TECHNICAL REPORT

Population and Distribution Objectives and Identification of Critical Habitat for Seven Herds of Woodland Caribou in the South Peace Area of British Columbia

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MARCH 31, 2014

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Prepared for West Moberly First Nations

CITATION: McNay, R.S., V. Brumovsky, and B. Muir. 2014. Population and distribution objectives and identification of critical habitat for seven herds of woodland caribou in the south Peace area of British Columbia. Wildlife Infometrics Inc. Report No. 464. Wildlife Infometrics Inc., Mackenzie, British Columbia, Canada.

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
BC	British Columbia
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DU	Designatable Unit
EC	Environment Canada
CSR	Calving/Summer Range (caribou)
Ha	Hectare
HEWR	High-Elevation Winter Range (caribou)
Km	Kilometre
LER	Low-Elevation Range (caribou)
m.	Metre
M.	Million
ROW	Right-of-way
SARA	Species at Risk Act (federal)
WMFN	West Moberly First Nation

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INTRODUCTION

Planning Context

Treaty No. 8 was signed in 1899 on the shores of Lesser Slave Lake, Alberta. As a beneficiary of Treaty No. 8, the people of West Moberly First Nations ("West Moberly") have, among other things, established substantive rights to their mode of life without forced interference, which include harvesting caribou in accordance with their traditional seasonal round. For thousands of years the species has been an integral species in the health and well-being of their culture. Stories, songs, legends, in addition to manufactured items derived from the caribou as well as the consumption of the species, support their cultural subsistence (WMFN 2009). Historically, the distribution of the caribou was referred to as a "sea of caribou" and the population level was described as "like bugs on the land"; the modern-day phenomenon of caribou herds (or subpopulations") was not a characteristic of baseline conditions (WMFN 2009). These characteristics began to considerably decline in and around the late 1960s, which is temporally marked by the construction of the W.A.C. Bennett Hydroelectric Dam and the subsequent flooding of 1,700 km^2 of habitat to create the Williston Reservoir (WMFN 2009).

Woodland caribou (*Rangifer tarandus caribou*) in the Southern Mountain Population were listed as a "threatened" species under Schedule 1 of the *Species at Risk Act* ("SARA") in 2003 due to the considerable decline in spatial distribution and population levels. In accordance with SARA, a Recovery Strategy was legislatively required to be prepared no later than 2007. It was eventually posted by Environment Canada for public comment in January 2014 (EC 2014). The seven herds (henceforth, subpopulations) addressed herein are constituent subpopulations to be recovered pursuant to the posted Recovery Strategy. The work to identify critical habitat and population and distribution objectives was initiated in 2009 and thus was undertaken coincidental to development of the Recovery Strategy with the intent that results may be incorporated into the Recovery Strategy pursuant to s. 44(2) of SARA, and/or may become, or be incorporated into, an Action Plan for the species under s. 51 of SARA. An Action Plan for one of the subpopulations, the Klinse-Za herd (the "Action Plan for the Klinse-Za Herd"), has already been developed by West Moberly First Nations (McNay et al. 2013) and was presented in June 2013 to both the Government of Canada and the Provincial Government of British Columbia for inclusion into their respective recovery planning processes.

The seven subpopulations addressed in this technical report are the Scott, *Klinse-Za*,[1] Kennedy, Burnt Pine, Quintette, Graham, and Narraway subpopulations. Caribou of these subpopulation, compared to caribou of other ecotypes, forage primarily on terrestrial lichens during winter and inhabit a geographic region of relatively shallow snow. While all seven subpopulations are within the Southern Mountain National Ecological Area, which is an approach that does not necessarily align with traditional knowledge of West Moberly, the Graham is located within the Northern Mountain Designatable Unit (DU7) and the remaining subpopulations are all within the Central

[1] The *Klinse-Za* caribou herd was formerly referred to as the "Moberly" caribou herd by the colonial governments. The name was changed by order of Chief and Council of West Moberly First Nations in order to be reflective of the sacred area that the caribou form an integral component of from a cultural perspective.

Mountain Designatable Unit (DU8) (COSEWIC *in draft*). All of these subpopulations are within the preferred Treaty territory of West Moberly.

There are currently an estimated 1,038 caribou within the study area (Table 1). Most subpopulations, with the possible exception of the Graham, are known to be decreasing in size and the Burnt Pine is considered to be essentially extirpated (Seip and Jones 2013). All seven subpopulations are of significant value to the culture of the West Moberly and have historically represented important opportunities to practice cultural activities in relation to caribou and caribou habitats within the study area. These activities would, for example, include the harvesting other species (e.g., marmots) and medicinal plants (e.g., lichens). Since the 1970s, the Elders of West Moberly have imposed a moratorium on hunting caribou until the decline of subpopulations has been reversed and their critical habitat is protected with appropriate conservation measures. West Moberly has taken aggressive actions (including the preparation of the Action Plan for the Klinse-za Herd and this technical report) to support recovery of caribou populations within their preferred Treaty territory.

Table 1. Population size and trend information for seven herds of woodland caribou in the south Peace area of British Columbia (from EC 2014).

