*Extension Note*

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

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## Abstract

This review and synthesis of silviculture practices was conducted to identify options that could be used in managing forest stands in and adjacent to ranges designated for the protection and conservation of mountain caribou in British Columbia. The characterization of mountain caribou habitat, silviculture options, and guiding principles are intended to promote silviculture planning and practices to support, and possibly accelerate, the return of suitable habitat conditions needed to assist with mountain caribou habitat and population recovery.

**KEYWORDS:** Alectoria *spp.;* Bryoria *spp.; caribou habitat rehabilitation; General Wildlife Measures; Government Actions Regulation Orders; mountain caribou (*Rangifer tarandus*); predation; silviculture practices; suitable winter caribou habitat.*

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## Introduction

Mountain caribou are one of three ecotypes of woodland caribou subspecies (*Rangifer tarandus*) found in British Columbia. The non-taxonomical ecotype classification is based primarily on differences in distribution, behaviour, and habitat requirements. The mountain caribou ecotype inhabit the rugged mountainous regions of central and southeastern British Columbia, where they traverse the range of forested and subalpine habitats from valley bottoms to alpine, exhibiting unique habitat use patterns, seasonal migrations, predator-avoidance, and winter diet selection that differ from other woodland caribou ecotypes. In winter, they feed almost exclusively on arboreal hair lichens (*Bryoria* spp. and *Alectoria* spp.) associated with mature and old forests (Spalding 2000; Mountain Caribou Technical Advisory Committee 2002).

Mountain caribou have been in decline in recent decades, resulting in the Committee on the Status of Endangered Wildlife in Canada to designate mountain caribou as threatened and the BC Conservation Data Centre to place mountain caribou on the provincial Red list. In 2007, the provincial government announced the Mountain Caribou Recovery Implementation Plan, designed to recover caribou to their pre-1995 level of 2500 animals throughout their existing provincial range (Integrated Land Management Bureau 2007). To protect critical mountain caribou winter habitat, Government Actions Regulation orders were enacted in 2009 for Ungulate Winter Range (UWR) and Wildlife Habitat Areas (WHAs) and associated General Wildlife Measures (GWM) for designated areas requiring additional management not otherwise provided for under orders or other enactments needed to protect and conserve mountain caribou and their habitat.

Mountain caribou require large areas of old-growth forests in the Interior Cedar–Hemlock and Engelmann Spruce–Subalpine Fir biogeoclimatic zones (Mountain Caribou Technical Advisory Committee 2002; Stevenson et al. 2001). Clearcut logging has removed old forests that support arboreal lichens on which mountain caribou depend during the winter period. It may take a century or more to recover the lichen biomass that has been lost to clearcut logging (Armleder and Waterhouse 2010). Maintaining and, where feasible, accelerating recovery of suitable winter habitat is essential to mountain caribou recovery.

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A key objective of the Forests for Tomorrow program is to reduce to the amount of Crown forest land that is not satisfactorily restocked (stemming from wildfires and mountain pine beetle epidemics) and to assess the effects of these disturbances on future timber supply and other non-timber resource values (i.e., risks to biodiversity, water, fish, wildlife, and habitat). Strategic silviculture planning undertaken by Forests for Tomorrow is designed to identify timber supply and habitat supply (Type I and II) issues and to support development of silvicultural strategies that address these issues (Forsite 2008). Forests for Tomorrow can thereby direct silviculture activities and select sites with the highest potential for enhancing multiple economic, environmental, and social values (i.e., improving timber supply; potentially accelerating mountain caribou habitat recovery; and possibly reducing risks to biodiversity, water, fish, and other wildlife and their habitats).

The objective of this extension note is to synthesize the latest scientific information on silviculture management options that could be used in and adjacent to ranges designated for the protection and conservation of mountain caribou in British Columbia. This characterization of mountain caribou habitat, silviculture options, and guiding principles is intended to promote silviculture planning and practices that support, and possibly accelerate, the return of the suitable habitat conditions that are needed to assist with mountain caribou habitat and population recovery.

## Methods

A literature review was completed and information compiled on the status of mountain caribou populations and habitat characteristics, and on research and operational trials that involve forestry and silviculture activities in mountain caribou habitat, in consultation with various experts. Consistent with the mountain caribou recovery planning direction, emphasis is placed on early- and late-winter caribou ranges and habitat attributes.

## Background

### Current population status and trend

Hatter (2006) estimated that 1912 mountain caribou were distributed among 15 local herds occupying the mountainous interior wetbelt of central and southeastern British Columbia (Table 1). Over four-fifths (83%) of the remaining population of mountain caribou exists in four herds in the east-central portion of their range. Ten herds have 50 or less caribou; six of these comprise less than 20 animals. The Purcell Central and George Mountain herds were recently considered extirpated.

Figure 1 illustrates that the current range of mountain caribou in British Columbia is estimated at 62 788 km$^2$, and the potential range available for occupancy, based on habitat suitability and expert opinion, is 85 965 km$^2$ (McNay et al. 2006). The range of the trans-boundary South Selkirk herd extends into northern Idaho and Washington in the United States.

