU projections).

### 2.3.1.2 Coordinated Reclamation and Best Practices

Figure 22 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 21 (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 22). Optimization simulations indicate that the influence of coordinated reclamation diminishes after 10-15 years when most historic footprint has been reclaimed. Shortening delineation well access road lifespan by using minimum ground disturbance construction methods and rapid reforestation has the next largest effect (DAR simulations in Figure 22, number after represents lifespan in years, compared to BAU assumption of 35 years).

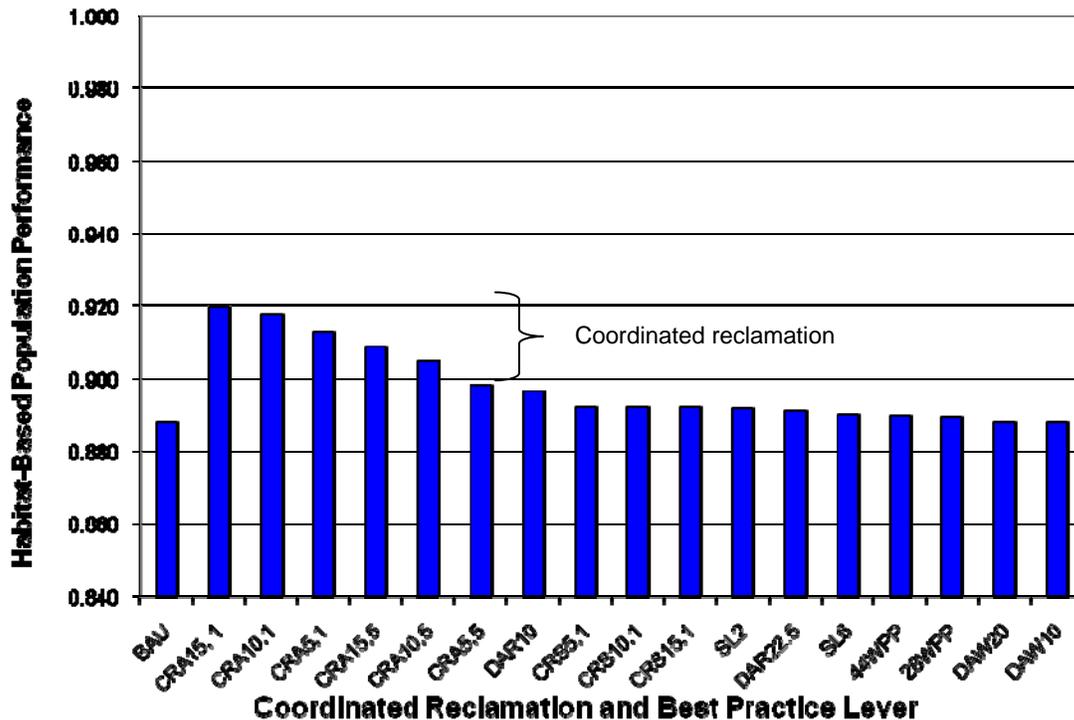


Figure 22. Influence of coordinated reclamation and best practices levers in the WSAR planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; DAW = 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” [2<sup>nd</sup> bar] means that coordinated reclamation of seismic, pipelines and temporary roads were reclaimed at 15% at a one year interval; “SL2” [12<sup>th</sup> bar] indicates a seismic line length of 2 years compared to the BAU assumption of 10 years; and “44WPP” [15<sup>th</sup> bar] indicates 44 production wells per pad compared to the BAU assumption of 10/pad.).

Conducting coordinated seismic line reclamation (CRS), increasing the number of production wells per pad (WPP) and reducing lifespans of seismic lines (SL), delineation well roads (DAR), and delineation wellpads (DAW) also have a beneficial effect on future Habitat-Based Population Potential (bars 9-16 in Figure 22), but their incremental effect is comparatively small relative to other levers considered

### **2.3.2 Mortality Management Levers**

ALCES<sup>®</sup> simulations of WSAR with footprint management levers, coordinated reclamation, and to a lesser extent best practices 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 in response to the rapidly increasing deer population and slowly increasing moose population size. This indicates that high caribou predation will continue for decades, regardless of whether habitat restoration is implemented in the short-term. Simulation results for WSAR indicate that some form of mortality management lever (wolf control, with or without other prey control; or cow-calf penning) is needed to prevent caribou extirpation within two to four decades.

As anticipated, the simulated success of predator control was highly dependent on assumptions regarding wolf control (depredation) rate, control interval, and wolf immigration rate (Figure 23). Sensitivity simulations for the WSAR planning area suggest that with a wolf immigration rate of 50/year, wolf control should occur at a minimum interval of 5 years, and remove at least half of the wolves in the area for every iteration (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.

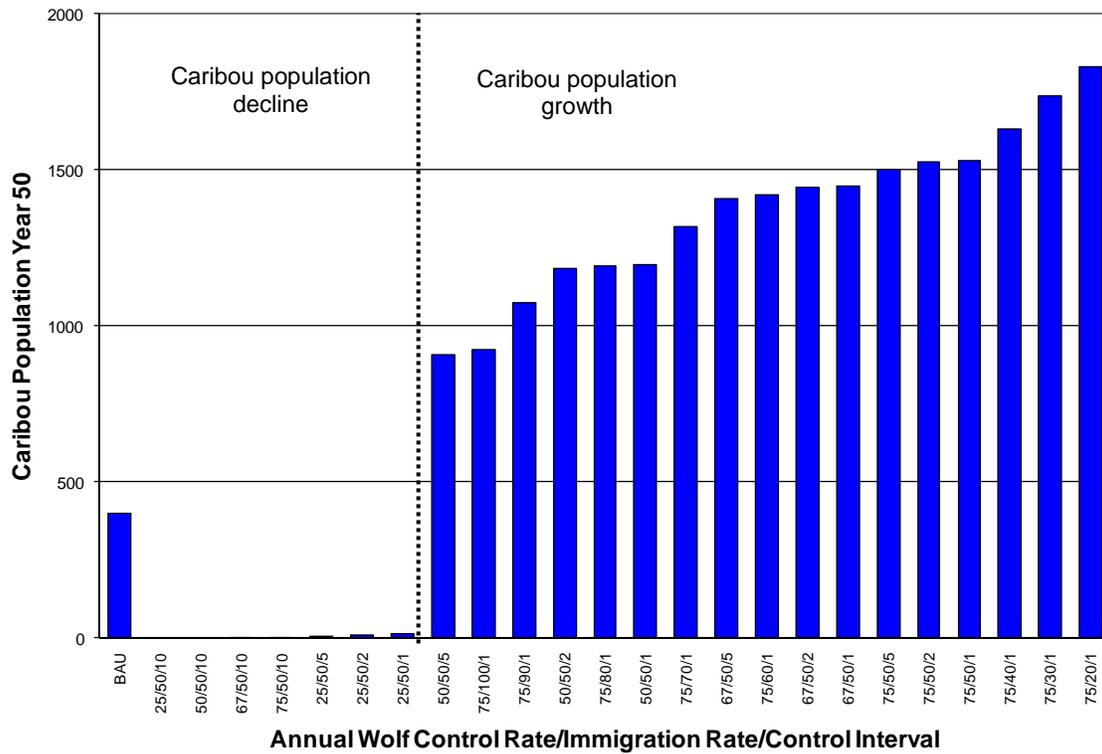


Figure 23. Interaction between wolf control and wolf immigration rates on simulated caribou population in the WSAR planning area (Numbers on y-axis reflect assumed annual wolf control rate/wolf immigration rate/control interval in years for that simulation. For example “50/50/5” [9<sup>th</sup> bar] means that 50% of the wolves are removed, there are 50 wolves immigrating in to the area every year, and wolf removal is done at 5 year intervals).

Simulations on cow-calf penning (pulled as a single management lever under Business as Usual assumptions), with the proportion of cows penned ranging from 8% to 25%, and at 1, 2, and 5 year intervals indicated that the associated increase in calf survival would not substantially improve population trend of the WSAR caribou population over a 50 year period. Figure 24 shows the population becoming extirpated within 50 years despite a cow penning scenario where 25% of all pregnant cows were captured and penned annually.

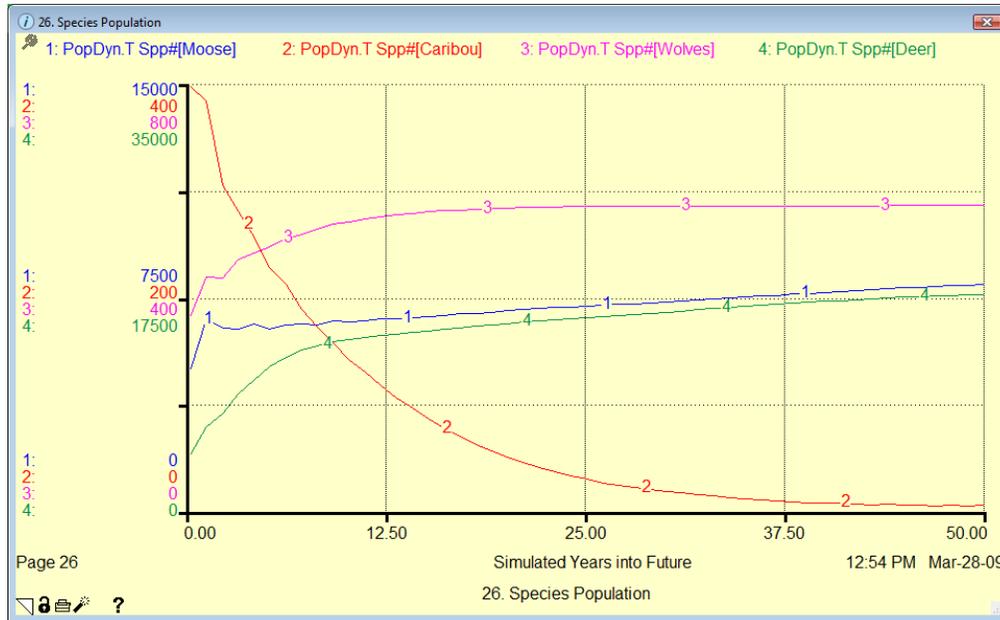


Figure 24. Influence of an annual cow – calf penning program on predator and prey populations in the WSAR planning area (25% cows penned annually, with 80% calf mortality reduction and initial population size of adult females was 130 animals).

Results of other prey control simulations are less straightforward because reduced densities of other prey can increase short-term caribou predation (i.e., prey switching) in the absence of simultaneous wolf control. The 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.

### 2.3.3 Combined Management Levers

Simultaneous application of all management levers will be required to recover and sustain caribou in the WSAR 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.

### 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 25). The defined range consists of isolated peatlands in a mixedwood landscape. Small to medium-sized watercourses drain uplands along the eastern edge of the planning area.

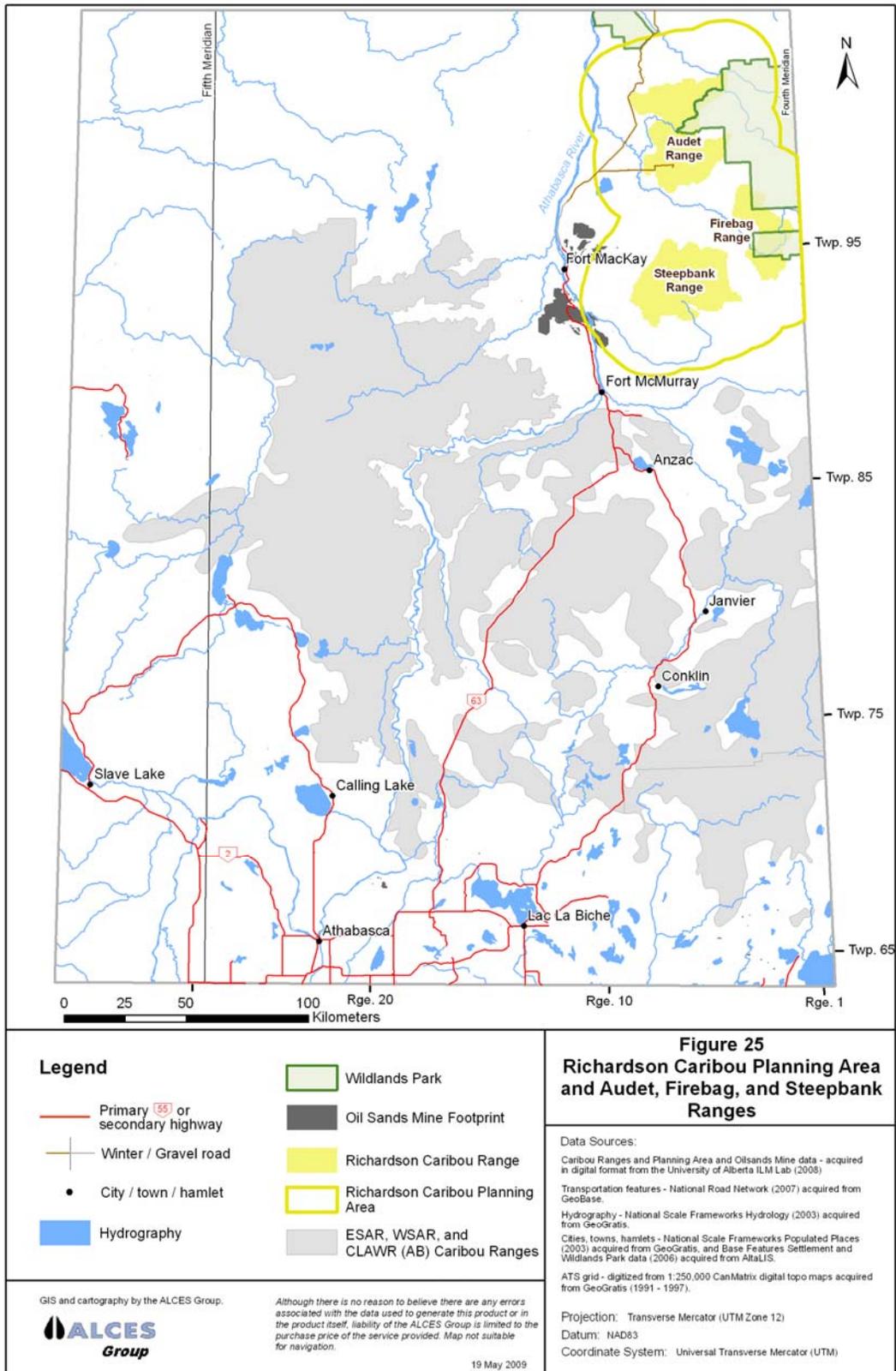
Richardson caribou are poorly understood and few data exist for the 3 potential ranges (herds) identified in the planning area (Audet, Firebag, and Steepbank). Total caribou number in this area is guesstimated to be less than 100 by ASRD (ALT 2008). During winter 2008/2009 surveys, a minimum of 91 caribou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

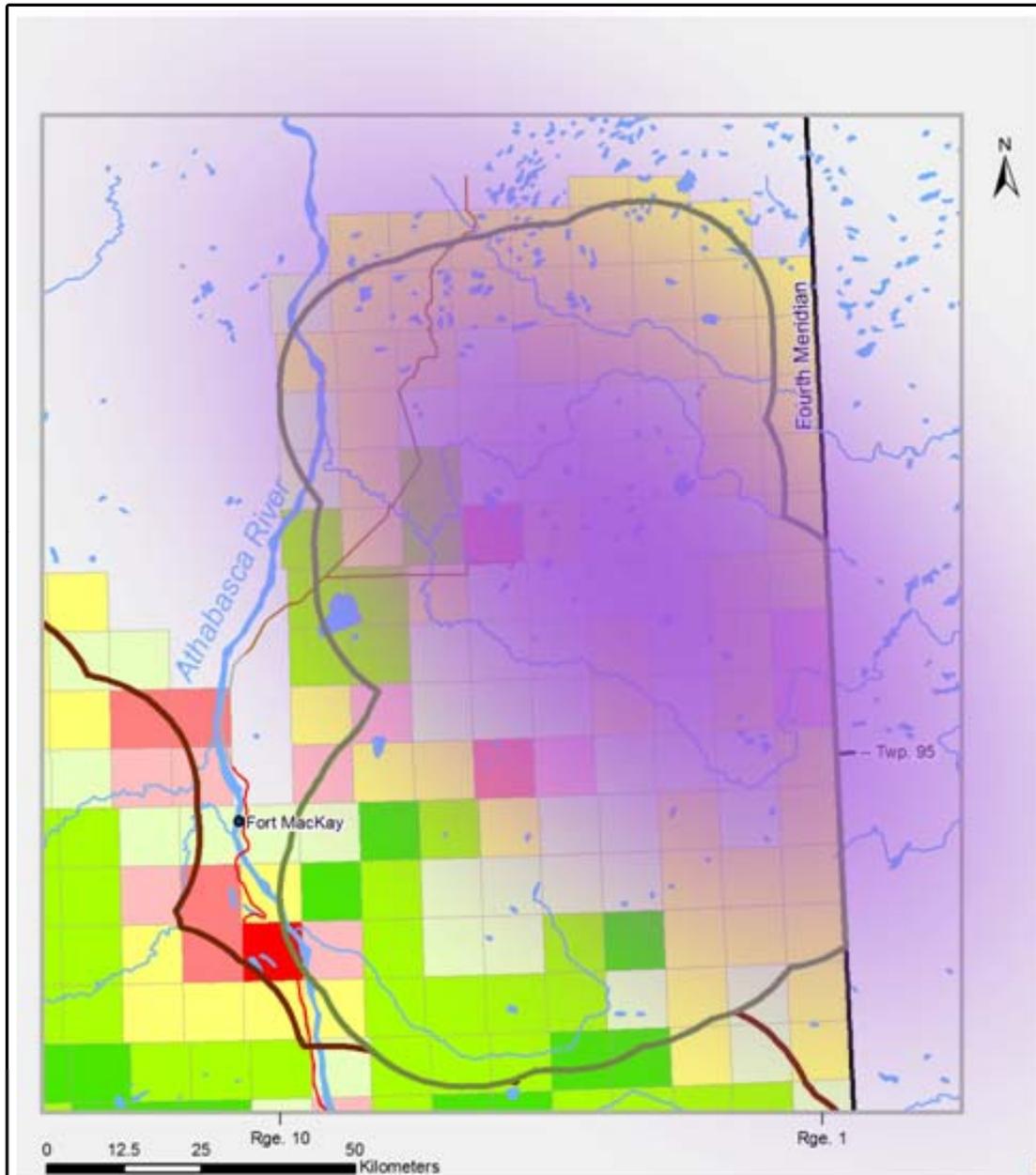
Range polygons shown on Figure 25 were described with wetland/peatland data (% polygons) and expert opinion (Halsey and Vitt, Rippin and Gunderson, ASRD). These discrete caribou habitat areas comprise a total area of 268,717 ha, or 24% of the planning area (ALT 2008). Because these caribou habitats are 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 26). 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 area during winter 2008/2009 (T. Powell pers. comm.).

Seismic lines are the most common linear corridors in the planning area, and linear feature density is highest in the Steepbank range polygon. Commercial bitumen reserves and anticipated development activities overlap the Steepbank caribou habitat area, but forest harvest is projected to have comparatively limited effect on habitat in this planning area (ALT 2008).

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 Richardson planning area. The Maybelle River Wildland Provincial Park is just north of the northern boundary of the planning area (Figure 25).





**Legend**

- Candidate Zone 1 Area
- Richardson Planning Area
- Primary <sup>(SS)</sup> 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

GIS and cartography by the 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 26**  
**Richardson Planning Area**  
**Relative Intactness and**  
**Candidate Zone 1 Area**

**Data Sources:**

Planning Area boundary - 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  
 Candidate Zone 1 Area - provided by the Athabasca Landscape Team (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 (2008) 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)

Although the Richardson planning area is moderately intact relative to other Athabasca Landscape planning areas (Figure 26), 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. Long term development risk for the Steepbank range is high because thick bitumen deposits occur over much of the range. Development risk appears to be lowest in the Audet range, highest in the Steepbank range, and intermediate in the Firebag range.

### 3.1 NON-INDUSTRIAL SCENARIO

Based on ten random model simulations, between 700 and 900 caribou could be supported in the Richardson planning area with no wolves or land-use footprints (Figure 27). If wolves and moose are introduced into this system, caribou numbers fluctuate cyclically and can be driven to extirpation through predator-prey dynamics on this small population.

