WINTER HABITAT SELECTION OF LYNX *(Lynx canadensis)*

IN NORTHERN WASHINGTON

By

BENJAMIN THOMAS MALETZKE

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN NATURAL RESOURCE SCIENCES

WASHINGTON STATE UNIVERSITY
Department of Natural Resource Sciences

DECEMBER 2004

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of BENJAMIN THOMAS MALETZKE find it satisfactory and recommend that it be accepted.

____
Chair

____

____

____

ACKNOWLEDGMENTS

Funding and support for this research were provided by grants from the US Fish and Wildlife Service (USFWS), Washington Department of Fish and Wildlife (WDFW), USDAFS Okanogan National Forest (ONF), USDAFS Pacific Northwest Research Station (PNW) and Washington State University (WSU).

Within those organizations, I would like to thank John Rohrer (ONF) and Robert Naney (ONF) for providing bunkhouse space, snowmobiles, GIS information, and knowledge of the area. I thank Beth Galleher (PNW) and Leslie Jagger (PNW) for their help and expertise with GIS and GPS technology. Cathy Raley (PNW) for her help with statistical analyses, and for gathering equipment used during the project. I would like to thank Dr. Bruce Frazier (WSU) and Richard Rupp (WSU) for their assistance in developing the habitat coverages and fielding the many questions I had. I owe a special thank you to Carly Walker (Univ. of Montana, Missoula), Jeff von Kienast (USDAFS), and my friends, faculty and staff at the Natural Resources Department at WSU for all their help and support.

Dan Harrington, Michelle Crabb, Joshua Porter, and Jesse Tigner worked extremely hard through some very difficult conditions. Their work ethic and dedication made this project possible.

I am indebted to my wife, Amber, and son, Brennan, for allowing me to pursue my dreams and for keeping me focused on what is important. Also to my parents, Skip and Ann Maletzke, thank you for your encouragement and support throughout my career.

Finally, I thank the members on my committee: Robert Wielgus (WSU), Gary Koehler (WDFW), Keith Aubry (PNW), and Marc Evans (WSU) for their support and guidance. I appreciate their willingness to listen, patience, and ability to challenge me to be a better biologist. Thank you for the opportunity to conduct this research and further my education.

WINTER HABITAT SELECTION OF LYNX *(Lynx canadensis)*

IN NORTHERN WASHINGTON

Abstract

by Benjamin Thomas Maletzke, M.S.
Washington State University
December 2004

Chair: Robert B. Wielgus

I investigated habitat selection of lynx on a 211 km^2 portion of the Okanogan National Forest in north-central Washington. I completed two winter field seasons, 2002-2003 and 2003-2004, snow-tracking lynx for a total of 155 km using precise-positioning Global Positioning Systems to record movements and behaviors of lynx. A Geographic Information Systems (GIS) analyses of these movements was used to determine winter habitat selection on a study area comprised of Engelmann spruce/subalpine fir and Douglas-fir/ponderosa pine forest with very little lodgepole pine. The area was fragmented by recent wildfire and timber harvest. Habitat variables included forest vegetation type, overstory canopy cover, understory cover, slope, aspect, and elevation. I used t-tests and selection ratios (S) to compare differences in proportions of lynx use trails versus random availability trails. Lynx selected $P < 0.05$ for Engelmann spruce/subalpine fir forest types (S=1.66), canopy cover of 11-39% (S=1.29), and understory of 11-39% (S=1.18), but avoided forest openings (S=0.28), recent burns (S=0.38), Douglas-fir/ponderosa pine (S=0.41), canopy cover <10% (S=0.62), understory <10% (S=0.55), and slope >30° (S=0.62). From these results, I determined significant variables (P<0.05) for inclusion in a logistic regression model of vegetative and physiographic variables important to lynx. Logistic Regression indicated lynx selected ($P<0.05$) for Engelmann spruce/subalpine fir forest types, slopes <30°, elevations of 1524 m – 1828 m, and canopy cover of 11-39%. My results suggest that lynx do not always require and select lodgepole pine forests, but that Engelmann spruce/subalpine fir forest types are important to and selected by lynx. The logistic regression model I developed will enable forest managers to predict the relative probability of lynx presence for most areas of Washington and the North Cascades region, which share similar characteristics of vegetation and elevation found in the Black Pine Basin study area.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Forest management to conserve lynx *(Lynx canadensis)* habitat in the United States has become important since the lynx was listed as threatened in the contiguous US by the US Fish and Wildlife Service (USFWS 2000). Current lynx range in the continental US includes Washington (WA), Montana, Idaho, Wyoming, Colorado, Minnesota, and Maine (McKelvey et al. 2000a). Because the vegetation and physiography of landscapes vary greatly within the range of lynx, forest managers require locally collected data for effective management of lynx habitat.

Four studies (Koehler 1990; Brittell et al. 1989; McKelvey et al 2000b; and von Kienast 2003) have examined habitat selection by lynx in WA. However, these studies were conducted on the same general study area known as "The Meadows" (latitude 49°N, longitude 120°W), in the Okanogan National Forest in what is considered to be the highest quality lynx habitat in WA (Figure 1). This is high-elevation habitat (>1460 m) comprised of extensive and homogenous lodgepole pine (*Pinus contorta)* forest with lesser components of Engelmann spruce (*Picea engelmannii)*, subalpine fir (*Abies lasiocarpa)* (Brittell et al. 1989; Koehler 1990). Koehler (1990) and McKelvey et al. (2000b) found that lynx most often selected for lodgepole pine (LP), but not Engelmann spruce – subalpine fir (ESSF), and avoided Douglas-fir (*Pseudotsuga menziesii*)/ponderosa pine (*Pinus ponderosa*) forest (DFPP), and large openings such as clear cuts or burns. Although these studies provided important information on lynx habitat selection in WA, Geographic Information Systems (GIS) analyses indicate that there is a relatively small amount of such high-quality, high-elevation LP lynx habitat in the state. Most of the remaining lynx range in WA occurs at lower elevations, has steeper slopes, and consists mostly of ESSF and DFPP forests (Ruediger et al. 2000). To investigate habitat-use patterns and improve the management of lynx habitat in WA, I conducted my study in a portion of lynx range where ESSF and DFPP habitats predominated to determine which if any habitat types are preferred by lynx in portions of their range in WA where LP does not predominate. The Black Pine Basin area (latitude 48°N, longitude 120°W) is typical of much of lynx range outside "The Meadows" in WA and is more fragmented due to intermixed forest types, recent fires and logging activities. The primary objective of the study was to develop a model of habitat selection for lynx at the landscape scale to predict the relative probability of lynx presence across much of the North Cascades region. Understanding how lynx use this landscape will allow forest managers to make scientifically sound decisions on how to manage forests for lynx.

STUDY AREA

The study area (Figure 2) consists of a 211 km^2 portion of the Okanogan National Forest in north-central WA. It ranges from the Black Pine Basin north to the Pasaytan Wilderness, east to Falls Creek, and south to Fawn Peak and Buck Mountain. The area is mountainous with elevations ranging from 643 m to 2134 m. Temperature ranges from -26°C to 38°C (Western Regional Climate Center). The average annual snowfall is 315 cm at 655 m in elevation.

Vegetation consists primarily of ESSF with a small component of LP at higher (1524 m – 2134 m) elevations. Dominant tree species at lower elevations (<1066 m) consist of DFPP. Vegetation in the mid-elevation range (1066 m - 1524 m) varies depending on the physiographic features of the landscape. Wide drainage bottoms and south-facing slopes contain DFPP forest types. Steep, narrow drainage bottoms and more northerly facing slopes generally contain ESSF forests.

GIS analyses showed the study area was comprised of 2% forest openings; 3% whitebark pine (*Pinus albicaulis*) forest; 6% recently (<10 yrs) burned areas; 7% LP; 37% DFPP; and 45% ESSF (Figure 1). Forty three percent of the study area was at elevations ranging from 1220 m to 1524 m, 28% was from 1525 m to 1829 m, 22% was from 850 m to 1219 m, and the remaining 7% was >1829 m.

The density of roads within the study area was 1.8 km of primarily narrow gravel roads/km^2. During the winter, the majority of these roads were accessible by snowmobile. Tank traps, gates, and debris blocked motorized traffic during summer.

METHODS

Delineating the Study Area Boundary

The Black Pine Basin was selected as the study area because of road and snowmobile access, a history of lynx presence, and forest vegetation and elevations that differed from those studied previously in The Meadows study area. I first compiled and plotted the locations (Figure 3) of lynx observations, from 1996 to 2002, from snow tracking and hair-snare surveys that were conducted by the Okanogan National Forest in the Black Pine Basin, Eightmile Creek, and Banker Pass area (J. Rohrer, personal communication). I selected this area, with a fairly well distributed system of roads, because the majority of the forests in WA were roaded and my study design required access by snowmobile to locate lynx trails (Figure 3).

Locating Tracks

I used snow-tracking to assess habitat selection by lynx during winter (von Kienast 2003). I identified 6 search zones (Figure 4); each approximately 39 km^2 (about the average size of a female lynx home range; Koehler 1990), to evenly disperse the search effort over the study area and to track as many individual lynx as possible. The zones were also used to obtain a representative sample thru time during each winter. Within each zone, I established 4 sub-zones approximately 9 km^2 to reduce bias when searching each zone for tracks. Each day I surveyed a new zone and randomly selected a new sub-zone to begin systematically searching all accessible roads for lynx tracks. I waited a minimum of 12 hours since the last snowfall to ensure that animals had sufficient time to move throughout the study area and leave tracks across roads. If no tracks were found in the first sub-zone, I moved to an adjacent sub-zone and continued searching until a track was found.

When I found a set of lynx tracks, I followed them on snowshoes. If more than one lynx trail was located I followed the freshest trail. Each trail was followed in the direction the lynx traveled if the track was estimated >24 hours old, or in the opposite direction the lynx traveled if the track was <24 hours old - to avoid disturbing the animal. If 2 crews followed the same track, one forward-tracked while the other back-tracked the lynx trail. I used sub-meter precision Trimble Pathfinder ProXL and ProXR receivers with TSC1 datalogger Global Positioning System (GPS) (Trimble Navigation Limited, 749 North May Avenue, Sunnyvale, CA 94085) to record track locations and lynx behavior. The datalogger records a trail feature by collecting a coordinate location every 2 seconds and automatically connects those points to form a line segment. When I stopped while snowtracking, I paused the GPS from collecting points and resumed the GPS trail feature collection as we moved, recording points at about 1 m to 3 m spacing. I created a data dictionary (see Appendix A) within the datalogger to allow attributes, such as the number of lynx in a group or behaviors associated with trail and point features, to be collected along the lynx trails.

