Managing early seral vegetation to reduce the availability of moose and deer winter browse in the upper Columbia River Valley: an approach to relieving stress on mountain caribou (*Rangifer tarandus*) populations

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1 Introduction

Declines in woodland caribou (*Rangifer tarandus*) populations have been observed across Canada, including in the upper Columbia River drainage near Revelstoke, British Columbia, where the mountain caribou ecotype occurs. In 2002, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the species as "threatened" within the Southern Mountains National Ecological Area (Thomas and Gray 2002), and the B.C. government became legally responsible for preparing a recovery plan that would ultimately allow the species to be de-listed. In response, the Revelstoke Caribou Recovery Committee was formed to coordinate local strategies and activities.

In 2003, the Revelstoke Caribou Recovery Committee invited a panel of scientific experts to review the problem and provide guidance regarding an appropriate strategy for caribou recovery (Messier et al. 2004). The panel noted that, although historic climatic changes may partially explain the declines, human-induced changes to the landscape and disturbance of habitat also play a role and may hasten the effects of changes that result from natural phenomena (Wittmer 2004). In their analysis, the most critical factor influencing caribou declines in the upper Columbia valley has been the increase in early seral forest types (0-40 years-old) that support abundant winter browse for moose and deer, and which has attracted both ungulates and their associated predators (wolves and cougars) into areas that have traditionally been caribou habitat. As harvesting activities and other forms of disturbance move upslope, the crucial spatial separation between mountain caribou and other major ungulates and their predators is being lost, and caribou mortality rates are increasing. The panel concluded that landscape-level planning to reduce the presence of early-seral conditions is critical; however, it also noted that the overall caribou recovery plan must consider other factors, including protection of old-growth forest, reduction of disturbance, and management of ungulate and predator populations.

As a first step to following the recommendations of the panel, seven shrub species were identified as the primary sources of winter forage for moose and deer in the upper Columbia Valley. Willow (*Salix* spp.), black cottonwood (*Populus balsamifera* ssp. *trichocarpa*), Douglas maple (*Acer glabrum*) and western redcedar (*Thuja plicata*) were selected on the basis of local surveys (Serrouya and D'Eon 2002, D'Eon et al. 2003, Serrouya and D'Eon 2003), and western yew (*Taxus brevifolia*), hazelnut (*Corylus cornuta*), and red-osier dogwood (*Cornus sericea*) were added to the list based on expert knowledge of the feeding habits of large ungulates in the Revelstoke area (R. Serrouya, pers. comm., Dec., 2004). All these species are documented in the literature as preferred winter browse for ungulates (e.g., Stearns 1974; Smithberg 1974; Haeussler et al. 1990; Campbell and Nicholson 1995).

This report summarizes autecological information about these browse species, and presents information about their expected responses to various types of forestry related disturbance, based on information in the literature. It is accompanied by four Summary Tables that include information about:

- Environmental characteristics of the BEC units that occur in the caribou recovery area (Summary Table 1)
- Vegetation complexes that occur in those BEC units (Summary Table 2)
- Autecological characteristics of key browse species (Summary Table 3)
- A summary of individual research study results regarding responses of key browse species to forestry-related activities (Summary Table 4)

The purpose of the report and the accompanying tables is to provide a starting point for the development of (a) forest management plans to minimize the availability of moose and deer browse in the Upper Columbia Valley and (b) a model to predict the abundance of moose and deer browse under different stand- and landscape-level management scenarios. The caribou recovery area is well defined within the ICH wet-belt, we have tried to include local research results wherever possible.

The information provided in this report is based on existing studies regarding vegetation responses to forest management treatments and it is intended to be used as reference material during the development of management plans. It does not make recommendations about the extent to which any particular treatment should be included in the caribou recovery plan because all objectives, not just the objective of reducing early seral browse, must be considered at both the stand- and the landscape level. Objectives for caribou recovery may conflict with those of other interests, and even within the realm of forest management, objectives for control of early seral browse may conflict with those concerning conifer performance. In addition, the choice of appropriate treatments depends on the time since disturbance and the developmental stage of the vegetation community. Ideally, the planning process should begin at the pre-harvest stage because season and method of harvesting often influence subsequent vegetation development and the need for vegetation management treatments

2 Characteristics of the caribou recovery management area

The geographic area of concern for caribou recovery in the upper Columbia valley extends from the Mica Dam and Kinbasket Lake (including Encampment Creek) south to Revelstoke (Figure 1). Moose are most prevalent in the wetter ecosystems (ICHvk1 and ICHwk1), and deer are most prevalent in the small area of ICHmw3 that lies just north of Downie Creek (Figure 2). These three BEC units have similar elevational ranges (approximately 400 – 1400 m), and are highly productive due to the moist to wet climate and moderate temperatures. A range of vegetation communities develop following harvest in these ecosystems, including the *Mixed Shrub*, *Bracken*, *Fireweed*, *Fern*, *Wet Alder*, *Cottonwood-Shrub*, *Willow*, *Bluejoint*, *Mixed Broadleaf-Shrub*, *Dry Shrub*, and *Aspen* complexes. Of these complexes, the identified browse species are mainly associated with the *Mixed Shrub*, *Cottonwood-Shrub*, and *Willow* complexes.

