Cumulative Effects of Landscape Change on the Distribution of American Marten (*Martes americana*)

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Introduction

Natural resource managers recognize the importance of the cumulative effects of forestry-related landscape change when managing and conserving wildlife populations (Schneider et al. 2003, Johnson 2011). Compared to acute, immediate changes to habitat, cumulative effects can be complex and difficult to understand (Johnson 2011). This is certainly true for American marten (*Martes americana*) habitat within central-interior British Columbia (BC). Marten occur over large geographic areas and may be subjected to multiple forms of anthropogenic landscape change. Little is known, however, how these varying levels of landscape change may be affecting their habitat, and inevitably, their distribution. British Columbia has been subjected to unprecedented levels of landscape change following rapid development in forestry-related resource sectors. In central-interior BC, timber harvest levels remain high, particularly in response to the mountain pine beetle (*Dendroctonus ponderosae*) epidemics that ravished pine stands (BC MoFML 2010, Morris 2011). The logging blocks and access roads associated with forestry practices may result in distribution changes due to direct habitat loss or through habitat fragmentation. In addition to the direct, immediate impacts, these forestry practices may persist and have profound effects on marten habitat and populations for many years.

Marten are considered to be a species dependent on late-successional forests, particularly during winter (Thompson 1994, Proulx et al. 2006, Webb and Boyce 2009). In addition to mature forest stands, marten require continuous tracts of forests containing structural complexity (Hargis et al. 1999, Fuller and Harrison 2005). Many studies have found that marten avoid open areas associated with forestry practices, such as logging blocks and roads (Fuller and Harrison 2005, Proulx 2009). Preserving large stands of ideal forest habitat may be instrumental in maintaining healthy marten populations.

The objective of this study was to determine the cumulative effects of forestry-related landscape change on the availability of marten habitat on a reference landscape in central-interior

BC. By developing a winter habitat model for marten and applying it spatially at three time intervals (1990, 2000, and present-day) using geographical information systems (GIS), I predicted that I would be able to observe changes in habitat availability over time.

American marten, structurally complex old-growth marten habitat, and a typical post-harvest logging block

Study Area

I selected a trapline in central-interior BC to serve as the reference landscape for this study. The registered trapline (ID # TR0724T010) had an area of 63399 ha and was found approximately 95 km north of the city of Prince George (Figure 1). The location of the reference landscape falls within the Sub-Boreal Spruce (SBS) biogeoclimatic zone. Meidinger and Pojar (1991) described the SBS zone as having seasonal temperature extremes, with cold, snowy winters, and warm, moist summers. Moderate annual precipitation occurs, 25-50% of which is in the form of snow. The mean annual temperature is between 1.7-5° C. The reference landscape was between 680-1250 m in elevation, and was dominated by upland coniferous forests. Hybrid spruce (*Picea engelmannii x glauca*) was the leading climax species, while lodgepole pine (*Pinus contorta*) was a common seral species. Subalpine fir (*Abies lasiocarpa*), black spruce (*Picea mariana*), and trembling aspen (*Populus tremuloides*) were also common tree species. The reference landscape included large amounts of lakes and wetlands. Timber harvesting was extensive in this study area and increased significantly over time, likely in response to mountain pine beetle outbreaks.

Analysis and Methods

I collected data from multiple sources in order to map the reference landscape at three different time intervals. The following data were acquired from the BC Land and Resource Data Warehouse (LRDW; http://archive.ilmb.gov.bc.ca/lrdw/): Registered BC traplines, Vegetation Resources Inventory (VRI), Forest Tenure Cut Blocks, and Forest Tenure Road Segment. Additional data, including a digital elevation model (DEM) and Terrain Resource Information (TRIM) were acquired from the UNBC GIS

Lab Data site (http://www.gis.unbc.ca/resources/data_download/download.php). All data were downloaded in, or later converted to, BC Albers projection.

The two primary components of this project included 1) building and applying a winter habitat model for marten, and 2) mapping disturbance in the form of logging blocks and roads over time. I developed a marten habitat model based on literature reviews and previous habitat models created for marten within the SBS zone (Hargis et al. 1999, Fuller and Harrison 2005, Proulx et al. 2006, Proulx 2009). In order to build the habitat model, I converted all necessary layers into raster format. This allowed me to use the Spatial Analyst tools in ArcMap10.1 to carry out a variety of raster analyses. I built the model by using the VRI and disturbance (logging blocks and roads) data. The model contained eight parameters, which were ranked and weighted based on their influence on marten distribution during winter (Table 1). The model was created using raster calculations. The model was then applied spatially to the reference landscape at the three time intervals (Figure 2). Raster cells that had values of less than or equal 0.7 were considered unsuitable habitat; values between 0.7 and 3.1 were considered moderate habitat; values greater than 3.1 (up to a maximum of 3.7) were considered highly suitable.

