Discussion Paper

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Silviculture options for use in ranges designated for the conservation of northern caribou in British Columbia

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Abstract

This review and synthesis of silviculture strategies was conducted to clarify options for managing forest stands in areas designated for conservation of habitat for the northern ecotype of woodland caribou in British Columbia. Information about the ecology, distribution, population status, and legal management measures for herds of northern caribou provided the background for assessing risk to forestry operations. A review of current scientific research and operational trials was used to reveal potential impacts of forestry on caribou life requisites. Specific attention was paid to the implications of the recent mountain pine beetle infestation. General guidelines (desired conditions) are provided for operating in areas designated for the conservation of caribou.

KEYWORDS: *forest harvesting; life requisites; predation;* Rangifer tarandus *(woodland caribou); silviculture; terrestrial lichens; ungulate winter range; wildlife habitat.*

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Introduction

Taxonomically, woodland caribou (*Rangifer tarandus*) are one of seven extant subspecies that occur within Eurasia and North America. The northern ecotype of woodland caribou is a classification based on regional location and behaviour rather than taxonomy and refers to woodland caribou of northern British Columbia. Northern caribou forage primarily on terrestrial lichens (*Cladina* spp. and *Cladonia* spp.) in winter and, in comparison to other woodland caribou, also generally have distinct horizontal as well as vertical change in location when migrating from low-elevation winter ranges in early winter to higher-elevation ranges in late winter (Heard and Vagt 1998; Spalding 2000). Northern caribou occur in the mountainous and lowland plateau areas of west-central and northern British Columbia, from the Williston Lake area in the north-central part of the province north to the Yukon and northwest to Atlin, and southeast along the east side of the Rocky Mountains near Kakwa Park and the Alberta border (Figure 1).

The conservation status of caribou is important from both federal and provincial perspectives because declining populations have been recognized globally (Vors and Boyce 2009), nationally (Sleep 2007), and provincially (Wittmer et al. 2005). Concern is usually expressed over any anthropogenic activity within caribou range, including that from forestry. Fifteen herds of northern caribou inhabit the Southern Mountains National Ecological Area (SMNEA) and are federally listed as "threatened"; that is, the species could regress to a state of imminent extirpation if limiting factors are not reversed (Thomas and Gray 2002). The remaining 16 herds of northern caribou inhabiting the Northern Mountains Ecological Area (NMNEA) are federally considered to be of "special concern"; that is, the species may become threatened (Thomas and Gray 2002). These designations and the fact that the British Columbia government is a signatory of the National Accord for Protection of Species at Risk[1] means that the provincial government is required to prepare management plans for caribou in the NMNEA and recovery plans for those in the SMNEA. Provincially, all woodland caribou are designated as "ungulates and a species at risk." The designation affords all woodland caribou legal[2] habitat protection through regulated General Wildlife Measures (GWMs) specific to Ungulate Winter Ranges (UWRs) and (or) Wildlife Habitat Areas (WHAs),[3] or in the absence of these, forest stewardship plans specifying a result or strategy that achieves the desired level of conservation made explicit in government notices.

The objective of this paper is to synthesize the latest scientific information on silviculture options that could be used within and adjacent to ranges designated for the protection and conservation of northern caribou in British Columbia. This is especially important because recent forest policy promotes a relatively aggressive salvage of timber killed by the mountain pine beetle.

The objective of this paper is to synthesize the latest scientific information on silviculture options that could be used within and adjacent to ranges designated for the protection and conservation of northern caribou in British Columbia. This is especially important because recent forest policy promotes a relatively aggressive salvage of timber killed by the mountain pine beetle (*Dendroctonus ponderosae*) and specific silviculture investment has been allocated to rehabilitate beetle-affected forest areas that may otherwise not be salvaged (B.C. Ministry of Forests and Range 2010). Many of these beetle-affected forest areas are also habitat for northern caribou, so the silviculture options presented here may be useful as further guidance for site-level treatment decisions when harvesting and rehabilitating within or adjacent to range designated for conservation of northern caribou.

Methods

A literature review was completed and information compiled to address population status and characteristics of habitat for northern caribou. Land use plans, recovery planning, and government orders and notices all helped provide the spatial context for, and

[1] See *http://www.ec.gc.ca/media_archive/Press/2001/010919_b_e.htm* (Accessed March 2010).
[2] By regulations of the *Forests and Range Practices Act*.
[3] Provided these measures do not unduly limit the supply of timber from the forests of British Columbia.