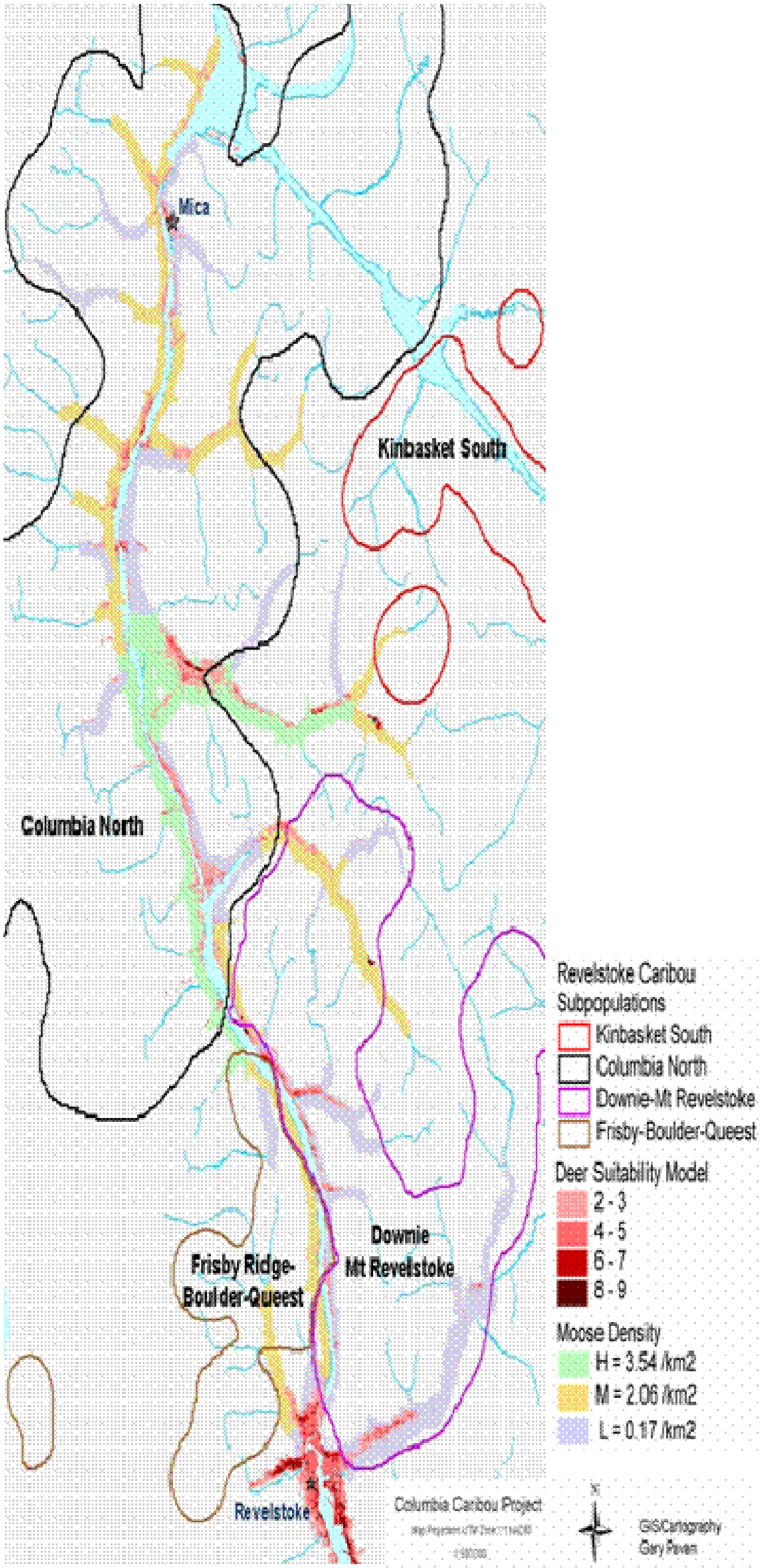

Figure 1. Map showing winter range population density of moose and deer in relation to caribou subpopulations (prepared by R. Serrouya).

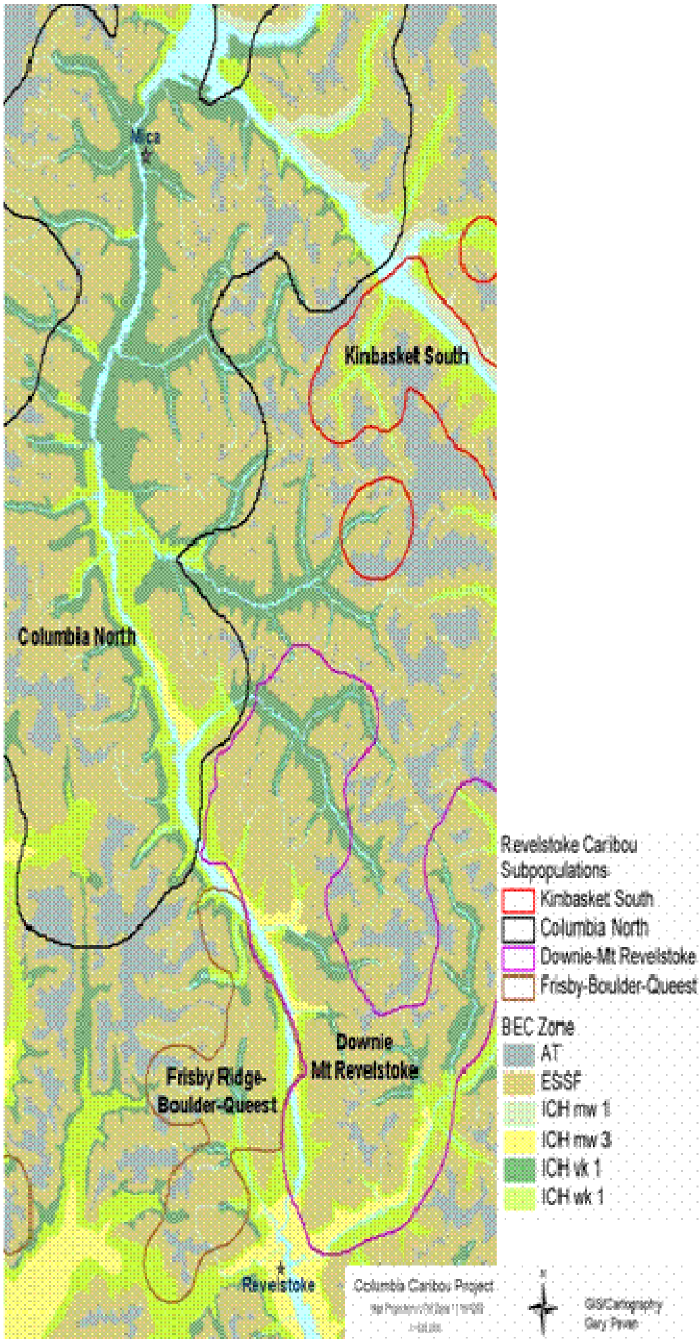

Figure 2. Map showing location of caribou subpopulations in relation to biogeoclimatic ecosystem units (prepared by R. Serrouya).

3 Autecological characteristics of the browse species and their expected responses to disturbance

This section summarizes autecological information and discuss the effects of harvesting, site preparation, and brushing activities on development and abundance of the target browse species. Table 8 provides a summary of management activities that are most likely to result in increased abundance of the target browse species. The general effects of other silviculture treatments are summarized in Section 4 because individual species information was not available.

3.1 Willow

Willow grows on a range of different site types, but it is most common on subhygric and wetter sites, and has its best growth best in deep, moist bottomlands (Haeussler et al. 1990). Based on local information, the willow species that are most likely to be of concern in the caribou recovery area are Drummond’s willow (*Salix drummondiana*), smooth willow (*S. glauca*), and Sitka willow (*S. sitchensis*) (S. Hall, pers. comm., Feb. 2005). Information from regional ecologists suggests that for the ICH units found in the caribou recovery area, willow is most likely to develop into a distinct vegetation complex on sites that are subhygric – subhydric (i.e., site series 06 in the ICHvk1, site series 05, 06, 08 in the ICHwk1, and site series 06, 07, 08, 09 in the ICHmw3, Sachs et al. 2004). Anecdotal evidence suggests the abundance of willow seed sources in individual drainages is important to the ability of willow to occupy newly exposed mineral soil (P. Gribbon, pers. comm., Dec. 2004). P. Gribbon also remarked that the*Willow c*omplex occurs in site series 01 in the wetter subzones, which can be confirmed by field sampling tentatively scheduled for summer 2005.

Willow is moderately to very shade-intolerant, and it will increase in vigour and cover following canopy removal. However, the spread from existing willow plants is likely to proceed relatively slowly as long as stems are not damaged during harvest (Coates et al. 1990). Increases in willow abundance following canopy removal will be related mainly to vegetative sprouting from cut or damaged stems and from root and stem fragments that have been buried in most soil, and seeding in. Mature and decadent willow stems that existed prior to harvest will increase seed production following canopy removal (Boateng and Comeau 1997b). Willow disperses seed in early to mid-summer, and although the seed is relatively short-lived, abundant germination can occur if suitable seedbeds (i.e., mineral soil) exist. Interpretations of autecological factors are made in Table 1.