	Population Estimate		Population Trend	
Subpopulation	Estimate	Year	Current	Long-term
Graham	708	2009	Stable	Unknown
Scott	47	2013	Unknown	Unknown
Klinse-Za	16	2013	Decreasing	Decreasing
Kennedy	41	2012	Decreasing	Decreasing
Burnt Pine	1	2013	Decreasing	Decreasing
Quintette	129	2013	Decreasing	Decreasing
Narraway	96	2012	Decreasing	Decreasing

The Study Area

The study area includes all of the caribou range known and mapped in recent times, as the seven subpopulations noted above (Figure 1). It also includes sufficient area surrounding those herds to reflect the traditional knowledge of West Moberly and other First Nations, including Elders from Saulteau First Nations, which is the historical reference point (baseline condition) of caribou in the study area prior to population decline (current condition).[2] Having undergone severe population declines in the recent past, it is probable that the seven subpopulations, with the possible exception of the Graham, no longer are composed of all behavior types and are now primarily represented by more sedentary and less wide-ranging individuals than would have occurred in historic times (Spalding 2000). The spatial extent of the study area, which is 5.988 M ha, was also purposefully designed to address opportunities for genetic

[2] Note that the caribou, according to traditional knowledge, included those that were in the mountains (high elevation habitats), came out to see the people (low elevation habitats), and resided in the forests. The latter likely reflects the boreal caribou ecotype, which have not been considered in this technical report as the majority of such habitat in the study area has been significantly altered by anthropogenic activities, such as agriculture, human settlements, and oil and gas operations.

exchange and other natural population interactions (e.g., dispersal events) among the seven herds. An exception to this approach to the study area definition exists in the Narraway where it was not possible to obtain spatial data for the Alberta portion of the herd area.

Disturbance and Threats to Caribou Range

A technical science team, in support of developing a recovery strategy for boreal caribou, used landscape disturbance data and caribou population information to define a national landscape disturbance threshold of no less than 65% of undisturbed habitat EC 2011); caribou populations on ranges having less than the threshold were considered to have a reasonable probability of becoming stabilized over time and those on ranges having greater than the threshold were considered to have a poor chance of becoming stable and were more likely to be declining if no corrective management actions were undertaken. Disturbance was defined as a 500m buffered area around any land modified by anthropogenic sources <40 years old (EC 2011). Natural wildfires < 40 years old were also considered to be a disturbance, but were not buffered.

Anthropogenic and natural disturbances to landscapes can lead to a variety of threats to caribou. An example is a disturbance-induced increase in the numerical and functional response by predators. This condition of increased predation risk subsequently leads to coincidental increased mortality rate on caribou (Seip 1992, Stotyn 2008, Williamson-Ehlers 2012, Wittmer et al., 2005, Whittington et al. 2011). The two disturbances that are considered most relevant are: (1) any activities that convert old-seral vegetation to young-seral vegetation; the latter of which support other ungulate species that are primary prey for many predators (Serrouya et al. 2011); and, (2) any activities that create unnaturally straight (i.e., linear) features where vegetation has been cleared away or converted to, and maintained at, a young-seral condition. This condition is considered to lead to an increased encounter rate (i.e., a functional response) between predators and their prey, including caribou (Whittington et al. 2011).

Other threats to caribou resulting from landscape disturbances are direct loss of habitat components (e.g., removal of forage, removal of snow-intercepting forest canopies, barrier to movement); however, these threats are considered secondary to the increased rate of predation noted above.

