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# USING FOREST INVENTORY DATA TO PREDICT THE DISTRIBUTION OF POTENTIAL WINTER HABITATS FOR AMERICAN MARTENS

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**Abstract**: This study assessed the possibility of predicting the distribution of potential winter habitats for American martens (*Martes americana*) in the Sub-Boreal Spruce (SBS) biogeoclimatic zone of British Columbia (BC) with the BC Vegetation Resources Inventory (VRI) dataset that is used to produce forestry maps. We selected the following criteria to identify marten winter habitat: ≥ 80 years old conifer-dominated stands with a canopy closure ≥ 30% and/or a basal area of ≥ 20 $m^2$/ha in mature trees, and circum-mesic soils. Using these criteria, we produced predictive habitat distribution maps (1:20,000 scale) that we tested in the field by snow-tracking along 10 and 12 transects (> 500 m long) in winters 2000 and 2003, respectively. During both years, marten track distribution differed significantly ($P < 0.001$) from random. All tracks (16 in 2000 and 17 in 2003) were found exclusively in polygons composed of late-successional conifer-dominated stands with a canopy closure ranging from 30 to 50%; the majority had a basal area ≥ 20 $m^2$/ha in trees with ≥ 27.5 cm dbh, and mesic soils. This study showed that it is possible to predict the distribution of potential winter habitats for American martens in the SBS biogeoclimatic zone of British Columbia using simple habitat criteria and the VRI dataset.

## Introduction

In north-central British Columbia (BC), the Regional Resource Management Committee has identified the American marten (*Martes americana*) as a high-profile species for which high suitability habitat must be identified and maintained in managed landscapes (BC Government 1999). Although the American marten is commonly found in late-successional forests in winter in western North America (Buskirk and

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Powell 1994), one cannot readily recognize habitats meeting the needs of the species. The objectives of this study were to 1) select parameters describing American marten winter habitat in the SBS biogeoclimatic zone of British Columbia; 2) develop maps to predict the distribution of potential winter habitats in this zone; and 3) field test maps using snow-tracking.

## Study Area and methods

### 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), located approximately 100 km northeast of the city of Prince George (Figure 1). TFL 30 encompasses 181,000 ha of land overlapping the SBS and the Engelmann Spruce – Sub-alpine Fir (ESSF) Biogeoclimatic zones (Meidinger and Pojar 1991).

Most of the study area was within the SBS zone 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. White spruce (*Picea glauca*) and sub-alpine fir (*Abies lasiocarpa*) were the dominant climax 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 (>900-1,700 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).

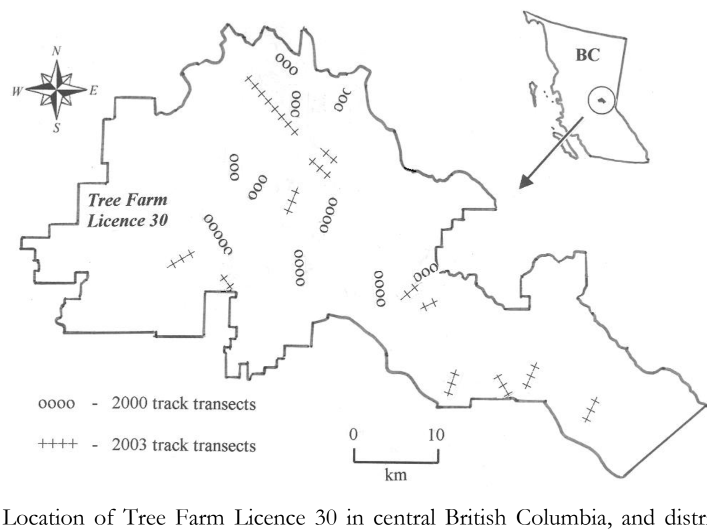


Figure 1. Location of Tree Farm Licence 30 in central British Columbia, and distribution of snow-tracking transects for surveying American marten.

**Selection of habitat criteria**

Johnson (1980) introduced the concept that animals select resources at several different spatial scales, which he labelled "selection orders". A selection process is of higher order than another if it is conditional upon the latter. The 1st order corresponds to the geographic extent of the species; the 2nd order, the selection of a home range; the 3rd order, the selection of stands within the home range; and the 4th order, the selection of particular sites for specific activities such as denning, resting, and hunting. In this project, the 1st order was considered too small a map scale to assess the importance of specific parameters on the use of sites by martens. The 4th order, although important for the selection of sites by martens, relates to elements that are not usually part of datasets used for the production of forest cover maps. Habitats of the 2nd and 3rd orders may be identified using current datasets. We assumed that if habitats are selected on the basis of their maturity, species composition, and expected vertical structure, selected areas will inevitably encompass developed overstoreys and 4th order elements that are critical for American martens, i.e. complex understoreys where downed woody debris and surface vegetation are available (Lieffers and Woodard 1997).