### Characteristics of mountain caribou habitat

The majority of mountain caribou habitat in British Columbia (84%) is found in the forested Interior Cedar–Hemlock (ICH; 23%) and Engelmann Spruce–Subalpine (ESSF; 61%) biogeoclimatic zones (Figure 2; Mountain Caribou Technical Advisory Committee 2002; Cichowski et al. 2004), with variation in range selection strategies among herds being primarily related to climatic conditions, terrain, and, particularly in low-elevation habitats, snow conditions (Stevenson et al. 2001; Apps in McNay et al. 2006). The southern herds that occupy the drier south Purcell Mountains (South Purcells and South Selkirks) use the ESSF almost exclusively and seldom move to lower-elevation ICH in early winter (Rominger and Oldemeyer 1990; Kinley and Apps 2007). The herds in the steep, rugged, very wet, and high-snowfall North Columbia Mountains (Nakusp, Duncan, Monashee, Columbia South, Columbia North, Central Rockies, Frisby-Boulder, and Monashee) are noted for their vertical seasonal migrations between the ICH and

**TABLE 1.** Mountain caribou population estimates, trends, risk status, herd range size, and density estimates for mountain caribou herds in British Columbia

| Caribou herd | Population estimate[a] | Recent trend[b] | Risk status[c] | Range[d] (km$^2$) | Density (no./1000 km$^2$) |
|---|---|---|---|---|---|
| Barkerville | 50 | unknown | S | 741 | 67 |
| Central Rockies | 3 | declining | SD | 759 | 4 |
| Columbia North | 140 | stable | | 4652 | 30 |
| Columbia South | 14 | declining | SD | 1691 | 8 |
| Duncan | 7 | declining | SD | 447 | 16 |
| Frisby-Boulder | 12 | declining | SD | 692 | 17 |
| Groundhog | 23 | unknown | S | 1006 | 23 |
| Hart Ranges | 718 | unknown | | 12 466 | 58 |
| Monashee | 7 | declining | S | 194 | 36 |
| Nakusp | 77 | declining | SD | 2342 | 33 |
| Narrow Lake | 48 | declining | SD | 424 | 113 |
| North Cariboo | 265 | unknown | | 2327 | 114 |
| Purcells South | 15 | declining | SD | 772 | 19 |
| South Selkirks | 43 | declining | S | 1296 | 33 |
| Wells Gray | 490 | unknown | | 9405 | 52 |
| ***Mountain total*** | ***1912*** | | | ***39 214*** | ***42*** |

[a] (Hatter 2006).

[b] Recent trend is defined as a population change of greater than 20% within the last 7 years.

[c] S = sensitive (< 100 animals); SD = sensitive herds suspected of being in decline.

[d] Current occupied range.

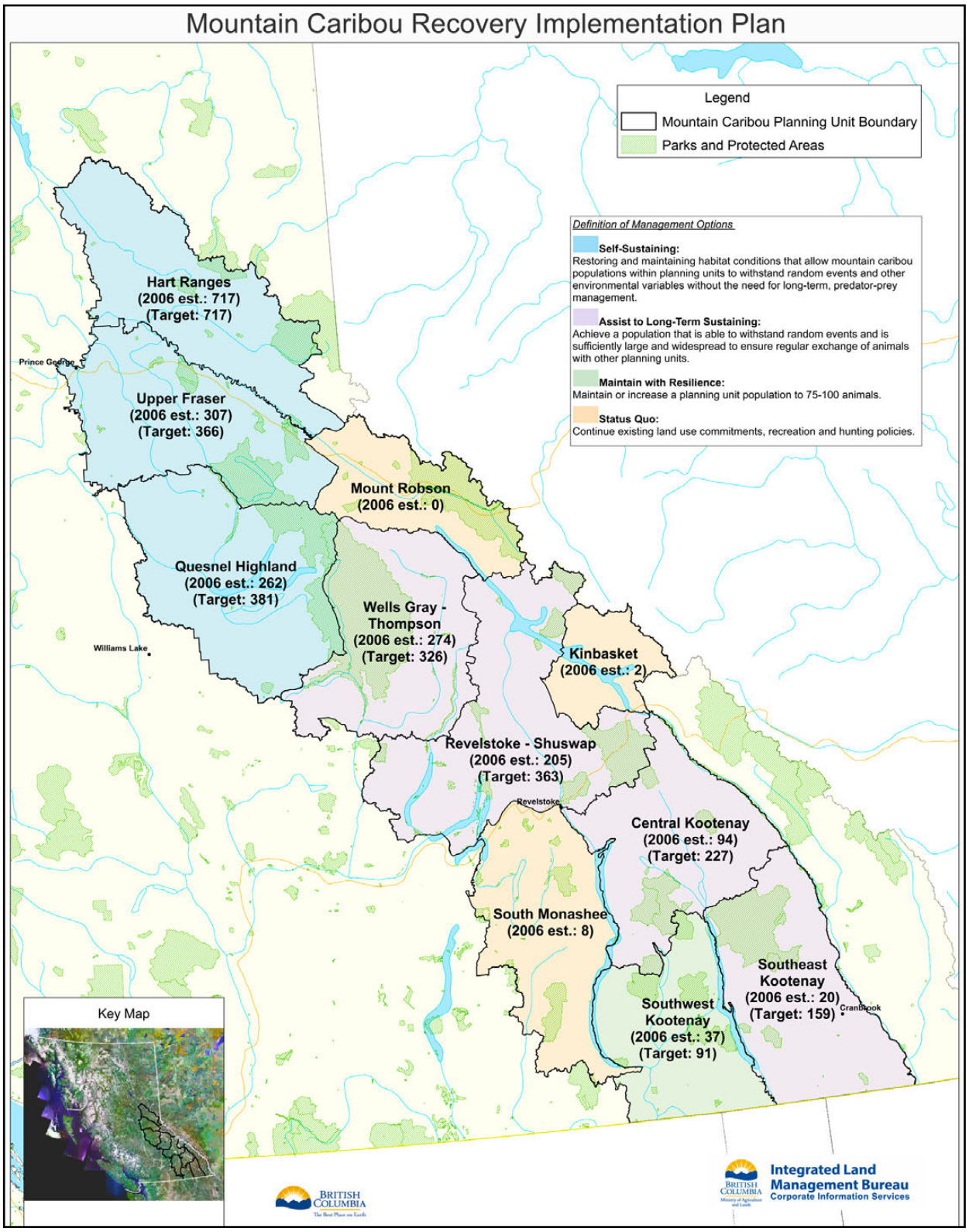


**FIGURE 1.** Identified Mountain Caribou Recovery Area by Planning Unit, including 2006 population estimates and recovery population targets (B.C. Ministry of Environment 2009).

