Extension Note

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Modelling critical winter habitat of four ungulate species in the Robson Valley, British Columbia

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Abstract

A modelling exercise was conducted to identify potential critical winter habitat for four ungulate species in the Robson Valley in east-central British Columbia: mule deer (*Odocoileus hemionus hemionus*), white-tailed deer (*Odocoileus virginianus*), Rocky Mountain elk (*Cervus elaphus nelsonii*), and moose (*Alces alces*). The model was developed to provide land managers with an effective decision-making tool to include critical winter habitat in land-use planning. Forest cover data, biogeoclimatic data, and a digital elevation model were used to reflect snow depth, forage availability, thermal cover, and security cover values during winter months. The model identifies low-elevation, south-facing, older forests where snowpacks are less deep as potential critical winter habitat for deer and elk. Because moose are better adapted to northern Interior winter conditions, the model identifies coniferous and deciduous stands with greater forage potential. Recent mild winters have limited the field validation process. Habitat assessment, using local sites as benchmarks for model evaluation, found that the distribution of resources varied within and between high-rated polygons and that the model overestimates the amount of critical ungulate winter habitat in the Robson Valley. Forage availability, followed by snow interception, were shown to be the limiting factors in most cases. The model is a broad filter of critical ungulate winter habitat; it is intended for field use as a management tool to identify the boundaries of critical winter range. The limitations of the model and priorities for improvement are reviewed.

KEYWORDS: *moose, Rocky Mountain elk, mule deer, white-tailed deer, winter habitat, winter range, forest management, model, British Columbia.*

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Introduction

During recent decades, the management of ungulate winter habitat has received increased attention as a necessary means of maintaining healthy ungulate populations in British Columbia's managed forests. Winter is the most difficult season for ungulates because their energy costs are greater than compared to other seasons, yet forage resources are limited. As a result, during winter, ungulates select forest and terrain features that minimize energy costs (Lyon and Ward 1982; Skovlin 1982; Parker *et al.* 1984). Some researchers identify "critical" ungulate winter range, which refers to the habitat that ungulates depend on when winter conditions are extreme and snow depths are at their greatest (e.g., Gilbert *et al.* 1970; Nyberg and Janz 1990). Severe winters can have a dramatic effect on ungulate populations. This was highlighted during the severe winter of 1982 in the Robson Valley when high deer mortality occurred because of the unusually deep snowpack (D. King, Habitat Section Head [retired], B.C. Ministry of Environment Lands and Parks, Prince George, B.C., pers. comm., November 2001).

This project focuses on four ungulate species in the Robson Valley Land and Resource Management Plan area (RV LRMP) in east-central British Columbia: moose (*Alces alces*), Rocky Mountain elk (*Cervus elaphus nelsonii*), white-tailed deer (*Odocoileus virginianus*), and mule deer (*Odocoileus hemionus hemionus*). The RV LRMP area encompasses a wide range of ecosystems, from the dry hot subzone of the Sub-Boreal Spruce biogeoclimatic zone (SBSdh), with the driest conditions in the valley, to the northernmost portions of the Interior Cedar–Hemlock (ICH) and the Engelmann–Spruce Subalpine Fir (ESSF) zones found at higher elevations. In the Robson Valley, deer and elk are at the northern limit of their range west of the Rocky Mountains; their distribution becomes increasingly scattered as one moves north and west into the interior of the province. Moose, however, are abundant in the SBS zone (Meidinger 1991).

The RV LRMP (1999) outlined an objective to manage for ungulate winter habitat. Stand-management activities in managed forests have significant potential to affect winter habitat values. To properly mitigate any conflict between critical winter habitat values and other land-use values, critical winter habitat areas (i.e., critical winter range) must be defined using a baseline understanding of the habitat parameters and local distribution of each ungulate species. With the exception of Ingham's (2000) study of mule deer and white-tailed deer in the Tête Jaune Cache and Valemount areas (SBSdh), few detailed habitat-use studies of moose, Rocky Mountain elk, white-tailed deer, or mule deer have been undertaken in the Robson Valley. Thus, baseline data about habitat use in winter and the distribution of these four ungulates are limited in the RV LRMP area.

This model was developed to provide land managers with an effective decision-making tool to include critical winter habitat in land-use planning.

As part of the Enhanced Forest Management Pilot Project (EFMPP),[1] a modelling exercise was conducted to identify potential critical winter habitat for moose, Rocky Mountain elk, white-tailed deer, and mule deer in the Robson Valley. Our objective was to use available modelling resources to develop a process for identifying critical winter habitat. The model developed is the starting point in defining critical winter habitat. After undergoing field testing and further refinement, the model will improve knowledge about winter habitat use by these four ungulates in the RV LRMP area. This paper describes the process of developing a multi-species model in an area where ecosystem-based mapping and ungulate habitat-use studies are limited.

Review of Winter Habitat Use

Moose

In areas where snow depth is not limiting, selection of winter habitat is determined primarily by forage availability (Peek 1997). Areas of abundant browse include old burns, harvested areas, riparian zones, shrub land, and shrub-meadow (Tefler 1978; Peek 1997). Coniferous stands provide security and thermal cover for moose, as well as relief from deep snowpack.