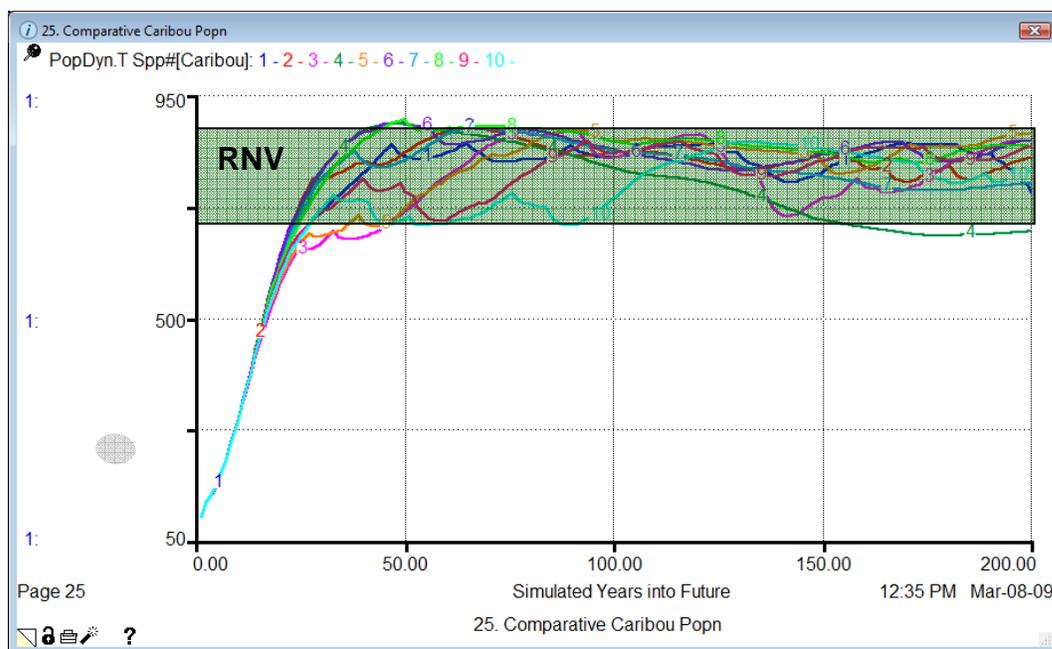


Figure 27. Forecast Non-industrial caribou population in Richardson planning area (assumes random disturbance; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

### 3.2 BUSINESS AS USUAL SCENARIO

The current guesstimate for 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 footprint and young forest increase and Habitat-Based Population Performance indicator declines from 0.98 to 0.90, and as shown in Figure 28, deer numbers increase to an average density of 40/100 km<sup>2</sup>, wolves increase to a density of 1.8/100 km<sup>2</sup>, and moose increase slowly to a density of 17/100 km<sup>2</sup>.

### 3.3 ALTERNATIVE FUTURES SCENARIO

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 3.3.1, 3.3.2, and 3.3.3, respectively. Management levers and assumptions for the Richardson planning area were identical to those for the WSAR planning area, with the exception that for wolf control simulations in the Richardson area, wolf immigration rate was reduced (from 50/year to 25/year) to account for its smaller area.

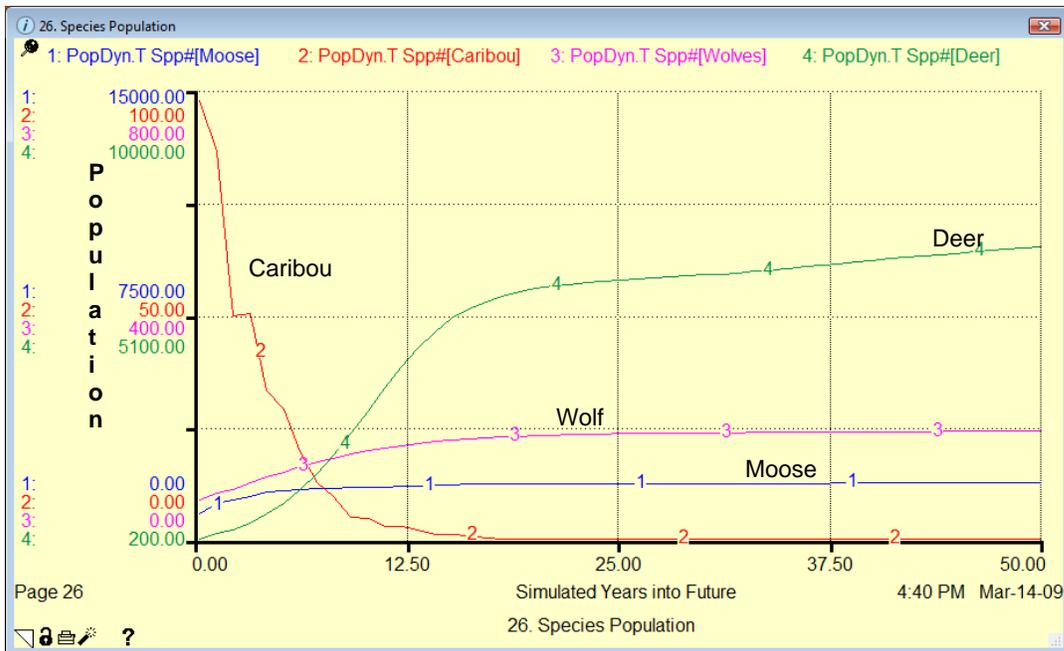


Figure 28. Forecast caribou, moose, wolf, and deer populations in Richardson planning area with Business as Usual assumptions and constant disturbance.

### 3.3.1 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 best practices on a project-by-project basis to reduce future land-use footprint size or lifespan.

### 3.3.2 Footprint Minimization

The chart provided in Figure 29 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.

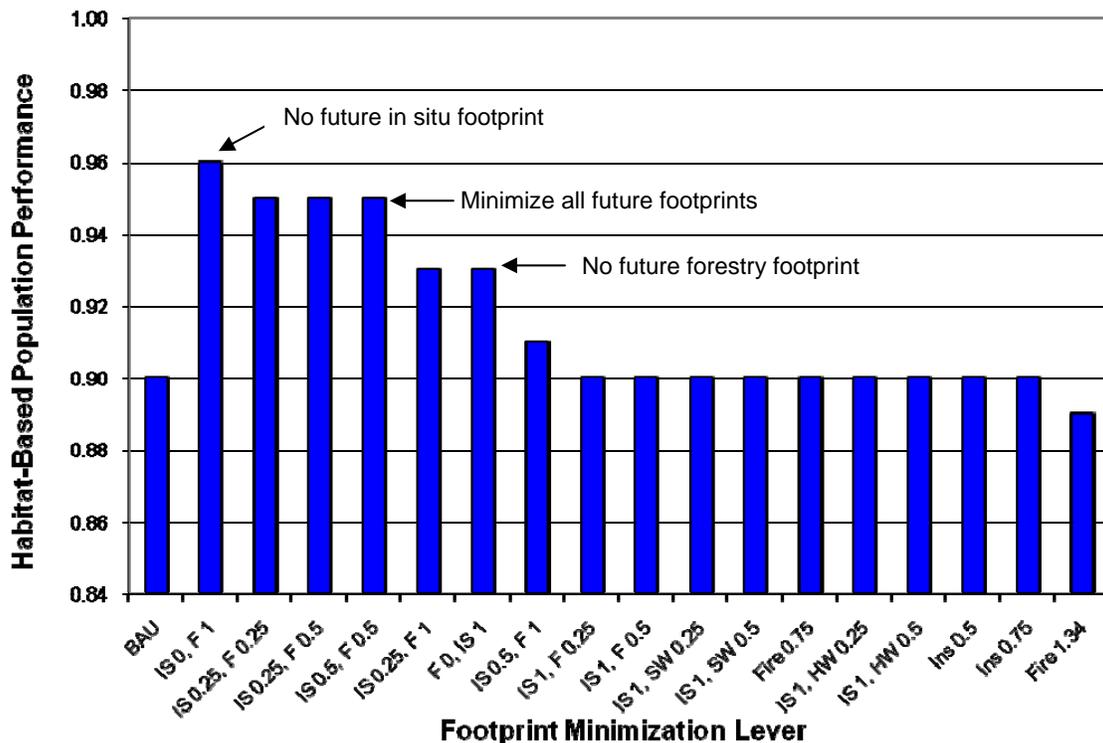


Figure 29. Influence of footprint minimization levers in the Richardson planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions).

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 had no effect on Habitat-Based Population Performance.

### 3.3.2.1 Coordinated Reclamation and Best Practices

Figure 30 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 29 (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 30) has the largest incremental effect on functional habitat restoration, followed by feature overlap (not shown in Figure 30), shortening delineation well access road lifespan (DAR simulations in Figure 30), and shortening seismic line lifespan (SL simulations in Figure 30).

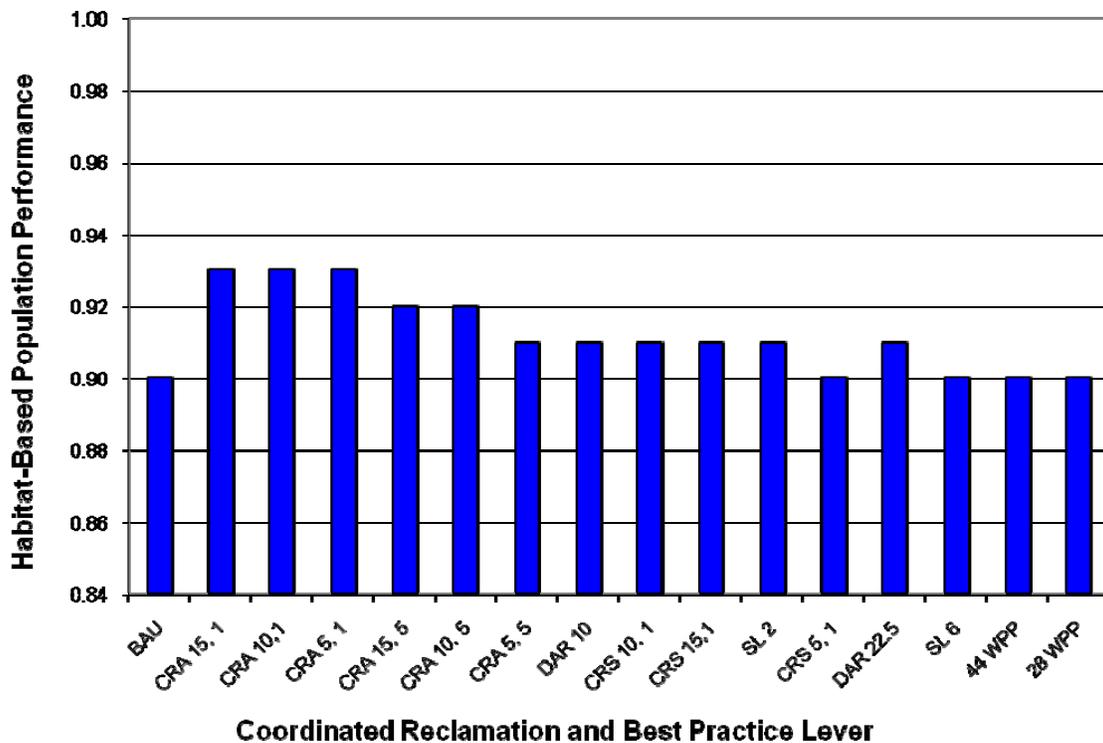


Figure 30. Influence of coordinated reclamation and best practices levers in the Richardson planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; 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).

### 3.3.3 Mortality Management Levers

Simulations of the Richardson planning area with footprint management levers, and coordinated reclamation resulted in the greatest improvements to 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 depredation, 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 (Figure 31). This outcome was sensitive to assumed wolf immigration rates: for example, changing assumed wolf immigration rate from 25 to 30 per year resulted in a change from caribou growth to population decline.

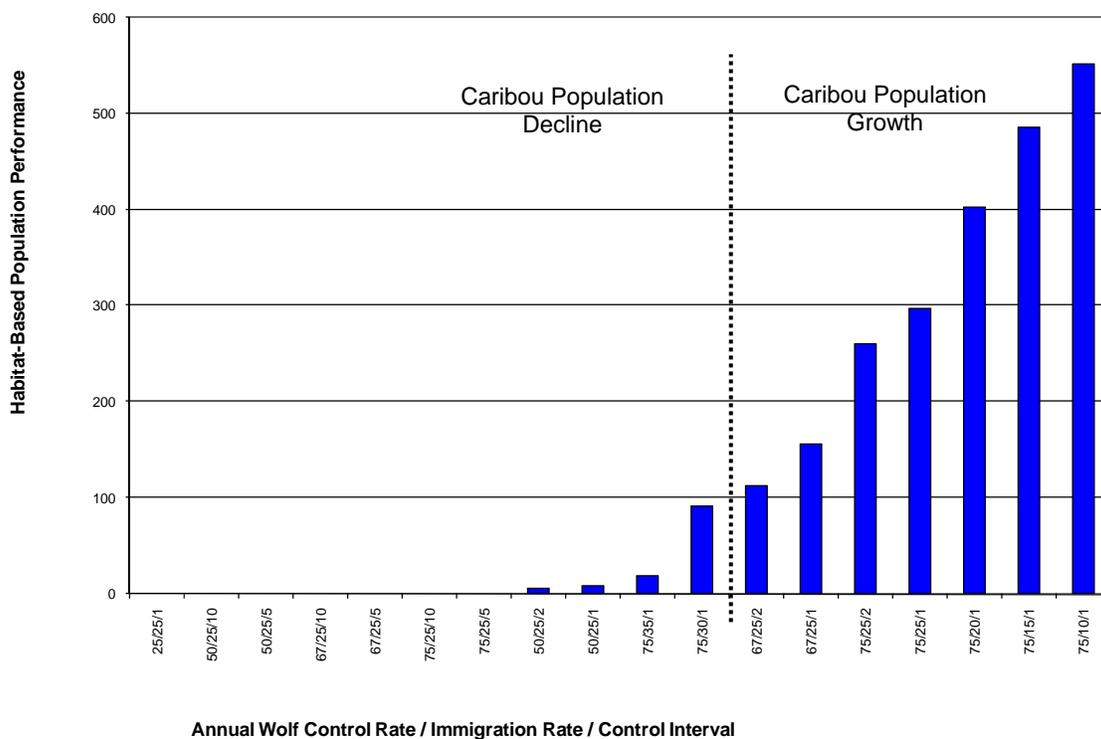


Figure 31. Interaction between wolf control and wolf immigration rates on simulated caribou population in the Richardson planning area.

Based on the small number of adult females ( $n=41$ ) currently in the Richardson planning area (see Supplemental Data Table 1), cow-calf penning simulations for this area were conducted with the proportion of cows penned set at 60% and 100%, with penning intervals of 1, 2, and 5 years (to achieve the calf survival targets identified by the ALT). 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 32). Due to the small size of the Richardson population, simulation results where 100% of the cows were penned were also highly sensitive to assumptions on frequency of penning

events. Figure 33 shows that caribou did not persist in a 50-year simulation where 100% of the cows were penned every 2 years.

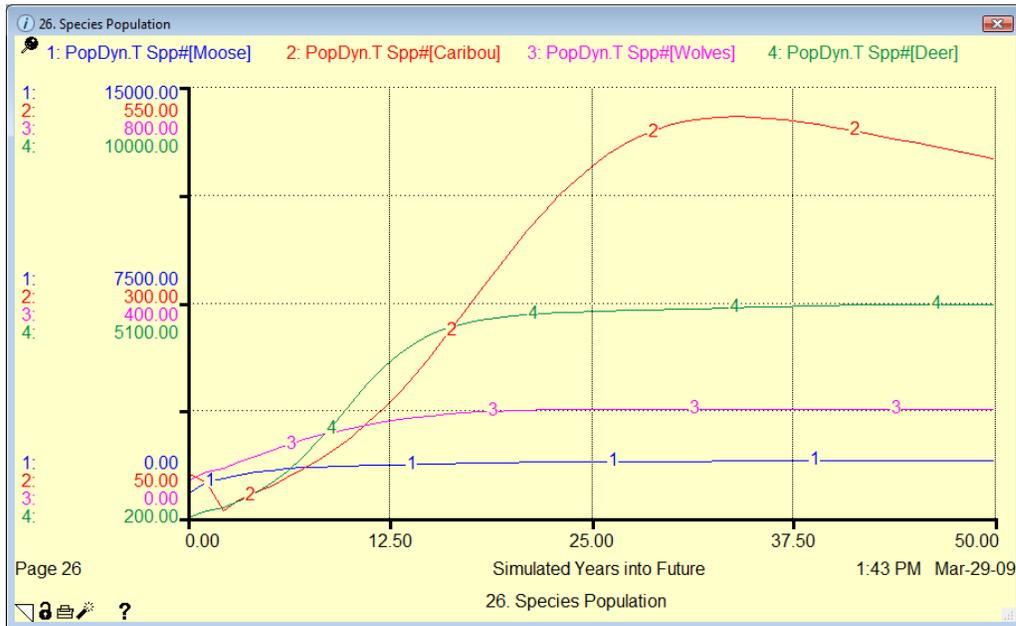


Figure 32. Influence of an annual cow – calf penning program on predator and prey populations in the Richardson planning area (BAU land-use assumptions, 100% cows penned, 80% calf mortality reduction, 1 yr intervals, and 2/yr wolf immigration).



Figure 33. Influence of an annual cow – calf penning program on predator and prey populations in the Richardson planning area (BAU land-use assumptions, 100% cows penned, 80% calf mortality reduction, 2 yr intervals, and 2/yr wolf immigration).

Figure 34 presents results of a representative simulation for control (depredation) of other prey species (moose and deer). In the Richardson planning area, control of other prey alone (i.e., without wolf control) substantially reduced populations of other prey, but also accelerated a decline in caribou due to their higher vulnerability to predation. The trend in Figure 34 also suggests that aggressive control of other prey species in small areas may induce a lag effect in the feedback between wolves and their prey biomass, with wolves declining precipitously once their prey base has been extirpated. Note that simulations assume no immigration of caribou, moose or deer, 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 planning area.

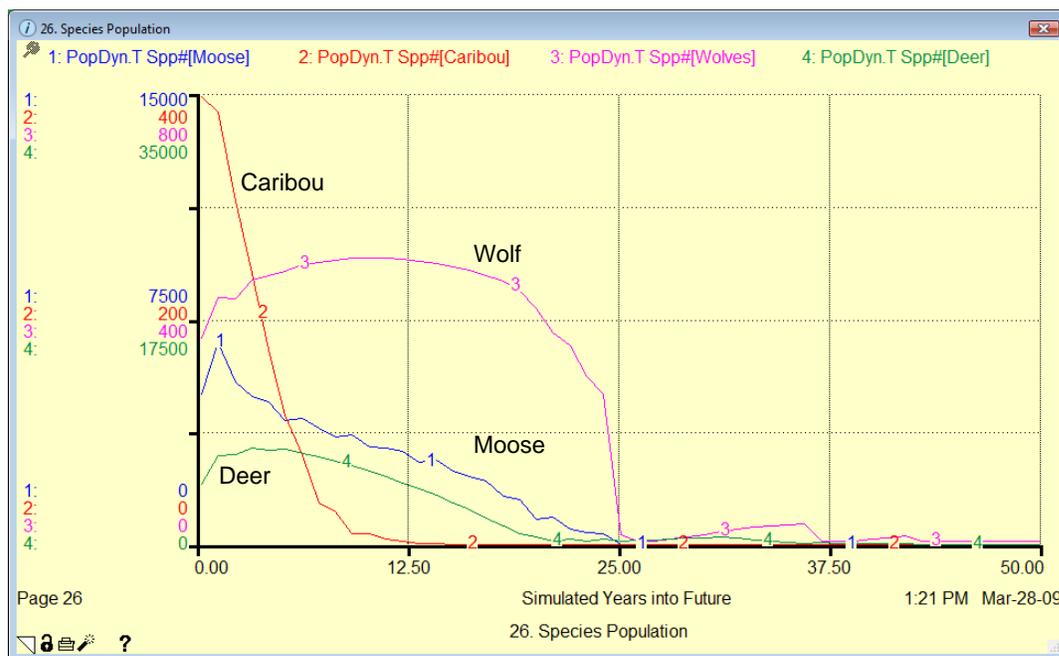


Figure 34. Influence of annual control of 15% moose and 15% deer on predator and prey populations in the Richardson planning area.

### 3.3.4 Combined Management Levers

Simultaneous application of all management levers 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.

#### 4. EAST SIDE ATHABASCA RIVER PLANNING AREA (ESAR)

The 3,624,722 ha ESAR is bounded to the west by the Athabasca River, to the east by the Alberta-Saskatchewan border, to the south by the Cold Lake Air Weapons Range and White Area, and to the north by the Clearwater River (Figure 35). The ESAR caribou range polygons shown on Figure 35 were defined based on peatland habitat and 14 years of telemetry data. This defined habitat area also includes patches of upland mixedwood habitat and represents approximately 1,468,384 ha, or 41% of the planning area. Approximately 18% of the ESAR was classified as young forest (<30 years old), and young forest associated with the large House River fire is evident northwest of Conklin (Figure 36). Because much of the lowland caribou habitat is close to mixedwood uplands, it is expected to be sensitive to indirect effects of land-use and predator-prey dynamics in the surrounding buffer.