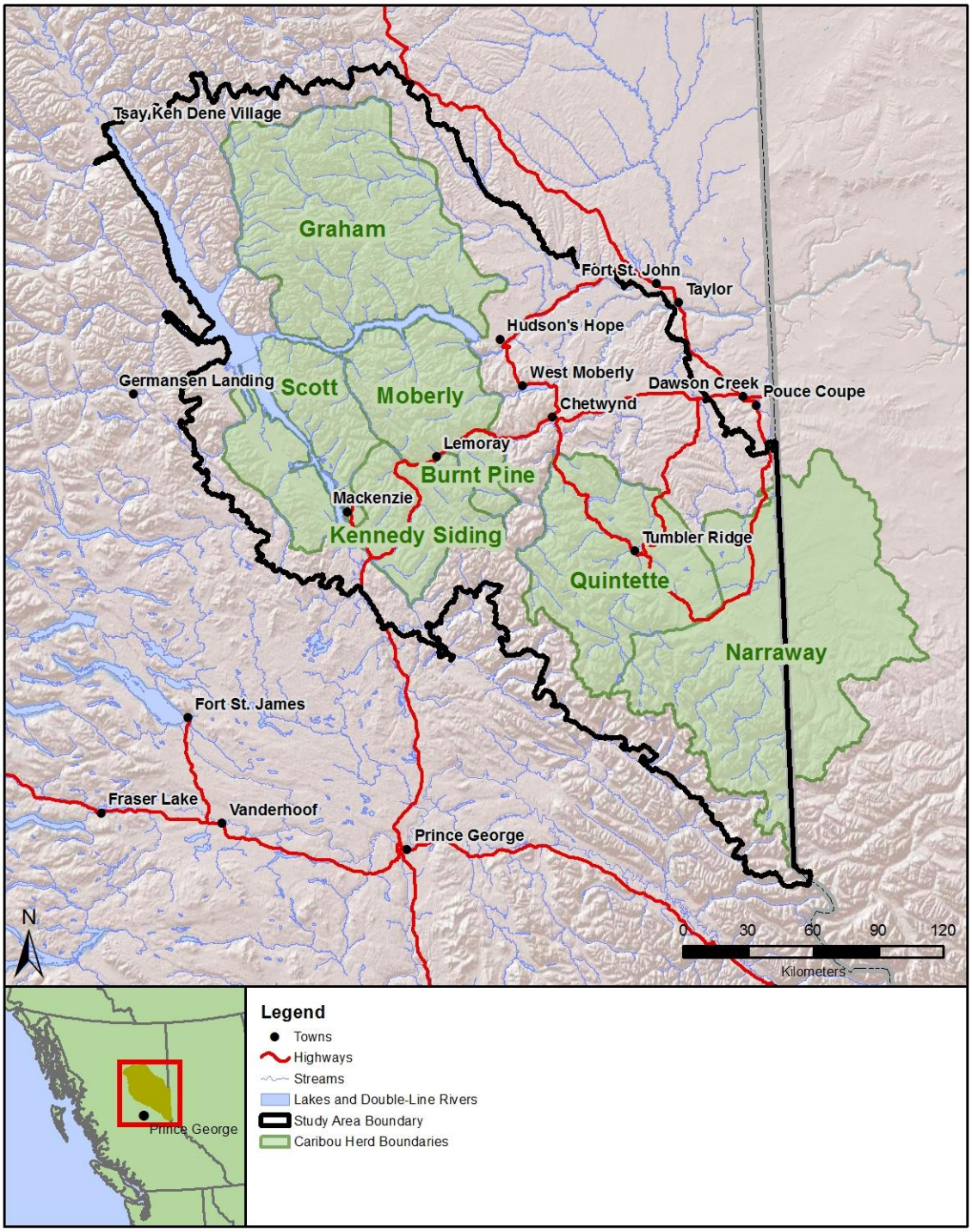

Figure 1. The plan area for which population objectives and critical habitat were defined for seven subpopulations of woodland caribou in British Columbia.

In this report, we considered disturbance to components of range to include, but may not be limited to:

- Increased risk of mortality;

- Inability for individual caribou to breed or raise their calves successfully due to the occurrence of anthropogenic activity that displaces caribou from their range;
- Damage to and/or destruction of forage lichens (e.g., removal of terrestrial lichens during exploration activities and/or the construction of project infrastructure or removal of trees that provide support for arboreal lichens);
- Changes in snow interception and thermal cover due to changes in the forest canopy (e.g., removal of trees);
- Increased barriers to movement (i.e., two spatial scales are contemplated; loss of foraging habitat and/or isolation from other herds) that could result from project infrastructure (e.g., above ground pipes, intensively used roads, camp/plant facilities, fencing, reservoirs, berms, etc.) or portions of landscapes managed for other resource purposes (e.g., dense, even-aged forests of specific types and geographic position, agricultural areas, etc.); and,
- Loss of contiguous habitat for caribou to use.

Potential threat factors and activities in the study area include:

- Resource exploration and development activities (e.g., forestry, minerals and coal mining, hydroelectric, wind power, and oil and gas in including use of helicopters, construction, and normal operation of onsite equipment and disturbances to land) during all stages of natural resource development (e.g., planning, exploration, construction, operations, reclamation, decommissioning, and ecological restoration);
- Natural disturbances (e.g., fires, forest insects, avalanches) and climate change;
- Recreational activities (e.g., snowmobiling, heli-skiing, all-terrain vehicles, hiking);
- Natural resource activities of non-First Nations (e.g., hunting, trapping, guide-outfitting);
- Habitat enhancement for other ungulate species;
- Settlements and agriculture, including the associated land uses (e.g., cattle grazing, residential housing, urban/rural amenities and services) and infrastructure (e.g., power lines, roads);
- Management to limit large natural disturbances and their effects (e.g., fire suppression, salvage harvesting); and,
- Development of roads and other linear infrastructure (e.g., utility and service lines, seismic lines, pipelines, railways) and activities on the respective right of ways ("ROW") associated with construction and operational management of the factors above.

ANALYTICAL METHODS

Modeling and Mapping Critical Habitat

SARA defines ''habitat'' as:

> a) *In respect of aquatic species, spawning grounds and nursery, rearing, food supply, migration and any other areas on which aquatic species depend directly or indirectly in order to carry out their life processes, or*

areas where aquatic species formerly occurred and have the potential to be reintroduced; and

b) *In respect of other wildlife species, the area or type of site where an individual or wildlife species naturally occurs or depends on directly or indirectly in order to carry out its life processes or formerly occurred and has the potential to be reintroduced.*

SARA defines "critical habitat" as:

> *"The habitat that is necessary for the survival or recovery of a listed wildlife species and that is identified as the species' critical habitat in the recovery strategy or in the action plan for the species."* **[SARA, ss.2(1)]**

Modeling of critical habitat necessary to meet population and distribution objectives for the seven caribou subpopulations was identified using a Bayesian modeling technique (McCann et al. 2006). This method has been successfully used in previous recovery planning projects (McNay et al. 2008, Sutherland et al. 2007, McNay et al. 2014). The modeling approach is deductive (rather than inductive) and thereby allows for identification of habitat necessary for an animal to perform its life functions regardless of whether the habitat is currently being used or not. This is important in recovery planning because the focus is on recovering subpopulations that now exist in remnants of their previous geographic distributions, numbers, and behaviors (Spalding 2000, WMFN 2009). In some cases (e.g., *Klinse-Za* or Burnt Pine) there are simply not enough animals to expect them to occupy all the currently suitable range. Furthermore, there is unlikely to be the behavioral representation within the subpopulations to indicate all potential habitats that would have been used historically (i.e., the small remaining subpopulations are those portions of the herds that have been best able to survive in the currently disturbed landscape). The modeling of potential range for this project therefore identifies the landscape conditions that will be necessary to provide the basic life requisites for caribou (i.e., abundant forage, reduced snow depths in winter, relative security from predators, etc.). The modeling was conducted under hypothetical conditions where historic disturbances (e.g., forest harvest, road construction, oil/gas exploration) to the land were removed to represent a potential landscape scenario likely to be more characteristic of the historically functional range.

The relative importance of some caribou life requisites varies seasonally. The potential range identified in this project therefore includes habitat used during four critical seasons: rut, winter, calving, and summer (Cichowski et al. 2012). Critical habitat for these caribou herds occurs wherever these life requisites occur on the landscape during those seasons. For management purposes, and because of the similarity in range locations, we grouped results for rut with winter and results for calving with summer. Winter habitat can occur at both high- and low-elevations while calving and summer range occurs only at high-elevation. Three zones of caribou range can therefore be depicted as the following: (1) low-elevation range ("LER"); (2) high-elevation winter range ("HEWR"), and, (3) calving and summer range ("CSR"). The model resultant for the LER, HEWR, and CSR caribou range zones were divided into management unit polygons using methods that were similar for each zone but tailored to the spatial representation of each range zone (see Appendix A).

