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Using forest inventory data to predict winter habitat use by fisher *Martes pennanti* in British Columbia, Canada

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This study assessed the possibility of predicting the distribution of potential winter habitats for fisher *Martes pennanti* Erxleben, 1777 in central interior British Columbia (BC) with the BC Vegetation Resources Inventory (VRI) dataset used to produce forestry maps. I predicted that fisher winter habitat would correspond to coniferous or coniferous-deciduous stands with the following characteristics: (1) absence of disturbance, (2) ≥ 80 years old, (3) mature and old forest structural stages, (4) ≥ 20 $m^2 \cdot ha^{-1}$ basal area in mature trees, (5) ≥ 30% canopy closure, (6) shrub cover ≥ 20%, and (7) diameter at breast height ≥ 27.5 cm. I allocated weight values to these criteria to classify map polygons into excellent-, high-, medium-, and low- quality habitats, and produce predictive maps of winter habitat use by fishers. I tested predictive maps in the field by snow-tracking along 27 transects (44.2 km) in winter 2003–2004, and 16 transects (31.4 km) in winter 2004–2005. A total of 89 tracks were recorded during both years. The proportion of fisher tracks within each polygon type was significantly different from random ($p < 0.001$). The majority of tracks (> 83%) were in structurally complex coniferous stands. This study showed that it is possible to predict the distribution of potential winter habitats for fisher in central interior British Columbia using simple habitat criteria and the VRI dataset. This study's query may be used in other regions with similar vegetation composition to identify forests be inhabited by fishers in winter, and develop effective conservation programs in managed landscapes.

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Introduction

Fishers *Martes pennanti* Erxleben, 1777 are widely distributed throughout much of central British Columbia (BC), Canada (Weir 2003). They occur primarily in mature and old coniferous and mixed coniferous-deciduous forests, particularly at elevations of < 1000 m (Jones and Garton 1994, Weir and Harestad 2003), but also use younger stands, especially as foraging habitat (Jones 1991, Powell and Zielinski 1994, Weir and Harestad 2003). Fishers inhabit forests with multi-storied and continuous overhead cover, and complex structure near the ground that typically includes abundant coarse woody debris and a well-developed understory (Proulx *et al.* 2004a). Since fishers in British Columbia have large spatial requirements (eg ≥ 35 km^2; Weir 2003), harvesting of late-successional forests may have a detrimental effect on fisher populations (Proulx *et al.* 2004a, Weir *et al.* 2004). In BC, fisher is a species at risk (Proulx *et al.* 2004b).

In the past, habitat models have been used to predict species distribution and habitat capability from hypothesized habitat relationships (Corsi *et al*. 2000). Field-tested models may help wildlife managers to develop comprehensive forest management programs. Models have been developed for mustelids, eg wolverine *Gulo gulo* (Rowland *et al.* 2003), and American marten *Martes americana* (Proulx *et al.*, in press). Also, Proulx *et al.* (2004a) recommended that fisher habitat monitoring and modelling be investigated to improve forest development plans. This is particularly necessary in winter when harsh environmental conditions may impact significantly on the survival of animals (Weir *et al.* 2004). The objectives of this study were to (1) select criteria describing fisher winter habitat in central interior BC; (2) develop maps to predict the distribution of potential winter habitats in this region; and (3) field test maps using snow-tracking.

Study area

The study was conducted on the east side of the Prince George Forest District, BC, in Canadian Forest Products Ltd.'s (Canfor) Tree Farm Licence 30 (TFL 30), an 181 000-ha area located approximately 100 km northeast of the city of Prince George (54°16' N, 122°5' W) (Fig. 1). TFL 30 encompassed Sub-boreal Spruce (SBS), Engelmann Spruce – Sub-alpine Fir (ESSF), and Interior Cedar-Hemlock (ICH) Biogeoclimatic zones (Meidinger and Pojar 1991).

The study area was characterized by a continental climate with seasonal extremes in temperature: severe, snowy winters; warm, moist, short summers and moderate annual precipitation. Upland coniferous forests dominated the landscape. In the SBS zone, white spruce *Picea glauca* and sub-alpine fir *Abies lasiocarpa* were the dominant climax