In order to build disturbance layers at three time intervals, I selected for logging blocks, from both the VRI and Forest Tenure data, based on their completion date. I merged these two layers to provide the most complete representation of logging blocks across the landscape. Roads were selected from the Forest Tenure data based on their completion date. These layers were added to their respective maps based on the dates of the disturbances (Figure 3). For example, the map dated 2000 in Figure 3 includes all logging blocks and roads that were completed prior to, or during the year 2000. I quantified the area of logging blocks and length of roads to determine the amount of forestry-related disturbance present at each time interval.

Table 1. Variables used to rate marten habitat across the reference landscape

Habitat Variable	**Explanation**	**Ranking** (From 1 – 5, where 5 is most important)	**Weighting**
1. Forest stand age greater than or equal to 80 years (Class 5 or greater)	Marten prefer mature, late-successional forest stands. These forests are associated with the structural complexity that marten select for (Fuller and Harrison 2005, Proulx et al. 2006).	4	Forest stand attributes (variables 1-4) = 50%

2. Crown closure greater than or equal to 30%	Dense crown closure provides cover for marten during winter months (Fuller and Harrison 2005, Proulx et al. 2006, Proulx 2009).	5	
3. Basal area of >=20m^2/ha	Marten prefer densely forested stands, as opposed to open forests (Fuller and Harrison 2005, Proulx et al. 2006).	4	
4. Mesic soils	These soils are associated with developed understory, providing ideal habitat for marten and their prey (Proulx et al. 2006).	3	Soil attributes = 20%
5. Areas greater than or equal to 100m from any roads or logging blocks	This created a buffer around any forestry-related disturbances, as marten tend to avoid open features (Hargis et al. 1999, Fuller and Harrison 2005, Proulx 2009).	3	Disturbance buffer attributes = 20%
6. Future logging block areas	In order to fill the gaps resulting from the current VRI data, future logging blocks were given some value when mapping the 1990 and 2000 landscapes. This compensated for future losses of habitat.	1	Future logging blocks = 10%
7. Logging blocks were considered unsuitable	Previous studies have found that marten avoid open logging blocks and early successional forests (Hargis et al. 1999, Fuller and Harrison 2005, Proulx 2009).	Unsuitable	Logging block areas were automatically considered unsuitable habitat

Results

I created maps displaying marten winter habitat availability and landscape changes at three different time intervals (1990, 2000, and present-day). Overall, marten habitat declined over time, while forestry-related disturbance increased (Table 2). The highly suitable marten habitat declined by 13.5% from 1990 to present-day, while moderately suitable habitat declined by 40.9%. There was a 433.1% increase in logging blocks over that time period, and a 9.1% increase in major logging roads. The significant increase in logging activity on the reference landscape appeared to have had a considerable impact on the amount of suitable habitat available to marten. The landscape also appeared to have become increasingly fragmented. Given the propensity for marten to select for ideal, intact forest stands, I would conclude that forestry-related landscape change has had an impact on the distribution of marten across the reference landscape.

Table 2. Changes in marten winter habitat availability and forestry-related disturbances over time.

	1990	**2000**	**Present-day**	**Overall Change**
Highly Suitable Habitat	3354.2 ha	3223.4 ha	2902.5 ha	13.5% decline
Moderately Suitable Habitat	28560.4 ha	24098.1 ha	16873.7 ha	40.9% decline
Logging Blocks	9419.2 ha	15369.0 ha	50211.1 ha	433.1% increase
Logging Roads	398.3 km	416.1 km	434.7 km	9.1% increase