Matrix habitat is any habitat within the study area that was not modeled as LER, HEWR, or CSR. Matrix habitat is also considered critical habitat because caribou may use these

areas occasionally for travel or migration, and because conversion of matrix habitat through disturbance events can indirectly lead to increased threats to caribou that are using adjacent ranges.

Disturbance Footprint

We calculated the level of disturbance within the study area using a 250m buffer[3] around the following physical disturbance types:

- Oil and gas sumps;
- Oil and gas well sites;
- Railroads;
- Roads;
- Seismic lines;
- Oil and gas facilities;
- Oil and gas pipeline ROWs;
- Oil and gas waste disposal sites;
- Mines and mining activities;
- Agricultural areas;
- Urban areas;
- Private land (fee simple);
- Electrical transmission ROWs;
- Windfarms and wind energy investigative tenures; and,
- Forestry cut-blocks.

Population and Distribution Objectives

Population objectives were calculated for the study area by using the density of woodland caribou populations of the northern ecotype in BC[4] factored by the total amount of non-overlapping potential range. The likelihood of achieving those objectives were assessed by considering population growth potential for each subpopulation[5] in a demographic model (Appendix B) using the following parameter assumptions:

- Initial population sizes as determined by recent population surveys;
- Adult survival rates based on results of recent population surveys;
- Age-specific parturition rates for female caribou based on a study of northern caribou (McNay and Giguere, *in prep*.).
- A ratio of 40/100 for adult males to adult females; and
- A series of 5 management scenarios each with different management actions concerning varying use of wolf removal, use of maternal penning to reduce cow and calf mortality during the calving season, and use of translocations to

[3] It has been recommended that the use of a 500m buffer is more appropriate (EC 2011) although that has been debated (Boutin and Arienti 2008, Sleep and Loehle 2010). In the Recovery Action Plan for the Klinse-Za herd of caribou, although a 250m buffer was used the results differed by less than 1% from a similar analysis that used a 500m buffer.

[4] The weighted average density using 2008 population statistics is 130 caribou per 1,000km^2; (data from McNay and Hamilton 2010).

[5] We did not model a management scenario for the Burnt Pine because the herd is essentially already extirpated.

augment the subpopulation from a donor subpopulation (see scenario descriptions in Appendix B).

Distribution objectives were developed based on the spatial extent of potential caribou ranges and critical habitat. The likelihood of achieving those objectives were then assessed by considering the extent to which critical habitat was already disturbed and how much restoration would be required if necessary.

RESULTS

Critical Habitat

The study area is 5.988 M ha, of which large water bodies (181,133 ha) and slivers of slightly different spatial layers (1,793 ha) were ignored in the calculation of seasonal range values and critical habitat, leaving a total area of 5.805 M ha. Critical habitat (i.e., the combination all non-overlapping seasonal ranges and matrix habitat) totaled 3.292 M ha within designated herd areas leaving 2.513 M ha (43%) of critical habitat within areas that are not currently designated as caribou subpopulation area (henceforth, that area is referred to as non-designated) (Table 2).

Matrix habitat comprised 1.257 M ha (22%) of the area, being least represented in the Narraway area (1%) and most represented in the Burnt Pine and Non-designated areas (31% and 33% respectively) (Table 2). LER (1.520 M ha), CSR (1.496 M ha), and overlapping CSR and HEWR (1. 109 M ha) are apparently the largest contributors to critical habitat in the plan area (Table 2, Figure 2, and Figure 3).

Disturbance Footprint

The amount of critical habitat that has not yet been disturbed is 3.344 M ha (58%) which is 7% below the threshold of 65% that has been used for boreal caribou range (Table 2). The amount of undisturbed area ranges widely though from 14% above target for the Graham to 28% below target in the Quintette. The Kennedy subpopulation is the only other area with undisturbed area being above the threshold.

Population and Distribution Objectives

The population and distribution objective for the study area is to achieve, within 3 generations (or 21 years), a stable or increasing population of 5,913 caribou distributed throughout their range (Table 2) as depicted in Figure 2 and Figure 3, with connectivity among adjacent subpopulations. Recovery initiatives leading to increases in each subpopulation would presumably lead to expansion of the spatial distribution with approximately 2,200 caribou occupying previously used areas that are now outside of any designated range (Table 2). Currently, there is sufficient range to support 3,361 caribou but presumably threats associated with adjacent disturbed matrix habitat and other seasonal ranges have limited populations to a little over 1,000 animals (Table 1). This difference between current range potential and actual range potential is greatest in the Narraway and Quintette where disturbance of caribou range is the greatest.

Table 2. Critical habitat and population objectives for woodland caribou within seven subpopulations of caribou in British Columbia.

Range[1]	Undesignated[2]	Burnt Pine	Graham	Kennedy	Klinse-Za	Narraway	Quintette	Scott	Grand Total
Matrix	820,725	21,857	130,884	52,420	72,904	3,930	41,015	113,055	1,256,791
CSR/HEWR/LER	874	0	1,414	0	42	2,893	1,446	171	6,841
CSR/HEWR	256,630	11,015	362,083	5,682	84,810	190,297	117,763	81,244	1,109,524
LER/CSR	59,597	0	37,378	4,164	11,682	97,733	92,894	6,170	309,618
LER	780,566	0	176,942	13,723	26,870	214,582	218,720	88,920	1,520,323
CSR	553,864	38,092	167,885	218,730	128,873	141,109	132,320	115,241	1,496,113
HEWR	40,776	0	51,165	1,125	3,205	319	2,269	7,536	106,396
Total CH[3]	2,513,031	70,963	927,751	295,844	328,388	650,862	606,428	412,338	5,805,606
Total range[4]	1,692,306	49,106	796,867	243,424	255,483	646,933	565,413	299,282	4,548,815
Potential population[5]	2,200	64	1,036	316	332	841	735	389	5,913
Not disturbed	1,339,686	28,298	733,978	215,447	202,389	359,795	225,331	239,209	3,344,133
% Not disturbed	53%	40%	79%	73%	62%	55%	37%	58%	58%
Deviation from 65%	-12%	-25%	14%	8%	-3%	-10%	-28%	-7%	-7%
Effective range[6]	990,578	21,378	641,300	193,706	175,719	358,110	213,905	198,613	2,793,309
Possible current population[7]	1,288	28	834	252	228	466	278	258	3,631

1- CSR – Calving and summer range, HEWR – High-elevation winter range, LER – Low-elevation range, CH – Critical habitat.