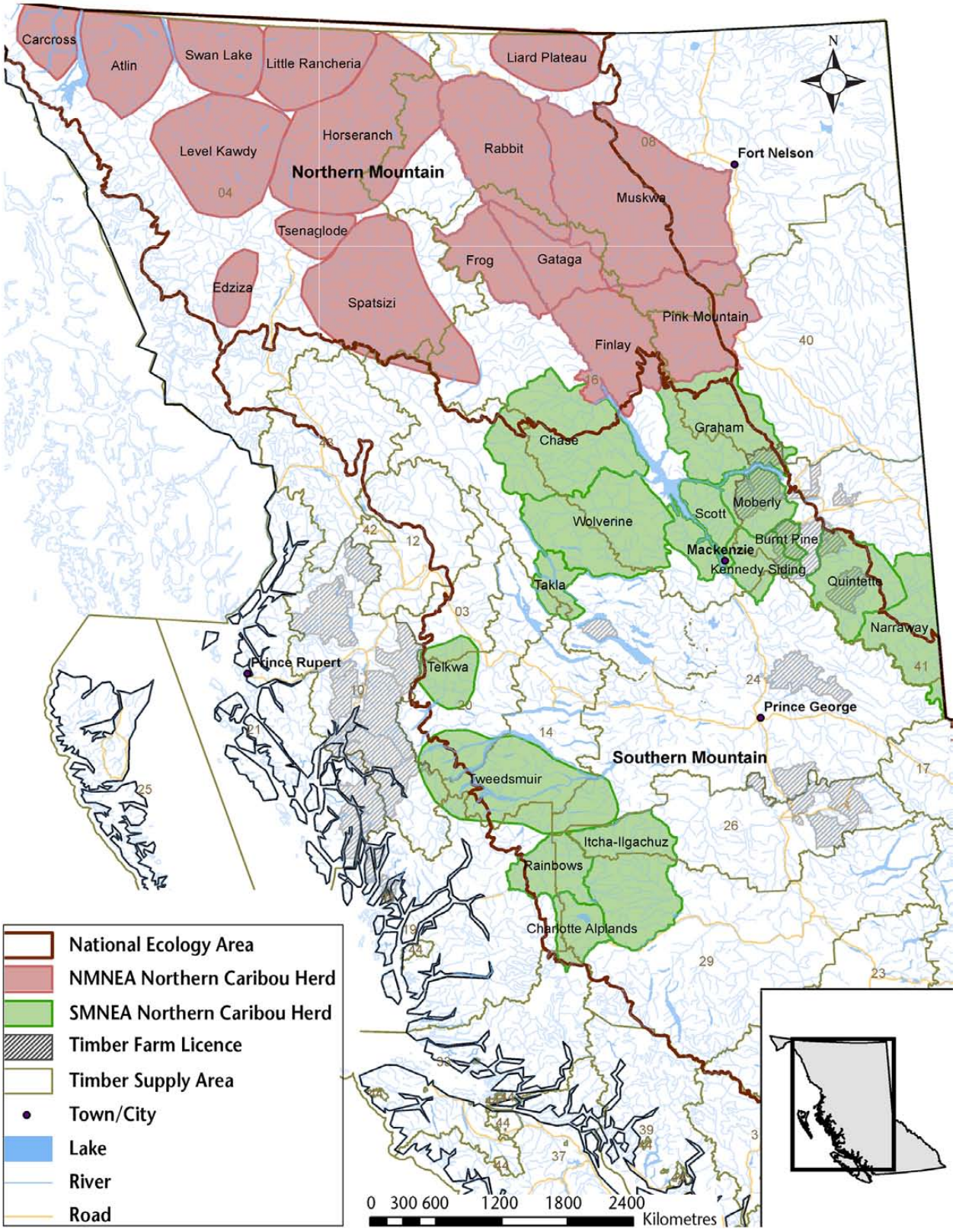

FIGURE 1. The distribution of the northern ecotype of woodland caribou in British Columbia. NMNEA and SMNEA are the Northern and Southern Mountain national ecological areas, respectively.

legal objectives associated with, land use designations that specifically address conservation of northern caribou habitat. A subsequent review of past research and forestry-based operational trials in northern caribou habitat provided a list of harvesting and silviculture activities that can mitigate risk to, or otherwise maintain or improve the supply of, caribou habitat. This information was then used to establish the desired conditions for northern caribou range. A list of caribou life requisites was rated for risk of being affected by industrial forest operations and the potential silviculture mitigations identified. In support of recovery planning efforts, emphasis was placed on the conservation of early- and late-winter range, calving areas, and rut range.

Background

Current population status and trend

There are approximately 17 550 northern caribou in British Columbia, distributed among 31 individual herds.[4] Herd population size and the area over which they range vary considerably (Table 1).

Characteristics of range

Northern caribou in British Columbia occupy 23 million ha of land and all but four biogeoclimatic zones. However, five of the occupied zones account for only 1% of the herd areas and therefore these zones can be considered insignificant. The Spruce–Willow–Birch (SWB), Boreal White and Black Spruce (BWBS), Engelmann Spruce–Subalpine Fir (ESSF), and Boreal Altai Fescue Alpine (BAFA) zones account for 86% of the area used by northern caribou in the province (Figure 2).

Winter

Differences in local topography and snow accumulation (among herds) can lead to considerable variance in the use of winter range (December through April). For example, mountain-bound herds may have lost access to low-elevation range because of anthropogenic disturbance, predation risk, or a combination of both, or they may live in areas where alpine and subalpine habitat is naturally the best available habitat. Mountain-bound herds are also typically small—examples include the Takla, Telkwa, Finlay, Scott, Moberly, Narraway, and Quintette herds. Only one of these herds, the Finlay, occurs in the NMNEA. Mountain-bound northern caribou are often referenced as foraging on arboreal lichens (primarily *Bryoria* spp. in northern latitudes) and sometimes do (e.g., Telkwa [Telkwa Caribou Standing Committee 1999] and Takla [Poole et al. 2000]), but in other situations they forage mostly on terrestrial lichens (*Cladina* spp. and *Cladonia* spp.) on windswept, alpine ridges (e.g., Moberly [Jones et al. 2007], Finlay [personal observations]). Most other northern herds, and the majority of northern caribou, typically use low-elevation or mid-slope forests dominated by lodgepole pine (*Pinus contorta*) in early winter, and windswept alpine ridges in late winter, where they dig or "crater" for terrestrial lichens. They may also feed on arboreal lichens, especially along edges of low-elevation meadows (Johnson et al. 2004; Cichowski 2008; Goddard 2009).

Calving and rut

Ranges used for calving (late May through mid-June) and during the reproductive period (mid-September to mid-October) tend to be high elevation in ESSF or alpine areas (Terry and Wood 1999; Cichowski 2009). Bulls breed with a number of cows, so the rut is characterized by aggregations of caribou. Range is partitioned between the sexes during calving, with cows occurring relatively alone in isolated and rugged areas of high-elevation subalpine or alpine.

Planning context and considerations

There is no recovery plan for northern caribou, although a draft provincial strategy was constructed in 2004 for the SMNEA herds (Northern Caribou Technical Advisory Committee 2004) and the federal government is leading a plan for the management of herds in the NMNEA.[5] An ad hoc standing committee prepared a herd-specific recovery plan for the Telkwa herd (Telkwa Caribou Standing Committee 1999), but this is not recognized by government as an official recovery plan. As an implementation action from the draft recovery strategy, a recovery action plan was developed for the north-central herds (Scott, Wolverine, Takla, and Chase) (McNay et al. 2008) but was never sanctioned by government. A similar recovery action plan was begun for the north-eastern herds in the SMNEA (Kennedy, Moberly, Graham, Quintette, and Narraway) but was "temporarily suspended" by government.[6]

[4] McNay, R.S. and D. Hamilton. A strategy for the management of woodland caribou (*Rangifer tarandus caribou*) in British Columbia. B.C. Ministry of Environment, Victoria, B.C. Draft internal report. In preparation.

[5] See *http://www.yfwmb.yk.ca/northernmountaincaribou/* (Accessed March 2010).

[6] See *http://www.centralbccaribou.ca/crg/10/central+rocky+mtns* (Accessed March 2010).