Table 1. A summary of the relationship between willow autecological factors and forest management practices

Autecological factor	Management practices likely to promote willow
Willow seed germinates quickly on mineral soil	• Practices that expose mineral soil such as road building, summer logging with random ground-based skidding, high-intensity burns, MSP treatments.
Willow sprouts prolifically from the stem base and root collar of cut or damaged stems	• Harvesting practices that damage existing stems • Manual cutting as a brushing treatment.
Willow sprouts from stem and root fragments buried in moist soil	• Harvesting and MSP practices that disturb the forest floor and crush stem and root fragments into the soil
Willow germinates quickly in full sunlight, under moist, high humidity conditions	• Practices that create full sun conditions (e.g., canopy removal).
Willow is moderately to very shade intolerant, and has its best growth in the open or in partial shade	• Activities that increase light availability (e.g., canopy removal)

Harvesting – In areas where willow is present in the understory, harvesting in winter rather than summer will reduce forest floor disturbance and damage to existing willow stems, particularly on low-slope areas where crawler tractors or rubber-tired skidders would be used. The exposure of mineral soil during harvesting, including road and skid trail construction, should be minimized. Willow tolerates a range of light conditions and thrives in partial shade, so partial cutting is unlikely to reduce its abundance relative to clearcutting, as long as disturbance to the forest floor and existing willow stems is minimal.

Road building – Although no references were found that specifically report the responses of willow to road building operations, we can assume that the creation of mineral soil seedbeds would stimulate regeneration of willow in areas with a willow seed source.

Site preparation - If mature or decadent willow stems are abundant at the time of harvest, and the objective is to reduce the abundance of ungulate browse, site preparation treatments should aim to remove these stems, which will be a source of abundant seed. Chemical site preparation has the advantage of not disturbing the forest floor, but the effects of glyphosate on willow are variable and often short-lived (e.g., Balfour 1989). However, a local study in the ICHvk1 reports that glyphosate applied at 1.78 – 2.14 kg ai/ha has 48-80% efficacy for control of willow (Thompson 1989). Triclopyr ester applied as a foliar, cut-stump, or basal bark treatment can give effective control of willow (Boateng and Comeau 1997b).

Mechanical site preparation and prescribed burning have the potential to expose mineral soil or damage willow stems and roots without killing them, and are likely to promote development of the *Willow* complex. Willow resprouts vigorously following burning, to the extent that prescribed fire is widely used as a wildlife management tool to rejuvenate decadent willow and increase browse availability (Haeussler et al. 1990). Severe burning treatments may set back existing willow colonies, but they also expose mineral soil and promote establishment of willow from seed. Prescribed burning is therefore not recommended as a treatment in areas where the objective is to reduce the availability of ungulate browse. Mechanical site preparation also has potential to promote willow, but for sites where some form of site preparation is necessary to establish conifer seedlings, low to medium-impact treatments that minimize mineral soil exposure will promote willow less than more severe treatments. In wet areas, mounding may be the best choice because it creates raised planting spots while disturbing only 10-30% of ground surface (von der Gönna 1992). Spot scarification is also a relatively low-impact treatment with regard to the amount of soil disturbance that is created. Mechanical site preparation treatments should be applied in August or later in order to avoid the period of willow seed dispersal. Information from northern B.C. suggests applying brush blading and piling treatments in the winter to minimize soil disturbance (Boateng and Comeau 1997b), but unless treatments were done in very early or very late winter, this would likely not be possible in the Revelstoke study area because of snow depth. Livestock grazing is also a potential site preparation treatment since willow is palatable to sheep (Boateng and Comeau 1997b), however, treatments must be applied before willow reaches 1.5 m tall, and would likely result in a similar amount of sprouting as manual cutting.

***Brushing* –** Glyphosate applied as a cut stump or stem injection treatment is likely to be the most successful brushing option where the objective is to reduce the abundance of willow. Basal or cut-stump application of triclopyr are also reported to be effective (Boateng and Comeau 1997b). Foliar glyphosate results in variable control of willow, and the effects may be short-lived (e.g., Balfour 1989). Manual cutting treatments should be avoided for purposes of reducing ungulate browse because they stimulate willow to sprout (e.g., Biring et al. 1996). Limited information from PROBE suggests that willow also sprouts following girdling. As noted above for site preparation, sheep grazing reduces willow abundance (Boateng and Comeau 1997b), but treatments must be applied before willow reaches 1.5 m tall, and multiple treatments may be required.

3.2 Douglas maple

Douglas maple has relatively high nutrient requirements, but it grows on a range of different site and soil conditions; in the ICH zone, it is most common on sites at the drier end of the moisture spectrum (Haeussler et al. 1990). Douglas maple is a common component of the *Mixed Shrub* complex (Boateng and Comeau 1997a), but regional ecologists did not identify it as a species commonly associated with that complex in the ICH units within the Revelstoke caribou recovery project (Sachs et al. 2004). The presence of Douglas maple in these units will be examined during field sampling in 2005.

Douglas maple is moderately shade-tolerant, and the limited information available regarding its responses to canopy removal suggest that it does not increase substantially in cover as a result of increased light availability, and that it will begin to naturally decline in abundance about 25 years after canopy removal (Haeussler et al. 1990). Increases in abundance of Douglas maple following may occur as a result of vegetative reproduction or seeding in following soil disturbance during forestry operations. Douglas maple sprouts readily from root crowns following disturbance, but does not spread by way of rhizomes or root suckers. Seed is produced from an early age, and will germinate on mineral soil or areas with thin forest floor, but it requires chilling prior to germination. Information regarding treatment responses of this species is limited, but interpretations are made in Table 2.

Table 2. A summary of the relationship between Douglas maple autecological factors and forest management practices

Autecological factor	Management practices likely to promote Douglas maple
Douglas maple sprouts readily from root crowns	• Harvesting practices that damage existing stems
Douglas maple sprouts readily from cut stumps	• Cutting understory stems during harvest • Manual cutting as a brushing treatment.
Douglas maple is moderately shade intolerant. It grows in open forests and under full sun, but rarely in deep shade.	• Canopy removal may not cause increases in abundance.

Harvesting – In stands where Douglas maple is present in the understory, harvesting in winter rather than summer to avoid forest floor disturbance and damage to existing maple stems will reduce the risk of increasing Douglas maple abundance. This is particularly relevant on low-slope areas where crawler tractors or rubber-tired skidders would be used. Since Douglas maple does not appear to spread as a result of increased light availability, the use of partial cutting or small opening systems in preference to clearcutting is unlikely to affect its abundance.

Road building – Although no references were found that specifically report the responses of Douglas maple to road building operations, we can assume that the creation of mineral soil seedbeds would stimulate seedling establishment in areas near a seed source.

Site preparation – Severe burns can reduce the presence of Douglas maple, but low to moderate intensity burns stimulate sprouting in this species (Haeussler et al. 1990). Low intensity spot burns are therefore not recommended for sites with a substantial Douglas maple presence. Mechanical site preparation treatments severe enough to expose mineral soil may reduce the presence of Douglas maple during the short term, but the creation of seedbeds could result in increased abundance over the longer term. Less severe MSP treatments that damage but do not kill maple stems may stimulate sprout production (Coates et al. 1990). The application of glyphosate at 1.4 – 2.1 kg ai/ha as a site preparation treatment is effective for reducing the presence of Douglas maple (e.g., Boyd et al. 1985). These results are confirmed by a local study in the ICHvk1, where 2 years after glyphosate application, maple presence was reduced by 67-73% compared with pre-treatment levels (Dyck 1987). Very little resprouting was reported following application of glyphosate to Douglas maple, which some studies report was killed at 2.1 kg ai/ha. No references were found regarding the use of sheep to control Douglas maple, but both vine maple and bigleaf maple are known to be moderately palatable to sheep (Biring et al. 1996).