2- Undesignated is caribou range that is located outside of currently designated herd areas.

3- Total CH – is all identified ranges plus matrix habitat

4- Total range – is all identified ranges (used for the purpose of calculating population estimates)

5- Potential population – is an estimated population size based on the median density of northern caribou in BC factored by the area (ha) of total range.

6- Effective range – is the amount of identified range that has not been disturbed.

7- Possible current population – estimated population size based on the median density of northern caribou in BC factored by the area (ha) of effective range.

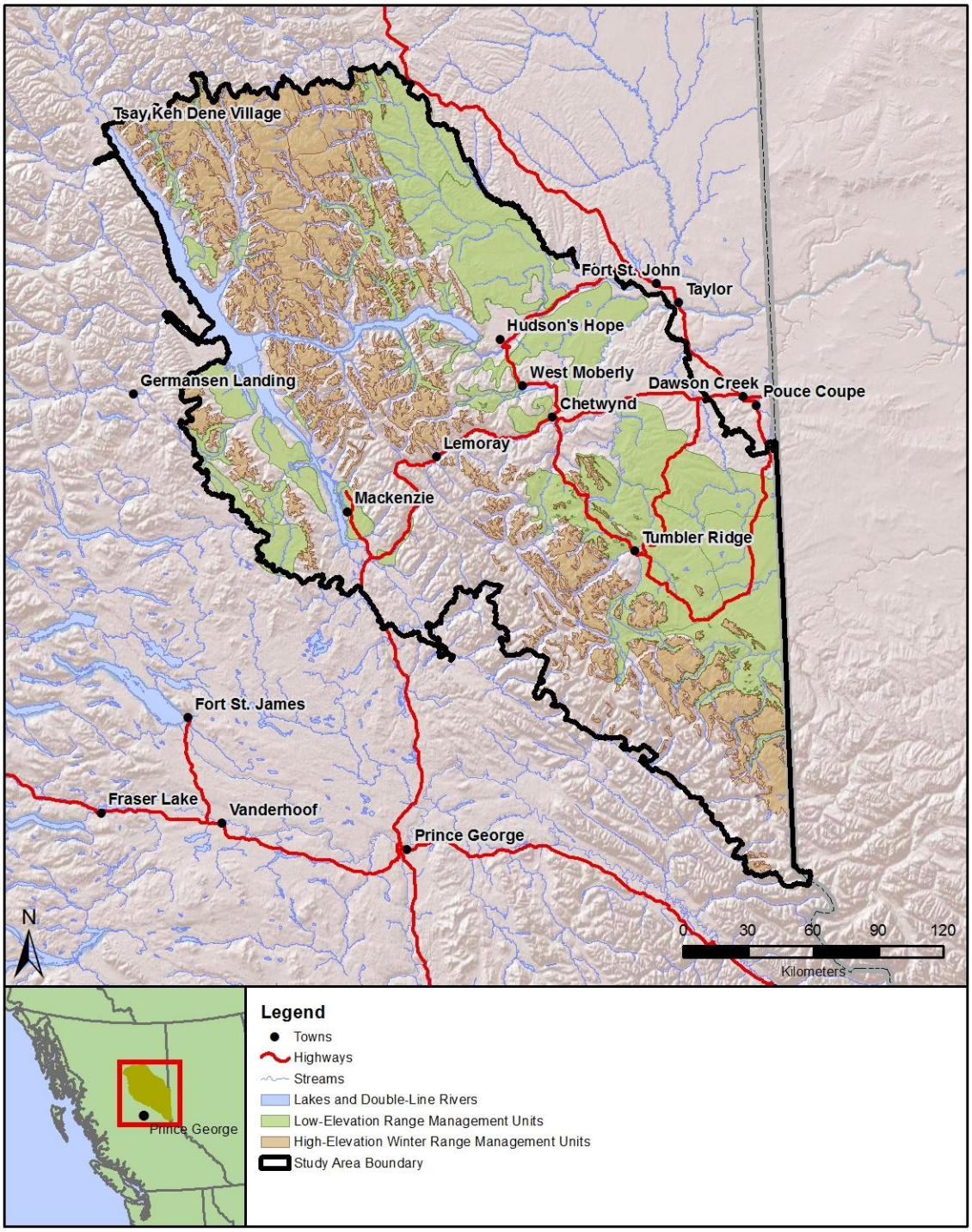

Figure 2. Potential low-elevation range and high-elevation winter range in a plan area for which population objectives and critical habitat were defined for seven subpopulations of woodland caribou in British Columbia.