Local expertise indicates that low-elevation riparian habitat along the Fraser River is the core winter habitat

[1] The EFMPP is a co-operative effort between government, the forest industry, and the academic community. Its goal is to establish new, or to enhance existing, forest management processes or tools by utilizing the expertise and experience of other EFMPP sites, model forests, academia, and researchers. For further background, refer to: *http://www.for.gov.bc.ca/hcp/enhanced/robson/efmpp/index.htm*

for moose in the Robson Valley (G. Watts, Regional Wildlife Biologist, B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001; D. King, Habitat Section Head [retired], B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001). Results of winter aerial surveys of the Robson Valley found the majority of moose in four forest categories: the largest number of moose were found in deciduous forests greater than 60 years old, followed by deciduous stands less than 60 years old, cleared sites and brush-dominated sites, and mixed forests (Ingham 1994). During more severe winters, spruce forests provide greater snow interception and forage opportunities (G. Watts, Regional Wildlife Biologist, B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001). Expansion of agricultural areas and settlement throughout much of the Robson Valley is considered to have had a negative effect on the winter habitat of moose (D. King, Habitat Section Head [retired], B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001).

Rocky Mountain Elk

Although they demonstrate a preference for edge habitat between forests and clearings (Skovlin 1982), elk are considered generalists because of their ability to adapt to a wide variety of habitats (Jones 1997). Elk winter at lower elevations on south-facing aspects and ridge tops where less snow accumulates (Skovlin 1982; Resources Inventory Committee 1997). Young burns, grassy slopes, riparian zones, and floodplains provide suitable winter habitat (Goulet and Haddow 1985); however, mature conifer stands are critical for cover and snow interception during severe winters.

In the Robson Valley, local sources indicate that habitat used by elk during winter consists of south-facing slopes with aspen, mixed forests, and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) stands on drier sites (L. Ingham, Program Biologist, Columbia Basin Fish and Wildlife Program, Nelson, B.C., pers. comm., November 2001). Elk have been noted to forage on hay bales in agricultural areas during periods of deep snowpack. Local sources also indicate that elk have been increasing in numbers and expanding their range into and within the Robson Valley during recent decades (G. Watts, Regional Wildlife Biologist, B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001; D. King, Habitat Section Head [retired], B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001). Fragmentation of forests, agricultural development, and recent mild winters have facilitated expansion of their range. Although elk are perceived as recent arrivals, Spalding (1992) reports that they existed in most ecoprovinces of British Columbia, and specifically the Upper Fraser River, between one and two centuries ago.

White-tailed Deer

During winter, white-tailed deer select agricultural land, shrub land, aspen forest, riparian zones, and young Douglas-fir stands if snow depths are shallow enough to permit access (Martinka 1968; Smith 1977). During more severe winters in southeastern British Columbia, white-tailed deer were restricted to closed canopy forests. In these forests, forage values were significantly lower than in more open canopy forests (Smith 1977). Habitat providing shallow snow depth is integral to white-tailed deer survival (Tefler 1978). Wishart (1984) reports that south-facing slopes and open exposures during spring increase survival of white-tailed deer.

Winter habitat in the Robson Valley is located primarily in riparian flats along the Fraser River, and on south-facing slopes in the valley bottom below 1000 m elevation (L. Ingham, Program Biologist, Columbia Basin Fish and Wildlife Program, Nelson, B.C., pers. comm., November 2001). A study of radio-collared white-tailed deer in the SBSdh subzone of the Robson Valley showed that they preferred old and mature deciduous forests during winter; however, the deer showed a preference for leading spruce and Douglas-fir stands in the coniferous forests selected (Ingham 2000). Over the last two decades, white-tailed deer have expanded rapidly in a northwesterly direction into the ICH zone along the Fraser River (D. King, Habitat Section Head [retired], B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001; C. Jeck, Rancher, Robson Valley [McBride area], B.C., pers. comm., November 2001). This expansion is likely due to the development of agricultural lands, the creation of early successional vegetation and forest edge, and recent mild winters.

Mule Deer

During winter, mule deer select habitat with a shallower snowpack to reduce their energy costs (Armleder *et al.* 1994). In the interior of the province, mule deer winter habitat use is strongly associated with mature and old Douglas-fir stands in the Interior Douglas-fir (IDF) zone (Dawson *et al.* 1990; Armleder *et al.* 1994). These structurally diverse stands provide considerable snow interception, thermal cover, and security cover, in conjunction with adequate winter forage.

In the Robson Valley, western redcedar (*Thuja plicata*)/western hemlock (*Tsuga heterophylla*) forests in the ICH zone have high canopy closure and are used by mule deer during winter in some locations despite the limited understorey forage (D. King, Habitat Section Head [retired], B.C. Ministry of Environment, Lands and Parks, Prince George, B.C., pers. comm., November 2001). The arboreal lichen and branch litterfall from mature and old trees are believed to be important forage. In the SBSdh subzone, Ingham (2000) reports that mule deer prefer gentle south-facing slopes below 1000 m during winter. Preliminary results from this study suggest that mule deer have a preference for old and mature spruce and Douglas-fir stands, whereas pine forests were not preferred relative to pine forest availability. Generally, mule deer are con-sidered as more of an upland forest ungulate than are white-tailed deer. Agricultural and urban development has reduced mule deer winter range at lower elevations in the Robson Valley.

Model Development

When dealing with complex land-use decisions involving wildlife habitat, managers desire economical, easily applied tools to assist them with decision making (Bunnell 1989). In many regions of the Pacific northwest—including Vancouver Island (Harestad 1985; McNay 1995), the Cariboo (Dawson *et al.* 1990; Armleder *et al.* 1994), the Kooteneys (Smith 1977; Boulanger *et al.* 2000), and the eastern slopes of the central Rocky Mountains (Jones 1997)—research concerning ungulate winter habitat has defined landscape and vegetation parameters which provide a basis for modelling winter habitat. The model development process used here takes advantage of work from other regions, and refines habitat parameters to the local level through a field validation process that applies site-level data to the broader landscape.

We developed the model using the following procedure.

