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A Recovery Action Plan for Northern Caribou Herds in North-central British Columbia

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R. Scott McNay, Doug Heard, Randy
Sulyma, and Rick Ellis



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ABSTRACT

A recovery action plan for recovery of caribou (*Rangifer tarandus caribou*) in north-central British Columbia is presented. This plan represents work completed by a technical team in support of the Northern Caribou Recovery Implementation Group for North-central British Columbia (henceforth the RIG). Work focussed on operational definitions for survival and recovery habitats using a habitat supply model called the Caribou Habitat Assessment and Supply Estimator. Successive applications of this model were conducted to estimate a range of likely habitat values for five seasonal ranges across four planning areas using simulations of assumed natural disturbance under unmanaged conditions. Results were used as a baseline reference point to set context for subsequent development of herd-specific recovery actions. Theoretical potential values for seasonal ranges were also calculated, plotted as maps, and used as a second reference point to further the recovery context.

Our goal was to recommend management actions that would lead to self-sustaining populations of “threatened” woodland caribou. This goal was more specifically defined by:

- Ecological conditions that allow populations to be self-sustaining—this condition is to be accomplished within nine generations or 60 years;
- Herd-level targets of >100 animals and a density of > 50 animals/1000 km²; and
- Amounts of all seasonal ranges within or above the range of variation expected based on assumed patterns of natural disturbance (i.e., seasonal ranges were characterized by forage values, potential displacement of caribou through human activities, and risk of mortality—all modelled using the Caribou Habitat Assessment and Supply Estimator);

In places where the recovery goal was considered ecologically feasible, management actions focus on establishing recovery of caribou to the defined conditions. In places where herds were in decline, management actions focussed on halting the decline of caribou within one generation (7 years) and promoting stable or increasing population trends over the next three generations (20 years).

A second goal was to keep stakeholders informed of efficacy of recovery planning through implementation of, and regular reporting on, an effectiveness monitoring program.

Ecological feasibility to recover caribou in the planning areas was significantly affected by the assumption that moose (*Alces alces*) were a relatively recent and now permanent part of the natural predator-prey system. On the basis of habitat supply analyses, this assumption led to predictions of reduced quality and quantity of low-elevation habitats for caribou (i.e., pine-lichen winter range, post-rutt range, movement corridors), the outcome of which was interpreted to lead to reduced caribou herds compared to historic levels. However, with respect to the general recovery targets we predicted:

- Recovery can likely be achieved for the Chase herd given the sufficient and relatively well-balanced seasonal range values estimated from modelling;
- By comparison, there was lower probability of recovery for the Wolverine herd. The worst case scenario within this recovery planning area was that population stability in the future would likely be accompanied by a significant reduction from current herd size given the estimated minor amount of quality, low-elevation ranges (i.e., we predicted insufficient low-elevation range area to keep this herd from evolving into one that uses high-elevation ranges exclusively);

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- The Takla herd is expected to remain relatively stable at current numbers (i.e., we noted this herd had a natural, historic trend for using high-elevation ranges exclusively and we expected the quality of these ranges can be maintained in the future); and
- Recovery of the Scott herd was least likely of all the four herds (i.e., we predicted this herd to continue declining and to develop similar habitat-use behaviour as Takla, becoming isolated in distribution to the mountains east of the Williston Reservoir).

Results from habitat supply analyses were also used to guide development of specific recovery actions focussed on:

- Retention of high-elevation range values (high-elevation winter range, calving and summer range) in all recovery planning areas;
- Retention of low-elevation range values (pine-lichen winter range, post-rut range, movement corridor range) in the Chase and Wolverine planning areas;
- Mitigation of the forecasted fall-down of pine-lichen winter range that was predicted to occur in the Chase and Wolverine recovery planning areas;
- Mitigation of the predation risk where spatial configurations of early-seral forests depart from that expected under natural disturbance; and
- Enhanced monitoring by way of:
 - Regular census of caribou populations; and
 - Annual evaluation of modelled early-seral forests; and
- Further research associated with:
 - The potential for poor-quality low-elevation ranges to become a barrier between seasonal ranges;
 - Interactions between mountain pine beetle salvage and implementation of recovery actions; and
 - Efficacy of management to mitigate predation risk.

We outline issues that need to be addressed in a social and economic review of the recovery actions. We also forward procedures whereby proponents for natural resource development can assess impacts of future development plans and regularly monitor change to the amount and quality of seasonal ranges.

The work of the technical team and the RIG grew from a research program first implemented by Slocan Forest Products Ltd., and Finlay Forest Industries in 1998. Since that time, support for the team came from a variety of partners as follows: BC Ministry of Forests and Range, BC Ministry of Environment, BC Ministry of Agriculture and Lands, Peace/Williston Fish and Wildlife Compensation Program, Canadian Forest Products Ltd., and Abitibi Consolidated Company of Canada.

KEYWORDS: *habitat supply modelling, habitat threats, north-central British Columbia, Rangifer tarandus caribou, recovery actions, risk of predation, species at risk, woodland caribou.*

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- BC Forest Investment Account—Land Based Investment Program (Slocan, Canfor, Abitibi); and
- BC Forest Investment Account—Forest Science Program (Slocan, Canfor, Wildlife Infometrics, Resources North Association).

Members of the RIG (see Appendix B) included a wide variety of interest groups represented by individuals who had at least some expertise in issues related to the ecology of woodland caribou. Many of these individuals gave freely of their time or were supported in-kind through their respective institutions. Randy Hart (Canfor) and Wayne Lewis (Abitibi) were especially supportive throughout all phases of the work and often arranged the necessary funding. We thank all the members of the RIG for contributing in a constructive way to the completion of this plan.

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PREFACE

This recovery action plan, for four herds of woodland caribou in north-central BC, was developed from December 2003 to December 2006 as an activity under the direction of the Northern Caribou Recovery Implementation Group for North-central BC (for more information see www.centralbccaribou.ca). The group, with a diverse membership representing a wide range of stakeholder interests, was formed at the request of government to work toward the development of recovery actions for the herds. The plan was written according to guidance provided by the 2004 Operations Manual produced by the Recovery of Nationally Endangered Wildlife Working Group. It thus may not be consistent with current requirements of provincial or federal governments.

The plan presents a comprehensive foundation of information to support decisions regarding management of caribou range in north-central BC. In particular, the recommended recovery actions point to specific measurable activities that, if implemented, are likely to support the maintenance of caribou populations in the area. Furthermore, the data, analyses, and habitat supply modelling will provide baselines for comparisons made in the future and could be used at that time to assess effectiveness of recovery implementation.

The objective of this publication is to ensure that the knowledge gathered, information developed, methods used to develop recovery actions, and the recovery action recommendations are made broadly available to the conservation specialists, scientists, government decision makers, resource managers, and others who may otherwise be involved in recovery planning.

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INTRODUCTION

Recovery Background

Woodland caribou (*Rangifer tarandus caribou*) are threatened throughout the Southern Mountains National Ecological Area (SMNEA) in British Columbia (BC) (COSEWIC 2000). Population declines in many herds (Bergerud 1974; Thomas and Gray 2001; MCTAC 2002) and reduction in the range of caribou since the early 1900s (Spalding 2000) have contributed to their current threatened status. Because BC is a signatory on the National Accord for the Protection of Species at Risk,¹ the status of caribou is a significant conservation issue in the province (Paquet 2000; MCTAC 2002; BCFPB 2004; Page *et al.* 2005).

To help address this conservation issue, the BC Government formed the Northern Caribou Recovery Implementation Group for North-central British Columbia (henceforth, the RIG) which operated under the auspices of the Northern Caribou Technical Advisory Committee and in latter years, the Species at Risk Coordination Office.² While other RIGs were established in other parts of caribou range in BC, the goal of the North-central RIG was to recommend ecologically based recovery actions for the most northern local populations of the terrestrial-lichen feeding ecotype of woodland caribou in the SMNEA. Specifically, in north-central BC the SMNEA herds are known as the Wolverine, Takla, Chase, and Scott herds. The RIG fulfilled this obligation under direction from NCTAC, by taking guidance from the Recovery of Nationally Endangered Wildlife Programs recovery operations manual (National Recovery Working Group 2004), and by referencing information from recent studies of caribou in north-central BC: Wood and Terry 1999, Terry and Wood 1999, Johnson 2000, Poole *et al.* 2000, and Lance 2002.

Strategy for Recovery of Northern Caribou in the Southern Mountain Population

Population status of the caribou herds in north-central BC was summarized by NCTAC (in prep)³ for all but the Scott herd (Table 1). Based primarily on the perceived population trend for these herds, NCTAC provided a viability rating for the Wolverine, Chase, and Takla herds as vulnerable. Strategic recovery goals for northern caribou that pertain to the herds in north-central BC were presented by NCTAC (in prep) as follows:

- Goal 1: Northern caribou are to be distributed throughout their current range in the SMNEA including:
 - Stable local populations with ≥ 50 adult caribou/1000 km² or ≥ 100 adult caribou (whichever is greater);
 - Viable local populations in the north-central meta-population and connectivity between local populations;
 - A minimum population goal will be set for the north-central meta-population when better local population estimates and trends are available; and
 - Sufficient critical habitat to support local population goals in the long term.
- Goal 2: Recovery of identified local populations at risk; and
- Goal 3: Public support for the recovery of northern caribou and their habitats.

¹ See the Environment Canada web site at www.ec.gc.ca/press/widl_b_e.htm

² See <http://ilmbwww.gov.bc.ca/sarco/>

³ NCTAC. In Prep. A strategy for the recovery of Northern Caribou in the Southern Mountain National Ecological Area in British Columbia. BC Ministry of Environment, Biodiversity Branch, Victoria, BC.

TABLE 1 Population size, trend, and density for woodland caribou herds of north-central British Columbia (adapted from NCTAC in prep).

Herd	Size ^a	% of northern caribou in SMNEA	Trend ^b		Reliability ^c		Range (km ²) ^d	RMZ (km ²) ^e	Density (number/1000 km ²) ^f
			ST	LT	ST	LT			
Wolverine	400	8	I	I	M	H	8 315	8 443	71
Takla	100	2	S	S	M	M	1 850	4 920	54
Scott ^g	NE	NE	NE	NE	NE	NE	NE	NE	NE
Chase	700	14	S	S	M	H	11 390	17 330	50

a Numbers are estimated 2002 late winter population as in NCTAC (in prep)

b Population trend includes long-term (LT) or 20 years, and short-term (ST) or 7 years. I = increasing, S = Stable, D = declining.

c Reliability of estimates is subjectively determined as not all local population estimates are done in a manner that allows calculation of confidence intervals. L = low, M = moderate, H = high reliability.

d Current occupied range by Northern Caribou.

e RMZ is Resource Management Zone

f Density = (Local Population Size/Current Range)*1000

g NE = Not estimated

Primary threats to caribou and their habitat were noted by NCTAC (in prep) as:

- Loss of space in which to avoid predators (increased predation) due to:
 - Fragmentation of habitats through industrial development; and
 - Improved access and mobility experienced by predators;
- Loss of winter food supply on winter habitats due to human activities;
- Loss of alternative habitats;
- Illegal human kill of caribou; and
- Disturbance/displacement due to human activities.

The North-central RIG

Under the auspices of NCTAC and its strategic recovery goals for caribou, we developed a Terms of Reference for the RIG (Appendix A) which, among other administrative details, included its organizational framework, role, and responsibilities. Although membership intentionally spanned a wide variety of stakeholder and interest groups (Appendix B), we asked members to provide participants who had some background knowledge in the ecology of woodland caribou. Also, even though key stakeholders participated in the RIG, we acknowledged as part of the Terms of Reference, that the focus for work was clearly placed on recovery of caribou. Potential social and economic consequences of recovery were to be the subject of government review once our scientific advice on the ecological measures for recovery was delivered. To that end, consistent with NCTAC strategic recovery goals for caribou, our over-riding goal was to effect recovery of the four herds within our jurisdiction and this was largely to be accomplished through submission of recommended recovery actions to government. Guidance on evaluating progress from a biological perspective was not available from the National Recovery Working Group (2004) and, therefore, we do not address this evaluation specifically. In a more general way, we considered that our success could be monitored on the basis of the following:

- The extent to which recovery goals and objectives have been met;
- Changes in population size, trend, and productivity;
- Identification of recovery/survival habitat;

- Proportion of identified recovery/survival habitat that is identified for management under some recovery action;
- Success in mitigating identified threats;
- The extent to which stakeholders have been consulted or have become involved in recovery activity;
- Success of public outreach, awareness, and education programs initiated by the recovery team; and (or);
- Level of public support for recovery work (e.g., number of favourable or unfavourable media reports; change in level of public funding being invested in recovery of the species).

This recovery action plan, and the work of the RIG through regularly scheduled meetings, was structured to provide:⁴

- A statement of measurable recovery goals, threats to habitat, and the management tools available to mitigate threat;
- Systematic and transparent identification of habitat, including analytical approaches to define critical habitat and consideration of the requirement for residence;
- Recovery actions specific to local herds; and
- An outline for socio-economic implications of recovery options.

Caribou in North-central British Columbia

Description of Recovery Planning Areas and Caribou Ranges

Intersected by the northern boundary of the SMNEA, the Mackenzie and Fort St. James Forest Districts are adjacent forest management units extending more than 6.1 million ha and 3.1 million ha, and with annual allowable timber volume harvests of 3.1 million m³ and approximately⁵ 3.7 million m³, respectively. Four threatened caribou herds occur in these management units. We updated the NCTAC delineation of these herd areas (Appendix A) by subjectively enclosing all relocations of radio-collared caribou using boundaries based on identifiable topographical features such as major rivers or valleys (Figure 1).

Relocations of radio-collared caribou were observed from 1996 to 2005 (n = 70 787 relocations). To address the priority for recovery of threatened herds, we delineated four planning areas by way of encompassing the historic and current range use by caribou while allowing for spatial connectivity among herds (Figure 2). Spatial connectivity among herds was assumed to be demonstrated where the herds apparently still overlap (Figure 1). Where spatial overlap apparently did not occur, we assumed connectivity could occur, and therefore included land between herds allowing for the possibility of habitat recovery (e.g., the area between the Scott and Wolverine herds in Figure 2).

The Wolverine recovery planning area was 844 312 ha in rolling high-elevation foothills and included four major watersheds of the Omineca, Manson, Klawli, and Germansen rivers. The Scott recovery planning area was 594 894 ha and due east of the Wolverine recovery planning area and situated along the floodplain of the historic watercourse of the Parsnip River (now the Williston Reservoir). The Chase recovery planning area was 1 733 038 ha situated in steep mountainous terrain and had three major watersheds including the Ingenika, Osilinka, and Mesilinka rivers. The Takla recovery planning area was 492 051 ha and due west of the Wolverine recovery planning area and surrounds a large freshwater lake. Valley bottoms and mid-slopes of the four recovery planning areas are dominated by relatively cool and

⁴ Specific information about the function of the RIG, including meeting agendas and minutes, is available at ftp.mcgregor.bc.ca.

⁵ The lead author calculated this figure as a direct proportion of the annual allowable cut (9.1 million m³) for the larger Prince George Timber Supply Area (7.6 million ha) within which the Fort St. James Forest District occurs.

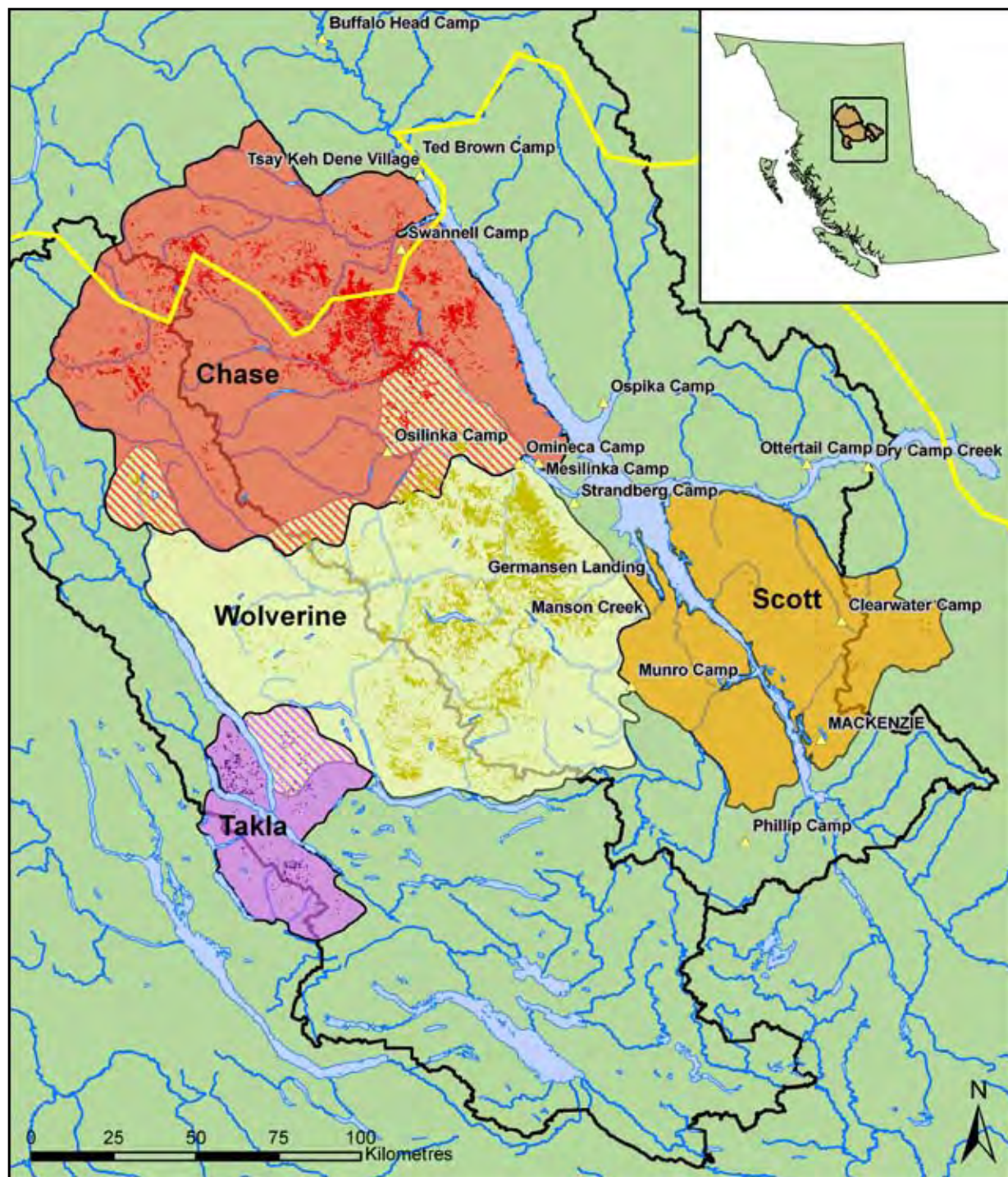


FIGURE 1 Location of herd areas for the Chase, Wolverine, Takla, and Scott woodland caribou herds in north-central British Columbia. Darker areas within the herd represent individual relocations of radio-collared caribou. The yellow line represents the northern border of the Southern Mountain National Ecological Area.

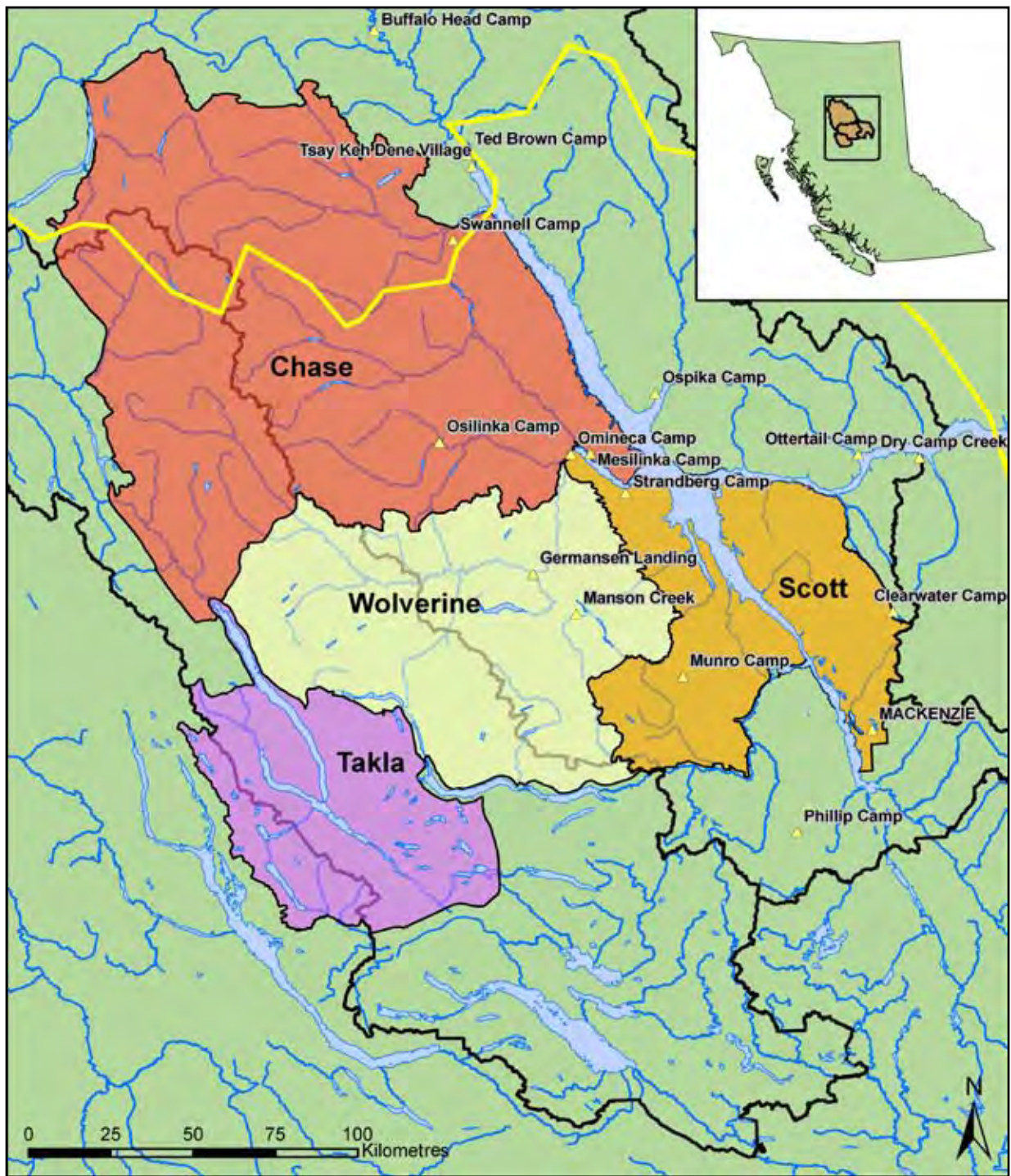


FIGURE 2 Location of recovery planning areas for the Chase, Wolverine, Takla, and Scott woodland caribou herds in north-central British Columbia. The yellow line represents the northern border of the Southern Mountain National Ecological Area.

dry, or cool and moist macroclimates of short growing seasons leading to boreal ecosystems of white and black spruce (*Picea glauca* and *P. mariana*) (Meidinger and Pojar 1991). Cold temperatures dominate the climate with average daily temperatures below freezing for half the year and three-quarters of the annual precipitation falling as snow. Large-scale and frequent wildfires were characteristic prior to fire control policy (DeLong 2002). Common in these ecosystems are large, relatively flat areas of well-drained fluvial deposits, which in combination with frequent and large fires gave rise to large areas of even-aged lodgepole pine (*Pinus contorta*) dominated forest stands. Generally, a cold moist macroclimate with long, cold winters characterizes upper slopes where Englemann spruce (*P. engelmannii*) dominates. At the northern extent of the Chase recovery planning area, deciduous shrubs can dominate these upper slopes. Alpine tundra prevails above tree line throughout the recovery planning area.

The Wolverine, Chase, and Takla herds have an estimated 460 (Wilson *et al.* 2004a), 550 (Zimmerman *et al.* 2002), and 125 (Wilson *et al.* 2004b) caribou, respectively (Table 2). No formal population estimate has been made for the Scott herd but anecdotal reports range from a few individual animals to, on one occasion, a group of 23 animals.

Seasonal range use varies within and among herds, and some individual caribou switch seasonal range use among years. In general, migratory caribou move relatively long distances (60–120 km). In mid-October through November caribou congregate on post-rut ranges at relatively high elevations and by about late December, move to low-elevation pine-lichen winter ranges. Depending on snow conditions on pine-lichen winter ranges, caribou may move back and forth through the winter between this range at low-elevation and a high-elevation winter range (Cichowski 1993; Terry and Wood 1999; Wood and Terry 1999; Johnson *et al.* 2002). Although primarily differentiated by their relative elevation and snow conditions, these two winter ranges also differ in tree species composition and forage availability (Johnson *et al.* 2001). In April through mid-May, caribou travel from high-elevation winter ranges, through movement corridor ranges, to calving and summer ranges where they stay until the post-rut congregation. Other caribou, in some years, remain relatively sedentary finding all seasonal resources within smaller areas. Generally, caribou choose to stay at higher elevations as long as possible as a way to avoid relatively higher risk of predation by wolves (*Canis lupus*) that typically exists at lower elevations (Bergerud and Page 1987; Seip 1992; Johnson *et al.* 2002).

In contrast with the rest of the Southern Mountains National Ecological Area, our planning areas had relatively large, unmanaged forests with extensive industrial development beginning only after construction began on the W.A.C. Bennett hydro-electric dam in 1961. Subsequent flooding of the Finlay, Peace, and Parsnip rivers created BC's largest body of freshwater which has likely been a barrier to caribou migration and contributed to reductions of caribou, particularly in the Scott recovery planning area. Prior to hydro-electric and forest development, the area was occupied primarily by Carrier (Tsay Keh Dene) and Sekani (Kwadacha) First Nations and by gold miners occupying small communities in the Wolverine and Takla herd areas. First Nations reported historic seasonal use of the area by wolves, a primary predator of caribou. Traditional knowledge from First Nations describes an increase in the abundance of wolves and their more persistent presence throughout the year following the first appearance of moose (*Alces alces*) in the early 1920s (McKay 1997).

Basic Factors of Decline

Although the life history and range use of caribou vary widely (Heard and Vagt 1998), at the northern extent of their distribution in the SMNEA, caribou prefer lodgepole pine forests at mid-to low-elevations during fall and winter (Johnson *et al.* 2002). Caribou use these pine-lichen winter ranges continuously from mid-October through mid-May, or only for intervals dispersed through that time period, or not at all in some years, depending on the specific ecological setting and winter climate (Seip 1998; Terry and Wood 1999; Wood and Terry 1999; Poole *et al.* 2000; Johnson *et al.* 2002). This winter range is typically

TABLE 2 *Woodland caribou population survey results for herds in north-central British Columbia^a*

Month	Year	Herd ^b	Area ^c	Type ^d	No. ^e	Min	Mean	Max	Classification ^f										Area ^g	Calves: 100 Cows
									M	F	ADUN	JM	JF	JUN	CM	CF	CUN	U		
Oct	1978	WOL	P	TC	8															
Oct	1979	WOL	P	TC	15															
Oct	1978	CHA	P	TC	13															
Feb	1989	WOL	P	TC	214				46	133				35						
Feb	1989	WOL	E	EX		200		250												26
Sep	1990	CHA	P		63				15	35							13			
Mar	1993	CHA	P	TC	397				101	198		6	24		25	42		1		33
	1993	CHA	P	TC		396	690	1085												
	1993	CHA	P	TC																
	1993	CHA	E	EX		600		700												
Feb	1993	WOL	P	TC	66		100		15	43							8			19
	1993	WOL	P	TC		200		250												19
	1993	WOL	E	EX		250		300												
Jun	1994	WOL	P	CS	45				2	22		3	2				16			73
Mar	1996	WOL	P	TC	204		204		74	109					6	13	2			19
	1996	WOL	E	EX		262	361	580											4933	
Feb	1998	TAK	P	TC	102															
Feb	1999	WOL	P	SRS	91				31	42		4	1		5	4	4			30
Mar	2000	CHA	T	TC	127				25	78	1	1	2	2	4	3	8	3		19
May	2000	CHA	T	CS																20
Jun	2000	CHA	T	CS																44
Jun	2000	CHA	T	CS																69
Jun	2000	CHA	T	CS																60
Jun	2000	CHA	T	CS																54
Mar	2000	WOL	T	TC	115				28	67	4	4	1		4	6		1		15
May	2000	WOL	T	TC																
Jun	2000	WOL	T	TC																
Jun	2000	WOL	T	TC																
Jun	2000	WOL	T	TC																
Jun	2000	WOL	T	TC																

TABLE 2 *Continued*

Month	Year	Herd ^b	Area ^c	Type ^d	No. ^e	Min	Mean	Max	Classification ^f										Area ^g	Calves: 100 Cows
									M	F	ADUN	JM	JF	JUN	CM	CF	CUN	U		
Mar	2001	CHA	T	PC	174				58	76	5	1		1		1	27	5		36
Mar	2001	WOL	T	PC	134				39	62	11				3		16	3		31
Mar	2002	CHA	T	SRS	225	290	369	448	50	73	46			11			28	17	9700	28
	2002	CHA	E	EX			575												9700	
Jan	2002	WOL	P	TE		25		30												
Mar	2002	WOL	T	SRS	152	412	471	530	27	62	20			1			36	6	5623	58
Mar	2002	WOL	E	EX			590												5623	
Jan	2004	SCO	T	TE	28															
Jan	2004	TAK	T	TC	125				32	65	3				2	11	12			39
Feb	2004	WOL	T	SRS	205	183	460	863	41	88	37						39			37
Feb	2006	CHA	T	SRS	100															

^a References: Corbould 1993, Hatler 1989, Hengeveld and Wood 2000, Lance 2002, MELP 1983, Wilson *et al.* 2004a, Wilson *et al.* 2004b, Wood 1993, Wood 1994, Wood 1996, Wood 1998, Zimmerman *et al.* 2001, and Zimmerman *et al.* 2002.