We selected specific stand criteria on the basis of an extensive literature review of the ecology of the American marten, emphasizing western boreal, subalpine, and montane populations. On the basis of previous studies, we concluded that marten winter habitats were best described with a series of interrelated variables: cover type, successional stage, canopy closure, basal area, tree diameter at breast height (dbh), site moisture level, understorey density, amounts of coarse woody debris (CWD) and snags, and type and extent of natural and anthropogenic disturbances. Unfortunately, a few of these variables could not be estimated with vegetation inventory datasets developed for the management of harvestable timber. While there is a significant variation in CWD volume within and between subzones (Spies and Cline 1988, Proulx and Kariz, Alpha Wildlife Research & Management Ltd. unpublished data), insufficient information existed to estimate accurately its amount in polygons. Similarly, density of the understorey and the level of disturbance of stands that had been selectively harvested could not be estimated because of a lack of information. We therefore selected the following criteria for which we had reliable information: 1) conifer-dominated stands (excluding pure lodgepole pine stands, which have little structural complexity at ground level (Corn and Raphael 1992, Proulx and Kariz, Alpha Wildlife Research & Management Ltd. unpublished data); 2) ≥ 80 years old stands; 3) circum-mesic soils; 4) canopy closure ≥ 30%; and/or 5) basal area of ≥ 20 $m^2$/ha in mature trees (≥ 27.5 cm dbh) (Table 1). These variables allowed us to identify stands that usually have CWD and a developed understorey. Minimum levels of canopy closure and basal area allowed us to reject stands with too much disturbance.

Table 1. Criteria used in the development of maps to predict the distribution of potential winter habitats for American martens in the Sub-Boreal Spruce biogeoclimatic zone of British Columbia.

| Criterion | Description |
|---|---|
| Conifer-dominated stands | The potential of various stands for martens varies with regions and stand availability (Buskirk and Ruggiero 1994). In a landscape dominated by spruce/fir stands such as TFL 30, martens are expected to use spruce or mixed coniferous stands with a well-developed ground structure and a multi-storey canopy, rather than pure pine or black spruce (*Picea mariana*) stands with little ground structure and a single-storey canopy, or pure deciduous stands with little overhead cover in winter (Burnett 1981, Wilbert 1992). |
| ≥ 80 year-old stands | Martens are more selective for late-successional coniferous stands in winter compared with summer (Campbell 1979, Wilbert 1992), in deep compared with shallow snow (Koehler and Hornocker 1977), and in cold rather than warm weather (Buskirk et al. 1989). |
| ≥ 30% canopy closure | Martens inhabit forests with a ≥ 30% canopy closure in which more than half is provided by mature or old coniferous trees (Koehler and Hornocker 1977, Spencer et al. 1983, Huggard 1999). |
| ≥ 20 $m^2$/ha basal area in mature trees with a dbh > 27.5 cm | In the SBS zone, martens mostly use habitats with > 20 $m^2$/ha basal area of trees (Lofroth 1993). In a study of selective cutting, Soutiere (1979) concluded that the retention of 20-25 $m^2$/ha basal area in pole and larger trees provides adequate habitat for martens. The size of trees characterizing mature and old stands used by martens varies with regions. In TFL 30, mature trees have a minimum dbh > 27.5 cm (R. Verbisky, Timberline Forest Inventory Consultants Ltd., Prince George, Canada, personal communication). Large old trees, snags and logs with ≥ 50 cm dbh are important as denning and resting sites (Hauptman 1979, Simon 1980, Hargis and McCullough 1984, Raphael and Jones 1997). |
| Circum-mesic (i.e. sub-mesic, mesic, and sub-hygric) sites | Martens prefer mesic sites over xeric ones (Campbell 1979, Buskirk and Powell 1994). Mesic sites are associated with developed understorey and high densities of microtine rodents (Tevis 1956, Koehler et al. 1975, Nordyke and Buskirk 1991). |

**Development of predictive distribution maps**

Predictive 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.