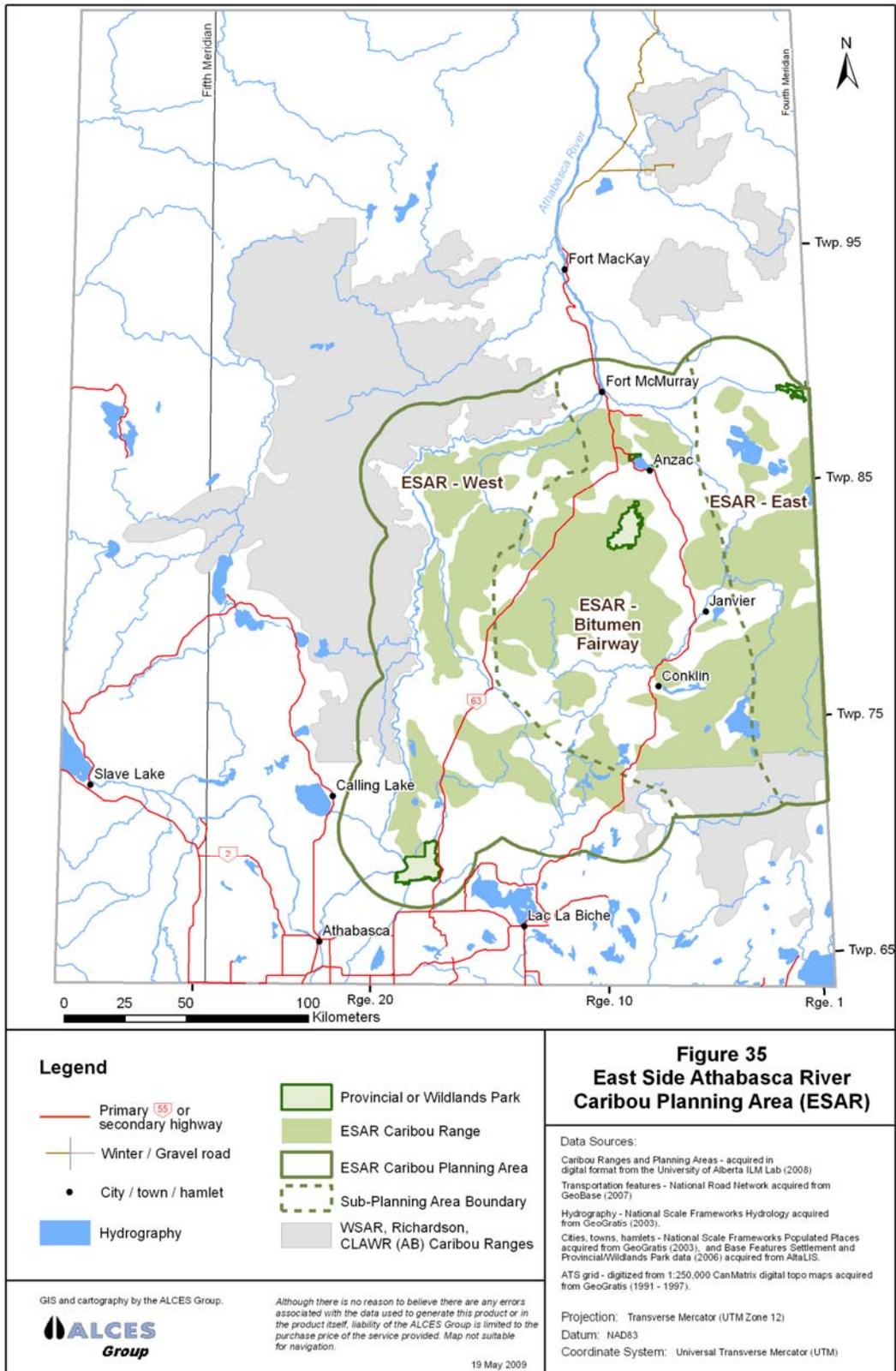
The ESAR has a moderate to high linear corridor density, and caribou habitat varies in intactness (Figure 36). Total current land-use footprint is 135,852 ha, or 3.7% of the planning area. Forest harvest blocks contribute just over half of this footprint. The least intact area within the planning area is from the large land-use footprint associated with bitumen extraction in the Bitumen Fairway (ALT 2008). Since management options for caribou may be limited within the Bitumen Fairway, we conducted separate simulations for ESAR – W and ESAR – E (Figure 35).

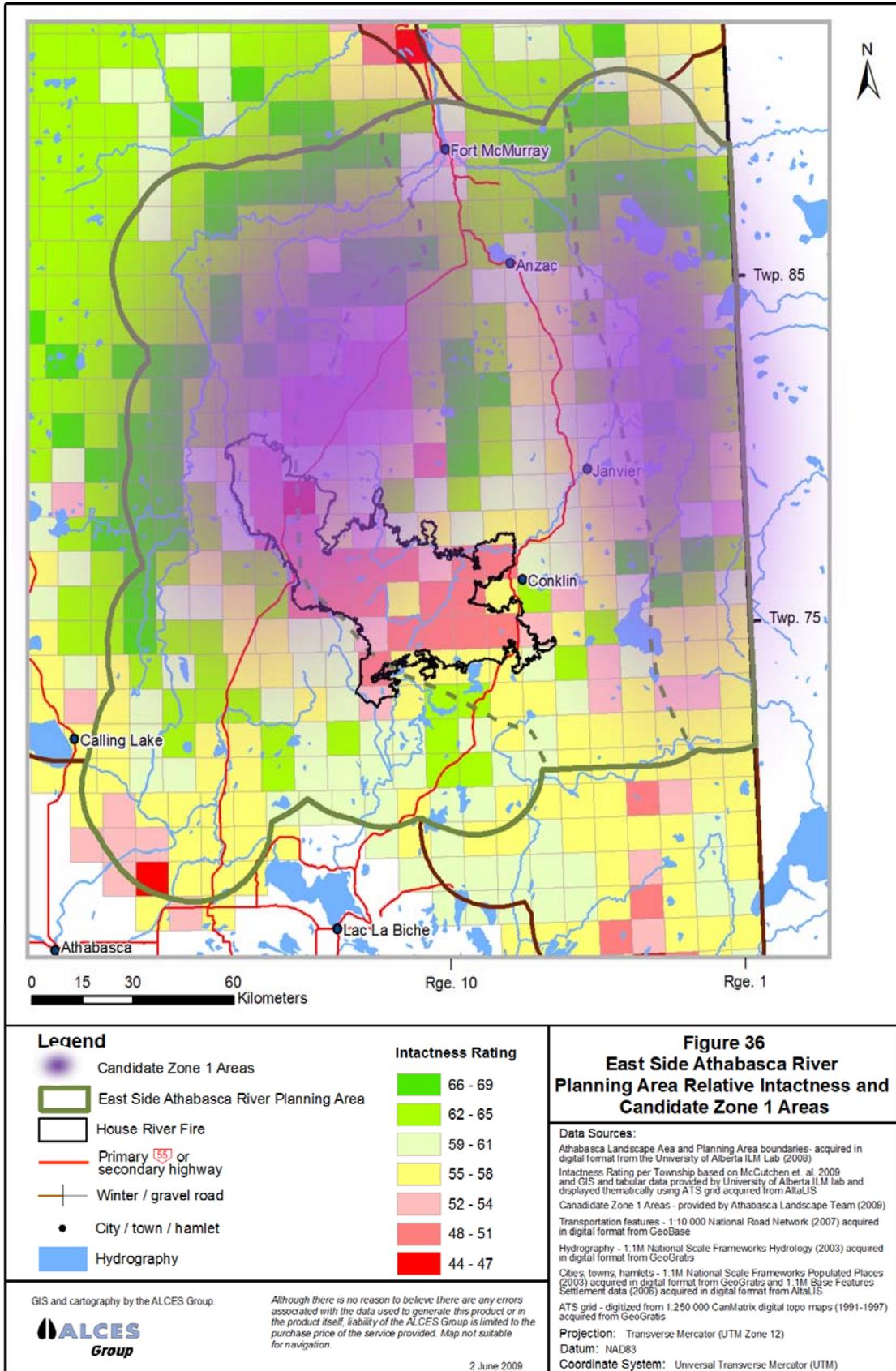
The ESAR – W sub-planning area is 1,538,420 ha in size and has a total current land-use footprint of 69,630 ha or 4.5% (harvest blocks make up two thirds of this footprint). The ESAR – E sub-planning area is 682,390 ha in size and has a total current land-use footprint of 8,883 ha or 1.3% (harvest blocks make up a little over half of this footprint); it is relatively intact, as is the northern portion of ESAR – W (Figure 35). ESAR – E currently has more young forest (13.1%) than ESAR - W (9.9%), but has less land-use disturbance and lower densities of linear corridors compared to ESAR – W.

Caribou in the ESAR were stable to declining between 1992/1993 and 1999/2000, but have been declining since; population lambda in 2007/2008 was 0.81. The ESAR population is guesstimated to include 200-250 animals (ALT 2008). The ESAR appears to have high wolf densities, a stable moose population, and increasing deer population and distribution. Densities of these prey species decrease from south to north. Deer and wolf densities are highest in the Athabasca River valley.

Several protected areas are found within the ESAR including Gregoire Lake Provincial Park, Whitemud Falls, Stony Mountain, and La Biche River Wildland Provincial Parks (Figure 35).

The ESAR has a high overall risk rating, but ratings differ for the three sub-planning areas. Due to existing and projected bitumen development, that portion of the ESAR within the Bitumen Fairway is considered to have a high risk rating. ESAR – W is likely to be adversely altered over the next 50+ years by bitumen development and forest harvest and is also considered to have a high risk rating. The ESAR – E sub-planning area has the lowest risk rating of the three ESAR sub-regions.





#### 4.1 NON-INDUSTRIAL SCENARIO

Non-industrial scenario simulations for caribou and moose in the ESAR planning area show that caribou and moose fluctuate naturally in response to the combined effects of random fire and insect disturbance, and forest succession. Based on ten random model simulations, 1,500 to 4,500 caribou and 7,500 to 10,000 moose could be supported in the ESAR planning area with no land-use and no wolves (Figure 37 and 38 respectively). Current guesstimated caribou abundance (<250) is substantially lower than their simulated natural population range. The estimated moose population (3600) is also below their simulated range under a non-industrial scenario.

Under a non-industrial scenario, the simulated population size range for caribou and moose in the ESAR-E and -W sub-planning areas (also based on ten random model simulations) showed that 700 to 1000 caribou and 1500 to 2300 moose could be supported in the ESAR – W area (Figures 39 and 40 respectively), and 400 to 840 caribou and 1300 to 1700 moose could be supported in the ESAR – E area (Figures 41 to 42 respectively). Current guesstimated caribou abundance in the ESAR – W (60 caribou) and ESAR – East (50 caribou) sub-planning areas are substantially lower than their simulated natural population ranges. Current estimated population sizes for moose in ESAR – W and ESAR - E are 2600 and 1160 respectively. Those current estimates are similar to the non-industrial population ranges.

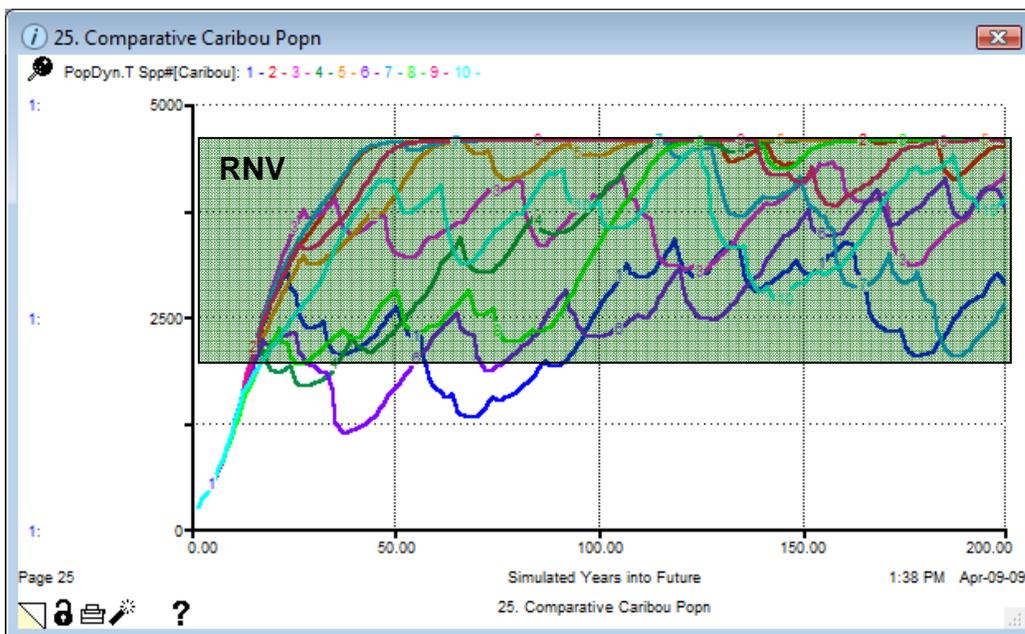


Figure 37. Forecast Non-industrial caribou population in ESAR planning area (assumes random disturbance; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

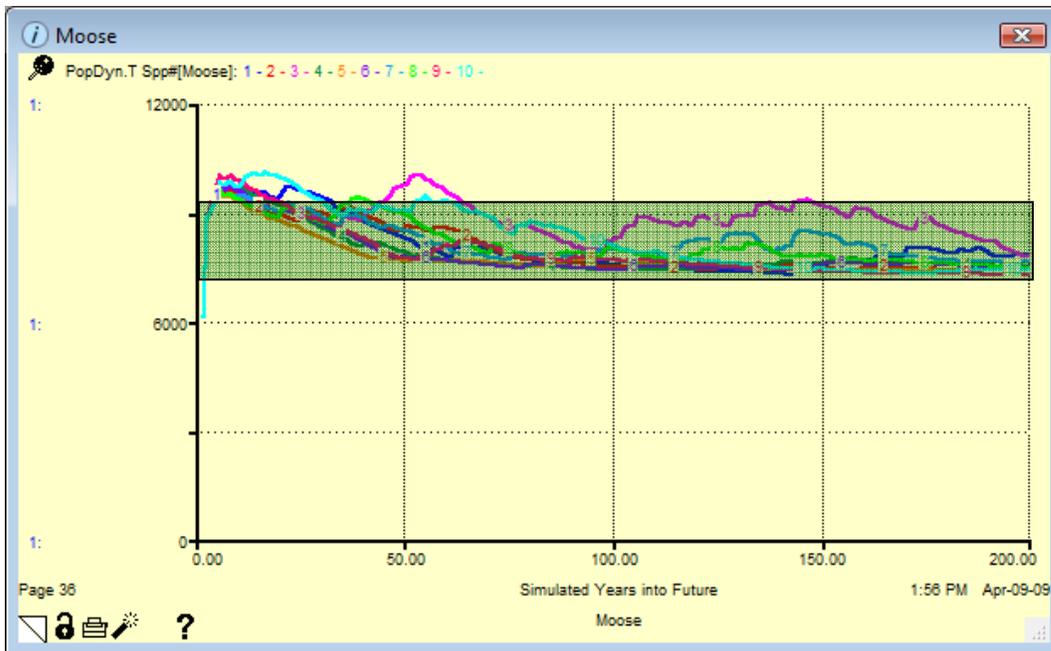


Figure 38. Forecast Non-industrial moose population in ESAR planning area (assumes random disturbance; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

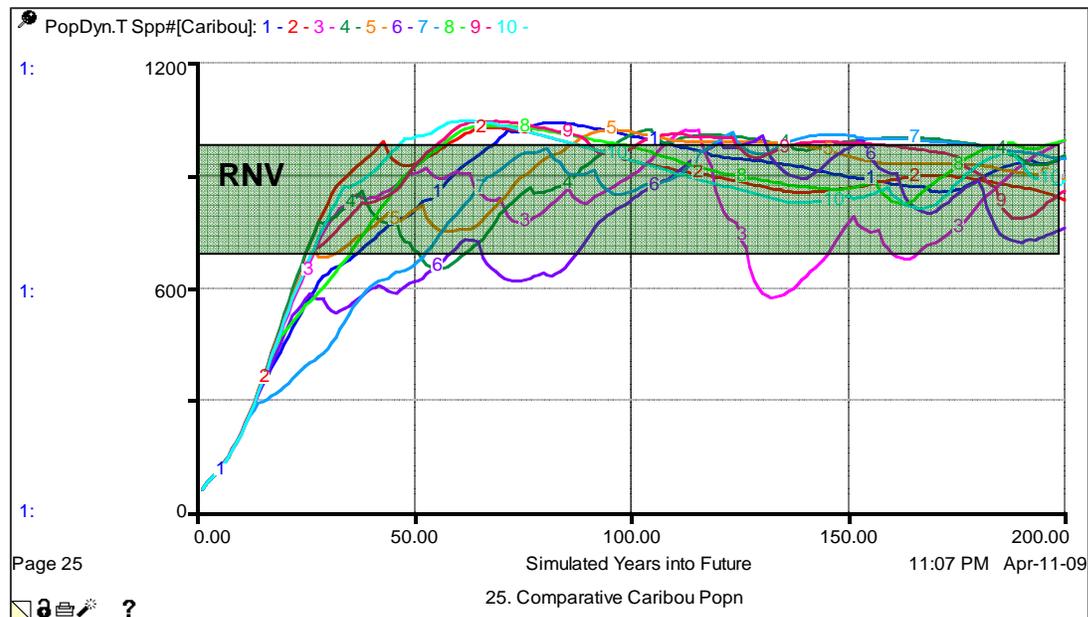


Figure 39. Forecast Non-industrial caribou population in ESAR – W sub-planning area (assumes random disturbance; wolves and moose present at current numbers, no wolf immigration; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

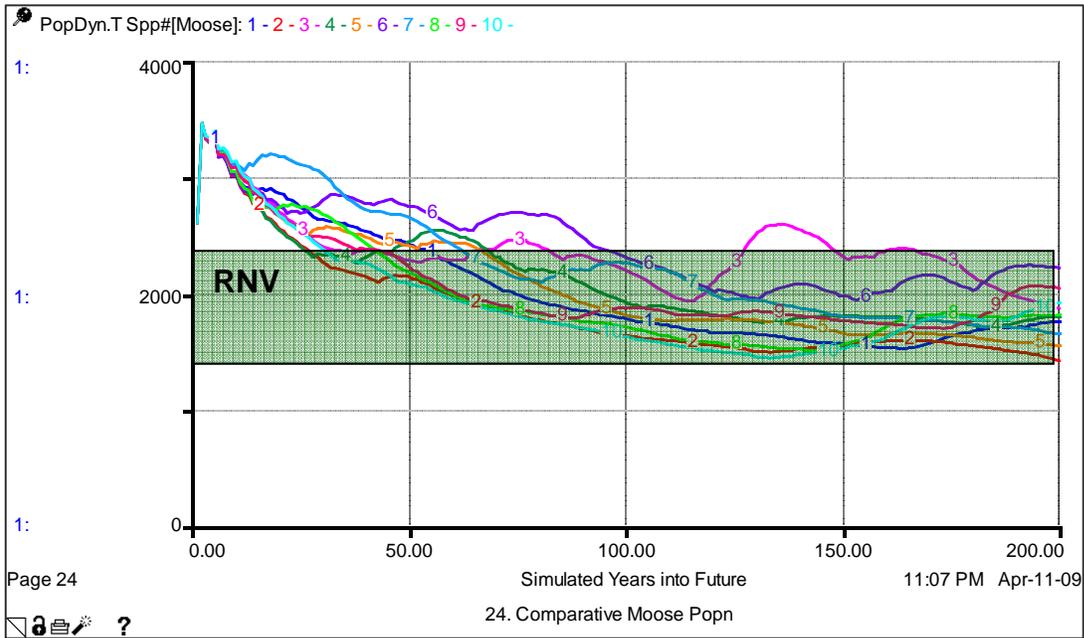


Figure 40. Forecast Non-industrial moose population in ESAR – W sub-planning area (assumes random disturbance; wolves and moose present at current numbers, no wolf immigration no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

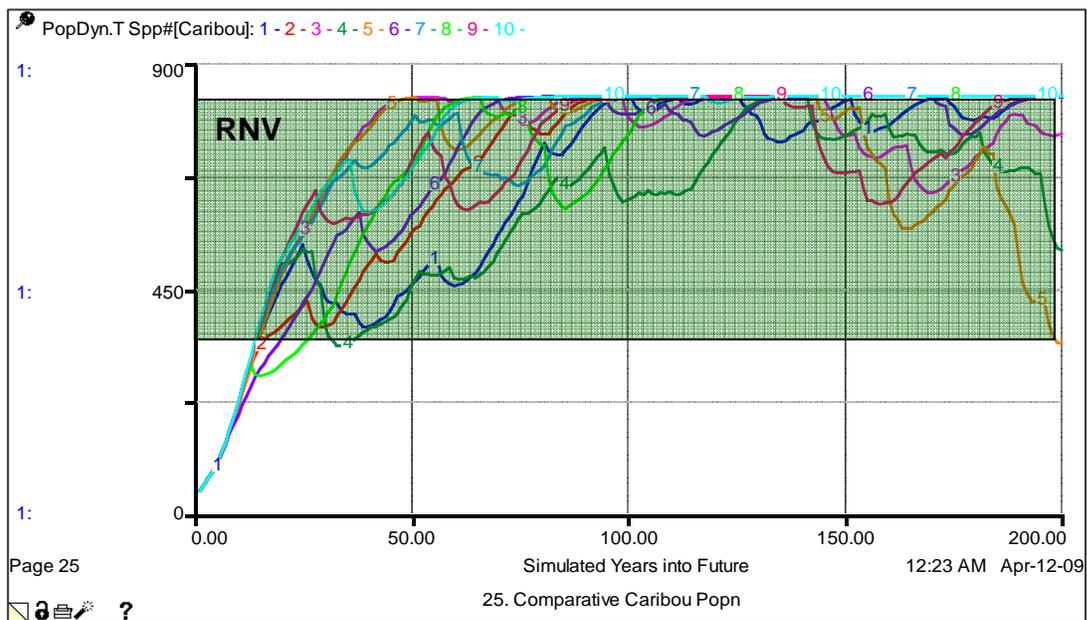


Figure 41. Forecast Non-industrial caribou population in ESAR – E sub-planning area (assumes random disturbance; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

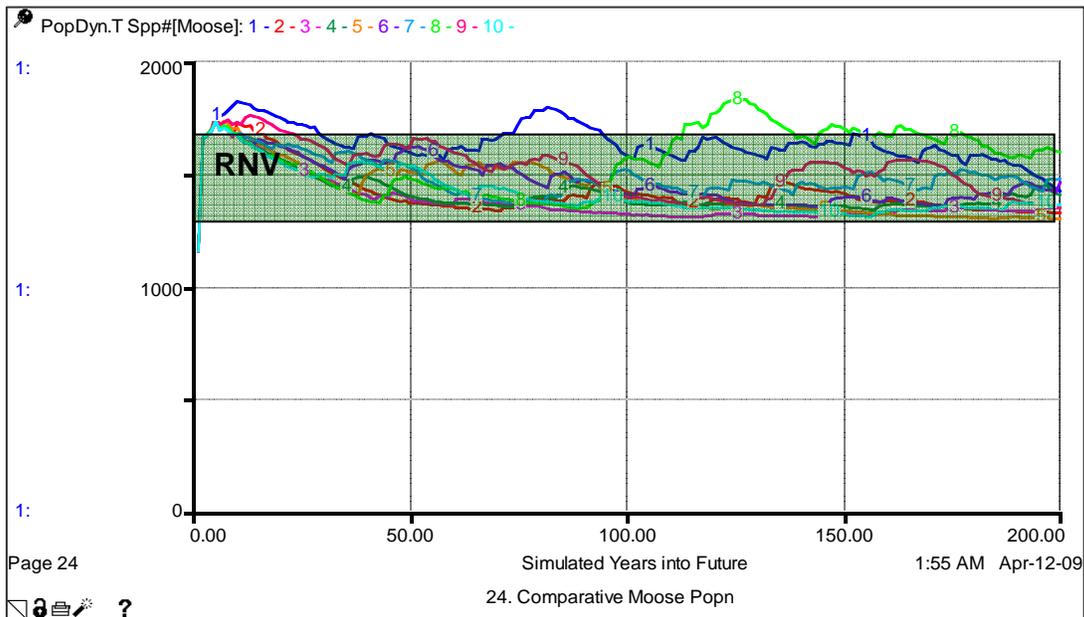


Figure 42. Forecast Non-industrial moose population in ESAR – E sub-planning area (assumes random disturbance; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

## 4.2 BUSINESS AS USUAL SCENARIO

Business as Usual scenario simulations suggest that boreal caribou in the ESAR planning area will be extirpated within the next two decades as footprint increases and Habitat-Based Population Performance gradually declines from 0.971 to 0.88. As shown in Figure 43, deer and moose numbers slowly increase to a density of ca. 50/100 km<sup>2</sup> and 23/100 km<sup>2</sup> respectively, and wolves increase to a density of ca. 1.8/100 km<sup>2</sup>.