^b Caribou herds: WOL = Wolverine, CHA = Chase, TAK = Takla, and SCO = Scott;

^c Area refers to the portion of the herd area surveyed: P = partial, T = total, and E = extrapolated to total based on sample;

^d Type of survey: TC = total count, SRS = stratified random sample, CS = calf point-count, PC = point count, and EX= point-count extrapolated;

^e No. is the total population counted or estimated;

^f Classification: M = male adults, F = female adults, ADUN = adult unknown gender, JM = juvenile male, JF = juvenile female, JUN = juvenile unknown gender, CM = male calf, CF = female calf, CUN = calf unknown gender, and U = unknown; and

^g Area is the area covered by the survey.

found on relatively flat terrain and is therefore also easily developed for residential, agricultural, recreational, and industrial use. Until the recent mountain pine beetle (*Dendroctonus ponderosae*) epidemic (Eng *et al.* 2005), disturbance of pine-lichen winter range in north-central BC was mostly from natural fires and, more recently, from road building and timber harvesting. When not using pine-lichen winter ranges, caribou use other ranges at higher elevations that, by comparison, undergo fewer human-caused and natural disturbances.

Where timber harvesting occurs in caribou range, the resulting early seral forests support abundant moose (Eastman 1977; Cumming 1992; Franzmann and Schwartz 1998), which leads to high densities of wolves (Messier 1994; Messier *et al.* 2004). Timber harvesting, and the resulting early seral forests, lead to patches of increased moose and increased wolves throughout the milieu of older forest. Compounding this spatial distribution of increased wolves is the development of roads that provide wolves' ease of travel and, purportedly, an increase in their hunting efficiency (James and Stuart-Smith 2000). Whether wolves prey primarily on moose and kill caribou incidentally (Messier 1995), switch to caribou as easier prey (Dale *et al.* 1995; Messier 1995), or continue an original selection for caribou and use moose as an alternate prey (Messier 1995, Ballard *et al.* 1997), we expect caribou populations to experience greater mortality than they would without moose as a co-habitant. When moose are abundant, wolves apparently do not experience negative feedback from declining caribou populations (Chowns and Gates 2004; James *et al.* 2004; Messier *et al.* 2004). The increased predation effect on caribou, indirectly caused by logging, has been demonstrated by Wittmer *et al.* (2005), and is a consistent focus within recovery strategies for caribou in the southern part of their range in British Columbia (MCTAC 2002) as well as elsewhere in Canada (Chowns and Gates 2004).

Historic Efforts to Conserve Habitat for Caribou

The earliest efforts to map caribou habitat in north-central BC arose after the first data were collected on radio-collared caribou from 1991–1997 (Wood and Terry 1999, Terry and Wood 1999), but the mapping was not published until the initiation of the Mackenzie Land and Resource Management Plan (MLRMP) process in 1999. By current standards, the MLRMP maps were of coarse resolution spatially and lacked range definition (i.e., no seasonal context). On the basis of this mapping and founded on information concerning the apparent interactions among road building, timber harvest, other ungulates, predators, and caribou mortality, the Government of BC (BC Govt 2000; BC Govt 1999) developed three strategies to conserve habitat for caribou in north-central BC:

- 1) Protect portions of caribou range by prohibiting industrial development (BC Govt 2000);
- 2) In unprotected areas, set limits on the total allowable impact to caribou range due to industrial development (BC Govt 1999); and
- 3) Where timber harvesting occurs within caribou range, promote “large patch” forest management (e.g., Racey *et al.* 1999). Large patch management is intended to spatially concentrate forest harvest thereby leaving larger patches of undisturbed caribou range (BC Govt 2000).

Concurrent to the development of MLRMP strategic direction, and following the initial six-year study of caribou in the area, Johnson (2000) began a three-year study of caribou in the Wolverine herd area extending the monitoring of radio-collared caribou to 1999. Simultaneously, Poole *et al.* (2000) were monitoring radio-collared caribou in the Takla herd area. Lance (2002) overlapped these studies with monitoring in a small portion of the Wolverine herd area from 1997–2001. In 1999, and largely as a MLRMP implementation tactic, a larger and more comprehensive study, the Omineca Northern Caribou Project (ONCP), was begun and is ongoing.

The ONCP was focussed primarily on the Chase and Wolverine herds (Heard and Vagt 1998) but in latter years expanded to include the Takla and Scott herd areas. We strategically structured the ONCP to be comprehensive on a number of study themes.

1. The study design included four related and complementary sectors: modelling, policy, adaptive management, and monitoring.
2. The study was intended to cross trophic levels and therefore focussed not only on the vegetative characteristics of caribou range, but also addressed the distribution of other ungulates (i.e., moose) and primary predators (i.e., wolves).
3. The study was intended to address a range of spatial levels so adaptive management projects focussed on site-specific issues (e.g., abundance of terrestrial lichens) as well as landscape-level issues (e.g., risk of predation).
4. Goals for the study extended beyond the accumulation of data and scientific information and so modelling focussed on transparency and tool development as well as forming a framework for more traditional hypothesis structuring and testing.

The ONCP has been primarily supported through the forest industry, a variety of government agencies, Peace/Williston Fish and Wildlife Compensation Program, and independent, unsolicited research proposals. Total funding for the program since January 1999 and anticipated to March 2007 has been \$6.4 million, resulting in a wide variety of products which generally include population surveys (caribou, moose), relocation of radio-collared animals (caribou, moose, wolves), weather monitoring, habitat sampling, mortality site investigations (caribou, moose, wolves), habitat supply modelling, seasonal range maps, contributions to ungulate winter range policy, technical reports, newsletters, posters, and slide show presentations.⁶ Among other outcomes, the results of the ONCP and other studies of caribou in the area, have provided a wealth of information and hence placed the RIG in a position to provide a solid scientific basis for recommendations to government on the ecological aspects for recovery of caribou.

Traditional Knowledge about Caribou from First Nations People

Knowledge about caribou in north-central BC was gathered from First Nations people living within the caribou recovery planning areas in two ways:

1. Summary of an intensive series of individual, repeated interviews with elders and other long-standing residents of the backcountry (e.g., trappers and miners) in and around Takla Lakes, Valleau Creek, and the Klawli River area extending as far north and east as Germansen Landing (McKay 1997). The First Nations bands contacted were primarily Takla, Tl'azt'en, and Nak'azdli; and
2. A series of interviews with a small collection of Tsay Keh Dene people conducted by the authors during the summer of 2004.

Summary of Takla/Nak'azdli Interviews

The interviews (McKay 1997) were conducted in the vicinity of Vanderhoof, Fort St. James, Takla Landing, Manson Creek, and Germansen Lake and involved discussions with First Nations people and other long-term residents having first-hand knowledge about caribou, or descendants of those having significant knowledge about caribou. The following are key observations extracted from the account by McKay (1997).

⁶ More specific reference to products from the ONCP and other studies of caribou in north-central BC can be obtained at <http://www.centralbccaribou.ca/crg/15/studies>.

- Observations repeated in multiple interviews:
 - Caribou using lakes (during ice-free times) as refuge from wolves;
 - Caribou using lakes in winter to “lick the clear ice”;
 - Caribou being hunted and killed on lakes (i.e., especially Johannsen, Takla, Germansen, and Wolverine lakes when they were frozen);
 - First moose observed 1914–1921;
 - More wolves since about 1938;
 - By the 1940s, caribou were disappearing—no noticeable change prior to 1937;
 - One mountain (Meska Mountain) could be black with caribou; up to 500 or 600 animals. We note that this could be the “Too-Dinie Mountain”, now known as Two Man Mountain, which came up a few times as a preferred hunting ground. This area is northwest and just outside the Chase recovery planning area.
 - Caribou numbers, southwest in the Wolverine recovery planning area, were never very large—the most in any one group would be about 40.
 - Caribou used to winter at lower elevations in the Takla Lake area (apparently they no longer do).
- Observations taken from single accounts:
 - Bear predation on calves is significant;
 - Milder winters (since the early to mid-1800s) resulted in more frequent fires and a higher tree line, which in turn led to two major changes:
 - more moose; and
 - more persistent occurrence of wolves;
 - Major migrations of caribou (i.e., days of continuous movement of animals past a point) have not occurred since about 1930 and the change in climate, and the repercussions mentioned above, were considered to be the ultimate cause;
 - Mining of the 1930s didn’t help the already poor situation for caribou;
 - Caribou numbers on Baldy Mountain (n = groups of 15–20) and Germansen Lake (n = 35–40) in the 1960s;
 - Caribou eat the black hanging fuzz (interpreted as arboreal lichens);
 - Caribou migration to Mount Milligan during 1936–1940 (now basically no known use by caribou);
 - Observations of about 20 caribou in the Scott herd area;
 - Caribou numbers have increased in the past two decades.

Summary of Tsay Keh Dene Belief Model

The following belief model is an interpretation of evidence collected in a brief meeting with a small collection of individuals and is not intended to necessarily represent the common belief of all Tsay Keh Dene. In its current format, the model is only conceptual.

Identification of Seasonal Ranges

Classification of seasons as they apply to caribou ecology was interpreted from observations of caribou movement patterns through time. Caribou generally began appearing in April and May when they tended to use “over-flow waters” on lakes that were still ice-bound, mineral licks where they were available, and most often, the pine-dominated areas with abundant “white moss.”⁷ Caribou then disappeared in late May, presumably initiating a period of migration. It is noteworthy that this latter belief comes only from the observation of caribou disappearing rather than from direct observation of where caribou

⁷ Note that we confirmed this as terrestrial lichens through the use of pictures.

went. Caribou were encountered next at higher elevations during summer with their calves. Therefore, it was believed the migration in late May was for calving. The migration in May therefore indicated the end of spring and beginning of the calving season. Summer was estimated to be July through the beginning of September, which then led to the interpretation that the calving season extended through June. Observations of caribou continued to be made primarily at high elevations during the rut period of late September through October and rut was noted as a specific season. A second migration period began in mid-November to early December when caribou again appeared more frequently at low elevations. This migration indicated the beginning of the early winter season. Some caribou, but not always all caribou, disappeared again in January. Caribou were presumed to go to higher elevations where they stayed until April. Use of high elevation in this late winter season was based on the apparent disappearance of some caribou from low elevations and the observation of cast bull⁸ antlers distributed in the alpine area.

Calving Range – Late May through June

Tsay Key Dene participants inferred that caribou use high-elevation sites near the tree line for calving although there was no direct evidence of this. It was put forth that the animals preferred sites that had a south aspect and deep snow conditions. The deep snow provided a means of protection, through limiting access, whereby caribou would not be harassed/disturbed by either humans or predators.

The calving model produces an output, or final value, called Calving Range Value to Caribou (Figure 3). To estimate this value, a relationship between the suitability of a site for calving (*Calving Suitability*), and the risk of using that site (*Risk of Predation*), was assessed. The *Risk of Predation* was determined to be the likelihood of a caribou being preyed upon while using the site. The occurrence of moose at low elevations, and hence the attraction of wolves to these sites, were influential in assessing risk of mortality for caribou. This relationship is expressed in the “Predation and Moose” model (see the section on Risk of Predation) and was a function present in all range models. *Calving Suitability* was recognized to be a function of site-level attributes (*Site Conditions*) and the likelihood that a caribou would be displaced from a site (*Displacement Factors*). A variety of disturbances were identified, such as those from snowmobiles and helicopters, or disturbance from industrial activities such as mining. In discussions with band members, the most important site factors identified in determining good Site Conditions were aspect (*Aspect*) and being near the tree line (*Tree Line-Elevation*). It was felt that being near the tree line provided deeper snow conditions during this time of the year (calving season) that helped to isolate caribou from predators.

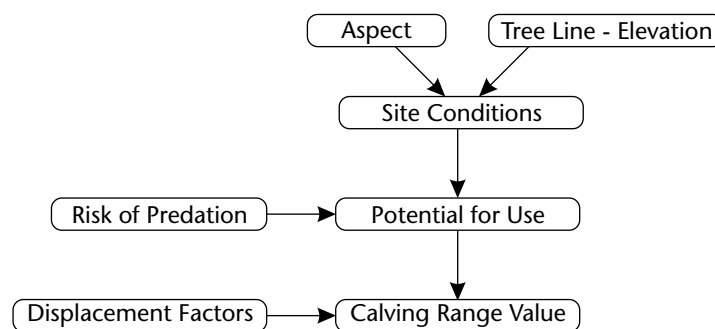


FIGURE 3 *Traditional knowledge calving range caribou model.*

⁸ We had to distinguish between bull and cow antlers because cow antlers would also have been cast at high elevations but during the calving season.

Summer Range – July through August

In the early summer, caribou were observed lying on patches of snow, which was believed to be an attempt to limit contact with flies. During this period, caribou forage primarily on crowberry bushes (*Empetrum nigrum*). Hunting by First Nations usually occurs during summer with the kill being primarily focussed on young bulls, for food, clothing, and other uses.

Rut Range – September through October

Caribou were believed to stay in the alpine areas during this time in order to “dry their horns”.

Low-elevation Early Winter Range – Mid-December through January

Early winter habitat was identified as low-elevation sites that provided terrestrial lichens for foraging. There was an assumption that caribou moved to these sites primarily to get away from fresh accumulations of snow at higher elevations. During this period caribou foraged primarily on terrestrial lichens. A number of site characteristics, selecting for physical attributes to identify lichen types, were proposed. In general, band members identified characteristics of lichen types as being consistent with open pine forests which were located on sandy and gravelly soils that were not recently disturbed. Foraging areas for early winter range were only identified at lower elevations because it was believed there was too much snow at higher elevations for caribou to forage.

The model developed for this range type produces a summary value called *Early Winter Range Value to Caribou* (Figure 4). The *Early Winter Range Value to Caribou* was determined by summarizing the relationship between *Potential for Use* with *Displacement Factors* and risk (*Risk of Predation*). Displacement factors during this season were considered to be primarily by humans. The *Potential for Use* was determined by assessing the potential for a site to provide forage (*Lichen Potential*) and the elevation of the site (*Elevation*). To be early winter range, it was identified that a site must be at a low elevation, otherwise there would be too much snow. *Lichen Potential* was driven by five factors: three of the factors identified where lichen sites would be located and two were used to identify what condition the lichen community would be in. The key site factors were: *Soil Characteristics*, *Tree Species*, and *Crown Closure*. *Stand Age* was used to identify the time since the last disturbance and a *Stand Disturbances* node was included to recognize variations in lichen development that result from different disturbance events.

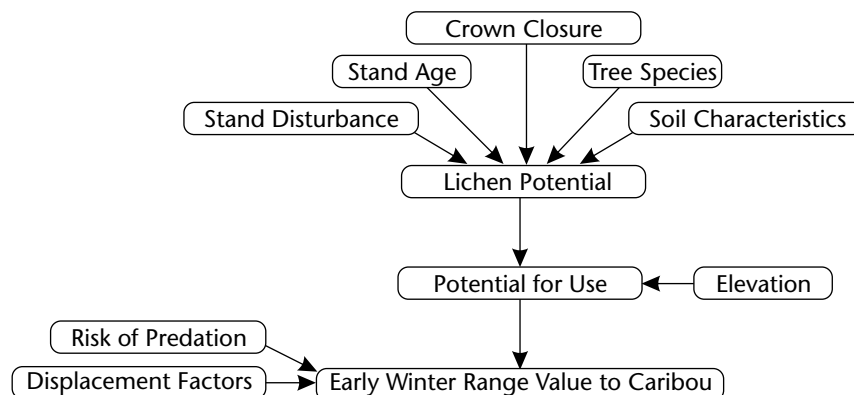


FIGURE 4 *Traditional knowledge early winter range caribou model.*

High-elevation Late Winter Range – February through April

There was an assumption that caribou moved to this range to access comparatively better snow conditions. Again, caribou likely sought these areas at high elevation as evidenced by cast male antlers observed later in the year. Given where these cast antlers were found, we interpreted “better” snow conditions to mean less snow than would have occurred at lower elevations (i.e., alpine areas blown free of snow). High-elevation windswept areas provided access to forage without the need to dig through snow. There was also mention of caribou foraging on tree moss⁹ during this time but we cannot confirm how this observation was made (i.e., directly or inferred from other evidence). Hence, the presence of lichens and crowberries were identified as important attributes necessary to identify areas good for caribou. In this latter case, we interpreted “better” snow conditions to mean deep, consolidated snow allowing caribou access to arboreal lichen forage.

Late Winter Range Value to Caribou was determined by identifying areas that should provide abundant forage (*High Elevation Forage Availability*) and a low *Risk of Predation* (Figure 5). It was identified that abundant forage was found on sites expressing characteristics to grow suitable vegetation (*Likelihood of Lichens and Crowberry*), which was considered to be terrestrial lichens and crowberry. These sites also had to be free of snow (*Windswept Sites*) and free of disturbance factors (*Displacement Factors*). Snow-free areas were considered to be windswept ridges and the primary disturbance factor identified to influence late winter range was snowmobiles. The *Likelihood of Lichens and Crowberries* was determined to be a function of three physical site factors: *Elevation*, *Vegetation Characteristics*, and *Aspect*. For a site to have a high likelihood to provide preferred vegetation, it needed to be at a high elevation, in a vegetated state (i.e., not rock), and have a southeast aspect.

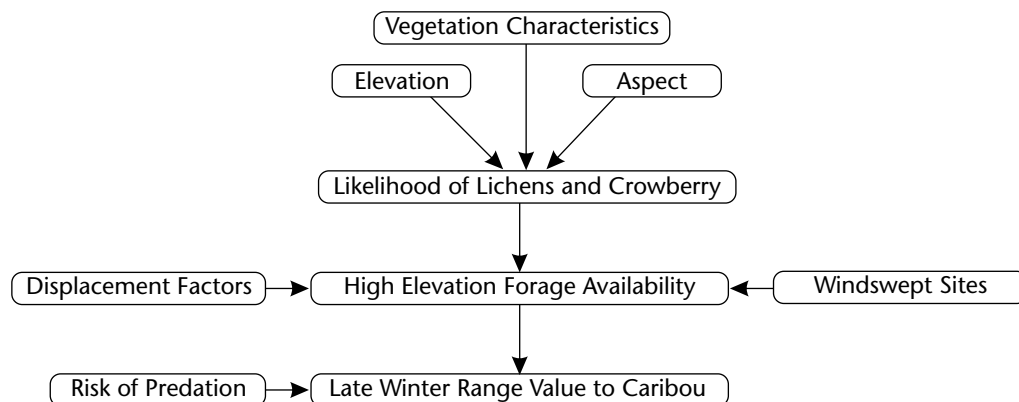


FIGURE 5 *Traditional knowledge late winter range caribou model.*

Migration – Late May, Mid-December, Mid-January, and Early April

Tsay Key Dene participants identified that key migration routes were consistent with river valleys. It was also identified that the value of a migration route decreased with the influence of predation and of the occurrence of stand-level disturbances that created a younger forest matrix. It was believed that caribou used only mature forest stands and were not considered to be adaptable to young stands, especially those less than 20 years old.

⁹ We confirmed this as arboreal lichens through the use of pictures.

Corridor Value was identified as the output for the migration areas model (Figure 6). *Corridor Value* was a function of an area being a preferred route used by caribou (*Preferred Route – Caribou Use*) that had a low risk associated with using the route (*Risk of Predation*). To determine if a route was a preferred route it needed to have potential as a *Migration Route* that was not impacted by site-level disturbances (i.e., logging, wildfire). The influence of site-level disturbance was determined to be associated with the time since the site was disturbed. As such, *Stand Age* was used as the measurable factor to identify young stands (< 20 years) that would be the least desirable for caribou use. The determination of whether a location had *Migration Route Potential* was based on factors such as *Topographic Position* and *Distance from Major Rivers*. For the location to be good, it needed to be a major river valley (i.e., in a valley within a defined distance [e.g., 500 m] of a major river).

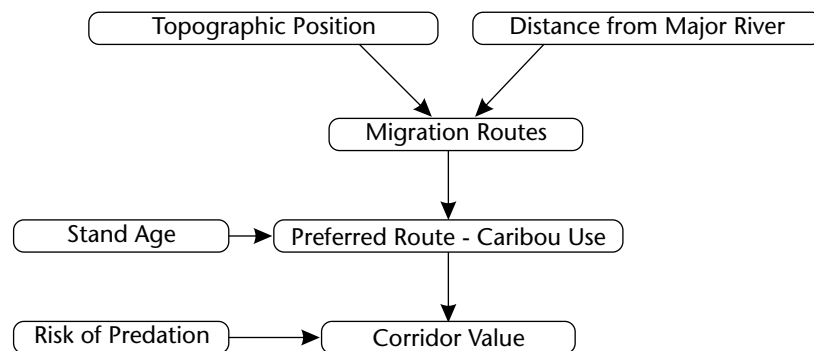


FIGURE 6 Traditional knowledge migration corridor caribou model.

Risk of Predation

Predation is a factor that was believed to have potential to influence caribou year-round. This influence was described as a multifaceted correlation between caribou, wolves, and moose. The general framework presented was that moose were able to adapt to disturbance and could succeed in young stands more so than caribou. Thus, when levels of landscape disturbance were high, there were more moose and likewise there were more wolves. In landscapes with more wolves, the risk of predation to caribou was higher. While these beliefs tend to be correlated with popular professional interpretations (e.g., Messier *et al.* 2004), there was direct evidence of traditional knowledge about the relationship among moose, wolves, and caribou independently reported by elders from other bands interviewed earlier by McKay (1997).

The output (*Risk of Predation*) for the risk model is based on how well wolves can move—access to packed roads and trails (*Wolf Mobility Factors*) and how many wolves there are (*Wolf Abundance*) (Figure 7). *Wolf Abundance* was recognized to be a relationship between *Moose Abundance* and *Wolf Hunting Areas*. Band members identified that wolves reside at select areas where they are more likely to scavenge on natural mortality (for example near slide areas). Moose abundance was identified to be an expression of the amount of young stands (*Stand Age*) and the presence of certain plant communities, those that have willow and dogwood (*Plant Communities*); the greater the abundance of young stands and willow and dogwood plant communities on the landscape, the more moose that would be present.

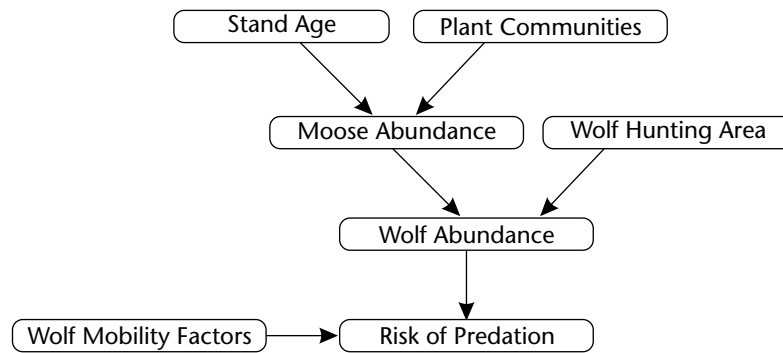


FIGURE 7 *Traditional knowledge risk of predation model.*

The Recovery Conundrum

In working through this conceptual model of traditional knowledge, and in particular the piece focussed on risk of predation, two principles became apparent:

1. Recovery of habitat conditions in some herd areas would take a long period of time due to rates of forest growth and road rehabilitation; and
2. In the interim, recovery of caribou may need to address short-term restrictions in the abundance and spatial distribution of moose.

This presented an obvious conundrum for the Tsay Keh Dene because of the importance of having abundant moose populations as a food source while having a fundamental connection to the land that called for maintenance of ecological structure including the persistence of caribou populations.

The Caribou Habitat Assessment and Supply Estimator

As a function of work leading up to the RIG and its focus on caribou recovery, we constructed a habitat supply model to estimate current and future levels of habitat – the Caribou Habitat Assessment and Supply Estimator (CHASE) (McNay *et al.* 2003, McNay *et al.* 2006). Information for model construction was collected using Netica (version 2.17, Norsys Systems Corp., Vancouver, British Columbia) a software shell used for constructing Bayesian Belief Networks (BBNs) and Influence Diagrams. In general, BBNs consist of nodes and linkages, where nodes represent environmental correlates, disturbance factors, and response conditions (see Marcot *et al.* 2006, for descriptions of terms and components of BBNs). All nodes are linked by probabilities. Input nodes (the range and environmental prediction variables) contain marginal (“prior”) probabilities of their states; intermediate nodes (e.g., describing attributes of caribou range) contain tables of conditional probabilities; and output nodes (caribou range values) are calculated as posterior probabilities expressed as suitability values from +1.0 (high) to –1.0 (low). Our modelling methods generally followed guidelines for creating and updating BBNs presented by Marcot *et al.* (2006). This entailed initially developing simple influence diagrams to depict nodes and linkages, expanding these into initial alpha-level BBN models in which the node states and linkage probabilities were parameterized mostly from expert judgment and initial observations, and then refining those into beta- and higher-level BBN models from peer review, empirical testing, and updating from field data.

The BBNs we developed for caribou depict the likely state or condition of seasonal ranges given the observed states or conditions of environmental correlates. Our choices of seasonal range types to model, the environmental correlates, and the probabilistic relationships among correlates, were based on a series of consultative workshops with species experts prior to initiation of the RIG (McNay *et al.* 2003). These

professionally facilitated workshops occurred over two years (2000–2002) during which five technicians explored and documented ecological relationships with six domain experts. Domain experts had direct involvement with or thorough knowledge of the recent studies of caribou in the area (Wood and Terry 1999, Terry and Wood 1999, Johnson 2000, Poole *et al.* 2000, and Lance 2002). Consensus was dealt with either through verbal facilitation or by structuring competing views as explicit hypotheses in the product. Workshop minutes and model refinement plans were recorded and circulated to the experts for review after each workshop. Comprehensive documentation of the workshop results has been presented by McNay *et al.* (2003). Model refinement was expected to be an ongoing process as new knowledge is gained and empirical data become available for testing the BBNs.

Bayesian approaches are particularly well-suited to the problem of recovery planning. The threatened existence of an important resource has usually not been predetermined but rather has occurred from a lack of information and therefore, the solution to the problem is, by definition, uncertain. Also, resource management guidelines can change faster than our ability to learn from them so our understanding is, by definition, challenged. Characterizing problem solutions is the objective held by normal statistics based on frequency of observations. However, in the case of rare species and uncertain causes of decline, the solution is usually one that cannot be characterized easily, if at all. Nevertheless, decisions must be made and such decisions are typically based on problem-solving probabilities rather than solution-characterization (Horvitz *et al.* 1988, Dagum *et al.* 1993). For example, it would be impossible to characterize recovery actions for low-elevation habitats based on observations of threatened caribou populations that now only exist in high-elevation habitats (e.g., mountain caribou in southern British Columbia).