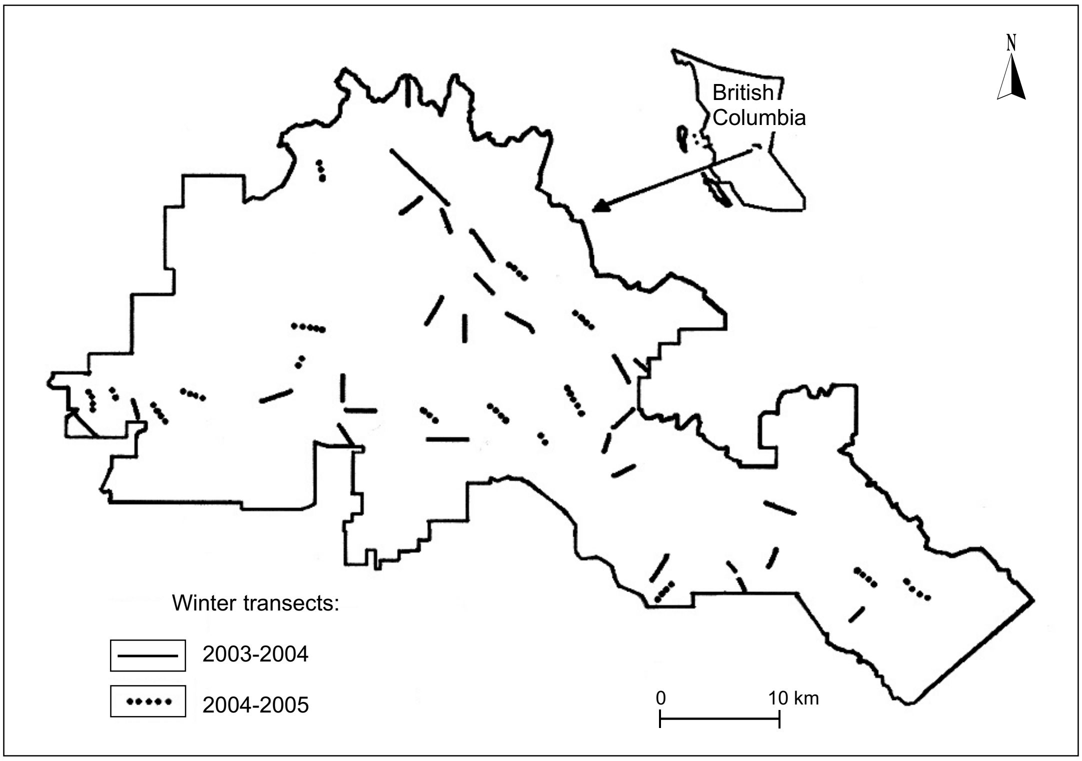

Fig. 1. Location of Tree Farm Licence 30 in central British Columbia, and distribution of track inventory transects within the study area.

tree species. Lodgepole pine *Pinus contorta* was common in mature forests in the drier part of the zone, and both lodgepole pine and trembling aspen *Populus tremuloides* pioneered the early successional stands (Meidinger *et al.* 1991). The ESSF zone occurred predominantly in mountainous terrain (> 900–1700 m elevation) characterized by steep and rugged terrain and a cold, moist and snowy continental climate. Engelmann spruce *Picea engelmannii* and sub-alpine fir were the dominant climax tree species (Coupé *et al.* 1991). The ICH zone was limited to the eastern portion of the study area. This zone was dominated by western redcedar *Thuja plicata* and western hemlock *Tsuga heterophylla*. White spruce, Engelmann spruce, their hybrids, and subalpine fir were common and were part of climax stands with either western hemlock or redcedar, especially in areas of cold air drainage or of higher elevations (Ketcheson *et al.* 1991).

Material and methods

Selection of habitat criteria

Because fisher movements may be hindered in deep soft snow (Leonard 1980, Raine 1983, Johnson 1984, Krohn *et al.* 2004), I limited the study to SBS and ICH zones, which are more accessible and receive less snow than ESSF. On the basis of an extensive literature review of the ecology of the fisher emphasizing western boreal and montane populations, I concluded that fisher winter habitats in the SBS and ICH biogeoclimatic zones would be best described with the following series of interrelated variables: (1) absence of disturbance, (2) age class, (3) structural stage, (4) basal area, (5) crown closure, (6) shrub cover, and (7) diameter at breast height (dbh) (Table 1).

Development of predictive distribution maps

Predictive vector maps were developed using the BC Vegetation Resources Inventory (VRI) (BC Ministry of Sustainable Resource Management 2003). VRI is the provincial standard for assessing the quantity and quality of BC'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. Cutblock delineations were obtained from Canfor's Forest Development Plans.