The winter habitat selection criteria are interrelated, i.e. they all play an important role in the selection of stands that may be inhabited by martens. Therefore, a weight value of 1 was allocated to each of them. The sum of criteria led to the classification of polygons into various categories. A colour code was used to differentiate between polygons where all habitat selection criteria were present and those where some were missing. Polygons were coloured in red if they had 5 points (i.e. 5 habitat selection criteria), in green for 4, in yellow for 3, and in white for 0-2. Observations gathered before track surveys (and subsequently confirmed during inventories) revealed that red and green polygons generally corresponded to late-successional stands (≥ 80 years old). Yellow polygons represented mid-successional coniferous stands (i.e. 41 to < 80 years old), or disturbed mature stands lacking 2 criteria (usually canopy closure and basal area). White polygons corresponded to early-successional coniferous stands (1-40 years old), pure pine stands (usually on xeric sites), or deciduous-dominated stands.

**Field testing**

Maps were field-tested using snow-tracking from 6 to 17 December, 2000 (snow depths: 45-60 cm), and from 27 November to 8 December, 2003 (snow depths: 60-150 cm), along > 500-m-long transects that were spaced more than 1 km apart; different transects were inventoried in 2000 and 2003 (Figure 1). Transect locations were chosen at random on a 1:400,000 scale map, along roads accessible by motor vehicles or snowmobiles. In TFL30, early-, mid-, and late-successional stands covered 34%, 6%, and 60% of the forested landscape (Canfor 2001). We took into account these proportions when laying out transects across polygons of different colours. Transects were plotted on predictive maps, and starting points were tied by compass bearings and distance to distinctive topographic features. Transects were snowshoed 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 2003, because snowshoeing through 150 cm of fresh snow was slow, a snowmobile was used to inventory 1 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, i.e. less than 24 h old (subjective assessment based on the experience of the researchers). Due to the similarity between fisher (*Martes pennanti*) 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). Notes on habitat characteristics along transects were collected to validate the classification of polygons, and track positions relative to polygons.

**Data analyses**

On the basis of previous work on American martens in western North America (Buskirk and Powell 1994, Proulx, Alpha Wildlife Research & Management Ltd., unpublished data gathered in Alberta and BC), we believe that the American marten is truly a forest specialist most often associated with late-successional stands. Field observations gathered before track surveys indicated that such stands corresponded to red and green polygons, i.e. with 5 and 4 selection criteria, respectively. Consequently, we hypothesized that marten tracks would not be distributed at random among habitat types, and that they would be found in habitats with ≥ 4 selection criteria. Our hypothesis was declared before examining the track survey data. We used a one-tailed Fisher Probability test (Siegel 1956) to compare the proportion of marten tracks in 2 types of habitats: stands with ≥ 4 selection criteria vs. stands with < 4 criteria. The proportions of inventory transects within each habitat type were used to determine the expected frequency of tracks per habitat type if tracks were distributed randomly with respect to habitat types (Parker 1981). Results from both years were also pooled to increase track sample size and statistical power. We report below the results of conventional statistics using $\alpha = 0.05$. Because we reject the null hypothesis of random distribution in 2000 and 2003, a Type II error is not possible. The power of the tests, although estimated at 1, is virtually infinite; there was no variation in our track samples.

Autocorrelation is often present in ecological data and may not be totally avoided (Legendre 1993, Bowman and Robitaille 1997). 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. Although some investigators (e.g. Thompson 1949, de Vos 1952) recommended not counting repeated crossings by the same animals, 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 (Buskirk and Ruggiero 1994) and winter dispersal movements are known to occur (Clark and Campbell 1976). Because of rugged environmental conditions, we 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, we deduced that 2 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). In order to minimize further the impact of non-independent observations on our conclusions, we also analysed data using only tracks ≥ 1000 m apart (minimum diameter of female home ranges, Strickland et al. 1982).

## Results

**Field assessment of predictive habitat maps**

Ten transects were inventoried in 2000 (1.4 to 4.3 km; total: 30.4 km), and 12 in 2003 (0.5 to 7.8 km; total: 22.7 km). Temperatures ranged from -3°C to 1°C in 2000, compared with -15°C to -3°C in 2003. During both years, snowfall and flurries occurred daily during surveys, thus assuring that tracks were fresh, but likely reducing encounter rates as tracks were quickly covered with fresh snow.

In 2000, approximately 74% of the 30.4 km snowshoed was within stands with ≥ 4 selection criteria. Sixteen tracks were recorded in 7 transects: 3 tracks in 3 different transects, and 13 in 4 other transects. Distances between tracks within the same transect ranged from 350 to 1630 m, and averaged 858 m. All tracks were in stands with ≥ 4 selection criteria. The observed distribution of marten tracks was significantly different from a random distribution of tracks among habitat types ($P = 0.05$).