Brushing **–** Manual cutting stimulates Douglas maple to sprout vigorously, and should be avoided for purposes of reducing the availability of ungulate browse (Haeussler et al. 1990). Although Douglas maple was not included as a target species on most PROBE sites where manual cutting treatments were applied, its presence tended to increase in treated plots relative to the control (see Summary Table 4). As described above for site preparation, glyphosate applied at 1.4–2.1 kg ai/ha provides good control of Douglas maple. No information was found regarding Douglas maple responses to cut stump-glyphosate, cut-stump triclopyr, or triclopyr basal bark treatments, but triclopyr applied as a spray at 1.7-2.2 kg ai/ha had a moderate to severe impact on sites in Oregon and Idaho (Conard and Emmingham 1983).

3.3 Black cottonwood

Black cottonwood is often associated with floodplains, river banks, gravel bars, and low lying land, but it also grows on upland sites having loams, clays, and rich humic soils. It has high nutrient requirements and only occurs where sufficient moisture is present. Regional ecologists suggest that for the ICH units found in the caribou recovery area, cottonwood was most likely to develop into a distinct vegetation complex on sites that are subhygric – subhydric (i.e., site series 05, 06 in the ICHvk1, site series 06, 07, 08 in the ICHwk1, and site series 07, 08 in the ICHmw3, Sachs et al. 2004).

Cottonwood is shade-intolerant, and does not occur under the forest canopy, although it may be a component of the mature forest (Haeussler et al. 1990). Reproduction from seed is more significant than vegetative reproduction on harvested sites in British Columbia, but very specific conditions are required for successful germination. Mortality of cottonwood germinants is high unless mineral seedbeds remain moist for at least one month following germination, but this factor is offset by cottonwood's abundant annual seed production. Cottonwood also reproduces vegetatively – it sprouts abundantly from cut stumps and can also sprout from broken root or stem fragments that are buried in soil. However, cottonwood is generally a minor stand component in mature forests, and does not grow in the understory - as a result vegetative reproduction tends to play a less important role following harvest than reproduction from seed. Mature cottonwood stems are often retained as wildlife trees on logged sites, and seed production from these stems could result in abundant cottonwood germinants becoming established on mineral soil seedbeds. Interpretations of autecological factors are made in Table 3.

Table 3. A summary of the relationship between black cottonwood autecological factors and forest management practices

Autecological factor	Management practices likely to promote cottonwood
Cottonwood seed germinates quickly on moist mineral soil and is considered to be more important than vegetative reproduction in BC	• Practices that expose mineral soil such as road building, summer logging with random ground-based skidding, high-intensity burns, MSP treatments.
Cottonwood seed requires moist conditions for at least a month after germination	• Practices that expose mineral soil on moist to wet sites.
Cottonwood sprouts from the stump of cut stems	• Cutting large cottonwood stems during harvest • Manual cutting as a brushing treatment.
Cottonwood sprouts from stem and root fragments buried in moist soil	• Harvesting and MSP practices that disturb the forest floor and crush stem and root fragments into the soil.
Cottonwood is shade intolerant, and has its best growth in full sun. It does not occur under the forest canopy	• Removal of the forest canopy.

Harvesting - In stands that have a cottonwood component, or where cottonwood is present in adjacent stands or cutblocks, harvesting practices that expose mineral soil will promote seeding in by this species. This is probably the most important consideration for avoiding abundant regeneration of cottonwood, particularly where mature cottonwood are retained for wildlife purposes. Harvesting in winter rather than summer will minimize forest floor disturbance, particularly on low to moderate slope areas where ground-based skidding techniques are used. Vegetative reproduction from cut mature cottonwood stumps could be avoided by treating stumps with glyphosate at the time of, or soon after, harvest. This would only be practical if there was a significant cottonwood component within the stand. Due to its shade intolerance, cottonwood will not thrive in low light environments, which suggests there is some potential for discouraging cottonwood reproduction through the use of partial cutting or small opening silviculture systems. Threshold values for germination and survival of cottonwood seed were not found in the literature, but cottonwood diameter growth is known to increase almost linearly with increasing light availability (Wright et al. 1998).

Road building **–** Although no references were found that specifically report the responses of cottonwood to road building operations, we can assume that the creation of mineral soil seedbeds would stimulate regeneration in areas with a nearby seed source. Observations from PROBE sites suggest that cottonwood patches occur most often on old skidtrails.

Site preparation **–** As cottonwood is not likely to be present in the understory prior to harvest, site preparation treatments are not necessary to reduce its presence. On the contrary, most site preparation treatments are likely to create soil disturbance that will promote cottonwood. The *Cottonwood* vegetation complex has its best growth on moist sites that also support abundant growth of understory shrubs, and conflicts may arise between the objectives of avoiding cottonwood reproduction and creating suitable conditions for conifer seedling establishment. Where site preparation is necessary to createplanting spots and/or control other vegetation, practices that expose mineral soil should be avoided. This is particularly important in areas with a nearby cottonwood seed source. Boateng and Comeau (2002) suggest the use of mechanical spot cultivation in 1.5 x 1.5 m patches to establish seedlings, which would result in mineral soil exposure over approximately 30% of the total area. Cottonwood is highly susceptible to prescribed fire of all intensities, but severe burns that expose mineral soil will create excellent conditions for seed germination, and may ultimately increase its presence. Spot chemical treatments have the advantage of not exposing mineral soil, but conflicts may arise in riparian areas.

Brushing – Due to the stature of cottonwood in relation to juvenile conifers, appropriate application of vegetation management treatments may differ between the objectives of attaining free-growing status for conifers and reducing the presence of cottonwood sprouts as ungulate browse. For purposes of attaining free-growing status, and assuming a conifer crop has been established, practitioners may wish to brush when seedlings are approximately 5-7 years old in order to avoid the need for a repeat treatment prior to free-growing age. For purposes of reducing ungulate browse, however, cottonwood sprouts should be dealt with at a much earlier age in order to avoid their appearance above the 1-2 m snowpack (based on Figure 2 in Serrouya and D'Eon 2002). Manual cutting treatments stimulate cottonwood to sprout (e.g., Hart and Comeau 1992) and should be avoided. Cottonwood is severely injured by glyphosate applied at rates of 1.5 – 2.1 kg ai/ha (e.g., Biring et al. 1996) and non-replicated PROBE results suggest its presence is severely set back for at least 5-10 years in the ICHwk1 and ICHmw3 (Mather and Simard 1998a,b). Cut stump treatment or stem injection with either glyphosate or triclopyr is also reported to be very effective (Biring and Comeau 1996). However, for purposes of reducing ungulate browse, it may be desireable to treat cottonwood stems before they are large enough for cut stump or stem injection treatments to be appropriate. Double-girdling can also be used on cottonwood >3 cm dbh, although trees die slowly and basal sprouting may still occur (Boateng and Comeau 2002). Except for red-osier dogwood and bluejoint, most species that occur in the *Cottonwood* complex (presumably this includes cottonwood) have moderate to low palatability to livestock, suggesting that sheep grazing would not be a successful brushing treatment (Boateng and Comeau 2002).

3.4 Red-osier dogwood

Red-osier dogwood is associated with moist to wet sites throughout its range, but it is also common in open upland woods and along forest margins. It is a common component of the *Mixed Shrub* and *Cottonwood-Shrub* vegetation complexes (Boateng and Comeau 1997; 2002). Regional ecologists suggest that for the ICH units found in the caribou recovery area, red-osier dogwood is most likely to have a major presence on sites that are subhygric in the ICHvk1 (site series 05), and subhygric – subhydric in the ICHvk1 (site series 06, 07) (Sachs et al. 2004).