Similarly, Business as Usual scenario simulations of the ESAR – W sub-planning area provided in Figure 44 suggested that boreal caribou will be extirpated within the next three decades as footprint increases and Habitat-Based Population Performance gradually declines from 0.95 to 0.92. Figure 44 shows that deer and moose numbers slowly increase to densities of 25/100 km<sup>2</sup> and wolves increase to a density of 1.8/100 km<sup>2</sup>.

In the ESAR – E sub-planning area, simulations also suggest that boreal caribou will be extirpated within the next two decades as footprint increases and Habitat-Based Population Performance gradually declines from 0.97 to 0.94. Figure 45 shows the trend in deer and moose numbers increases slowly to a density of ca. 45/100 km<sup>2</sup> and 20/100 km<sup>2</sup>, respectively, and wolves increase to a density of ca. 2.0/100 km<sup>2</sup>.

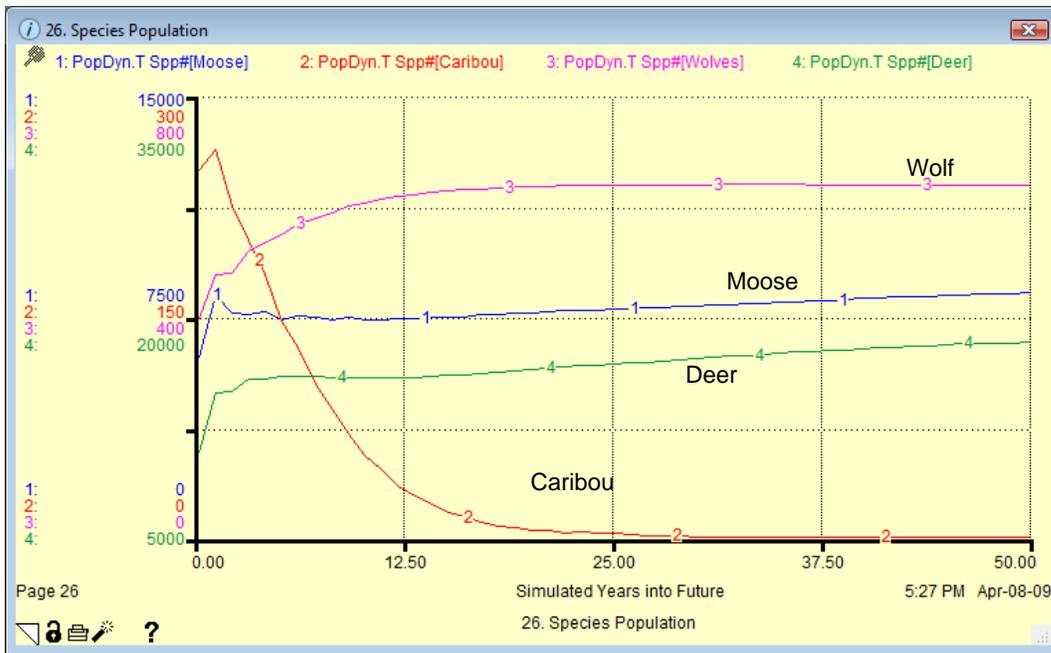


Figure 43. Forecast Business as Usual caribou, moose, wolf, and deer population size in ESAR planning area (assumes constant disturbance, all species at current numbers; standard vulnerability and buffers assumptions; forecast land-use; 50 year simulation period).

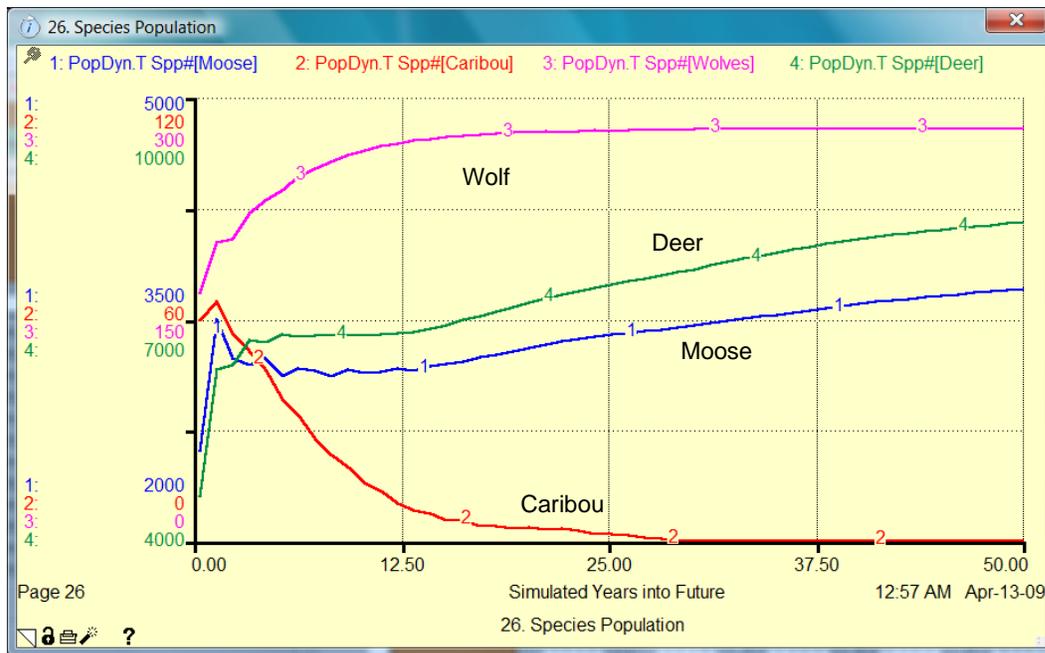


Figure 44. Forecast Business as Usual caribou, moose, wolf, and deer population size in ESAR - W planning area (assumes constant disturbance, all species at current numbers; standard vulnerability and buffers assumptions; forecast land-use; 50 year simulation period).

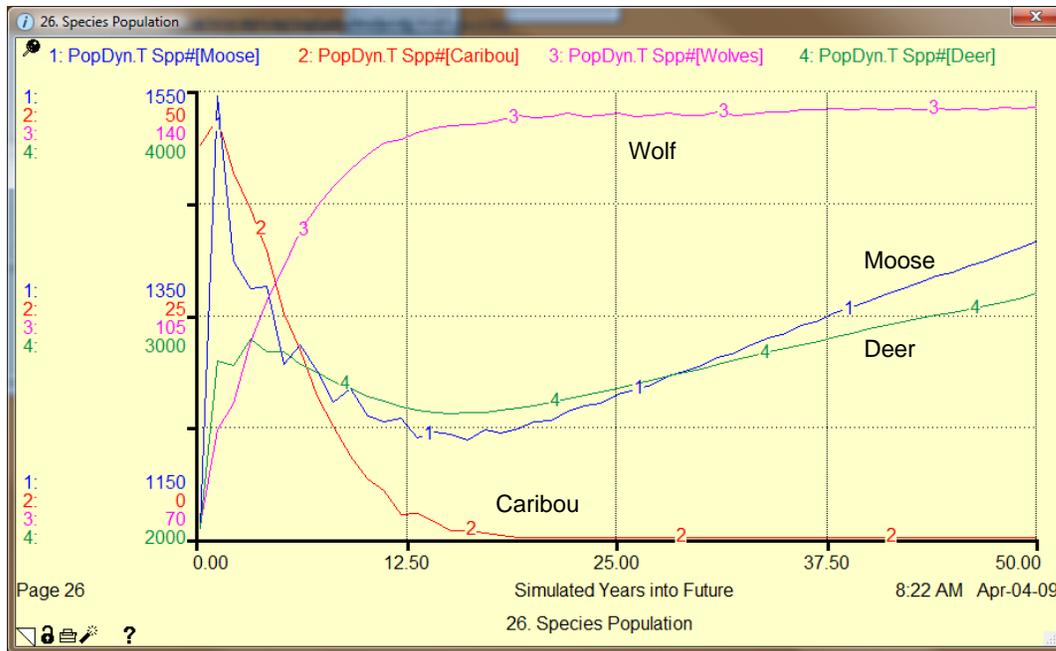


Figure 45. Forecast Business as Usual caribou, moose, wolf, and deer population size in ESAR – E planning area (assumes constant disturbance, all species at current numbers; standard vulnerability and buffers assumptions; forecast land-use; 50 year simulation period).

### 4.3 ALTERNATIVE FUTURES SCENARIO

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 4.3.1, 4.3.2, and 4.3.3, respectively.

#### 4.3.1 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 best practices on a project-by-project basis to reduce future land-use footprint size or lifespan.

##### 4.3.1.1 Future Footprint Minimization

Figure 46 summarizes the influence of future footprint minimization levers on Habitat-Based Population Performance in ESAR at year 50. The BAU scenario simulation is provided for reference as the furthest bar to the left; 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).

Results are similar to those provided earlier for the WSAR planning area. Figure 46 shows that in ESAR the most effective option is to reduce the future footprint of all industrial sectors. Results show that future in-situ development (IS) has the greatest effect on habitat function, while the influence of the forestry footprint (F) is smaller, which is consistent with the fact that a large portion of ESAR includes the bitumen fairway (Figure 35, and Figure 4 in ALT management report). Reducing the fire return interval through fire suppression and manipulating insect outbreak rates would also improve habitat function, but would have a comparatively small effect on Habitat-Based Population Performance in ESAR.

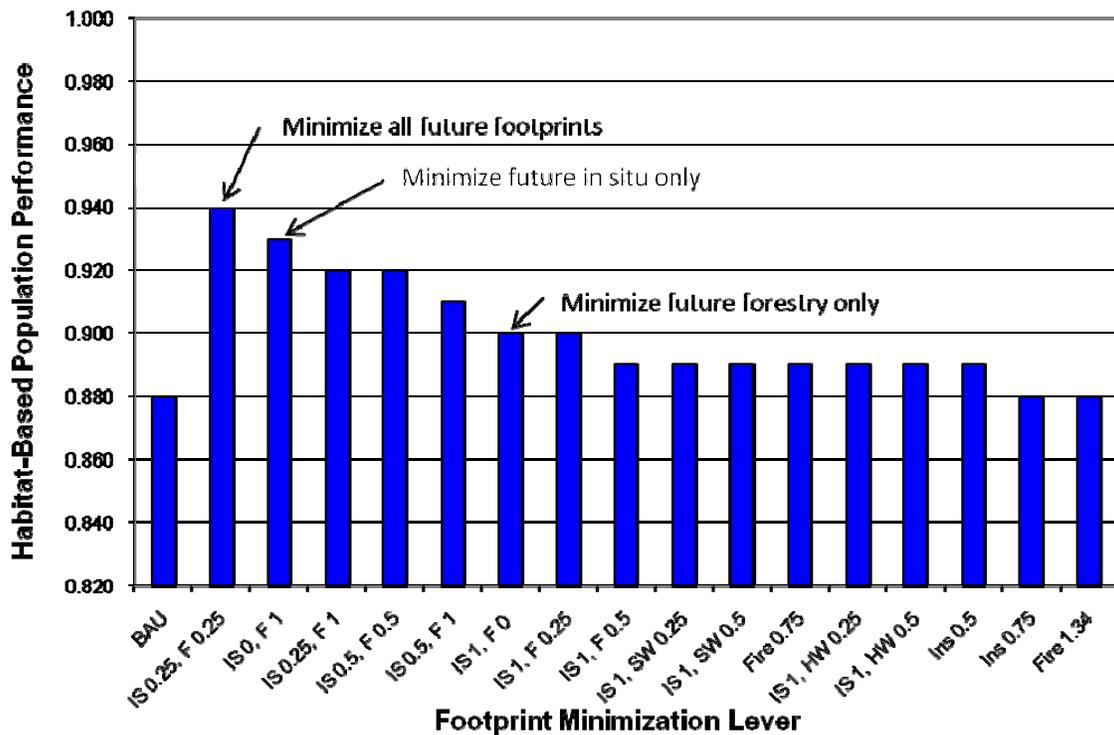


Figure 46. Influence of footprint minimization levers in the ESAR planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions).

Similar to the whole ESAR planning area, the most effective option in the ESAR – W sub-planning area is to reduce all future footprints (Figure 47). However, in ESAR - W, results show that the forestry footprint has a greater effect on habitat function than in-situ development. In the ESAR – E sub-planning area, simulation results also show that the most effective option is to reduce the future footprint of the forestry sector (Figure 48). These results differ from those at the ESAR planning area scale, and reflect the much smaller economic bitumen reserve volume in ESAR-W and ESAR-E (see Supplemental Data Table 2), which is tied to the original rationale for delineation around the bitumen fairway (Figure 35). In summary however, none of the individual levers or combinations considered here is sufficient to restore functional caribou habitat.

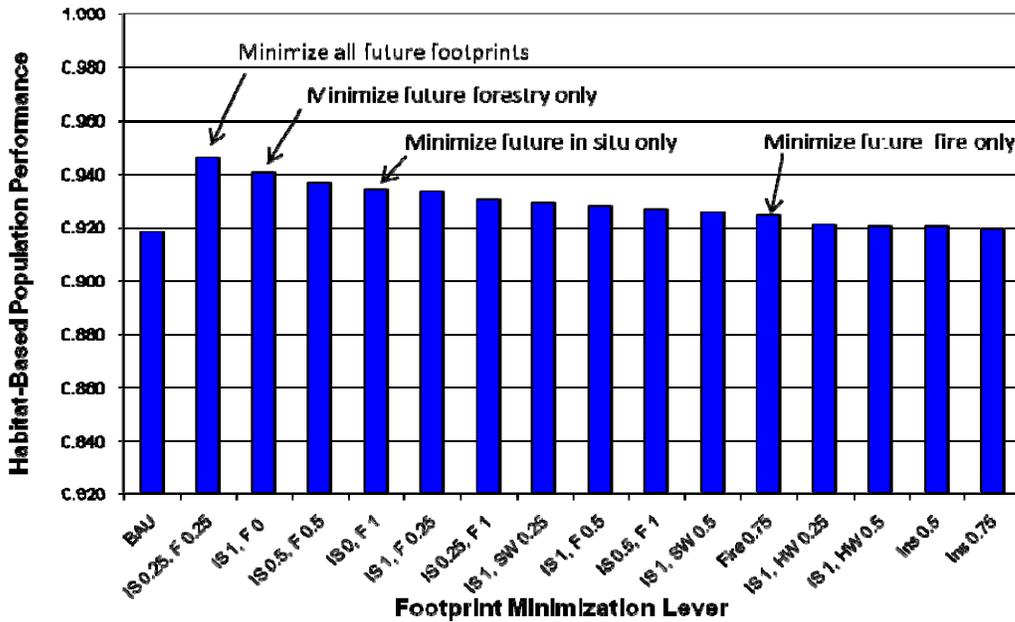


Figure 47. Influence of footprint minimization levers in the ESAR - W sub-planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions).

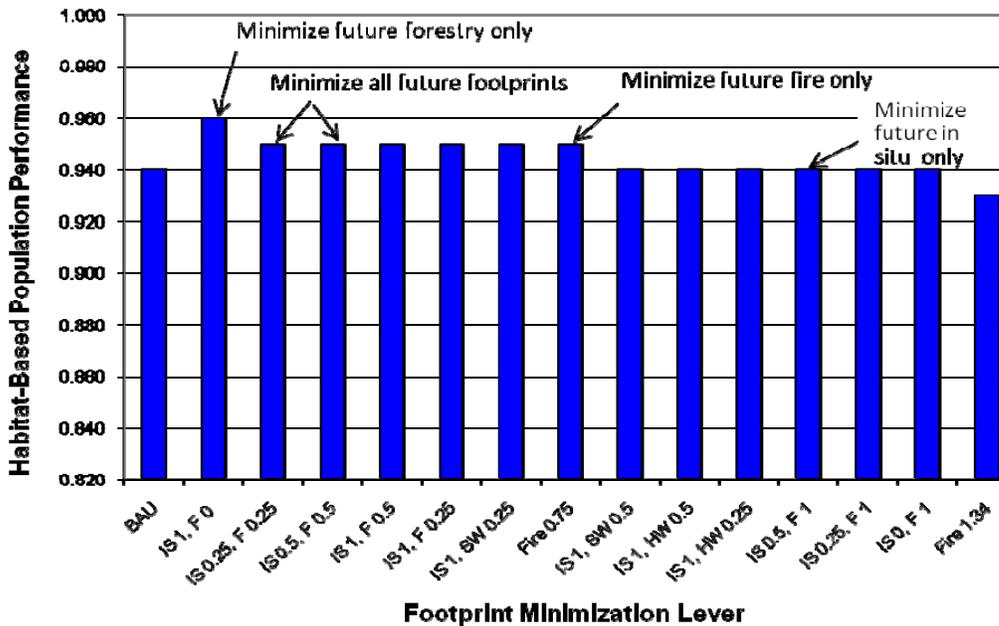


Figure 48. Influence of footprint minimization levers in the ESAR- E sub-planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions).

#### 4.3.1.2 Coordinated Reclamation and Best Practices

Figure 49 summarizes the influence of coordinated reclamation and best practice levers on Habitat-Based Population Performance at year 50 in the ESAR planning area when conducted independently. Note that these management levers have less overall effect than the footprint reduction levers summarized in Figure 46 (restoration of Habitat-Based Population Performance to 0.92 vs. 0.94 respectively).

Similar to WSAR and Richardson, coordinated reclamation of seismic lines, pipelines, and temporary roads in ESAR has a much larger incremental effect on functional habitat restoration than seismic lines alone or any single best practice (CRA simulations in Figure 49). 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. The benefit of coordinated reclamation and best practices is consistent with the large contribution of in-situ bitumen development (associated with the bitumen fairway) to anthropogenic footprint in the ESAR planning area.