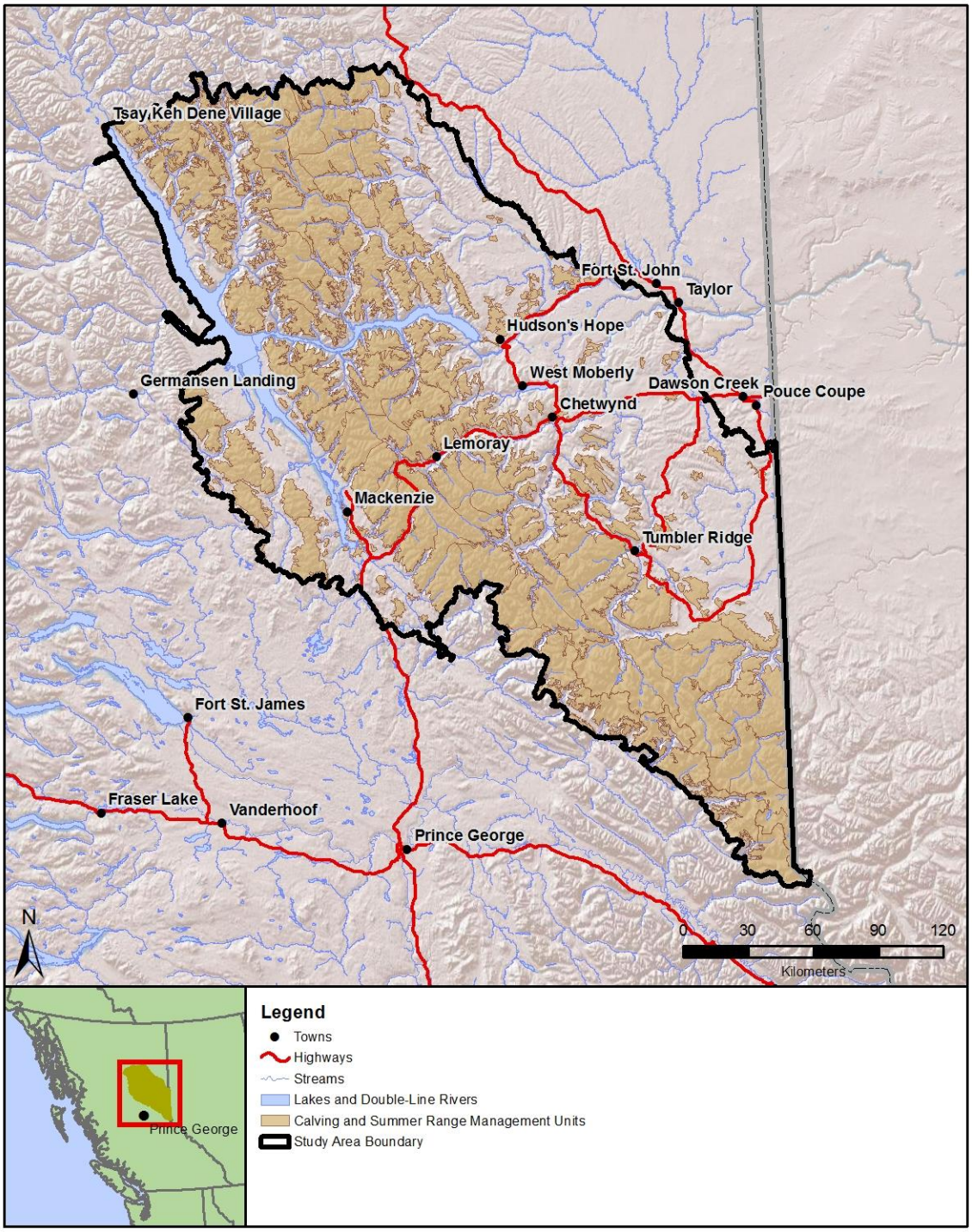

Figure 3. Potential calving and summer range in a plan area for which population objectives and critical habitat were defined for seven subpopulations of woodland caribou in British Columbia

ASSESSMENT OF RECOVERY POTENTIAL

Lack of management actions is forecasted to lead to continued decline of population size and eventual extirpation in all subpopulations. Extirpation is estimated for around 2021, or prior, in the *Klinse-Za*, Narraway, and Scott subpopulations.

The combined actions of removal of wolves and penning of pregnant cows for the areas of the subpopulations will apparently provide for the most aggressive response in population recovery, with the exception of the Graham area as the management of wolves alone provides nearly the same response (Figure 4). In the Quintette subpopulation, removal of wolves alone can perhaps bring the population back to its current potential; however, for most subpopulations that management action is forecasted to be insufficient as a lone recovery action. Also, in the Quintette subpopulation, it would appear as though any management action could eventually lead to the realization of current population potential. For the Narraway subpopulation only the most aggressive management is forecasted to allow the subpopulation to reach it current potential; even then, the subpopulation is still not forecasted to reach its actual potential before 2037. If the proper actions were undertaken and were effective, the recovery of the Klinse-Za, Scott, Kennedy Siding, Burnt Pine, and Quintette subpopulations to at least the current potential is forecasted to take a minimum of 10 years, while the recovery of the Graham is likely < 10 years whereas the recovery of the Narraway is likely at least 15 years.

