Late-Winter Habitat Use by Mule Deer, *Odocoileus hemionus*, in Central Interior British Columbia

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In central interior British Columbia, extensive cut blocks to recover timber killed by the Mountain Pine Beetle (*Dendroctonus ponderosae*) could impact negatively on Mule Deer (*Odocoileus hemionus*) late-winter habitat. This study assessed the possibility of predicting the distribution of potential late-winter habitat for Mule Deer with the BC Vegetation Resources Inventory (VRI) dataset used to produce forestry maps. On the basis of literature review and roadside inventories in December 2004, I predicted that high-quality Mule Deer late-winter habitat would correspond to mature and old conifer-dominated stands with ≤ 20% deciduous species, a canopy closure ≥ 45%, tree heights ≥ 23 m, tree diameter at breast height ≥ 24 cm, and basal area ≥ 45 m²/ha, and would be located on < 60% slopes on south, southeast, southwest or west aspects, or on flat ground. I allocated weight values to these criteria to classify map polygons into high-, medium- and low-quality polygons, and produce predictive maps of late-winter habitat use by Mule Deer. I tested my predictive habitat rating by snowtracking along 18 km of transects in February-March 2006, and 15.6 km of transects in February 2007. I recorded 31 and 12 Mule Deer tracks in 2006 and 2007, respectively, all in high-quality polygons. The observed frequency of tracks per polygon type was significantly (*P* < 0.001) different from expected. All tracks were in mature and old conifer-dominated stands including 10-60% Lodgepole Pine (*Pinus contorta*) and 10-20% Trembling Aspen (*Populus tremuloides*). This study showed that it was possible to predict the distribution of potential late-winter habitat for Mule Deer using a series of habitat criteria and the VRI dataset. The extensive harvesting of Lodgepole Pine in mixed coniferous stands will undoubtedly have a negative impact on Mule Deer late-winter habitat quality and quantity. The rating of habitat types developed in this study should be used in forest management plans to determine sites that should be protected from logging.

Key Words: Mule Deer, *Odocoileus hemionus,* Lodgepole Pine, *Pinus contorta*, Mountain Pine Beetle, *Dendroctonus ponderosae*, sub-boreal forest, winter habitat, British Columbia.

The ability of a forest stand to intercept snow and provide both thermal cover and accessible forage are the primary habitat variables influencing deer (*Odocoileus* spp.) winter habitat selection in British Columbia and the Pacific Northwest (Kirchhoff and Schoen 1987; Hanley et al. 1989*; Nyberg et al. 1990; Armleder et al. 1994). In central British Columbia, however, recent epidemics of Mountain Pine Beetle (*Dendroctonus ponderosae*) have resulted in the infestation of at least 4.2 million hectares of Lodgepole Pine (*Pinus contorta*) stands (generally > 80 years) and the use of extensive clearcut silviculture programs to recover the timber (Readshaw 2003*). One of the goals of the new Forest and Range Practices Act (FRPA) of British Columbia is to ensure that forest cover and forage will be conserved over an area necessary for winter survival of ungulate species, recognizing regional variance in the ecology of the ungulate species. The British Columbia Ministry of Environment voiced its concerns regarding timber harvesting in the southwest portion of the Prince George Forest District where extensive cut blocks could impact negatively on Mule Deer (*Odocoileus hemionus*) late-winter habitat.

Using Mule Deer studies conducted in Douglas-fir (*Pseudotsuga menziesii*) – dominated landscapes (e.g., Kirchhoff and Schoen 1987; Armleder et al. 1994; and others), Yaremko (2003*) identified Ungulate Winter Ranges (UWRs) in the Vanderhoof Forest District.