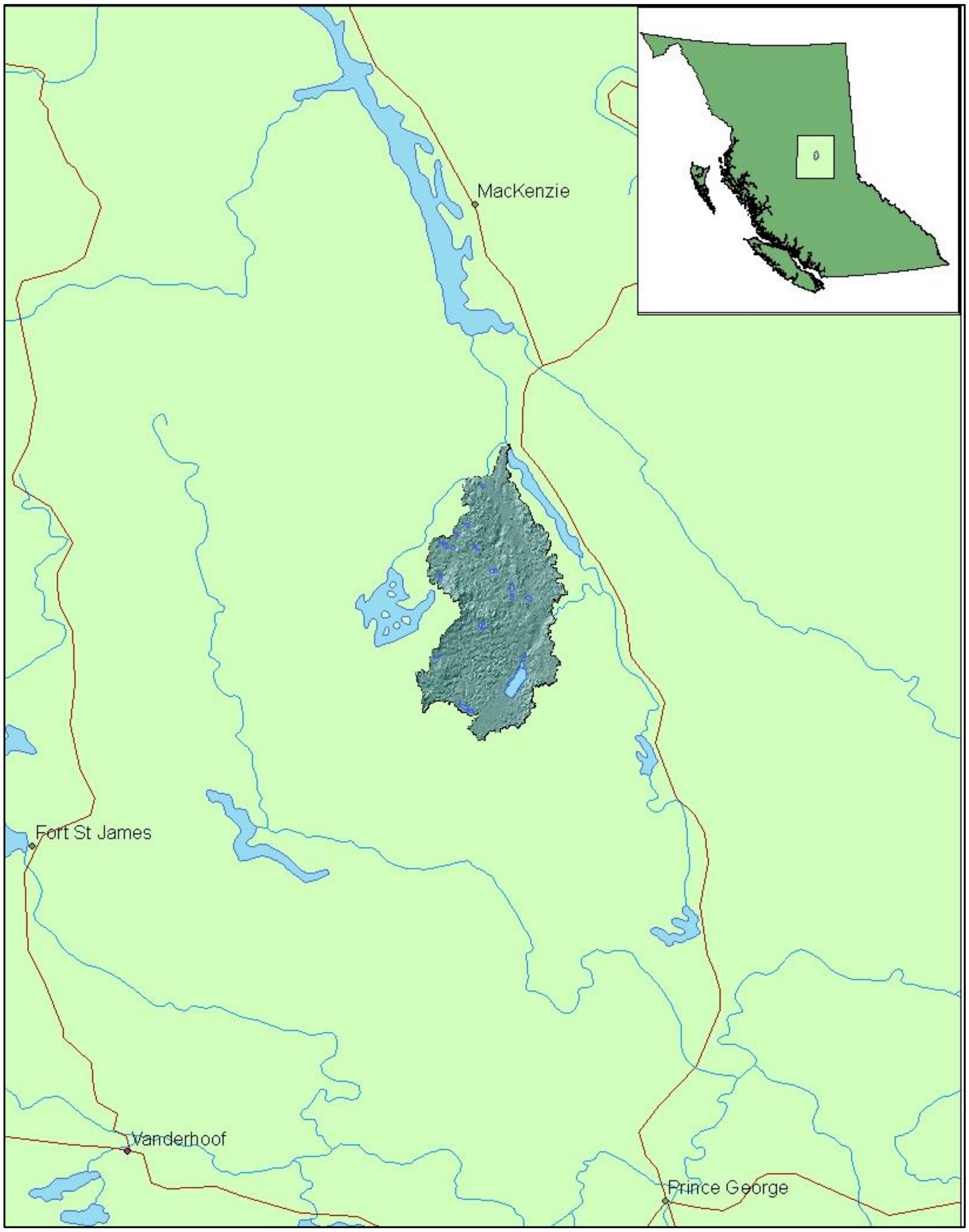

Figure 1. Map displaying the trapline (ID # TR0724T010) that served as the reference landscape for the analysis during this study. The trapline had an area of 63399 ha and was located approximately 95 km north of Prince George, BC.