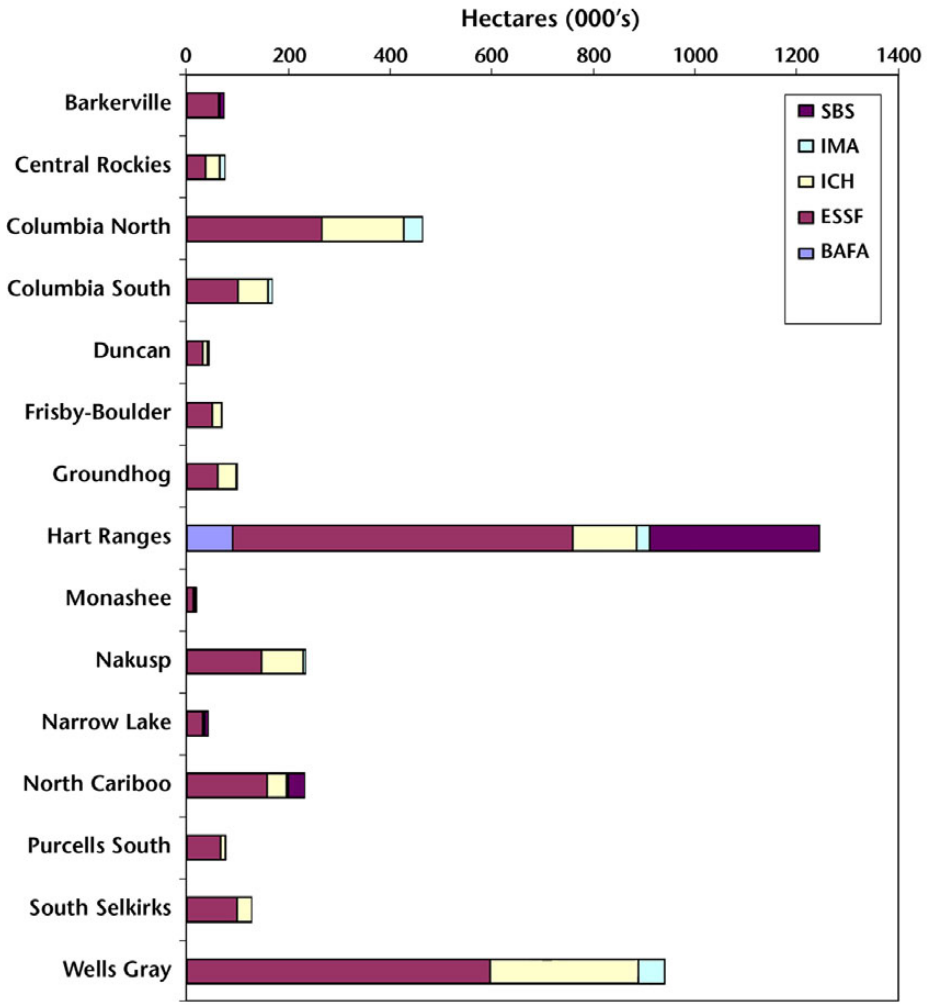


**FIGURE 2.** Biogeoclimatic zones (Meidinger and Pojar [editors] 1991) occupied by mountain caribou ecotype in British Columbia (SBS = Sub-Boreal Spruce; IMA = Interior Mountain-heather Alpine; ICH = Interior Cedar–Hemlock; ESSF = Engelmann Spruce–Subalpine Fir; BAFA = Boreal Altai Fescue Alpine).

ESSF, and their extensive use of the ICH during the early-winter snow-accumulation period (Hamilton et al. 2000; Apps et al. 2001). Caribou that live in the less rugged terrain of the moderately wet Quesnel Highland (Hart, Narrow Lakes, Barkerville, North Cariboo, Wells Grey, Allen Creek, and Groundhog) may shift to lower elevations in any given year and make use of the Sub-Boreal Spruce (SBS) zone instead of (or in addition to) the ICH, but a significant proportion of the population more often remains at high elevations, where it feeds on the arboreal hair lichens and terrestrial lichens found in subalpine bowls and windswept ridges (Seip 1990; Apps and Kinley 2000; Terry et al. 2000; Johnson et al. 2004).

### *Winter habitat*

In early winter when snow begins to accumulate (November to mid-January), mountain caribou that live in the high-snowfall and rugged mountainous terrain of the North Columbia Mountains typically migrate to low-elevation ICH and mid-elevation ICH/ESSF mature/old forest ecotone habitats (Antifeau 1987; Apps et al. 2001). It is during the early winter period when snow conditions limit locomotion and reduce forage availability that caribou forage on a combination of ground vegetation such as falsebox (*Paxistima myrsinites*), wintergreen (*Pyrola*), and arboreal hair lichens (*Bryoria* spp. and *Alectoria* spp.) available as lichen litterfall and on windthrown trees (Simpson et al. 1997; Rominger et al. 1996). In contrast, caribou in the southern Purcell Mountains rarely descend to lower elevations during early winter but remain primarily in the ESSF alpine forest, where they feed on grouseberry (*Vaccinium scoparium*),

terrestrial lichen (*Cladonia* spp.), and arboreal lichen. Caribou that live in the less rugged terrain on the Quesnel Highland may shift to lower elevations in any given year, but a significant proportion of the population more often remains at high elevations where they feed on arboreal lichens dominated by subalpine fir and terrestrial lichens found on windswept ridges or subalpine bowls (Seip 1990; Apps and Kinley 2000; Terry et al. 2000; Johnson et al. 2004).

During late winter (January to mid-April), after the snowpack deepens and consolidates, the caribou's relatively large hooves enable them to travel on top of the snowpack, to feed almost exclusively on arboreal hair lichens (Wilson 2005). Suitable habitat consists of mature and old subalpine fir-dominated stands (generally less than 140 years old) that are relatively open canopied (400–500 stems per hectare) and on flat to gentle slopes, and that include subalpine bowls and ridgelines, which support standing live and dead trees with abundant arboreal lichen (Rominger et al. 1996; Mountain Caribou Technical Advisory Committee 2002; Stevenson et al. 2001; Waterhouse et al. 2007).