- Create a conceptual model of critical winter habitat based on a review of literature and on local expertise (see Safford 2001).
- Create a knowledge table that rates forest and terrain categories for habitat values for each ungulate species.
- Develop polygons from GIS database layers and apply the knowledge table ratings to create "high," "moderate," and "low" potential winter habitat polygons for each ungulate species.
- Evaluate and field test the model on its capacity to identify critical winter habitat, and refine the knowledge tables to better reflect local habitat parameters.

We made two primary assumptions in developing the model. First, we assumed that information in the literature, together with local expertise regarding ungulate winter habitat, was sufficient to develop a model of adequate accuracy. Second, we assumed that databases used to create the model were sufficiently accurate and relevant to reflect habitat values. For example, forest cover has been used in ungulate habitat studies in other areas of the province to define habitat parameters (e.g., Ingham 1994; Boulanger *et al.* 2000). We, therefore, assumed it would be reasonable to use forest cover for this modelling exercise.

Conceptual Model

Forage, thermal cover, and security cover are key requirements for moose, Rocky Mountain elk, mule deer, and white-tailed deer (Figure 1). Winter weather can severely limit the ability of ungulates to obtain these life requisites, and can affect their survival and reproductive success. However, certain combinations of forest and terrain features can, if available, improve their survival in winter conditions. Therefore, the model focuses on forest and terrain features that influence snow depth and forage availability, provide security cover, and assist in maintaining thermoregulatory balance.

For deer and elk, selection of winter habitat is determined primarily by snow depth (Gilbert *et al.* 1970; Smith 1977; Parker *et al.* 1984; Sweeney and Sweeney 1984; Wishart 1984) because snow depth has the greatest impact on forage availability, energy expenditure (through travel), and predator avoidance (Parker *et al.* 1984). Sweeney and Sweeney (1984) noted that a snow depth of 40 cm caused elk to move to areas with less snow, and depths greater than 70 cm severely limited their movement. Other researchers observed that a snow depth of 25 cm was limiting for deer, and that depths greater than 45 cm excluded deer from an area (Gilbert *et al.* 1970; Tefler 1978; Parker *et al.* 1984). A review of historical weather data for the Robson Valley (B.C. Ministry of Water, Land and Air Protection) showed that it is reasonable for this model to focus on snow depth for deer and elk. For example, the winter of 1982 was particularly severe in the Robson Valley, with snow depths of greater than 80 cm at low elevations (B.C. Ministry of Water, Land and Air Protection). Thus, for the purposes of the model, we considered snow depth as the primary limiting factor for deer and elk in selecting winter habitat, and the primary limiting factor for their survival.

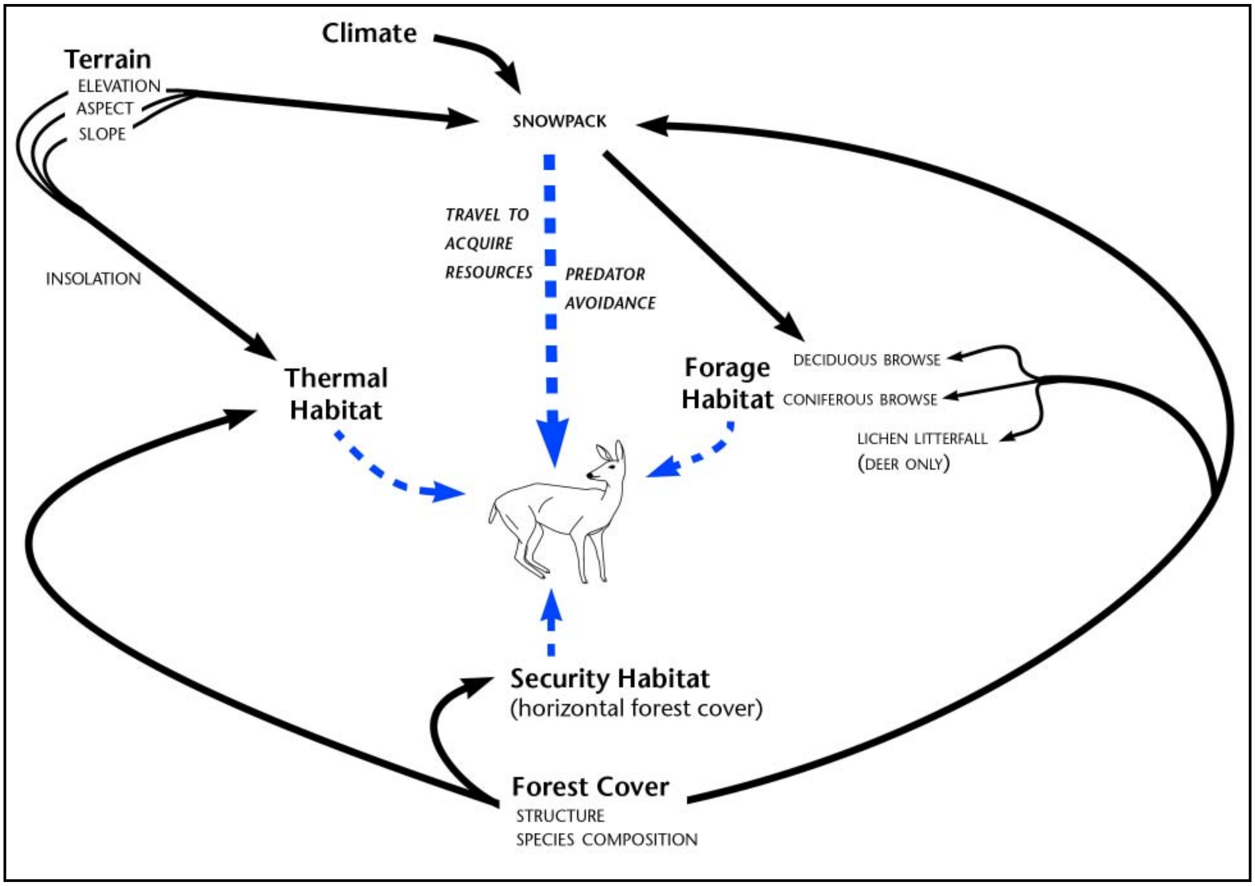

FIGURE 1. Diagram representing assumptions of the conceptual model. Black arrows represent the factors that influence winter habitat attributes. Dashed blue arrows indicate factors that influence the condition of ungulates (adapted from Armleder *et al.* 1994).