UWRs consisted of Douglas-fir – dominated forests that were > 140 years old with a 36-65% canopy closure, located on 16-47% slopes and various aspects. Likewise, in the southern portion of the Prince George Forest District, Brade and Stevenson (2003*) identified UWRs consisting of Douglas-fir – leading stands with 0-25% slopes on southeastern or western aspects. In 2004, Canadian Forest Products Ltd. and the B.C. Ministry of Water, Land, and Air Protection identified one representative UWR in each forest district to assess their use by Mule Deer. Proulx (2004*) conducted track surveys when snow depths ranged from 15 to 60 cm. He found only one track in one UWR encompassing a Douglas-fir – Lodgepole Pine forest. He recorded three more tracks outside UWRs, in late-successional Lodgepole Pine-aspen (*Populus*) stands with ≥ 45% canopy closure, tree heights ≥ 20 m, tree diameter at breast height (dbh) > 22 cm, 0-42% slopes, and southeastern aspects. Proulx (2004*) pointed out that, while Yaremko (2003*) and Brade and Stevenson (2003*) largely based their UWR selection on the presence of Douglas-fir stands, the Vanderhoof and the southern portion of the Prince George Forest districts were dominated by pure or mixed Lodgepole Pine stands. Proulx (2004*) suggested that local Mule Deer populations would be more likely found in large contiguous pine or spruce (*Picea*) stands with proper canopy and browse rather than small, disconnected Dou-

glas-fir patches. He recommended that the late-winter Mule Deer distribution be investigated in these forest districts in order to identify UWRs that would effectively meet the needs of the species.

The objective of this study was to assess and predict the late-winter distribution of Mule Deer by (1) rating the potential of forest stands according to their composition and structural characteristics; and (2) verifying habitat use by Mule Deer using snowtracking.

Study Area

The study area was southwest of Prince George (53°53'N, 122°41'W), British Columbia (Figure 1), in the Sub-boreal Spruce Biogeoclimatic Zone (Meidinger et al. 1991). Hybrid White Spruce (*Picea engelmanii × glauca*) and Subalpine Fir (*Abies lasiocarpa*) were the dominant climax tree species. Lodgepole Pine was common in mature forests in the drier parts of the zone, and both Lodgepole Pine and Trembling Aspen (*Populus tremuloides*) pioneered the extensive successional stands (Meidinger et al. 1991). The distribution of Douglas-fir was patchy (D. Bernier, Timberline Natural Resource Group, personal communication 2004). Black Spruce (*Picea mariana*) occurred occasionally in climax upland forest (Meidinger et al. 1991).

Methods

Rating the potential of forest stands

The selection of variables to rate the potential of forest stands to meet late-winter Mule Deer habitat requirements was first based on a literature review. It considered two important concepts used in Mule Deer winter habitat management: (1) a mixture of plant communities provides better habitat than any single community (Wallmo 1978; Mackie et al. 1982); and (2) cover and forage must be properly interspersed in order to meet Mule Deer habitat needs (Kerr 1979*; Hall 1985*). On the basis of Wood et al.'s (1999*) mule deer habitat suitability index model in pine, spruce and fir ecosystems, the following variables were identified to rate the potential of forest stands: (1) stand composition; (2) age; (3) canopy closure; (4) tree height; (5) tree diameter at breast height; (6) basal area; (7) percentage of shrub cover; (8) aspect; and (9) slope. Distance from food-rich, early-successional stands to cover was not selected as a variable because in the southwest portion of the Prince George Forest District, early- and late-successional forests are closely interspersed.