### *Arboreal lichens*

During winter, mountain caribou rely almost exclusively on arboreal lichen, and tend to choose *Bryoria* spp. over *Alectoria* lichens (Stevenson and Hatler 1985; Rominger et al. 1996). Studies have confirmed that mature and old forests have more abundant, diverse, and variable lichen communities than younger stands (Goward 1998; Stevenson et al. 2001). At the forest-stand and individual-tree scales, the relationship between lichen abundance and the foliated versus defoliated branches is very important (Goward 1998; Goward and Campbell 2005). Although lichen colonizes trees at early ages, it does not usually achieve appreciable biomass until much later.

Waters and Delong (2001) found that *Bryoria* spp. biomass in trees is much heavier in the defoliated zone than in the foliated zone, probably because of the intolerance of *Bryoria* spp. to prolonged wetting in the foliated zone, and because the distribution and abundance of arboreal lichens in forest stands is intimately connected with the structure of those stands. Within trees, arboreal lichen distribution and abundance is influenced by vertical gradient differences created by sun exposure, moisture, air movement, and stand ventilation (Coxson et al. 1984; Goward 1998; McNay et al. 2006).

Waterhouse et al. (2007) measured the response of arboreal lichen to harvesting of 30% of the forested area using three partial-cutting treatments, which created small (0.03 ha), medium (0.13 ha), and large (1.0 ha) openings, and a no-harvest treatment. Treatments were replicated on four sites, and monitored over a 10-year post-harvest period. The short-term loss of lichen associated with removal of approximately one-third of the trees was partially offset by a significant ($P = 0.01$) increase in lichen abundance on trees in the caribou-feeding zone (up to 4.5 m) in the three partial-cutting treatments relative to trees in the uncut forest. Differences among treatments in the change of lichen composition, as measured by the percentage of *Alectoria* spp. and *Bryoria* spp. were marginally significant ($P = 0.10$). The partial-cutting treatments showed a greater likelihood of shifting towards more *Bryoria* spp.

Waters and Delong (2001) concluded that silviculture treatments applied to managed stands have the potential to accelerate the development of key habitat attributes for mountain caribou (including abundance of arboreal lichen and understorey falsebox) and open-stand structure conditions, with some large trees providing good sightlines and snow interception cover.

## Planning context

### *Legal orders*

As part of the Mountain Caribou Recovery Implementation Plan (Integrated Land Management Bureau 2007), the Ministry of Environment has put into effect Government Actions Regulation orders for WHA, UWR, and associated GWM (Figure 3):

- No Harvest Zone
- Modified Harvest Zone
- Restricted Harvests Zone
- Connectivity Zone

Road and silviculture activities within these zones will need to align with the goal of maintaining or returning areas to a suitable habitat condition as soon as possible. Recognizing that suitable caribou habitat conditions may take decades to recover, silviculture activities must promote, or even accelerate, the development of suitable forest species and forest structural characteristics and conditions.

The Orders, accompanying Government Actions Regulation rationale, and detailed mapping are available at these Ministry of Environment websites:

- WHA – *http://www.env.gov.bc.ca/cgi-bin/apps/faw/wharesult.cgi?search=show_approved*
- UWR – *http://www.env.gov.bc.ca/wld/frpa/uwr/approved_uwr.html*