Data from the TSC1 datalogger was downloaded into Trimble GPS Pathfinder Office Software (Trimble Navigation Limited, 749 North May Avenue, Sunnyvale CA 94085) for differential correction using the Colville National Forest base station in Kettle Falls, WA (http://www.fs.fed.us/database/gps/kettle.htm) or CORS Whidbey Island, WA base station (http://www.ngs.noaa.gov/CORS/cors-data.html).

I exported differentially corrected data using Trimble Pathfinder Office software to a shapefile format. I connected all trail segments where a new trail feature started or ended during data collection so that each segment of lynx trail was one solid line using ArcView 3.2 editing tools (Figure 5) (ESRI, 380 New York St, Redland, CA 92373). I also deleted any clusters of vertex points that were repetitive positions due to failing to hit the pause button on the GPS.

I used the methods from von Kienast (2003) to record and measure vegetative and physiographic conditions. I established a plot center every 200 m along lynx trails, measured with a hip chain, and recorded slope, aspect, vegetation, canopy cover, and understory cover. Within a 5-m radius around the plot center, I estimated stand density. I recorded all vegetation 1m above snow level by species and diameter at breast height (DBH). Diameter classes included; < 10, 10-18, 19-28, 29-51, and > 51 cm. I measured the diameter of any tree >51 cm. Canopy cover for overstory (all structure > 2.5 m above snow level) and understory (all structure < 2.5 m above snow level) was visually estimated at the plot center as < 10, 10-39, 40-69, and 70-100% of the sky covered. The plot data was compiled into a GIS habitat coverage of vegetation type, canopy cover, and understory cover as measures of use by lynx for habitat selection analyses.

GIS Coverages for Habitat Selection Analyses

I used a 10-m resolution Digital Elevation Model (DEM) from the Okanogan National Forest and Spatial Analyst in ArcMap 8.3 (ESRI Inc. 380 New York St. Redlands, CA 92373) to derive slope, aspect and elevation polygon coverages.

The vegetation coverages that encompassed the entire study area included the Landsat-derived 1997 Utah Vegetation Grids database (Bio/West Inc. 1999) and the Pacific Meridian 1983 Grids database for the Okanogan National Forest. However, existing GIS data were miss classified in certain elevation zones needed for my analysis and had no delineated forest stand boundaries, so I developed a separate GIS coverage to provide a more accurate depiction of the forest stand boundaries, vegetation type, canopy cover, and understory cover. I obtained the coverages and shapefiles from the USDA Okanogan National Forest timber harvest and wildland fire history maps to build a base map of landscape disturbance from 1950 to present. I classified the remaining unharvested and unburned areas by digitizing forest stand boundaries, from visual boundaries of stand ages, and configurations from 1:40,000 scale orthophotos with 1-m resolution taken in 1998 (PNW Research Station, Olympia, Washington). This resulted in a digitized coverage containing 984 polygons with an average size of 21 hectares (SD = 48.21 hectares). I used vegetation measurements from 725 habitat plots collected along lynx trails and inspection of 374 random plots to classify 512 of the 984 polygons in the vegetation coverage map. I classified the remaining 472 polygons using aerial photos from flights during the summers of 1998 and 2000 at 1:12,000 and 1:15,840 scales, respectively, to determine the vegetation type and percent canopy cover (Paine, 1981). Based on aerial photo interpretations of vegetation type, canopy cover of the overstory trees, topography, and notes on observations made during summer field investigations, I estimated the understory cover class for these remaining polygons. Vegetation type was divided into 6 categories; burned (<10 years), forest openings, DFPP, LP, ESSF, and whitebark pine forest. Overstory canopy cover (structures >2.5 m above the snow) and understory cover (structures <2.5 m above the snow) were comprised of 3 classes; <10%, 11-39%, and 40-100%. Stand age was not analyzed because GIS coverages for timber harvest and wildland fire history were incomplete.

To determine the accuracy of the polygons classified from the aerial photos, I interpreted 308 of the polygons that had been ground-truthed with habitat plots. I created a classification error matrix with the data and calculated the kappa coefficient (khat) and overall accuracy for the habitat polygons interpreted by aerial photos based on methods presented by Lillesand et al. (2004, pg 586-593). The khat statistic is similar to the interpretation of R-square and indicates the extent to which the percentage of correct values of an error matrix was due to "true" agreement versus "chance" agreement (Lillesand et al. 2004, pg 586-593). Khat usually has a value of 0 to 1, with higher values having a better classification performance (Tso and Mather 2001). The overall accuracy was 77% and khat = 0.66 (the observed classification is 66% better than one resulting from chance) for the 6-class vegetation coverage. The 3-class canopy coverage and understory coverage had an overall accuracy of 68% and 60% and a khat = 0.52 and 0.37 respectively, (See appendix B). However, only 48% of the polygons in the study area were classified using aerial photos and were related to these accuracies and the other 52% of the polygons were classified from ground-truthed points greatly increasing the accuracy of the overall coverage.

Use and Availabity Habitat Data

A lynx use trail was defined as a continuous independent trail segment (e.g. following one lynx or one group) collected by following lynx tracks and recording the movements with GPS (Figure 6). There was a total of 51 lynx use trails with a minimum distance of 600 m.

Availability trails were created by randomly relocating the lynx use trails within the study area. For each availability trail, I randomly generated a start point along a road within the study area boundary. I then shifted each lynx use trail to the newly generated point, creating a random mirror image of the routes traveled and recorded for lynx, but moving the location of the entire trail. The replications were repeated until the means and standard deviations of the proportion of lynx trails in each vegetative and physiographic condition reached an asymptote. This asymptote was reached after the Monte Carlo simulations were repeated three times for each trail for a total of 153 random trails (Figure 7). Because all lynx use trails started on or were associated with roads, only random trails that intersect roads were used in this analysis. Failure to account for this potential bias, comparing used trails associated with roads with random trails not necessarily associated with roads could result in high Type I error rates (Katnik and Wielgus, In Press).

Each trail was considered to be one sample unit. Since I examined trail segments and not point data, elevations, slope, and aspect were presented as categorical data. I used the proportion of the lynx use trails or random availability trails in each habitat type for analyses of selection. Proportions were calculated in ArcGIS 8.3 (ESRI Inc, 380 New York St., Redlands, CA 92373) by intersecting each trail with a polygon coverage of vegetation type, canopy cover, understory cover, slope, aspect, and elevation. The sum of lengths of the trail segments found in each condition was tallied for each trail;

proportions were calculated using Excel 2000 (Microsoft Corporation, One Microsoft Way, Redmond, WA 98052, Table 1).

Statistical Analyses

I used separate-variance t-tests to compare lynx use trails with random trails to determine which variables should potentially be included in a multivariate model. Only those variables that yielded statistically significant ($P \leq 0.05$) differences between used and random trails were considered for inclusion in logistic regression models. I calculated the selection ratio (*S*) by dividing the mean proportion of use trails by the mean proportion of available trails for each physiographic or vegetative condition (Manly et al. 2002). For the selection ratios, I calculated the 95% Bootstrap confidence intervals and estimated standard errors (Efron and Tibshirani 1993).

Adjacent habitat categories that shared similar trends (e.g. both appeared to be avoided or selected for) were pooled to increase sample sizes per category for multivariate analyses (Wilkinson et al. 1992). I pooled five slope classes (0-10°, 11-20°, 21-30°, 31-40° and 41-76°) into two classes (0-30° and 31-76°), and six vegetation classes (forest openings, recently burned, DFPP, LP, ESSF, and whitebark pine forest) into four classes (forest openings, recently burned, DFPP, and ESSF with LP/whitebark pine). These habitat categories resulted in adequate sample sizes for statistical tests (e.g., mean expected values >2, Roscoe and Byers 1971; <20% of cells with expected values <5, Wilkinson et al. 1992; Alldrege and Ratti 1986) and satisfied the recommended minimum of 5 used trails for each parameter estimated (Tabachnick and Fiddell 1983).

I used logistic regression for modeling the relative probability of presence for lynx (Manly et al 2002; McKelvey et al. 2000b). To select variables for possible inclusion in the model, I compared the proportions of vegetative and physiographic conditions within lynx trails and within randomly located trails using t-tests and cumulative percent curves in SPSS 10 for windows (SPSS Inc, 233 S. Wacker Drive, Chicago, IL 60606). I considered variables to be correlated if Spearman's rank correlation coefficient $\geq$0.50. I selected the collinear variable that showed the most significant ($P \leq 0.05$) differences, or those I presumed to be biologically meaningful for lynx. Using the uncorrelated variable set, I ran a forward stepwise logistic regression for all possible combinations of main effects and 2-way interactions. Inclusion of variables was based on the χ^2 improvement statistics, and the model that yielded the largest log-likelihood χ^2 was selected as best (Manly et al. 2002). Equation [1] defines the relative probability equation for the logistic regression model.

[1] $$P = \frac{\exp(Bo + B1a + B2b + B3c...)}{1 + \exp(Bo + B1a + B2b + B3c)}$$

Where *P* is the probability of lynx use, *Bo* was a constant, and *B1a-B3c* were parameter coefficients.

The analysis of resource selection was similar to design I with an SP-A protocol (Manly et al. 2002) where measurements are made at the population level. This application of resource selection is valid under the following assumptions from Manly et al. (2002): (1) With the exception of two small fires (1.3 km^2 or 0.6% of study area) during the summer of 2003, the distribution of habitat variables did not change during the course of this study. (2) The locations of the lynx were correctly identified and any trails that had missing segments were removed from the habitat analyses. (3) Lynx had equal access to all parts of the study area. The study area boundary was designed around previous lynx detections from hair-snare and winter-track surveys. (4) The study design ensured that I searched the entire study area evenly and thoroughly to make sure we did not miss any tracks or sign of lynx. The original starting zone and sub-zones where we began our search effort each sequential day were random to ensure that the lynx trails we followed were random and independent. (5) Also, to the best of our ability, the variables that influence selection have been correctly identified and measured.