Moose, on the other hand, are well adapted to the long snowy winters of the central Interior (Meidinger 1991). Although snow depth of about 1 m can severely limit the travel of moose, moose can tolerate snow depths up to 80 cm (Peek 1997; Resources Inventory Committee 1997). Thus, for moose, we assumed that snow rarely reaches critical depths at lower elevations in the Robson Valley and that snow depth will not prevent moose from using more open-canopied stands. We assumed that forage availability plays a stronger role than snow depth in determining winter habitat selection.

Knowledge Tables

We created a set of tables that identify important forest and terrain features of potential winter habitat for each of the four ungulate species modelled. These features are:

- Forest tree species (leading and secondary)
- Stand structure (separated into climax and seral species)
- Slope
- Aspect
- Elevation
- Climate (based on biogeoclimatic ecosystem classification)

These categories were further divided into subcategories, and subcategory parameters were defined based on the conceptual model (Table 1). Numerical ratings were applied according to the capacity of a subcategory to influence snowpack development, and on the capacity to provide forage, thermal cover, and security cover values during winter months. The ability to reduce snowpack was given the highest numerical value for deer and elk, whereas the ability to provide forage was given the highest numerical value for moose (Table 2).

TABLE 1. Knowledge table: categories and subcategories of forest and terrain features

Category	Subcategory	
1 Forest tree species (leading & secondary species)	Examples: Douglas–fir/lodgepole pine, western redcedar/spruce	
2 Stand age		
a. Late seral, climax species (coniferous)	Cleared	(Age Class 1)
	Pole sapling	(Age Class 2)
	Young forest	(Age Class 3–5)
	Mature forest	(Age Class 6–7)
	Old forest	(Age Class 8–9)
b. Early seral species (deciduous, pine)	Cleared	(Age Class 1)
	Pole sapling	(Age Class 2)
	Young forest	(Age Class 3–4)
	Mature forest	(Age Class 5–7)
	Old forest	(Age Class 8–9)
3 Slope	Level	(0–10°)
	Mid slope	(11–55°)
	Steep slope	(≥ 56°)
4 Aspect	South	(110–250°)
	West	(250–290°)
	North	(290–70°)
	East	(70–110°)
	No aspect	
5 Elevation	1000-m boundary (mule deer, white-tailed deer)	
	1100-m boundary (moose, elk)	
6 Subzone/variant	Examples: SBSvk, SBSdh, ICHwk3, ICHmm, ESSFwc	

TABLE 2. Base rating scheme for habitat feature subcategories

	Forage	Security	Thermal	Snow interception
Moose	0.5	0.25	0.25	0.25
Rocky Mountain elk	0.25	0.25	0.25	0.5
White-tailed deer	0.25	0.25	0.25	0.5
Mule deer	0.25	0.25	0.25	0.5

GIS Analysis

The knowledge table ratings were applied to habitat polygons created in ArcInfo (Environmental Systems Research Institute 1998). Forest cover maps (B.C. Ministry of Forests 2000), biogeoclimatic ecosystem classification maps (B.C. Ministry of Forests 1995), and a 1:20 000 scale gridded digital elevation model (DEM) of the RV LRMP area (B.C. Ministry of Environment 1998) were used to develop the model's information layers and to create polygons. We used ArcInfo's built-in slope and aspect functions to develop slope and aspect from the DEM. The categories of slope, aspect, and elevation were reclassified into the subcategories defined in the knowledge table. These three layers were then combined with the biogeoclimatic ecosystem classification grid layer. The combined grid layers were converted to a polygon layout and intersected with the forest cover database. Subcategory ratings from the knowledge table were combined for an overall numerical rating of habitat polygons.

Using key criteria, we applied ratings to database layers to establish polygons of potential winter habitat. In each forest and terrain category, one key criterion receives the highest rating (e.g., Douglas-fir stands for mule deer). We used the number of key criteria in a given habitat type to define the range of values for potential winter habitat. Habitat types with two or fewer key criteria received a "low" rating, those with three to four key criteria received a "moderate" rating, and those with four to six key criteria received a "high" rating.

Model Results

Each polygon has forest, terrain, and climate categories associated with it, resulting in a cumulative numerical rating that is classified as high, moderate, or low potential critical ungulate winter habitat (Table 3). The model identifies older forests on low-elevation, south-facing slopes (> 11°) in the drier regions of the RV LRMP area as important winter habitat for all four species of ungulates. In addition, for moose, the model identifies low-elevation deciduous stands and low-elevation old spruce stands in flat areas as high potential winter habitat.

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Model Validation

Model validation is perhaps a misnomer; model development is a process of re-testing assumptions, re-evaluating goals, and improving the model's design as knowledge about habitat structure improves and more detailed databases become available. Nevertheless, a habitat model can be corroborated, evaluated on the practicality of its use, and improved upon in its ability to predict habitat values (Bunnell 1989). Is the model going in the right direction? Is it a valuable tool for the users? Does it reflect winter habitat values of ungulates with sufficient accuracy?