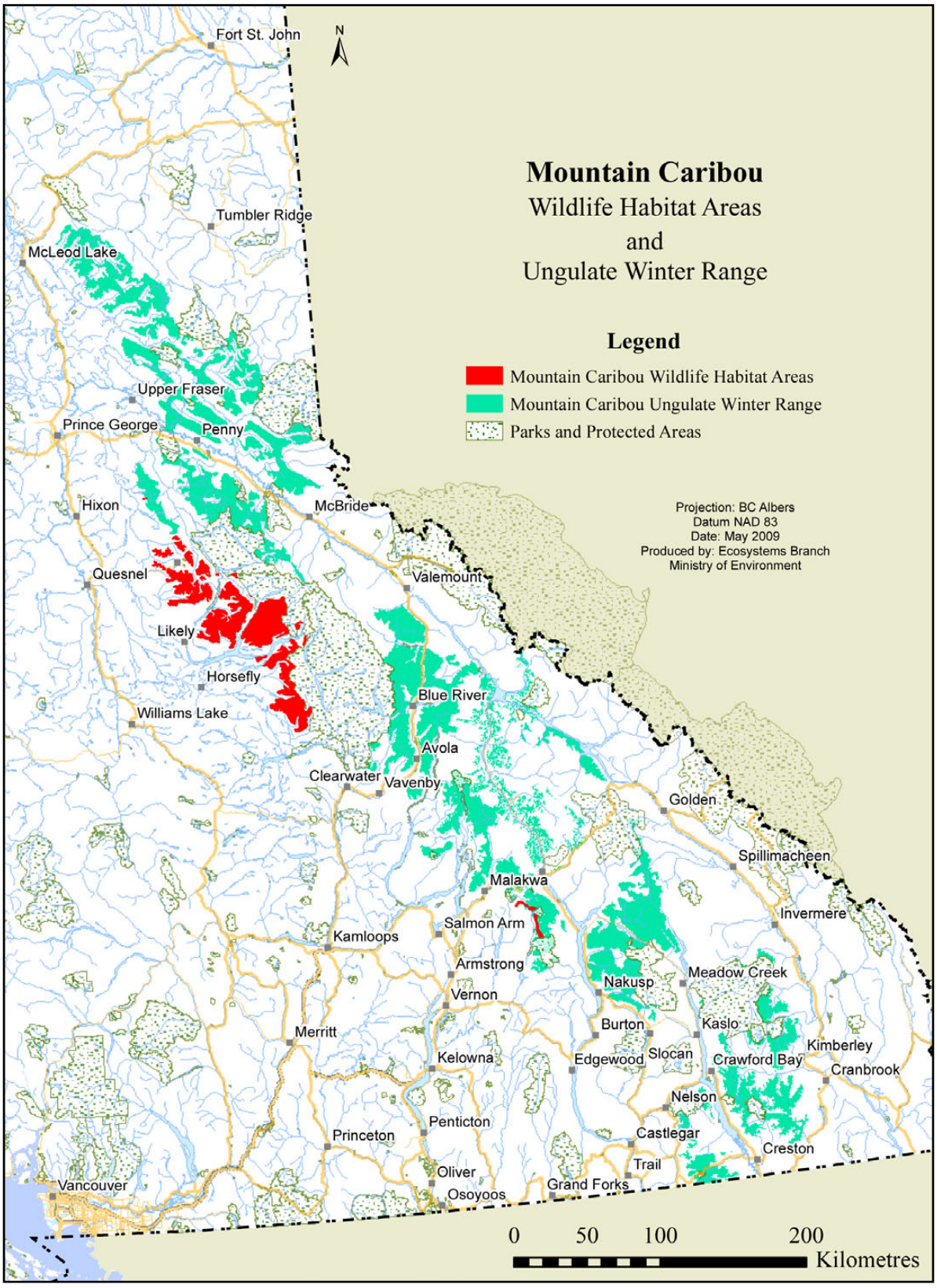


**FIGURE 3.** Mountain caribou Wildlife Habitat Areas and Ungulate Winter Ranges.

***Guiding principles***

The goal for conducting silviculture activities in designated caribou habitat is to maintain forest stands continuously as suitable habitat by maintaining and promoting trees and forest stand conditions with forest stand characteristics known to be important to caribou.

1. Mountain caribou require large areas of suitable old-growth forests and rely almost entirely on arboreal (and some terrestrial) lichens during winter. Providing quality, lichen-bearing habitat is only one important requirement for caribou (Stevenson et al. 2001; Armleder and Waterhouse 2010). Recent declines have been attributed directly to predation and indirectly to the results of habitat loss and fragmentation, and human disturbances from motorized recreation activities (Wilson 2005).
2. Suitable early- and late-winter caribou habitats that are not heavily fragmented as a result of past harvest and (or) road development should be retained for as long as possible.
3. Harvesting and silviculture practices that achieve desired stand- and landscape-level mountain conditions should be applied (or not applied) to the extent that they will reduce and mitigate risks, and maintain, enhance, or accelerate the supply and suitability of habitat for caribou. Resource managers and forest practitioners are strongly advised to contact local government representatives and caribou specialists for information on managing caribou habitat in local designated areas.
4. Mountain caribou prefer balsam and balsam-spruce forest stands over spruce and spruce-balsam forest stands.
5. Mountain caribou prefer stands dominated by western hemlock and western redcedar to stands dominated by white spruce, lodgepole pine, or Douglas-fir.
6. Important factors for the development of arboreal hair lichen, a primary winter food source for caribou, include availability of defoliated branches (attachment sites), openness of the forest stand (ventilation), and a stable environmental condition (Goward and Campbell 2005).
7. Partial-cutting systems are the preferred alternative to clearcuts. The plan should be for multiple harvests over a 240-year period, with a minimum 80-year cutting cycle (Stevenson et al. 2001).
8. The maximum level of removal should not exceed 30% by volume, basal area or area, exclusive of roads, landings, wildlife tree patches, and other reserves. A harvest level of 33% may be acceptable if 10% of the block has been designated as a "within block" wildlife tree patch (Stevenson et al. 2001).
9. Many standing trees that are dead or dying support substantial amounts of arboreal lichen and are a source for dispersal of lichen propagules. Worker training and certification (Wildlife Danger Tree Assessor's course) will be required to ensure these important habitat features can be assessed and safely retained, where applicable.
10. To reduce the overall landscape-scale impact on caribou, new forest openings should be concentrated in time and space into areas where habitat suitability values have already been compromised through previous harvest and road access (i.e., aggregate cutblocks and harvesting in already fragmented habitat).
11. Forest openings should be targeted into areas where there are higher concentrations of less desirable species (lodgepole pine, Douglas-fir, western larch, spruce) and where there are fewer lichen-bearing trees. To support multiple objective management decisions, it may be desirable to model the implications of silviculture management activities on the habitat supply of key caribou habitat characteristics and desired conditions.

## Silviculture activities in designated mountain caribou habitat

In 2005, the Mountain Caribou Science Team called for the provision of large, contiguous tracts of suitable habitat, with abundant forage for early and late winter, to assist with population recovery and minimize predation risk. The space required by mountain caribou populations may be significantly greater than the space required to attain sufficient forage (Stevenson et al. 2001). Mountain caribou require these large tracts of old-growth forest habitat (Armleder and Waterhouse 2010), where they can exist in low densities (30–50 caribou per 1000 $km^2$; Mountain Caribou Technical Advisory Committee 2002) and rotate use of their winter ranges as an anti-predator strategy (Identified Wildlife Management Strategy 2004).

One of the principles of prey management set forth in *Recommendations for Predator–Prey*

*Management to Benefit the Recovery of Mountain Caribou in British Columbia* (Wilson 2009) is that moose density targets[1] fall within the ranges expected under a natural disturbance regime applied to their habitat. Analysis from the report showed that suitable moose habitat (forests less than 40 years old) represent 35% of the caribou matrix habitat[2] compared to 18% for the natural disturbance regime model. Mountain caribou have also been noted to avoid young forests (Rominger et al. 1996; Seip 1992; Apps and Kinley 2000; Serrouya et al. 2006).

Areas with limited or no vehicle access and reduced human disturbance are essential. Fragmentation by roads and recreational use should be considered when planning for connectivity at the landscape scale (Stevenson et al. 2001; Waters and Delong 2001; Serrouya et al. 2006).