RESULTS

I recorded 68 separate lynx trails (155 km) during two winter field seasons. Thirty lynx trails (52 km) were obtained during the winter of 2002-2003 and 38 trails (103 km) from the winter of 2003-2004. I was unable to use 17 of the 68 trails for habitat analysis because I was unable to follow the trails for at least 600 m due to poor snow conditions (e.g. melting and sloughing of snow from trees, icing under the forest canopy, or wind in the open areas). For the habitat analysis, I used 51 lynx trails: 19 from 2002-2003, and 32 from 2003-2004. Mean distance and standard deviation for lynx use trails was 2591 ± 1495 m for 2002-2003 and 3138 ± 1296 m for 2003-2004.

Univariate Analyses

Table 1 shows the results of t-tests for 51 lynx trails compared to 153 random trails for each of the vegetative or physiographic classes. Lynx avoided forest openings (*S* = 0.27, 95% C.I. = 0.05 to 0.73, SE = 0.20), recently burned areas (*S* = 0.38, 95% C.I. = 0.12 to 0.77, SE = 0.10), and DFPP (*S* =0.41, 95% C.I. = 0.24 to 0.63, SE = 0.11); but selected for ESSF (*S* = 1.50, 95% C.I. = 1.41 to 1.95, SE = 0.11) and used LP (*S*=0.58, 95% C.I. = 0.16 to 1.40, SE = 0.03) and whitebark pine (S = 5, 95% C.I. = 0.30 to 55.9, SE = 0.07) as they occurred on the landscape. Lynx avoided open (< 10%) canopy areas (*S* = 0.62, 95% C.I. = 0.44 to 0.87, SE = 0.09) such as clear cuts, meadows, and burns, but selected for a moderate canopy cover of 11 - 39% (*S* = 1.29, 95% C.I. = 1.04 to 1.59, SE = 0.10). They were neutral for canopy cover > 40% (*S*=0.99, 95% C.I. = 0.75 to 1.29, SE = 0.23). Lynx selected against <10% understory cover (e.g. clear cuts, meadows) (*S* = 0.55, 95% C.I. = 0.35 to 0.78, SE = 0.10), but selected for a moderate understory cover of 11 - 39% (*S* = 1.18, 95% C.I. = 0.99 to 1.39, SE = 0.16). There was no selection for understory cover of 40 to 100% (*S*=1.15, 95% C.I = 0.81 to 1.62). In summary, lynx appeared to prefer ESSF, canopy cover of 11-39%, and understory cover of 11-39%.

Lynx selected against elevations < 914 m (*S* = 0.22, 95% C.I. = 0 to 1.05, SE = 1.08) and elevations from 915 m - 1219 m (*S* = 0.69, 95% C.I. = 0.20 to 1.41, SE = 0.216). Lynx used the elevation classes of 1220 m - 1524 m (*S*=0.95, 95% C.I. = 0.70 to 1.26, SE = 0.14), 1525 m - 1829 m (*S*=1.25, 95% C.I. = 0.87 to 1.70, SE = 0.31), and > 1829 m (*S*=1.36, 95% C.I. = 0.06 to 4.17, SE = 2.87) as they occurred on the landscape. Lynx used slopes 0 - 10° (*S* = 1.22, 95% C.I. = 0.85 to 1.77, 0.14), 11 - 20° (*S* = 0.98, 95% C.I. = 0.78 to 1.18, SE = 0.14) and 21 - 30° (*S* = 1.11, 95% C.I. = 0.93 to 1.30, SE = 0.11) as they occurred on the landscape, but avoided slopes 31 to 40° (*S* = 0.62, 95% C.I. = 0.46 to 0.92, SE = 0.11) and >40° (*S*= 0.13, 95% C.I. = 0.05 to 0.33, SE = 20.65). I detected no selection for aspect. In summary, lynx appeared to prefer elevations ranging from 1220 m to 2134 m with relatively flat slopes (<30°).

Logistic Regression Analyses

I selected 5 groups of variables (vegetation type, canopy cover, understory cover, elevation, and slope) for inclusion in logistic regression analyses (Table 1). Four variables (ESSF, canopy of 11-39%, elevation 1525-1828 m, and slope <30°) were included in the best-fit model (Table 2). Understory of 11-39% was not significant in the final model due to its strong correlations to canopy cover (Spearman's rho = 0.31, r^2

=0.62), vegetation type (Spearman's rho = 0.356, r^2=0.71) and elevation (Spearman's rho = 0.13, r^2=0.26). Equation [2] shows the final model of habitat selection. I derived:

$$[2]\quad P = \frac{\exp(-7.792 + 2.967(ESSF) + 3.888(slope < 30) + 1.601(elev1525 - 1828m) + 1.594(Canopy11 - 39\%))}{1 + \exp(-7.792 + 2.967(ESSF) + 3.888(slope < 30) + 1.601(elev1525 - 1828m) + 1.594(Canopy11 - 39\%))}$$

Avoidance of DFPP, forest openings, recent burns, canopy cover < 10%, understory cover < 10%, and slopes > 30° was reflected in the large negative constant. Selection for ESSF, canopy cover 11-39%, elevation from 1525 to 1829 m, and slope <30° was reflected in the large positive parameter coefficients (Table 3). The odds for relative use by lynx was 19 times greater for ESSF when compared to the odds for other forest types. In addition, the odds was 5 times greater for canopy cover between 11 - 39% relative to the odds for other canopy cover types, 5 times greater for elevations between 1525 m - 1829 m, relative to other elevation categories, and 49 times greater for slopes <30° relative to slopes >30°. According to Steinberg and Colla (2000) and Hensher and Johnson (1981), this model of lynx habitat use shows a good fit to the data (Likelihood ratio χ^2 = 43.447, df = 4, P<0.01, McFadden's Rho-squared = 0.19).

DISCUSSION

Areas selected by lynx had higher proportions of ESSF, canopy cover 11 – 39%, elevations ranging from 1525 - 1829 m, and slopes <30°. A re-analysis of Koehler (1990) and Brittell's (1989) data from The Meadows by McKelvey et al (2000b) found selection for elevations of 1700 - 2000 m, which was higher than in my study area. Von Kienast (2003) found similar results, in which the mean elevation of lynx trails was about 1865 m each year of the study. Eighty-four percent of my Black Pine Basin study area was below 1700 m (Figure 1), and lynx selected for these lower elevations. Seventy-four percent of lynx trails occurred in ESSF, but only 45% of the study area consisted of that forest type and there was very little LP in my study area. Koehler (1990) and Mckelvey et al.'s (2000b) reanalysis showed that lynx selected for relatively homogeneous LP forest, an early seral component of ESSF, during winter; with > 80% of lynx telemetry points were in LP or associated ESSF forest. By contrast, my results indicate that lynx select for ESSF regardless of the elevation zone in which it was found and that LP is not necessary for lynx to occur. In my study area, ESSF forests provided habitat conditions that were sufficient to support lynx populations.

Lynx selected for a canopy cover of 11-39%. Species such as Engelmann spruce, subalpine fir and lodgepole pine in this canopy-cover class generally have branches extending to the ground, which offers an understory component for snowshoe hares and cover for lynx. These results were similar to that observed by Murray et al. (1995) who found lynx chased hares more frequently per distance of trail within sparse canopy cover where overstory was 6-26%. Murray et al. (1994) found lynx heavily used forests with an open canopy of 26-50% in the Southwestern Yukon. I found a negative relationship between lynx use and forest openings, burns, and areas with canopy closure <10%. Murry et al. (1994) and Koehler (1990) also found that lynx avoided forest openings. However, I observed that lynx traveled across greater distances of burned habitat than forest openings, possibly due to the vertical structure of snags left by catastrophic fires providing security cover for lynx.

In my study area, lynx appeared to prefer habitat conditions occurring between 1525 – 1828 m in elevation. Below 1525 m there was a negative relationship between elevation and lynx presence, most likely due to fewer ESSF stands and more DFPP. Since the DFPP stands generally were associated with an open understory, they may also lack the snowshoe hare densities to support lynx (Koehler 1990).

Snowshoe hare density has been shown to be positively correlated with understory cover density (Hodges 2000; Wirsing et al. 2002). However, Major (1989) and Murray et al. (1995) found lynx were most successful hunting and hunted most frequently in low-stem-density and relatively high-visibility stand types. Results from my univariate analyses showed lynx prefer an understory of 11-39% with 60% of the trails found in this class. In my logistic regression analyses, vegetation type, canopy cover, and elevation were collinear with understory and this could account for understory being non-significant in the model.

Slopes <30° increased the probability of lynx presence. Across the range of lynx in southern boreal forests, it has been shown that lynx select for flatter slopes (McKelvey 2000b, von Kienast 2003, and Apps 2000). This preference may be related to energetic demands. Another possibility is that vegetation types may be more contiguous on flatter slopes, which increases the size of the forest stand and allows the lynx more area to hunt and find prey without leaving that particular patch (G. Koehler, personal communication, WDFW, Olympia, WA). Regardless of the reason why, lynx generally avoided steep slopes.

Management Implications

In previous studies conducted in WA, lynx selected for extensive, homogeneous stands of LP (Koehler 1990; McKelvey 2000b). But, in areas with elevations ranging from 915 m - 1829 m, there are very few homogenous stands of LP in the Black Pine Basin study area. Rather, vegetation in these areas is a mixture of ESSF and DFPP forest types. Lynx selected for these lower elevation, mixed forests as long as ESSF components are present. Perhaps snowshoe hares are as abundant in ESSF as in LP or that ESSF forest stand structure results in higher predation success. Regardless of the reason why, it appears that the presence of ESSF was as valuable to lynx as the presence of LP in other areas, and ESSF forests in northern WA may provide adequate habitat for lynx.