TABLE 1. Current population estimates, recent trends, risk status, range size, and density of northern caribou herds in British Columbia[a]

Herd name	Population estimate	Years since last survey	Recent trend[b]	Risk status[c]	Range[d] (km^2)	Density (no. per 1000 km^2)
Burnt Pine	19	0	unknown	SD	710	27
Charlotte Alplands	50	9	unknown	S	2650	19
Chase	475	1	stable	S	12 465	38
Graham	311	1	stable	S	9291	33
Itcha-Ilgachuz	2150	1	decreasing	SD	9457	227
Kennedy Siding	119	8	unknown	S	2962	40
Moberly	171	2	stable		3291	52
Narraway	200	2	unknown	S	6372	31
Quintette	195	2	unknown	S	6078	32
Rainbows	50	2	decreasing	SD	3804	13
Scott	60	4	unknown	S	4149	14
Takla	122	6	stable		2122	57
Telkwa	73	2	increasing	S	3098	24
Tweedsmuir	250	4	stable	S	13 425	19
Wolverine	378	1	stable	S	10 541	36
SMNEA Total	***4623***				***90 415***	***44 (average)***
Atlin	800	3	stable		6857	117
Carcross	775	2	stable		3174	244
Edziza	150	3	stable		2341	64
Finlay	26	8	unknown	SD	8175	3
Frog	250	9	unknown	S	5039	50
Gataga	338	9	unknown	S	5008	67
Horseranch	600	11	unknown	S	17 720	34
Level Kawdy	1500	11	unknown	S	11 305	133
Liard Plateau	141	5	stable	S	5069	28
Little Rancheria	1200	11	unknown	S	6999	171
Muskwa	1300	6	stable		22 025	59
Pink Mountain	850	10	unknown	S	9583	89
Rabbit	1300	3	increasing		11 791	110
Spatsizi	3000	14	unknown	S	15 628	192
Swan Lake	700	3	increasing		5516	127
Tsenaglode	NA	11	unknown	S	2463	NA
NMNEA Total	***12 930***				***138 693***	***99 (average)***
Total	***17 553***				***229 108***	***72 (average)***

[a] McNay and Hamilton (in prep.; see footnote 4, p. 58).

[b] Recent trend is defined for herds > 30 as a population change of > 20% within the last 7 years. Trends for herds < 30 or lacking a population survey in the last 7 years were considered unknown.

[c] Where S are herds considered to be sensitive because they are not > 100 animals, stable or increasing, and > 50 animals per 1000 km^2 and SD are sensitive herds suspected of being in population decline or herds with < 30 animals.

[d] Is current occupied range.

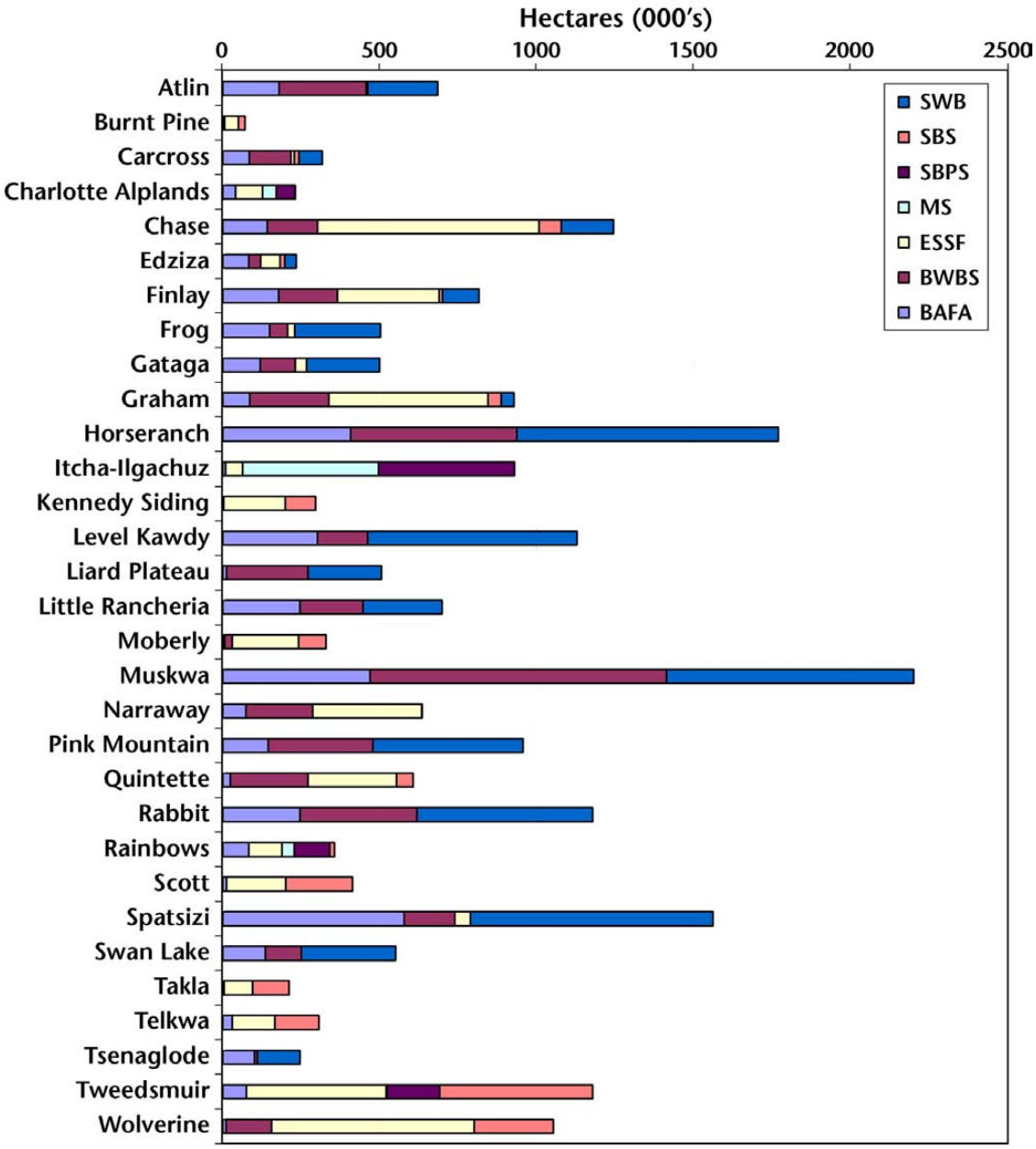

FIGURE 2. Biogeoclimatic zones (Meidinger and Pojar [editors] 1991) occupied by the northern ecotype of woodland caribou in British Columbia.