Table 2 describes landscape- and stand-level winter habitat conditions for mountain caribou. Table 3 suggests alternative silviculture practices that should be encouraged, to promote or accelerate mountain caribou habitat recovery in designated areas.

[1] The predator-prey plan recommends that moose be the focus of the prey reductions and deer populations should be prevented from increasing, where feasible.

[2] Matrix habitat is defined as an area inhabited outside of caribou habitat (with caribou habitat defined by Government Actions Regulation Orders) that provides habitat that influences wolf or cougar density in the caribou range (Wilson 2009).

**TABLE 2.** Desired conditions for mountain caribou winter habitat

| Biogeoclimatic zone | Landscape-level habitat considerations |
|---|---|
| BAFA, ESSF, ICH, IMA, MS, SBS | • **Connectivity –** Mature and old forests that provide travel corridors between suitable seasonal habitats (landscape linkages) and dispersal areas within seasonal habitats. Important habitat attributes include security and thermal cover on all seasonal ranges, and snow interception cover on early winter ranges.<br>– Ensure a habitat connectivity continuum from upper elevation subalpine parkland, BAFA, and upper ESSF winter habitat through to mid- to lower-elevation ICH, MS (Montane Spruce), SBS early winter habitat (GWM for "connectivity and travel corridors").<br>– Planning for connectivity should consider habitat fragmentation caused by roads and recreational use and avoidance by caribou of young forests (< 40 years old).<br>– Maintain or restore connectivity corridors to facilitate predator avoidance and migratory movement of caribou between seasonal ranges.<br>• **Patch size distribution –** Maintain early-seral matrix forest conditions (amount and distribution) similar to hypothetically unmanaged, natural disturbance regimes to avoid excessive morality risk associated with colonization by, or increases in, primary prey species.<br>• **Seral stage distribution –** Maintain or move toward a proportion of mature and old forest to younger stands that would be similar to hypothetically unmanaged, natural disturbance regimes at the ecosystem scale of mountain caribou population distribution.<br>• **Access management –** Connectivity planning needs to consider that caribou are known to avoid young forests. Fragmentation by roads and recreational use should be included in evaluating and planning for connectivity. Minimize motorized access and recreation related impacts on caribou and their habitats. Protect caribou from access-related impacts through developing access management plans.<br>• **Arboreal hair lichens –** Maintain a sustainable supply of arboreal lichen forage (*Bryoria* spp. and *Alectoria* spp.) on early and late winter caribou ranges (≥ Lichen Class 3, with some Class 4 and 5; Armleder et al. 1992). |
| | **Stand-level planning considerations** |
| | • Maintain forest stands with habitat conditions suitable for caribou use continuously through time by maintaining forest stands and trees with late seral stand structural characteristics needed to support key habitat elements (Stevenson et al. 2001; Mountain Caribou Technical Advisory Committee 2002). |

**TABLE 2.** (Continued)

| Biogeoclimatic zone | Stand-level habitat considerations |
|---|---|
| **Early and Late Winter** | • Maintain pre-harvest species composition.<br>• Manage for abundant arboreal forage lichens available on standing live, dying, and dead trees. Retain a component of declining trees/snags (Wildlife Tree Classes 2-4).<br>• Ensure there are no obstructions to visibility (line of sight distances) or restriction to movement within and between stands.<br>• Manage for winter recreation access controls on high suitability winter ranges. |
| **Early Winter**<br>**ICH, SBS, upper ICH/ lower ESSF ecotone, MS** | • Ensure a sustainable supply of arboreal hair lichens in the mid- and upper-tree canopy (i.e., early winter forage as lichen litterfall from live and dead standing trees and on downed wood, windthrown trees) as lichen productivity is often restricted by the vertical gradient limitations associated with low elevation, closed canopy forests of the Interior wetbelt (Coxson et al. 1984; Goward 1998).<br>• Provide snow interception cover with forest crown conditions that will hold snow in the forest canopy (high canopy closure, multi-layered structure dense, wide, long crowns) thereby reducing ground snow depths, increasing caribou locomotion and movement to feeding sites, and exposing low evergreens such as falsebox (*Pachistima myrsinites*).<br>• Avoid harvesting or site preparation activities that enhance shrub species such as willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), elderberry (*Sambucus* spp.), and Douglas maple (*Acer glabrum*), which are preferred by moose, elk, and deer. |
| **Late Winter**<br>**Alpine parkland, upper ESSF, IMA, BAFA** | • Manage for abundant arboreal hair lichen forage in the caribou feeding zone in the lower tree canopy (< 4.5 m) on live and dead standing trees (preferred) and individual trees (less productive) in a clumpy arrangement and with a significant component of trees and tree clumps with more than Lichen Class 3 (Waterhouse et al. 2007; Hamilton et al. 2009).<br>• Encourage *Bryoria* spp. lichen. It prefers the wetter macroclimates (mesic to subhygric), more open stands (< 35% canopy closure), and tends to be more abundant higher in the canopy unless there is either dead or defoliated branches low in the canopy (Goward 1998; Goward and Campbell 2005).<br>• Manage for early development of an inner defoliated zone to support arboreal hair lichen. |

**TABLE 3.** Silviculture options in designated mountain caribou areas

| Activity | Caribou habitat management strategies |
|---|---|
| **Single tree** | ***This system is most suited to balsam-spruce and mixed forest types where multi-storied stand structure conditions are selection present.***<br>• Retention of clumps and diversified tree densities enhances lichen abundance (e.g., trials indicate *Bryoria* spp. maintained same growth rate where trees were clumped but had lower growth rates in irregular shelterwood, where trees were more uniformly distributed; Jull and Stevenson [editors] 2001; Waterhouse et al. 2007). If a choice must be made between two trees, retain the tree with the most lichen. Clumps of trees with lichen are preferred where they occur naturally (3–10 trees or one tree length in size; Stevenson et al. 2001; Waters and Delong 2001; Waterhouse et al. 2007; Hamilton et al. 2009).<br>• Maintain the existing vertical stand structure during removal: Retain representative trees/clumps from the dominant, codominant, and intermediate crown classes, sizes, and distribution (Hamilton et al. 2007).<br>• No harvesting of largest trees on site and retain standing live and dead trees (particularly those trees/clumps supporting arboreal lichens):<br>– ICH – minimum 30 snags per hectare, with 10 snags per hectare > 50 cm DBH (diameter at breast height)<br>– ESSF – minimum 25 snags per hectare, with 5 snags per hectare > 50 cm DBH (Stevenson et al. 2001; Waters and Delong 2001; Manning, Cooper and Associates 2004). |