The logistic regression model for predicting the probability of use by lynx requires accurate GIS coverages of ESSF. Coverage classes in the Utah Vegetation Grids (Bio/West Inc 1999) may be much less accurate in the elevation range where ESSF and DFPP forest types merge. Douglas-fir and ponderosa pine trees have broad canopies whereas Engelmann spruce and subalpine fir trees have an “A-frame” growth form to slough heavy loads of snow during the winter. When classifications were made from pixels containing both species, the broader canopy trees (Douglas-fir/ponderosa pine) tend to mask the narrow canopy trees (Engelmann spruce/subalpine fir). This may cause many of the pixels containing ESSF species in this mixing elevation zone to be misclassified with the broader canopy species (Figure 8). To accurately use this logistic regression model, it is very important to correctly classify the ESSF component. Canopy cover from Landsat imagery measures the reflectance values from the vegetation and the ground to determine the percent coverage of vegetation on the landscape. Because it is difficult to distinguish between overstory and understory vegetation, actual canopy closure of the overstory trees as measured from ground inspections may be much less than the calculated value for canopy cover from Landsat imagery. In the case of lynx habitat, this misclassification may be the difference of correctly identifying suitable lynx habitat or not. To overcome these difficulties, I recommend ground-truthing of ESSF, DFPP, and canopy cover in elevation zones where the two vegetation classes intermix.

Lynx avoidance of forest openings has significant implications with relation to managing forests for timber harvest. Based on personal observations in the Loomis State Forest, ESSF and LP stands left to regenerate naturally after timber harvest may only grow back densely in small patches, leaving the majority of the harvest area very open. This may create adverse conditions for snowshoe hares and lynx until stand regeneration becomes more complete, despite high densities of trees in small patches. In the Black Pine Basin study area, most clear cuts are replanted after timber harvest allowing the regenerating stands to grow back much faster and more densely than with natural regeneration, creating a better dispersion of high-quality habitat for snowshoe hares and lynx over shorter time frames. In this case, intensive forest management and replanting may be beneficial for lynx.

My logistic regression model can help forest managers identify areas that are capable of supporting lynx in portions of the Okanogan National Forest and North Cascades region with similar vegetation conditions and elevation ranges. Because the model describes proportions (or percentage) of lynx trails within each vegetative or physiographic condition, it could be used in landscapes where inventories of forest cover type, canopy cover, elevations, and slopes are available at various spatial scales. It is important to understand, however, that this model of lynx occurrence is restricted to the winter period and may not identify habitat that is important for denning or during snow-free periods.

The majority of the documented occurrences of lynx in WA were from the north-central or northeastern portions of the state, and there have been no verifiable occurrences in the southern portion of the state in the last century (McKelvey 2000a). The area within and around the Black Pine Basin study area is typical of the southern extent of lynx range in WA. This landscape was more fragmented (i.e., with a greater dispersion of ESSF and DFPP and much less LP), but it contained habitat components that are capable of supporting lynx. Identifying these habitat characteristics will improve the ability of forest managers to manage forests for lynx.

Habitat quality in the study area appeared adequate for lynx, as reproduction and kitten survival was documented during both winters. I documented a female with 2 kittens and one with 1 kitten during the winter of 2002-2003, and a female with 1 kitten during the winter of 2003-2004. Although I documented reproduction during both winters, research is needed on the population demographics of lynx in ESSF and LP forests to determine if both of these habitat types are capable of supporting viable populations.

LITERATURE CITED

Alldredge, J.R. and J.T. Ratti. 1986. Comparison of some statistical techniques for analyses of resource selection. Journal of Wildlife Management. 50: 157-165.

Apps, C.D. 2000 Space-use, diet, demographics, and topographic associations of lynx in the southern canadian rocky mountains: a study. Chapter 12 in L.F. Ruggiero, K.B. Aubry, SW.Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecololgy and conservation of lynx in the United States. University of Colorado Press, Boulder, CO. 351-371.

Brittell, J.D., R.J. Poelker, S.J. Sweeney, and G.M Koehler. 1989. Native cats of Washington. Unpublished. Olympia, WA, Washington Department of Wildlife.

Bio/West Inc. 1999. Vegetation mapping on the Okanogan and Colville National Forests using Landsat Thematic Mapper images. Bio/west Inc. 1063 west 1400 north, Logan, Utah 84321.

Efron, B. and R.J. Tibshirani (1993). An introduction to the Bootstrap. Chapman and Hall, New York.

Hensher, D. and L.W. Johnson. 1981. Applied discrete choice modeling. John Wiley and Sons, Inc. New York, NY.

Hodges, K.E. 2000. Ecology of snowshoe hares in southern boreal and montane forests. Chapter 7. in L.F. Ruggiero, K.B. Aubry, SW.Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecololgy and conservation of lynx in the United States. University of Colorado Press, Boulder, CO. 163-206.

Katnik, D.D., and R.B.Wielgus, 2004. Landscape proportions versus Monte Carlo simulated home ranges for estimating resource availability. Journal of Wildlife Management. (*In Press*).

Koehler, G.M. 1990. Population and habitat characteristics of lynx and snowshoe hares in north central Washington. Canadian Journal of Zoology. 68: 845-851.

Lillesand, Thomas M., Ralph W. Kiefer, and Jonathan W. Chipman. 2004. Remote Sensing & Image Interpretation Fifth Edidtion. John Wiley and Sons, Inc. New York, NY. Chapter 7:16. Pg 586 – 593.

Major, A.R. 1989. Lynx *Lynx canadensis canadensis* (Kerr) predation patterns and habitat use in the Yukon Territory, Canada. MS Thesis, State University of New York, Syracuse.

McKelvey, K.S., K.B. Aubry, Y.K. Ortega. 2000a. History and distribution of lynx in the contiguous United States. Chapter 8 in L.F. Ruggiero, K.B. Aubry, SW.Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecololgy and conservation of lynx in the United States. University of Colorado Press, Boulder, CO. 207-259.

McKelvey, K.S.; Y.K. Ortega; G.M. Koehler; K.B. Aubry; J.D. Brittell. 2000b. Canada lynx habitat and topographic use patterns in north central Washington: a reanalysis. Chapter 10 in L.F. Ruggiero, K.B. Aubry, SW.Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey, and J.R. Squires, eds. Ecololgy and conservation of lynx in the United States. University of Colorado Press, Boulder, CO. 307 – 336.

Murray, D.L., S. Boutin, and M. O'Donoghue. 1994. Winter habitat selection by lynx and coyotes in relation to snowshoe hare abundance. Canadian Journal of Zoology. 72:1444-1451.

Murray, D.L., S. Boutin, M. O'Donoghue, and V. O. Nams. 1995. Hunting behaiour of a sympatric felid and canid in relation to vegetative cover. Animal Behavior. 50, 1203-1210.

Paine, David. 1981. Aerial Photo Mensuration. In: Aerial Photography and Image Interpretation for Resource Management: John Wiley and Sons Inc. Pg. 417-445,

Roscoe, J.T. and J.A. Byars. 1971. An investigation of the restraints with respect to sample size commonly imposed on the use of the chi-square statistic. Journal of American Statistics Association. 66: 755-759.

Ruediger, B., J. Claar, S. Gniadek, B. Holt, L. Lewis, S. Mighton, B. Naney, G. Patton, T. Rinaldi, J. Trick, Anne Vandehey, F. Wahl, N. Warren, D. Wenger, and A. Williamson. 2000. Canada lynx conservation assessment and strategy. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication #R1-00-53, Missoula, MT. 142pp.

Steinberg, D. and P. Colla. 2000. Logistic Regression. In: Systat I Statistics I: SPSS Inc. Chicago, IL. I-549-I-616

Tabachnick, B.G. and L.S. Fiddell. 1983. Using multivariate statistics. Harper and Rowe Publ., New York.

Tso, B. and P.M. Mather. 2001. Classification Methods for Remotely Sensed Data. Pg. 95-100. Taylor & Francis Inc. New York, NY. 332pp.

USFWS. 2000. Final rule to list the contiguous United States distinct population segment of the Canada lynx. Federal Register 65:16052-16086.

Von Kienast, J. 2003. Winter Habitat Selection and Food Habits of Lynx on the Okanogan Plateau, Washington. M.S. Thesis. University of Washington, Seattle.

Wilkinson, L., M. Hill, J.P. Welna, and G.K. Birkenbeuel. 1992. Tables. Pages 620-673. Systat for Windows, Version 5 Edition. Systat Inc., Evanston, IL. 750pp.

Wirsing, A.J., T.D. Steury, and D.L. Murray. 2002. A demographic analysis of a southern snowshoe hare population in a fragmented habitat: evaluating the refugium model. Canadian Journal of Zoology. 80: 169-177.

Table 1. Separate variances t-tests comparing the proportion of lynx trails for each habitat variable for lynx use trails (n = 51) collected by snow-tracking lynx in the Black Pine Basin Study area in the Okanogan National Forest, Washington, 2002 - 2004 and availability (random) trails (n = 153) generated using GIS.

	Lynx Use Trails		Availability Trails				
Variable	**Mean**	**SD**	**Mean**	**SD**	**t-test**	**df**	**P-value**
Elevation (m)							
610 – 914	0.006	0.042	0.027	0.120	-1.832	202	0.069
915 – 1219	0.105	0.293	0.151	0.282	-0.966	83	0.337
1220 – 1524[a]	0.449	0.404	0.472	0.395	-0.368	84	0.714
1525 – 1828[b]	0.398	0.394	0.319	0.377	1.255	83	0.213
1829 – 2134	0.041	0.179	0.030	0.102	0.413	61	0.681
Slope (degrees)							
0 – 10	0.158	0.166	0.129	0.165	1.104	85	0.273
11 -20	0.321	0.211	0.329	0.204	-0.244	83	0.808
21 – 30	0.415	0.216	0.373	0.204	1.23	82	0.222
31 – 40	0.103	0.114	0.154	0.172	-2.396	131	0.018
41 – 76	0.002	0.006	0.015	0.038	-4.042	174	<0.01
0 – 30[bc]	0.895	0.114	0.831	0.189	2.888	144	0.004
31 – 76[c]	0.105	0.114	0.169	0.189	-2.888	144	0.004
Understory cover (%)							
0 - 10[a]	0.148	0.190	0.271	0.287	-3.507	131	0.001
11 – 39[a]	0.604	0.291	0.512	0.332	1.876	97	0.064
40 – 100	0.249	0.259	0.217	0.252	0.772	84	0.442
Canopy cover (%)							
0 - 10[a]	0.175	0.193	0.281	0.293	-2.948	131	0.004
11 - 39[b]	0.481	0.301	0.373	0.292	2.248	84	0.027
40 – 100	0.343	0.283	0.345	0.286	-0.051	86	0.959
Vegetation Types							
Recently Burn (<10 years)	0.045	0.115	0.118	0.277	-2.643	193	0.009
Forest Openings	0.005	0.016	0.018	0.070	-2.079	190	0.039
DFPP[a]	0.137	0.220	0.333	0.351	-4.662	139	<0.01
LP	0.046	0.152	0.079	0.182	-1.256	102	0.212
ESSF	0.747	0.278	0.449	0.343	6.209	105	<0.01
White Bark Pine Forest	0.020	0.104	0.004	0.026	1.112	52	0.271
ESSF (pooled)[bc]	0.813	0.241	0.532	0.371	6.228	133	<0.01

[a]Variables considered in the modeling process but not used in the logistic regession model.