Bayesian approaches are not new and have proven useful in many other resource management issues: aspen (Haas 1991), wheat (Jensen and Jensen 1996), water quality (Reckhow 1999), sockeye salmon (Schnute *et al.* 2000), bull trout (Lee 2000), natural resource management generally (Cain 2001), fish and wildlife population viability (Marcot *et al.* 2001), sage grouse (Wisdom *et al.* 2002), wolverines (Rowland *et al.* 2003), marbled murrelet (Stevenson *et al.* 2003), sport fisheries in general (Peterson and Evans 2003), spotted owl (Sutherland *et al.* 2004), and Eurasian black vulture (Poirazidis *et al.* 2004). A series of BBNs that have been used in British Columbia is currently in press where these include the following modelling applications: adaptive management, ecosystem mapping, northern caribou, and marbled murrelet.

Our objectives in the use of BBNs were to: (1) summarize expert understanding about seasonal range use by caribou; (2) formalize relationships between range value and potential threats to caribou; and (3) evaluate the relative efficacy of conservation of caribou and their seasonal ranges under alternative management scenarios.

Modelling Caribou Seasonal Ranges

Pine-lichen winter range and post-rut range

Pine-lichen winter range and post-rut range were considered by experts to be similar in ecological setting, differing only in elevation and snow accumulation. Hence, although caribou use the ranges differently, both ranges were described by the same influence diagram and BBN (Figure 8). Capability for terrestrial lichens (*Cladina* spp.), the primary forage used by caribou during fall and winter (Johnson *et al.* 2001), was based on topographic aspect, ecological unit (i.e., a combination of soil moisture and nutrient regime), percentage of lodgepole pine in the overstorey forest, and overall productivity of the site. We estimated productivity using an index of tree height at 50 years old. Generally, terrestrial lichens grow most successfully on south-facing sites having soils that are well drained with poor nutrient levels (Coxson and Marsh 2001). Lodgepole pine also competes well on these sites and therefore was used as an indicator of terrestrial lichens (Sulyma 2001).

We used forest age, density of trees, and forest floor characteristics to determine current suitability of the sites for producing terrestrial lichens. The nature of site disturbance determined suitability of the soil substrate for growing lichens, with slightly exposed soil being best. As forest conditions change with age, stands exceeding 140 years old have higher and more developed canopies leading to sub-canopy microclimates that are cool and moist where lichens do not grow as successfully as other vegetation (Coxson and Marsh 2001; Sulyma and Coxson 2001). Terrestrial lichen communities also tend to be dominated by *Cladonia* spp., less preferred forage (Johnson 2000), in early seral communities (Coxson and Marsh 2001). Therefore, experts agreed that favourable conditions for terrestrial lichens used as forage, occurred on sites between 70 and 140 years old. Lance and Eastland (1999) developed a technique for assessing relative abundance of forage lichens so we expressed conditions at the response node in their relative abundance classes.

Use of winter ranges by caribou has been correlated with snow conditions (Fancy and White 1985) and some research indicates that caribou will not crater (dig) for terrestrial lichens if snow depth is greater than 90 cm (Johnson *et al.* 2004; however, see Brown and Theberge 1990). We used elevation and modelled solar insolation (Solar Analyst 1.0, Hu and Rich 2000) to index the modifying effect of ambient temperature on accumulation of snow during early winter. Experts presumed that open sites between 1000 and 1300 m ASL, although unusable in winter due to deep winter snow, would begin to accumulate snow only later in the season wherever relatively high amounts of solar insolation were received. These specific sites therefore could be used by caribou as post-rut range prior to winter. Similar sites at lower elevation would generally have relatively less snow as winter progressed and experts therefore classified these sites (lower-elevation) as pine-lichen winter range. In some winters, snow depths may exceed those preferred by caribou even on pine-lichen winter ranges, forcing caribou to use high-elevation winter range (discussed below). Experts assumed if a site had abundant terrestrial forage lichens and little snow accumulation, that the site would be preferred by caribou. Since calculation of preference indices is now widely available (Manly *et al.* 2002), we chose to express the response conditions at this preference node in terms of Chesson's (1983) statistical test for preference.

Although risk of predation by wolves could alter caribou selection of lichen sites, experts concurred that caribou would exhibit preference for sites with abundant and accessible forage, and if these sites were near abundant moose and wolves, then caribou would experience higher mortality rates. We then modelled higher probability of mortality at, or adjacent to, those sites. Risk of predation, therefore, was a probability of population reduction applied to the lichen site preference node to calculate a final value for seasonal range (Figure 8).

High-elevation winter range

When snow depth at low elevations exceeds that in which caribou can crater for terrestrial lichens, the snow pack is usually consolidated sufficiently allowing caribou to walk on its surface and move to higher elevations (Seip 1992; Paquet 2000; Johnson *et al.* 2001). At these higher elevations, caribou use 2–3 m deep snow packs to reach arboreal lichens (*Bryoria* spp., *Alectoria* spp.) in the lower crowns of subalpine fir (*Abies lasiocarpa*). Experts judged that a site was favourable for supporting arboreal lichens if subalpine fir composed > 80% of the stand, was > 15 m in height, and was > 120 years old (Figure 9).

At the highest elevations, in alpine tundra, caribou seek areas where persistent winds reduce snow to depths allowing them to crater for terrestrial lichens (Terry and Wood 1999; Wood and Terry 1999; Johnson *et al.* 2001; Johnson *et al.* 2002). Terrestrial lichen abundance in alpine tundra was judged by experts to occur at most locations within the recovery planning area except for non-vegetated rock, glaciers, or hygric to subhydryc soil moisture conditions (Figure 9). We determined potential for these areas to be windblown using a topographic curvature function to assess relative convexity of a digital elevation model in a 3 × 3 cell neighbourhood around the cell being assessed.

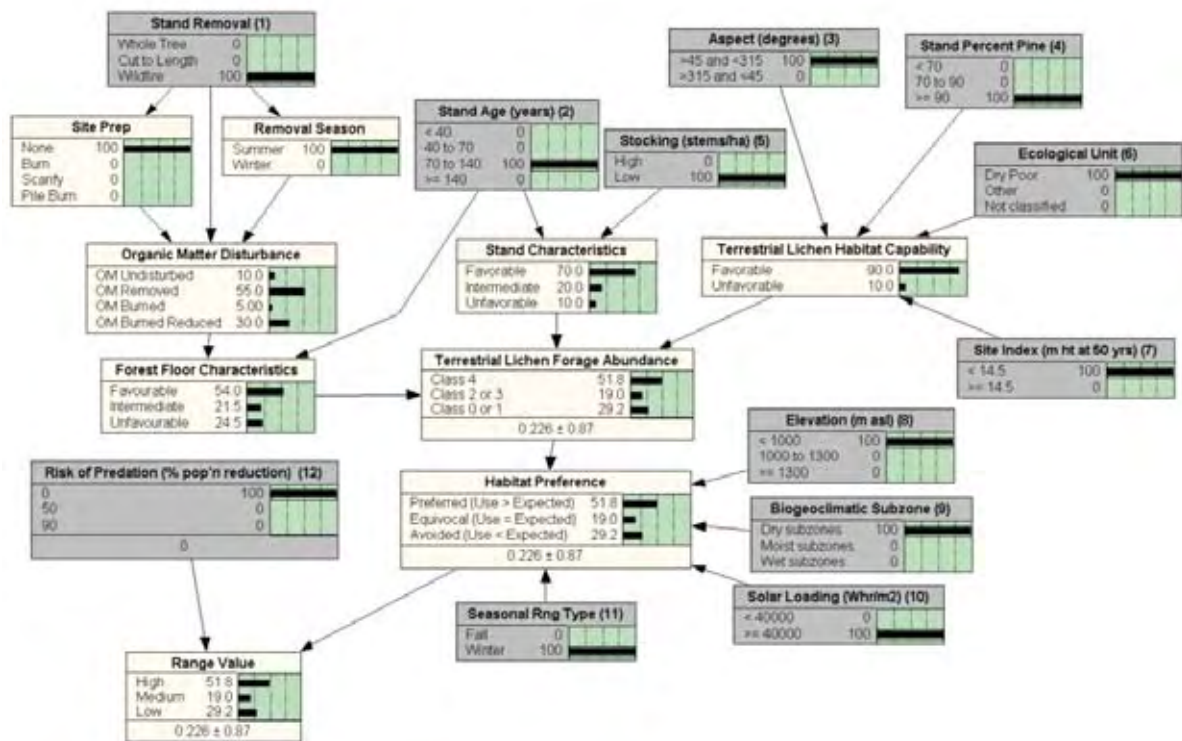


FIGURE 8 A Bayesian belief network used to predict the likely value (high, medium, low) of ranges (post-rut range or pine-lichen winter range) used by woodland caribou in north-central British Columbia. All networks shown are beta-level models as described in the text. Input nodes are numbered for ease of reference.

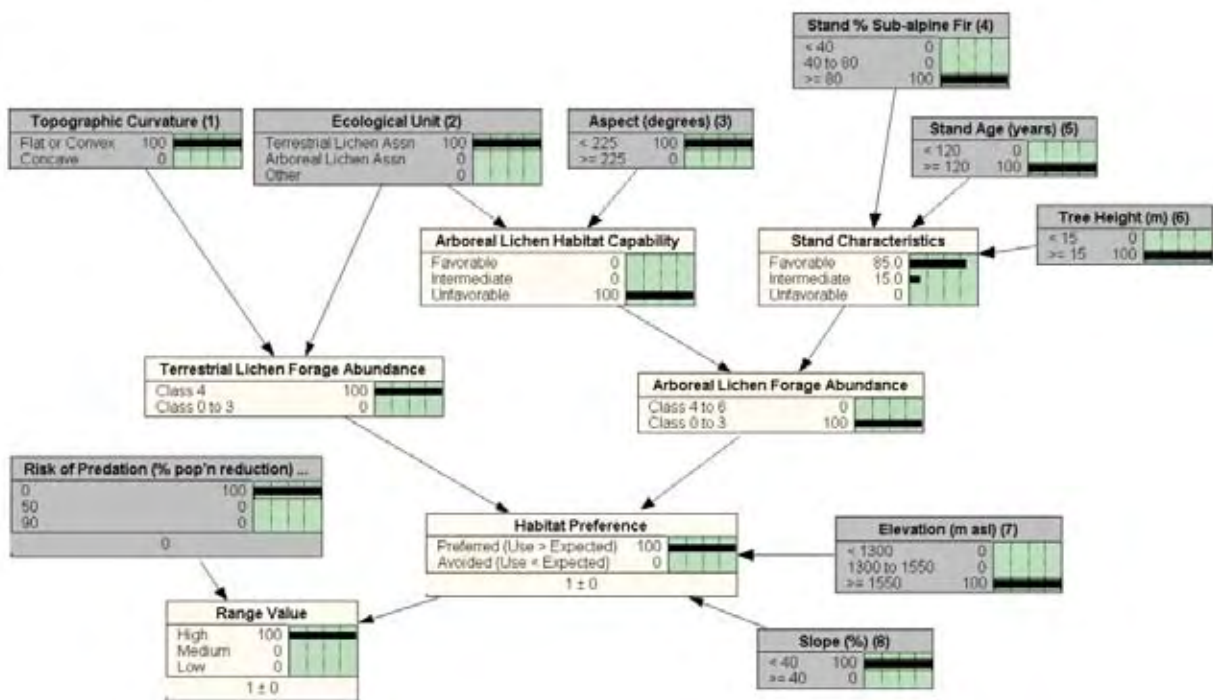


FIGURE 9 A Bayesian belief network used to predict the likely value (high, medium, low) of high-elevation winter ranges used by woodland caribou in north-central British Columbia.

As in the previous models, we expressed the response node, abundance of forage lichens, in terms of the manner in which they might be measured for both terrestrial (Lance and Eastland 1999) and arboreal (Armleder *et al.* 1992) lichens. Experts assumed that if a site > 1300 m ASL met conditions for abundant forage lichens and was in relatively gentle terrain (i.e., slope < 40%), then the site would be preferred by caribou (Chesson 1983). As in the previous range model, predation risk was a probability of population reduction applied against the preference node to calculate high-elevation winter range quality (Figure 9).

Calving and summer range

Caribou seek security from predators during calving (Bergerud 1978; Bergerud and Page 1987; Seip 1991). This explains why genders separate their ranges, with females moving away from typical foraging sites to the security of islands or shorelines in lacustrine environments (Bergerud 1985; James *et al.* 2004) and areas with relatively deep and/or soft snow in mountainous terrain (Cichowski 1993). We used alpine tundra and occurrence of subalpine fir adjacent to alpine tundra as indicators that deep snow would persist into the calving period of late May to early June (Figure 10). Sites with deep snow and gentle slopes are used by caribou but less so by wolves (Bergerud 1978; Seip 1991).

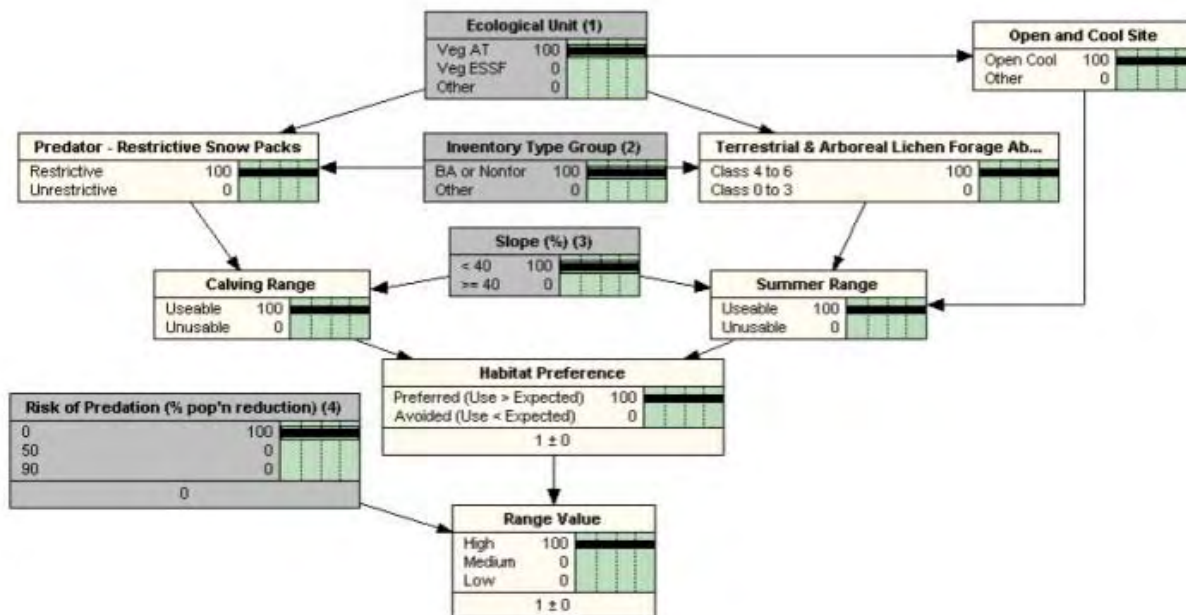


FIGURE 10 A Bayesian belief network used to predict the likely value (high, medium, low) of calving and summer ranges used by woodland caribou in north-central British Columbia.

Caribou show little selection for specific conditions in summer. Rather, caribou herds disperse across large areas during summer—presumably to reduce encounters with predators (Bergerud 1978; Seip 1991). Although forage is accessible at low elevations, caribou tend not to occur there, presumably due to the relatively higher risk of predation. Experts therefore described summer range using the same site conditions as those used for calving range (Figure 10) but emphasized use of alpine areas by caribou where cool, windy conditions lessen harassment by flies (Ion and Kershaw 1989). Predation risk was again used as a probability of population reduction applied against the preference node to calculate calving and summer range quality.

Movement corridor range

Experts disagreed on factors determining caribou selection of movement corridor range. However, Johnson *et al.* (2002) found that caribou travelled consistently with landscape features such as valley bottoms and lowlands with lakes and rivers. Based on this generalization, experts delineated general movement corridors on maps, which we buffered by a 1-km distance where slope was < 40%. Within buffers, predation risk was a probability of population reduction applied against the corridor node to calculate movement corridor range quality.

Predation risk

We modelled predation risk as a function of wolf density (Messier 1994). We also considered linear corridors such as roads, to have high risk of predation. Although woodland caribou are susceptible to many forms of mortality (Wittmer *et al.* 2005), wolf predation was considered by Seip (1992) to be the principal factor in decline of caribou in south-eastern BC. Experts generally agreed that wolves were the principal predator in our recovery planning area because grizzly bears (*Ursus arctos*) were at one of the lowest densities in BC (Hamilton *et al.* 2004) and cougars, another major predator of caribou, were rare to non-existent. Experts concurred on representing predation risk for caribou using a 100-m buffer around linear features (mostly active roads) (James and Stuart-Smith 2000), and a 5-km buffer around areas where wolves would most likely be hunting moose which was largely determined by moose density (Messier 1994). Other prey that might influence the distribution of wolves (e.g., *Odocoileus* spp.) were largely lacking in our recovery planning areas. Aside from moose and caribou, the most abundant ungulates are stone sheep (*Ovis dalli stonei*) and mountain goats (*Oreamnos americanus*), both of which experts agreed were not likely to influence the distribution of wolves. We estimated moose density with a BBN predicting range value for moose and proportional reduction in moose density through either regulated or subsistence hunting (Figure 11). We defined winter moose range as elevations < 1200 m and sites with abundant shrubby forage, the latter identified by nutrient-rich, subhygric to mesic sites < 40 years old. Summer moose range was similar but not restricted by elevation.

Input data and node sensitivity

A table of all node inputs for each BBN is presented in Appendix C. Where possible and appropriate, we represented environmental correlates as being affected by management activities or “levers” that, depending on management choice, would affect the relative threat to caribou through their influence on seasonal range value (Table 3). Strategic control of management levers could presumably mitigate threats to caribou and thereby aid recovery of threatened caribou populations. The management levers in our BBNs were primarily associated with forest harvesting, development of roads, and hunting regulations. Among all the levers, those affecting predation risk had the greatest influence on caribou seasonal range values (Table 3). Stand age as influenced by forest harvesting was the next most influential management lever, particularly as it affected pine-lichen winter range and post-rut range. However, stand age affected all BBNs either directly as a determinant of forage or indirectly through the predation risk BBN, where the latter affected each caribou seasonal range spatially.

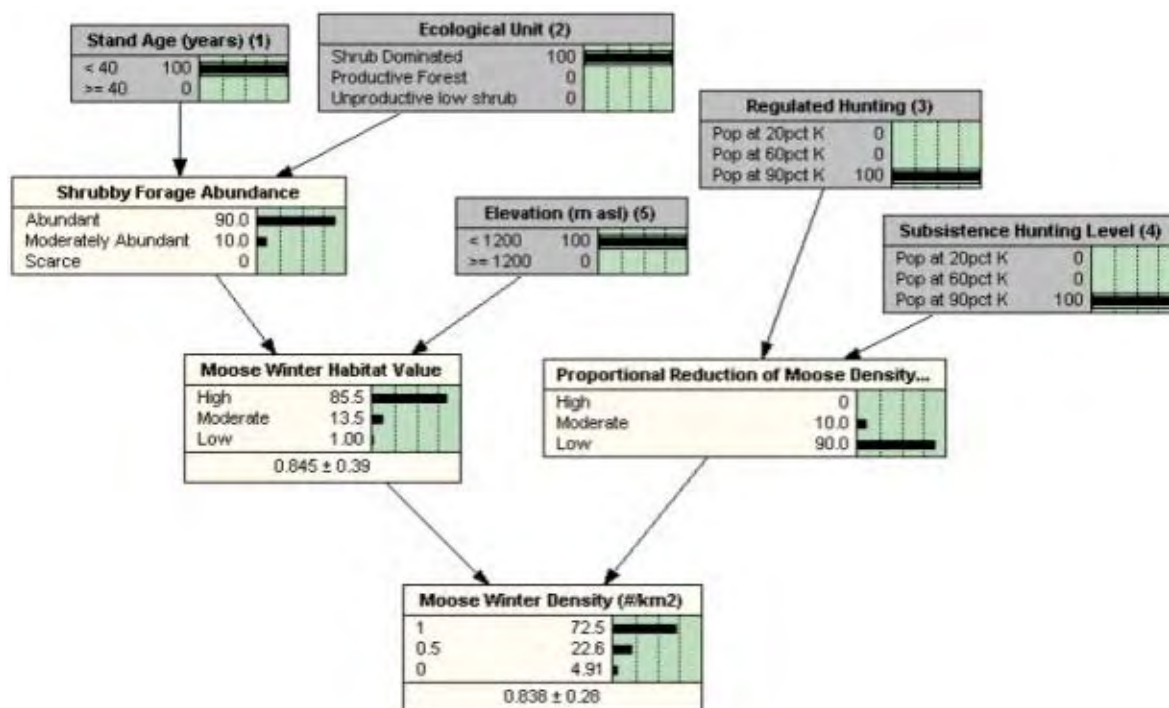


FIGURE 11 A Bayesian belief network used to predict the likely density of moose in winter in north-central British Columbia.

TABLE 3 Sensitivity (percent entropy reduction) of predicted values of woodland caribou seasonal ranges to environmental correlates used as management levers in Bayesian belief network models. Blank cells mean that the correlate was not used in that network model.

	Seasonal Range Bayesian Belief Network ^a						
Environmental Correlate	PLWR	PRR	HEWR	CSR	MC	MDS	MDW
Tree Species	7.86		0.40				
Stand Age	1.67		0.18			0.02	0.29
Stand Preparation	0.66						
Stand Removal Method	0.04						
Stocking				0.00			
Subsistence Hunting						1.95	1.07
Regulated Hunting						1.95	1.07
Predation Risk	9.80		21.90	42.9	100		

^a Bayesian belief networks were constructed for pine-lichen winter range (PLWR), post-rut range (PRR), high-elevation winter range (HEWR), calving and summer range (CSR), movement corridor range (MC), and for predation risk as a function of moose density in summer (MDS) and winter (MDW).

METHODS

Five general steps for developing an effective approach to habitat identification were recommended by the National Recovery Working Group (2004).

1. Develop a general description of habitat (i.e., key biotic and abiotic features such as space, food, and cover).
2. Develop site descriptions as a basis for focussing conservation effort (e.g., patch, corridor, or other geographical reference).
3. Establish specific criteria to determine priorities for conservation.
4. Identify known occupied sites.
5. Identify potential sites for occupation.

Our approach to habitat identification relied on the use of historic information about caribou and their habitat-use behaviour as understood by domain experts and the traditional knowledge of First Nations people. This understanding was represented by CHASE and used to systematically define potential, current, and future habitat conditions for specific seasonal range values. Range values were dependent on forage resources and risk of predation. Priorities for conservation were assessed based on a comparison of modelled range values to the values expected under assumed conditions of natural disturbance. This information (explained in detail later) was then used in workshop sessions with the RIG to inform their decisions about herd-specific habitat limitations, threats to habitat, potential mitigating actions, and finally a set of recovery actions.

Use of the Caribou Habitat Assessment and Supply Estimator

We applied the CHASE model to the recovery planning areas and spatially assessed the value of each seasonal range at discrete time steps through simulated scenarios of landscape disturbance. We used the resulting information to set the context for making decisions about specific recovery actions in each planning area. The model was applied by first calculating the amount of potential range (i.e., a theoretical construct where all input nodes were constrained to their optimal state for caribou). We then evaluated current range conditions and forecasted future range conditions based on simulated landscape disturbances.

We used ArcView 3.2 (ESRI, Redlands, California) and Microsoft Access 2000 (Microsoft Corp., Redmond, Washington) to construct and manage case files of environmental correlates taken from 1-ha cells in the recovery planning area (3 664 295 ha). The environmental correlates that we used came primarily from the BC Forest Inventory Planning attribute database¹⁰ and the BC Terrain Resource Information Management program¹¹. Case files (i.e., one file for each BBN) were lists of records (i.e., one record for each cell in the study area) containing columns (i.e., one column for each input node) specifying the existing condition or state of the environmental correlates represented by input nodes. Our decision to map results at 1-ha resolution was based on our interests in focussing the management problem and did not imply accuracy of the input data. We used Netica in batch mode to process the case files before preparing the modelled results in Access for display in ArcView and analysis in SAS (SAS Inst. Inc., Cary, North Carolina). We displayed seasonal range values on maps as the expected value from the seasonal range node (i.e., the probability of a state multiplied by the state value, summed across all states) classified into three outcomes of low, medium, or high based on equidistant intervals of the

¹⁰ See Ministry of Sustainable Resource Management web site at <http://srmwww.gov.bc.ca/gis/Databases>

¹¹ See Ministry of Sustainable Resource Management web site at <http://srmwww.gov.bc.ca/bmgs/trim>

potential outcome. The expected value ranged from -1 (low range value), through 0 (medium), to +1 (high). Further, CHASE also displayed the standard deviation of the expected value.

Uncertainty in expected caribou range value was depicted in three ways: (1) as the spread of probabilities for each of the three caribou range value states (low, medium, high); (2) as the standard error term; and (3) sensitivity structure of the model. The first of these represented the degree to which the model structure and expert understanding did not perfectly account for all factors influencing caribou range value. We described the spread of probabilities as the observed average absolute deviation from the mean (the mean in this case of three potential outcome states would be 0.33). The second uncertainty represented residual error and reflects the degree of imprecision inherent in the expected value calculations. The third uncertainty represented the degree to which the calculated expected values were sensitive to each input variable (see Marcot *et al.* 2006 for discussion of sensitivity analysis in BBN models). We estimated this uncertainty by systematically varying conditional probabilities upward by 10 points, and downward by 10 points, from the values provided by experts. Although we calculated all three kinds of uncertainty, managers would likely be most interested in the first and third as they reflect the degree to which managing for the input variables could reasonably be expected to influence caribou range.

Forecasting Range Values from Simulated Landscape Disturbances

Landscape disturbance was simulated over 250 years in 10-year time steps from current conditions (year 2005) using the Spatially Explicit Landscape Event Simulator (SELES; Fall and Fall 2001). SELES is a modelling shell that simulates vegetation or environmental conditions across a landscape over time, given initial conditions and disturbances to, or succession dynamics of, each condition. In SELES, the user allocates defined disturbances to a geographic area based on rule sets applied to spatial cells. In our application, we mimicked two different landscape disturbance scenarios as follows: (1) a conservation policy scenario which represented the current forest management strategies for caribou range (BC Govt 1999; BC Govt 2000); and (2) a natural disturbance scenario which represented historic patterns (i.e., patch sizes and return intervals) of wildfire experienced within the recovery planning area (DeLong 2002).

In both scenarios, we used variable density yield prediction (VDYP) growth curves (BCMOF 1999) to determine post-disturbance forest conditions where forest stands were always completely replaced (i.e., stand age set to zero) by disturbance. We defined ecological succession stages solely by forest age classes (i.e., regenerating forest stands were identical in species mix and composition to original pre-disturbance conditions). Disturbances occurred in multiples of adjacent 20-ha cells where the size of each disturbance varied according to its type and intensity.

In the conservation policy scenario, for a cell to be available for logging it was required to: (1) be part of a pre-defined timber harvesting land base (BCMOF 2001); (2) be greater than or equal to the minimum cutting age for the predominant tree species (BCMOF 2001); (3) be consistent with regulated patch-size and seral distribution targets; and (4) not contradict regulations for conservation of other resource values. To increase the reality of the simulation, we assigned available harvesting cells a probability of being selected based on proximity to predetermined locations of main haul roads. As SELES simulates forest harvest within cells, roads are added in the model using a 'least-cost' approach based on the topographical and biophysical features of the landscape within the cells. Roads are activated and deactivated according to their usefulness to the harvesting schedule as time progresses. The conservation policy scenario included constraints on harvest of trees in the pine-lichen winter range such that $\leq 50\%$ of this range could be < 70 years old and patch sizes > 250 ha were favoured. Contrary to current forest policy, we allowed natural disturbances to occur as part of the conservation policy scenario but only within parks.

In the natural disturbance scenario, we simulated historic fire using Delong's (2002) parameters for fire size and return interval. We ran this scenario over a 400-year cycle to eliminate any footprint (start-up bias) from forest management. We ran four natural disturbance simulations and calculated a mean and standard deviation for the resulting seasonal range values at each time step in each planning area.