Beginning in 1992, the provincial government undertook broad-scale land use planning and the first and only government sanctioned land use plan for caribou was developed for the Itcha-Ilgachuz herd in 2002 (Youds et al. 2002). Management unit-specific Land and Resource Management Plans developed throughout northern British Columbia all address conservation of woodland caribou where herds exist (Table 2) but these plans, with the exception of Youds et al. (2002), provide general policy rather than specific legal objectives. The Muskwa-Kechika Wildlife Management Plan (B.C. Ministry of Environment 2009) provides general management direction specifically for the Graham, Pink Mountain, Muskwa, Rabbit, Gataga, Finlay, Frog, and Horseranch herds (Table 2).

TABLE 2. Land use plans and government orders and notices that provide details on desired habitat conditions for northern caribou (caribou herds) existing within forest management units (MU) and national ecological areas (NEA) of British Columbia

National ecological areas	Management unit type[a]	Management unit	Caribou range (ha)	Caribou herds	Land use plans[b]	Orders		Notices	
						UWR	WHA	UWR	WHA
NMNEA	TFL	TFL41	8036	Tweedsmuir			NA	NA	
	TSA	Cassiar	6 562 042	Atlin, Carcross, Edziza, Frog, Horseranch, Level Kawdy, Little Rancheria, Spatsizi, Swan Lake, Tsenaglode	Skeena LRMP, MKMA		NA	Cassiar	
		Fort Nelson	4 400 746	Finlay, Gataga, Horseranch, Liard Plateau, Muskwa, Pink Mountain, Rabbit, Spatsizi	Mackenzie LRMP, Skeena LRMP, M-KWMP		NA	NA	NA
		Fort St. John	577 379	Finlay, Pink Mountain	Mackenzie LRMP, M-KWMP		NA		NA
		Kalum	51 050	Tweedsmuir	Skeena LRMP, Vanderhoof LRMP		NA	NA	
		Lakes	667 690	Tweedsmuir	Skeena LRMP, Vanderhoof LRMP		NA	NA	
		Mackenzie	2 219 867	Finlay, Frog, Gataga, Muskwa, Pink Mountain, Rabbit, Spatsizi	Mackenzie LRMP, M-KWMP	U7-007	NA		Mackenzie
		Mid Coast	144 098	Tweedsmuir	Skeena LRMP, Vanderhoof LRMP		NA	NA	
		Morice	244 933	Tweedsmuir	Skeena LRMP, Vanderhoof LRMP		NA	Morice	
		Prince George	288 463	Spatsizi, Tweedsmuir	Skeena LRMP, Prince George LRMP, Fort St. James LRMP, Vanderhoof LRMP	U-7-012	NA		Fort St. James, Nadina, Vanderhoof
		Quesnel	11 504	Tweedsmuir			NA		
		Williams Lake	178	Tweedsmuir	Skeena LRMP, Vanderhoof LRMP, CCLUP		5-086, 5-087, 5-118		

TABLE 2. (Continued)

National ecological areas	Management unit type[a]	Management unit	Caribou range (ha)	Caribou herds	Land use plans[b]	Orders		Notices	
						UWR	WHA	UWR	WHA
SMNEA	TFL	TFL1	412	Telkwa			NA		
		TFL48	459 264	Burnt Pine, Graham, Kennedy Siding, Moberly, Quintette	Mackenzie LRMP, Dawson LRMP, M-KWMP	U-9-004, U-9-002	9-044, 9-055–057, 9-061–065		
	TSA	Bulkley	82 198	Telkwa			NA		
		Dawson Creek	1 279 278	Burnt Pine, Graham, Kennedy Siding, Moberly, Narraway, Quintette, Scott	Mackenzie LRMP, Dawson LRMP, M-KWMP	U-9-002	9-051–054, 9-058–061, 9-065–073, 9-144, 9-145		NA
		Fort St. John	524 557	Graham	Dawson LRMP, M-KWMP	U-9-004	9-032–034, 9-041–049, 9-103–106		NA
		Kalum	41	Telkwa	Skeena LRMP		NA		
		Kingcome	27 696	Charlotte Alplands	CCLUP		NA	NA	
		Lakes	14 860	Takla			NA	NA	
		Mackenzie	2 482 637	Chase, Graham, Kennedy Siding, Moberly, Scott, Wolverine	Mackenzie LRMP, Ft. St. James LRMP, Dawson LRMP, M-KWMP	U-7-009, U7-007, U-9-004	9-035–040, 9-102, 9-102, 9-103, 9-106		Mackenzie
		Mid Coast	228 458	Charlotte Alplands, Rainbows	CCLUP		NA	NA	
		Morice	266 395	Takla, Telkwa	Mackenzie LRMP, Ft. St. James LRMP, Vanderhoof LRMP		NA		
		Prince George	1 002 769	Chase, Itcha-Ilgachuz, Kennedy Siding, Narraway, Quintette, Rainbows, Takla, Wolverine	Mackenzie LRMP, Ft. St. James LRMP, Dawson LRMP, CCLUP	U-7-015, U-7-012	5-086, 5-087, 5-118		Fort St. James, Nadina, Vanderhoof
		Quesnel	312 389	Itcha-Ilgachuz, Rainbows	CCLUP		5-086, 5-118		
		Robson Valley	6	Narraway	Dawson LRMP		NA		
		Williams Lake	1 017 223	Charlotte Alplands, Itcha-Ilgachuz, Rainbows	CCLUP		5-086, 5-087, 5-118		

[a] Where *TFL* is Tree Farm Licence, and *TSA* is Timber Supply Area.

[b] Where *LRMP* is Land and Resource Management Plan, *MKMA* is Muskwa-Kechika Management Area, *M-KWMP* is Muskwa-Kechika Wildlife Management Plan, and *CCLUP* is Cariboo Chilcotin Land Use Plan.

By regulation, forest stewardship plans must address the intent of GWMs provided in government notices for northern caribou unless conservation of habitat has already been adequately addressed through UWRs and (or) WHAs. These measures are available for all northern caribou range in the province (Table 2). Furthermore, the forest industry recognizes caribou habitat as a primary indicator of sustainability and Sustainable Forest Management Plans are therefore generally consistent with GWMs and any specified recovery actions where they occur.