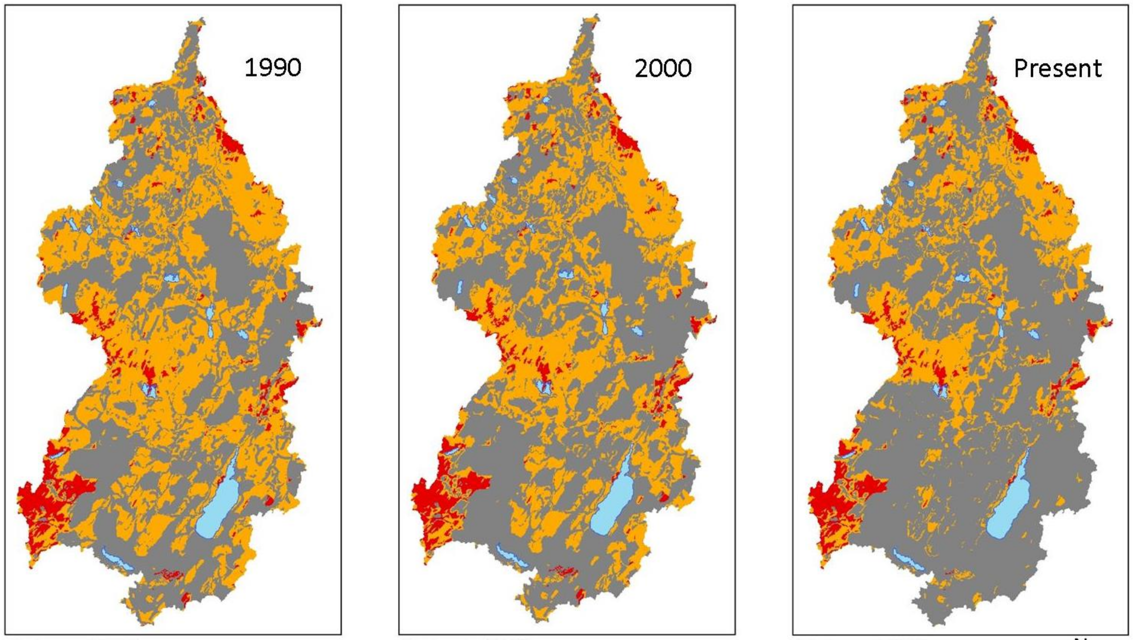

Figure 2. Changes in marten (*Martes americana*) habitat availability over time on a trapline north of Prince George, British Columbia

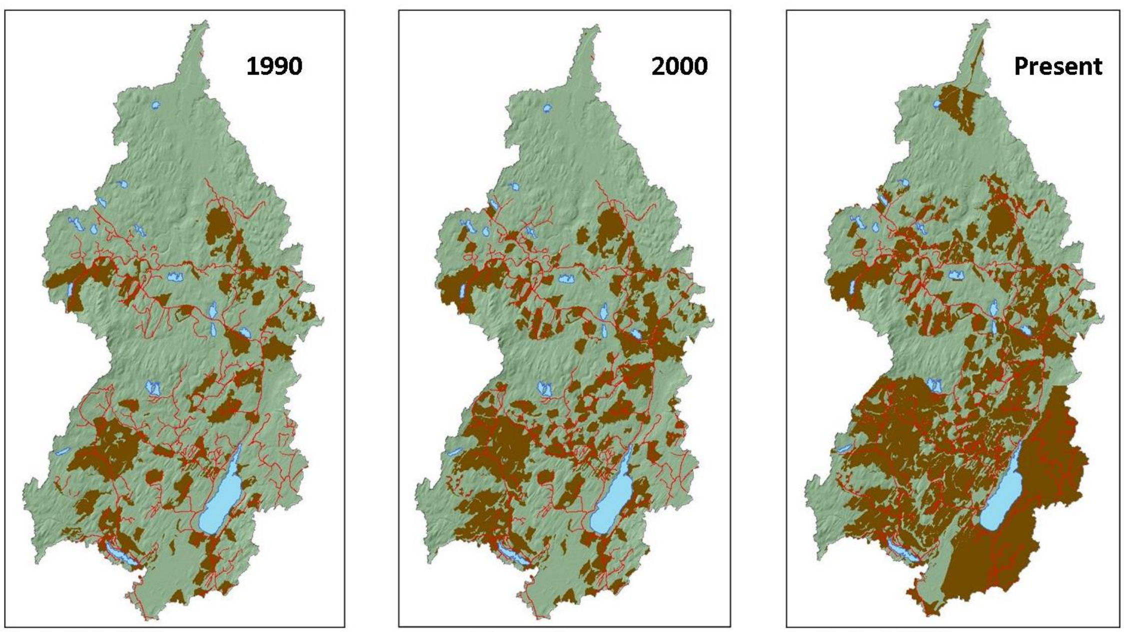

Figure 3. Landscape changes over time in the form of roads and logging blocks on a trapline north of Prince George, British Columbia

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