In order to quantify the selected variables, I conducted road inventories in the southern portion of the Prince George Forest District with a 4×4 truck after a heavy snowfall in December 2004. Road inventories were based on presence/not detected survey standards developed by the Resource Information Standards Committee (RIC 1998*). Transects were conducted on primary and secondary forestry roads that crossed a diversity of habitat types characteristic of the study area (Figure 1). Only fresh tracks (i.e., ≤ 48 h old) were recorded. Both Mule Deer and White-tailed Deer (*Odocoileus virginianus*) inhabit the southwest portion of the Prince George Forest District, and their tracks cannot be distinguished accurately in the field (Murie 1975). However, Mule Deer are widespread in the region while White-tailed Deer are relatively scarce (Shackleton 1999; Proulx 2004*, personal observations). For this reason, I considered that deer tracks encountered in the study area were those of Mule Deer. As it was not possible to consistently determine if crossings were made by the same individual, all crossings were tallied (Raphael and Henry 1990*). Deer track locations were determined with a GPS unit (Garmin GPSMAP 76S, Olathe, Kansas, USA). Snow depths (average of three measurements taken 1 m apart) along roadsides and in adjacent forest stands were also recorded (Proulx and Kariz 2001*). Track locations were fed into the B.C. Vegetation Resources Inventory (VRI) dataset (B.C. Ministry of Sustainable Resource Management 2003*) in order to properly describe site characteristics. VRI is the provincial standard for assessing the quantity and quality of British Columbia's timber and other vegetation resources. It uses both photo interpretation and detailed ground sampling to arrive at an accurate assessment of timber volume and other vegetation resources within a predefined unit. The VRI program is a significant replacement for old "Forest Cover" mapping, as it is a broader "vegetation" inventory, designed to support a range of applications. Although snow accumulations are less important at this time of year than in February, the December survey allowed me to quantify the variables that I selected to rate the potential of forest stands and, along with data from the literature review, to predict the late-winter distribution of Mule Deer in the southern portion of Prince George Forest District.

I subjectively allocated weight values to selected variables on the basis of my evaluation of their importance in the selection of sites by Mule Deer. The sum of weights led to the classification of vector map polygons (i.e., homogeneus areas with similar forest stand characteristics) into various categories of potential winter habitat: (1) high-quality, 15-19 points; (2) medium-quality, 10-14 points; (3) low-quality, ≤ 9 points; and (4) none, 0 points. Observations gathered before and during track surveys revealed that high-quality polygons corresponded to mature (≥ 80 years old) and old, coniferous and coniferous-deciduous stands. Medium-quality polygons represented mature or old coniferous stands with poor ratings for the criteria identified in Table 1, mature coniferous-deciduous stands richer in deciduous than in coniferous species, or young (40-80 years old) coniferous forests. Low-quality polygons were immature and pole stands (1-40 years old).
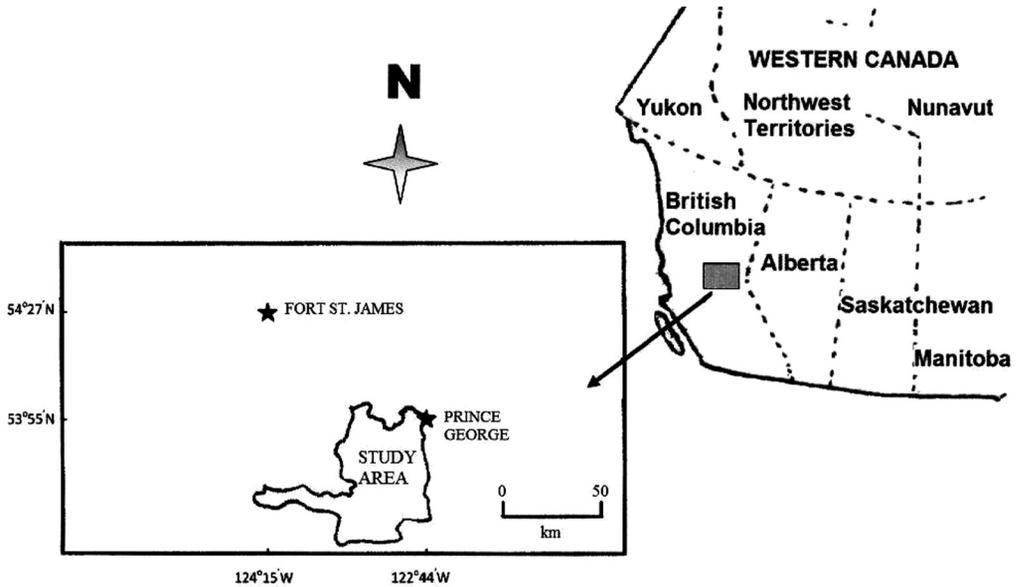
FIGURE 1. Location of study area in the southern portion of the Prince George Forest District, British Columbia.