**TABLE 3.** (Continued)

| Activity | Caribou habitat management strategies |
|---|---|
| | • Basal area live trees > 20–25 m (Rominger et al. 1996; Manning, Cooper and Associates 2004).<br>• Minimize damage to residual stems. |
| **Group selection** | ***This system is suited to almost any stand in mountain caribou habitat.***<br>• ≤ 30% volume removal on an area basis, including skid trails, over an 80-year cutting cycle (Stevenson et al. 2001; Waters and Delong 2001; Manning, Cooper and Associates 2004)<br>• Openings should be 0.2–1.0 ha, with a mean opening size of 0.5 ha (Stevenson et al. 2001; Waters and Delong 2001; Armleder and Waterhouse 2010).<br>• Shape of the openings can vary to incorporate natural clumps of trees within the stand.<br>• Distribute openings throughout the block so that the second and third entries can also be well distributed.<br>• Keep openings at least three tree lengths apart.<br>• Retain a minimum 25–30 standing dead and dying trees per hectare (Stevenson et al. 2001; Manning, Cooper and Associates 2004). |
| **Restoration** | • Densely stocked stands may reduce caribou movement within and across landscapes, which can isolate other suitable habitats and reduce ability of caribou to disperse across the broad landscape. This dispersion habitat use pattern is especially important during summer when predation rates on caribou are highest (Wittmer et al. 2005).<br>• Densely stocked stands in the wetter ESSF and ICH/ESSF ecotone may preclude development of suitable microclimate stand conditions needed to provide the appropriate branching structure more likely to support an abundance of *Bryoria* spp. low in the canopy. Such conditions include relatively low canopy closure, and sun exposure and air flow to facilitate the frequent drying that *Bryoria* spp. requires (Goward 1998; Campbell and Coxson 2001; Apps in McNay et al. 2006).<br>• Management intervention can be applied to accelerate the recruitment of suitable habitat conditions for caribou (e.g., spacing and thinning to reduce stocking densities, promoting open-growing conditions for individual trees and tree clusters/clumps, and reducing high shrub domination of understorey; Hamilton et al. 2009). |
| **Planting and site preparation** | • Manage for relatively low stocking density (300–600 live and 25–30 standing dead/dying stems per hectare) of predominately subalpine fir trees with Engelmann spruce, distributed in variable size clumps/clusters and spacing densities.<br>• Moderate (1000–1100 stems per hectare) rather than low tree densities early in stand history will discourage browse species for other ungulates (alternative prey/predators) and later encourage dieback of lower branches, which improves sightlines and tree inner core lichen conditions. Thinning or spacing later in stand development should focus on stem density, clumpy patches, and intertree spacing for habitat enhancement (400–500 stems per hectare; Waterhouse et al. 2007).<br>• The species mix and composition of the regenerating stand should be, as it nears maturity, as similar as possible to that of the unharvested stand (i.e., pre-harvest tree species composition).<br>• The regenerating stand should be composed of a mixture of shorter- and longer-lived, shade-tolerant conifer species.<br>• Regeneration prescription should recognize existing residual/advanced regeneration as preferred crop trees (i.e., uneven-aged/multi-layer stocking standards). Retention of advance regeneration provides stand structural elements not provided for many years by planted or newly established regeneration.<br>• Define acceptability criteria for advanced regeneration in the block prescription.<br>• Short-lived, shade-intolerant species (i.e., lodgepole pine, western larch, hardwoods) should not be permitted as preferred or acceptable in the stocking standards for the block because the silvics and stand structure characteristics produced by such species are incompatible with long-term maintenance of caribou habitat. |

**TABLE 3.** (Concluded)

| Activity | Caribou habitat management strategies |
|---|---|
| **Planting and site preparation *(continued)*** | • Seedlings should be planted to mimic the natural tendency to clumpy stocking. Reduce intertree distance to 1.0 m and "cluster" plant seedlings in groups of four to six trees. Space clumps 5–7 m apart.<br>• Where single tree selection systems are used, set basal area targets for the post-harvest stand. A stand with a well-distributed (by area and vertical structure), retained basal area of 18–20 $m^2$/ha should be considered for caribou.<br>• Utilize excavator mounding to create raised microsites for planting where needed. Clumpy mounding (groups of two to five mounds per group) is recommended to mimic the natural pattern of clumpy stocking that occurs in natural stands. |
| **Brushing** | • Avoid harvest or site preparation activities that may promote growing conditions or re-establishment of seral shrub communities such as willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), elderberry (*Sambucus* spp.), and Douglas maple (*Acer glabrum*), which are preferred forage by moose, elk, and deer. |
| **Herbicides** | • Do not use herbicides on sites with potential to promote growing conditions or re-establishment of seral shrub communities such as willow (*Salix* spp.), red-osier dogwood (*Cornus stolonifera*), elderberry (*Sambucus* spp.) and Douglas maple (*Acer glabrum*), which are preferred forage by moose, elk, and deer. |
| **Spacing and thinning** | ***ESSF and ICH/ESSF ecotone***<br>• Dense young forest and pole/sapling stands that are homogeneous may be spaced or thinned to encourage or even accelerate development of multi-layered stand structure with heterogeneous spacing.<br>• Protect gaps, hardwoods, wolf trees, and old-growth remnants to promote epiphytic macrolichens in young conifer forests.<br>• Moderate rather than low densities early in stand history will discourage browse species for other ungulates (alternative prey and associated predator pressure) and encourage dieback of lower branches, which improves sightlines and tree inner core lichen conditions (Goward 1998).<br>• Thinning or spacing later in stand development should focus on stem density, clumpy patches, and intertree spacing for habitat enhancement (300–600 live and 25–30 standing dead/dying stems per hectare). |
| **Pruning** | • Do not prune in the ESSF, where caribou feed off the lichens on the lower branches of the trees (i.e., caribou feeding zone).<br>• Pruning could be used to improve sightlines (visibility) in ICH stands, as these low-elevation stands generally provide very limited lichen forage in the lower portions of the canopy that would be within reach of caribou (Manning, Cooper and Associates 2004). |
| **Protection** | • Caribou have adapted to forests that regenerate through natural, gap-dynamic processes. A district fire plan should be developed in consultation with Ministry of Environment to identify and prioritize mountain caribou ranges where some level of natural fire disturbance may be acceptable (i.e., terrestrial lichen ecosystems) and ranges to be protected (i.e., arboreal lichen ecosystems). |