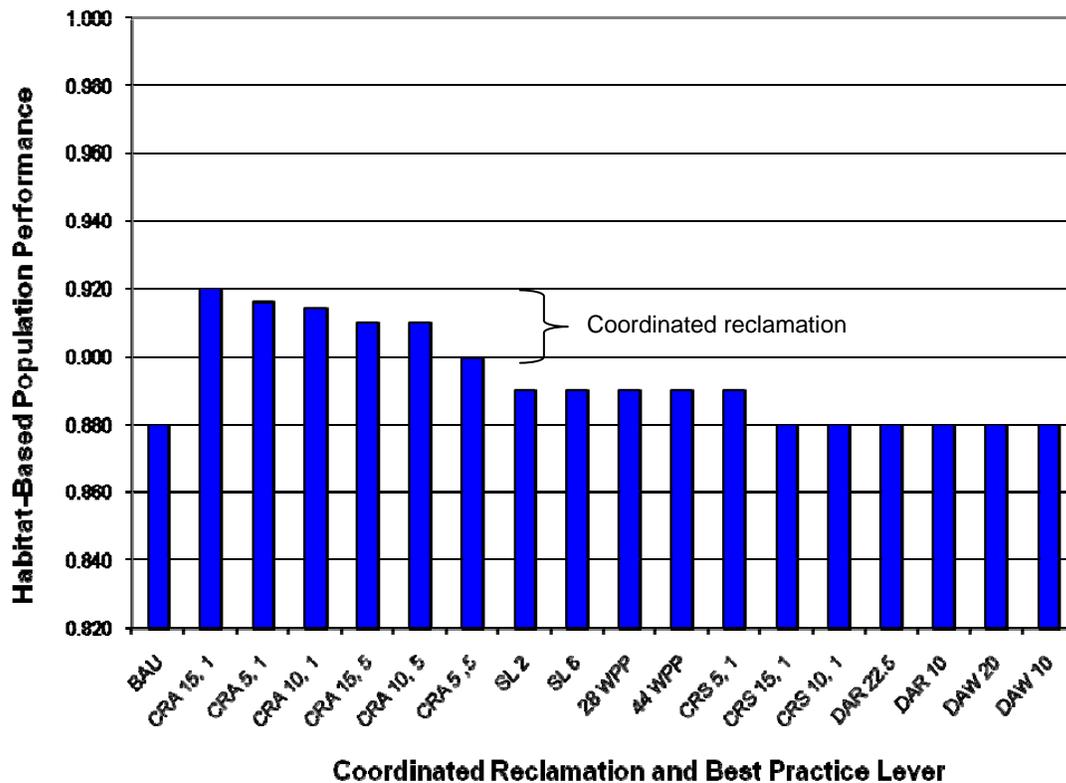


Figure 49. Influence of coordinated reclamation and best practices levers in the ESAR planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; DAW = delineation wellpad lifespan; CRA and CRS numbers represent percent reclaimed per year and interval; number for other levers are proportional change from BAU assumptions).

A similar but less pronounced pattern of results were obtained for simulations in the ESAR – W sub-planning area (Figure 50), where coordinated reclamation of seismic lines, pipelines and temporary roads had the greatest effect on improving Habitat Based Population Performance. In contrast, simulations in ESAR – E (Figure 51) showed that coordinated reclamation and all best practice levers small incremental benefit – compared to BAU – at restoring functional habitat in year 50.

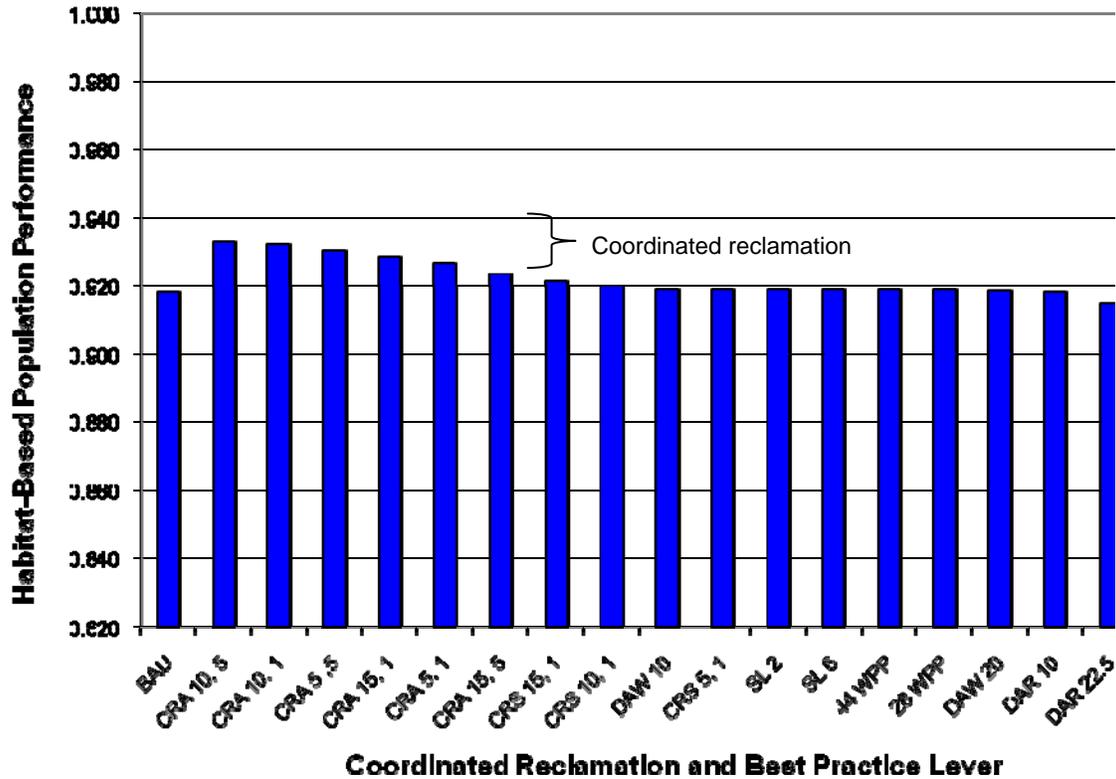


Figure 50. Influence of coordinated reclamation and best practices levers in the ESAR – W sub-planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; 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).

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. Coordinated reclamation of linear corridors in ESAR-E and ESAR-W is projected to have negligible measurable benefit at year fifty because most existing corridors 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 planning areas, coordinated reclamation is the most influential option to effectively restore caribou habitat.

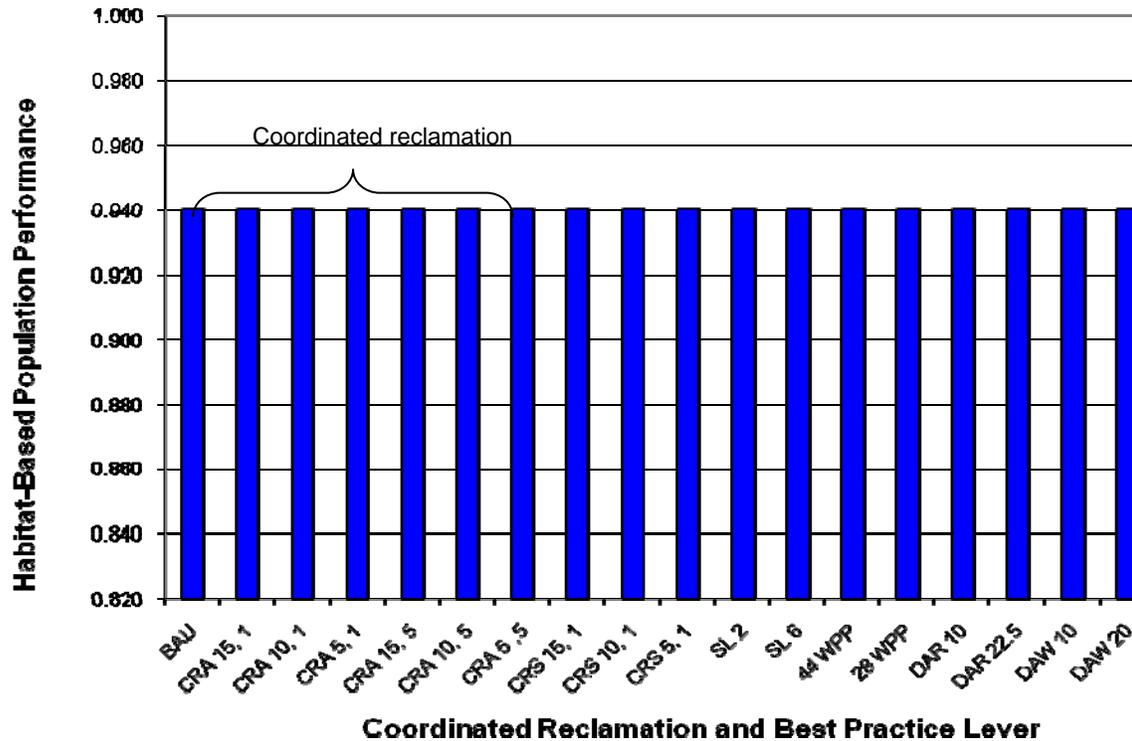


Figure 51. Influence of coordinated reclamation and best practices levers in the ESAR – E sub-planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; 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).

### 4.3.2 Mortality Management Levers

Although habitat related management levers in ESAR, ESAR – W and ESAR – E improved Habitat-Based Population Potential, scenario results did not show an improvement in population persistence. Simulation results for ESAR indicate that some form of wolf control is needed to prevent caribou extirpation within two to four decades (Figure 52). Wolf control reduced the current high wolf numbers immediately and maintained their population at 100 -200 individuals. Simulations suggest that wolf control of at least 50% every 5 years would be required to maintain viable caribou population levels over a 50 year period (Figures 52 and 53).

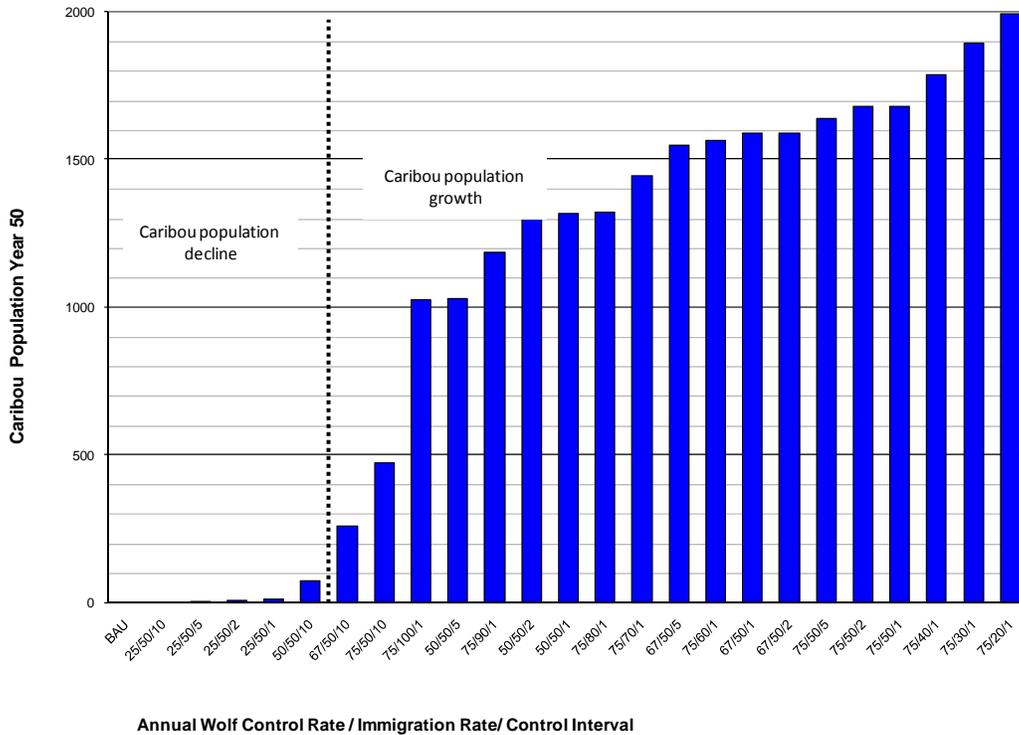


Figure 52. Interaction between wolf control and wolf immigration rates on simulated caribou population in the ESAR planning area (Numbers on x-axis reflect assumed annual wolf control rate / wolf immigration rate / control interval in years for that simulation).

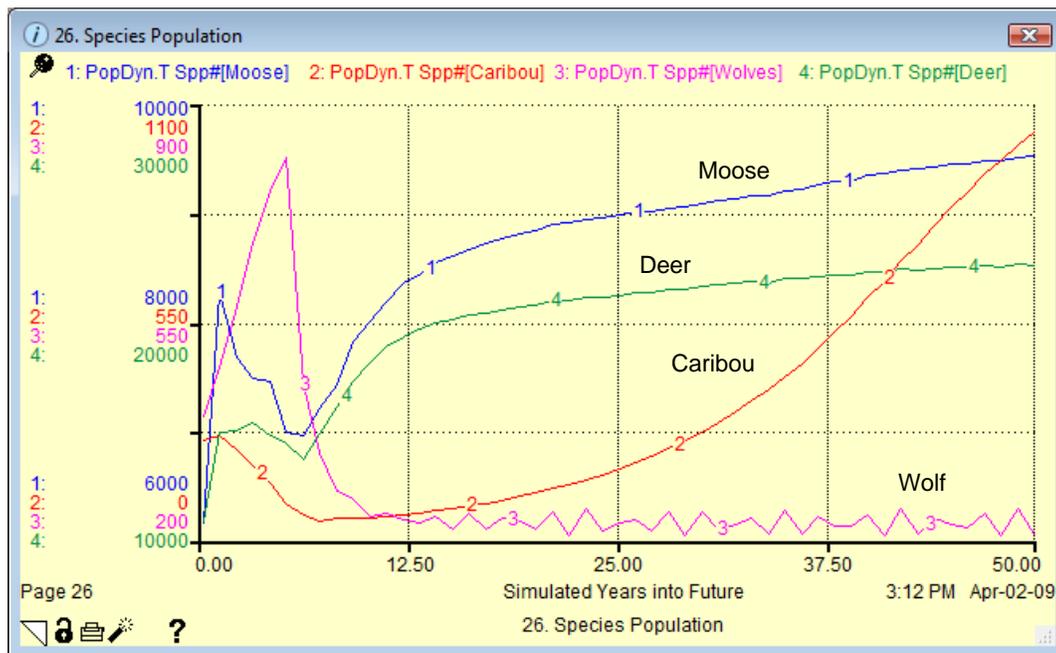


Figure 53. Influence of 50% wolf control every five years on predator and prey populations in the ESAR planning area.

In the ESAR – W and ESAR-E planning areas, simulations suggest that, to maintain or increase caribou size over a 50 year period, more aggressive wolf control would be required. Wolf depredation of at least 67% every 2 years would be required for ESAR – W (Figures 54 and 55) and at least 75% annually with wolf immigration at 20 animals per year for ESAR - E (Figures 56 and 57).

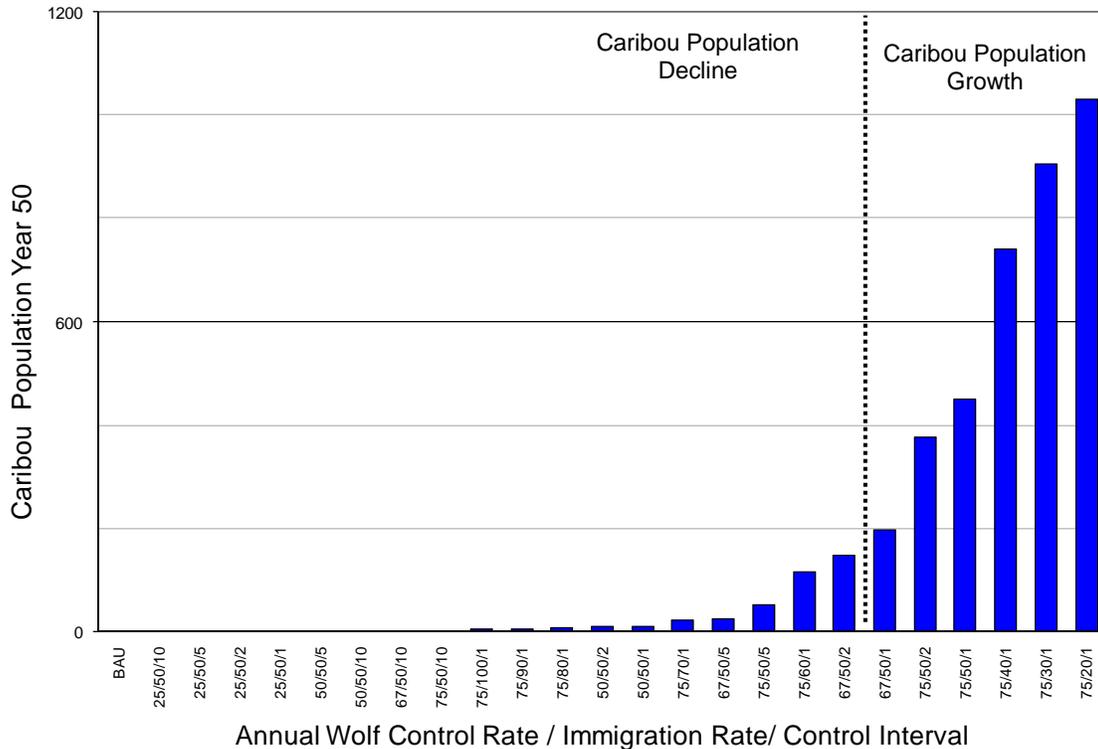


Figure 54. Interaction between wolf control and wolf immigration rates on simulated caribou population in the ESAR - W sub-planning area (Numbers on x-axis reflect assumed annual wolf control rate/wolf immigration rate/control interval in years for that simulation).

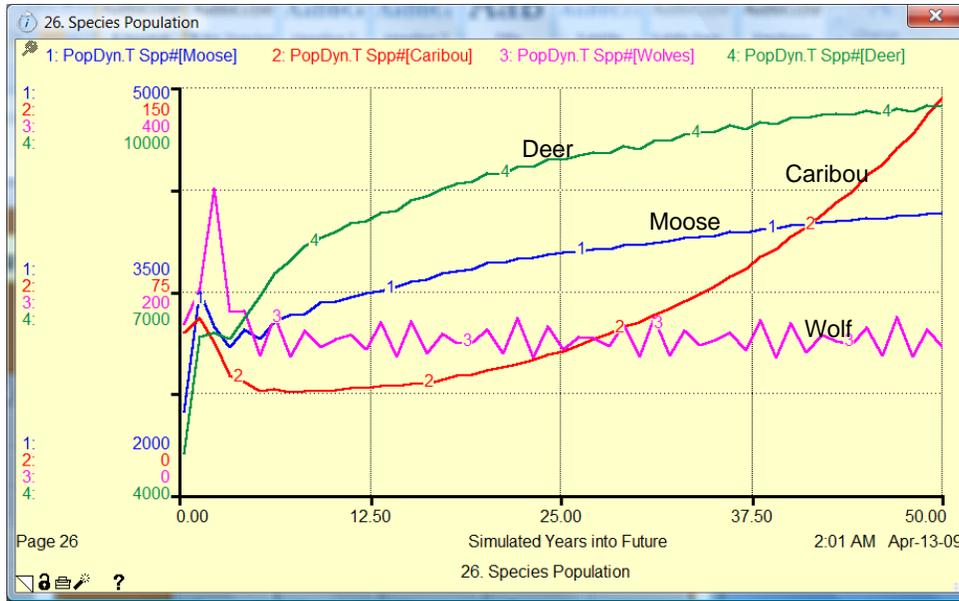


Figure 55. Influence of 67% wolf control every two years on predator and prey populations in the ESAR - W sub-planning area.

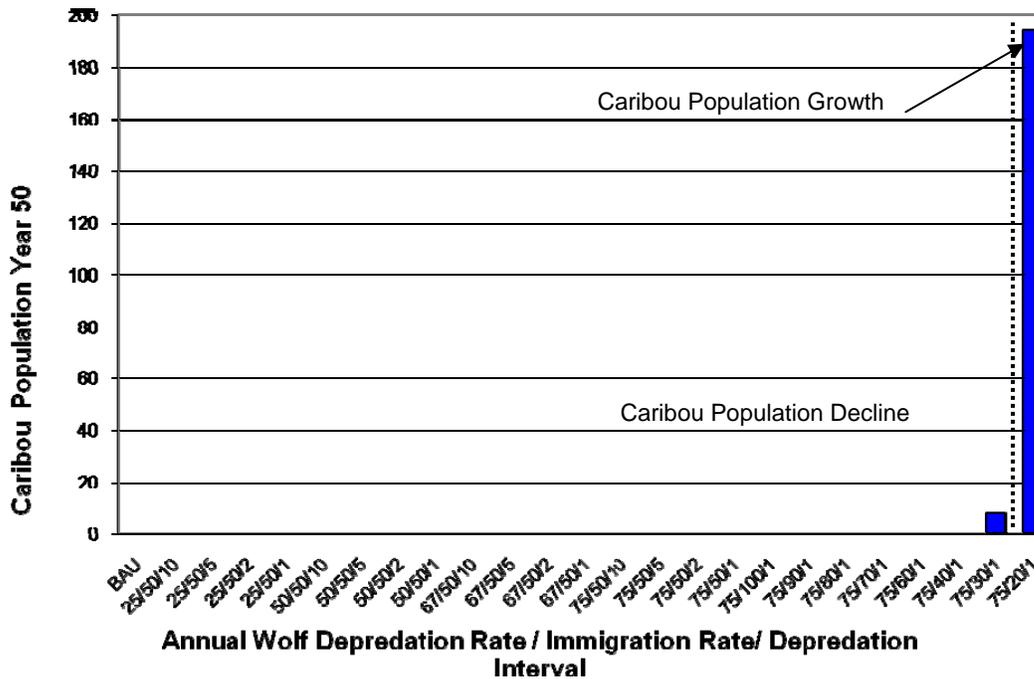


Figure 56. Interaction between wolf control and wolf immigration rates on simulated caribou population in the ESAR – E sub-planning area (Numbers on x-axis reflect assumed annual wolf control rate/wolf immigration rate/depredation interval in years for that simulation).