A certain level of variability in the model's accuracy was anticipated, in part because the RV LRMP area encompasses a wide range of forest ecosystems and climatic conditions. In addition, the forest cover and DEM have a limited capacity to reflect habitat values. The information in the forest cover database is collected and presented as an inventory of timber resources for forestry activity; therefore the sizes, descriptions, and boundaries of the forest cover polygons are not expected to reflect winter habitat at a detailed level. Similarly, the 1:20 000 scale DEM may not provide sufficient detail to reflect terrain habitat features at the site level, and must be assessed during field investigations.

Evaluating the model will identify which model components (database and knowledge table features) best reflect habitat attributes, and will allow for refinement of model design. First, we reviewed the polygons generated by the model, and this indicated that the model identifies specific features as intended (Table 3). Subsequently, the focus of model evaluation consisted of conducting field work to collect evidence-of-use data (track transects) and habitat attributes at the site level. Ideally the model should be tested during severe winter conditions when ungulates would be restricted to critical habitat; however, recent winters have been particularly mild and snow depths have been below average (B.C. Ministry of Water, Land and Air Protection). Track transect data were collected during the winter of 2001, but snow depths did not restrict the four species of ungulates to any particular habitat. As a result, evaluation of the model's performance focused on habitat assessment, which compared high-rated deer and elk polygons to local benchmarks of critical winter habitat.

Habitat Assessment

To compare field and model ratings, the model was assessed using local winter habitat as benchmarks (Table 4). Benchmark sites, which represent critical winter habitat, were established by reviewing local knowledge, by checking literature sources (e.g., Ingham 2000), and by undertaking field assessments. Benchmarks, or equivalents, were established for each pertinent biogeoclimatic zone or subzone to represent ungulate winter habitat values in different forest types (e.g., mule deer in Table 4). Data on forest and terrain features was collected from sample plots focused on high-rated polygons for deer and elk (assessing high-rated moose polygons was secondary for this particular field season). Snow depth was measured at plots, along transects, and in open-canopied stands on flat terrain. The latter represented areas of greater snow depth, which allowed for comparison with the plot and transect measurements in high-, moderate-, and low-rated polygons. The data were summarized and used to compare forage availability, security cover, thermal cover, and snow interception values, and to determine an overall field rating of plots (i.e., high, moderate, or low) relative to the benchmarks. The influence of adjacent habitat was also considered in field plot ratings.

TABLE 3. Examples of high, moderate, and low polygon ratings for mule deer, white-tailed deer, elk and moose

Ungulate species	Aspect (degrees)	Elevation (m)	Slope (degrees)	Zone/subzone	Tree species (leading, secondary)	Forest structure	Forest type (age class)	Rating	Code
Moose	South (110–250)	< 1100	Mid (11–55)	SBSvk	Trembling aspen/ hybrid spruce	Mature (5–7)	Deciduous/ seral	5.5	High
Moose	No aspect	< 1100	Nil (0–10)	SBSdh	Douglas-fir/ lodgepole pine	Young (3–5)	Coniferous	4	Moderate
Moose	East (70–110)	< 1100	Mid (11–55)	ICHwk	Western redcedar/ western hemlock	Mature (6/7)	Coniferous	3.25	Low
Rocky Mountain elk	South (110–250)	< 1100	Mid (11–55)	SBSdh	Douglas-fir/ lodgepole pine	Young (3–5)	Coniferous	5.25	High
Rocky Mountain elk	No aspect	< 1100	Nil (0–10)	SBSdh	Hybrid spruce	Old (8/9)	Coniferous	4.25	Moderate
Rocky Mountain elk	No aspect	< 1100	Nil (0–10)	ICHwk	Western redcedar/ hybrid spruce	Old (8/9)	Coniferous	3.25	Low
White-tailed deer	South (110–250)	< 1000	Mid (11–55)	SBSdh	Hybrid spruce/ Douglas-fir	Old (8/9)	Coniferous	5.5	High
White-tailed deer	South (110–250)	< 1000	Mid (11–55)	ICHwk	Western redcedar/ hybrid spruce	Old (8/9)	Coniferous	4.5	Moderate
White-tailed deer	North (290–70)	< 1000	Steep (> 56)	SBSdh	Lodgepole pine	Young (3–5)	Deciduous/ seral	3.25	Low
Mule deer	South (110–250)	< 1000	Mid (11–55)	ICHwk	Western redcedar/ western hemlock	Old (8/9)	Coniferous	5.5	High
Mule deer	South (110–250)	> 1001	Mid (11–55)	SBSdh	Douglas-fir/ lodgepole pine	Young (3–5)	Coniferous	4.5	Moderate
Mule deer	No aspect	< 1000	Nil (0–10)	SBSdh	Black spruce	Old (8/9)	Coniferous	3.5	Low

TABLE 4. Benchmark sites used to assess model performance

Ungulate species	Zone/ subzone	Aspect (degrees)	Slope (degrees)	Elevation range (m)	Tree species[a]	Structural stage[b]	% canopy closure		No. of shrub species in plots	Range of plot shrub cover (%)
							Mean	Range		
Moose	SBSvk	NA	0	680	hybrid spruce/ poplar	YF	16.8	0–47.2	5–9	25–45
Rocky Mountain elk	SBSdh	39–206	0–30	750–763	Douglas-fir	YF	38.0	13.6–63.0	3–7	20–38
White-tailed deer	SBSdh	195–208	0–32	750–765	Douglas-fir	YF	42.7	13.6–63.2	3–5	30–40
Mule deer	SBSdh	39–208	0–32	750–765	Douglas-fir	YF	40.0	13.6–63.2	3–9	20–40
Mule deer	ICHwk3	210–272	20–25	680–835	western redcedar (hybrid spruce/ Douglas-fir)	OF	65.1	64–65.6	4–7	15–30

[a] Leading species/secondary species.