Field assessment of potential Mule Deer habitats

Habitat use by Mule Deer was assessed in the field using snowtracking: 23 transects from 2 February to 4 March 2006, and 30 transects in February 2007. I used a stratified random sampling approach to select sample locations (Krebs 1999). Transects (≥ 500 m long and ≥ 500 m apart) were plotted on forestry maps, and starting points were tied by compass bearings and distance to distinctive topographic features. They were laid out perpendicular to the boundaries of the inventoried areas in order to include ecotones used by Mule Deer. Transects were snowshoed using a compass and 1:20 000 forestry maps.

Forest stands along survey transects were described, and classified as immature-pole (7.5-12.4 cm dbh with little understorey), young (achievement of dominance by some trees and death of others, uneven dbh, multi-storied canopy), mature (even canopy of trees, developed understorey as the canopy opens up), and old (structurally complex, established shade-tolerant species, mortality of tall and large canopy trees, canopy gaps, large down woody material) (Proulx and Kariz 2005).

Only fresh tracks (i.e., ≤ 48 h old) crossing transects were recorded. At deer track intersects, presence of crust, and snow depths in the habitat (average of three measurements taken 1 m apart) and within deer

tracks (average of measurements taken in three consecutive tracks), were recorded (Telfer 1970; Proulx and Kariz 2001*). Approximate locations along transects were determined using hip chain distances and forestry maps. In 2006, track locations were fed in VRI database in order to identify site attributes. The VRI information was compared to field observations to ensure that the classification of polygons was appropriate. In 2007, VRI data were not available for the sites inhabited by Mule Deer. Only field observations were used for stand composition, aspect and slope.

Data analyses

The proportion of inventory transects within each polygon type or habitat type was used to determine the expected frequency of tracks per polygon or habitat type. The Fisher Exact Probability Test (Zar 1999) was used to compare observed to expected frequencies of track intersects per polygon or habitat type (Proulx et al. 2006; Proulx and O'Doherty 2006). Student t-test was used to compare mean snow depths in stands and in Mule Deer tracks. Probability values ≤ 0.05 were considered statistically significant.

Results

Road inventories

Mule Deer tracks were encountered at five locations during road inventories. Snow depths ranged from

TABLE 1. Rating of habitat types to predict Mule Deer late-winter distribution maps in the Sub-boreal Spruce Biogeoclimatic Zone, southwest of Prince George, British Columbia.

Variables	Criteria	Weights
Stand composition	Coniferous-deciduous stands with ≥ 80-95% conifers (all species) and 5-20% deciduous (birch, aspen, cottonwood)	6
	Coniferous-deciduous stands with ≥ 60-<80% conifers (all species) and 21-40% deciduous (birch, aspen, cottonwood)	4
	Coniferous (≥95%)	2
	Coniferous-deciduous stands with ≥ 20-<60% conifers (all species) and 41-79% deciduous (birch, aspen, cottonwood)	1
	Deciduous (birch, aspen, cottonwood) (>80%)	Rejected polygon
Age	≥140 years	2
	≥80 years	1
	<80 years	0
Canopy closure	≥45-≤80%	3
	10-<45%, >80%	1
	0-9%	0
Tree height	≥23 m	1
	<23 m	0
Tree dbh	≥24 cm	1
	<24 m	0
Basal area	≥45 m²/ha	2
	≥20-<45 m²/ha	1
	<20m²/ha	0
% shrub cover	≥10%	1
	<10%	0
Aspect	S, SE, SW, W, flat	2
	N, NE, E, NW	1
Slope	<60%	1
	≥60%	0

Potential	Range of weights
High	15-19
Medium	10-14
Low	1-9
None	Rejected polygons

21 to 25 cm along roadsides, and 13-16 cm in coniferous-deciduous stands. All tracks were in late-successional (≥ 93 years old) conifer stands dominated by Lodgepole Pine or Hybrid White Spruce, with ≤ 30% Trembling Aspen. All the stands had > 50% canopy closure, tree height > 24 m, tree dbh > 24 cm, basal area ≥ 45 m²/ha, and were located on 5-20% slopes on west or south-southwest aspects.