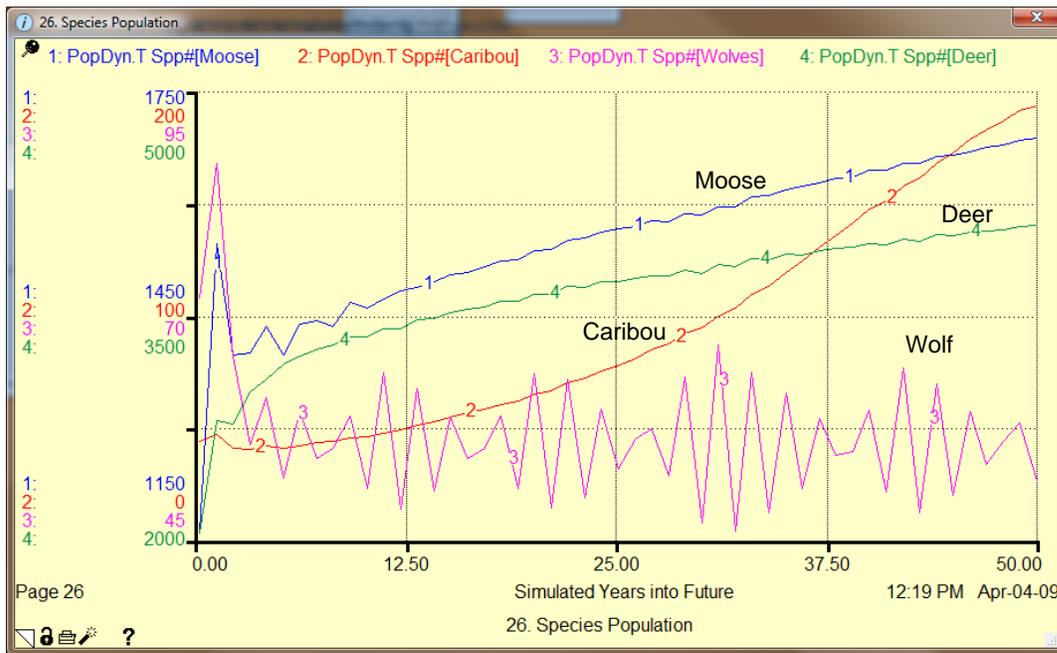


Figure 57. Influence of 75% wolf control every year with 20/yr wolf immigration on predator and prey populations in the ESAR – E sub-planning area.

Several cow penning simulations were run for the ESAR planning areas at 1, 2 and 5 year intervals. The main difference between simulations was in the proportion of cows that were penned, which was related to the assumed number of adult cows within a planning area and the calf survival targets identified by the ALT.

- ESAR (91 initial cows) simulations were run with 8% and 25% cows penned;
- ESAR-W (23 initial cows) simulations were run with 8%, 17%, 25%, and 42% cows penned; and
- ESAR-E (17 initial cows) simulations were run with 60% and 100% cows penned.

Simulation results showed that the only simulation that resulted in caribou persistence was a scenario in ESAR-E in which 100% of the cows were penned annually; at the end of that 50-year simulation period, there were 370 caribou. All other cow penning scenarios were not successful in maintaining caribou populations in ESAR (Figure 58), ESAR – W (Figure 59) and ESAR – E (Figure 60) over the 50 year scenario.

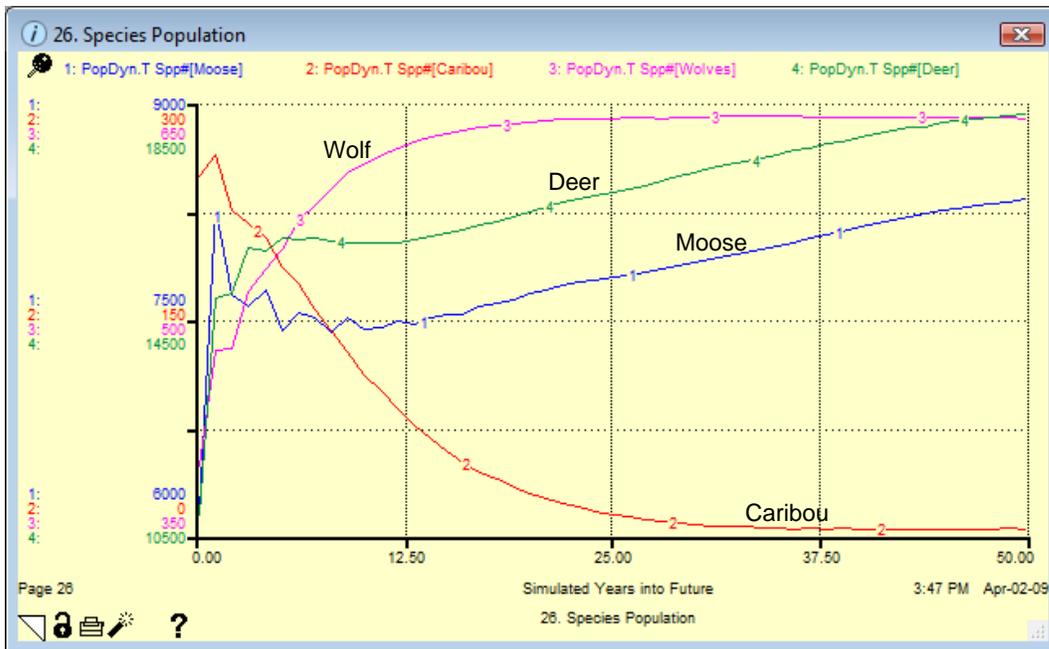


Figure 58. Influence of an annual cow – calf penning program on predator and prey populations in the ESAR planning area (25% cows penned and 80% calf mortality reduction).

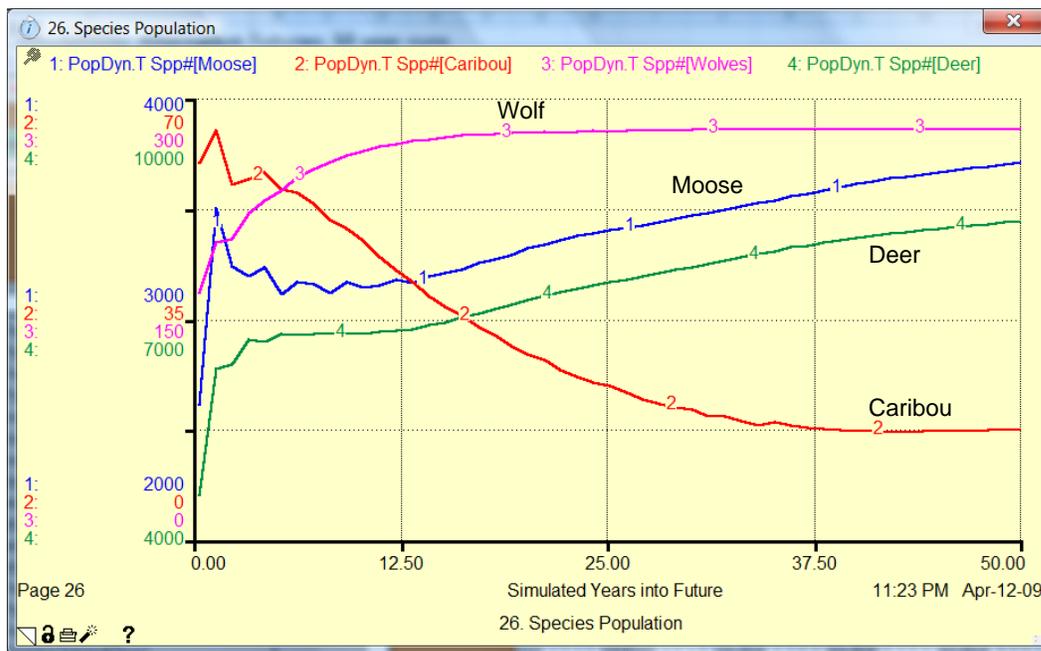


Figure 59. Influence of an annual cow – calf penning program on predator and prey populations in the ESAR – W sub-planning area (42% cows penned and 80% calf mortality reduction).



Figure 60. Influence of an annual cow – calf penning program on predator and prey populations in the ESAR - E sub-planning area (60% cows penned and 80% calf mortality reduction).

Figure 61 presents results of a representative other prey control simulation (i.e., moose and deer). Control of other prey alone (i.e., without wolf control) substantially reduces wolf and other prey populations in the ESAR planning area but does not sustain caribou because predation effort is redirected to them. Note that simulations assume no immigration of caribou or other prey, so once they are extirpated, they do not return. This pattern is similar when control of other prey is pulled as a single management lever in ESAR-W and ESAR-E (Figures 62 and 63).

Simulations that combined various control rates of other prey and wolves did not result in improving caribou persistence in the ESAR planning areas. As observed in the Richardson planning area, the highest probability of success occurs when aggressive wolf control is combined with less aggressive control of other prey. However, there are additional complexities and uncertainties imposed in scenarios where wolves and other prey species are controlled including: assumptions on wolf immigration rates; effects of prey switching (i.e., increasing predation rates on caribou) if other prey species are removed too aggressively; and positive feedbacks to population growth rates of other prey as wolf densities are reduced. As suggested in the Richardson mortality management scenarios, it is likely that the strongest benefits of controlling other prey species in combination with wolf control is in areas where relative densities of other prey species, i.e., deer, are currently low and the objectives are to reduce their future distribution and abundance, as opposed to attempting to reduce densities of deer in areas where they have already become established.

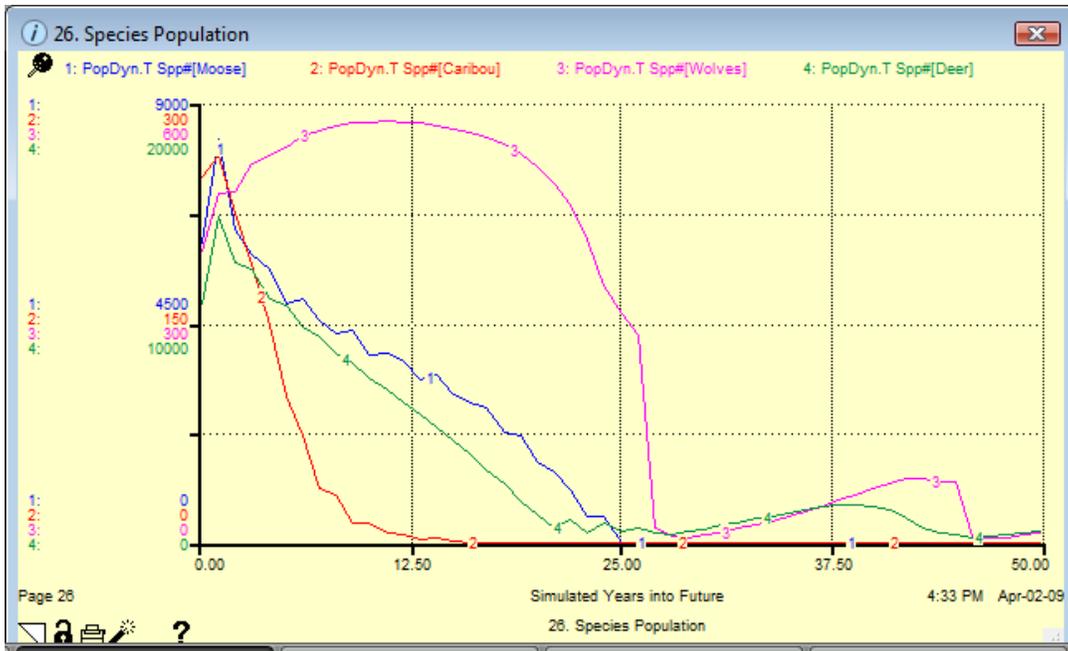


Figure 61. Influence of an annual control of 15% moose and 15% deer on predator and prey populations in the ESAR planning area.

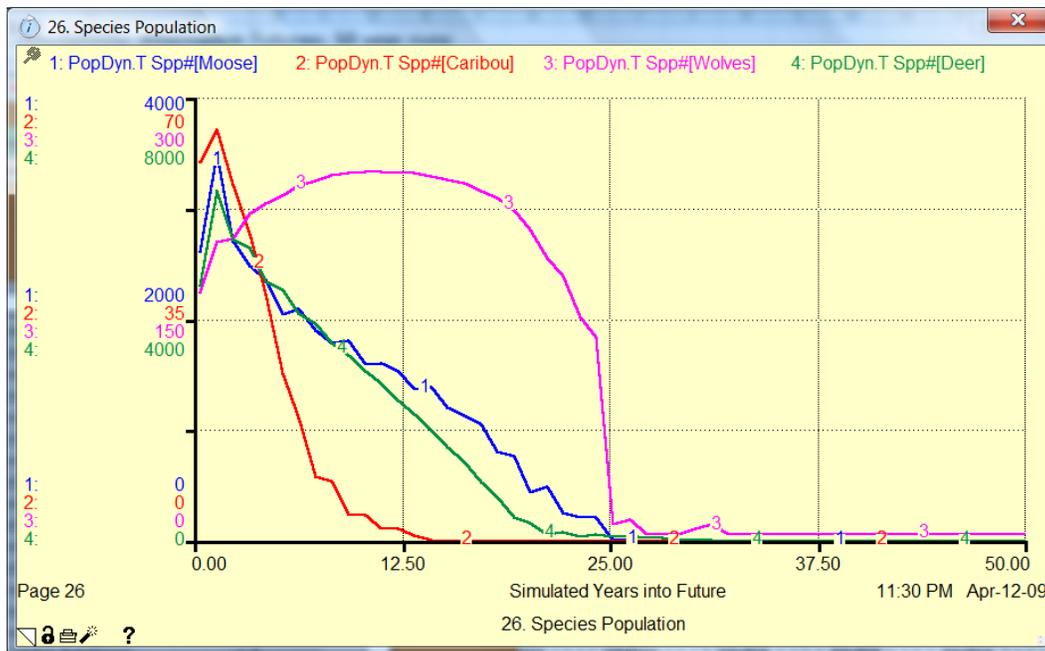


Figure 62. Influence of an annual control of 15% moose and 15% deer on predator and prey populations in the ESAR-W sub-planning area.

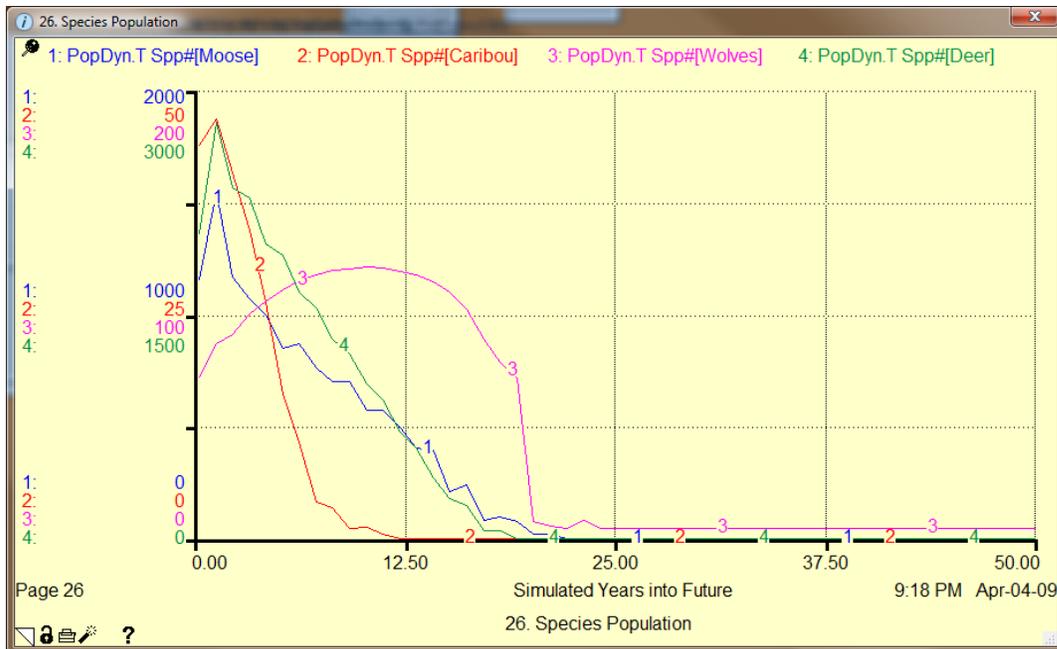


Figure 63. Influence of an annual control of 15% moose and 15% deer on predator and prey populations in the ESAR-E sub-planning area.

### 4.3.3 Combined Management Levers

A combination of management strategies will be required in the ESAR planning area to maintain caribou. It is likely that ongoing wolf control for at least 50 years will be a minimum requirement to assure persistence of caribou. Coordinated reclamation of existing seismic lines, temporary roads and pipelines, and implementation of all best practices considered by the ALT were beneficial at the ESAR planning area scale, with diminished to negligible benefits within the subregional ESAR-W and ESAR-E areas respectively at the end of the 50 year simulation period.

At the planning area scale, simulations indicated that coordinated reclamation and best practices would not be sufficient to restore functional habitat in overall area within 50 years without reducing future land-use footprint. This also holds true for both sub-planning area (ESAR-W and ESAR-E), although in these areas there is a shift to reducing young forest associated with forestry because there is little industrial activity and footprint associated with future in-situ bitumen development. The general conclusion is that footprint minimization, reclamation, and best practices are fundamental for restoring caribou habitat, and that they should be applied in all areas where footprint is currently high or is likely to grow.

## 5. COLD LAKE AIR WEAPONS RANGE – ALBERTA PLANNING AREA (CLAWR)

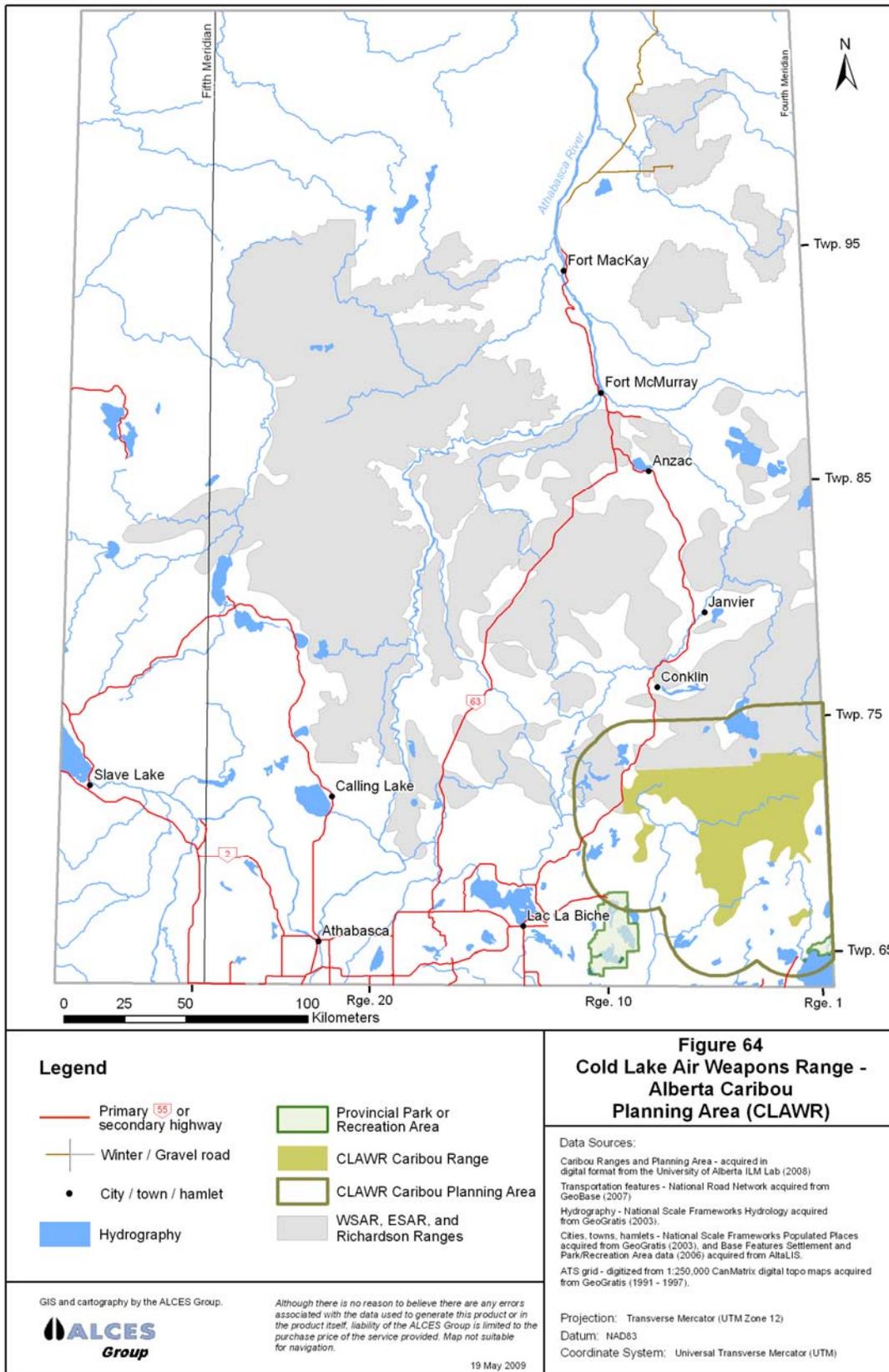
The 961,564 ha CLAWR is based on the federally-managed air weapons range and bounded to east by the Alberta-Saskatchewan border, and to the south by the White Area (Figure 64). The caribou range polygon shown on Figure 64 was defined based on 9 years of telemetry data and includes peatlands interspersed in a matrix of upland mixedwood habitat. Caribou habitat constitutes about 28% of the planning area, and because much of it is close to mixedwood uplands and proximate to the interface with the white zone to the south, it is expected to be sensitive to indirect effects of land-use and predator-prey dynamics in the surrounding buffer.