Red-osier dogwood is semi shade-intolerant to shade-tolerant, and while it occurs under the forest canopy, it has its best vigour at forest margins and in openings (Haeussler et al. 1990). Both the vegetative and sexual reproductive characteristics of this species should be considered to predict its development on harvested forest sites in British Columbia. It produces large seed that is mainly distributed by animals, but most importantly, it is a seed banker, and germination can be stimulated by forest floor disturbance. It also reproduces vegetatively by several means, including stolon production, layering, suckering from root buds, and sprouting from old branches and stem bases. Interpretations of autecological factors are made in Table 4.

Table 4. A summary of the relationship between red-osier dogwood autecological factors and forest management practices

Autecological factor	Management practices likely to promote red-osier dogwood
Red-osier dogwood seed remains viable for several years and germinates best when slightly buried in soil	• Practices that incorporate seeds into soil materials
Red-osier dogwood spreads vegetatively by layering, by producing suckers from dormant root buds, and by producing sprouts from old branches or stem bases	• Harvesting or site preparation practices that damage or partially bury existing red-osier dogwood stems
Red-osier dogwood is semi-shade tolerant to shade tolerant but has its best growth in openings and at forest edges	• Activities that increase light availability through removal of the forest canopy. • Activities that create abundant forest edge

***Harvesting* –** Information is limiting regarding specific responses of red-osier dogwood to canopy removal, but Haeussler et al. (1990) cite at least one reference that suggests cover increases in response to canopy removal in the ICH zone. In stands where red-osier dogwood is present in the understory, harvesting operations that minimize opening size or utilize partial retention systems may be preferable to larger clearcut openings. Harvesting operations should also be carried out in winter rather than summer to (a) minimize forest floor disturbance which could stimulate banked seed to germinate and (b) avoid pressing branches into the forest floor which could promote layering. Red-osier dogwood is likely to sprout more abundantly if cutting takes place early in the growing season than in winter (Coates et al. 1990). Proposed sampling for summer 2005 may provide further information about the effects of opening size and partial cutting on the presence of red-osier dogwood.

***Road building* –** Although no references were found that specifically describe the responses of red-osier dogwood to road building operations, severe disturbance of the forest floor and exposure of mineral soil may stimulate germination of banked seed.

***Site preparation* –** Prescribed fire is likely to result in low to moderate severity burns on sites that are moist enough to support abundant growth of red-osier dogwood. Such fires will stimulate banked seed to germinate and result in increased abundance of the shrub (Haeussler et al. 1990). Low intensity spot burns are therefore not recommended for sites with a substantial red-osier dogwood presence. Mechanical site preparation treatments are predicted to stimulate vegetative spread of red-osier dogwood through sprouting of broken stem and root fragments that are incorporated into the soil and from damaged stem bases. Banked seed may also be stimulated to germinate following MSP treatments that are severe enough to expose mineral soil (Haeussler et al. 1990). Red-osier dogwood is reported to have variable responses of to glyphosate, ranging from increases in cover following treatment to excellent control (Haeussler et al. 1990). A relatively local study in the ICHmw3 reports that glyphosate reduced abundance of red-osier dogwood for at least 8 years (Clement and Keeping 1996). Red-osier dogwood is not a preferred forage species for sheep, but they will eat it if grazing pressure is high and stems are less than 1.5 m tall and (Boateng and Comeau 2002).

Brushing **–** Red-osier dogwood sprouts following manual cutting (Boateng and Comeau 2002), although it apparently does so less prolifically if cutting is done in the dormant season rather than early in the growing season (Coates et al. 1990). Dogwood sprouts are reported to be about 60 cm tall one year after cutting (Haeussler et al. 1990), which is supported by a PROBE study in the ICHmw3 near Clearwater (Mather and Simard 1997). Manual cutting is therefore not recommended for purposes of reducing ungulate browse availability. As described above for site preparation, foliar glyphosate application is reported to have variable effects of red-osier dogwood. Sheep grazing is unlikely to be very successful because red-osier dogwood is not a preferred forage (Boateng and Comeau 2002).

3.5 Beaked hazelnut

Beaked hazelnut occurs in open woods, clearings, thickets, and pastures, and grows best on well-aerated loamy sites that are well-drained and rich to very rich. It is not a common component of any of the major vegetation complexes that develop following logging because its occurrence is patchy and it is associated mainly with valley bottom areas that have been removed from forest production (Haeussler et al. 1990). Regional ecologists did not identify hazelnut as a major post-logging species in any of the ICH units associated with the Revelstoke caribou recovery project (Sachs et al. 2004), but it is known to be a preferred winter browse species for moose and deer (Haeussler et al. 1990). The presence of hazelnut in these units will be examined during field sampling in 2005.

Hazelnut is shade-tolerant to intolerant, but has its best growth on sites where there is at least 30% full sunlight (Klinka et al. 1989; Haeussler et al. 1990). There are many factors that naturally restrict the ability of hazelnut to reproduce from seed but it reproduces readily by vegetative means. Most commonly, hazelnut spreads by sprouting from horizontal underground stems that radiate outward from the parent plant, but it also reproduces by layering and vigorous resprouting from cut stems (Haeussler et al. 1990). Stearns (1974) comments that beaked hazelnut is not highly preferred by deer, but as preferred species disappeared in the Great Lakes area, it gained in importance. Deer prefer new sprouts and vigorous shoots (Stearns 1974). Interpretations of autecological factors are made in Table 5.

Table 5. A summary of the relationship between beaked hazelnut autecological factors and forest management practices

Autecological factor	Management practices likely to promote beaked hazelnut
Hazelnut seed has low survival and germination rates, except in good seed years (approximately every 5 years)	• Not a major concern
Hazelnut mainly reproduces vegetatively by sprouting from underground stems	• Low intensity MSP treatments that slightly damage underground stems
Cut hazelnut stems sprout vigorously	• Cutting hazelnut stems during harvesting • Manual brushing
Hazelnut has its best growth where there is at least 30% full sunlight	• Practices that open up the forest canopy or create mixed stand conditions (e.g., partial cutting)

Harvesting - Existing hazelnut colonies expand rapidly following canopy removal (Haeussler et al. 1990). Although hazelnut vigour is known to be reduced by shading, and plants growing under low light conditions may never produce seed (Stearns 1974), no specific information was found to say whether the use of small opening sizes or partial cut silvicultural systems restricts the spread of hazelnut colonies. It seems unlikely that these practices would reduce light much below 30%, which is the minimum light requirement for hazelnut to have its best growth. Harvesting should take place in winter to minimize forest floor disturbance, because hazelnut is likely to sprout in response to low-level forest floor disturbance (Stearns 1974). This is especially important on low to moderate slope sites that would be harvested using ground-based skidding.

Road building – Although no references were found that specifically report the responses of beaked hazelnut to road building operations, it is likely that the disturbance would be severe enough to destroy underground stem and root systems. Field surveys planned for summer 2005 will provide additional observations.