[b]Variables used in the final logistic regression model.

[c]Variables pooled for the logistic regression analysis.

Table 2. Process of model selection for the logistic regression analysis of landscape habitat selection in the Black Pine Basin study area in the Okanogan National Forest of Washington, USA, 2002 - 2004.

Model Variables	**Likelihood Ratio $\chi 2$**	**df**	***P*-value**	**Improvement $\chi 2$**	**df**	***P*-value**	**Rho-sq**[b]
ESSF	26.310	1	0.000				0.12
ESSF, Slope 0-30	30.852	2	0.000	4.542	1	0.03	0.13
ESSF, Slope 0-30°, Elev 1525-1828 m,	37.011	3	0.000	6.159	1	0.01	0.16
ESSF, Slope 0-30°, Elev1525-1828 m, Can11-39%[a]	43.447	4	0.000	6.436	1	0.01	0.19
ESSF, Slope 0-30°, Elev 1525-1828 m Can11-39%, Undr0-10%	45.050	5	0.000	1.603	1	0.21	0.20
ESSF, Slope0-30°, Elev 1525-1828 m, Can11-39%, Canopy*Elevation	45.105	5	0.000	1.658	1	0.20	0.20

[a]Model with the best fit

[b]McFaddens's Rho-squared

Table 3. Logistic regression model distinguishing lynx habitat use trails (response = 1) from availability trails (response = 0) in the Okanagon National Forest of Washington, USA, 2002 –2004. The Wald Statistic for each of the habitat variables was significant at P<0.05, -2 log likelihood = 185.986, model $\chi^2 = 43.447$, df = 4, $P < 0.001$.

Variables	**B**	**SE (B)**	**T-ratio**	***P*-value**	**Odds Ratio**[a]
ESSF[b]	2.967	0.676	4.386	<0.01	19.424
Slope 0 - 30 Degrees	3.888	1.386	2.805	0.01	48.822
Elevation 1524 - 1828 meters	1.601	0.566	2.827	0.01	4.956
Canopy Cover 11 - 39%[c]	1.561	0.642	2.479	0.01	4.924
Constant	-7.792	1.584	-4.919	<0.01	

[a]Odds ratio = Exp (β); the factor by which the odds that an area will be used by lynx change for every unit increase in the independent variable.

[b]Forest containing a component of Engelmann's Spruce, Subalpine Fir, or Lodgepole Pine.

[c]Canopy Cover estimated >2.5 meters above snow surface or through aerial photo interpretation

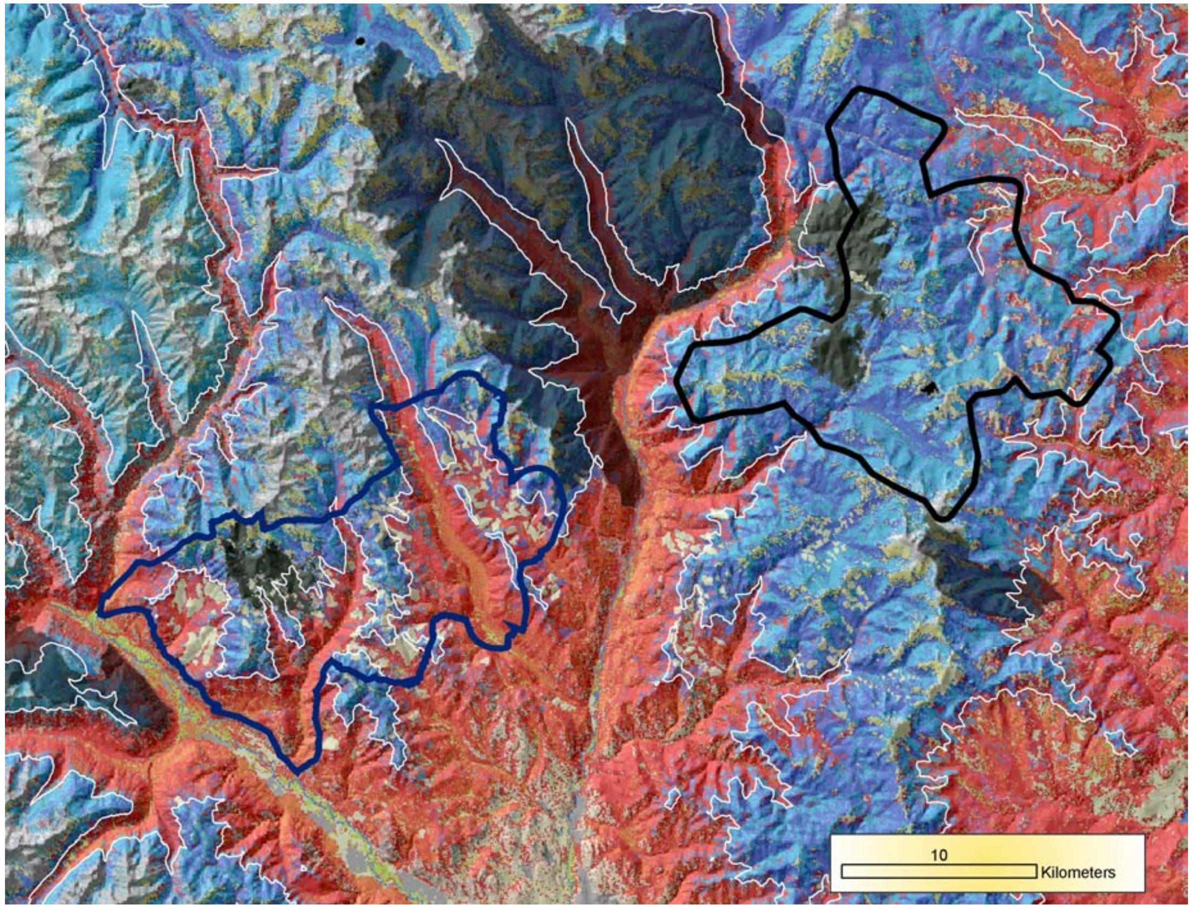

Figure 1. Map of Black Pine Basin Study area (blue outline) and The Meadows Study area, where previous lynx work has been conducted, in the Okanogan National Forest and Loomis State Forest, Washington (black outline) overlayed on the Utah Vegetation Grids (Bio/West Inc 1997) and elevation hillshade. The blue shades are Lodgepole pine and Engelmann spruce/subalpine fir forest types and the red shades are the lower elevation Douglas-fir/ponderosa pine forest types. The black shading are recent (<15 years) catastrophic burns. The white line represents the 1525 m elevation contour.

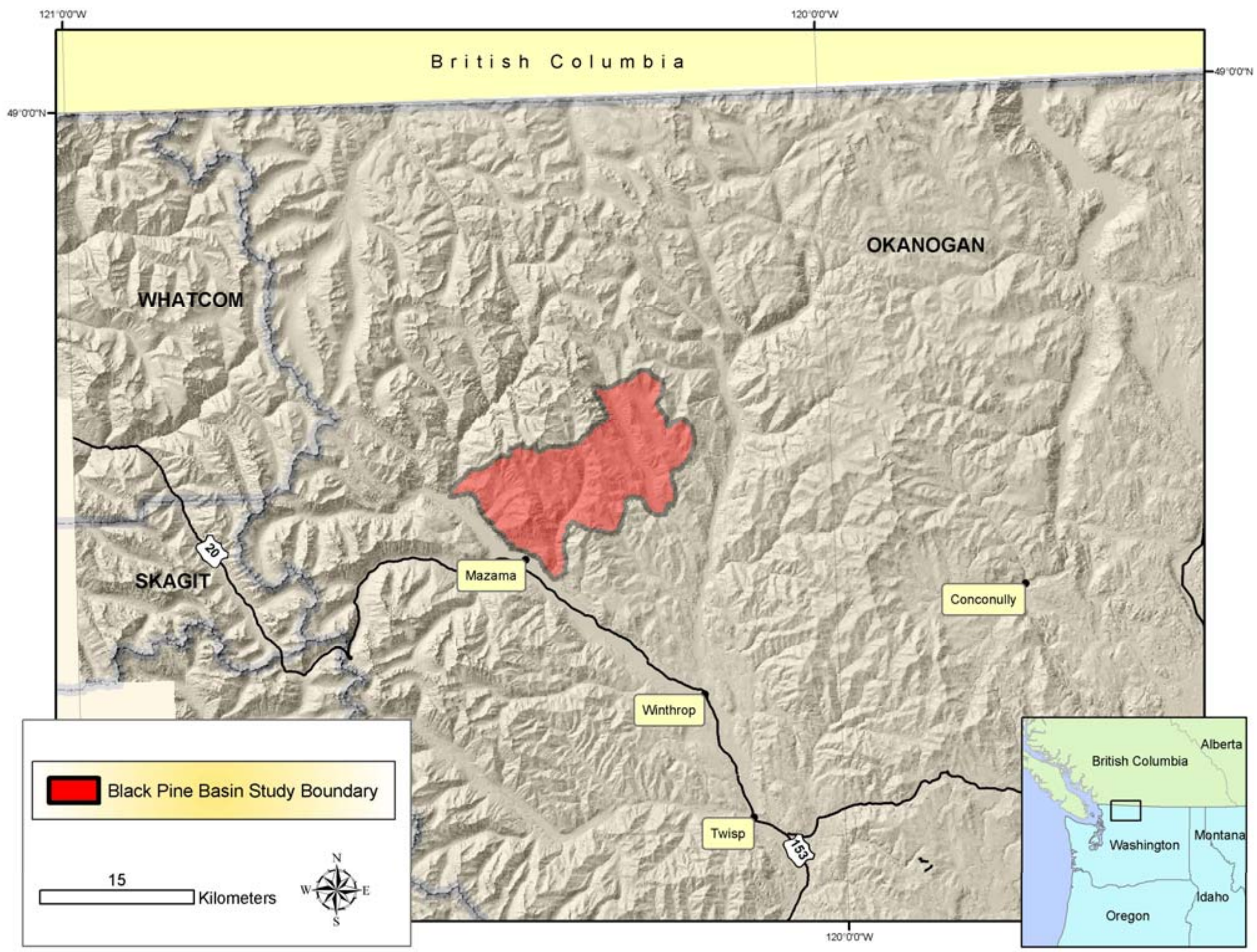

Figure 2. Black Pine Basin Lynx study area location in the Okanogan National Forest of north-central Washington, 2002-2004.