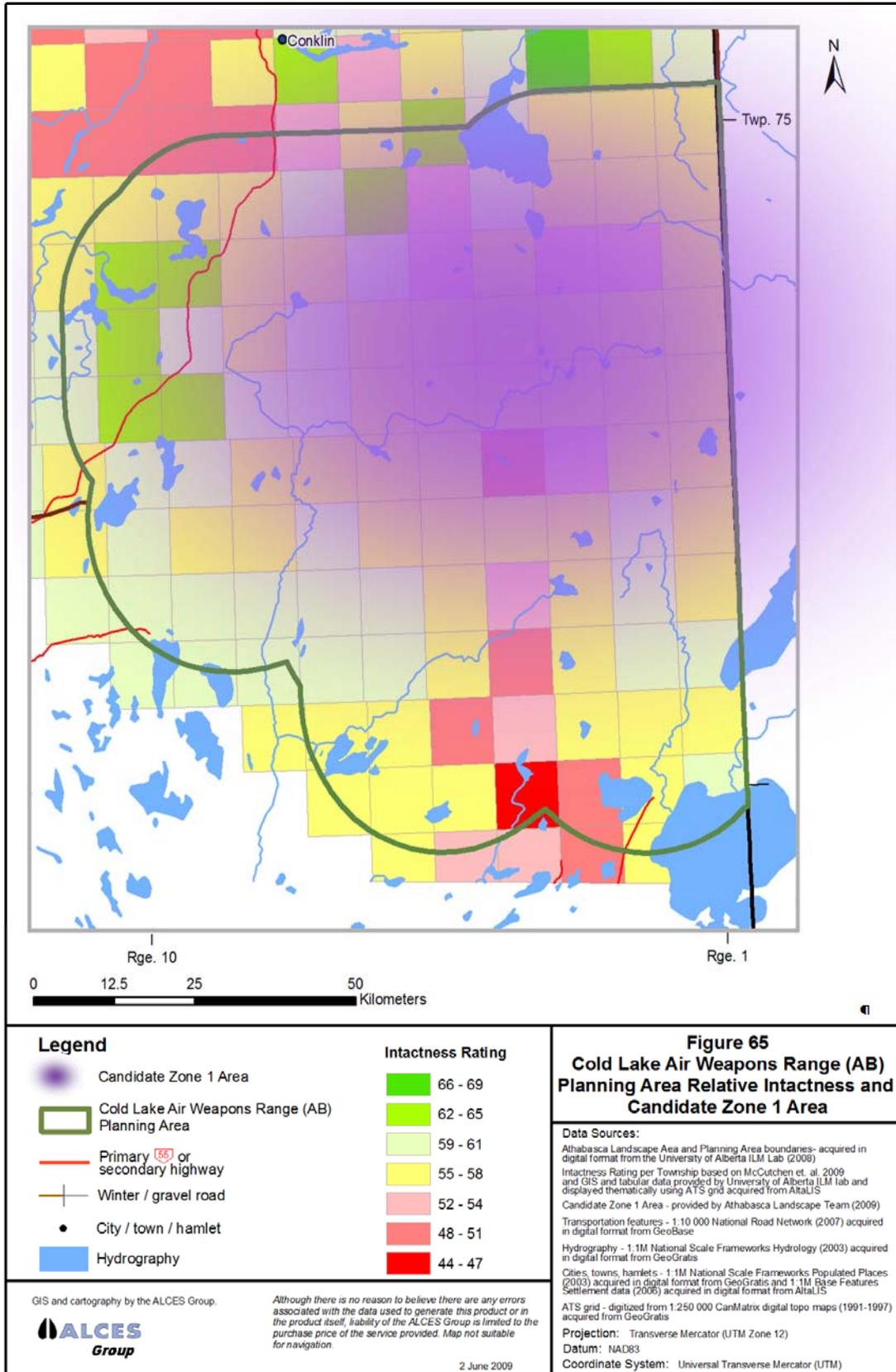
The CLAWR planning area has low to moderate intactness relative to other Athabasca Landscape planning areas (Figure 65). Approximately 20% of the CLAWR was classified as young forest (<30 years old); young forest is slightly more common within caribou habitat than in the surrounding buffer. Total current land-use footprint is 24,160 ha, or 2.5% of the planning area; linear corridor density is currently lower in the east half. Harvest blocks contribute about 26% of this footprint while conventional and in-situ hydrocarbon developments comprise half of the total footprint. The CLAWR has a moderate to high linear corridor density and ongoing in-situ bitumen and conventional hydrocarbon development is anticipated in the western half of the planning area. Future forest harvest will have comparatively limited effect on habitat availability and quality at the planning area scale. Military activities occur all year on the Cold Lake Air Weapons Range. This includes low flying jet activity during the calving/post-calving period (ALT 2008).

Caribou in the CLAWR planning area have been monitored continuously for 9 years as of April 2008. The lambda value calculated in 2005/2006 for the Alberta side of the Cold Lake Air Weapons Range is 0.86. The CLAWR population trend was stable between 1997/1998 and 2001/2002 and has been in continuous decline from 2003/2004 to 2006/2007, suggesting that the population is half the size that it was in 2000/2001. The adjoining Saskatchewan population occurs in an area with limited land-use and is stable to decreasing. The combined caribou population is declining, and the Alberta component is guessestimated to include 100-150 animals. Ungulate and wolf surveys have not been conducted by Alberta Sustainable Resource Development within the CLAWR, but coyotes are very common on the planning area (ALT 2008).

Several protected areas are found within the CLAWR planning area: Cold Lake and Lakeland Provincial Parks; and Lakeland Provincial Recreation Area.

The CLAWR planning area has a high overall risk rating. Caribou habitat areas are fragmented by mixedwood uplands, agricultural landscapes, and industrial development. Consistent population declines have been documented. The potential population size based on the product of average density values and available habitat is 80 animals. This is substantially below the 500 required for a low risk population rating and would need to be supported by immigration from Saskatchewan, ESAR, and WSAR.





## NON-INDUSTRIAL SCENARIO

Non-industrial scenario simulations for caribou and moose in the CLAWR planning area show that caribou and moose numbers fluctuate naturally in response to the combined effects of random fire and insect disturbance and forest succession (Figures 66 and 67).

Based on ten random model simulations, 725 to 850 caribou and 1,950 to 2,050 moose could be supported in the CLAWR planning area with no land-use footprints or wolves present. Current estimated caribou abundance (<150) is substantially lower than their simulated natural population range; the estimated moose population (2,019) is within its simulated natural range.

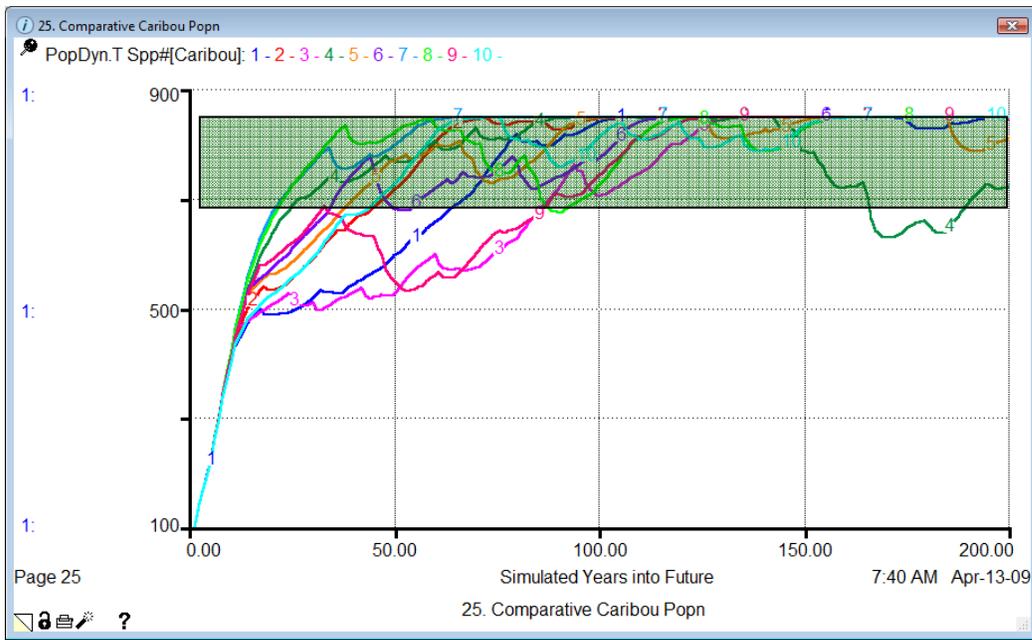


Figure 66. Forecast Non-industrial caribou population in CLAWR planning area (assumes random disturbance, caribou present at current numbers; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

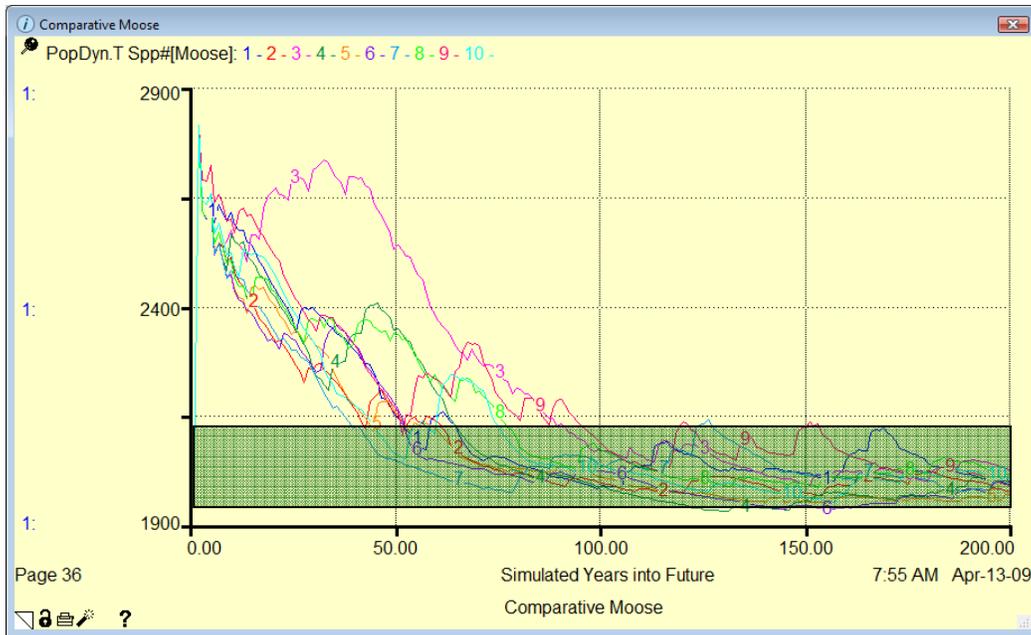


Figure 67. Forecast Non-industrial moose population in CLAWR planning area (assumes random disturbance, moose present at current numbers; no vulnerability, no land-use, 200 year simulation period. Green band shows range of natural variability for comparative purposes).

## 5.2 BUSINESS AS USUAL SCENARIO

Business as Usual scenario simulations suggest that boreal caribou in the CLAWR planning area will be extirpated within the next three decades as footprint increases, Habitat-Based Population Performance decline further from 0.95 to 0.79, and as shown in Figure 68, deer numbers decline to a density of 45/100 km<sup>2</sup>, wolves increase to a density of 1.9/100 km<sup>2</sup>, and moose decline slowly to a density of 17/100 km<sup>2</sup>. Declines in other prey species are associated with net habitat loss from increased land-use footprint.

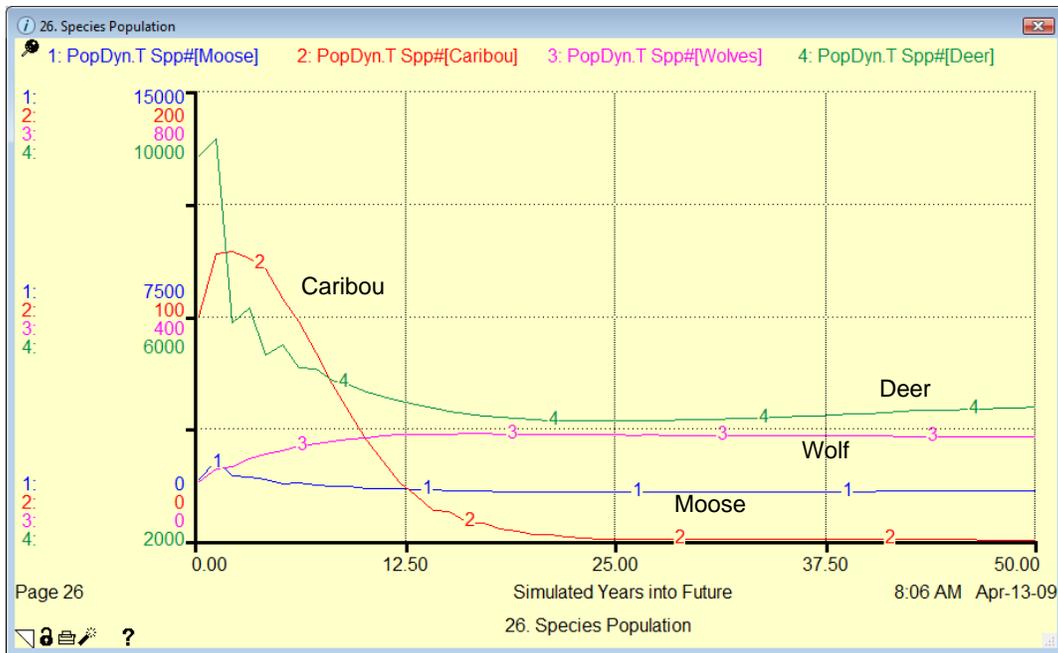


Figure 68. Forecast Business as Usual caribou, moose, wolf, and deer population size in CLAWR planning area (assumes constant disturbance, all species at current numbers; standard vulnerability and buffers assumptions; forecast land-use; 50 year simulation period).

### 5.3 ALTERNATIVE FUTURES SCENARIO

Simulation results for habitat restoration levers, mortality management levers, and combined management levers are summarized below in Sections 5.3.1, 5.3.2, and 5.3.3, respectively.

#### 5.3.1 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 best practices on a project-by-project basis to reduce future land-use footprint size or lifespan.

##### 5.3.1.1 Future Footprint Minimization

Figure 69 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 69 shows that in CLAWR, like all other planning areas, future in-situ development has the greatest effect on habitat function, either alone or in combination with reducing the forest footprint. Limited forest harvest is planned for CLAWR, so its influence on caribou habitat function in the CLAWR is limited relative to the energy sector. Reducing the fire return interval through fire suppression or manipulating insect outbreak rates also have comparatively limited effect on Habitat-Based Population Performance in this planning area.

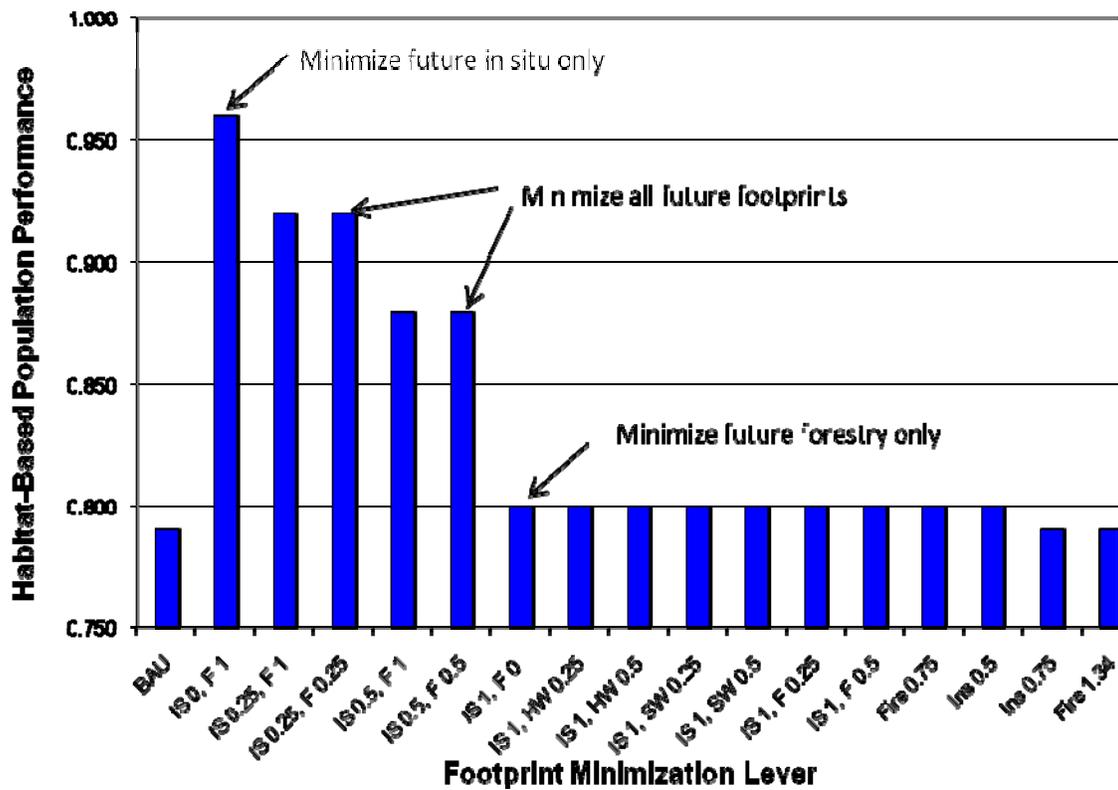


Figure 69. Influence of footprint minimization levers in the CLAWR planning area (IS = in-situ footprint reduction; F = forestry footprint reduction; HW = hardwood footprint reduction; SW = softwood footprint reduction; Fire = alter fire interval; Ins = alter insect outbreak frequency; numbers represent proportional change from BAU assumptions).

### 5.3.1.2 Coordinated Reclamation and Best Practices

Figure 70 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 69 (restoration of Habitat-Based Population Performance to 0.89 vs. 0.96 respectively).

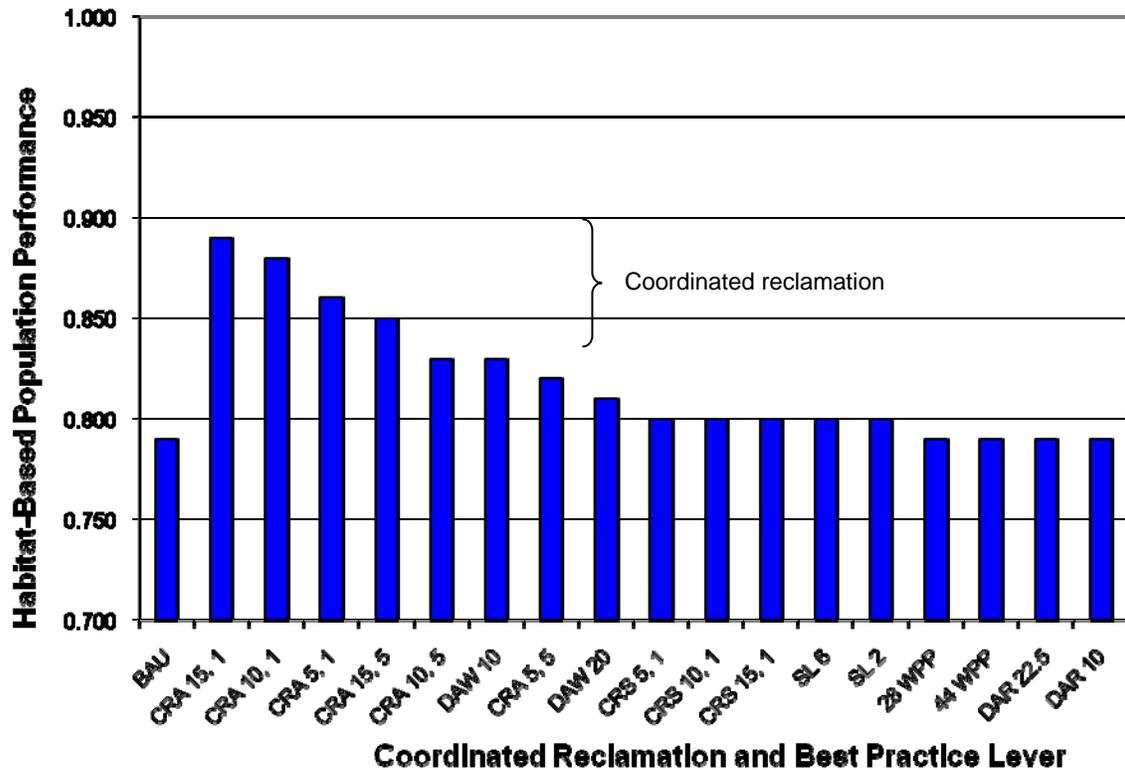


Figure 70. Influence of coordinated reclamation and best practices levers in the CLAWR planning area (CRA = coordinated reclamation seismic, pipelines, temporary roads; DAR = delineation well road lifespan; WPP = production wells per pad; CRS = coordinated reclamation seismic; SL = seismic lifespan; DAW = delineation wellpad lifespan; DAR = delineation access road lifespan; CRA and CRS numbers represent percent reclaimed per year and interval; number for other levers are proportional change from BAU assumptions).