[b] YF = young forest; OF = old forest.

In general, for deer and elk, the model highlights forest and terrain features that provide a shallower snowpack (though not necessarily less than critical depths) than provided by adjacent habitat. For moose, the model identifies areas of greater deciduous browse. However, at the site level, the model is less accurate. With few exceptions, the model overestimates a polygon's value as critical winter habitat; high-rated polygons were frequently of moderate or low critical winter habitat value in the field. There were few cases where low-rated polygons were of high critical winter range value in the field (due to either the proximity of the low-rated habitat to higher-value winter habitat, or to finding a different composition of tree species and forest structure than was expected by the forest cover database). The result is an overestimation of the area of critical winter habitat in the RV LRMP area. For all species, forage availability was the primary limiting factor, particularly in the western redcedar and western hemlock forests of the ICH zone. For deer and elk, snow interception (i.e., canopy closure) values were also limiting in some high-rated polygons consisting of younger stands.

The variability of winter habitat values in high-rated polygons is attributed primarily to the limited capacity of the forest cover database to accurately reflect the forest habitat attributes at the site level. Stand age in the forest cover database was an inconsistent predictor of forest structure and understorey composition. The heterogeneous structure of old-growth forests, which was anticipated in the older age classes, was rarely found. For example, many of the cedar-hemlock forests sampled in the ICH zone were mature even-aged stands that had high snow interception capacity juxtaposed with minimal forage availability. In homogeneous terrain in these high-rated cedar-hemlock forests, subcanopy forage, security, and thermal values were entirely lacking, or were widely spaced. As Armleder *et al.* (1986) noted, the spatial distribution of habitat values is an important consideration because accessibility of different habitat types relates directly to energy costs in acquiring life requisites. The result was that forage availability, security cover, and thermal cover values varied in distribution and quality within and between similarly rated polygons.

The data from the DEM were more consistent with field observations, although site-level attributes and heterogeneous terrain were lost at the 1:20 000 scale. Thus, the DEM did not identify site conditions that influence the spatial distribution of habitat attributes. For example, terrain breaks that provide edge habitat in forested stands were not always identified.

Priorities for Improving the Model

Field assessment provided some insight into the limits of the model, and consequently several changes are recommended for improving site-level prediction of ungulate winter habitat. See Safford (2003) for a detailed review of all recommended changes to the knowledge tables and database layers.

The following additions and changes to the databases are recommended:

- Create a more detailed DEM at 1:5000 or 1:10 000, so that definition of the site attributes (e.g., terrain breaks and depressions) that influence habitat is possible.
- Add Terrestrial Ecosystem Mapping (TEM) and (or) Vegetation Resource Inventory (VRI) databases to improve the model's ability to predict understorey attributes. Identifying the quality and quantity of winter forage values is the priority.
- Add an insolation index. This will reduce the rating of south-facing slopes in steep east–west running drainages where the southern ridgeline blocks the sun. Although this option would apply throughout the province, it would be particularly advantageous in mountainous terrain.
- Model snow depth to create snowpack zones such as those already developed on Vancouver Island (Nyberg *et al.* 1989), and (or) use biogeoclimatic ecosystem classification zones to apply knowledge tables to smaller, manageable landscape units. This will allow for the creation of unique rating schemes for forest and terrain features at a more localized level, and will thus help refine the model.

Developing more detailed forage availability and snow interception ratings and removing the security and thermal habitat ratings is being considered. In the field, security and thermal cover values did not appear to be limiting factors. High security values are found in shallow snowpack and horizontal forest cover (hiding cover), and are sufficiently represented in the forage and snow interception components of the model. High thermal values are found in canopy closure and terrain (i.e., in terms of providing sun exposure or shelter from inclement weather) and are generally represented well in the snow interception rating scheme. Both security and thermal cover values should be included in future field assessments to ensure they are represented in winter habitat.

To develop confidence in the model's assumptions, collecting ungulate habitat-use data during a year when snow depths are normal or above average is a priority. This will allow further evaluation of the subcategory parameters to determine whether the parameters are applicable across the RV LRMP landscape. For example, the elevation boundary (1000 m for deer, 1100 m for moose and elk) is not expected to be appropriate for the entire RV LRMP area. Identifying an accurate elevation boundary is particularly important because winter habitat values may be lost or forestry values constrained if it is incorrectly identified.

Model Use and Defining Critical Winter Range

The model is a landscape-level filter for critical ungulate winter habitat and as such it provides a crude estimate at the operational level. For each of the four ungulate species, the model provides a general overview of the distribution of potential winter habitat. Using the model for operational-level planning requires that field investigations be conducted to assess critical winter habitat values and to determine the boundaries of ungulate winter range management areas. Benchmark sites and habitat-use data (e.g., evidence of use and track transects) can be used to verify ungulate winter range in the field.

The model was recently used to identify candidate ungulate winter range management areas in the Robson Valley for designation under Section 69 of the Operational Planning Regulations of the *Forest Practices Code* (Safford 2002). Maps produced by the model were used to select sites for field visits, and to assist in defining boundaries. Because the model overestimates the amount of critical ungulate winter habitat, field work focused on high-rated polygons and moderate-rated polygons on south-facing slopes. Benchmark sites were used to standardize field crews to local winter habitat attributes, and to provide a comparison for site assessment. Edge habitat, habitat connectivity, and proximity to mild[2] winter range and spring range were important considerations in defining critical winter range.