Site preparation – Fires severe enough to kill the underground stem and root systems will eliminate hazelnut (Stearns 1974), but prescribed fire of low or moderate intensity will stimulate this species to produce abundant sprouts. Low intensity spot burns are therefore not recommended for sites with a substantial beaked hazelnut presence. Mechanical site preparation treatments severe enough to turn up the underground stems may set growth back for several years (Haeussler et al. 1990), but unless underground stems are completely destroyed or removed, hazelnut will sprout and ultimately increase in abundance. Most reports suggest that glyphosate results in moderate control of beaked hazelnut (e.g., Boateng and Herring 1990), so localized application of glyphosate to hazelnut thickets following harvesting may meet the objective of reducing ungulate browse. Hazelnut is moderately palatable to sheep (Biring et al. 1996), but will sprout following clipping.

Brushing – Beaked hazelnut sprouts as a result of manual cutting and sheep grazing, and these treatments are therefore not recommended where the objective is to reduce the abundance of ungulate browse (Haeussler et al. 1990). As described above for site preparation, glyphosate is reported to provide variable control of hazelnut.

3.6 Western yew

Western yew occurs across a wide range of site and soil types, but has its best growth on deep, moist, moderately well-drained soils. In the ICH zone, it is most common on podzolic soils. It grows best on rich sites, but is more common on poor and medium sites. Western yew generally grows under forest canopies, and following harvest, it is sometimes associated with the *Mixed Shrub* complex. In the ICH units associated with the caribou recovery area, regional ecologists think western yew is most likely to be a main component of the *Mixed Shrub* complex in site series 04 of the ICHvk1 variant (Sachs et al. 2004). However, it is common in the understory prior to harvest in site series 01 and 03 of the same variant (Braumandl and Curran 1992), and would continue to be present following harvest.

Western yew is shade-tolerant (Klinka et al. 1989), and although it may occur as a small tree, it most often takes the form of an understory shrub in interior B.C. (Campbell and Nicholson 1995). Yew reproduces both by seed and vegetatively. The seed is mainly dispersed by small animals and cold is required to break its dormancy – as a result, it rarely germinates until at least the second year after it is shed. It also does not germinate in dense shade, so that seedlings are most commonly found in openings such as clearcuts, canopy gaps, and road edges. Organic soils provide the best seedbed for western yew, but it will also germinate on mineral soil or rotten wood (Campbell and Nicholson 1995). Yew regenerates vegetatively by layering and by sprouting from rootstocks and stumps. In interior B.C., vegetative reproduction is most common on steep slopes where snowpress encourages layering and in clearcuts, probably because machinery has pressed branches into the soil. Interpretations of autecological factors are made in Table 6.

Table 6. A summary of the relationship between western yew autecological factors and forest management practices

Autecological factor	Management practices likely to promote western yew
Western yew is shade tolerant	• Canopy removal will not stimulate rapid growth of this species
Western yew seed germinates mainly in open areas such as canopy gaps, clearcuts, and road edges	• Canopy removal and road building may stimulate reproduction by seed
Western yew sprouts from cut stumps and rootstocks, but this is more successful in partial shade than full sun	• Cutting yew stems during harvesting • Manual brushing • Partial cutting
Vegetative reproduction is most common on steep slopes because branches are pressed down which results in layering	• Clearcutting on steep slopes

Harvesting **–** Western yew grows well in the forest understory because of its shade-tolerance, but foliage becomes more abundant following canopy removal, and fruiting also increases (Campbell and Nicholson 1995). Although no specific information was found about the response of yew to gradations of light, it is possible that the increases in foliage and fruiting would be less pronounced in small openings and partial cuts than in clearcuts. Little is known about the effects of forest floor disturbance on western yew, so recommendations cannot be made about harvesting season and method.

Road building **–** Although no references were found that specifically report the responses of western yew to road building operations, seed germination is reported to be more common in open areas (including roadcuts) than under the forest canopy. Field surveys planned for summer 2005 will provide additional observations.

Site preparation **–** Wetern yew has thin bark and it is easily killed by fire, so that prescribed fire of even low or moderate severity is likely to kill existing stems. Little is known about the effects of mechanical site preparation on western yew, but it recovers rapidly from harvesting damage in the absence of site preparation (Campbell and Nicholson 1995). No information was found regarding the susceptibility of western yew to glyphosate, but based on the impacts of glyphosate on other conifers, yew is likely susceptible to damage during the growing period. No information was found regarding the palatability of western yew to sheep.

Brushing **–** Virtually no information was found regarding the responses of western yew to brushing treatments because it is not a species that competes with crop conifers. Campbell and Nicholson (1995) note that yew reproduces by sprouting from stumps, and that vegetative reproduction is evident on clearcut sites, so presumably manual cutting treatments would stimulate western yew to increase in abundance. No information was found regarding the responses of western yew to herbicides or its palatability to sheep.

3.7 Western redcedar

Western redcedar is most common on fresh to moist soils, but it also tolerates dry and wet conditions. In the caribou recovery area, western red cedar is common in most site series except those that are the most dry or the most wet (i.e., site series 03, 04, 01, 05, 06 in the ICHvk1; 04, 01, 05, 06, 08 in the ICHwk1; 04, 05, 01, 01-YC, 06, 07, 08 in the ICHmw3, Braumandl and Curran 1992).

Western redcedar is shade-tolerant to shade-tolerant/intolerant (Klinka et al. 1989) and advance regeneration is common under the forest canopy. Cedar starts producing seed at about age 10, and heavy seed crops are common. The heaviest seedfall occurs in October, and germination is most successful on mineral or burned soil. Western redcedar also reproduces vegetatively by layering, by the rooting of fallen branches, and by the vertical development of branches from fallen trees.

Western redcedar has been identified as a preferred browse species for moose and deer in the Revelstoke caribou management area, but conflicting management objectives are likely to arise because it is also a primary regeneration species for the majority of the ICHwk1 and ICHvk1 site series within the management area (Braumandl and Curran 1992). Interpretations of autecological factors are made in Table 7.

Table 7. A summary of the relationship between western redcedar autecological factors and forest management practices

Autecological factor	Management practices likely to promote western redcedar
Western redcedar is shade tolerant	• Canopy removal will not stimulate rapid growth of this species
Regenerates from seed on mineral soil or burned soil	• Broadcast burns, MSP treatments that expose mineral soil, road building
Vegetative reproduction by layering	• Harvesting or site prep practices that crush or partially bury advance regen stems

Harvesting **–** Western redcedar grows well in the forest understory because of its shade-tolerance, but its growth rates increase following canopy removal. Coates and Burton (1999) found that height and diameter growth of cedar increased with light availability, with no saturation point below full sunlight. Harvesting in winter rather than summer may reduce layering because advance regeneration will not be pressed into the soil.

Road building **–** Cedar seed is likely to germinate on exposed mineral soil seedbeds created by road building.

Site preparation **–** No references directly discussed the effects of site preparation treatments on existing cedar stems. It is likely that both mechanical and burning treatments would damage advance regeneration. MSP treatments that expose mineral soil would create seedbeds for western redcedar, and so would severe fire. Cedar is moderately susceptible to glyphosate (Boateng and Herring 1990) and would be set back by chemical site preparation.

Brushing **–** No references were found regarding the responses of western redcedar to brushing because it has not been studied as a brushing target. Based on other information, manual brushing treatments should aim to cut cedar stems as close to the ground as possible to minimize the potential for lower branches to develop into vertical stems. As for site preparation, cedar would be moderately damaged by glyphosate application.

4 The effects of other silviculture activities on abundance of identified browse species

Limited information was available regarding the effects of the following activities on abundance of our identified browse species, so information is presented in general terms.