In 2003, approximately 53.5% of the 22.7 km snowshoed crossed stands with ≥ 4 selection criteria. Seventeen tracks were recorded in 7 transects: 4 tracks in 4 different transects, and 13 in 4 other transects. Distances between tracks within the same transect ranged from 100 to 835 m, and averaged 284 m. All tracks were in stands with ≥ 4 selection criteria; the observed distribution of marten tracks was significantly different from an expected one (P = 0.003).

Combining data from both years, approximately 65% of the 53.1 km snowshoed were within stands with ≥ 4 selection criteria. All 33 tracks were in stands with ≥ 4 selection criteria. The observed distribution of marten tracks differed significantly from random (P < 0.001).

When using only tracks that were > 1000 m apart within the same transect, 11 tracks (4 in 4 transects, and 7 in 3 transects) were recorded in 2000, and 11 tracks (5 in 5 transects, and 6 in 3 transects) were recorded in 2003. All 22 tracks were in stands with ≥ 4 selection criteria. The observed distribution of marten tracks was significantly different from random ($P = 0.002$).

**Attributes of polygons with marten tracks**

In 2000 and 2003, late-successional stands corresponded to 34.7 km (65.3%) of the total length of transects; mid-successional stands, 5.5 km (10.4%); and early-successional, 12.9 km (24.3%). In contrast, marten tracks were found exclusively in polygons composed of late-successional stands, dominated by either spruce or sub-alpine fir. All tracks were in stands with a canopy closure ranging from 30 to 50%; 75% of them were in stands with a basal area ≥ 20 $m^2$/ha in trees with ≥ 27.5 cm dbh. The majority (64%) of tracks were in mesic stands; 30% were in sub-mesic, and 6% in sub-hygric.

## Discussion

This study showed that American marten winter habitats corresponded to well-developed, late-successional circum-mesic coniferous stands with relatively high canopy closure and/or high basal area. This study also demonstrated that the VRI dataset was a useful tool to predict the distribution of such habitats at landscape level. The late-successional stands identified as potential marten habitats may not all be inhabited by martens. In fragmented areas, such stands may be inaccessible to martens because they are surrounded by large openings. In other areas, such stands may be unoccupied because resident martens have died for various reasons. On the other hand, our findings suggest that in our study area, stands with < 4 selection criteria are less likely to be used by martens in winter. It is noteworthy to mention that the value of the predictive winter habitat maps may be limited to the SBS zone only. In other regions with different forest composition and structure, it may be necessary to modify habitat selection criteria to account for variations in the life history of American marten populations.

As landscapes change over time, it may be necessary to re-evaluate habitat selection criteria used to identify American marten winter habitats. The TFL30 landscape is currently dominated by late-successional stands (Canfor 2001). Because of forestry practices and a bark-beetle (*Dendroctonus* spp.) epidemic, forests will become younger in the future, and mid-successional stages will become more abundant. In areas where late-successional stands are unavailable or in limited supply, martens 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. Yeager (1950) indicated that outbreaks of the Engelmann spruce bark-beetle (*Dendroctonus engelmannii*) resulted in forests of standing dead trees that were still inhabited by martens. In the eastern United States, in landscapes where a spruce-budworm (*Choristoneura fumiferana*) epidemic reduced canopy closure and increased snags, stumps, woody debris and ground cover, martens apparently used young stands as well as mature ones (Chapin et al. 1997).

Winter track surveys are a rapid and cost-effective method to determine where martens occur (Proulx and O'Doherty 2006), and to field-test maps that predict the distribution of marten habitat. Marten tracks were recorded in 14 transects in 2000 and 2003. In half of them, only 1 marten track was recorded. In 7 other transects, > 1 track per transect occurred. In some cases, tracks were far apart and, on the basis of their size, they probably belonged to different animals. In other cases, tracks may have belonged to the same animal but the likelihood of this among transects was reduced by the temporal and physical separation of transects. We acknowledge the possibility of some spatial autocorrelation remaining in the data, especially within transects; however, we doubt it affected the interpretation. Even when sample size was reduced by only considering tracks at least 1000 m apart in the analysis, the trend was unambiguous: all tracks were in mature and old coniferous stands with proper canopy closure and/or basal area.

We have demonstrated that it is possible to predict the distribution of potential winter habitats for American martens using simple criteria. In an American marten conservation program, such a finding may have a significant impact on the determination of late-successional stands that need to be protected in the future. We recommend that the map query used in this study be tested in other similar areas, and in regions where American marten ecology may be slightly different.

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