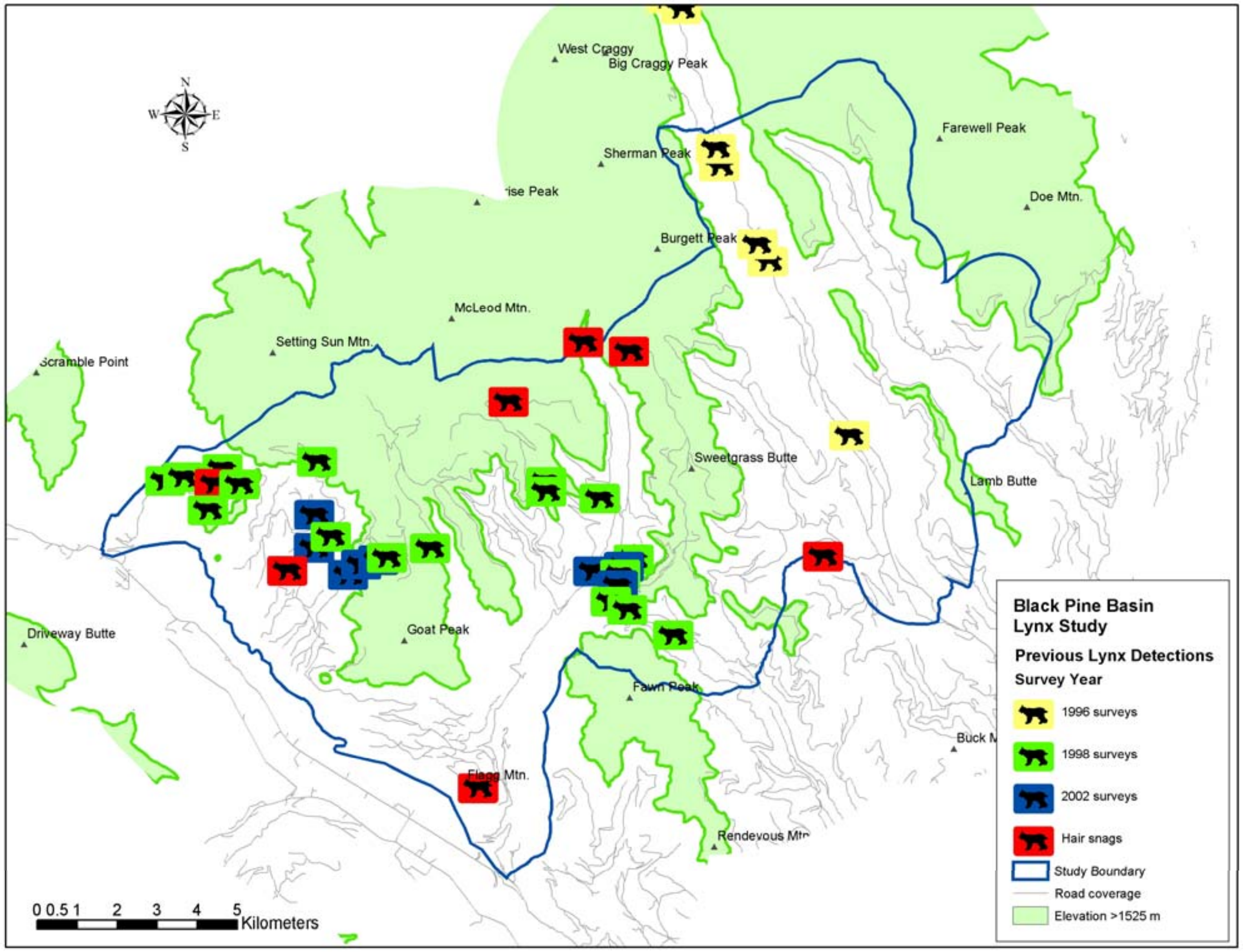

Figure 3. Map of Black Pine Basin study area boundary in the Okanogan National Forest in north-central Washington with the locations of lynx tracks and hair-snare surveys positively identified as lynx from the previous six years. Lynx location data supplied by USDAFS Okanogan National Forest.

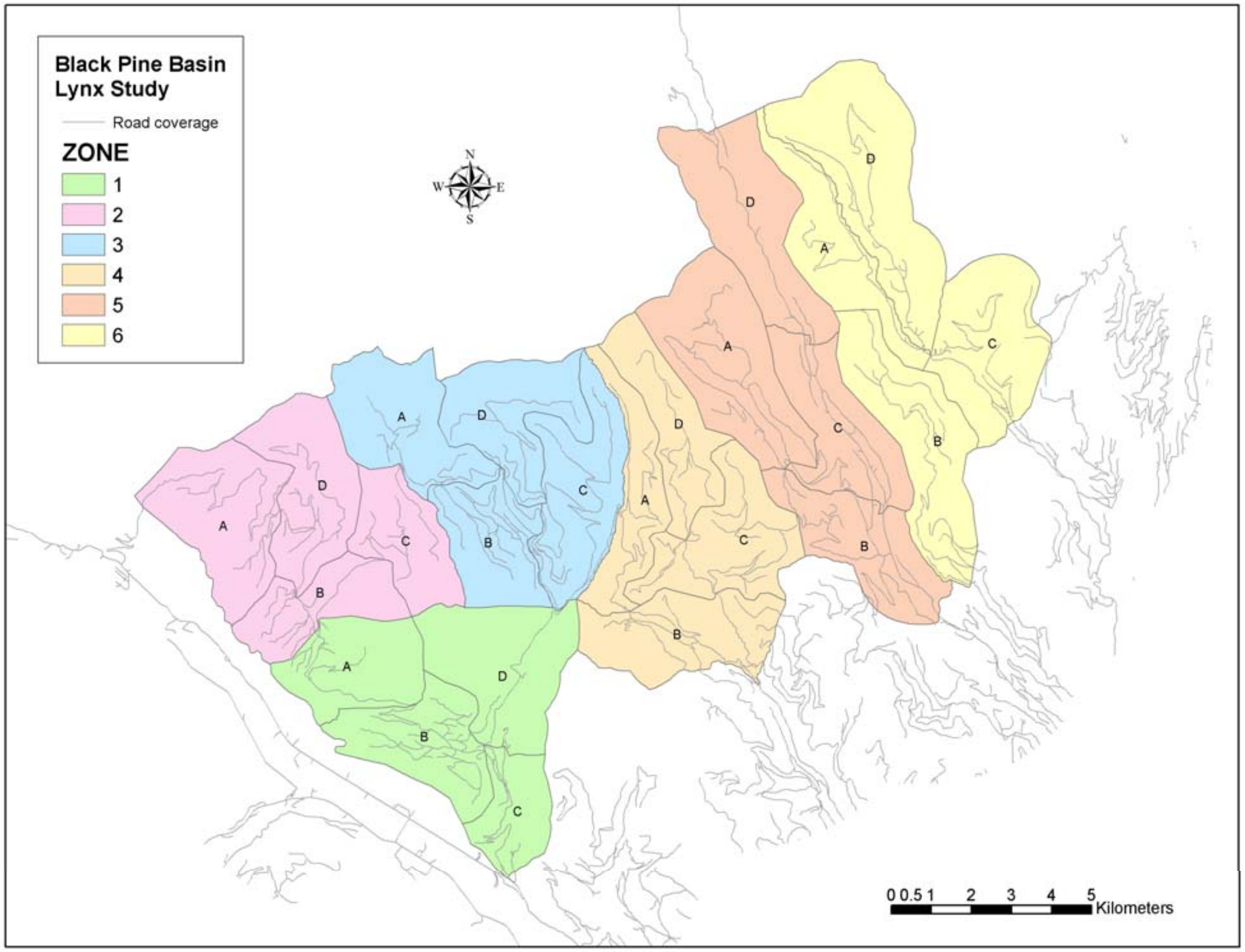

Figure 4. Map of the study area design and road coverage within each zone (1-6) and sub-zone (A-D) for the Black Pine Basin Study area in the Okanogan National Forest in north-central Washington, 2002 - 2004. Zones were used to obtain a representative sample across the study area and thru time during each winter to track as many lynx as possible. Sub-zones were randomly selected daily to reduce bias when searching each zone.