Weight values were subjectively allocated to criteria used to develop predictive maps of winter habitat use by fishers (Table 1). The sum of weights led to the classification of map polygons into various categories, ie, excellent- (14–18 points), high- (11–13 points), medium- (6–10 points), or low- (< 6 points) quality habitats. Observations gathered before track surveys (and qualitatively confirmed during inventories) revealed that excellent- and high- quality polygons generally corresponded to mature and old stands (≥ 80 years old), or young stands (40–80 years old) with many of the criteria identified in Table 1. Low-quality polygons corresponded to immature (1–40 years old) coniferous or deciduous-dominated stands. Medium-quality polygons represented stands that were transitional between immature and young stands, or older stands that had been partially harvested and lost many of their structural attributes.

Field testing

Predictive maps were field-tested during two winters, ie, from 27 November 2003 to 5 March 2004, and from 6 December 2004 to 13 February 2005, along ≥ 0.4-km-long transects that were spaced more than 1 km apart, a minimum distance used by Proulx *et al.* (in press) in a concurrent study of American marten in TFL 30. Different transects were inventoried in winters 2003–2004 and 2004–2005 (Fig. 1). Transect locations were chosen at random on a 1:400 000 scale map, along roads accessible by motor vehicles or snowmobiles. In TFL 30, immature, young, and mature-old stands covered 34, 6, and 60% of the forested landscape (Proulx *et al.*, in press). We took into account these proportions when laying out transects across polygons of different quality. Transects were plotted on predictive maps, and starting points were tied by compass bearings and distance to distinctive topographic features. Transects were traversed on snowshoes using a compass, 1:20 000 scale maps, and a hip chain to record linear distances. Transect lengths varied according to accessibility, safety, and environmental conditions. In winter 2003–2004, because snowshoeing through 150 cm of fresh snow was slow, a snowmobile was used to inventory one transect along an unused forestry road. We recorded only well-defined tracks, those not melted or deformed, not filled with crusty snow, and judged to be fresh, ie, less than 24 h old (subjective assessment based on the experience of the researcher). Due to the similarity between fisher and American marten footprints (Halfpenny *et al.* 1995), when mustelid tracks were encountered, they were investigated on both sides of transects and within forest stands to find the best tracks available. The combination of footprint (pattern and size, presence/absence of toe pad prints) and trail (gait, distance between jumps, and dragging of the feet) characteristics was used to identify all tracks (Murie 1975, Rezendes 1992, Halfpenny *et al.* 1995). Fisher tracks are usually larger and farther apart, although the footprints of female fishers and male American martens may be of similar size. In winter, the under surface of American marten's feet is heavily covered with hair and the pads do not show (Murie 1975, Rezendes 1992). The under surface of fisher's feet has sparse hair, and pads show well in clear prints (Halfpenny *et al.* 1995). Compared to American martens, fishers seldom tunnel under the snow (Halfpenny *et al.* 1995), and tend to walk more, create through when walking in soft snow, drag their feet, and leave tail drag-marks in the snow (de Vos 1951, Raine 1983). When encountering animals, I studied footprints and trails to ascertain criteria to differentiate fisher from American marten. I also collected notes on habitat characteristics along transects to validate the classification of polygons, and track positions relative to polygons.

Data analyses

The proportion of inventory transects within each polygon type was used to determine the expected frequency of track intersects/polygon type (ie, availability) if tracks were distributed randomly with respect to polygon types (Proulx *et al.*, in press). Chi-square statistics with Yates correction (Zar 1999) were used to compare observed to expected frequencies of track intersects per polygon type. When χ^2 analyses suggested an overall significant difference between the distribution of observed and expected frequencies, comparisons of observed to expected frequencies for each habitat class were conducted using the *G*-test for correlated proportions (Sokal and Rohlf 1981). Because of a

Table 1. Criteria used in the development of maps to predict the distribution of potential winter habitats for fishers in central interior British Columbia