Seasonal Range Habitat Index

Without specific information on seasonal range carrying capacity, relative comparisons both within and among seasonal range values becomes problematic. We created a habitat index by multiplying the amount of seasonal range (ha) by a seasonal range value weight. The habitat index provided a convenient and consistent means to compare among seasonal ranges and among qualities of range and also provided a way to concisely summarize results. The weights we used can be expressed as (Figure 12):

$$\text{HVW} = -0.53 + 0.04\text{RV} + 0.79\text{RT} - 0.35\text{RT}^2 + 0.04\text{RT}^3; \text{ where}$$

HVW is the habitat value weight, RT is the range type (i.e., pine-lichen winter range, post-rut range, high-elevation winter range, or calving and summer range) and RV is the range value (i.e., high, medium, or low) predicted by CHASE. Because migration corridors were evaluated solely on their function of linking ranges, the habitat index for this range was simply the percentage of area that was in a functional

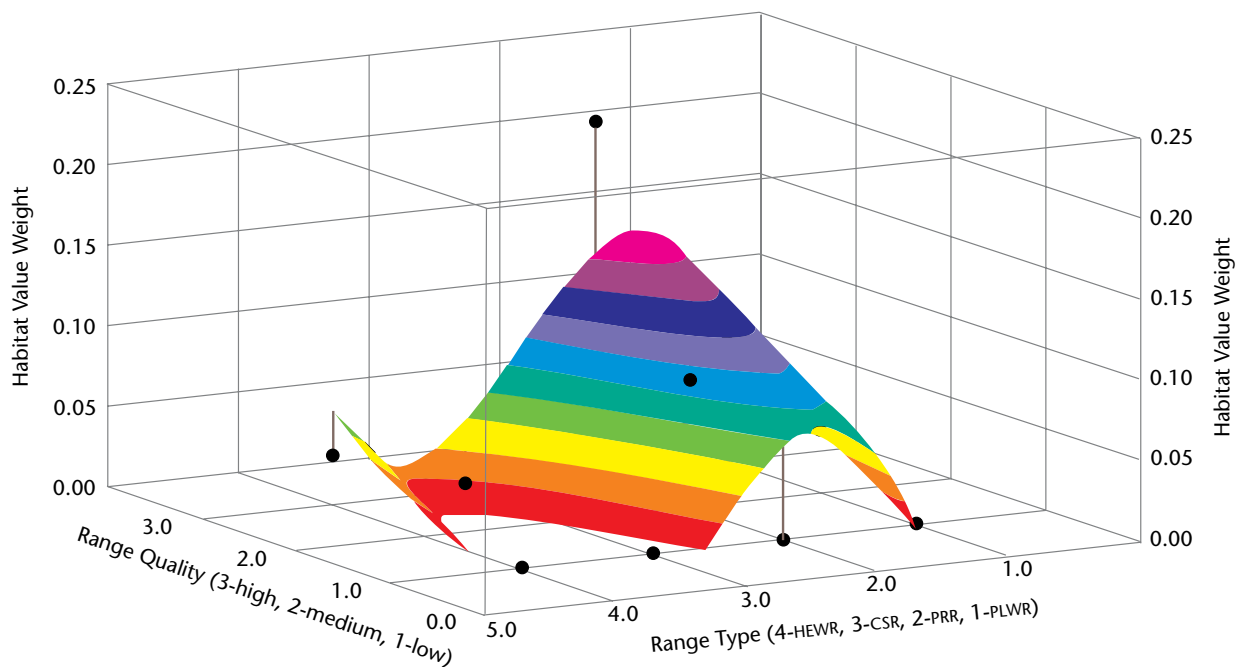


FIGURE 12 Graphical representation of a habitat value weight created to allow for relative comparisons among estimated quality (high, medium, low) of seasonal ranges (HEWR – high-elevation winter range, CSR – calving and summer range, PRR – post-rut range, and PLWR – pine-lichen winter range) used by woodland caribou in north-central British Columbia. Range qualities were estimated using CHASE.

condition (based on CHASE). Methods for creating the seasonal range value weight for the other ranges were based on the following assumptions:

- We ranked seasonal range forage values from best to worst as follows: post-rut range, pine-lichen winter range, high-elevation winter range, and calving and summer range;
- We ranked low-value ranges much lower than medium- and high-valued ranges;
- We considered that summer and calving range, even though lower ranked in forage quality, was still unlikely to limit caribou populations because of its extensive nature; and
- We considered fall and winter ranges to be additive generally but high-elevation winter range could become limiting (i.e., the post-rut range and pine-lichen winter range could become unavailable and caribou would still persist using high-elevation winter range but the opposite may not be true).

Use of RIG Workshops

Specific recovery actions were derived through a series of ten, professionally facilitated workshops scheduled periodically from December 2002 to March 2006. During these workshops, the RIG worked sequentially through the following basic activities:

1. Reviewed and consolidated current data, information, and knowledge for each herd;
2. Convened the RIG and confirmed:
 - a. a terms of reference,
 - b. stakeholders' participation,
 - c. planning area boundaries, and
 - d. background to the CHASE model and its use in recovery planning;
3. Identified recovery goals within the context of the NCTAC strategy;
4. Identified threats and mitigating management tools stratified by herd, seasonal range, and habitat element;
5. Used CHASE to identify seasonal range values;
6. Composed recovery actions; and
7. Established a basis for socio-economic review of recovery actions.

Each workshop was conducted under a standard protocol beginning with a meeting announcement and request for attendance sent to all RIG members. Agendas were constructed and final meeting arrangements set on the basis of membership response to the meeting call. Minutes were recorded by an RIG secretary and salient points (e.g., decision points, action items, etc.) were recorded by the facilitator on flip charts. Minutes and flip charts were summarized, documented, and sent to RIG members after each meeting.

MODELLING RESULTS

Assessment of Seasonal Range Values

Potential Range

Spatial output from CHASE can be exemplified by maps of the Wolverine recovery planning area for (Figure 13): A) post-rut range, B) calving and summer range, and C) moose density during winter. See Appendix D for maps of potential range for all range types in all planning areas. Generally, the location of potential seasonal ranges within planning areas indicated that caribou would need to move relatively long distances among seasonal ranges, and that calving and summer range was more generally dispersed around the recovery planning areas than were the other types of range. Experts agreed that this spatial difference in the location and dispersion among the types of ranges fit their experience with observed caribou movement patterns and correctly represented how caribou occur at low density during summer.

Across all recovery planning areas, the potential for calving and summer range far exceeded potential for any other range type, and there was more of this potential range in the Chase and Wolverine recovery planning areas (Table 4). Potential for high-elevation winter range was the next most abundant range across all areas and again, this potential was best in the Chase and Wolverine recovery planning areas. The greatest potential area of post-rut and pine-lichen winter ranges combined occurred within the Wolverine and Chase herd recovery planning areas (Table 4), although the Scott had the most potential area of pine-lichen winter range. Generally across the recovery planning area, the Scott and Takla were distinct in their relative lack of potential area of any range as a percentage of the recovery planning area, particularly for post-rut range (< 1%). The one exception was the apparent disproportionate amount of pine-lichen winter range in the Scott recovery planning area (Table 4). The Takla was distinct in that, as a percent of the recovery planning area, almost all potential range was at high elevations.

Current Range

For the most part, the current abundance of seasonal ranges across the recovery planning area was consistently much lower than potential (Table 4) with the exception that calving and summer range was almost equal to potential in all areas. Current high-elevation winter range was close to half the potential in the Scott and Takla but lower in the Chase and Wolverine recovery planning areas (71% and 68% reduction from potential), respectively. Current abundance of both post-rut and pine-lichen winter ranges was generally high in all areas. Because these two ranges reach optimal value if forest age is 70–140 years old, the area of current range would be half the area of potential range under a stable forest age-class distribution.

The Scott recovery planning area was distinct in this respect because it had a 70% difference between potential and current area of pine-lichen winter range. All other recovery planning areas have more pine-lichen winter range than would be expected under a stable age-class distribution and all recovery planning areas had more post-rut range than would be expected. Regardless, if increases in moose and wolves were due to a natural colonization of moose or if this was precipitated from past land use and management, our model predicts that predation risk now has a dramatic effect on seasonal range values for caribou in all recovery planning areas where reductions in abundance of seasonal ranges are usually from 21–100% (Table 4). Reductions in range value were highest on post-rut ranges (83–100%) for the Scott, Takla, and Wolverine recovery planning areas and on pine-lichen winter range (86%) for the Scott recovery planning area. Range value in the Chase area appeared to be affected the least by predation risk (Table 4) and had the lowest reduction of any seasonal range (21% on high-elevation winter range). By comparison, when predation risk was considered, the Scott and Takla areas were left with less than 1000 ha of post-rut and pine-lichen winter ranges combined.

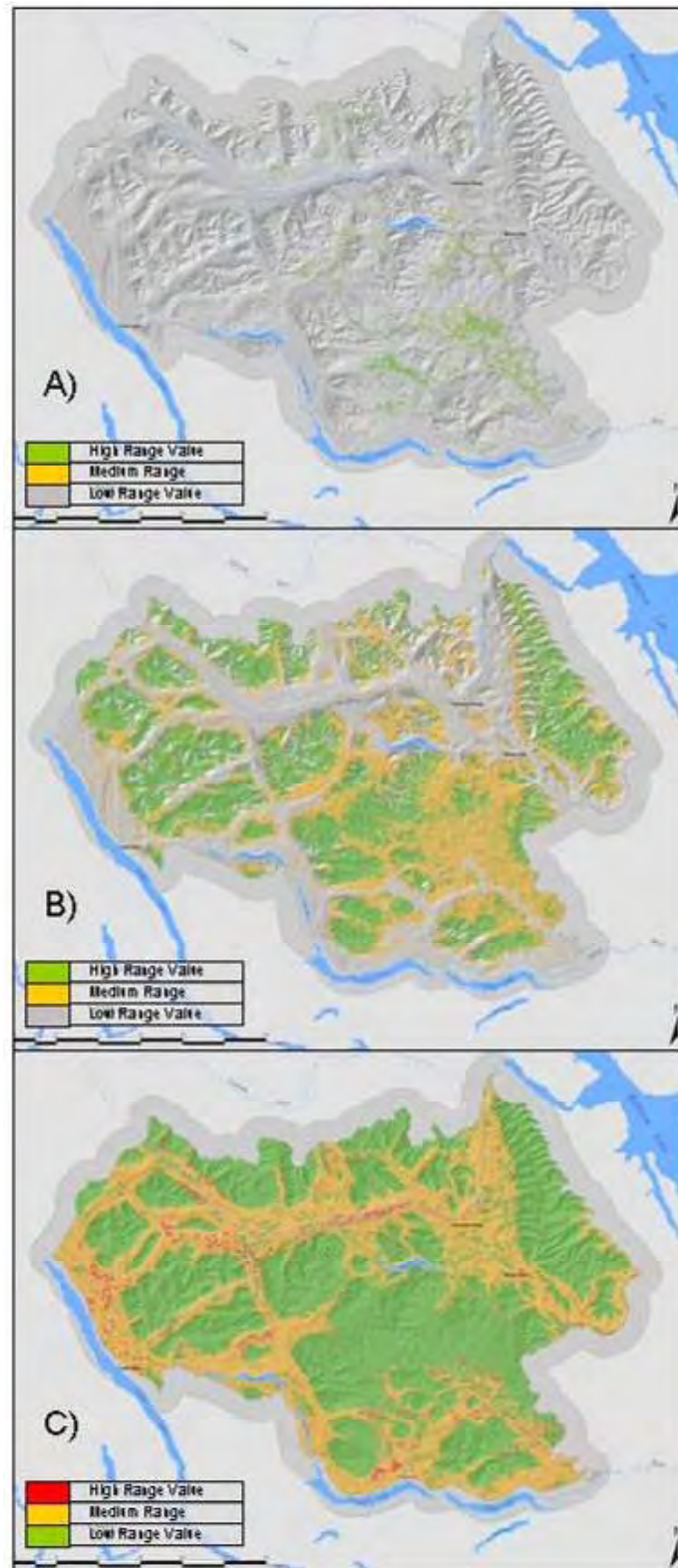


FIGURE 13 Spatial location of modelled, potential ranges for woodland caribou during A) post-rut and B) calving and summer seasons, and C) potential moose range during winter. The example range maps are for the Wolverine herd recovery planning area of north-central British Columbia.

TABLE 4 High- and medium-quality woodland caribou seasonal ranges predicted using Bayesian belief network models applied to simulated landscape conditions in recovery planning areas in north-central British Columbia. Amount of range was calculated as (a) area (ha) of potential range and, in parentheses, the percent of the recovery planning area, (b) percent reduction in range area from potential to current range, (c) area (ha) of current range, (d) percent reduction in range area due to predation risk, (e) area (ha) of range when predation risk is considered as an influence on range quality, and (f) area (ha) of range expected under conditions of assumed natural disturbance

Recovery Planning Area		Seasonal Range Type			
		Post-rut range	Pine-lichen winter range	High-elevation winter range	Calving and summer range
Chase	(a)	22,500 (1)	17,184 (1)	208,505 (12)	1,094,879 (63)
	(b)	26	28	71	2
	(c)	16,679	12,407	59,462	1,069,999
	(d)	56	63	21	47
	(e)	7,343	4,587	47,078	579,012
	(f)	4,324	2,100	35,997	492,419
Scott	(a)	2,319 (<1)	21,883 (4)	26,069 (4)	204,831 (34)
	(b)	13	70	56	0
	(c)	2,009	6,525	11,419	204,060
	(d)	100	86	53	56
	(e)	0	929	5,354	90,172
	(f)	0	21	2,556	32,312
Takla	(a)	492 (<1)	835 (<1)	22,420 (4)	186,322 (38)
	(b)	3	3	53	0
	(c)	477	812	10,529	186,122
	(d)	97	55	56	57
	(e)	12	374	4,613	80,635
	(f)	12	0	3,827	48,741
Wolverine	(a)	26,703 (3)	11,722 (1)	78,785 (9)	484,830 (57)
	(b)	30	6	68	1
	(c)	18,762	10,981	24,918	478,449
	(d)	83	59	38	48
	(e)	3,101	4,545	15,430	249,703
	(f)	2,001	595	9,141	111,754

By way of an example, we demonstrate the three types of uncertainty estimates available from a BBN for current pine-lichen winter range in the Wolverine herd area (Figure 14). All parameters depict decreasing certainty in the range value outcome as range value increased. Standard deviation of the expected range value increased and the average absolute deviation from the mean probability for each of the three range value states (high, moderate, and low) decreased. The average absolute deviations in probabilities reached its lowest point within moderate range values indicating complete uncertainty, but began increasing for high range values indicating greater certainty for both high- and low-valued ranges. The response in more certainty for higher range values was flatter when conditional probabilities were arbitrarily lowered by 10 points and sharper when they were increased by 10 points (compared to the original conditional probabilities set by experts).

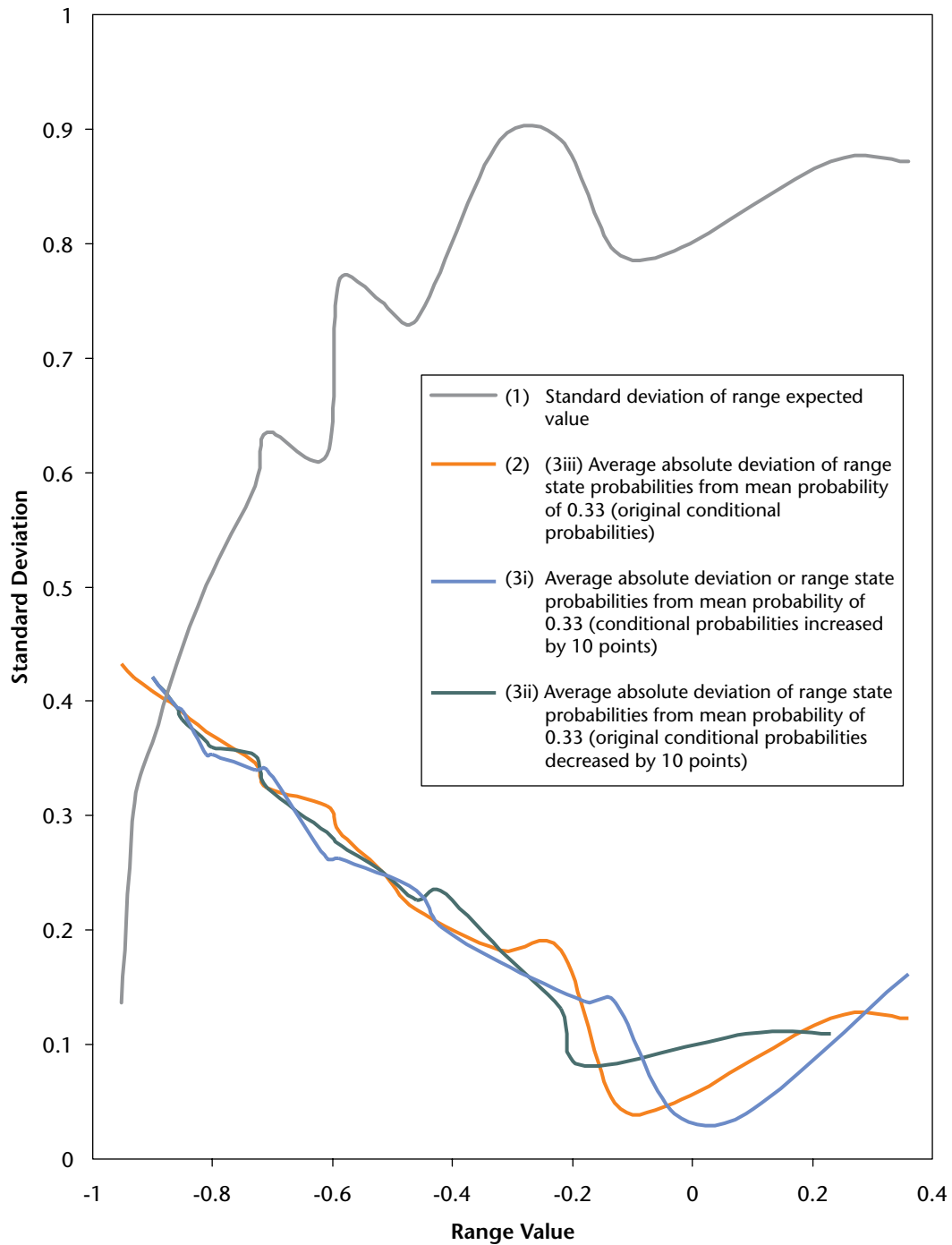


FIGURE 14 Uncertainty in estimates of pine-lichen winter range values evaluated as: (1) the standard deviation of the expected range state, (2) the average absolute deviation of range state probabilities from the mean probability (0.33), and (3) the sensitivity of the outcome when conditional probabilities were arbitrarily increased (3i) and decreased (3ii) from the original (3iii) values.

Forecasted Range under Conservation Policy and Natural Disturbance Scenarios

By way of an example of where CHASE was used to assess discrete time steps of simulated landscape disturbance, we focussed on the results for the conservation policy and natural disturbance scenarios in the Wolverine recovery planning area and for predicted values of pine-lichen winter range. Results for all range types are presented in Table 4 and later by way of comparisons using our habitat index. Under simulated conditions of forest harvest, and as evaluated by CHASE, the conservation policy succeeded in sustaining the supply of pine-lichen winter range (Figure 15Ai). The simulation begins with the current “over-stocked” condition of the range and, for the following five decades, showed a steep decline in forecasted supply of the range. At 2055, the amount of high- and medium-quality range under the conservation policy scenario was less than that expected under the natural disturbances as we projected them. Three decades later, however, the amount was more stable and remained greater than would be expected under natural disturbance for the rest of the simulation. The conservation policy was theoretically best at achieving an even supply of range because the sequence of cell disturbance was controlled as opposed to being based strictly on a probability of disturbance as it was in natural disturbance. However, gaining relative equilibrium in supply of pine-lichen winter range in this conservation scenario was only expected after a period of severe decline.

When risk of predation was considered, the decline of pine-lichen winter range was only exacerbated (Figure 15Aii). Although the amount of high- and medium-quality pine-lichen winter range never dropped below that expected under the natural disturbance scenario, only about one-eighth of the range, < 350 ha in 2075, was predicted as being free from relatively high predation risk. High-elevation winter range did not fare as poorly under assumed conditions prior to (Figure 15Bi), or after (Figure 15Bii), colonization by moose. Although the amount of high- and medium-quality high-elevation winter range was far below the landscape potential, it was always above the amount expected under the natural disturbance scenario. This result was expected from the conservation policy which biased disturbances from forest harvesting to lower elevations (easier access to higher volumes of wood fibre) and minimized fire-initiated disturbance at both high and low elevations. Risk of predation did not affect this range nearly as much as the lower-elevation ranges because risk during winter was associated with moose habitat at lower elevations (Figure 13C).

Relative Comparisons of Modelled Results: Herd Areas, Seasonal Ranges, and Scenarios

Our habitat index allowed a direct relative comparison of weighted, seasonal range values (high, medium, and low) among herd areas for estimated conditions modelled for the conservation policy and natural disturbance (Figure 16). These comparisons allowed for the following general conclusions about range quality in the recovery planning areas.

There was little to no potential for low-elevation ranges (either post-rut or pine-lichen) in the Takla recovery planning area and, among the recovery planning areas, Takla had the least potential for high-elevation winter range. Scott had the greatest potential for pine-lichen range but relatively low potential all other ranges. Chase had the best all-round potential across range types. Wolverine, with the second best all-round potential, differed from the Chase by having more potential post-rut range and less potential high-elevation range.

The natural disturbance scenario with moose as part of the predator-prey system showed dramatic effect in lowering the habitat index. This influence affected post-rut range in the Wolverine area the most. By comparison, it had relatively little effect on Takla high-elevation range. Pine-lichen range was affected by predation risk to the extent that very little effective range is expected in any recovery planning area; for example, the habitat index for the Chase recovery planning area (value was 108) is equivalent to about 2100 ha.

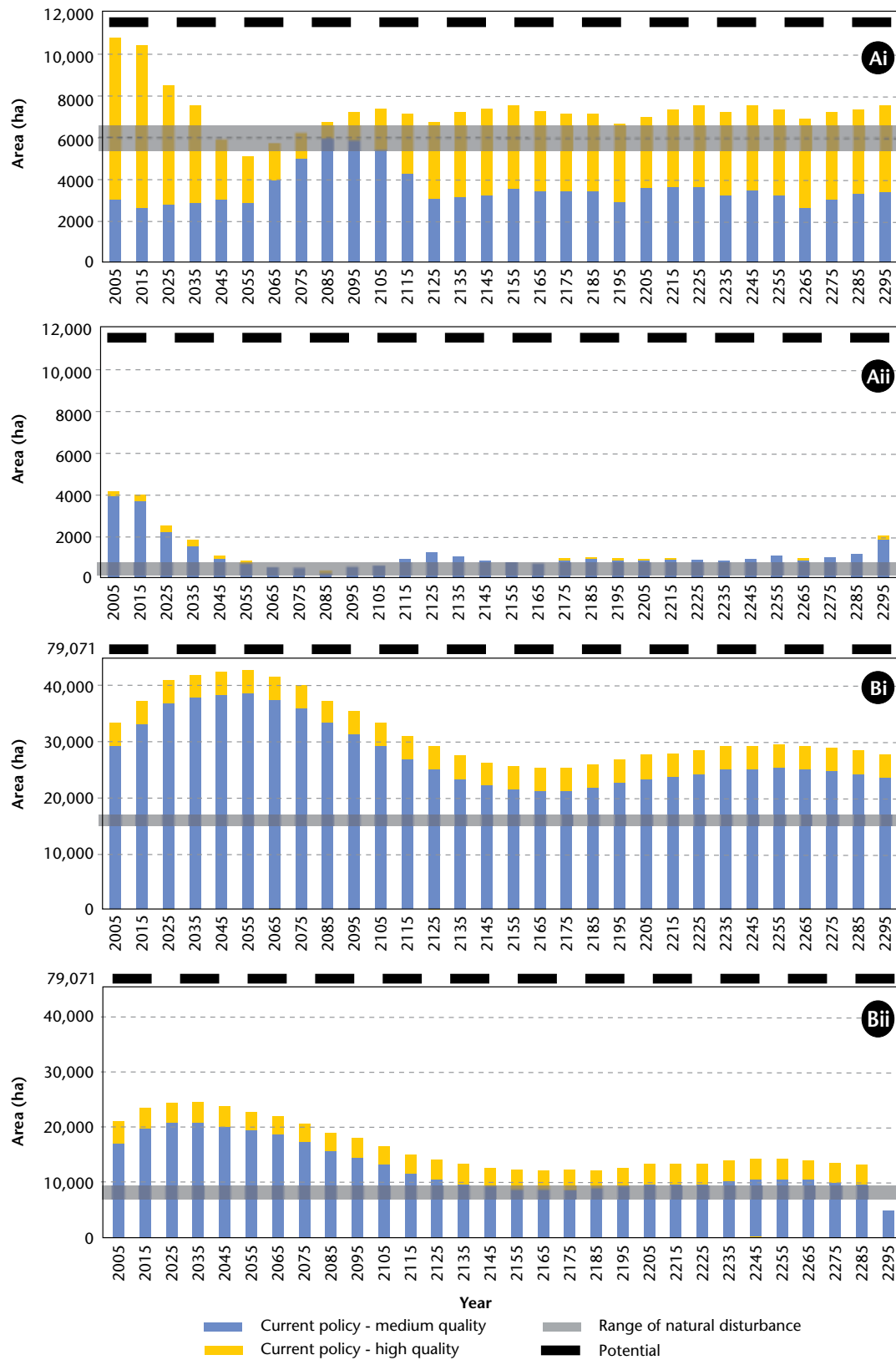


FIGURE 15 Forecasted supply of (A) pine-lichen winter range and (B) high-elevation winter range simulated for four alternative management scenarios under conditions (i) prior to the colonization of moose and (ii) after the colonization of moose within the Wolverine caribou herd recovery planning area in north-central BC.

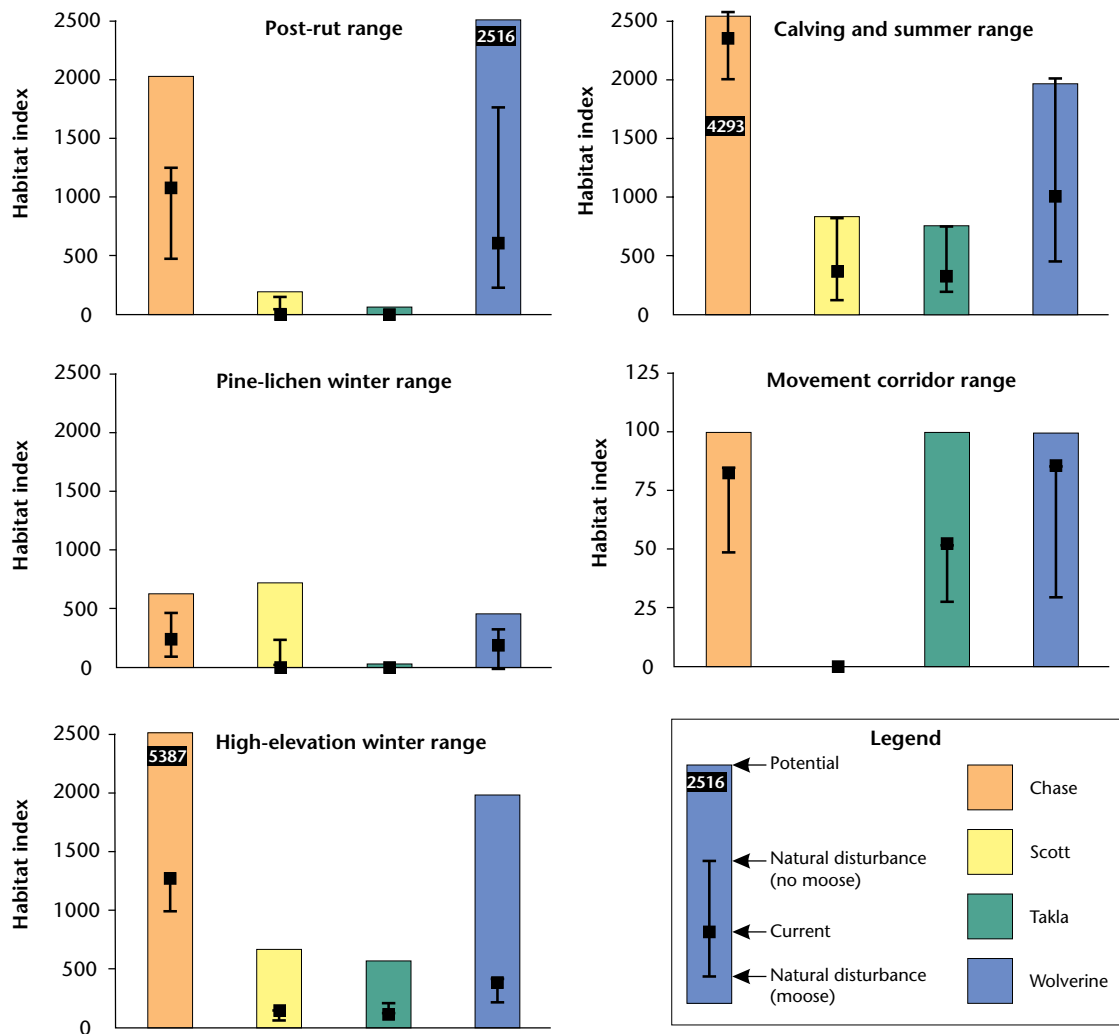


FIGURE 16 Relative amount of habitat (Habitat index) predicted using seasonal range (Post-rut, Pine-lichen winter, High-elevation winter, Calving and summer, and Movement corridor) Bayesian belief network models applied to conditions in recovery planning areas (Chase, Scott, Takla, Wolverine) in north-central British Columbia. Results are presented for ranges under hypothetical management conditions for potential, current, and two natural disturbance scenarios (with moose and no moose).