The structure of the model can be applied to most regions of the province because forest cover, topographic, and broad-scale biogeoclimatic ecosystem classification maps are readily available. New databases can be added and new categories created in the knowledge table(s), and the overall rating scheme can be adjusted to reflect local forest and terrain conditions. A similar model structure was used in the Prince George Land Resource Management Plan area, which could provide a uniform product across the Prince George and Robson Valley LRMP jurisdictions when the forest cover databases are of a similar age.

[2] Mild winter ranges are areas used during periods of shallow snowpack that provide greater forage densities compared to critical winter habitat.

Limitations of the Model

The model has several limitations. It does not consider:

- **Habitat capability.** The model cannot predict the capability of a site to provide winter habitat if, for example, habitat enhancement activities were applied. Many of the forests in the Robson Valley are in young climax or early seral stages of development. As these stands mature and become more structurally diverse, critical winter habitat values will improve.
- **Human disturbance.** Habitat selection by ungulates is influenced by: road density and level of use; recreational activities, such as snowmobiling and hiking, hunting, and poaching; and timber harvesting (Smith 1977; Morgantini 1979; Thomas *et al.* 1979; Jones 1997).
- **Agricultural impacts.** If they are readily available, hay bales are a high-energy food source that will be used by elk, white-tailed deer, and mule deer during the winter.
- **Inter-specific and intra-specific competition for habitat.** For example, the influence of white-tailed deer expansion into traditional mule deer range can affect the distribution of mule deer. Peek (1997) suggests competition between elk and moose may occur during winters of deep snowpack because elk can adapt to a browse diet.

Conclusions

In regions such as the Robson Valley where the land base is constrained by numerous objectives (e.g., settlement, agriculture, and forestry), land managers increasingly require detailed knowledge of critical wildlife habitat to refine the boundaries of habitat management areas. Applying studies from other regions has provided a baseline from which to identify ungulate winter habitat in the Robson Valley; however, improving the ability of the model to reflect winter habitat values at a more detailed level is clearly needed. Developing the model further (i.e., by incorporating new databases and by refining its structure with the application of site-level field data to the broader landscape) is one means of improving our understanding of local habitat use. At present, the shortcomings of the forest cover database limit the ability of the model to accurately reflect the attributes of ungulate winter habitat at the site level.

The challenges in defining the boundaries of critical winter range are significant because these four ungulate species use a complex set of criteria to select habitat over time.

As we found during this project, caution needs to be exercised when relying on forest cover data to consistently reflect habitat values.

Use of local sites as benchmarks provided consistency in habitat assessment; however, the benchmarks may be too narrowly defined, which means important winter habitat may be left out of defined winter range management areas. Harestad (1985) argued that mild winter range can provide greater food densities and may receive a greater number of deer-use days over winter. In addition, benchmarks may not represent the entire critical winter habitat available in the Robson Valley. Detailed studies of ungulate winter habitat use in Interior Cedar–Hemlock forests are lacking, and questions arise about winter range size and stand preference given the limited forage availability in mature cedar-hemlock stands. This is particularly relevant to mule deer who use cedar-hemlock forests on a regular basis during winter. In the future, track transects and (or) radio-collaring of ungulates during more normal snowfall years will be important to confirm winter use and to assist with the determination of appropriate winter range boundaries.

Ultimately the objective is to provide land managers with an effective decision-making tool to enable the inclusion of critical ungulate winter habitat in landscape and site level land-use planning. The challenges in defining the boundaries of critical winter range are significant because these four ungulate species use a complex set of criteria to select habitat over time. Rational boundaries can be defined through forest and terrain features; however, at present, a quantifiable link to maintenance of ungulate populations does not exist. It is anticipated that monitoring of populations and of critical habitats will play an essential role in assessing whether management strategies in ungulate winter habitat are effective over the long term.

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References

Armleder, H.M., R.J. Dawson, and R.N. Thomson. 1986. Handbook for timber and mule deer management co-ordination on winter ranges in the Cariboo Forest Region. Research Branch, B.C. Ministry of Forests, Victoria, B.C. Land Management Handbook No. 13.

Armleder, H.M., M.J. Waterhouse, D.G. Keisker, and R.J. Dawson. 1994. Winter habitat use by mule deer in the central interior of British Columbia. Canadian Journal of Zoology 72:1721–1725.

Boulanger, J.G., K. Poole, J. Gwilliam, G.P. Woods, J. Krebs, and I. Parfitt. 2000. Winter habitat selection by white-tailed deer in the Pend D'Oreille Valley, southeastern British Columbia. Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C.

British Columbia Ministry of Environment. 1998. Digital elevation model (based on trim 1). Base Mapping and Geomatic Services Branch, B.C. Ministry of Environment, Victoria, B.C.

British Columbia Ministry of Forests. 1995. Robson Valley biogeoclimatic ecosystem classification (1:250 000 scale) version 1. Research Branch, B.C. Ministry of Forests, Victoria, B.C.

_______. 2000 (data from 1999). Robson Valley forest cover. Resource Inventory Branch, B.C. Ministry of Forests, Victoria, B.C.

British Columbia Ministry of Sustainable Resource Management. 1999. Robson Valley land and resource management plan: April 1999. Resource Management Division, Victoria, B.C. URL: *http://srmwww.gov.bc.ca/rmd/lrmp/robson/toc.htm*

British Columbia Ministry of Water, Land and Air Protection. Historic snow survey data for British Columbia. Public Safety and Prevention Initiatives, Victoria, B.C. URL: *http://srmwww.gov.bc.ca/aib/wat/rfc/archive/historic.html* [Accessed 2001]

Bunnell, F.L. 1989. Alchemy and uncertainty: what good are models? U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-232.

Dawson, R.J., H.M. Armleder, and M.J. Waterhouse. 1990. Preferences of mule deer for Douglas-fir foliage from different sized trees. Journal of Wildlife Management 4(3):378–382.