Silviculture activities in northern caribou range

Forest harvesting and silviculture

Forestry and silviculture operations can affect a number of caribou life requisites (Figure 3), including abundance and availability of forage (Cichowski et al. 2008; Seip and Jones 2009; Waterhouse et al., in press), energetic cost of locomotion (inferred through the interception of snow during winter) (Boon 2007; Teti 2008), cover from thermal extremes (hypothetically at least), and

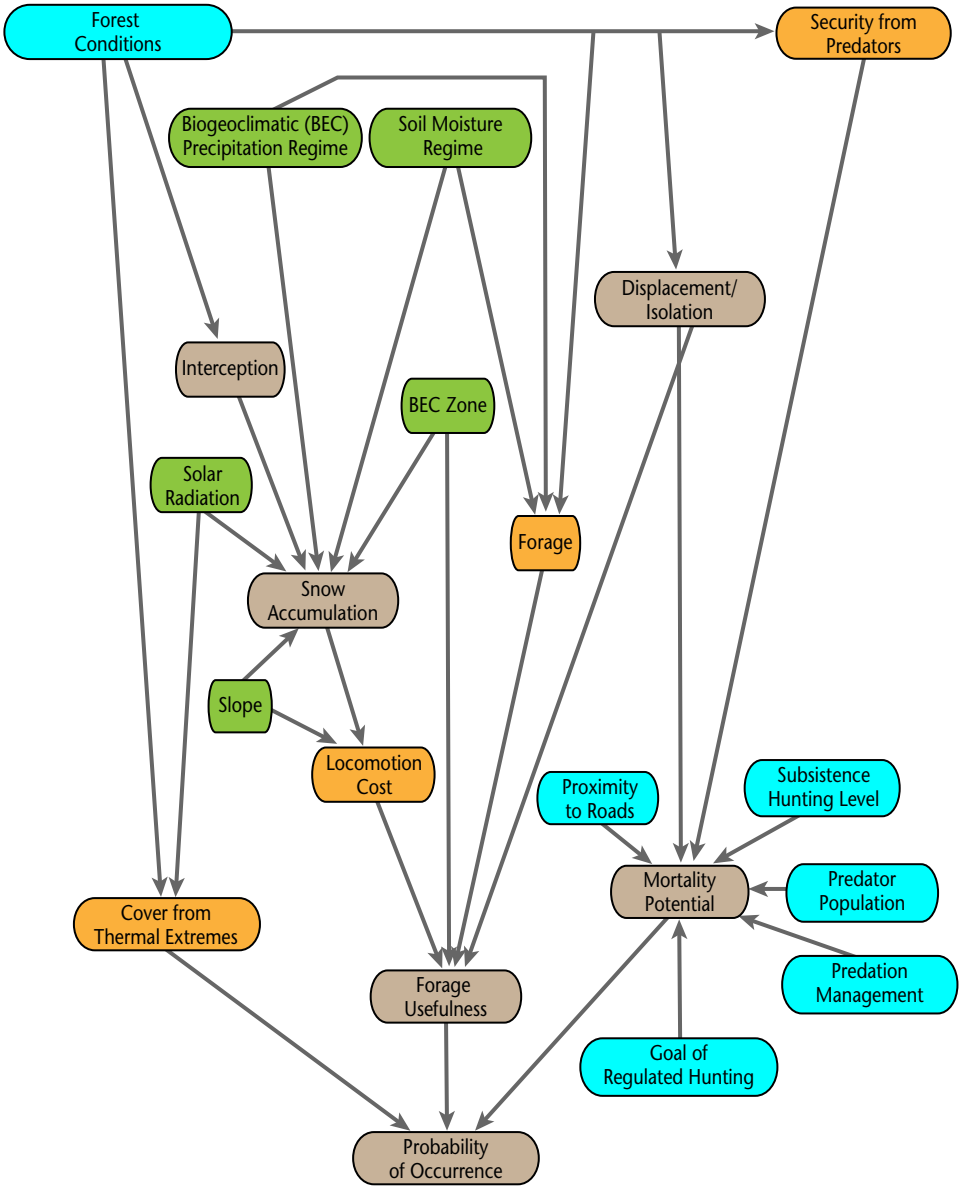

FIGURE 3. A general conceptual model of the probability of ungulate occurrence based on life requisites (orange nodes) and the ecological factors that affect them. Ecological factors can be distinguished as manageable (blue nodes) or not (green nodes).

risk of mortality (James and Stuart-Smith 2000; Chowns and Gates 2004; Boisjoly et al. 2010). Caribou may be displaced away from sites intensively used by people (Dyer et al. 2001; Seip et al. 2007) or may not be able to access sites because of barriers created either directly or indirectly by forest and other industrial operations (Dyer et al. 2002). Forest harvesting and the specific silviculture regime will change patch sizes, extent, and the amount of seral forest classes (a landscape-level effect) and basic and intensive silviculture will affect both understorey and overstorey characteristics of regenerating forests (a stand-level effect).

The potential effects from forest harvesting are most prominent in low-elevation forests dominated by lodgepole pine. In particular, the pine forests that are relatively well drained (high coarse fragment content in soils) tend to support abundant terrestrial forage lichens and, as a result, caribou spend much of their winters foraging in these areas. Most land use plans therefore have objectives associated with conservation of caribou range that are particularly applicable to forestry operations (Table 2). These objectives and those in legally designated UWRs and WHAs (Figure 4), or from government notices vary considerably, in an attempt to address the diverse range of northern caribou, but generally they are intended to mitigate the potential effect of harvesting and silviculture activities on caribou life requisites (Table 3). The objectives, in terms of desired range conditions, are summarized here (Table 4), but practitioners are advised to consult the specific objectives relating to individual herds and the management unit in which they are conducting work (Table 2).

In general, landscape-level objectives usually relate to the rate and spatial configuration of timber harvest (or salvage) and development of roads, with their primary intent being to minimize the potential for overlap between caribou and an early-seral predator–prey system. At low- to mid-elevations, a short period of intensive development over large areas (with equally large areas left undisturbed) is more desirable than a prolonged and dispersed pattern of development. At higher elevations, where arboreal lichens are the primary forage (e.g., ESSF), a slow rate of harvest or no harvest at all is preferable. At the stand level, basic silviculture objectives are focussed primarily on maintaining site conditions that are as similar as possible to the original conditions. Usually, this will mean planting at relatively low density, using pine rather than an off-site species, and avoiding any enhancement to the generally poor growing conditions through fertilization or other site preparation techniques. If the site is particularly poor growing, with terrestrial lichens as essentially a climax vegetation type, harvesting in winter on top of a snowpack is desirable. At sites that have better growth, harvesting in summer, followed by a prescribed burn and natural regeneration, is desirable. Increased silviculture effort will be required on sites where basic silviculture has failed to derive conditions that would eventually be representative of the harvested stand. Most often this will involve brushing, to reduce competition from vascular shrubs, and spacing, to reduce stems in high density stands.