In most comparisons, the habitat index based on current landscape conditions fell between the two natural disturbance scenarios (i.e., with and without moose). One exception was the Chase recovery planning area where high-elevation winter range was above both natural disturbance scenarios. Pine-lichen winter range in the Scott recovery planning area (current conditions) was very close to the value based on the natural disturbance scenario which was itself close to nil (i.e., a habitat index of 40 is based on approximately 929 ha of moderate value range). Natural disturbance (without moose) was equal to potential on the calving and summer range because we did not directly alter this range value by forest succession (Figure 10). However, similar to the other ranges, predation risk reduced the habitat index for this range considerably. Unlike many of the other results, calving and summer range remained relatively abundant in all planning areas.

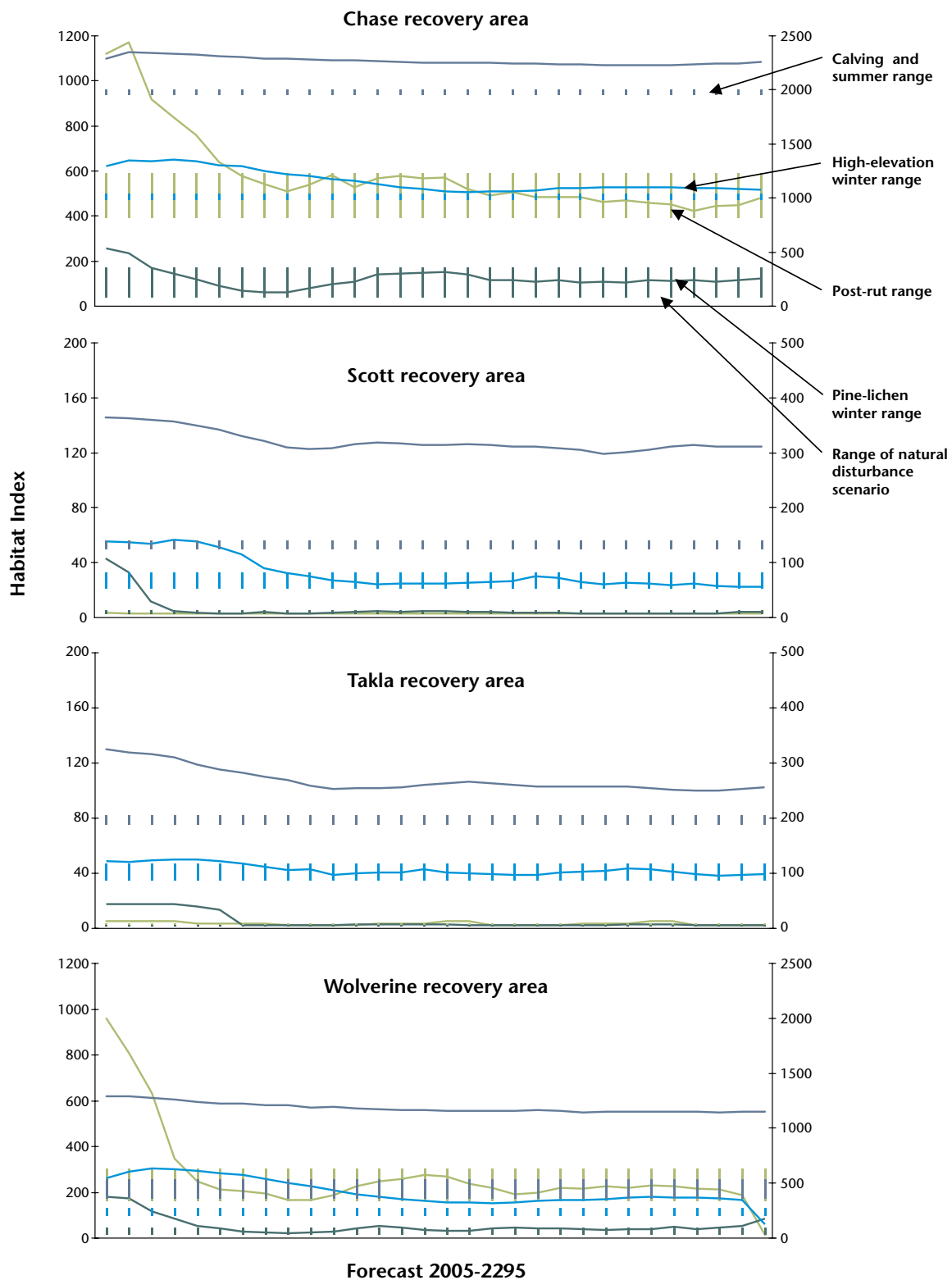


FIGURE 17 Relative amount of habitat (Habitat Index) predicted using seasonal range (Post-rut, Pine-lichen winter, High-elevation winter, and Calving and summer) Bayesian belief network models applied to simulated conditions (a conservation scenario [solid lines] and a natural disturbance scenario [vertical bars] in recovery planning areas (Chase, Scott, Takla, Wolverine) in north-central British Columbia.

The habitat index for movement corridors was high in both the Chase and Wolverine areas, about half the potential in Takla, and basically non-existent in the Scott. In all comparisons, natural disturbance with moose dramatically affected the habitat index for movement corridors, reducing it to half or less of the potential.

The results for the Chase and Wolverine areas showed that the conservation policy was able to maintain the amount and quality of pine-lichen winter range within the range of natural variation (with moose in the system) although the current uneven age distribution in this range type resulted in a “fall-down” 80 years into the simulation (Figure 17). The habitat index fell to 60 and 21 for the Chase and Wolverine areas, respectively, below the range of natural disturbance results, before it began increasing again. During some time periods, the habitat index for post-rut range draws close to the lower range of natural disturbance results but otherwise stays within that range. The habitat index for calving and summer range and for high-elevation winter range were forecasted to usually be above the range of natural disturbance since we did not simulate much direct disturbance on these high-elevation ranges. Apparently, sufficient forest development could occur in the Scott area to bring the habitat index for high-elevation winter range within the range expected under conditions of natural disturbance.

Conclusions from Modelling

We draw the following conclusions from use of the CHASE model:

1. There is a general lack of potential for low-elevation ranges in the Takla herd recovery planning area.
2. Although there is potential for low-elevation range in the Scott recovery planning area, all of this range is expected to have an associated high risk of predation even under natural disturbance (with moose).
3. If high-elevation winter range can act as a refuge for populations with little low-elevation range (i.e., low potential or where potential is affected by predation risk), then we should not anticipate large numbers of animals in either the Scott or the Takla recovery planning areas (approximately 100 or slightly less based on estimates of current numbers).
4. The best recovery opportunities (based on fall and winter range potential) should exist in the Chase and Wolverine recovery planning areas, Chase having slightly more potential than the Wolverine. Both areas have similar levels of pine-lichen winter range (potential, current, and under natural disturbance) but the Chase area should retain more post-rut and high-elevation winter ranges.
5. By comparison to other ranges, it is unlikely that pine-lichen winter range or post-rut range will limit populations as long as the habitat index is managed at least to the level that would occur under conditions of natural disturbance (with moose).
6. Lack of movement corridor in the Scott recovery planning area (i.e., Williston Reservoir has eroded this over a couple of decades) and little likelihood of recovering that value, has led to the spatial segregation of high-elevation ranges (i.e., calving and summer and high-elevation winter ranges) from low-elevation ones (pine-lichen winter range and rut range).
7. The general reduction in value of movement corridors is likely to mean that this range will become limiting, even under natural disturbance (with moose).
8. Without considering metrics other than the seasonal range habitat index (i.e., other metrics might include patch size, connectivity), the conservation policy appears to be able to provide for an even supply of all range types consistent with conditions expected under natural disturbance. That said, pine-lichen winter range and post-rut range are likely to have fall-downs from the current levels and undergo some stress over the next two to three decades.

WORKSHOP RESULTS

Results of the ten workshops that were held were posted for perusal by RIG members. These results included meeting agendas, minutes, and background material such as handouts, and project summaries.

Recovery Goals, Threats, and Management Tools

Local Recovery Goals and Definition of Recovery

It was agreed that the concept of recovery is generally more suited to the SMNEA population rather than to individual herds. However, there was no guidance from NCTAC to specify recovery targets for individual herds. We therefore concluded that if individual herds were self-sustainable, it could be argued that the herd itself will contribute to overall population recovery. Although our local recovery goal was constructed with similarities to the provincial statement, we also used elements of the NCTAC strategy to develop the following recovery goal.

“The goal for recovery of woodland caribou in north-central BC is to create:

- Ecological conditions that allow herds to be self-sustaining—this condition is to be accomplished within nine generations or 60 years;
- Individual herds of > 100 animals and densities of > 50 animals/1000 km²; and
- Amounts of all seasonal ranges within or above the range of expected variation (i.e., where expected variation is based on assumed patterns of natural disturbance and where amount of seasonal ranges is characterized by forage values, potential displacement of caribou, and risk of mortality as modelled using the Caribou Habitat Assessment and Supply Estimator).

In places where the recovery goal was considered ecologically feasible, management actions were assumed to focus on establishing recovery of caribou to the defined conditions. In places where herds are currently in decline, management actions should focus on halting the decline of caribou within one generation (7 years) and promoting stable or increasing population trends over the next three generations (20 years). A secondary goal was to keep stakeholders informed of efficacy through implementation of, and regular reporting on, an effectiveness monitoring program.”

We expected that accomplishing these goals would lead to:

- An overall stability in numbers of caribou at the prescribed levels or greater;
- Sufficient ecological conditions to maintain self-sustaining caribou populations although this may not be achievable at all locations given past and ongoing levels of disturbance and/or global climate change;
- Connectivity among herds where ecologically feasible (e.g., Takla and Wolverine herds);
- Modifications to some policy bounding current industrial development; and
- Monitoring that involves modelled projections of habitat and population to determine if future populations are expected to be stable (or increasing).

Attributes of Seasonal Ranges that can be Threatened

The RIG determined the primary life requisite of caribou to conserve on seasonal ranges was forage resources. Other life requisites such as shelter from specific thermal conditions were considered but determined to be less important. Other habitat attributes considered by the RIG to be important were:

- The freedom for caribou to choose sites and not be displaced or disturbed by human activities;
- Relative safety for caribou while using the sites; and
- Connectivity among caribou herds to support transfer of genetic material.

Potentially Threatening Activities

The RIG listed the following activities that could threaten the aforementioned attributes of seasonal ranges, but no measure or threshold of intensity was provided:

- Recreational activities such as:
 - Snowmobiling,
 - Heli-skiing, and
 - Boating;
- Resource development for:
 - Minerals,
 - Oil and gas, and
 - Forestry;
- Enhancement of habitat attributes for other ungulates such as:
 - Deer (*Odocoileus* spp.),
 - Elk (*Cervus elaphus*), and
 - Moose;
- Enhancement of habitat for the purposes of grazing cattle;
- Settlements and agriculture; and
- Management to limit large natural disturbances.

Specific locations where these threats may occur were noted (Table 5).

Summary of Potential, Local Recovery Actions and Priorities for Implementation

The following were considered by the RIG to be the management tools currently available for mitigating threats to caribou in support of their local population recovery:

- Predator management:
 - Increasing hunting bag limits for wolves,
 - Extending the wolf trapping season,
 - Extending the general open hunting season for wolves, and
 - Wolf control;
- Management of other species:
 - Reduction in numbers of alternative prey for predators via hunting, and
 - Reduction in the value of habitat for other ungulates (i.e., moose, elk, and deer);
- Caribou harvest management (legal and illegal):
 - Hunting regulations,
 - Increased enforcement action regarding illegal kill, and
 - Access management;
- Habitat management:
 - Forage availability, and
 - Control methods and timing of industrial activities to maintain forage;
- Displacement:
 - Control timing of human activities (both industrial and recreational), and
 - Access management controls including use closures and barriers;
- Predation:
 - Large patch management—roads and cutblocks managed to ensure large, contiguous areas of habitat are available (predator avoidance), and
 - Access rehabilitation to increase the rate of vegetation re-growth inhibiting use by wolves and recreational users.

TABLE 5 *A summary of potential threats to caribou and their seasonal ranges^a within recovery planning areas (Chase, Takla, Wolverine, and Scott) as expressed by the Recovery Implementation Group*

	Chase	Takla	Wolverine	Scott
Threats (Classes)	<ul style="list-style-type: none"> • Predation – roads and cutblocks, climate change • Loss of winter food supply – logging, natural disturbance, climate change • Unregulated human kill – access • Disturbance/displacement – ATVs, snowmobiles, commercial exploration, settlements, skiing, roads, industrial activities, gas and oil exploration • Isolation – loss of genetic exchange 	<ul style="list-style-type: none"> • Predation – roads and cutblocks, climate change • Loss of winter food supply – logging, natural disturbance, climate change • Unregulated human kill – access • Disturbance/displacement – ATVs, snowmobiles, commercial exploration, settlements, skiing, roads, industrial activities, gas and oil exploration • Isolation – loss of genetic exchange 	<ul style="list-style-type: none"> • Predation – roads and cutblocks, climate change • Loss of winter food supply – logging, natural disturbance, climate change • Unregulated human kill – access; • Disturbance/displacement – ATVs, snowmobiles, commercial exploration, settlements, skiing, roads, industrial activities, gas and oil exploration • Isolation – loss of genetic exchange 	<ul style="list-style-type: none"> • Predation – roads and cutblocks, climate change • Loss of winter food supply – logging, natural disturbance, climate change • Unregulated human kill – access; • Disturbance/displacement – ATVs, snowmobiles, commercial exploration, settlements, skiing, roads, industrial activities, gas and oil exploration • Isolation – loss of genetic exchange
Short-term threats (< 10 years)	<ul style="list-style-type: none"> • Predation (increased by timber harvesting/roads): <ul style="list-style-type: none"> • Summer range is more remote and less developed than Wolverine • Access corridor in Carina Tomias area PLWR • Disturbance: <ul style="list-style-type: none"> • Mineral exploration everywhere – HEWR, Movement Corridors, and PLWR 	<ul style="list-style-type: none"> • Predation: <ul style="list-style-type: none"> • In movement corridors • In high-elevation winter range (Nadina area) • Disturbance: <ul style="list-style-type: none"> • Proposal for snowmobile recreation in Takla Narrows area • Existing snowmobiling in Mitchells and Sidney Williams • Isolation: <ul style="list-style-type: none"> • Connectivity with the Wolverine herd 	<ul style="list-style-type: none"> • Predation (increased by timber harvesting/roads): <ul style="list-style-type: none"> • Along movement corridor from South Germansen to Jackfish Lake area • Valteau calving area • Eklund Creek calving area • All high-elevation areas • Disturbance: <ul style="list-style-type: none"> • Mineral tenure in the Nation area – HEWR, Movement Corridors, and PLWR 	<ul style="list-style-type: none"> • Predation throughout low-elevation ranges • Disturbance: <ul style="list-style-type: none"> • Pending tenure applications (wind farm, commercial snowmobile, heli-ski) • Isolation: <ul style="list-style-type: none"> • Evidence of isolation from Wolverine herd due to low population on west side of Williston Reservoir

TABLE 5 *Continued*

	Chase	Takla	Wolverine	Scott
Longer-term threats (> 10 years)	<ul style="list-style-type: none"> • Loss of food: <ul style="list-style-type: none"> • PLWR food both within and outside protected areas • Timber harvesting – PLWR and HEWR • Winter food supply loss due to climate change • Predation: <ul style="list-style-type: none"> • Connectivity with the Wolverine and Scott herds • Elk habitat enhancement influencing PLWR • Disturbance: <ul style="list-style-type: none"> • Snowmobiling in Johansen Lake area – calving summer range • Potential heli-skiing in HEWR • Mineral and/or oil and gas exploration everywhere 	<ul style="list-style-type: none"> • Disturbance: <ul style="list-style-type: none"> • Sidney Williams Peak mineral development in HEWR • Increased snowmobiling in the Mitchells and throughout in HEWR • Heli-skiing in HEWR • Boat traffic on Takla Lake – threats to animals swimming across • Loss of food: <ul style="list-style-type: none"> • Timber harvesting in HEWR • Winter food supply due to climate change 	<ul style="list-style-type: none"> • Isolation: <ul style="list-style-type: none"> • Connectivity with the Chase and Takla herds • Predation: <ul style="list-style-type: none"> • Squawfish Lake – post-rut • Loss of food: <ul style="list-style-type: none"> • PLWR food both within and outside protected areas • Loss of arboreal lichen in HEWR; • Squawfish area post-rut (due to timber harvesting) • Winter food supply loss due to climate change • Disturbance: <ul style="list-style-type: none"> • Mineral exploration and development everywhere affecting all habitats • Recreational snowmobiling 	<ul style="list-style-type: none"> • Predation • Disturbance • Isolation: <ul style="list-style-type: none"> • High- and low-elevation ranges irreparably separated by Williston Reservoir

^a PLWR – pine-lichen winter range, HEWR – high-elevation winter range, CSR – calving and summer range, PRR – post-rut range.

The potential management available for consideration in developing recovery actions ranged broadly in likelihood of success and in the degree to which it departed from an ecosystem management focus (i.e., where targets would be expected to fall within the apparent range of natural disturbance). The deployment strategy, therefore, was developed by subjectively considering both “likelihood of success”, and “conformity to natural disturbance”, to result in the following strategic position:

- Recognize that there is natural change of moose numbers because they have colonized the area, but that we have increased numbers with habitat alteration;
- First priority is then to manage habitat to reduce effects of increased predators;
- Second priority, short-term approach, while habitat is being restored, is to control or limit alternate prey species (e.g., moose) to reduce their numbers in specific areas;
- Third priority, also short-term approach while habitat is being restored, is to control or limit predators (e.g., wolf) to reduce predation on caribou;

- The RIG will not consider long-term predator control—if short-term measures do not work, it may be concluded that the caribou herd is not self-sustaining and recovery is not feasible; and
- Recognize that there will always be a human impact/footprint on the landscape.

Recovery Actions

Recovery actions are instructions to resource managers that, if co-ordinated and integrated among stakeholders and across jurisdictions, will allow for the recovery of a species at risk. In this plan, recovery actions were derived from the identification of threats and mitigating actions, as these interact with our conclusions about current and future seasonal range values. Recovery actions therefore specify instructions that reduce or eliminate the likelihood of:

- deleterious effects from human-caused disturbances on the value of seasonal ranges for caribou, and
- death to caribou from effects other than those that would likely occur under natural, unmanaged environmental conditions.

Recovery actions are intended to lead to improvements in caribou populations and to their range in such a way that the species population becomes self-sustaining. As a matter of priority, recovery actions focus on eliminating undue:

- displacement of caribou using seasonal ranges;
- risk of predation to caribou; and
- destruction of forage resources.

Recommended Recovery Actions

- 1) Within those recovery planning areas where caribou herds have failed to meet the definition of recovery, and unless deemed compatible with caribou recovery:
 - a) Do not kill, harm, harass, capture, or take an individual of a caribou herd within the recovery planning area; and
 - b) Do not possess, collect, purchase, sell, or trade an individual from a caribou herd within the recovery planning area.
- 2) If harvest of caribou is to occur, First Nations will have priority over harvest of caribou pending a process for negotiating activities that will be compatible with maintaining the recovered status.
- 3) Management responses to insect epidemics, forest fires, and other catastrophic natural events should be consistent with these recovery actions.
- 4) In all recovery planning areas, design the temporal pattern of human-caused disturbance to moose range (i.e., amount of area that is 0–40 years old) to be consistent with a trend toward patterns of natural disturbance, henceforth referred to as the range of natural variability.
- 5) Specific recovery actions:
 - a) Within pine-lichen winter range and post-rut range in the Chase and Wolverine recovery planning areas:
 - i) Manage the range temporally and spatially so that development of resource values, or management within protected areas, is conducted in area-based clusters $\geq 5\,000$ ha in size. These clusters may contain pine-lichen winter range, post-rut range, and/or surrounding area needed to make up a cluster. Note: Cluster sizes are to be specified in an approved plan. Forest harvesting or other forms of disturbance (e.g., prescribed fire) within a cluster are to be conducted within a 20-year period. Silvicultural activities within a cluster are to be com-

- pleted within 70 years. Remnant areas within a cluster that are interstitial to any disturbance are to be managed in the same time period as the rest of the cluster;
- ii) Do not reduce abundance of terrestrial lichens below the range of natural variability;
 - iii) Manage disturbances so that 40–60% of the range is within clusters that are 70–140 years old using a 140–year disturbance rotation where disturbances do not prevent achievement of 5(a)(ii);
 - iv) No displacement of caribou from the range when it is 70–140 years old, other than through approved use of current or future mainline roads;
 - v) Do not build permanent new roads (other than approved mainlines), or new trails, and do not maintain temporary roads within clusters that are 70–140 years old;
- b) Within high-elevation winter range in all recovery planning areas:
- i) No motorized recreation activities on this range during winter (December through April). Motorized activities may occur in conjunction with, and only in areas designated for trapping, recreational snowmobiling (see maps in Appendix E), and heli-ski tenures;
 - ii) Any industrial activity in this area is subject to approval of a plan compatible with caribou recovery;
 - iii) No industrial activities leading to reduction of the range area below the range of natural variability where activities that reduce range area are considered to be:
 - forest harvest in stands having arboreal lichens,
 - forest harvest that creates early seral moose range below 1200 m elevation and within 5 km of the range,
 - construction of permanent roads and trails within the range,
 - any activity that directly reduces abundance of arboreal or terrestrial lichens, and/or
 - any activity that causes direct displacement of caribou away from the range;
- c) Within calving and summer range in all recovery planning areas:
- i) Any industrial activity in this area is subject to approval of a plan compatible with caribou recovery;
 - ii) No industrial activities leading to reduction of the range area below the range of natural variability; where activities that reduce range area are considered to be:
 - forest harvest that creates early seral moose range below 1200 m and within 5 km of the range,
 - construction of permanent roads and trails within the range,
 - any activity that directly reduces abundance of arboreal or terrestrial lichens, and/or
 - any activity that causes direct displacement of caribou away from the range;
- d) Within movement corridor range in all recovery planning areas:
- i) Manage the amount of early seral moose range and active roads through the following:
 - do not create early seral moose range in or adjacent to (i.e., within 1 kilometre of) the corridors, and
 - design new mainlines to intersect rather than parallel movement corridors.
- 6) Specific mitigation instructions are focussed primarily on reducing risk of mortality for caribou. The RIG favours mitigation in order of priority as:
- a) reductions in moose through regulated hunting;
 - b) reductions in wolves through normal operation of regulated trap lines;
 - c) reduction of forage for moose, deer, or elk; or
 - d) reduction of predators through direct control mechanisms.

- e) Mitigation instructions include:
- i) Mitigate the forecasted downfall of pine-lichen winter range and post-rut range in the Chase and Wolverine recovery planning areas for the next 15 years:
 - locate area-based clusters for management (see 5(a)(i)) in areas predominated by older pine stands (> 90 years old). We anticipate this will be achieved by the mountain pine beetle (MPB) epidemic and/or MPB salvage operations,
 - avoid locating area-based clusters for management (see 5(i)) in areas predominated by mature pine stands that are between 70–90 years old,
 - pending research on methods, use silviculture (e.g., selection of harvest method, site preparation method, spacing, or thinning) to enhance the abundance of terrestrial lichens in pine stands between 40–60 years old (especially those attacked by MPB) and to minimize risk of predation for caribou, where such management is expected to include:
 - clustered, rather than uniform spacing of planted tree stock, and/or
 - pre-commercial or commercial thinning to reduce tree stem density (stems/ha).
 - ii) Where there is a high probability of long-term recovery of caribou, mitigate predation if either the amount of, or the spatial patterns of, early seral moose range is currently outside the range of natural variability. Spatially these sites occur:
 - in the Scott recovery planning area east of the Williston Reservoir,
 - throughout all other recovery planning areas, and
 - where priority should be placed on areas of early seral moose habitat that is adjacent to, or overlapping with, movement corridors and/or pine-lichen winter range;
 - iii) In movement corridors, mitigate potential mortality or displacement of caribou by:
 - regulating use (e.g., speed limits, closures) of existing mainlines during March through May and November through December,
 - reducing predation risk in current early seral moose range, and
 - vegetation management to reduce moose forage.
- 7) Specific monitoring instructions include but may not be limited to:
- a) co-ordinated census within all recovery planning areas once every three years where each census will be designed to provide information on population size, gender/age classes, and calf recruitment;
 - b) co-ordinated annual evaluation of the cumulative resource development activities and resulting amount and spatial configuration of seasonal range values (i.e., using the CHASE model); and
 - c) using the results of this monitoring as the basis for status assessment and approval of plans.
- 8) Specific research instructions include but may not be limited to:
- a) an assessment of the likelihood that poor-quality low-elevation ranges may become a barrier to movement and hence segregate seasonal ranges;
 - b) an assessment of the potential implications of salvaging forests killed by MPB (i.e., with respect to the efficacy of implementing recommended recovery actions) including continued measurement of installed adaptive management trials used to determine silvicultural techniques to maintain or enhance terrestrial lichens within pine-lichen winter ranges;
 - c) adaptive management of predation risk consistent with criteria and actions recommended in 6b; and
 - d) continued testing, improvement, and modification of the CHASE model as required.

DISCUSSION

Use of BBNS to Inform Decisions about Recovery

Decisions about how best to implement management actions that would lead to recovery of caribou populations are nontrivial. Ecological uncertainty, stakeholder interests, government policy, and dynamics of local and regional economies are some of the factors that become difficult to articulate, come to common agreement on, and balance in an equitable way so that all members of a diverse team remain satisfied. Our use of BBNS, and in particular our check on consistency of those BBNS with First Nations beliefs about caribou behaviour, led to a method to systematically, explicitly, and transparently track the disparate and often competing factors that entered into the decisions about recovery actions. There are many other modelling frameworks that we could have selected but many depend on the collection and synthesis of empirical data which would have been prohibitive for us financially and in the length of time required to develop conclusions. Also, we acknowledged from the onset that, even with the abundant studies of caribou in the area, data to characterize our recovery scenario were incomplete and likely would never be complete. In this sense, the use of BBNS allowed us to bridge these gaps in data and complete a reasonably concise account of our current understanding about caribou recovery. Through use of the BBNS, participants in the workshop sessions were better able to visualize how recovery actions could be partitioned to address specific threats to caribou and how the action could be assessed for efficacy in future monitoring programs. Not all members of the team were completely comfortable with the technical and analytical approach to resolving recovery actions. We considered this to be a healthy balance because some members, at times, became perhaps too believing in results (e.g., modelled outputs). BBNS were used to bring information to the table. It was the members who debated and then used that information to construct recovery actions. Once completed, some issues about the overall results remained unresolved and we discuss those below.

Recovery Actions

During the latter stages of deliberation among the RIG, some members grew increasingly anxious about the recovery actions and the potential indirect implications that could result from implementation. While direct implications were intended to achieve the outcome of recovery for caribou herds, the indirect implications were perceived to have potentially negative impacts on some social and economic conditions (see Factors to Consider in the Socio-economic Analysis). In addition, the following list of technical concerns was raised, many of which may not necessarily be addressed by the subsequent socio-economic review:

- Reduction of moose habitat would be counter to the fact that moose hunting contributes to a major industry throughout the plan area;
- Lack of comfort around remaining uncertainty associated with: 500 m buffers around seasonal ranges, unexplained annual variation in survival rates, potential for mortality in movement corridors, the fact that many disturbances result in incremental or cumulative impacts, magnitude and type of effects from recreational or commercial snowmobiling, and interactions with the mountain pine beetle epidemic;
- Incomplete comfort with the analytical approach we adopted (while acknowledging lack of resources to attempt alternative analyses); and
- Uncertain interaction between the recovery actions and the Mackenzie LRMP.