Environmental Systems Research Institute.1998. ArcInfo version 7.2. Redlands, Calif.

Gilbert, P.F., O.C. Wallmo, and R.B. Gill. 1970. Effect of snow depth on mule deer in Middle Park, Colorado. Journal of Wildlife Management 30(1):15–23.

Goulet, L.A. and D.J. Haddow. 1985. An inventory of wildlife resources on the Liard River, northern British Columbia: a report of the 1978, 1980, and 1981 field studies. BC Hydro. Report No. ESS-30.

Harestad, A.S. 1985. Habitat use by black-tailed deer on northern Vancouver Island. Journal of Wildlife Management 49(4):946–950.

Ingham, L. 1994. Robson Valley aerial moose survey. Mica Wildlife Compensation Program, Nelson, B.C.

_______. 2000. Interim report on a mule deer and white-tailed deer habitat study in the Robson Valley. Columbia Basin Fish and Wildlife Compensation Program, Nelson, B.C.

Jones, P.F. 1997. Winter habitat selection by elk (*Cervus elaphus*) in the lower foothills of west-central Alberta. MSc thesis. Department of Renewable Resources, University of Alberta, Edmonton, Alta.

Lyon, J.L. and A.L. Ward. 1982. Elk and land management. *In* Elk of North America: ecology and management. J.W. Thomas and D.E. Toweill (editors). Stackpole Books, Wildlife Management Institute, Harrisburg, Pa. pp. 469–473.

Martinka, C.J. 1968. Habitat relationships of white-tailed and mule deer in northern Montana. Journal of Wildlife Management 32:558–565.

McNay, R.S. 1995. The ecology of movements made by Columbian black-tailed deer. PhD dissertation. University of British Columbia, Vancouver, B.C.

Meidinger, D., J. Pojar, and W.L. Harper. 1991. Sub-Boreal Spruce zone. *In* Ecosystems of British Columbia. D. Meidinger and J. Pojar (editors). Research Branch, B.C. Ministry of Forests, Victoria, B.C. Chapter 14. pp. 209–221.

Morgantini, L.E. 1979. Habitat selection and resource division among bighorn sheep, elk and mule deer in western Alberta. MSc thesis. University of Alberta, Edmonton, Alta.

Nyberg, J.B. and D.W. Janz (technical editors). 1990. Deer and elk habitats in coastal forests of southern British Columbia. Research Branch, B.C. Ministry of Forests, Victoria, B.C. Special Report Series No. 5.

Nyberg, J., R.S. McNay, M.D. Kirchhoff, R.D. Forbes, F.L. Bunnell, and E.L. Richardson. 1989. Integrated management of timber and deer: coastal forests of British Columbia and Alaska. U.S. Department of Agriculture Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-226.

Parker, K.L., C.T. Robbins, and T.A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. Journal of Wildlife Management 48(2):474–487.

Peek, J.M. 1997. Habitat relationships. *In* The ecology and management of North American moose. Franzmann and Schwartz (editors). Wildlife Management Institute, Washington, D.C. Chapter 11. pp. 351–375.

Resources Inventory Committee. 1997. Standardized inventory methodologies for components of British Columbia's biodiversity: ground based census techniques for selected cervids: moose, elk, mule/black-tailed deer, white-tailed deer, and fallow deer. Wildlife Branch, B.C. Ministry of Environment, Lands and Parks, Victoria, B.C. Unpublished draft.

Safford, R.K. 2001. Robson Valley winter range model project: phase 1. The Enhanced Forestry Management Pilot Project, Robson Valley Forest District, Ministry of Forests, McBride B.C. Unpublished technical report.

________. 2002. Candidate mule deer ungulate winter range areas for designation in the Robson Valley. Omineca Region, Environmental Stewardship Division, B.C. Ministry of Water, Land and Air Protection, Prince George, B.C. Unpublished.

________. 2003. Robson Valley ungulate winter range validation project. Valemount Division, Slocan Forest Products Ltd. Valemount, B.C. Unpublished technical report.

Skovlin, J.M. 1982. Habitat requirements and evaluations. *In* Elk of North America: ecology and management. J.W. Thomas and D.E. Toweill (editors). Stackpole Books, Wildlife Management Institute, Harrisburg, Pa. pp. 369–413.

Smith, C.A. 1977. Habitat use patterns and associated movements of white-tailed deer in south-eastern British Columbia. MSc thesis. University of British Columbia, Vancouver, B.C.

Spalding, D. 1992. The history of elk (*Cervus elaphus*) in British Columbia. Royal British Columbia Museum, Victoria, B.C. Contributions to Natural Science No. 18 WR-248.

Sweeney, J.M. and J.R. Sweeney. 1984. Snow depths influencing winter movements of elk. Journal of Mammology 65(3):524–526.

Tefler, E.S. 1978. Cervid distribution, browse and snow cover in Alberta. Journal of Wildlife Management 42(2):352–361.

Thomas, J.W., H. Black, R.J. Scherzinger, and R.J. Pedersen. 1979. Deer and elk. *In* Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. J.W. Thomas (technical editor). U.S. Department of Agriculture Forest Service, Portland, Oreg. Agriculture Handbook No. 553. pp. 104–127.

Waterhouse, M.J., H.M. Armleder, and R.J. Dawson. 1994. Winter food habits of mule deer in the central interior of British Columbia. Research Program, B.C. Ministry of Forests, Victoria, B.C. Research Note No. 113.

Wishart, W.D. 1984. Western Canada. *In* White-tailed deer: ecology and management. Lowell K. Halls (editor). Stackpole Books, Harrisburg, Pa. Chapter 26. pp. 475–486,