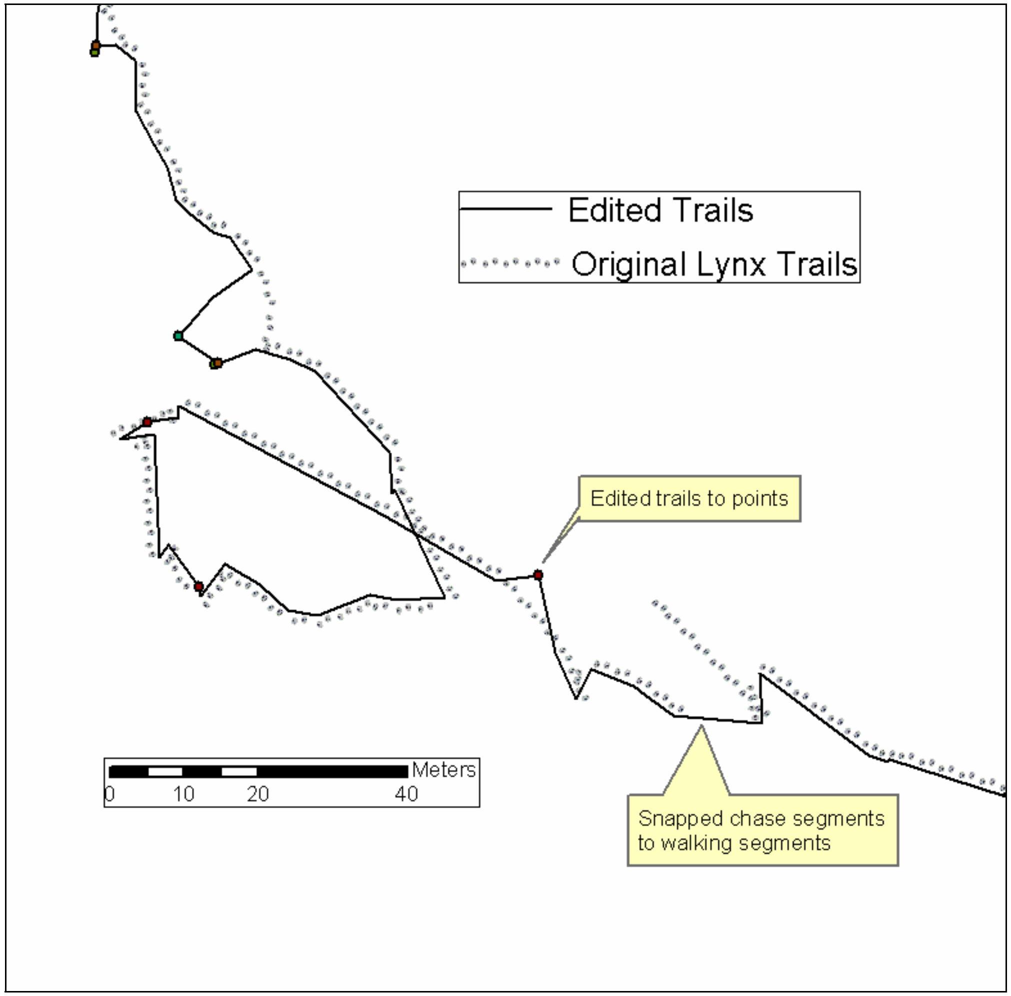

Figure 5. Lynx use trails edited in ArcView3.2 (ESRI, 380 New York St, Redlands, CA 92373) displaying how the trails were “cleaned” for the habitat selection analysis. Lynx trails (where1 vertex = 1 GPS point) were snapped to behavior points (where a location was averaged from 5 GPS points) collected along the trails and trail segments were snapped together to form one trail feature.

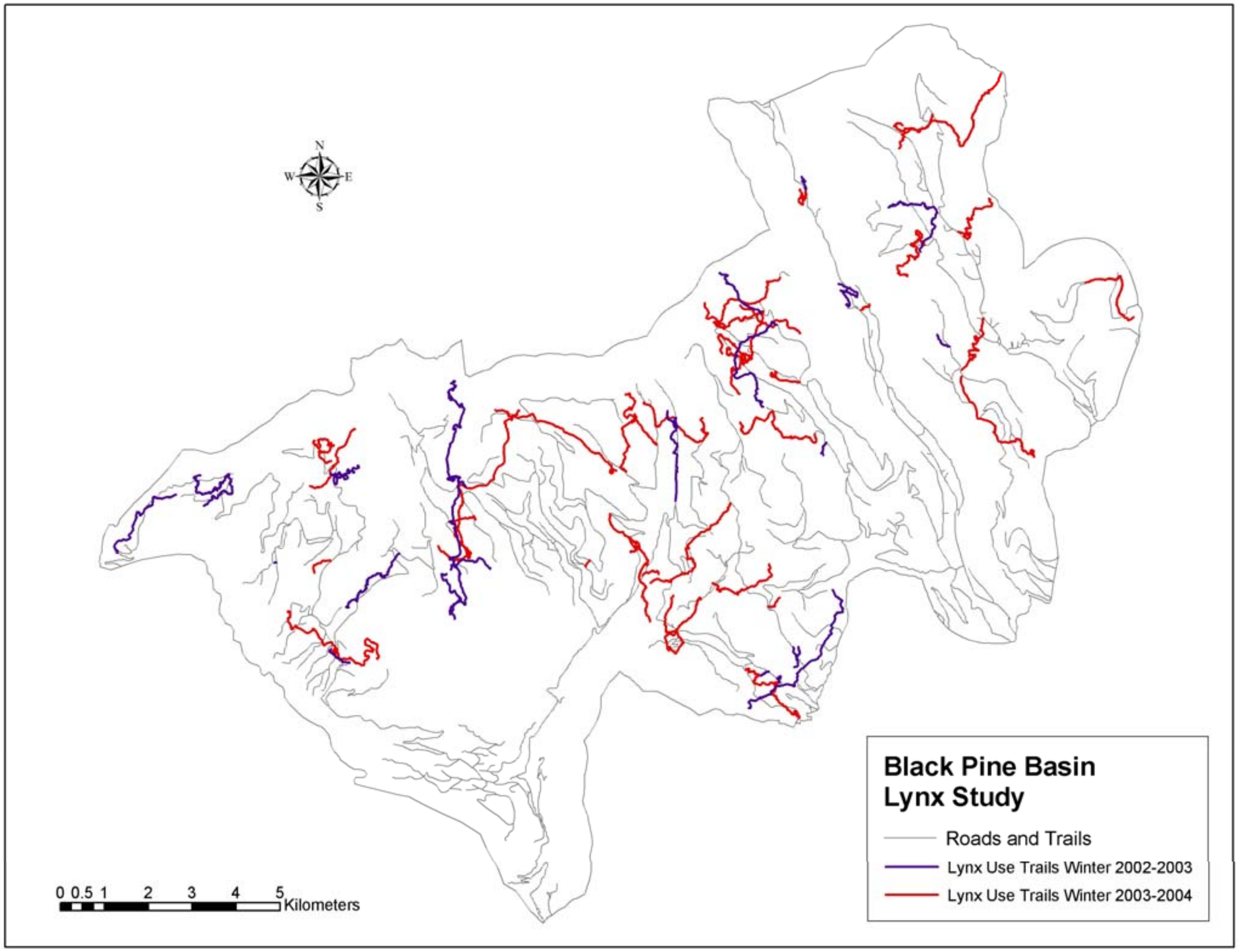

Figure 6. Lynx use trails (n=68) collected by snow-tracking lynx and using a precise-positioning Global Positioning System (GPS) to record movements and behaviors in the Black Pine Basin Study Area in the Okanogan National Forest in north-central Washington, 2002 - 2004.

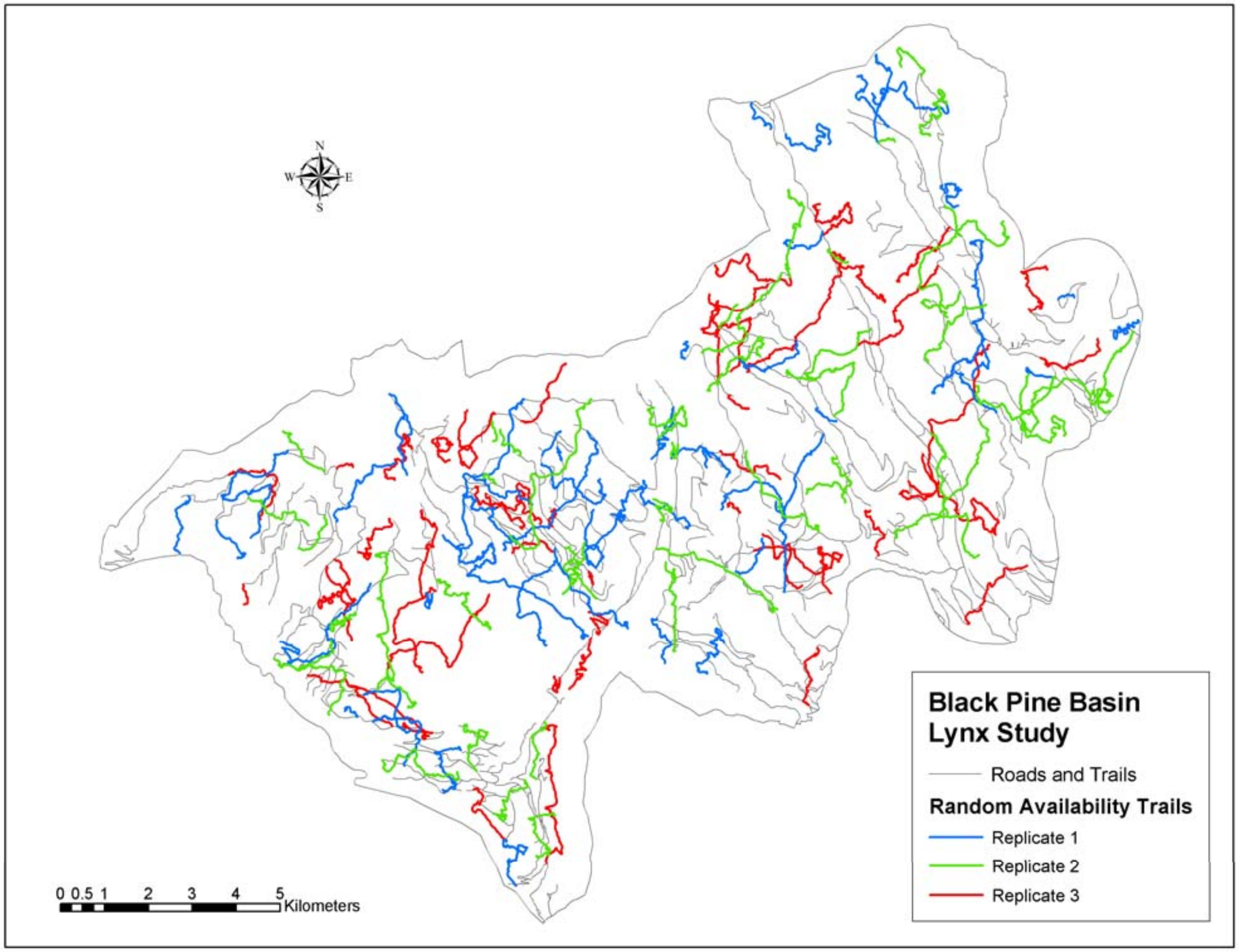

Figure 7. Map of Availibility trails (n=153) created by randomly generating new start or end points along the road coverage contained within the Black Pine Basin study area boundary in the Okanogan National Forest in north-central Washington, 2002 - 2004. The mirror image of the lynx use trails were moved to the new start points ensuring the trail shape and length remained the same.