Declaration of Critical Habitat

According to instructions in the RENEW recovery operations manual (National Recovery Working Group 2004), recovery teams should provide government with information allowing for the declaration of critical habitat for a species at risk. Our work has led to the general agreement among the RIG members that this declaration should consider other ecological values and that this is best accomplished by, to the extent practicable, emulating patterns of natural disturbance. For that reason, our recommendation for the declaration of critical habitat is to have occurring on the landscape, the amounts and qualities of seasonal ranges that would likely exist under natural, unmanaged conditions. This condition can be estimated and evaluated using the CHASE model. In some cases (e.g., the Scott herd), we know this is unlikely to support full recovery of caribou (i.e., a self-sustaining herd) and in other cases (e.g., the Wolverine herd), we expect this will lead to further reductions in number of caribou. However, these conditions were felt to be the best compromise when all resource values were considered (i.e., cannot implement full recovery of caribou at the cost of losing moose and/or wolves as components of the natural ecosystems). We do expect this definition of critical habitat, and implementation of the recovery actions to lead to population stability (barring unpredicted catastrophic events) and hence full recovery in the Wolverine, Chase, and perhaps the Takla herds.

Implementation Schedules

It is beyond the scope of this RIG to forecast or recommend a specific schedule for implementation of our suggested recovery actions. Several steps must occur prior to considering implementation including, but not limited to, the following:

1. Acceptance of the recovery actions and the plan by government;
2. A review of social and economic implications of implementing the recovery actions as forwarded;
3. Modification of the recovery actions if required;
4. Declaration of critical habitat; and
5. Approval and legislation for the final recovery actions.

Factors to Consider in the Socio-economic Analysis

The health of the forest industry is a major factor affecting change in the local population of approximately 6000 people in Mackenzie and surrounding communities (Germansen Landing, Manson Creek, Fort Ware, and Tsay Keh). This will be a major consideration in the subsequent analysis of recovery action implications since 65% of the employment and 71% of the income is derived from the forest sector (BC Govt 2000). Timber generates approximately \$105 million annually in government revenue.

In Fort St. James and surrounding communities (Tachie, Yekooche Village, Middle River, Takla Landing, and Bear Lake), the reliance on the forest industry is much the same as in Mackenzie and area. First Nations comprise approximately one third of the 4015 people estimated to occupy the planning area of the Fort St. James LRMP where the forest sector contributes significantly to the local economy (BC Govt 1999). About 40% of the labour force is involved in some aspect of the forest industry which generated \$131.5 million in 1997.

Due largely to the reliance on the forest industry, specific economic concerns about the recovery actions were primarily but not totally related to forestry, and were noted as:

- Mountain pine beetle salvage operations may conflict with recovery action 5(a)(i);
- Use of 5000 ha minimum for the size of area-based management clusters may be unduly restrictive for industrial development;

- Managing all areas within an area-based management cluster on the same forest rotation may unduly restrict timber supply; and
- Management to the range of expected variability based on Natural Disturbance Units (Delong 2002) will likely conflict with legal objectives under FRPA which imply managing to disturbance patterns reflecting Natural Disturbance Types.

Another theme to deliberations concerning the subsequent socio-economic analysis focussed on the recent trend toward economic diversification throughout the region. In particular:

- Although some recreational snowmobiling areas have been mapped in accordance with recovery action 5 (b)(i), there are other areas within the recovery planning areas that still require detailed mapping (Figure 18) and consideration of the potential interaction with caribou recovery;
- Some RIG members felt that the recovery actions may have unnecessary impact on recreational opportunities, trapping, guiding, and outfitting operations;
- There is a specific program underway to generate economic diversification in Mackenzie;
- New and unprecedented tenure applications have come about within the plan area which the RIG has not had time to contemplate including: a heli-ski operation (Scott herd area), commercial snowmobiling (Scott herd area), and wind-power generation (Wolverine and Chase herd areas).

Another consideration in the subsequent analysis includes the social implications of recovery actions on First Nations bands that have traditional territories within the recovery planning areas (i.e., Tsay Keh Dene, Kwadacha, Takla Lake, Nak'azdli, and McLeod Lake). RIG members were also generally concerned about the cost of recovery and who would ultimately forward the resources necessary to implement recovery actions and maintain function of the RIG itself. Noted was the fact that much of the funding, hence current progress, toward recovery of caribou was generated more from grass-roots than from government, and this was an over-riding concern of most RIG members. This latter point about cost of recovery became especially transparent and tangible given the fact that two large parks occur within the recovery planning area, both of which have primary objectives related to recovery of caribou and yet both of which lack clear management plans to establish sustainable flow of habitat for caribou.

Proponent Responsibilities and Monitoring

We developed an analytical approach to evaluate range suitability for woodland caribou. Benefits of this approach included the transparent establishment of base-case scenarios for caribou range, the availability of a tool to continually monitor the effect of future resource development, and a foundation for continual improvement through future research and management. Furthermore, recovery actions were intentionally written in a “results-based” language so that proponents of natural resource development have flexibility to pursue business under the condition that potential range impacts were forecasted to be consistent with recovery of caribou. We conclude that the activities of forecasting and monitoring the supply of critical habitat for caribou are technically feasible using the CHASE methods. Logistical difficulties are expected to be primarily limited to: 1) gathering disturbance data planned by multiple licensees, including those that span a range of industrial sectors, and 2) training required to implement CHASE methods. Although neither limitation is fatal to the process of forecasting and monitoring, they have been forwarded as focal problems for the RIG to engage in the near future. Assuming that these logistical limitations can be reduced, we expect resource development proponents to document consistency with recovery of caribou through a process that includes:

- Adding new resource development plans to a cumulative base of historic and planned disturbances;
- Evaluating and assessing cumulative change to the amount and value of seasonal ranges;

- Modifying the spatial and/or temporal characteristics of development plans if inconsistent with recovery of caribou;
- Re-evaluating modified plans if required;
- Retaining analytical results as evidence of consistency with recovery of caribou;
- Conducting annual monitoring of the amount and quality of season ranges to confirm consistency with recovery of caribou once development begins.

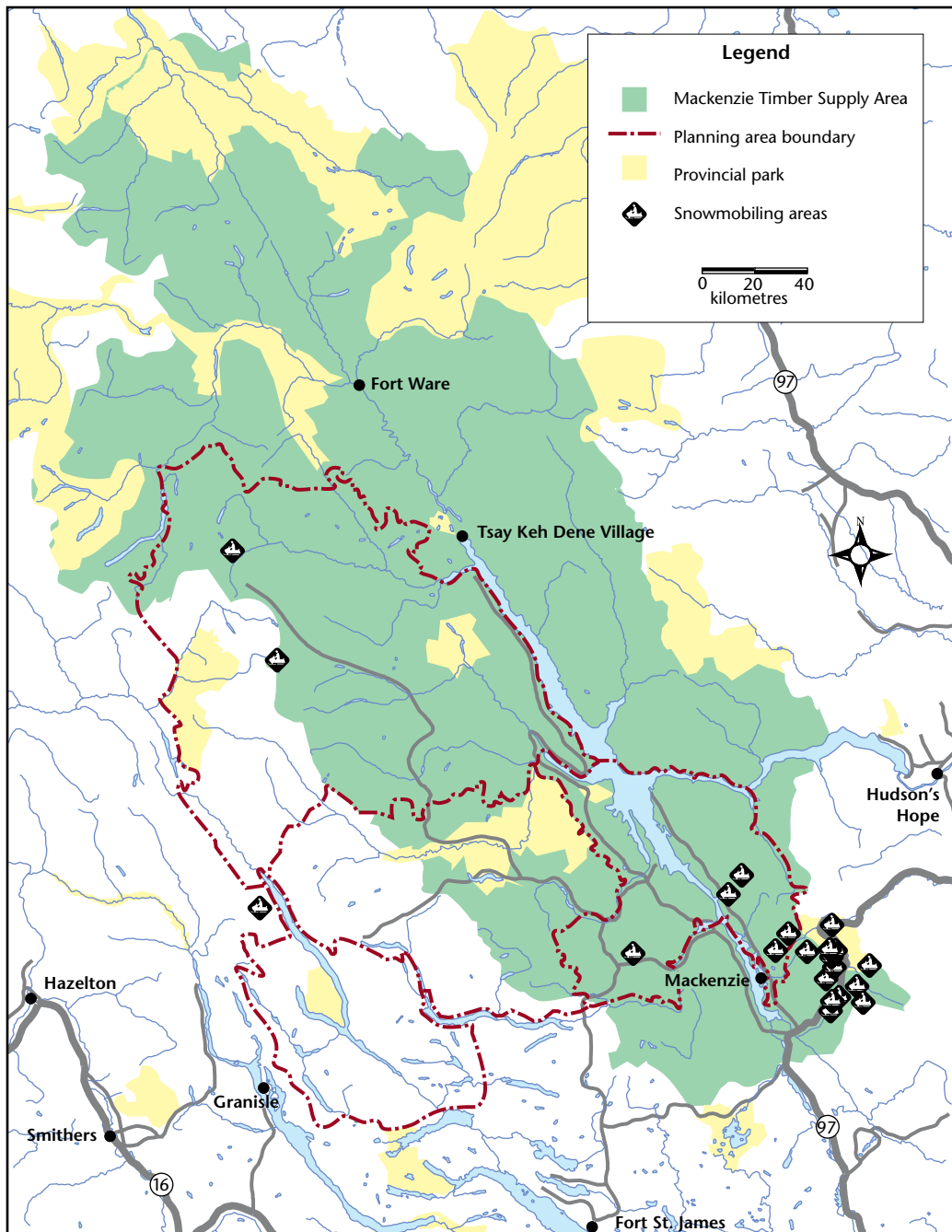


FIGURE 18 General location of recreational snowmobiling areas in and around four recovery planning areas for woodland caribou in north-central British Columbia.

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APPENDIX A TERMS OF REFERENCE: NORTHERN CARIBOU RECOVERY IMPLEMENTATION GROUP FOR NORTH-CENTRAL BC

Organizational Framework

The Northern Caribou Recovery Implementation Group for North-central British Columbia (NC RIG for NCBC) will work under the auspices of the Joint Steering Committee (JSC) for recovery of caribou within the Southern Mountains National Ecological Area (SMNEA). This JSC is composed of three subcommittees (Figure 19), which provide technical advice to government and others on recovery of woodland caribou (*Rangifer tarandus*):

- The Terrestrial Lichen–Winter Feeding Ecotype technical advisory committee in BC, currently known as the Northern Caribou Technical Advisory Committee or NCTAC;
- The Arboreal Lichen–Winter Feeding Ecotype technical advisory committee in BC, currently known as the Mountain Caribou Technical Advisory Committee or MCTAC; and
- The Terrestrial Lichen–Winter Feeding Ecotype technical advisory committee in Alberta.

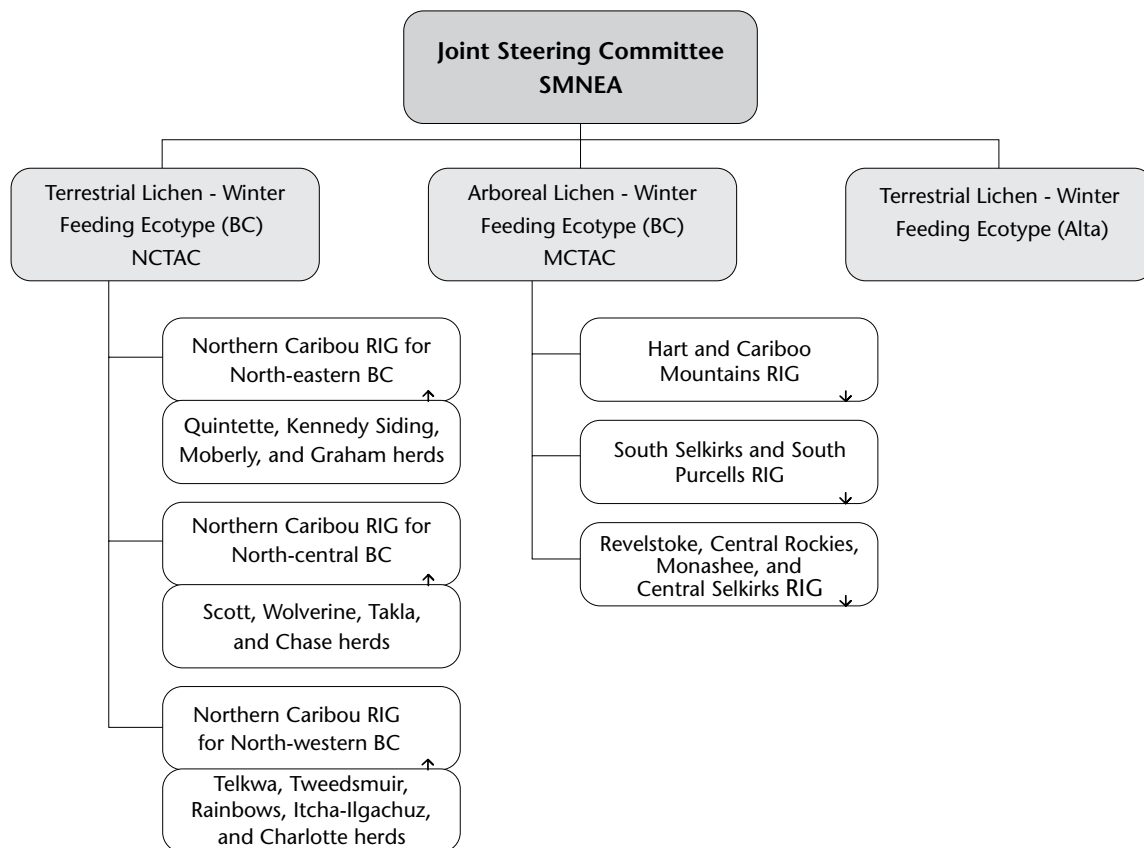


FIGURE 19 Organizational structure of teams associated with the recovery of woodland caribou in the Southern Mountain National Ecological Area (SMNEA).

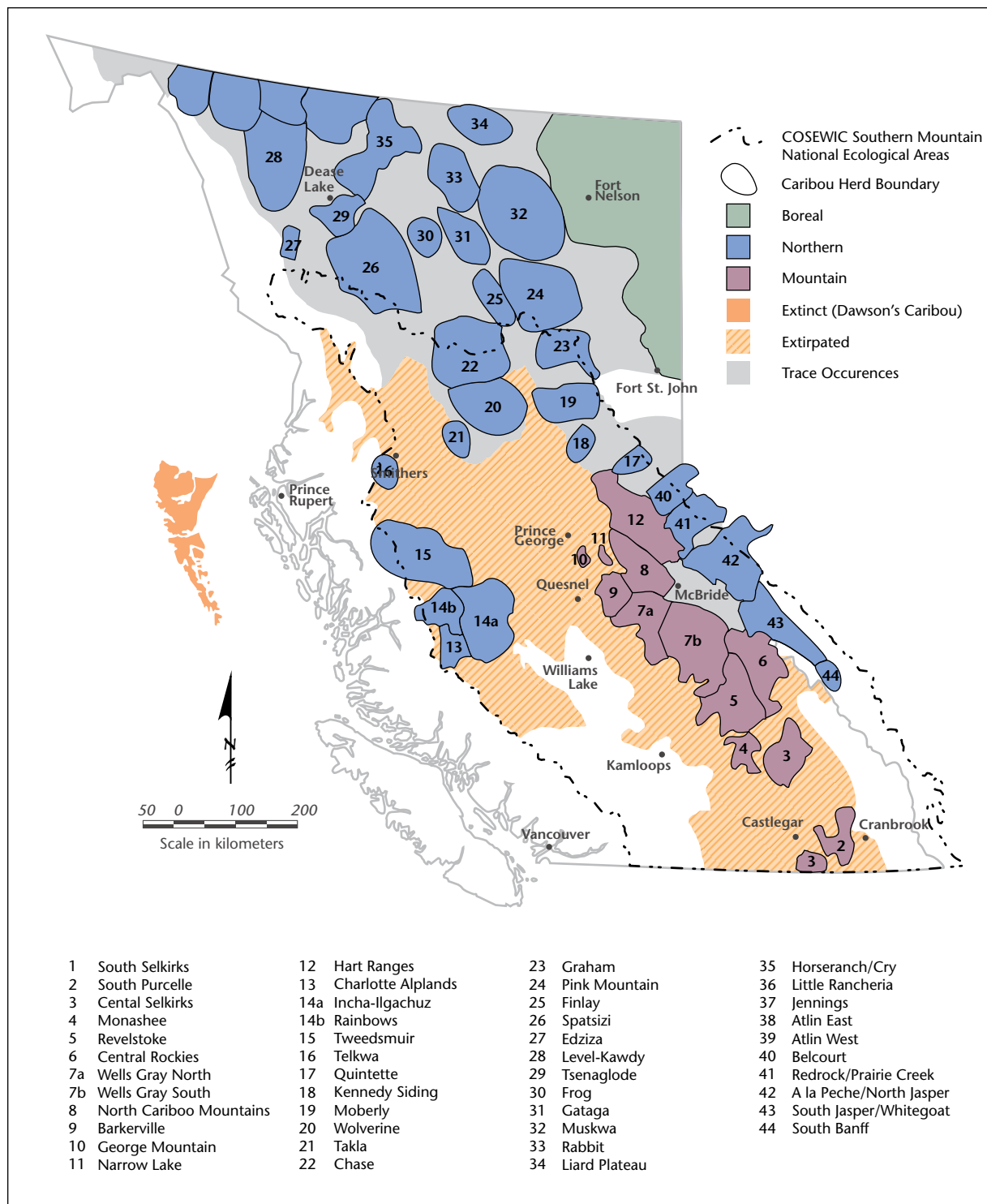


FIGURE 20 Identified herds of woodland caribou located within the province of British Columbia showing their ecotype (boreal, northern, or mountain), geographic range of historic populations (extinct, extirpated, trace), and spatial location relative to the jurisdiction where caribou are proclaimed threatened with extirpation (Southern Mountain National Ecological Area) (MCTAC 2002).

Each technical subcommittee is supported by Recovery Implementation Groups (RIGs). The NC RIG for NCBC covers the most northern local populations of the terrestrial lichen-feeding ecotype of woodland caribou within the SMNEA in central BC, including the Wolverine, Takla, and Chase populations (Figure 20). Five other RIGs work under the auspices of the JSC (Figure 19). The JSC–SMNEA co-ordinates the activities of all RIGs, provides technical advice to RIGs, and performs a number of other activities outlined in “*A Strategy for the Recovery of Northern Caribou in the Southern Mountain National Ecological Area in British Columbia*” (NCTAC, in prep).

Note: All RIGs report to and take direction from the NCTAC—including direction on such topics as how to address socio-economic impacts and guidelines for identification of critical habitat.

Role of the Northern Caribou RIG for North-central British Columbia

The overriding goal of the NC RIG for NCBC is to effect recovery of the most northern local populations of terrestrial lichen-feeding ecotype of woodland caribou within the SMNEA in central BC. For the purposes of this Terms of Reference, the relevant populations are the Wolverine, Takla, and Chase populations, including a remnant herd locally known as the Scott herd; all populations are henceforth referred to as the herds. The NC RIG for NCBC will provide to NCTAC, the best available scientific advice on the measures required to recover the herds where this advice will be in the form of one or more action plans. The NC RIG for NCBC will operate: in accordance with the most recent draft of the RENEW Recovery Operations Manual, under direction from the NCTAC, and under this terms of reference.

Responsibilities of the Northern Caribou RIG for North-central British Columbia

- To produce Recovery Action Plans for an area that encompasses the herds. These Recovery Action Plans will be consistent with the objectives approaches and priorities outlined in *A Strategy for the Recovery of Northern Caribou in the Southern Mountain National Ecological Area in British Columbia* and will follow the template suggested in the *Recovery Operations Manual*.
- To provide advice regarding socio-economic considerations affecting recovery and on evolving issues related to recovery or conservation of the herds.
- To recommend, co-ordinate, and/or facilitate the implementation of the Recovery Action Plans, ensuring that affected parties are consulted with and involved as appropriate.
- To build public support for, and understanding about, recovery of woodland caribou by extending the activities of the RIG to general public and stakeholders.
- To document activities and report regularly to the NCTAC.
- To integrate activities with those of other RIGs under the JCS and with RIGs on other teams operating in the same ecosystem or geographic area.

RIG Composition

- Members will normally be from government agencies, resource industries, the public, and First Nations.
- Members will have a minimum two-year term reviewed annually.
- Members should be knowledgeable about northern caribou technical information and/or land-use planning and management in the relevant area of British Columbia (i.e., RIG members must provide biological or management expertise relevant to caribou recovery, and/or must have a role to play in the implementation of the Recovery Action Plans).
- Maximum number: 20
- Members must be willing to participate in a team environment.

- Members must be able to commit to at least a minimum amount of time required for effective RIG function and be available, or have an alternate available, for each RIG meeting.
- The RIG will provide regional representation across the geographical area.
- The RIG will allow for attendance at meetings by, or for participation by, expertise external to the regular RIG membership as required.

RIG Chair

- The RIG Chair is a member of NCTAC.
- The RIG should choose the RIG Chair and may elect a co-chair.
- The RIG Chair has the following responsibilities:
 - Attend recovery team meetings (i.e., NCTAC) on a regular basis;
 - Ensure information flow between the recovery team and the RIG;
 - Co-ordinate work of the RIG;
 - Prepare agendas, chair meetings, ensure minutes are produced;
 - Ensure maintenance of recovery team files and provide copies to NCTAC as appropriate;
 - Provide information to NCTAC at least on an annual basis, or more often if required by funding or other agreements or government (i.e., RENEW), on the following:
 - Funding contributions (monetary, in-kind, person-years, volunteer);
 - Public contact and consultation activities;
 - Progress of action program;
 - Financial expenditures; and
 - Other as appropriate or defined by the recovery team.

RIG Operating Principles

- RIG members must be committed to the recovery and conservation of northern caribou in a timely manner.
- Non-RIG members can attend RIG meetings and will be provided with discussion opportunities during a regulated, and pre-determined time period at each meeting.
- Members' responsibilities:
 - Members, or their alternates, will endeavour to participate in all meetings;
 - Members are expected to contribute their knowledge and expertise to the work of the recovery team, and to carefully review and provide comments on draft documents; and
 - Members, other than the chair, will not represent the opinion of the RIG (including press, etc.)
- The Northern Caribou RIG for North-central British Columbia will work under the auspices of NCTAC. NCTAC will provide guidance to the RIG. All activities, communications, and documents are to be consistent with NCTAC decisions and policy. The Recovery Action Plan will be submitted to, and reviewed by, NCTAC.
- Consensus: Decisions will be made by consensus if possible.
 - Consensus means everyone feels that the decision is technically sound and supported by the best available information, with the view to reaching the overall vision of recovering caribou;
 - Consensus decisions will be reached by the group, with individual concerns and dissenting opinions with rationales clearly acknowledged and recorded in the plan and the minutes, as appropriate; and
 - If consensus cannot be achieved, there will a mechanism for recording the dissenting opinion(s) with rationales within the Recovery Action Plan.

- Decision-making will be transparent:
 - Agendas, minutes, reports and other documents will be made available to NCTAC and/or the public as appropriate; and
 - Regular reporting to NCTAC meetings as required.
- Members of the RIG will:
 - Be sensitive to, and address, potential conflicts of interest;
 - Track funding contributions (monetary, in-kind, person-years, volunteer);
 - Incorporate and track public consultation activities;
 - Seek outside peer review and evaluation;
 - Track progress of action plan (as per performance evaluation measures); and
 - Work with partners to raise and administer funds for RIG activities, in collaboration with other RIGs, the NCTAC, the JSC, and others.

Recovery Action Plans

- First complete version of the Recovery Action Plan(s) vetted by NCTAC and completed by December 31, 2004 (covers five-year period from January 01, 2005).
- The Recovery Action Plan will be revisited on a minimum five-year time frame, or as necessary.
- The Recovery Action Plan will generally be consistent with the existing recovery strategy, although alterations are possible through discussion with the NCTAC.
- The Recovery Action Plan should follow the template suggested in latest RENEW manual on Recovery Operations Planning.
- Establish performance evaluation measures which are linked to goals of the Recovery Action Plan.
- Include detailed descriptions of actions, priorities, timelines, and cost estimates.
- Include the following information:
 - Current status, by herd, and rationale; list threats;
 - Goals for recovery;
 - Identification of the species' critical habitat;
 - Identification of threats to the species or critical habitat;
 - Identification of knowledge gaps;
 - Measures proposed to protect the species' critical habitat;
 - Identification of any portions of the critical habitat that have not been protected; and
 - Statement of measures to be taken to implement the recovery strategy and when they are to take place.
- Identify social, economic, and ecological consequences (including costs where possible) of implementing the action plan and the benefits to be derived from its implementation.

APPENDIX B RECOVERY IMPLEMENTATION GROUP MEMBERSHIP LIST

Contact	Organization	Phone Number	Email
Recovery Implementation Group (Chairperson):			
Doug Heard	Ministry of Environment	(250) 614-9903	doug.heard@gov.bc.ca
Scott McNay	Wildlife Infometrics, Inc.	(250) 997-5700	scott.mcnay@wildlifeinfometric.com
Recovery Implementation Group (Stakeholders):			
Warren Waycheshen	District of Mackenzie	(250) 997-3221	warren@district.mackenzie.bc.ca
Lars Hulstein	Canadian Forest Products, Ltd.	(250) 997-2629	lars.hulstein@canfor.com
	Alternate: Doug Ambedian	(250) 997-2574	doug.ambedian@canfor.com
Shaun Kuzio	Abitibi Consolidated Co. of Canada	(250) 997-2738	shaun_kuzio@abitibiconsolidated.com
	Alternate: Mark Pride	(250) 997-2772	mark.pride@abitibiconsolidated.com
John Deal	Council of Forest Industries	(250) 962-3313	john.deal@canfor.com
Len Stratton	BCTS – PG Business Area	(250) 614-7515	len.stratton@gov.bc.ca
Karl Sturmanis	Tsay Keh Dene	(250) 562-8882	ksturmanis@tkdb.ca
	Alternate: Robert Tomah	(250) 562-8882	rtomah@tkdb.ca
Chief Jeanette West.	Takla First Nation	(250) 564-3704	Mail
James H. Breshere.	Alexander family	(250) 564-3704	Mail
Dave Crampton	Kwadacha Band		crampton@arborecos.com
Ryan Bichon	McLeod Lake Indian Band	(250) 750-4415	bichons@mackbc.com
Chris Johnson	University of Northern BC	(250) 960-5357	johnsoch@unbc.ca
Barry Booth	The Land Conservancy of BC	(250) 564-2064	bbooth@conservancy.bc.ca
Wayne Sawchuk	Canadian Parks & Wilderness Soc.	(250) 788-7871	wsawchuk@pris.bc.ca
Mari Wood	Peace/Williston Fish and Wildlife	(250) 565-4191	mari.wood@gov.bc.ca
	Alternate: Fraser Corbold	(250) 565-6856	fraser.corbold@gov.bc.ca
Dave King	Mountaineers Club	(250) 564-8887	kingjudi@bcgroup.net
Bill Arthur	Ministry of Environment	(250) 614-9902	bill.arthur@gov.bc.ca
Gail Ross	Ministry of Environment	(250) 614-9919	gail.ross@gov.bc.ca
Beryl Nesbit	Ministry of Agriculture and Lands	(250) 565-6422	beryl.nesbit@gov.bc.ca
Russ MacDonald	Ministry of Forests and Range	(250) 996-5285	russ.macdonald@g.gov.bc.ca
Dale Seip	Ministry of Forests and Range	(250) 565-4125	dale.seip@gov.bc.ca
Les Auston	BC Snowmobile Federation	(250) 845-2744	lauston@telus.net
	Alternate: Lawrence Napier, Rocky Mountain Riders		napierlr@hotmail.com
Bernard McKay	Guide Outfitters Association of BC	(250) 967-4269	Mail and cc to drown@goabc.org
	Alternate: Chris Addison	(250) 675-5296	addison@goabc.org
John Botham	BC Trappers Association	(250) 964-4775	T9644775@telus.net
Recovery Implementation Group (Technical Working Group):			
Viktor Brumovsky	Wildlife Infometrics Inc.	(250) 997-5700	victor.brumovsky@wildlifeinfometrics.com
Glen Watts	Ministry of Environment	(250) 614-9913	glen.watts@gov.bc.ca
Bill Arthur	Ministry of Environment	(250) 614-9902	bill.arthur@gov.bc.ca
Sandra Sulyma	Ministry of Environment	(250) 996-5259	sandra.sulyma@gov.bc.ca
Randy Sulyma	Ministry of Environment	(250) 567-3995	randy.sulyma@gov.bc.ca
Andrew Fall	Gowlland Technologies, Ltd.	(250) 391-4801	fall@cs.sfu.ca
Dan O'Brien	Cortex Consultants, Inc.	(604) 738-3736	dobrien@cortex.ca
Recovery Implementation Group (Facilitation):			
Rick Ellis	R. Ellis and Associates	(250) 544-2230	ellis@islandnet.com
Kathi Zimmerman	Resources North	(250) 612-4129	kathi@resourcesnorth.org
Woodland Caribou Recovery Team:			
Ian Hatter	Ministry of Environment	(250) 387-9792	ian.hatter@gov.bc.ca

TABLE 6 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of post-rut range for northern caribou in north-central British Columbia

Range	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Post-rut range	Lichen abundance						
	Site productivity	1	aspect	TRIM/DEM	good/poor	good	Dry nutrient-poor mature pine stand. Slope < 5%, or slope > 5% and aspect between 45° and 315°. SMR ^c = 0–2, SNR ^d = A–B.
		1	% Pl	.fc1/fip	< 70/70–90/≥ 90 %	≥90 %	
		1	ecological unit ^b	PEM/TEM	dry poor/other/not classified	dry poor	
		1	SI50 ^b	.fc1/.fip	< 14.5/≥ 14.5 m	≤14.5 m	
		1	stand age (years)	.fc1/fip	< 40/40–70/70–140/≥ 140	70–140	
	Site disturbance ^e	1	stand removal	(.fc1/fip)	whole tree/cut to length	wildfire	Open mature stand initiated by wildfire.
		1	site prep	.fc1/fip	none/burn/scarify/pile burn	burn	
		1	removal season		summer/winter	summer	
		1	stand age (years)	.fc1/fip	< 40/40–70/70–140/≥ 140 yrs	70–140	
		1	stocking level ^f	.fc1/fip	high/low	low	
	Forage Usability						
	Snow conditions	1	elevation (m)	TRIM/DEM	< 1000/1000–1300/≥ 1300 m	1000–1300 m	Mid-elevation site slow to accumulate snow in the fall and early winter.
		1	biogeo. zone	Prov BEC	dry/moist/wet subzones	dry or moist	
		2	solar loading (Wh/m ²)	TRIM/DEM	< 40000/≥ 40000 Wh/m ²	≥ 40000 Wh/m ²	
		1	seasonal range type		fall/winter	fall	
	Predation	2	<i>f</i> (proximity/distance/ecological variables)		0/50/90	0	Zones of relatively low risk of predation based on the relationship between moose and wolves, the amount of moose habitat, and the likelihood of interaction between wolves and caribou. 0 is low risk.