Forest protection and salvage

The recent and unprecedented infestation of mountain pine beetle in British Columbia (Eng et al. 2005) has resulted in significant ecological change to the range of northern caribou. In addition, British Columbia is experiencing chronic alteration of local and regional ecology because of global shifts in climate (Pojar 2010). As a result, many foresters expect a new management paradigm for protection of forests against other insect infestations, for salvage of dead timber, and for management of forest fires. Relatively new policy to direct stand-selection criteria (B.C. Ministry of Forests and Range 2010) is an example. How caribou will respond to the widespread ecological change or a new management paradigm is unclear (Bunnell 2005; Cichowski 2007; Whittaker and Wiensczyk 2007). Nevertheless, change can be anticipated (Cichowski 2007; Armleder and Waterhouse 2008), even though caribou have not apparently altered their habitat use behaviour after the red and gray mountain pine beetle attack phases (Cichowski 2009; Seip and Jones 2009). Preliminary results from research indicate that, in forests severely affected by the mountain pine beetle:

- snow conditions will not be as favourable for foraging on terrestrial lichens, either due to increased snow depth (Boon 2007; Teti 2008; Sulyma and McNay 2009a) or snowpack hardening conditions in late winter (Cichowski 2009; Seip and Jones 2009);
- abundance of terrestrial forage lichens will decline, at least in the short term (Cichowski et al. 2008; Seip and Jones 2009); and
- accumulated debris will eventually increase (Waterhouse and Armleder 2004; Lewis and Hartley 2006).

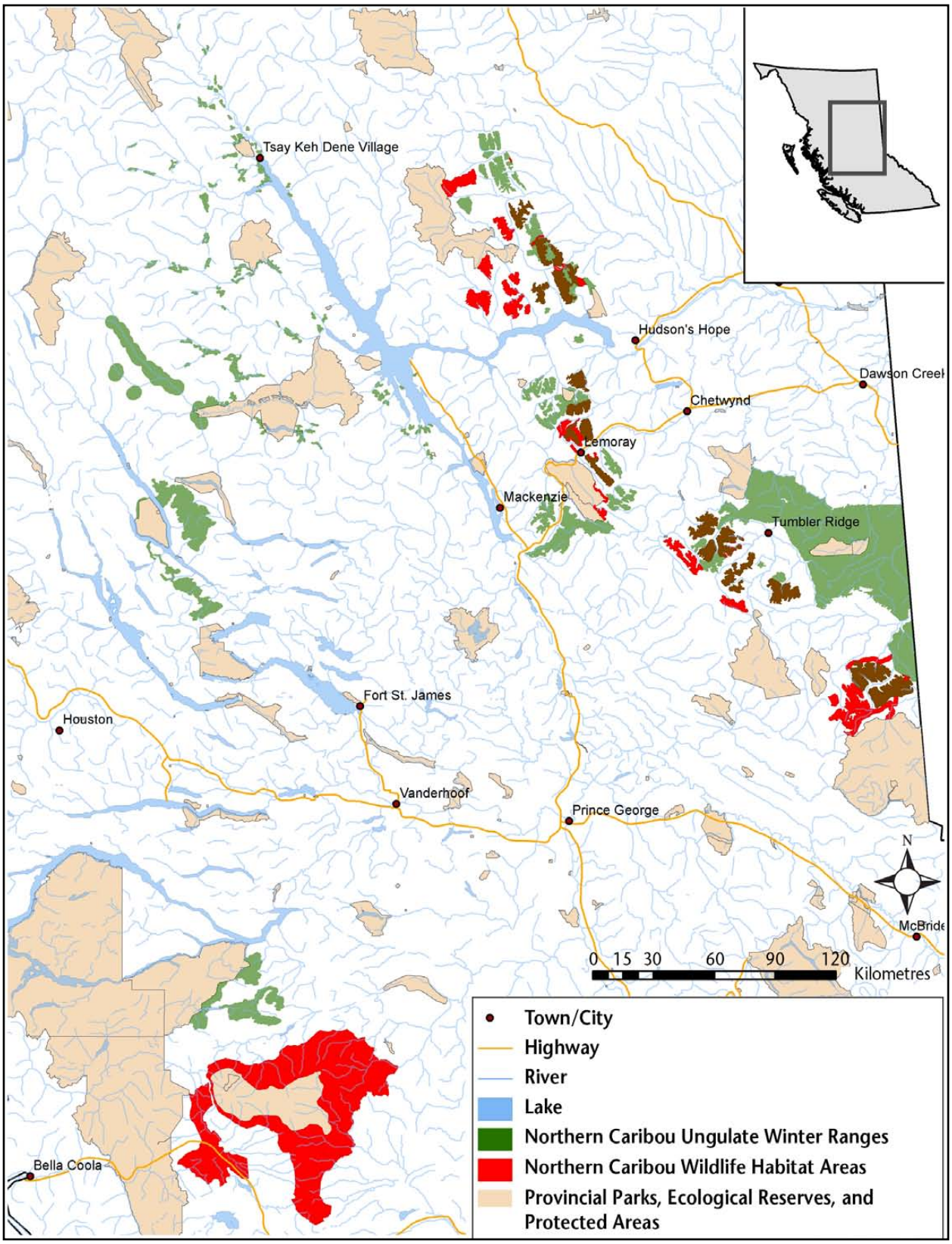

FIGURE 4. Wildlife Habitat Areas and Ungulate Winter Ranges designated for the conservation of the northern ecotype of woodland caribou in British Columbia.

TABLE 3. A matrix approach to the generalized identification of, and ranking of, forest harvest and silviculture activities that potentially threaten the maintenance of range for northern caribou in British Columbia. The example is low-elevation range in the Wolverine herd.