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 70). Optimization simulations indicate that the influence of coordinated reclamation diminishes after 10-15 years when most historic footprint has been considered to be reclaimed. Shortening delineation wellpad by using minimum ground disturbance construction methods and rapid reforestation has the next largest effect (DAW simulations in Figure 70, 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), reducing seismic line lifespan (SL), and reducing delineation well access road lifespan (DAR) also have a beneficial effect on future Habitat-Based Population Potential, but their incremental effect is comparatively small relative to other levers considered (Figure 70).

### 5.3.2 Mortality Management Levers

ALCES<sup>®</sup> CLAWR simulations 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 increased to a density approaching 1.9/100 km<sup>2</sup> (Figure 68). 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 CLAWR 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.

As observed in simulations for other planning areas, the success of predator control was highly dependent on assumptions regarding wolf control rate, control interval, and wolf immigration rate (Figure 71). Sensitivity simulations for the CLAWR planning area suggest that with a wolf immigration rate of 10/year, 75% wolf control every year would not be enough to sustain the caribou population at its current level. Actual wolf population dynamics will therefore be critical to understand in the CLAWR area as likelihood of success is inversely related to immigration rate.

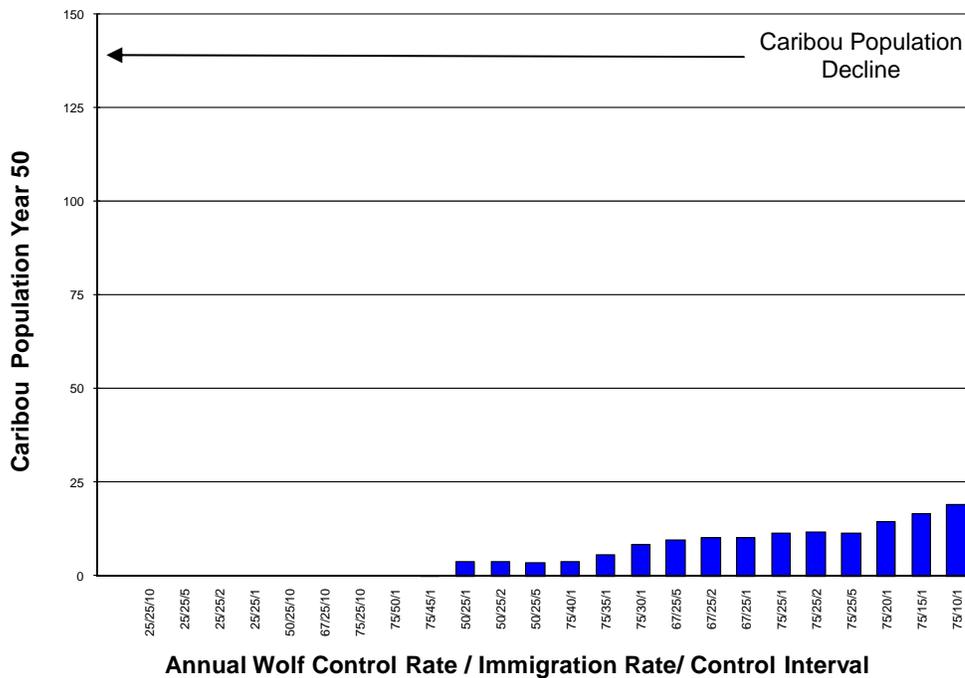


Figure 71. Interaction between wolf control and wolf immigration rates on simulated caribou population in the CLAWR planning area (Numbers on y-axis reflect assumed annual wolf depredation rate/wolf immigration rate/depredation interval in years for that simulation).

Similar to the Richardson planning area, the current number of adult females in CLAWR is small ( $n=46$ ; see Supplemental Data Table 1), and therefore to achieve the calf survival targets identified by the ALT, the cow-calf penning scenarios were set at 60% and 100% of cows penned, with penning intervals of 1, 2, and 5 years respectively. Simulations indicated that penning all cows and calves each year would not sustain the CLAWR caribou population. Figure 72 shows that caribou did not persist much beyond a 50 year simulation period even though 100% of the cows were penned every year. An increase in penning interval to two years resulted in caribou extirpation within about 30 years (Figure 73). These simulation results show the ineffectiveness of cow-calf penning as a single factor management lever when it is applied to small populations of caribou that are sympatric with higher densities of alternate prey and wolves.

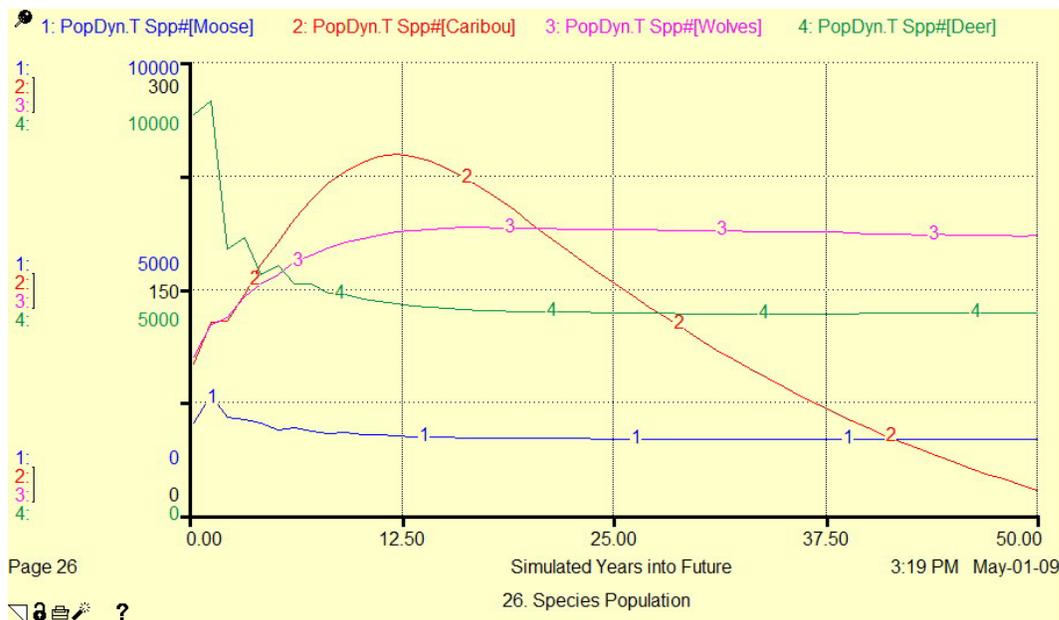


Figure 72. Influence of an annual cow – calf penning program on predator and prey populations in the CLAWR planning area (Business As Usual land-use assumption, 100% cows penned, 80% calf mortality reduction, 1 yr intervals, and 2/yr wolf immigration).

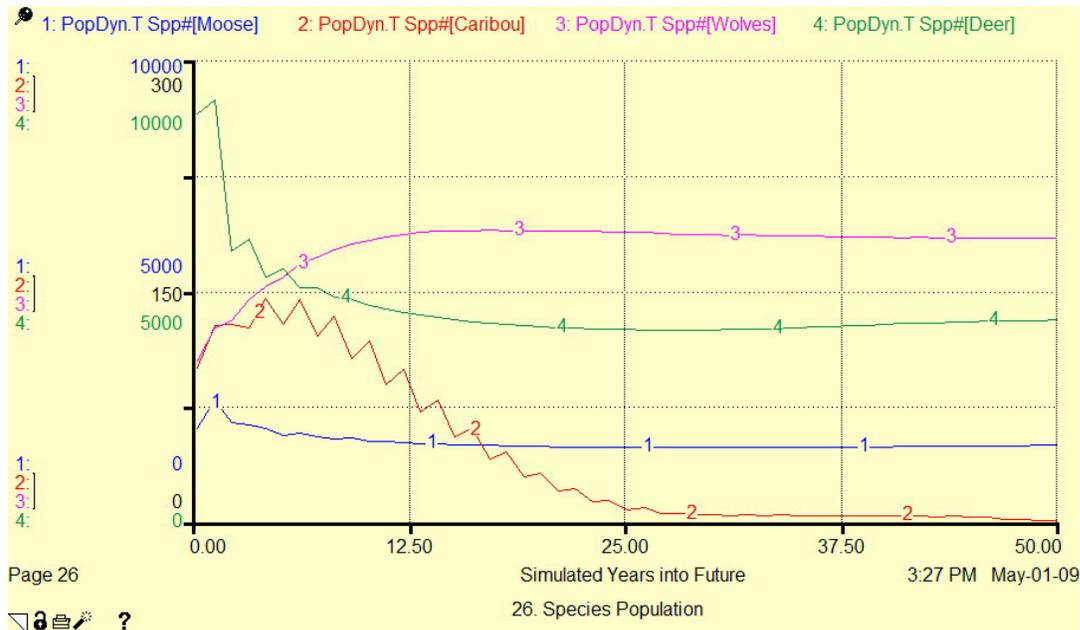


Figure 73. Influence of an annual cow – calf penning program on predator and prey populations in the CLAWR planning area (Business As Usual land-use assumption, 100% cows penned, 80% calf mortality reduction, 2 yr intervals, and 2/yr wolf immigration).

Results of other prey control simulations are less straightforward because removal of other prey can increase short-term prey switching to caribou in the absence of simultaneous wolf control. Nevertheless, even under a scenario with aggressive and combined approaches for mortality management (i.e., 75% annual wolf control and 15% annual moose and deer control and an assumed immigration rate of 25 wolves/yr), the long term persistence of caribou in CLAWR is unlikely given model assumptions (Figure 74); the assumptions about the rate of wolf immigration are a key uncertainty.

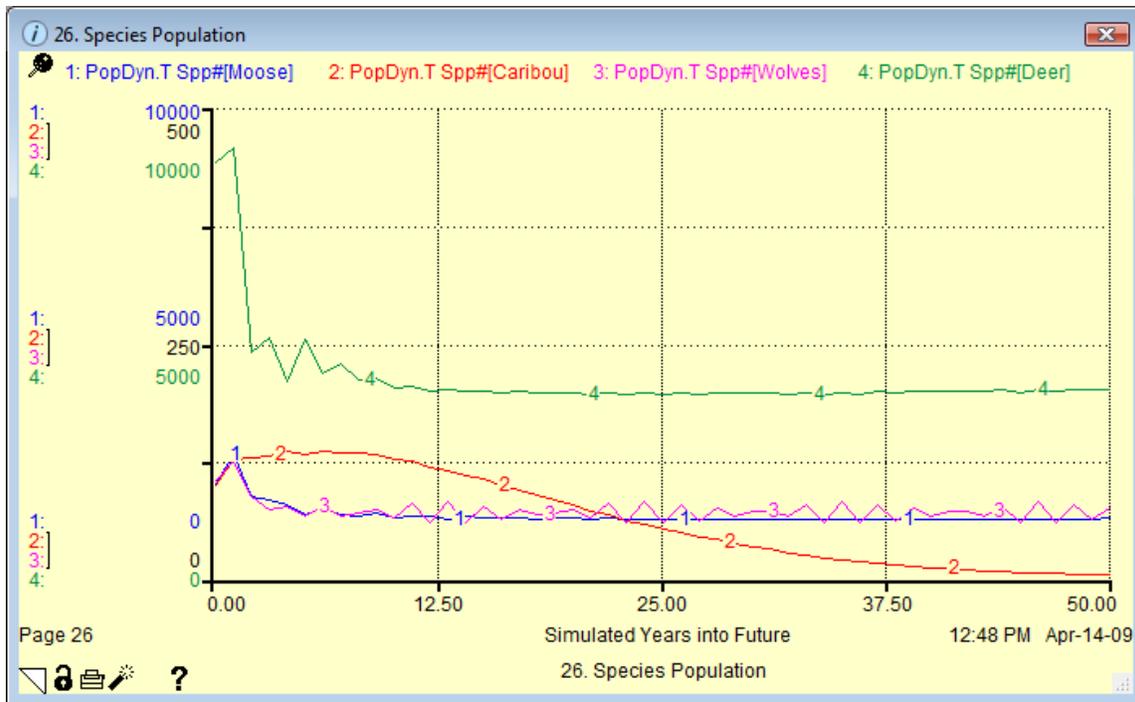


Figure 74. Interaction between wolf, moose and deer control on predator and prey populations in the CLAWR planning area (75% annual wolf control, 15% annual moose and deer control, 25 wolves/yr immigration).

### 5.3.3 Combined Management Levers

Based on scenario simulations, CLAWR had the lowest probability of caribou persistence. No combination of management strategies could be identified for the CLAWR planning area that showed a high likelihood of sustaining caribou with continued in-situ development. Simulations suggest that there is a strong likelihood of caribou extirpation inside CLAWR even in the presence of combined management priorities for habitat (no new footprint, coordinated reclamation of existing footprints) and combined wolf and other prey control for at least 50 years, and implementation of all best practices considered by the ALT.

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## **SUPPLEMENTAL DATA TABLES**

**Supplemental Data Table 1.** Parameter assumptions for predators and prey in population dynamics model in ALCES®

	Existing Popn Density (#/km <sup>2</sup> ) <sup>a</sup>	Existing Popn (#) - extrapolation from density and range area				Max Popn Density (#/km <sup>2</sup> )	Age Class Structure (% of pop'n; must sum to 1)			Age Class Duration (yrs.)			Avg Body Mass (kg)			Max Fecundity			Natural Mortality			Daily Food Intake (% of body)			Vulnerability Index to Wolf Predation <sup>b</sup>			Wolf Encounter Rate
		Total	YOY	Juv	Adult		YOY	Juv	Adult	YOY	Juv	Adult	YOY	Juv	Adult	YOY	Juv	Adult	YOY	Juv	Adult	YOY	Juv	Adult	YOY	Juv	Adult	
<b>WSAR</b>																												
Caribou	0.012	400	73	66	261	1.000	0.183	0.165	0.652	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	Density dependent
Wolf	0.011	367	114	62	191	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.15	5007	1252	751	3004	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.14	4673	1168	701	2804	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>ESAR</b>																												
Caribou	0.007	250	36	32	182	1.000	0.144	0.129	0.727	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.011	399	124	68	207	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.17	6162	1540	924	3697	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.3	10874	2719	1631	6524	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>Richardson</b>																												
Caribou	0.009	100	10	9	81	1.000	0.100	0.090	0.810	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.0065	71	22	12	37	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.08	869	217	130	522	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.02	217	54	33	130	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>ESAR - BF</b>																												
Caribou	0.007	94	13	12	68	1.000	0.144	0.129	0.727	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.011	154	48	26	80	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.17	2387	597	358	1432	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.3	4212	1053	632	2527	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>ESAR - W</b>																												
Caribou	0.004	62	9	8	45	1.000	0.144	0.129	0.727	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.011	169	52	29	88	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.17	2615	654	392	1569	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.3	4615	1154	692	2769	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>ESAR - E</b>																												
Caribou	0.007	46	7	6	33	1.000	0.144	0.129	0.727	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.011	75	23	13	39	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.17	1160	290	174	696	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.3	2047	512	307	1228	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	
<b>CLAWR</b>																												
Caribou	0.010	100	4	4	92	1.000	0.044	0.040	0.916	1	1	NA	60	125	160	0	0.3	0.95	0.3	0.05	0.05	0.025	0.025	0.025	0.25	0.25	0.25	
Wolf	0.011	106	33	18	55	0.060	0.310	0.170	0.520	1	1	NA	20	40	42	0	0	6	0.45	0.2	0.05	0.05	0.05	0.05	NA	NA	NA	
Moose	0.21	2019	505	303	1212	1.500	0.250	0.150	0.600	1	1	NA	170	365	430	0	0.4	2	0.1	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	
Deer	0.92	8847	2212	1327	5308	4.000	0.250	0.150	0.600	1	1	NA	35	70	82	0	1.75	2.1	0.1	0.03	0.03	0.025	0.025	0.025	0.08	0.08	0.08	

**NOTES**

<sup>a</sup> Population density for each range based on maximum popn estimate divided by total range area (including 20 km buffer)

<sup>b</sup> Vulnerability considers how likely the individual is to die if encountered by a wolf, with encounter rate related to density (e.g., deer fawns are killed at 10% of the rate predicted by their actual density)

In WSAR, Latham (pers. comm.) found that deer was numerically most common ungulate in diet (40%); moose comprised 40% of annual biomass; deer 30% of annual biomass; caribou 8-10% of annual biomass; beaver 30% c

Average adult ungulate weight from Renecker and Hudson in Stelfox 1993

Average adult wolf weight from Mech 1994; pups assumed to be half of juv/adult weight

Wolf age class structure from Algonquin in Mech 1994

Caribou demography from McLoughlin et al. 2003

Caribou, moose, and deer: YOY and juvenile weights assumed to be 40% and 85% of adult weight, respectively

**Supplemental Data Table 2.** Assumptions and development coefficients for bitumen formations in the Athabasca Landscape area.**Athabasca Landscape area**

Descriptor	BITUMEN FORMATION					Total	Percent of Total Bitumen
	Athabasca SAGD	Athabasca Mineable	Cold Lake Primary	Cold Lake CSS	Wabasca Primary + Cold WF		
Total Recoverable Bitumen in Place (m3)	48,140,000,000	23,000,000,000	386,170,000	2,093,000,000	638,400,000	74,895,970,000	100.0%
Bitumen Production Coefficient	0.15		0.022	0.095	0.075		
Bitumen Development Coefficient	0.002		0.02	0.01	0.015		
Make-up Water to Oil Ratio	0.55			1.05	1.05		
Bitumen Well Coefficient	2.83E-06		2.43E-06	2.83E-06	2.60E-06		
Bitumen Wells/Pad (#)	13		4	13	6		
Bitumen Pad Size (ha)	4		1.2	4	1.6		
Bitumen Support Well Coefficient	6.11E-07		6.25E-08	6.11E-07	7.63E-07		
Bitumen Support Pad Size (ha)	0.5		0.5	0.5	0.5		
D&A Well Coefficient	1.47E-05		3.75E-08	1.47E-05	6.65E-07		
D&A Well Pad Size (ha)	0.5		0.5	0.5	0.5		
Bitumen Pipeline Coefficient (km)	4.46E-06		2.36E-07	4.46E-06	4.20E-06		
Bitumen ROW to Pipeline Ratio	0.6		0.6	0.6	0.8		
Bitumen Seismic Coefficient (km; related to undeveloped recoverable reserves)	1.74E-07		1.01E-06	1.74E-07	5.36E-07		
<i>Area Weighted Proportions</i>							
Proportion of bitumen formation in WSAR	0.2771	0.1836	0	0	0.9101	18,143,401,840	24.2%
Proportion of bitumen formation in ESAR	0.5759	0.0244	0	0	0.0336	28,306,476,240	37.8%
Proportion of bitumen formation in ESAR-W	0.0575	0	0	0	0.0336	2,789,500,240	3.7%
Proportion of bitumen formation in ESAR_E	0.0026	0	0	0	0	125,164,000	0.2%
Proportion of bitumen formation in Richardson	0.1464	0.3554	0	0	0	15,221,896,000	20.3%
Proportion of bitumen formation in CLAWR	0.1248	0	0.0105	0.8519	0	7,794,953,485	10.4%

**Supplemental Data Table 3.** Bitumen exploitation (Hubbert-Naill) coefficients for Athabasca planning areas calculated based on area-weighted estimates of recoverable bitumen in place and data from Alberta Energy.

Athabasca planning area	Average coefficient for wells	Average coefficient for support wells	Average coefficient for D & A wells and total reserves	Average coefficient for pipelines	Average coefficient for seismic	Average coefficient for other wells	Discovery Coefficient	Production Coefficient
WSAR- area weighted calculations	2.82040E-06	6.17344E-07	1.41142E-05	4.44915E-06	1.89109E-07	1.47316E-05	2.54258E-03	0.1469
ESAR- area weighted calculations	2.82982E-06	6.11118E-07	1.46891E-05	4.45980E-06	1.74280E-07	1.53003E-05	2.00000E-03	0.1500
ESAR-W area weighted calculations	2.82823E-06	6.12169E-07	1.45921E-05	4.45800E-06	1.76784E-07	1.52042E-05	2.09997E-03	0.1494
ESAR-E area weighted calculations	2.83000E-06	6.11000E-07	1.47000E-05	4.46000E-06	1.74000E-07	1.53110E-05	2.00000E-03	0.1500
Richardson- area weighted calculations	2.83000E-06	6.11000E-07	1.47000E-05	4.46000E-06	1.74000E-07	1.53110E-05	2.00000E-03	0.1500
CLAWR- area weighted calculations	2.82979E-06	6.10715E-07	1.46924E-05	4.45780E-06	1.74436E-07	1.53031E-05	3.83929E-03	0.1374

**Supplemental Data Table 4.** Forest harvest target volumes for Athabasca planning areas

Land Use	Richardson	WSAR	ESAR	ESAR - BF	ESAR - W	ESAR E	CLAWR
<b>Herd Area + 20 km buffer (ha)</b>	1,086,734	3,337,806	3,624,722	1,403,913	1,538,420	682,390	951,564
<b>Future HW Harvest Target (m<sup>3</sup>)</b>	48,909	1,110,975	866,461	351,201	182,135	333,125	74,525
<b>Future SW Harvest Target (m<sup>3</sup>)</b>	171,299	1,243,593	1,300,980	402,402	248,282	650,296	88,807
<b>Future Total Wood Harvest Target (m<sup>3</sup>)</b>	220,208	2,354,568	2,167,441	753,603	430,417	983,421	163,332
<b>Wood Harvest Target - Area Index (m<sup>3</sup>/ha)</b>	0.20	0.71	0.60	0.54	0.28	1.44	0.17