^a Input type is either from GIS based digital geographic data (1) or from an analytical algorithm (2);

^b The model only uses one of Ecological Unit or SI50. If ecological mapping data (PEM/TEM) is available then SI50 is not used;

^c SMR is soil moisture regime on an edatopic grid;

^d SNR is soil nutrient regime on an edatopic grid;

^e Input fields exist in fip information from Forest Cover mapping for the associated variables; however, in some instances tables are not populated;

^f Lower stocking is assumed to be the most favourable condition. Research/documentation on stocking relationship is required. Node has little effect on the model outcome.

TABLE 7 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of pine-lichen winter range for northern caribou in north-central British Columbia

Range	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Post-rut range	Lichen abundance						
	Site productivity	1	aspect	TRIM/DEM	good/poor	good	Dry nutrient-poor mature pine stand
		1	% Pl	.fc1/fip	< 70/70–90/≥ 90%	≥ 90	Slope < 5%, dry poor/other/
		1	ecological unit ^b	PEM/TEM	not classified	dry poor	or slope > 5% and aspect
		1	SI50 ^b	.fc1/fip	< 14.5/≥ 14.5 m	≤ 14.5 m	between 45° and 315°.
		1	stand age (years)	.fc1/fip	< 40/40–70/70–140/>140	70–140	SMR ^c = 0–2, SNR ^d = A–B.
	Site disturbance ^e	1	stand removal	(.fc1/fip)	whole tree/cut to length /pile burn	wildfire	Open mature stand initiated by wildfire.
		1	site prep	.fc1/fip	none/burn/scarify	burn	
		1	removal season		summer/winter	summer	
		1	stand age (years)	.fc1/fip	< 40/40–70/70–140/>140	70–140	
		1	stocking level ^f	.fc1/fip	high/low	low	
	Forage usability						
	Snow conditions	1	elevation (m)	TRIM/DEM	< 1000/1000–1300/≥ 1300 m	< 1000 m	Low elevation in a low snow accumulation area.
		1	biogeo. zone	Prov BEC	dry/moist/wet subzones	dry	
		1	seasonal range type		fall/winter	winter	
	Predation	2	<i>f</i> (proximity/distance/ecological variables)		0/50/90	0	Zones of relatively low risk of predation based on the relationship between moose and wolves, the amount of moose habitat, and the likelihood of interaction between wolves and caribou. 0 is low risk.

^a Ibid

^b Ibid

^c Ibid

^d Ibid

^e Ibid

^f Ibid

TABLE 8 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of high elevation winter range for northern caribou in north-central British Columbia

Range	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
High Elevation Winter Range							
	Terrestrial Lichen Abundance						
	Site potential to provide terrestrial lichens	2 1	topographic curvature ^b ecological unit	TRIM/DEM PEM/TEM	flat or convex/concave terrestrial lichens association/arboreal lichen association/other	flat or convex terrestrial lichen association	Windswept flat or convex site in the alpine
	Arboreal Lichen Abundance						
	Site potential	1	ecological unit	PEM/TEM	terrestrial lichen association/arboreal lichen association /other	arboreal lichen association 225°–360°	Forested site, with appropriate ventilation to promote <i>Bryoria</i> spp.
	Stand potential	1 1 1 1	aspect % sub-alpine fir stand age (years) tree size (height)	TRIM/DEM .fc1/fip .fc1/fip .fc1/fip	225°–360°/0°–224° < 40/40–80/≥ 80% < 120/≥ 120 years < 15/≥ 15 m	≥ 80% ≥ 120 years ≥ 15 m	Mature to old sub-alpine fir stands with trees > 15 m tall.
	Forage Usability						
	Site Suitability	1 1	slope (%) elevation	TRIM/DEM TRIM/DEM	< 40/≥ 40 % < 1300/1300–1550/≥ 1550 m	< 40% ≥ 1550 m	Terrestrial lichen: moderate to flat slopes above 1500 m Arboreal lichen: moderate to flat slopes between 1300–1500 m elevation.
	Predation	2	f (proximity/distance/ecological variables)		0/50/90	0	Zones of relatively low risk of predation based on the relationship between moose and wolves, the amount of moose habitat, and the likelihood of interaction between wolves and caribou. 0 is low risk.

^a Ibid

^b Curvature is calculated “by fitting a four-order polynomial through grid cell and its 8 neighbours”

TABLE 9 *Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of movement corridors for northern caribou in north-central British Columbia*

Range	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Movement corridors	Corridor path	n/a	manually identified	professional opinion	usable	useable	Corridors are manually identified.
	Predation	2	f (proximity/distance/ecological variables)		0/50/90	0	Zones of relatively low risk of predation based on the relationship between moose and wolves, the amount of moose habitat, and the likelihood of interaction between wolves and caribou. 0 is low risk.

^a Ibid

TABLE 10 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of calving and summer range for northern caribou in north-central British Columbia

Range	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Calving and summer range	Calving site suitability						
	Calving cover	1	ecological unit	PEM/TEM	Veg AT/ Veg ESSF/Other	Veg AT	Flat to moderate-sloped vegetated sited in the alpine (i.e. not rock . . .) or in the ESSF flat to moderately sloped sites with a sub-alpine fir overstorey characterized by cooler moister ecosystems.
		1	inventory type	.fc1/.fip group	Ba or Nonfor/Other		
		1	slope (%)	TRIM/DEM	< 40/≥ 40 %	< 40%	
	Summer range suitability						
	Summer cover	1	ecological unit	PEM/TEM	Veg AT/ Veg ESSF/Other	Veg AT	Flat to moderate-sloped sites with a sub-alpine fir overstorey characterized by cooler moister ecosystems.
		1	inventory type	.fc1/.fip group	Ba or Nonfor/Other		
		1	slope (%)	TRIM/DEM	< 40/≥ 40 %	< 40%	
	Site risk						
	Predation	2	f (proximity/ distance/ relationship ecological variables)		0/50/90	0	Zones of relatively low risk of predation based on the relationship between moose and wolves, the amount of moose habitat, and the likelihood of interaction between wolves and caribou. 0 is low risk.

^a Ibid

TABLE 11 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of moose abundance during summer in north-central British Columbia

Sub-model	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Summer moose abundance	Favourable moose habitat						
	Usable forage	1	stand age (years)	.fc1/.fip	< 40/≥ 40 years	< 40 years	Mid- and high-elevation shrub-dominated ecosystems < 40 years old
		1	ecological unit	PEM/TEM	shrubs dominated/ productive forest/ unproductive low shrub	shrubs dominated	
		1	elevation	TRIM/DEM	< 1200/≥ 1200	≥ 1200	
	Hunting mortality						
	Hunting related mortality		regulated hunting	level defined by WLAP	pop at 20% κ/ pop at 60% κ/	pop at 90% κ	Hunting levels set/defined by WLAP ^b and First Nations communities.
			subsistence hunting level		pop at 20% κ/ pop at 60% κ/ pop at 90% κ	pop at 90% κ	

^a Ibid

^b BC Ministry of Water Land and Air Protection

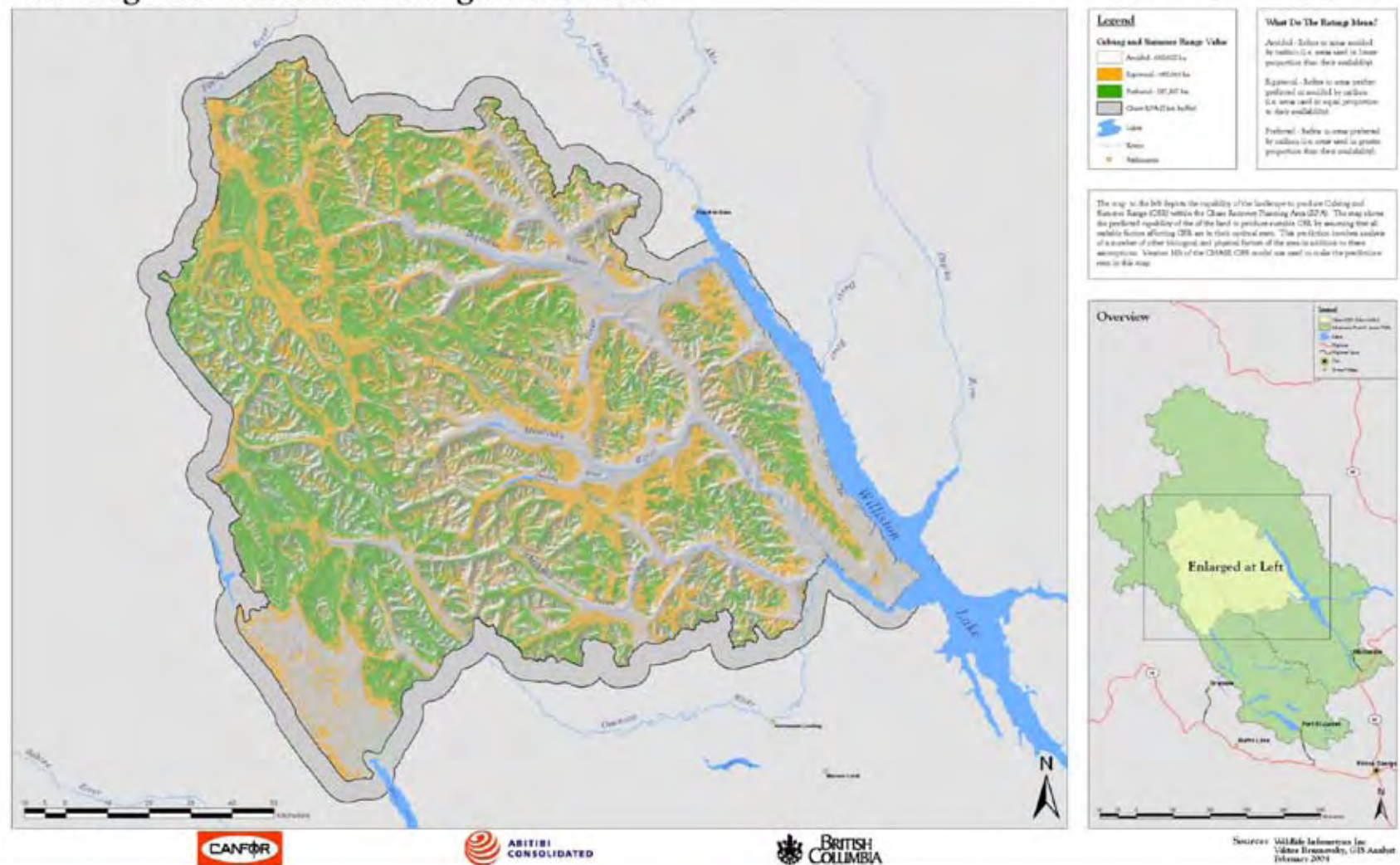
TABLE 12 Summary of data information requirements (inputs and sources) and best combination of state values to represent key ecological correlates of moose abundance during summer in north-central British Columbia

Sub-model	Ecological correlate(s)	Input type ^a	Input	Source	States	Best combination of state values	Best conditions
Winter moose abundance	Favourable moose habitat						
	Usable forage	1	stand age (years)	.fc1/.fip	< 40/≥ 40 years shrub dominated/ productive forest/ unproductive low shrub	< 40 years shrub dominated	Low-elevation shrub-dominated ecosystems < 40 years old
		1	ecological unit	PEM/TEM			
		1	elevation	TRIM/DEM	< 1200/≥ 1200	< 1200	
Hunting mortality							
	Hunting related mortality		regulated hunting	level defined by WLAP	pop at 20% κ/ pop at 60% κ/	pop at 90% κ	Hunting levels set/defined by WLAP ^b and First Nations communities.
			subsistence hunting level		pop at 20% κ/ pop at 60% κ/ pop at 90% κ	pop at 90% κ	

^a Ibid

^b BC Ministry of Water Land and Air Protection

Chase Recovery Planning Area



A detailed topographic map of the Williston Lake area in the Canadian Rockies. The map shows the lake's shoreline, surrounding mountain ranges, and various rivers and creeks. Key features include the Williston River, the Williston Lake, and the surrounding mountain peaks. The map is oriented with North at the top, indicated by a north arrow in the bottom right corner. A scale bar in the bottom left corner shows distances in kilometers (0 to 10 km) and miles (0 to 10 miles).

Legend

High Elevation Water Range Value

- Awariti (1,151-2,000 ft)
- Regional (1,011-2,000 ft)
- Fullwater (2,000 ft)
- Class 55A/2100 (no value)
- Lake
- Stream
- Settlement

The map to the left depicts the capability of the landscape to produce High-Absorption Waters (HAWs) within the Chase Research Watershed (CRW). The map shows the predicted capability of the land to produce suitable HAWs by assessing that all suitable bottom-land wetlands (HAWs) are in riparian zones. This information is useful to a number of other biological and physical factors of the river in addition to those mentioned. Version 12.0 of the CHAW-HAW model was used to make the predictions seen in the map.

[illegible]

SOURCE: MHAfile Information Inc.
Nikolai Romanovsky, GSN Analyst
February 2004

Pine-Lichen Winter Range Potential

Chase Recovery Planning Area



Legend

Pine-Lichen Winter Range Value

- Avoided: 1,275,000 ha
- Revised: 1,000 ha
- Revised: 1,000 ha
- Revised: 1,000 ha
- Revised: 1,000 ha

Water

- River
- Lake
- Wetland

What Do The Ratings Mean?

Avoided: Sites to avoid as much as possible (i.e. areas used in equal proportion to their availability).

Revised: Sites to avoid as much as possible (i.e. areas used in equal proportion to their availability).

Revised: Sites to avoid as much as possible (i.e. areas used in equal proportion to their availability).

Revised: Sites to avoid as much as possible (i.e. areas used in equal proportion to their availability).

Revised: Sites to avoid as much as possible (i.e. areas used in equal proportion to their availability).

This map to the left depicts the capability of the landscape to produce Pine-Lichen Winter Range (PLWR) within the Chase Recovery Planning Area (CRPA). The map shows the potential capability of the land to produce winter PLWR by ensuring that all variable factors affecting PLWR are in their optimal state. This potential is based on the analysis of a number of other biological and physical factors of the area in addition to those mentioned. Version 1.0 of the CHASE PLWR/PLR model was used to make the predictions seen in this map.

Overview



Source: Wildlife Information for
Winter Recovery, GIS Analysis
February 2009



Potential Summer Predation Risk

Chase Recovery Planning Area



Legend

Summer Predation Risk Value

- High - 50-100%
- Moderate - 10-50%
- Low - 0-10%
- Chase SNAI land buffer
- Lake
- Road
- Setback

What Do The Ratings Mean?

Low - Areas where conditions are likely to experience low vulnerability due to wolf predation.

Moderate - Areas where conditions are likely to experience moderate vulnerability due to wolf predation.

High - Areas where conditions are likely to experience high vulnerability due to wolf predation.

The map to the left depicts the potential wolf predation risk to Northern Goshawks in the Chase Recovery Planning Area (CRPA) during summer. The map shows the predicted risk by assessing that all suitable factors affecting observed density (and hence wolf predation) are in their optimal state. The prediction involves the analysis of a number of other biological and physical features of the same condition as those mentioned. Various data of the CHAMP Success Measure Density model was used to make the prediction over the risk map.

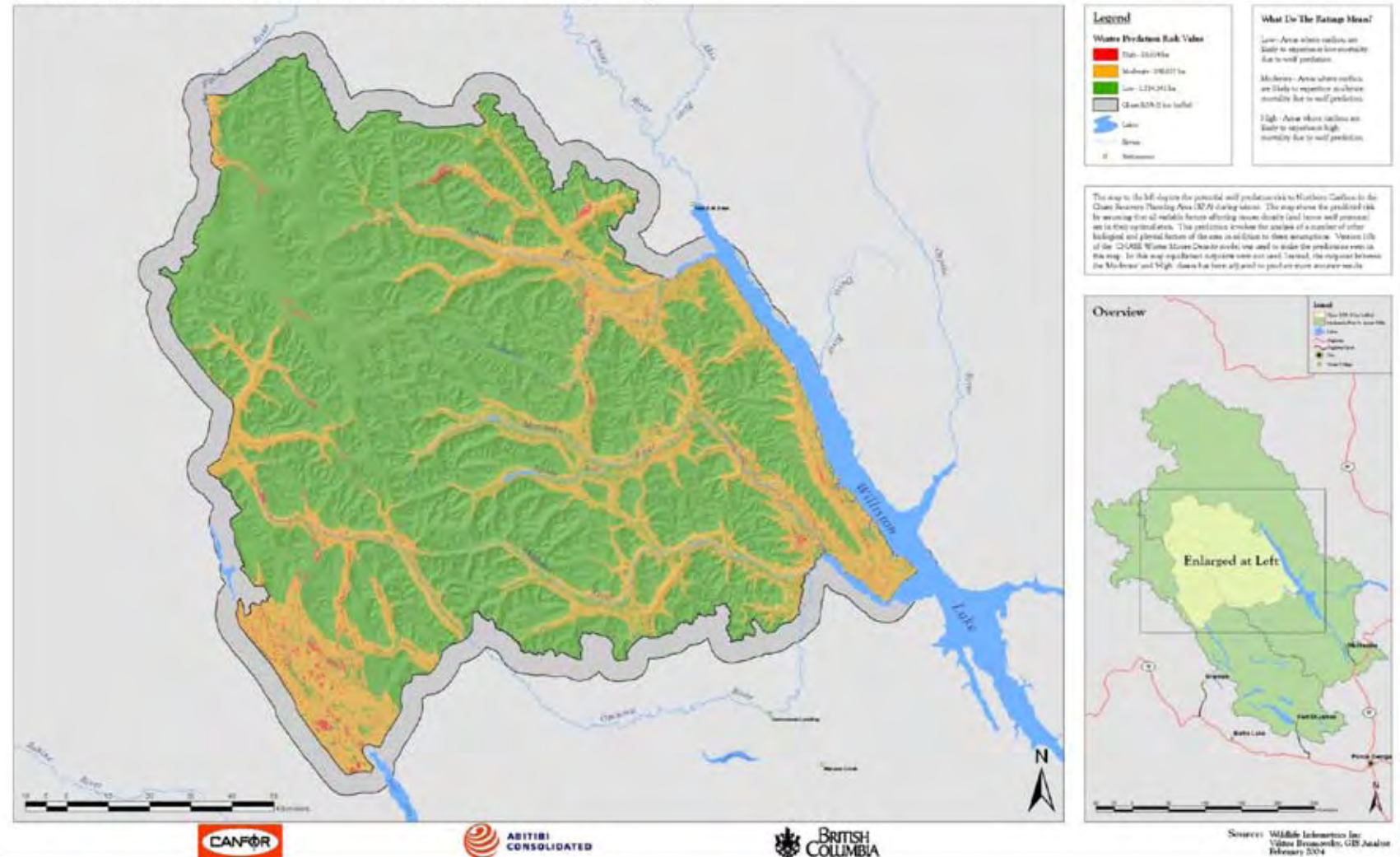


Source: Wildlife Information Inc.
Viktor Brumowski, GIS Analyst
February 2004



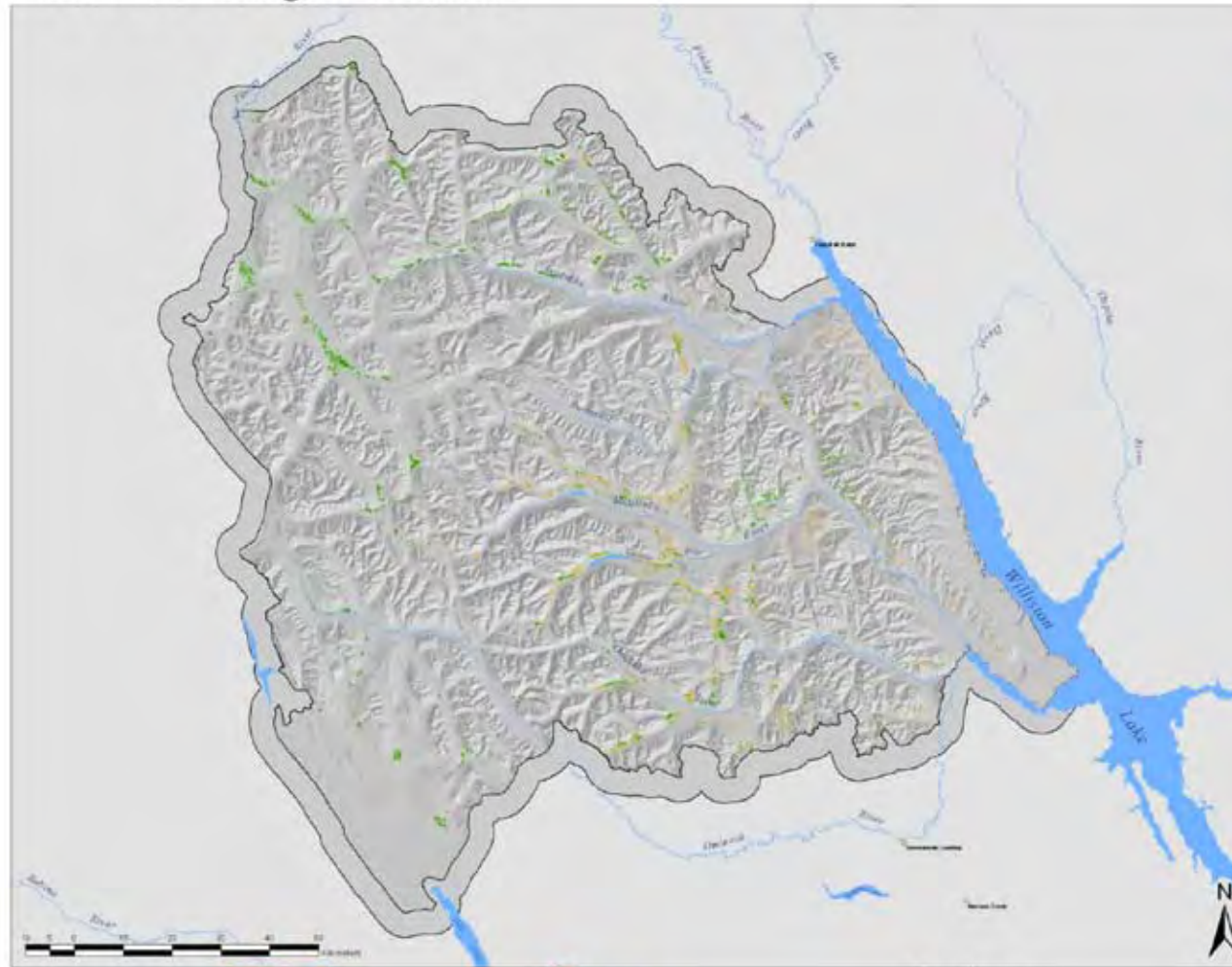
Potential Winter Predation Risk (v.2)

Chase Recovery Planning Area

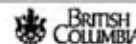


Post-Rut Range Potential

Chase Recovery Planning Area

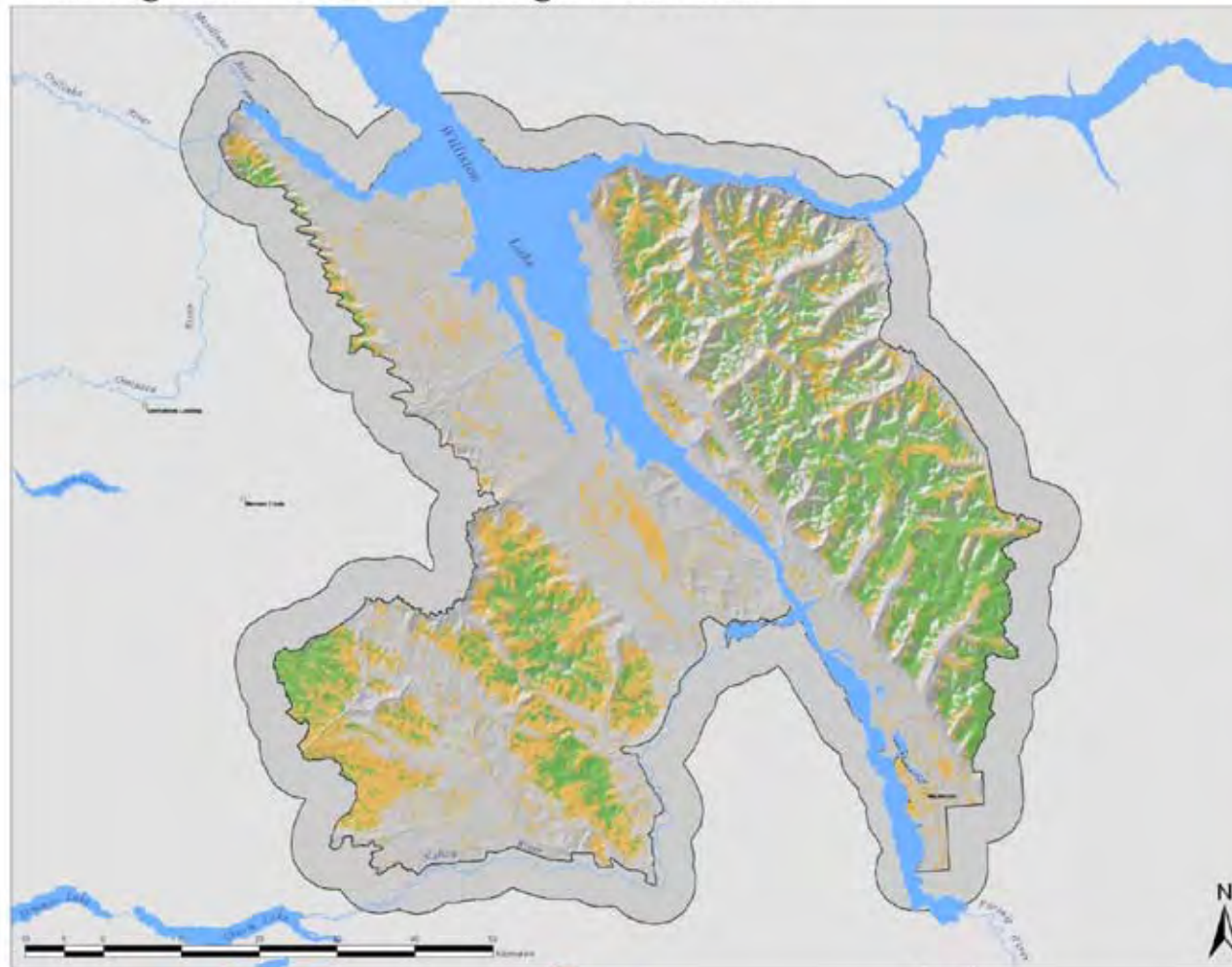


Sources: Wildlife Information for Value Assessment, GIS Analyst February 2004



Calving and Summer Range Potential

Scott Recovery Planning Area



Legend

Calving and Summer Range Value



What Do The Ratings Mean?