Criterion	Description	Weight (points)	
		Presence	Absence
Absence of disturbance	Although fishers use early-successional stands adjacent to forest cover, harvested areas may not meet fishers' winter habitat requirements (Badry *et al.* 1997, Weir 2003).	0	4
≥ 80 year-old stands	Late-successional stands are important for fisher in winter to intercept snow, and promote movements within the home range, and for hunting (Weir 2003, Weir and Harestad 2003).		
	0–60 years	0	–
	61–80 years	1	–
	81–100 years	2	–
	101–120 years	3	–
	≥ 121 years	5	–
Structural stages 6 and 7	There are 7 stand structural stages: (1) sparse/bryoid, (2) herb, (3) shrub/herb, (4) pole/sapling, (5) young forest, (6) mature forest, and (7) old forest (Proulx *et al*. 2003). Sructural stages 6 and 7 encompass snags, coarse woody debris, and other structural elements characteristic of mature and old forests (Weir 2003).	2	0
≥ 20 $m^2 \cdot ha^{-1}$ basal area in mature trees	Forests with a ≥ 20 $m^2 \cdot ha^{-1}$ basal area in mature trees are known to be used by snowshoe hares (Conroy *et al.* 1979), an important prey (Raine 1981, Powell and Zielinski 1994, Weir 2003). Such forests also correspond to the habitat of late-successional species such as American marten (Proulx *et al.*, in press) and red-backed vole *Clethrionomys gapperi* (Hayes and Cross 1987, Nordyke and Buskirk 1991). Large old trees, snags and logs are important as denning and resting sites (Weir 2003, Weir *et al.* 2004).	1	0
≥ 30% canopy closure	Such canopy closures provide fishers and their prey (eg understory) with adequate environmental conditions, and properly intercept snow (Jones 1991, Badry *et al.* 1997, Jones and Garton 1994, Thomasma *et al.* 1994, Weir 2003).	2	0
Shrub cover ≥ 20%	Important for fisher prey (Keith and Surrendi 1971, Weir and Harestad 2003)		
	0%	0	–
	5–20%	1	–
	20–40%	2	–
	> 40%	3	–
Dbh ≥ 27.5 cm	In TFL 30, mature trees usually have a dbh ≥ 27.5 cm (Proulx *et al.* 2006). Fishers use trees with dbh > 27 cm (Jones 1991, Jones and Garton 1994, Thomasma *et al.* 1994).	1	0
Habitat ranking		Sum of weights	
Excellent		14–18	
High		11–13	
Medium		6–10	
Low		< 6	

similar proportion of tracks per habitat class during the winters of 2003–2004 and 2004–2005, data from both years were pooled to increase track sample size and statistical power. I report below the results of conventional statistics using $\alpha = 0.05$.

Autocorrelation is often present in ecological data and may not be totally avoided (Legendre 1993, Proulx and O'Doherty, in press). It potentially occurs during analysis of track survey data because of the uncertainty in whether one or more animals have made the tracks being counted. It is sometimes difficult to confirm that a series of tracks along a transect belong to the same animal (de Vos 1951) because home ranges overlap (Weir 2003) and winter dispersal movements are known to occur (Arthur *et al.* 1993). Because of rugged environmental conditions, I did not follow tracks that crossed close together to learn whether the same animal made them. On the other hand, on the basis of track characteristics, I deduced that two different animals could be as close as 100 m apart along the same transect. To minimize spatial autocorrelation, only tracks ≥ 100 m apart within the same forest stand were recorded (Bowman and Robitaille 1997, Proulx *et al.*, in press).

Results

Field assessment of predictive habitat maps

Twenty-seven transects were inventoried in winter 2003–2004 (0.5 to 3.7 km; total: 44.2 km), and 16 in winter 2004–2005 (0.4 to 3.0 km; total: 31.4 km). During both years, approximately 60% of transects' total length was in excellent- and high- quality polygons. Temperatures ranged from –15°C to –3°C in 2003–2004, and from –30°C to 0°C in 2004–2005. Snow depths ranged from 45 to 150 cm; with a few exceptions, snowfalls or flurries occurred daily, thus assuring that tracks were fresh.

In winter 2003–2004, 61 fisher tracks were recorded. The majority (87%) of tracks were found within excellent- and high- quality polygons. The proportion of fisher tracks within each polygon was significantly different from random ($\chi^2 = 20.8$, df = 2, $p < 0.001$). Tracks were significantly less frequent than expected in medium- and low- quality polygons ($G = 9.2$, df = 1, $p < 0.01$).

In winter 2004–2005, 28 fisher tracks were recorded. Although 22 (78.6%) tracks were found in excellent- and high- quality polygons, the proportion of fisher tracks within each polygon type was not significantly different from random ($\chi^2 = 4.9$, df = 2, $p > 0.05$).

Pooling data from both years resulted in 75 (84.3%) of the 89 tracks in excellent- and high-quality polygons. The observed distribution of fisher tracks was significantly different from a random distribution of tracks among polygon types ($\chi^2 = 24.5$, df = 3, $p < 0.001$) (Fig. 2). Tracks were significantly less frequent in low-quality polygons (G = 7.3, df = 1, $p < 0.01$).