Habitat rating

Proulx's (2004*) findings and the December roadside inventories suggested that conifer-dominated stands with presence of Trembling Aspen would have greater potential for Mule Deer in late winter (Table 1). I assumed that stands with > 95% conifers or > 80% deciduous would be less valuable, the former offering valuable thermal cover but short-term forage, and the latter, abundant food but poor snow-intercepting cover (Table 1). Stands with greater potential for Mule Deer would have a canopy closure ≥ 45%, tree heights ≥ 23 m, tree dbh ≥ 24 cm, and a basal area ≥ 45 m²/ha, and would be located on < 60% slopes on south, southeast, southwest or west aspects or on flat ground (Table 1).

Field assessments

In 2006 and 2007, temperatures ranged from -10 to 0°C, and all inventories were conducted ≤ 48 h since a snowfall or flurries. In 2006, there was an average of 41 (± standard deviation 12.9) cm of snow in openings, and 32 (± 4.8) cm in forested habitats. At Mule Deer track intercepts, average snow depths in stands ($n = 5$, $\bar{x} = 31.6 \pm 5.3$ cm) were significantly ($t = 3.50$, $P < 0.05$) deeper than in deer tracks ($n = 5$, $\bar{x} = 18.8 \pm 6.2$ cm). In 2007, there was an average of 44 (± standard deviation 16.8) cm of snow in openings, and 32 (± 16) cm in forested habitats. At Mule Deer track intercepts, average snow depths in stands ($n = 7$, $\bar{x} = 24.6 \pm 10.2$ cm) were significantly ($t = 3.40$, $P < 0.05$) deeper than in Mule Deer tracks ($n = 7$, $\bar{x} = 11.2 \pm 4.6$ cm). During both years, a thin crust was present 8-12 cm below the snow surface.

Frequency of Mule Deer Tracks per Polygon Type

Thirty-one and 12 Mule Deer tracks were recorded in 2006 (17955 m of transects) and 2007 (15631 m of transects), respectively, all in high-quality polygons. During both years, the observed frequency of tracks per polygon type (Table 2) was significantly ($P < 0.001$) different from expected.

Frequency of Mule Deer Tracks per Habitat Type

In 2006, all Mule Deer tracks were in mature and old stands (Table 2). The observed frequency of Mule Deer tracks per habitat type was significantly different from expected ($P < 0.001$). Mule Deer frequented conifer-dominated stands with 10-60% Lodgepole Pine and 10-20% Trembling Aspen (Table 2).

In 2007, all Mule Deer tracks were in mature stands (Table 2). The observed frequency of tracks per habitat type was significantly different from expected ($P = 0.01$). All tracks were recorded in Hybrid White Spruce-Lodgepole Pine – dominated stands that also included Trembling Aspen (Table 2).

Attributes of Polygons with Mule Deer Tracks

In 2006, all tracks were in mature and old conifer-dominated stands with a 50-60% canopy closure, tree height > 30 m, dbh > 26 cm, a basal area ranging from 30 to 55 m²/ha, 10-20% shrub cover, on < 25%, slopes on NW and SW aspects.

In 2007, all tracks were located in mature conifer-dominated stands on < 30% slopes on W-SW aspects.

TABLE 2. Proportions of transects inventoried per polygon and habitat types, and distribution of Mule Deer tracks in late-winter 2006 and 2007, in southern Prince George Forest District.