4.1 Pruning

Pruning is an intensive silviculture treatment applied to improve tree form and wood quality when trees are at an intermediate age (Smith 1986). No information was found regarding the effects on surrounding vegetation in areas where the treatment was applied, and no local information was found regarding wet ICH subzones. Based on general principles, the removal of branches from the lower crown would open the canopy and increase light availability to the shrub layer, however, this activity is usually done early in the rotation, and its effects would be relatively brief (A. Vyse, pers. comm. Mar. 2005). uning is therefore expected to slightly increase abundance and vigour of willow, cottonwood, and red-osier dogwood, but would probably have little effect on the abundance of Douglas maple, beaked hazelnut, western yew, and western redcedar.

4.2 Fertilization

Fertilization of conifers, possibly in combination with increased planting density, has been suggested as an approach for hastening canopy closure to reduce the abundance of early seral browse species. However, available information suggests that, for a number of reasons, such a treatment would not have the desired effect. First, sites that produce abundant vegetation are not limited by nutrient availability, and fertilizer application would be unlikely to result in significant additional growth of conifers. Second, broadcast application of fertilizer would be more likely to stimulate growth of surrounding vegetation than conifers (e.g., Brown 1999), and third, fertilization of individual conifers at the time of planting (e.g., Gromax) is reported to have had short-lived effects and not to have increased the proportion of conifer seedlings that reached free-growing by age nine (Heineman 1999). Contrary to this information, anecdotal reports from licensees based in the ICHvk1 and ICHwk1 BEC variants, suggest that individual conifer fertilization is an effective way of establishing seedlings on brushy sites. Downie Sawmills is planning to initiate operational research trials to test the effectiveness of “teabag” fertilization at the time of planting.

4.3 Grass seeding

Information about the effectiveness of grass seeding to control the abundance of our particular browse species is limited. A study in the ICHwk1 near Revelstoke reported that willow re-invaded the study site regardless of grass and clover seeding (Thompson et al. 1996). In contrast, black cottonwood is reported to be very sensitive to competition from grass (Niemiec et al. 1995). Other studies, which mainly involve seeding of burned or scarified sites, suggest the re-invasion of shrubs varies by species. For sites where conifer seedling growth is also an objective, the presence of grass may restrict seedling establishment to unacceptable levels (B. Chapman, pers. comm., 2005). However, if grass seeding was carried concurrently with the planting with large stock, chances of success could be higher (A. Vyse, pers. comm., March 2005).

4.4 Juvenile spacing

As with pruning, the effects of juvenile spacing tend to be reported in the literature in terms of conifer rather than vegetation response. The expected effect with regard to our identified ungulate browse species is that willow, black cottonwood, and red-osier dogwood, which are most responsive to increases in light availability, will increase in abundance following juvenile spacing. This was observed to be the case for red-osier dogwood following juvenile spacing in the ICHmw (Hauessler et al. (1990). A secondary effect of juvenile spacing is that it creates slash that may influence the summer movement of moose and deer (Waterhouse et al. 1990). However, slash is not a concern for ungulate movement in the winter due to the snowpack.

4.5 Slash management

Although slash may influence the summer movement of moose and deer, our concern is the availability of winter browse. Slash is therefore not relevant to the accessibility of browse to moose and deer during winter months when there is a snowpack.

4.6 Planting

Planting high densities of conifer seedlings may result in earlier crown closure than planting at standard densities. The objective of this procedure would be to reduce shrub abundance by reducing light availability in the understory. Several licencees have recently established trials in the upper Columbia Valley to test this theory.

Table 8. Mangement activities that the literature suggests will increase the abundance of target browse species

	Harvesting				Site preparation						Site preparation and/or brushing							
Species	Clearcutting – summer logging	Clearcutting – winter logging	Partial cutting or small openings	Road building	Prescribed burns - light	Prescribed burns - moderate	Prescribed burns - severe	MSP – low intensity (e.g., spot scarification or rmounding)	MSP – medium intensity (e.g., disk trenching or plowing)	MSP – high intensity (e.g., bedding plow or madge)	Foliar glyphosate	Cut stump-glyphosate	Glyphosate stem injection	Triclopyr basal bark	Triclopyr stem injection	Sheep grazing	Manual cutting	Girdling
Willow	X			X	X	X	X		X	X							X	X
Douglas maple	X			X	X	X		X	X								X	
Black cottonwood	X			X			X		X	X							X	
Red-osier dogwood	X	(x)		X	X	X		X	X	X							X	
Beaked hazelnut	X	(x)	(x)	X	X	X		X	X							X	X	
Western yew				X													X	
Western redcedar				X														

X = the activity is likely to result in increased abundance
(x) = the activity is likely to result in increased abundance, but less so than “X”

5 The effects of "non-forest management" activities

5.1 BC Hydro

In the caribou recovery area, BC Hydro carries out vegetation management activities under powerlines every 5-7 years. Hydroaxes are used in low lying, flat areas and manual cutting is used on areas with greater slope. Occasionally, triclopyr is used to treat vegetation on knolls that are close to lines, but this is rare (K. Dalgarno, pers. comm., Feb. 2005). BC Hydro also has close-up orthophotos of their powerlines that are produced by LIDAR imagery. These could potentially be used to quantify abundance of individual ungulate browse species under powerlines

5.2 Cedar Foliage Harvest

Local interest has been expressed in establishing a small processing plant to extract oil from cedar foliage. Harvesting of cedar foliage from sites with high winter use by moose and deer could potentially reduce browse availability.

6 The effects of pests

6.1 Hemlock looper

No information was found regarding the effects of the western hemlock looper (*Lambdina fiscellaria lugubrosa*) on early seral browse availability. The looper is a defoliator whose principle host iswestern hemlock, but it will feed on several other tree species including western redcedar, white spruce, balsam fir (Taylor 1998). It is known to be common in the caribou recovery area (A. Vyse, Pers. Comm. Dec. 2004), and can be expected to elicit vegetation responses as a result of increased light availability. P. Gribbon (pers. comm. March 2005) comments that the hemlock looper also attacks Douglas-fir.

7 Concluding remarks

This report provides information that will facilitate the development of management plans that include the objective of reducing moose and deer winter browse in the Upper Columbia Valley. It also is intended to be used as a reference tool during the development of a model to predict the effects of forest management activities on browse abundance. Both these activities are scheduled for the upcoming fiscal year.

8 References

Balfour, P. 1989. Effects of forest herbicides on some important wildlife forage species. FRDA Rep. No. 20, For. Can. and B.C. Min. For., Victoria, B.C.

Biring, B.S., Comeau, P.G. and J.O. Boateng. 1996. Effectiveness of forest vegetation control methods in British Columbia. FRDA Handb. No. 11. For. Can. and B.C. Min. For., Victoria, B.C.

Boateng, J. and Comeau P.G. 1997a. Operational summary for vegetation management: Mixed Shrub complex. For. Prac. Br., B.C. Min. For., Victoria, B.C.

Boateng, J. and Comeau P.G. 1997b. Operational summary for vegetation management: Willow complex. For. Prac. Br., B.C. Min. For., Victoria, B.C.

Boateng, J. and Comeau P.G. 2002. Operational summary for vegetation management: Cottonwood complex. For. Prac. Br., B.C. Min. For., Victoria, B.C.