Life requisite	Threat	Agent	Affected factor	Risk assessment[a]				Mitigating factor
				Scope	Severity	Impact	Timing	
Terrestrial forage	Loss of forage	Tree removal[b]	Lichens: exposure/ competition	4	3	H	H	Opening size
		Equipment	Lichens: direct mortality	2	2	L	L	Protective snowpack
		Fertilization	Lichens: competition	1	4	M	L	None
Arboreal forage	Loss of forage	Tree removal	Lichens: removal	2	3	M	M	Rate of harvest
Locomotion	Increased energy cost	Tree removal	Snow depth	4	3	H	H	Canopy closure
	Barrier to movement	Planting	Movement space	3	1	L	H	Stems per hectare
		Juvenile spacing	Movement space	1	2	L	H	Stems per hectare
		Thinning	Movement space	1	3	L	L	Stems per hectare
Security	Increased mortality	Tree removal	Primary prey and predators	4	4	H	H	Seral juxtaposition
								Manual brushing
		Forest roads	Predator search rate	4	2	H	H	Road rehabilitation
All	Displaced from habitat	Operations	Occupy space	2	1	L	H	Timing

[a] Risk factors are adapted from Master et al. (2009). Their individual scores are:
- Scope of the threat (pervasive = 4, large = 3, restricted = 2, small = 1) within a 10-year time frame.
- Severity is the level of damage from the threat (extreme = 4, serious = 3, moderate = 2, slight = 1) within three generations (for caribou 21 years)
- Impact is the interaction between scope and severity (very high = 8, high = 6–7, medium = 5, low = < 5).
- Timing (high = continuing, moderate = future or suspended, low = future long term, negligible = only in the past).

[b] Tree removal was considered to be from timber harvest and from mountain pine beetle attack.

The current emphasis on recovery of declining caribou populations, coupled with the anticipated and widespread ecological change in their habitat, has intensified the need for restoration of caribou range. Many tactics for restoration will likely involve forestry-related activities. Examples of restoration activities are manual brushing and weeding, to reduce browse for other ungulates and expedite tree growth; road rehabilitation, to discourage use by predators; and prescribed burns, to enhance the succession of vegetation communities that include terrestrial forage lichens (Sulyma 2010).

Harvesting and silviculture risks

Determine the risk to harvesting and silviculture activities from an overlap with GWMs for caribou as follows.

1. For each herd in the management unit, determine the status of conservation (from Figure 1) and population risk (from Table 1).
2. Determine (from Table 2 and Figure 4) if designated conservation areas (UWR or WHA) exist in the management unit or if GWMs will come from a forest stewardship plan result or strategy (i.e., in response to a government notice).

TABLE 4. Landscape and forest stand conditions desired for provision of habitat for northern caribou in British Columbia (modified from Manning, Coopers, and Associates 2006)

Landscape Conditions	
A landscape for northern caribou is the area that bounds their seasonal ranges. Because migration distances can range from 10 to 40 km or more (Cichowski et al. 2004), landscapes tend to be in the order of 300–5,000 km^2. There are five silviculture-related objectives for northern caribou at this management level.	
All biogeoclimatic units[a]	1. Avoid constructing obstructive barriers to migration in order to minimize potential for isolation of seasonal ranges and fragmentation of caribou herds.
	2. Maintain early-seral, matrix forest conditions (amount and distribution) similar to hypothetically unmanaged ecological disturbance regimes in order to avoid excessive mortality risk associated with colonization by, or increases in, primary prey.
	3. In high-elevation ranges (rut, late winter, or calving and summer ranges), avoid timber harvest[b] in order to maintain a sustainable supply of arboreal and terrestrial forage, minimal predation risk, and minimal disturbance to caribou.
	4. Where applicable[c] in lower elevations, maintain at least half the designated area in suitable condition (i.e., greater than a specified minimum age[d] and in large patches[e]) to maintain a sustainable supply of terrestrial forage on winter ranges. In most situations, these forested areas will be dominated by beetle-killed trees and may, in some cases, require restoration. Example treatments to maintain effective range may include manual brushing to minimize early seral forage for other ungulates (thereby reducing subsequent predator impacts on caribou), or conducting stand removal activities (forest harvesting and prescribed burning) to promote the mid- and long-term development of terrestrial lichens. Specific stand conditions where these activities could be considered are discussed in the "Restoration" section (below).
MS	5. In higher-elevation plateau positions that are available for harvesting, maintain: • 80% of the area in mature or old forest but with an irregular group shelterwood silvicultural system (50% removal on a 70-year cutting cycle), with openings not exceeding two tree lengths wide by three to four tree lengths long, to maintain a sustainable supply of terrestrial forage[f] on winter range • 20% of the area in mature or old forest but with a group selection silvicultural system, with openings as above, to maintain arboreal lichens.
Stand conditions: Low-elevation or mid-slope winter ranges	
Unless otherwise noted, timber harvest and silviculture should conform to normal management on MS/SBPS (subhygric–hygric) and BWBS/SBS (mesic–hygric) sites as the production of terrestrial lichens cannot be achieved.	
Silviculture regimes	
SBPS/BWBS/SBS (drier sites)	Silviculture systems should be clearcut or successive patch cuts conducted in a manner that is consistent with landscape-level objectives.
MS (drier sites)	Silviculture system should be an irregular group shelterwood or a group selection with openings not exceeding two tree lengths wide by three to four tree lengths long.
Harvesting and access development	
MS/ESSF/SWB	Limit access, specifically by way of roads and trails, to exposed, windblown alpine slopes that have abundant terrestrial lichen.
SBPS/BWBS/SBS (drier sites)	Maintain or recruit winter range on sites of low site index (less than 14) that are pine dominated (greater than 85%) and of mature to old age (70–140 years old). Maintain clear line-of-sight across roads (or at least at intervals along roads). Minimize road access to winter ranges. Avoid excessive accumulation of logging debris and (or blown-over trees). Minimize surface disturbance to terrestrial lichens (e.g., log in winter if/when a protective snow cover has accumulated).
MS (drier sites)	Maintain or recruit winter range sites that are open canopied (25–55%), are mature and old (greater than 60 years old), and are pine and pine/spruce stands containing abundant terrestrial lichen.