Attributes of polygons with fisher tracks

Eighty-four (94%) of 89 tracks were in coniferous stands; 4 (4.5%) were in mixed coniferous-deciduous stands, and 1 (1.1%) in a bare site. The majority of tracks (> 83%) were in ≥ 80 years-old stands, with an advanced structural

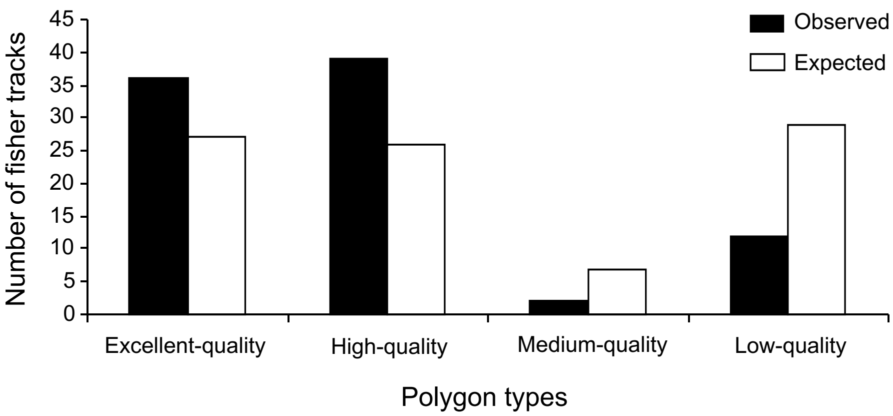

Fig. 2. Observed and expected number of fisher tracks in excellent-, high-, medium-, and low- quality polygons in Tree Farm Licence 30, central interior British Columbia.

stage (stage ≥ 6), a 30–60% canopy closure, and > 20 $m^2 \cdot ha^{-1}$ basal area in trees with > 21 cm dbh. Shrub cover in polygons used by fishers was variable: 46% of tracks were located in polygons with < 5% cover; the remaining were in polygons with shrub cover ranging from 5 to > 75%.

Discussion

This study demonstrated that the VRI dataset was a useful tool to predict the distribution of fisher winter habitats at landscape level. It also showed that fisher winter habitats corresponded to structurally complex coniferous stands with relatively high canopy closure and high basal area in trees with > 21 cm dbh. In such stands, fishers may find adequate resting and denning sites (Weir and Harestad 2003), and their main prey, which, in British Columbia, are snowshoe hare *Lepus americanus*, red squirrel *Tamiasciurus hudsonicus*, and southern red-backed vole *Clethrionomys gapperi* (Weir 1995).

Tracks were significantly less frequent in low--quality polygons. This finding is in agreement with Weir (2003) who concluded that in conifer--dominated forests of western North America, immature stages typically lack sufficient overhead cover to be used by fishers, particularly during winter. The presence of fisher in some immature stands may be related to the presence of dense shrub communities and snowshoe hares. However, fishers may have also used immature stands for travelling between suitable habitats rather than for foraging. For example, Heinemeyer (2002) found that marten paths were increasingly linear along clearcut edges; this reduced tortuosity possibly compensated for the greater distances marten travelled between foraging sites with highly impacted landscapes. The use of some immature stands by fishers warrants further investigations on the nature of the movements.

Fishers may not inhabit all excellent- and high- quality polygons. In fragmented areas, such polygons may be inaccessible to fishers because they are surrounded by large openings. In other areas, valuable polygons may be unoccupied because resident fishers have died for various reasons. These polygons may have yet to be colonized by an expanding fisher population. This study' s query may be used in other regions with similar vegetation composition to identify habitats that may be inhabited by fisher in winter. In managed landscapes, the development of effective, predictive winter distribution maps would be advantageous to foresters to identify reserves and connectivity corridors for fisher (Proulx 2005).

As landscapes change over time, it may be necessary to re-evaluate habitat selection criteria used to identify fisher winter habitats. Because of forestry practices and a bark-beetle (*Dendroctonus* spp.) epidemic (Safranyik 2004), immature and young forests will become more abundant in the future. In areas where mature and old forests are unavailable or in limited supply, fishers may decrease in numbers or make greater use of young forests, particularly if these include critical elements such as large diameter snags and coarse woody debris (Weir *et al.* 2004).

Winter track surveys are a rapid and cost-effective method to determine where fishers occur (Proulx and O'Doherty, in press), and to field--test maps that predict the distribution of their winter habitat. In some cases, only one fisher track was found along a transect. In other cases, several tracks crossed a same transect. Some of these tracks were of different size and likely belonged to different animals. Others, however, may have belonged to the same animal but the likelihood of this among transects was reduced by the temporal and physical separation of transects. I recognize the possibility of some spatial autocorrelation remaining in the data, especially within transects, however, I doubt it affected the interpretation.

This study suggests that it is possible to predict the distribution of potential winter habitats for fishers using simple criteria. In a fisher conservation program, such a finding may have a significant impact on the determination of mature and old stands that need to be protected in the future. I recommend that the map query used in this study be tested in other similar areas, and in regions where fisher ecology may be slightly different.

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