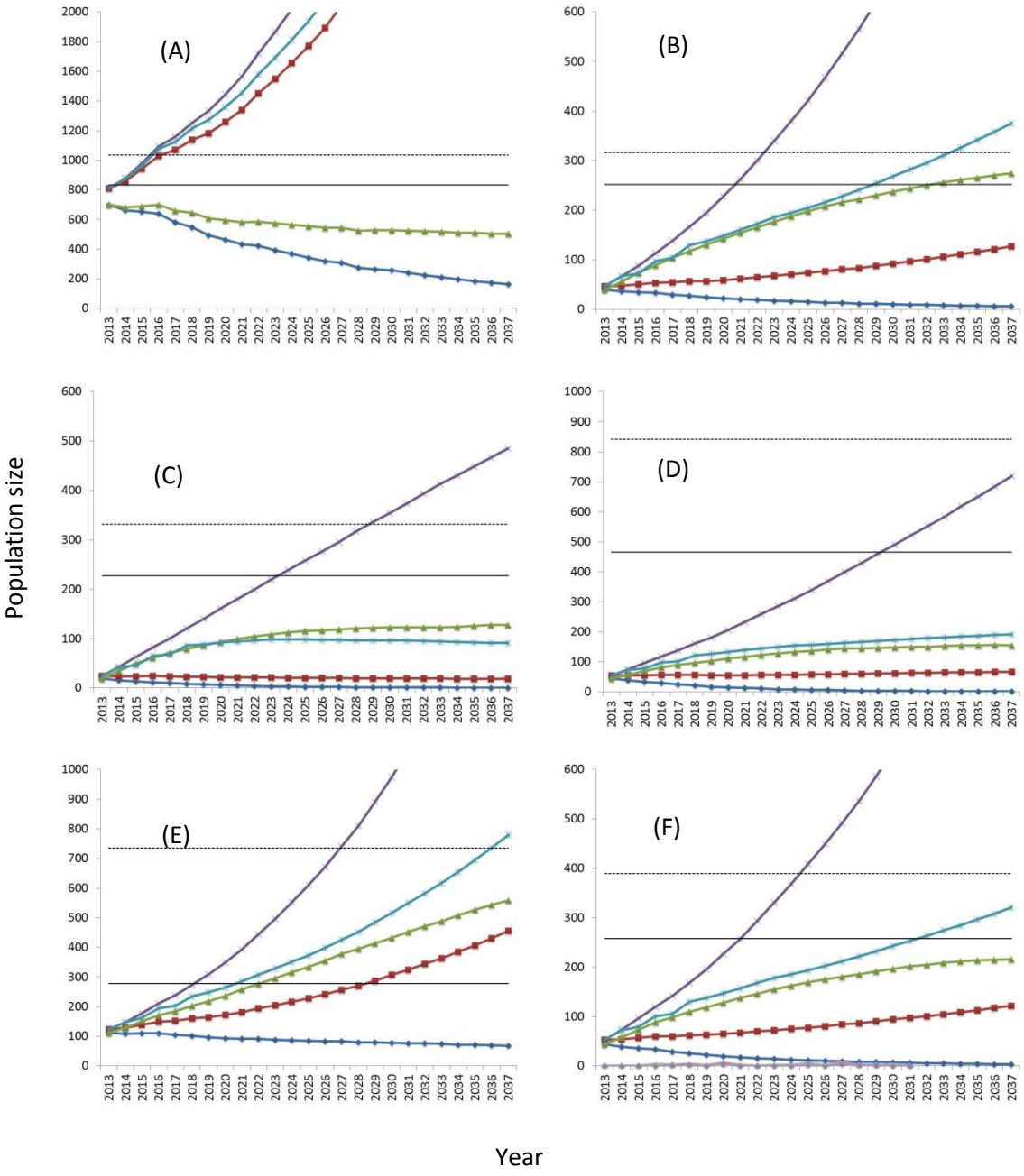

Figure 4. Modeled population response of woodland caribou subpopulations (A – Graham, B – Kennedy, C – Klinse-Za, D – Narraway, E – Quintette, and F- Scott) to five management scenarios: no management (blue diamonds); wolf control (red squares); maternal penning with augmentation from a donor herd (green triangles); wolf control, maternal penning and augmentation (purple x's); and wolf control with more selective penning and augmentation (aqua stars). Population growth is shown relative to critical habitat based potential population size (dotted line) and possible current population size (solid line). See Appendix B for model details.

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APPENDIX A: METHODS TO DRAW MANAGEMENT UNITS FOR CRITICAL HABITAT

- Low-Elevation Range (LER):
  - Draw management units around clusters of high-value low elevation habitat potential provided that no portion of a LER unit exceeds an elevation of 1300m.
  - Delete LER that is not part of a cluster of LER polygons unless the polygon is >150ha in area.
- High-Elevation Winter Range (HEWR):
  - Fill all voids in HEWR polygons
  - Delete all polygons <400ha in area
  - Subdivide large HEWR polygons along recognizable geographic features such as large valleys. The desired maximum target size for a HEWR unit is 30,000ha though geography forces some variation around this target.
- Calving and Summer Range (CSR):
  - Fill all voids in CSR polygons
  - Delete all polygons <400ha in area
  - Subdivide large CSR polygons along recognizable geographic features such as large valleys. The desired maximum target size for a HEWR unit is 30,000ha though geography forces some variation around this target. The following guidelines for subdividing CSR polygons were employed in decreasing order of precedence:

    - Provincial herd boundaries;
    - HEWR management units;
    - 5^{th} order streams or greater; and,
    - Contours –not followed directly but used to identify passes and ridges.

APPENDIX B: CARIBOU POPULATION DEMOGRAPHIC MODEL

Model Overview

To assist in exploring options for recovering the seven sub-populations or herds of caribou, we implemented a deterministic age-structured caribou population dynamics model assuming no density-dependence. This model projects annual population sizes by sex and age under different management options for a projection period of 25 years. Potential density-dependent effects on reproduction or mortality are not modelled because the current population size is assumed to be far below the sizes at which density-dependence factors are likely to come into play, even assuming successful recovery of the population.

Specifically, the model has the following characteristics:

- The caribou population is represented by annual age classes (up to 19 classes);
- Both sexes are explicitly represented;
- The basic population model is an aspatial and deterministic births-deaths model, with no modeling of density-dependent effects to caribou recruitment or mortality;
- Mortality is partitioned into a number of sources (e.g., wolves, other predators, malnutrition, accidental) defined by annual mean rates. The model has the capability to model targeted (source-specific) actions to reduce mortality from one or more of these sources;
- The model enables exploration of management actions such as annual penning of pregnant females from the population, augmentation (and penning) of pregnant females obtained from outside the population, and control of mortality due to wolves and cougars;
- The population parameters needed to initiate and run the model are obtained from annual surveys, and from long-term studies of mortality rates on collared animals; and,
- Outputs are text file summaries (in csv format) of: (1) expected total population size at the end of each projection year, stratified by stage (calves, year 1+ individuals), and sex; (2) more detailed projections by age (year); and (3) projected survival rates by age/sex as a result of management.