TABLE 4. (Continued)

Regeneration	
SBPS/BWBS/SBS	Maintain approximate tree-harvest species composition. On sites that have become dominated by bryophytes and herbaceous shrubs, consider light scarification or prescribed burning (post-harvest) to enhance succession of vegetation communities that include terrestrial forage lichens.
MS/SBPS (drier sites)	Maintain approximate tree-harvest species composition. Plant at lower than normal densities (less than 1200 stems per hectare). Do not scarify sites in preparation for planting.
Fertilization	
MS/SBPS/BWBS/SBS (drier sites)	No fertilization.
Spacing and thinning	
MS/SBPS/BWBS/SBS (drier sites)	Implement juvenile spacing as required (maximum density of 4000 stems per hectare), to ensure open-canopy conditions (25–55%). Post-spacing standards should be 80% of the target stocking standards.
Restoration	
MS/SBPS/BWBS/SBS (lower-elevation, drier sites)	In most situations, these forested areas will be dominated by beetle-killed trees. Restoration may be considered in forest stands that have been killed by mountain pine beetle, are not scheduled for salvage, and have a site index of 12–16 (lower-productivity stands are likely to retain terrestrial lichens; higher-productivity stands are unlikely to develop a vegetation community dominated by terrestrial lichens). Timber removal by prescribed burning or timber harvest followed by prescribed burning are recommended restoration treatments. Manual brushing may be considered in productive cutblocks (site index greater than 16) within or adjacent to designated areas, especially if the cutblock is a single, isolated unit surrounded by forests that have not been affected by mountain pine beetle.

[a] Biogeoclimatic zones are as follows: BWBS = Boreal White and Black Spruce; ESSF = Engelmann Spruce–Subalpine Fir; MS = Montane Spruce; SBPS = Sub-Boreal Pine–Spruce; SBS = Sub-Boreal Spruce; SWB = Spruce–Willow–Birch.

[b] This is the usual measure (e.g., Kennedy U-7-009: no timber harvest and no road construction) except in Telkwa, where the measure is to retain a minimum of 50% of the forested area in ESSF.

[c] Not all herds (e.g., Takla, Telkwa, Moberly) have suitable range at low elevation.

[d] Minimum ages are referred to in orders and notices and may vary.

[e] The general intent is to aggregate harvest and any anthropogenic disturbance into a localized (rather than dispersed) area. An example is from U-7-007 (Chase, Wolverine, Scott, Finlay herds) as follows: 50% of the area in defined units will be greater than 70 years old and spatially aggregated; harvest within a defined unit completed in less than 20 years; other primary forestry activities completed within 40 years. In some orders, spatially aggregated is defined as blocks of 250 ha.

[f] Practitioners are advised that while this specific silviculture regime has been shown to maintain terrestrial forage lichens, further monitoring may be necessary to prove the regime does not subject caribou to greater spatial overlap with an early-seral predator–prey system.

3. Using a data table of current forest information, determine if the landscape-level GWMs (see desired conditions) are being met.
4. Contact an experienced professional who is knowledgeable about the herd to inquire about the location of special features (e.g., migration routes, mineral licks).

Risks associated with specific forest harvesting and silviculture activities and potential mitigation activities for on-site work are identified in Table 3.

Growth and yield implications

Northern caribou tend to occupy forest that is of lower value for timber harvest (Chowns and Gates 2004), so general impacts on timber supply have usually been low to nil. Also, at least in north-central British Columbia, supply of terrestrial forage lichens in low-elevation habitat depends on periodic disturbance, because advanced vegetation succession tends to lead to bryophytes or vascular plants (Coxson and Marsh 2001; Sulyma and Coxson

2001) on some, but not all, winter ranges (Sulyma 2010). Forest harvest with silviculture is potentially one disturbance option for maintaining the supply of terrestrial forage lichens (Sulyma and McNay 2009b). In the relatively drier and colder climate of the Montane Spruce biogeoclimatic zone, lichen growth tends to persist as a climax vegetation type. Even so, it has been demonstrated that the reduction in lichen abundance resulting from forest harvest can eventually recover to pre-harvest levels using an irregular group shelterwood or group selection silviculture system (Waterhouse et al., in press). It is for these reasons that the implications for forest growth and yield, of managing for the conservation of caribou range, are generally considered to be low.

Monitoring

The Forest and Range Evaluation Program (FREP) is currently developing a monitoring framework for assessing the effectiveness of conservation measures for northern caribou in BC (K. Paige, B.C. Ministry of Environment, pers. comm., February 2010). An interim approach has been suggested by way of a conceptual diagram (Figure 5). In this approach, key

FIGURE 5. A conceptual model for monitoring the effectiveness of areas designated for the conservation of northern caribou in British Columbia. Blue nodes represent possible indicators of overall range effectiveness (green nodes).

indicators are used to judge the overall effectiveness of managing for the conservation of northern caribou range. Presumably, this effectiveness could be set within the context of other population stressors (e.g., other industrial disturbances, disease, hunting mortality, winter severity, etc.) and tested against vital population statistics. Thirteen specific indicators have been included, which essentially relate to the "desired conditions" for northern caribou range. Most of the indicators can be assessed using data tables of the forested land base. One indicator (% cover of lichen) has an established FREP inventory protocol (Sulyma and Sulyma 2008). Strategies and general guidelines outlined here provide options for managing forest stands in British Columbia that have been designated for the conservation of habitat of the northern caribou.

The current emphasis on recovery of declining caribou populations, coupled with the anticipated and widespread ecological change in their habitat, has intensified the need for restoration of caribou range. Many tactics for restoration will likely involve forestry-related activities.

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Test Your Knowledge . . .

Silviculture options for use in ranges designated for the conservation of northern caribou in British Columbia

How well can you recall some of the main messages in the preceding Discussion Paper? Test your knowledge by answering the following questions. Answers are at the bottom of the page.

1. Timber harvesting systems that are most suitable for northern caribou range can be characterized as:
   A) Short periods of intensive development over large areas while reserving equally large areas of no timber harvest
   B) A slow rate of harvest occurring in small openings (e.g., irregular group shelterwood)
   C) Either of the above depending on the herd area and local conditions

2. Examples of silviculture to restore habitat conditions for northern caribou include:
   A) Fertilizing
   B) Prescribed burning
   C) Manual brushing and weeding

3. In determining whether caribou present a risk to silviculture activities (or vise versa), foresters should:
   A) Consult a professional who is knowledgeable about caribou herds in the local area
   B) Follow General Wildlife Measures for the most adjacent Ungulate Winter Range
   C) Determine whether designated areas have been identified and approved

ANSWERS

1. C 2. B and C 3. A and C.