## Growth and yield Implications

Managing for caribou habitat within areas of the timber havesting land base may have the following implications on expected tree growth rates and forest regeneration.

- Modelling TIPSY losses of 20–30% aggregate retention equates to 25–40% volume reduction in regeneration.
- Shifts in tree species composition may result when managing sites for shade-tolerant species (i.e., western hemlock, western redcedar).
- Multi-entry silviculture systems can reduce the amount of grow space as more of the site can be occupied in more permanent road and landing infrastructure.

- Reduced tree stocking levels that promote tree crown development and wider, more fully developed crown characteristics will result in fewer trees than may be found in stands managed at higher tree stocking levels.
- Windthrow can be an issue with increased multi-entry systems.
- With the emphasis on retaining older veterans with full crown development, there is an expectation that the stand will be managed for a longer rotation period.

*Management actions needed to support maintenance, protection, and enhancement of caribou habitat and recovery planning are complex, in that caribou range is large and diverse, and recovery is expected to take a long time.*

## Monitoring

Several monitoring programs have been developed to evaluate management activities in mountain caribou habitat. Management actions needed to support maintenance, protection, and enhancement of caribou habitat and recovery planning are complex, in that caribou range is large and diverse, and recovery is expected to take a long time (Wilson and Nyberg 2009). In recognition of work already completed in this area, I recommend linking into four of the existing monitoring programs (adjustment may be needed based on local issues).

1. ***A Proposed Monitoring and Adaptive Management Strategy for Mountain Caribou Recovery Implementation*** (Wilson and Nyberg 2009): *http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs2010_2/468580/wilson_nyberg_adaptive_mgmnt_strategy_final_21sept09.pdf*
   The provincial recovery implementation plan for mountain caribou announced in 2007 includes a requirement to "support adaptive management and research and implement effectiveness monitoring plans for habitat, recreation and predator-prey management." The plan notes that the management actions required for implementation of the caribou recovery plan are complex, in that caribou range is large and diverse and recovery is expected to take a long time. A weight-of-evidence approach is adopted that allows for comparisons to be made among areas that are subject to different management regimes or through modelling of policy options and predicted outcomes.
2. ***Mountain Caribou in Managed Forests: Recommendations for Managers*** (Stevenson et al. 2001): *http://www.env.gov.bc.ca/wld/documents/techpub/r26_mtcaribou.pdf*
   This is probably the most comprehensive coverage in relation to forestry activities and mountain caribou habitat. Silvicultural systems are identified for maintaining caribou habitat, based on decades of management trials. Included are metrics for partial- and group-selection cutting at the landscape and stand levels.
3. ***Recruiting Caribou Habitat Using Silviculture Treatments*** (Waters and Delong 2001): *http://www.env.gov.bc.ca/wld/documents/fia_docs/recruit_caribou_guidelines_s.pdf*
   Adapted from work by Stevenson et al. (2001), the authors provide a stand-level ranking guide for pre-harvest (spacing, pruning, girdling, etc) and commercial harvest options (commercial thinning, late-seral stand attribute recruitment, single tree selection, and group selection) to help evaluate the potential of a stand for treatment.
4. ***Silviculture Guidelines and Practices for Maintaining or Recruiting Key Habitat Objectives*** (which includes a mountain caribou module; Manning, Cooper and Associates 2004): *http://www.env.gov.bc.ca/fia/documents/mca_silvbmp.pdf*
   This work provides operational management guidelines to forest managers for maintaining broad-level habitat objectives for mountain caribou (and other biodiversity values), as a companion document to the various provincial and regional forest management guidelines that have been already developed for managing selected species and their habitats. Monitoring standard metrics associated with caribou habitat and establishment to free-growing seral stage (stocking standard guidelines and cluster distribution) are described, including measures to determine the prescribed number of clusters per hectare in relation to caribou habitat objectives and stocking standards.

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# Test Your Knowledge . . .

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

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

1. What are important landscape-level habitat conditions to consider when managing for mountain caribou habitat?
   A) Forest patch size and seral stage distribution
   B) Connectivity within and between seasonal habitats
   C) Access management
   D) All the above

2. What are important stand-level habitat conditions to consider when managing for and/or promoting acceleration of recovery of mountain caribou winter habitat?
   A) Meeting free-to-grow stocking standards
   B) Clumpy/patchy tree distribution found at low stocking levels
   C) Lichen productivity
   D) B and C

3. Which type of silviculture systems is suited to almost any forest stand supporting mountain caribou habitat?
   A) Clearcut harvest
   B) Single tree selection
   C) Group selection
   D) Any of the above

## *ANSWERS*

*1. D (see Table 2) 2. D (see Table 2) 3. C (see Table 3)*