Boateng, J.O. and L. Herring. 1990. Site Preparation: Chemical. In Regenerating British Columbia's Forests. D.P. Lavender et al. (editors). UBC Press, Vancouver, BC, pp. 164-178

Boyd, R.J., Miller, D.L., Kidd, F.A. and C.P. Ritter. 1985. Herbicides for forest weed control in the inland northwest: A summary of effects onn weeds and conifers. USDA For. Serv. Gen. Tech. Rep. INT-195. Intermountain Research Station, Ogden, Utah.

Braumandl, T.F. and Curran, M.P. 1992. A field guide for site identification and interpretation for the Nelson Forest Region. Land Manage. Handb. 20, B.C. Min. For., Res. Br., Victoria, B.C.

Brown, K. 1999. Mineral nutrition and fertilization of deciduous broadleaved trees in Britishh Columbia. Working Paper 42, B.C. Min. For., Victoria, B.C.

Campbell, E. and A. Nicholson. 1995. A summary of western yew biology with recommendations for its management in British Columbia. Land Manage. Handb. 32. B.C. Min. For., Victoria, B.C.

Clement, C. and B. Keeping. 1996. Evaluation of forest vegetation community dynamics on the Bush River brushing trial site. FRDA Rep. No. 241, For. Can. and B.C. Min. For., Victoria, B.C.

Coates, K.D. and P.J. Burton. 1999. Growth of planted tree seedlings in response to ambient light levels in northwestern interior cedar-hemlock forests of British Columbia. Can. J. For.Res. 29:1374-1382.

Coates D, Haeussler, S. and J. Mather. 1990. A guide to the response of common plants in British Columbia to management treatments. FRDA Handb. No. 8., For. Can. and B.C. Min. For., Victoria, B.C.

Conard, S.G. and W.H. Emmingham. 1983. Herbicides shrub control on forest sites in northeastern Oregon and northern Idaho. Oregon State Univ. For. Res. Lab, Special Publ. 5.

D'Eon, R., Serrouya, R., and Pavan, G. 2003. Moose damage on cedar seedlings in the Lake Revelstoke Valley: Year 2 summary. Unpublished report prepared for Downie Timber Ltd., Revelstoke B.C.

Dyck, B. 1987. A comparison of effectiveness one and two years following treatment of 1985 Roundup applications in the Revelstoke forest district. Unpublished report.

Hart, D. and P.G. Comeau. 1992. Manual brushing for forest vegetation management in British Columbia: a review of current knowledge and information needs. Land Manage. Report No. 77, B.C. Min. For., Victoria, B.C.

Haeussler, S., Coates, D., and J. Mather. 1990. Autecology of common plants in British Columbia: A literature review. FRDA Rep. 158, For. Can. and B.C. Min. For., Victoria, B.C.

Heineman, J. 1999. Fertilization at the time of planting: nine-year response of Douglas-fir, Engelmann spruce, and lodgepole pine in the southern interior ICH. Silv. Note 19, For. Prac. Br., B.C. Min. For., Victoria, B.C.

Klinka, K., V.J. Krajina, A. Ceska, and A.M. Scagel. 1989. Indicator plants of coastal British Columbia. University of British Columbia Press, Vancouver, B.C.

Mather, J. and S. Simard. 1997. Third year response of planted Douglas-fir and Mixed Shrub complex to manual cutting in the ICHmw3 subzone. Probe memo 16-2. B.C. Min. For., Kamloops Forest Region, Kamloops, B.C. (unoublished report).

Mather, J. and S. Simard. 1998a. Fifth year response of planted spruce and Mixed Hardwood-Shrub complex to foliar application of glyphosate in the ICHwk1 subzone.Probe memo 9-2. B.C. Min. For., Kamloops Forest Region, Kamloops, B.C. (unpublished report)

Mather, J. and S. Simard. 1998b. First year response of planted lodgepole pine and Mixed Hardwood-Shrub complex to backpack foliar glyphosate spray in the ICHmw2 subzone. Probe memo 46-2. B.C. Min. For., Kamloops Forest Region, Kamloops, B.C. (unpublished report plus observations by J. Mather)

Messier, F., S. Boutin, and D. Heard. 2004. Revelstoke mountain caribou recovery: an independent review of predator-prey-habitat interactions. Prepared for the Revelstoke Caribou Recovery Committee, Revelstoke, B.C.

Newsome, T.A., J.L. Heineman, A. Nemec. 2003. Competitive effects of trembling aspen on lodgepole pine performance in the SBS and IDF zones of the Cariboo-Chilcotin region of south-central British Columbia. Tech. Rep. 005, BC. Min. For., Victoria, BC.

Niemiec, S.S., Ahrens, G.R., Willits, S. and D.E. Hibbs. 1995. Hardwoods of the Pacific Northwest. Research Contribution 8, Forest Research Laboratory, College of Forestry, Oregon Sate University.

Sachs, D.L., Heineman, J.L., Mather, W.J., Curran, M.P., Morrison, I.R., Simard, S.W., and Crane, C. 2004. Expert System for Site Preparation and Vegetation Management in Southern Interior British Columbia. (web based application) (http://www.myacquire.com/spvegman/expertsystem/

Serrouya, R. and R. D'Eon. 2002. Moose habitat selection in relation to harvesting in a deep snow zone of British Columbia. Unpublished report prepared for Downie Timber Ltd., Revelstoke B.C.

Serrouya, R. and R. D'Eon. 2003. Deer and elk winter habitat selection and deer winter food habits in the northern Columbia Mountains, British Columbia. Unpublished report prepared for Downie Timber Ltd., Revelstoke B.C.

Smith, D.M. 1986. The practice of silviculture (8th edition). John Wiley and Sons, NY

Smithberg, M. 1974. Red-osier dogwood. *In* Shrubs and vines for northeastern wildlife. J.D. Gill and W.M. Healy (compilers). USDA For. Serv., Gen. Tech. Rep. NE-9, pp 44-47.

Stearns, F.W. 1974. Hazels. *In* Shrubs and vines for northeastern wildlife. J.D. Gill and W.M. Healy (compilers). USDA For. Serv., Gen. Tech. Rep. NE-9, pp 65-70.

Taylor, S.P. 1998. Impacts of the hemlock looper in the ICH zone. In: Ecosystem dynamics and silviculture systems in interior wet-belt ESSF and ICH forests. Workshop Proceedings. June 10-12, 1997. University of Northern British Columbia.

Thomas, D.C. and D.R. Gray. 2002. Update status report on the woodland caribou (*Rangifer tarandus caribou*) in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa. 1-98 pp.

Thompson, C. 1989. Developing herbicide efficacy tables for the southern interior. FRDA Report 96, For. Can. and B.C. Min. For., Victoria, B.C.

von der Gönna, M.A. 1992. Fundamentals of mechanical site preparation. FRDA Report 178, For. Can. and B.C. Min. For., Victoria, B.C.

Waterhouse, M.J., Dawson, R.J. and H.M. Armleder. 1990. The effects of juvenile spacing on wildlife habitat use during winter in the Interior Douglas-fir zone of British Columbia. Research Report 89003-CA, B.C. Min. For., Williams Lake, B.C.

Wittmer, H.U. 2004. Mechanisms underlying the decline of mountain caribou (*Rangifer tarandus caribou*) in British Columbia. PhD thesis. University of British Columbia, Vancouver, B.C.

Wright, E.F., K.D. Coates, D.D. Canham, and P. Bartemucci. 1998. Species variability in growth response to light across climatic regions in north-western British Columbia. Can. J. For. Res. 28: 871-886.