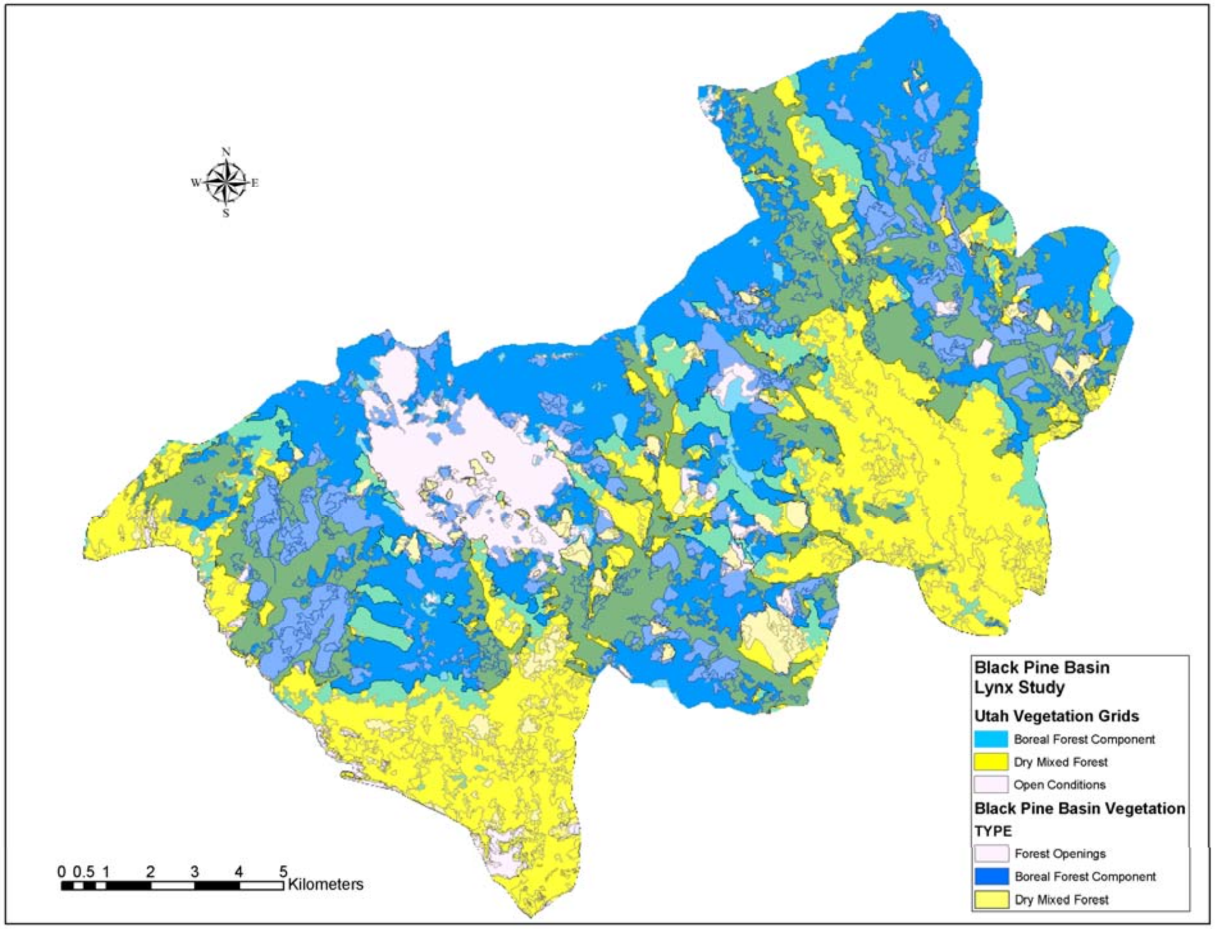

Figure 8. Map of the Utah Vegetation Grids (Bio/West Inc.) comparing the vegetation coverage map created for the Black Pine Basin study area in the Okanogan National Forest of north-central Washington. The dark green areas are forest stands with Engelmann spruce/subalpine fir components in the Black Pine Basin coverage classified as Douglas-fir/ponderosa pine forest types in the Utah Vegetation Grids. The light green shaded areas are classified as boreal forest by the Utah Vegetation Grids, but classified as Douglas-fir/ponderosa pine forest types in the Black Pine Basin coverage.

APPENDIX A

DATA DICTIONARY

1.)The far left "titles" are the Line or Point features.

2.)The 1st indented "" are the Attribute titles.

3.)The 2nd indented "" are the attribute values.

```
"Trails", line, "", 2, seconds, 1, Code
   "Walk", menu, normal, normal, Label1
      "1 Lynx"
      "2 Lynx"
      "3 Lynx"
      "4 Lynx"
   "Bounding", menu, normal, normal
      "1 Lynx"
      "2 Lynx"
      "3 Lynx"
      "4 Lynx"
   "Extended Stride", menu, normal, normal, Label2
      "1 Lynx"
      "2 Lynx"
      "3 Lynx"
      "4 Lynx"
   "Stalk", menu, normal, normal
      "1 Lynx"
      "2 Lynx"
      "3 Lynx"
      "4 Lynx"

"Vegetation Plot", point, "", 1, seconds, 5, Code

"Begin Chase", point, "", 1, seconds, 5, Code
   "Species Chased", menu, normal, normal, Label1
      "Snowshoe hare"
      "Red Squirrel"
      "Grouse"
      "Unknown"
      "Other"

"Chase Conclusion", point, "", 1, seconds, 5, Code
   "Outcome", menu, normal, normal, Label1
      "Successful"
      "Unsuccessful"
      "Unknown"

   "Species ", menu, normal, normal, Label2
      "Snowshoe hare"
```

```
      "Red squirrel"
      "Grouse"
      "Unknown"
      "Other"

"Bed", point, "", 1, seconds, 5, Code
   "Resting Bed", menu, normal, normal, Label1
      "Hair collected"
      "No hair found"
   "Ambush Bed", menu, normal, normal, Label2
      "Hair collected"
      "No hair found"
   "Sit", menu, normal, normal
      "Hair collected"
      "No hair found"


"Behavior", point, "", 1, seconds, 5, Code
   "Scent mark", menu, normal, normal, Label1
      "Fecal"
      "Urination"
   "Other behaviors", menu, normal, normal, Label2
      "Investigate structur"

"Snowmobile Trail", point, "", 1, seconds, 5, Code
   "Multi-track", menu, normal, normal, Label1
      "Walked on"
      "Walked off"
      "Crossed_no reaction"
      "Crossed_bolt across"
   "Single Track", menu, normal, normal, Label2
      "Walked on"
      "Walked off"
      "Crossed_no reaction"
      "Crossed_bolt across"

"Carnivore intercept", point, "", 1, seconds, 5, Code
   "Species", menu, normal, normal, Label1
      "Lynx"
      "Coyote"
      "Weasel"
      "Marten"
      "Cougar"
      "Bobcat"
      "Other"

"Trail Termination", point, "", 1, seconds, 5, Code
   "Reason", menu, normal, normal, Label1
      "End of day"
      "Track jumble"
      "Snow condition"
      "Pushing lynx"
```

APPENDIX B

HABITAT CHARACTERISTIC COVERAGES ACCURACY ASSESSMENT

Table 1. Accuracy assessment for the aerial photo interpreted portion of the GIS coverage for vegetation type in 5 classes for the Black Pine Basin Lynx study in the Okanogan National Forest of north-central Washington, 2002 - 2004.

	ESSF	Burn	LP	DF/PP	For_open	WB/SF	Row Total
ESSF	107	0	11	8	0	2	128
Burn	4	2	1	0	0	0	7
LP	10	0	6	4	0	0	20
DF/PP	17	0	3	94	2	0	116
For_open	0	0	0	3	23	0	26
WB/SF	4	0	0	0	1	6	11
Column Total	142	2	21	109	26	8	308

Producers Accuracy

Type	%Accuracy
Boreal	0.75
Burn	1.00
LP	0.29
DF/PP	0.86
For_open	0.88
WBP	0.75

Users Accuracy

Type	%Accuracy
Boreal	0.84
Burn	0.29
LP	0.30
DF/PP	0.81
For_open	0.88
WBP	0.55

Overall Accuracy 77.3%
Khat 0.657

Table 2. Accuracy assessment for the aerial photo interpreted portion of the GIS coverage of canopy closure in 3 classes for the Black Pine Basin Lynx Study area in the Okanogan National Forest of north-central Washington, 2002-2004.

	Canopy 0-10%	Canopy 11-39%	Canopy 40-100%	Row Total
Canopy 0-10%	94	34	4	132
Canopy 11-39%	14	61	25	100
Canopy 40-100%	1	21	54	76
Column Total	109	116	83	308

Producers Accuracy

Type	%Accuracy
Canopy 0-10%	86.2
Canopy 11-39%	52.6
Canopy 40-100%	65.1

User's Accuracy

Type	%Accuracy
Canopy 0-10%	71.2
Canopy 11-39%	61.0
Canopy 40-100%	71.1

Overall Accuracy- 67.9%
Khat 0.51758

Table 3. Accuracy assessment for the aerial photo interpreted portion of the GIS coverage of understory structure in 3 classes for the Black Pine Basin Study area of the Okanogan National Forest in north-central Washington, 2002-2004.

	0-10%	11-39%	40-100%	
0-10%	58	35	4	97
11-39%	32	87	31	150
40-100%	6	15	40	61
	96	137	75	308

Producer'sAccuracy

Type	%Accuracy
0-10%	60.4
11-39%	63.5
40-100%	53.3

User's Accuracy

Type	%Accuracy
0-10%	59.8
11-39%	58.0
40-100%	65.6

Overall Accuracy - 60.1%
Khat 0.37306