The modeling approach is conceptually similar to an age-structured caribou model developed by Serrouya and McLellan (unpublished). The model described here contains additional biological and management specification structure for (1) tracking individuals in all age and sex combinations, (2) modelling age-specific parturition rates, and (3) flexibility in specifying management scenarios. The model is parameterized from current inventories for the seven sub-populations, as well as from related studies in the general plan area.

Management Scenarios and Parameters

Population Parameters

Population parameters used in the model consist of three sets: (1) initial population size $\mathbf{N_0}$ and age distribution (Table A-1); (2) parameters related to annual survival by age and sex (Table A-2); and, (3) parturition rates by age (Table A-3). While the initial population size is known from annual population surveys, the age-structure is not. Therefore, an initial age distribution was assumed by assigning the observed number of individuals to ages 1-18 at random. Sexes were assigned using the commonly observed bull:cow ratio (0.40).

The age distribution results for the initial population $\mathbf{N_0}$ used in the scenarios below is shown in Table A-1. This age distribution was estimated using the overall assumed bull: cow ratio, and a random assignment of the total number of animals to each age class. This age distribution was applied to all modelled ranges to make them comparable under this assumption.

Table A-1. Initial relative population age distribution by sex.

Age	TotalN	NFemales	NMales
1	0	0	0
2	0	0	0
3	0.087	0.087	0
4	0.043	0	0.043
5	0.087	0.087	0.043
6	0.043	0.043	0
7	0.130	0.043	0.087
8	0.043	0.043	0
9	0	0	0
10	0.043	0.043	0
11	0.043	0.043	0
12	0.130	0.087	0.043
13	0.043	0.043	0
14	0.174	0.087	0.087
15	0.043	0	0.043
16	0	0	0
17	0.087	0.087	0
18	0	0	0

The current assumptions for specifying survival rates by age and sex are shown below in Table A-2.

Table A-2. Estimated model parameter values related to estimating survival and recruitment for all ranges.

	Range					
Parameter Description[1]	**Graham**	**Kennedy**	**Klinse-Za**	**Narraway**	**Quintette**	**Scott**
Current population size (N)	708	41	16	50	110	47
Proportion females at birth	0.5	0.5	0.5	0.5	0.5	0.5
# months females are penned	4	4	4	4	4	4
Survival Rate of Penned Adults	1	1	1	1	1	1
Proportion Calves of Population	0.09	0.13	0.14	0.09	0.15	0.115
Annual Survival of Wild Calves with no predator control	0.07	0.26	0.28	0.18	0.28	0.28
Captive (penned) calf surv to 1 mo.	0.95	0.95	0.95	0.95	0.95	0.95
Captive (penned) calf surv. 2-12 mos	0.75	0.75	0.75	0.75	0.75	0.75
Adult Sex Ratio: Bulls to Cows	0.40	0.40	0.40	0.40	0.40	0.40
Annual adult mortality rate (natural)	0.07	0.15	0.26	0.18	0.09	0.165
Annual adult male mortality rate (natural) to obtain obsd B:C ratio	0.08	0.17	0.29	0.21	0.10	0.183
Proportion of Natural Mortality from Wolves	0.73	0.67	0.70	0.73	0.5	0.73
Proportion of Natural Mortality from Cougars	0	0	0	0	0	0
Proportion of Natural Mortality from Bears and Wolverines	0.15	0.2	0.17	0.15	0.38	0.15
Proportion of Natural Mortality from Malnutrition	0.06	0.06	0.06	0.06	0.125	0.06
Proportion of Natural Mortality from Accidents	0.06	0.07	0.07	0.06	0	0.06

[1] Sources for recent demographic parameter estimates were Seip and Jones (2013) and Culling et al. (2005). For demographic parameters where no range-specific data was given, an average value derived from all other ranges was assumed.

The model uses age-specific parturition rates for female caribou based on a study of Northern Caribou by McNay and Giguere (*in prep*.). The rates used are given in (Table A-3):

Table A-3. Parturition rates for caribou used in the model for all subpopulations.

Age (yrs)	Parturition Rate
1	0.0
2	0.48
3-8	0.8
9+	0.625

Management Scenarios

The model currently implements 3 management actions: (1) a reduction in wolf predation rate (implemented as an annual proportional reduction in the annual mortality rate on calves and adults by sex) attributable to wolves; (2) number of local (pregnant) females penned per year; and, (3) number of pregnant females from an external source added to the population each year (augmentation). Augmented females are also assumed to be penned in this model. A fourth action, cougar control can be simulated in this version of the model, but presently is not implemented for these subpopulations.

Currently, 4 management scenarios have been implemented. These scenarios and their parameter values are given in Table A-4.

Table A-4. Management scenarios and parameter values tested with the model.

Management Scenario	# local females penned/yr	# females augmented/yr	Wolf Reduction (proportion)
1. No management action (null)	0	0	0
2. Wolf control only, starting in winter 2012 (at end of year 1) each year	0	0	0.5 in first year; 0.4 in subsequent years (2014-2038)
3. Annual Penning and Augmentation only (starting in 2014) each year	5 each year from 2014-2038	10 each year from 2014-2038	0
4. Wolf control + Penning/Augmentation each year after 2013 (2014-2038)	5 each year from 2014-2038	10 each year from 2014-2038	0.5 in first year; 0.4 in all subsequent years (2014-2038)
5. Wolf control + Penning/Augmentation for selected years	5 each year for 10 years (from 2014-2023	10 each year for 3 years (2014, 2016, 2018)	0.5 in first year; 0.4 in all subsequent years (2013-2038)