Category	2006 Inventory		2007 Inventory	
	Transect lengths m (%)	Mule Deer tracks (%) & stand composition	Transect lengths – m (%)	Mule Deer tracks (%) & stand composition
	Polygon quality			
High	6425 (35.8)	31 (100)	5751 (36.8)	12 (100)
Medium	6351 (35.4)	0 (0)	1876 (12)	0 (0)
Low	5179 (28.8)	0 (0)	8004 (51.2)	0 (0)
Total	17955 (100)	31 (100)	15631 (100)	12 (100)
	Habitat type			
Immature-Pole	4903 (27.3)	0 (0)	7334 (46.9)	0 (0)
Young	1004 (5.6)	0 (0)	1068 (6.8)	0 (0)
Mature	10150 (56.3)	19 (61.3) All in 80% Fd /10% PL / 10% At*	5379 (34.4)	12 (100) All in Sxw / Pl/ At*
Old	1898 (10.6)	12 (38.7): 7 in 70% Fd / 20% Sxw / 10% Pl* 1 in 60% Pl / 20% Sxw / 10% At* 4 in 50% Sxw / 30% Pl / 20% At*	1850 (11.8)	0 (0)
Total	17955 (100)	31 (100)	15631 (100)	12 (100)

*At: Trembling Aspen; Fd: Douglas-fir; Pl: Lodgepole Pine; Sxw: Hybrid Spruce (Engelmann × White)

Discussion

This study showed that, in the Sub-boreal Spruce Biogeoclimatic Zone southwest of Prince George, Mule Deer late-winter habitat corresponded to high-quality polygons, which included late-successional stands with a well-developed canopy that provided thermal protection and snow cover interception. This is in agreement with previous studies (Armleder et al. 1994; Poole and Mowat 2005) that found that in late winter, Mule Deer seek late-successional coniferous stands with greater crown closure. This study also showed that, in 2006, a large number of Mule Deer tracks were located in Douglas-fir-leading stands, as it was found in west-central (D'Arcy and Stark 1998*) and south-central (Armleder et al. 1994) interior regions rich in Douglas-fir stands. In this study, however, the distribution of Douglas-fir stands was patchy, and Mule Deer also used Lodgepole Pine-Hybrid White Spruce stands that provided animals with canopy cover. All these conifer-dominated stands had a small deciduous component that provided Mule Deer with food. Mule Deer selected these stands at a time of year when snow was deep enough to incite animals to seek snow-intercepting canopy cover. Indeed, deer energy expenditures increase by 50% in 25 cm of snow, and more than double in 40 cm (which represents about 60% of brisket height) (Parker et al. 1984). This study suggests that Mule Deer habitat preferences in central interior BC may change according to the availability of various coniferous stands.

Because an interspersion of forage and conifer cover may provide Mule Deer with valuable habitat year-round (Deschamp et al. 1979; Poole and Mowat 2005), timber harvesting programs should be compatible with Mule Deer habitat requirements. This study showed that the VRI dataset can be advantageously used to predict Mule Deer winter habitat use. The rating of habitat types developed in this study should be used in forest management plans to determine sites that should be protected from logging. The extensive harvesting of Mountain Pine Beetle-killed Lodgepole Pines will undoubtedly have a negative effect on Mule Deer late-winter habitat quality and quantity. In mixed coniferous stands with dead patches of Lodgepole Pine, canopy cover is still provided by Hybrid White Spruce and Douglas-fir; the loss of pine opens up the canopy and allows growth of deciduous shrubs and the production of browse. These mixed coniferous stands should be protected at the expense of pure Lodgepole Pine forests, which do not offer an interspersion of cover and food to Mule Deer. The harvest of pure Lodgepole Pine stands should be planned not to impact on the environmental conditions surrounding high-quality polygons for Mule Deer. Timber harvest up to the edge of high-quality polygons, and incursions within these polygons to remove patches of dead trees, impact considerably on forest interior conditions. Finally, because of extensive clearcuts to harvest dead Lodgepole Pine stands, landscapes located in the southern portion of the Prince George Forest District

have become highly fragmented. It is essential for the survival of Mule Deer during winters with cold temperatures and deep snow accumulations that connectivity between high-quality polygons be maintained through the establishment and protection of a corridor network encompassing late-successional, mixed coniferous stands with Trembling Aspen.

Acknowledgments

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