Assessed: Areas to areas assessed by the assessment team and to some proportion than their availability.

Excluded: Areas to areas excluded by the assessment team and to some proportion than their availability.

Excluded: Areas to areas excluded by the assessment team and to some proportion than their availability.

This map to the left depicts the mapping of the landscape to produce Calving and Summer Range (CSR) within the Scott Recovery Planning Area (SRPA). The map shows the potential capability of the land to produce suitable CSR, by assessing that all suitable factors affecting CSR are in their optimal state. This prediction involves analysis of a number of other biological and physical factors of the area in addition to those mentioned. Version 3.0 of the CSAP CSR model was used to make the predictions shown in this map.

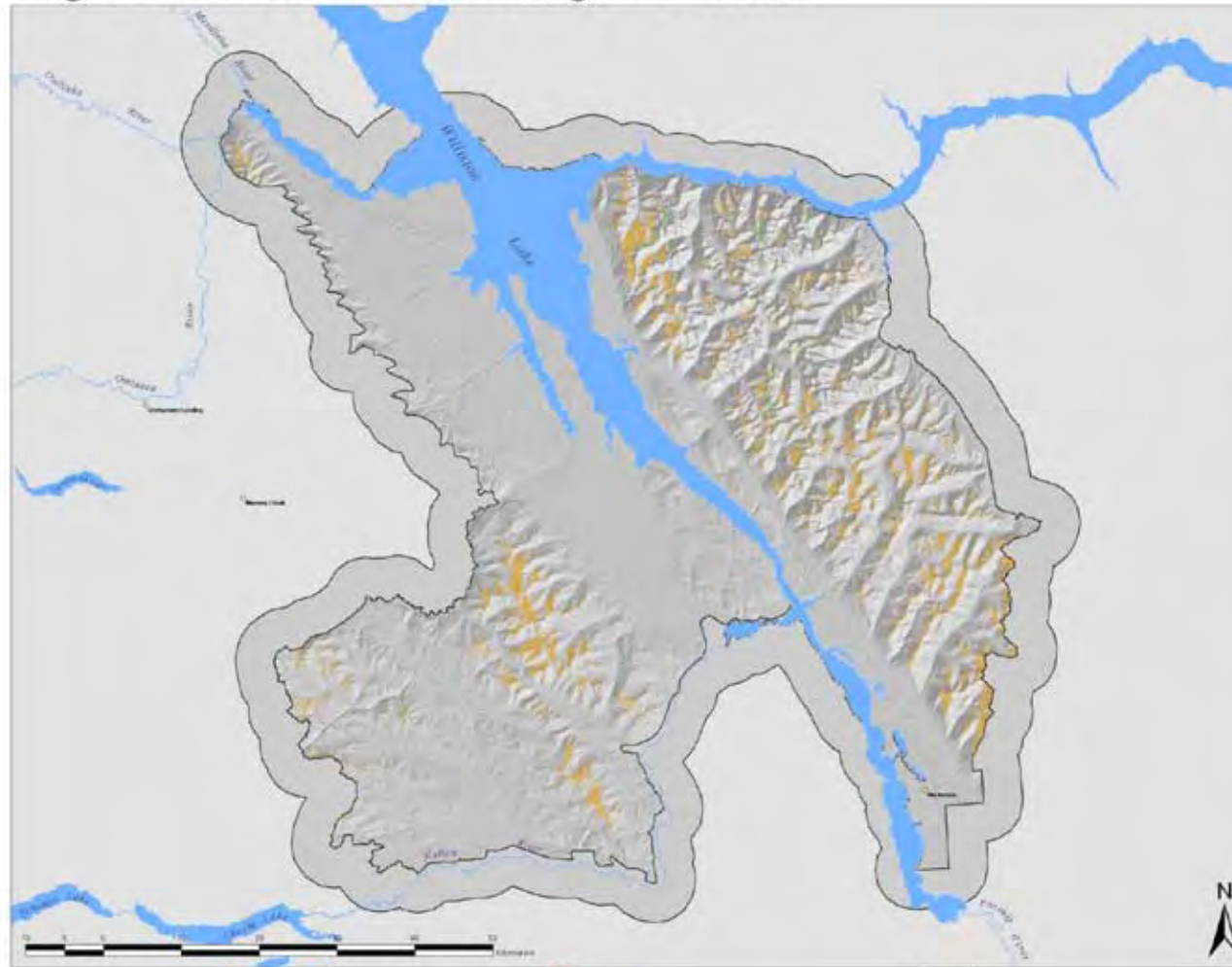
Overview



Sources: Wildlife Information for
Vancouver, GIS Analyst
February 2004

High Elevation Winter Range Potential

Scott Recovery Planning Area



Learned

High Elevation Winter Range Value

Aerial: 547,200 ha
 Equated: 26,440 ha
 Pastoral: 462 ha
 Near 3,500 ha (in buffer)

- ☐ **Salut**
- ☐ **Spune**
- ☐ **Profesional**

What Do The Ratings Mean?

Arctostaphylos - leaves to arms divided by cylindrical areas used to move propionate from their mouths

Explosion - before in some studies preferred or avoided by authors
i.e. some used in great proportion to their availability.

Fractured - Nylon is more preferred by surfboarders when used in greater proportion than that available).

The map to the left depicts the magnitude of the incentives to graduate high-earners (Wage Ratio (WR) 2002), within the Scott Research Funding Area (SRFA). The map shows the predicted equality of the land to produce relative H&E by assessing their available farms offering H&E are in a non-optimal state. This prediction involves analysis of a number of biophysical and physical factors of the area in addition to the incentives. Modeling the use of the CAPRI H&E tool can assist in making the predictions seen in this type.

Overview



Sources: Willife Industries Inc.
Vilma Brumovsky, GDS Analyst
February 2004

Pine-Lichen Winter Range Potential

Scott Recovery Planning Area



Legend

Pine-Lichen Winter Range Value

- Yellow: Potential - 10,000 ha
- Green: Potential - 10,000 ha
- Orange: Potential - 10,000 ha
- Blue: Lake
- Grey: River
- Black: Settlement

What Do The Ratings Mean?

- Assessed:** Areas to areas assessed by the SRPA, areas used to assess potential for their suitability.
- Explained:** Areas to areas assessed by the SRPA, areas used to assess potential for their suitability.
- Unassessed:** Areas to areas assessed by the SRPA, areas used to assess potential for their suitability.

The map to the left shows the potential of the landscape to produce Pine-Lichen Winter Range (PLWR) within the Scott Recovery Planning Area (SRPA). The map shows the potential capability of the land to produce winter PLWR by using the 10 variable factors affecting PLWR are in their optimal state. The prediction includes the analysis of a number of other biological and physical factors of the area to achieve optimum results. Most of the CHAB PLWR/PLR model was used to make the predictions seen in this map.

Overview



Sources: Wildlife Information for
Vancouver, GIS Analyst
February 2004



Potential Summer Predation Risk

Scott Recovery Planning Area



Legend

Summer Predation Risk Value

- High - 0.001 to 0.01
- Moderate - 0.01 to 0.1
- Low - 0.1 to 1.0
- Not Suitable for buffer
- Lake
- Road
- Settlement

What Do The Ratings Mean?

- Low - Areas where wolves are likely to experience low mortality due to wolf predation.
- Moderate - Areas where wolves are likely to experience moderate mortality due to wolf predation.
- High - Areas where wolves are likely to experience high mortality due to wolf predation.

This map to the left depicts the potential wolf predation risk to Northern Caribou in the Scott Recovery Planning Area (SRPA) during winter. The map shows the predicted risk by assessing that all wildlife favour affecting winter density (and hence wolf potential) are in their optimal state. The prediction includes the analysis of a number of other biological and physical factors of the area in addition to those shown above. Version 1.0 of the CHARR Summer Moose Density model was used to make the predation risk to the map.

Overview



Sources: Wildlife Information for Value Assessment, GDS Analysis February 2004



Potential Winter Predation Risk (v.2)

Scott Recovery Planning Area



Legend

Winter Predation Risk Value

- High - 10,000 to 15,000
- Moderate - 10,000 to 15,000
- Low - 10,000 to 15,000
- Very Low - 10,000 to 15,000
- Water
- Road
- Settlement

What Do The Ratings Mean?

- Low - Areas where wolves are likely to experience low mortality due to wolf predation.
- Moderate - Areas where wolves are likely to experience moderate mortality due to wolf predation.
- High - Areas where wolves are likely to experience high mortality due to wolf predation.

The map to the left depicts the potential wolf predation risk to Northern Goshawk in the Scott Recovery Planning Area (SRPA) during winter. The map shows the potential risk by assessing that all suitable factors affecting mortality (and hence wolf predation) are in their optimal state. This prediction involves the analysis of a number of ecological and physical factors of the area in addition to those mentioned. Various data of the (2010) Winter-Birds (Winter-Birds) was used to assess the predation risk. In this case, the map represents a prediction of risk and, therefore, the accuracy of the Moderate and High classes has been adjusted to produce more accurate results.

Overview



Sources: AMRIS Information Inc.
Vancouver, BC
February 2014

This topographic map illustrates the Williston Lake region in Montana. The lake is depicted in blue, with its shoreline clearly marked. The surrounding terrain is shown in shades of gray, indicating elevation changes and mountainous areas. Several rivers are labeled, including the Snake River, Lost River, and Snake River. A scale bar at the bottom indicates distances from 0 to 50 kilometers. A north arrow is located in the bottom right corner.

Legend

Forest Range Value

- Avoided (250,000)
- Restored (1,000,000)
- Protected (1,000,000)
- Rest (200,000)

100,000 200,000 300,000 400,000 500,000 600,000 700,000 800,000 900,000 1,000,000 1,100,000 1,200,000 1,300,000 1,400,000 1,500,000 1,600,000 1,700,000 1,800,000 1,900,000 2,000,000 2,100,000 2,200,000 2,300,000 2,400,000 2,500,000 2,600,000 2,700,000 2,800,000 2,900,000 3,000,000 3,100,000 3,200,000 3,300,000 3,400,000 3,500,000 3,600,000 3,700,000 3,800,000 3,900,000 4,000,000 4,100,000 4,200,000 4,300,000 4,400,000 4,500,000 4,600,000 4,700,000 4,800,000 4,900,000 5,000,000 5,100,000 5,200,000 5,300,000 5,400,000 5,500,000 5,600,000 5,700,000 5,800,000 5,900,000 6,000,000 6,100,000 6,200,000 6,300,000 6,400,000 6,500,000 6,600,000 6,700,000 6,800,000 6,900,000 7,000,000 7,100,000 7,200,000 7,300,000 7,400,000 7,500,000 7,600,000 7,700,000 7,800,000 7,900,000 8,000,000 8,100,000 8,200,000 8,300,000 8,400,000 8,500,000 8,600,000 8,700,000 8,800,000 8,900,000 9,000,000 9,100,000 9,200,000 9,300,000 9,400,000 9,500,000 9,600,000 9,700,000 9,800,000 9,900,000 10,000,000

The map to the left depicts the capability of the landscape to produce Pasture Rangeland (PLR) within the Southwestern Planning Area (SWPA). This map shows the predicted capability of the land to produce suitable PLR by assessing each cell available based on whether PLR can be in that spatial location. This prediction locates the number of a number of other biological and physical features of the area in addition to those assumptions. Version 1.0 of the COMBAT PLR/PLR model can be used to make the predictions seen in this map.

Source: Wildlife Laboratories Inc.
Vladimir Brumovsky, GIS Analyst
February 2004

Calving and Summer Range Potential

Takla Recovery Planning Area



Legend

Calving and Suckling Range Value

Amgen 11/01/14

Epistemic Worlding

Systemwide: No. (800) 541-5414

Wiley InterScience, Wiley Subscription Services, Inc., a Wiley Company

Source: <http://www.fishbase.org>

What Do The Ratings Mean?

*Attached: Letter to arms dealer
by author's wife used to force
execution of the withdrawal.*

Expanded: Refers to some method preferred or avoided by authors. I.e. some used to read properties in their conditions.

Fractured - broken in some portions by cathodic action used in gross proportion than first availability).

The map to the left depicts the morphology of the landscape in pasture-Growing and Rangeland (GR) within the Tully Rangeland Planning Area (2000). The map shows the predicted morphology of the land in pasture suitable GR, as occurring after suitable herons allowing GR use in its optimal state. This predictive analysis involves a number of other biological and physical factors of the area in addition to these morphologies. Version 10b of the CHARM GR model was used to render the predictions map in this view.

Overview



Sources: Wildlife Information Inc.
Valerie Henningsen, ODS Analyst
February 2004

High Elevation Winter Range Potential

Takla Recovery Planning Area



Sources: Wildlife Information for Value Assessment, GIS Analyst February 2004



Pine-Lichen Winter Range Potential

Takla Recovery Planning Area



Legend

Pine-Lichen Winter Range Value

- Preferred: 80% or more
- Avoided: 40-79% or less
- Takla 20% or less
- Lake
- River
- Setback

What Do The Ratings Mean?

Avoided: Rating to areas avoided by caribou (i.e. areas used in lower proportion than their availability).

Expected: Rating to areas neither preferred or avoided by caribou (i.e. areas used in equal proportion to their availability). Some are preferred by the wolf in the area.

Preferred: Rating to areas preferred by caribou (i.e. areas used in greater proportion than their availability).

The map to the left depicts the magnitude of the landscape to produce Pine-Lichen Winter Range (25,000) within the Takla Recovery Planning Area (TRPA). The map shows the predicted capability of the land to produce suitable (100%) by using that all available forest within 750m are in their optimal state. The prediction assumes the analysis of a number of other biological and physical factors of the area to achieve system integration. Studies 1 to 4 of the CHAB PLS/PLS model was used to make the predictions seen in this map.

Overview



Sources: VML/BC Information Inc.
V. Jones, B. Jones, G. Jones
February 2004

Potential Winter Predation Risk (v.2)

Takla Recovery Planning Area



Legend

Winter Predation Risk Value

- High > 25,000ha
- Moderate 10,000 to 25,000 ha
- Low < 10,000 ha
- Takla SPA 17,000 ha buffer
- Lake
- River
- Settlement

What Do The Ratings Mean?

Low: Areas where caribou are likely to experience low mortality due to wolf predation.

Moderate: Areas where caribou are likely to experience moderate mortality due to wolf predation.

High: Areas where caribou are likely to experience high mortality due to wolf predation.

The map to the left depicts the potential wolf predation risk to Northern Caribou in the Takla Recovery Planning Area (TRPA) during winter. The map shows the potential risk by assessing that all variable factors affecting caribou density (land cover and potential) are in their optimal state. This prediction involves the analysis of a number of other biological and physical factors of the area in addition to those mentioned. Various 1:25 of the CANFOR Winter Forest Density model are used to make the prediction seen in the map. In this map, population increase rates are not used. Instead, the output between the Moderate and High classes has been adjusted to produce more accurate results.



Sources: Wildlife Information for
Vancouver, GIS Analyst
February 2014

Post-Rut Range Potential

Takla Recovery Planning Area



Legend

Post-Rut Range Value

- Avoided: 415,438 ha
- Exposed: 27 ha
- Preferred: 531 ha
- Total: 415,438 ha buffer

Water

Roads

Setback

What Do The Ratings Mean?

Avoided: Areas to avoid avoided by carbon U.S. area used in proportion to their availability.

Exposed: Areas to avoid avoided by carbon U.S. area used in proportion to their availability.

Preferred: Areas to avoid avoided by carbon U.S. area used in proportion to their availability.

The map to the left depicts the capability of the landscape to produce Post-Rut Range (PRR) within the Takla Recovery Planning Area (TRPA). The map shows the predicted capability of the land to produce outside TRP by assuming that all suitable factors affecting TRP are in their optimum state. This prediction assumes the availability of a number of other biological and physical factors of the area in addition to those mentioned. Version 1.0 of the CH2M HILL/PRR model was used to make the prediction seen in the map.

Overview



Sources: Wildlife Information for Value Assessment, CH2M HILL/PRR model, February 2004



Calving and Summer Range Potential

Wolverine Recovery Planning Area



Legend

Calving and Summer Range Value

- Assess - 100,000 ha
- Assess - 100,000 ha
- Assess - 100,000 ha
- Wolverine RPA 2 ha total
- Value
- Road
- Setback

What Do The Ratings Mean?

Assess - Refer to area assessed by wildlife (i.e. area used in some proportion to their suitability).

Assess - Refer to area assessed by wildlife (i.e. area used in some proportion to their suitability).

Assess - Refer to area assessed by wildlife (i.e. area used in some proportion to their suitability).

This map to the left depicts the capability of the landscape to produce Calving and Summer Range (C&SR) within the Wolverine Recovery Planning Area (WRPA). The map shows the predicted capability of the landscape to produce wildlife C&SR, assuming that all wildlife have sufficient C&SR as to their optimal state. The production involves analysis of a number of other biological and physical factors of the area to address its future management. Version 100 of the (C&SR) C&SR model was used to make the predictions shown in this map.

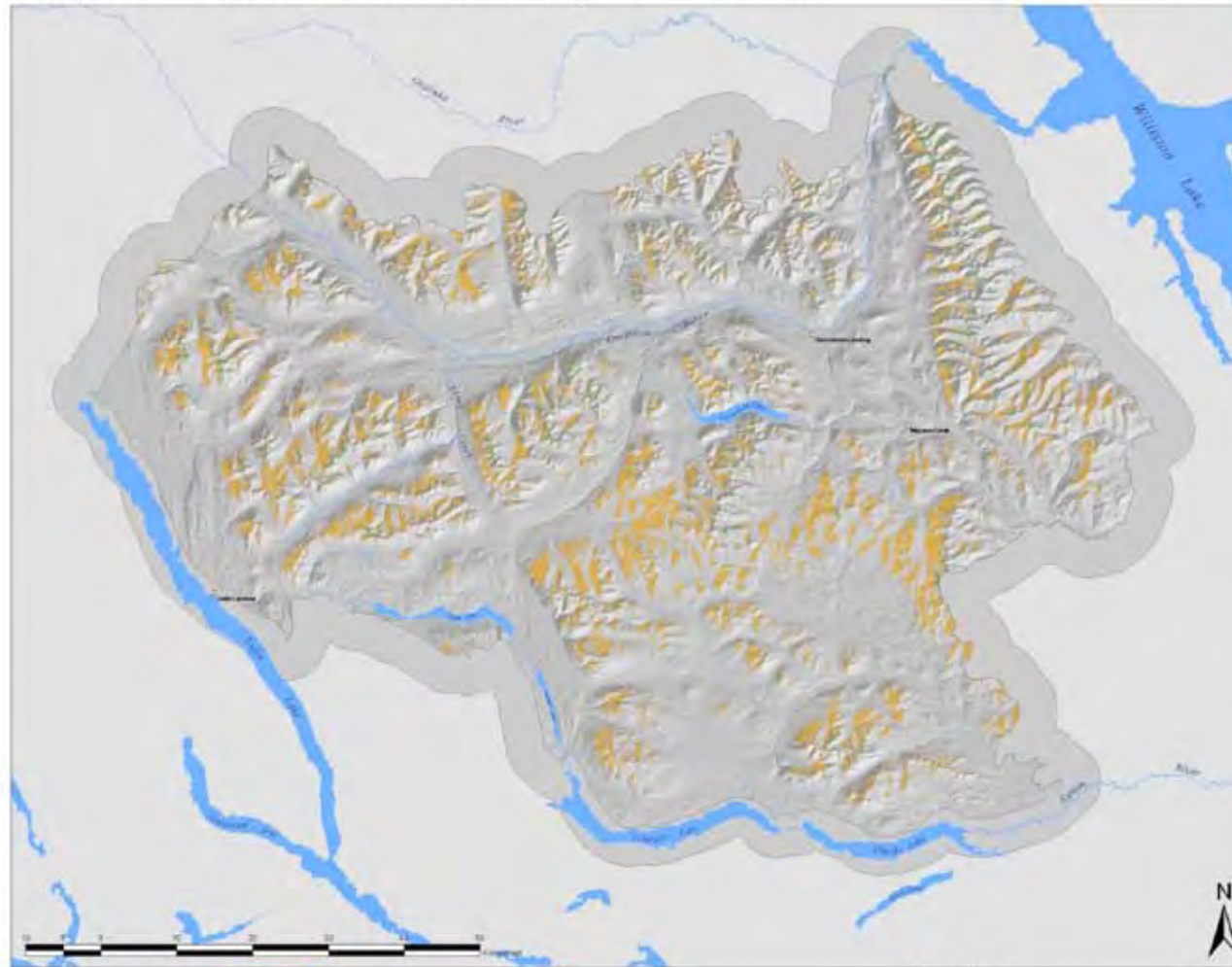
Overview



Sources: Wildlife Information for
Vancouver Region, GIS Analyst
February 2011

High Elevation Winter Range Potential

Wolverine Recovery Planning Area



Legend

High Elevation Winter Range Value

- Available: 7,022,10 ha
- Referred: 17,775 ha
- Preferred: 2,290 ha
- Wolverine RWS has failed
- Lake
- Road
- Settlement

What Do The Ratings Mean?

Available: Areas to areas available by nature (i.e. areas used in least proportion than their availability).

Referred: Areas to areas available preferred or needed by nature (i.e. areas used in more proportion to their availability).

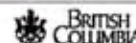
Preferred: Areas to areas preferred by nature (i.e. areas used in more proportion than their availability).

The map to the left depicts the magnitude of the landscape to produce High Elevation Winter Range (HEWR) within the Wolverine Recovery Planning Area (WRPA). The map shows the predicted magnitude of the land to produce winter HEWR by assuming that all suitable terrain offering HEWR are in their optimal state. This prediction includes analysis of a number of other biological and physical factors of the area in addition to those mentioned. Version 1.0 of the CHARS HEWR could be used to make the predictions seen in this map.

Overview



Sources: Wildlife Information for Value Assessment, GIS Analyst February 2005



Pine-Lichen Winter Range Potential

Wolverine Recovery Planning Area



Legend

Pine Lichen Winter Range Values

- Available: 40,000 ha
- Preferred: 100 ha
- Preferred: 10,000 ha
- Preferred: 400 (2 ha total)
- Other
- Other
- Other

What Do The Ratings Mean?

- Available: Sites to area avoided by wolves (i.e. area used in proportion to their availability).
- Preferred: Sites to area avoided by wolves (i.e. area used in proportion to their availability).
- Preferred: Sites to area avoided by wolves (i.e. area used in proportion to their availability).

The map to the left depicts the capability of the landscape to produce Pine-Lichen Winter Range (2000) within the Wolverine Recovery Planning Area (2000). The map shows the potential capability of the land to produce winter range (2000) by assessing the availability of winter range (2000) in the landscape. The prediction is based on the results of a number of other biological and physical factors of the area in addition to those mentioned. Version 1.0 of the CANOR 2000/2000 model was used to create the prediction map on this map.

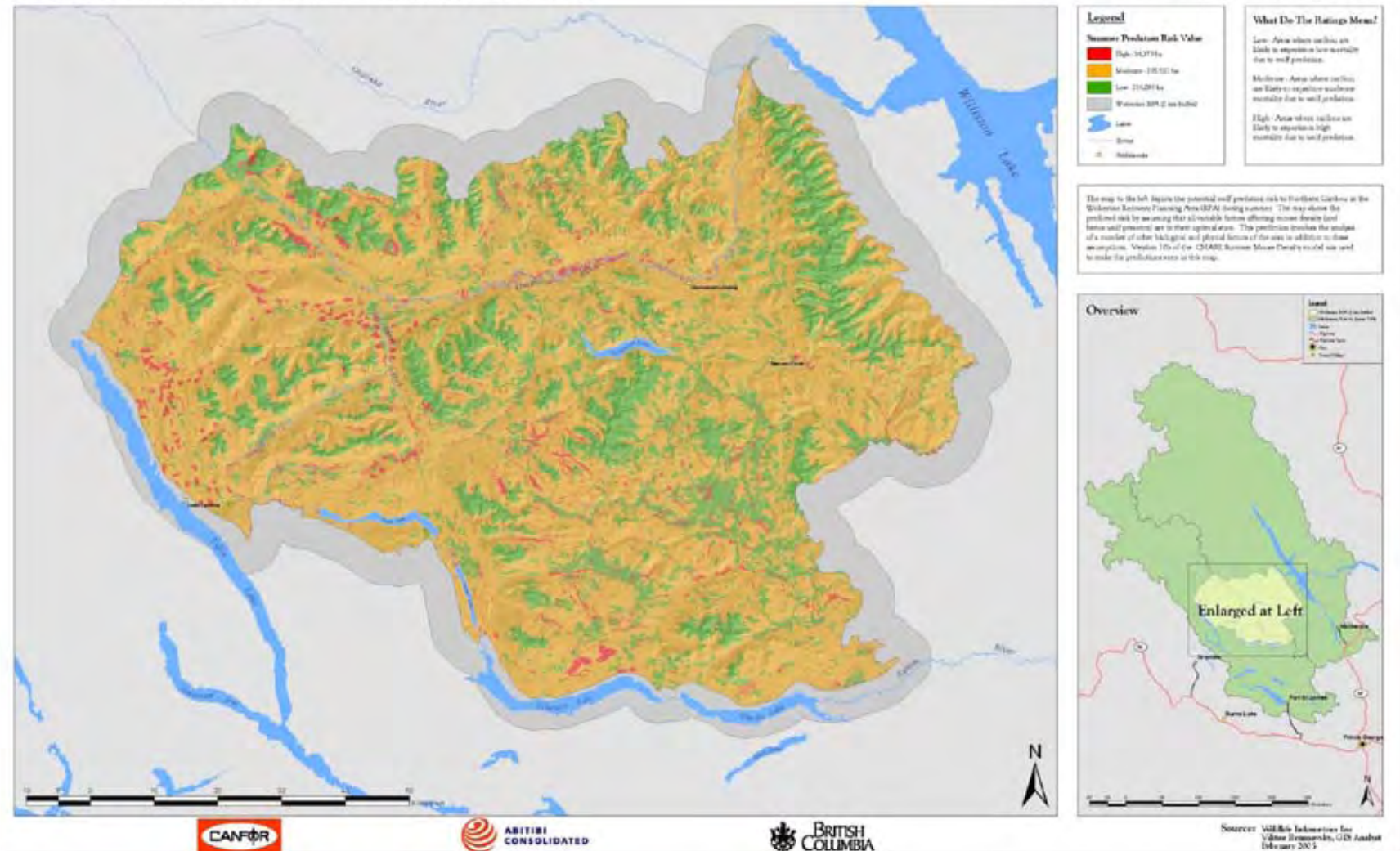
Overview



Sources: Wildlife Information for
Vancouver Region, GIS Analyst
December 2003

Potential Summer Predation Risk

Wolverine Recovery Planning Area



The map displays the topographic relief of the study area, characterized by rugged mountain terrain. The Tianshan Mountains are prominent, with several peaks labeled. The Tianshan River flows through the region, and the Tianshan Lake is visible in the upper right. The map includes a scale bar (0-50 km) and a north arrow.

Sources: Wildlife Information for
Váňa Ilmaväski, GIS Analyst
February 2004

APPENDIX E RECREATIONAL SNOWMOBILING AREA MAPS

