WINTER HABITAT USE AND DIET OF SNOWSHOE HARES IN THE GARDINER, MONTANA AREA

by

Jeremy Paul Zimmer

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

of

Master of Science

in

Fish and Wildlife Management

MONTANA STATE UNIVERSITY
Bozeman, Montana

April 2004

APPROVAL

of a thesis submitted by

Jeremy Paul Zimmer

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

Dr. Lynn R. Irby

Approved for the Department of Ecology

Dr. Scott Creel

Approved for the College of Graduate Studies

Dr. Bruce R. McLeod

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a master's degree at Montana State University, I agree that the Library shall make it available to borrowers under the rules of the Library.

I have indicated my intention to copyright this thesis by including a copyright notice page, copying is allowable only for scholarly purposes, consistent with "fair use" as prescribed in the U.S. Copyright Law. Requests for permission for extended quotation from or reproduction of this thesis in whole or in parts may be granted only by the copyright holder.

Jeremy Paul Zimmer

April 19, 2004

ACKNOWLEDGEMENTS

There are many people who were instrumental in the completion of this project: Dan Tyers, for his guidance, assistance with logistics and recruiting volunteers, and for reviewing this thesis; Tris Hoffman, for her help with statistics and GIS maps and her friendship; my parents, Lynn and Mavis Zimmer, for their continued support and prayers; and Angela Haas, for her help in the field and her enduring friendship. Thanks also to Ed Olexa for his assistance with statistics and to Ron Burke for his assistance with logistics and climate information. I also want to thank those who funded this project: Roger Gowan (USFS), Marion Cherry (USFS), John and Kathryn Harris, Mary Maj (GYCC), and Steve Kratville (USFS). Many thanks to my graduate committee for their guidance and review of this project, Drs. Lynn Irby, Robert Garrott, and Thomas McMahon. Thanks to the forest service volunteers who helped in the field and in the office: McCrea Cobb, Jack Hopkins, Sarah Coburn, Kim Olson, Matthew Tyers, Steve Yonge, Nicolle Smith, Katharine Callard, Katie Gunter, Rebecca Newton, Meaghan Hamilton, and Josh Rafkind.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES-CONTINUED

LIST OF FIGURES

ABSTRACT

Habitat preference and diet selection of snowshoe hares (*Lepus americanus*) in the Greater Yellowstone Area (GYA) are poorly understood. This study was initiated to provide base line data on snowshoe hares for the Environmental Assessment for the proposed Darroch-Eagle Creek Timber Sale and was continued subsequent to this analysis to further investigate snowshoe hare ecology. Hare habitat use and diet were monitored in the Bear Creek Drainage near Gardiner, Montana during the winters of 1999-2003, primarily by the means of snow tracking. Of the 8 most common cover types in my study area, I found the greatest densities of hare tracks in older regenerating stands (50 years post-harvest) of lodgepole pine (*Pinus contorta*) that had been thinned. My study area also contained young unthinned stands of lodgepole pine (25 years post-harvest) as well as several middle age and mature forest types. The 50-year-old lodgepole stands provided a dense understory and a well-developed overhead canopy as well as plentiful food sources. These 3 characteristics typically define good snowshoe hare habitat. I also found that snowshoe hares fed predominantly on 3 species during winter, lodgepole pine, Douglas fir (*Pseudotsuga menziesii*), and subalpine fir (*Abies lasiocarpa*), but also consumed a variety of other trees, shrubs, and forbs. Current forest management strategies do not allow precommercial thinning in areas of potential lynx (*Lynx canadensis*) habitat. My study showed that thinned stands can provide good habitat for hares. Thinning portions of harvested areas may also increase the amount of time that regenerating stands provide suitable habitat for hares.

INTRODUCTION

In recent years, research and management attention directed towards mid-sized forest carnivores, especially the Canada lynx (*Lynx canadensis*), has increased. In 2000, the lynx was listed as a threatened species in the contiguous United States under the Endangered Species Act. Due to its importance in the diet of many mid-sized forest carnivores, especially lynx, a more complete understanding of snowshoe hare (*Lepus americanus*) ecology has also become a primary interest of biologists (Ruggiero et al. 2000). Currently, biologists and mangers are developing a management protocol to provide and protect habitat for these species. Silvicultural prescriptions within forests that provide potential lynx habitat are a focus of these new management standards.

My research on snowshoe hare habitat use was conducted in response to a proposal by the Gallatin National Forest (GNF) to harvest timber in potential lynx habitat. Also, an understanding of snowshoe hare ecology specific to the Greater Yellowstone Area (GYA) had not been developed.

Beginning in January 1999, I conducted snowshoe hare and mid-sized forest carnivore detection surveys (Zielinski and Kucera 1995) in the Bear Creek Drainage, Gardiner Ranger District. The GNF needed baseline data to determine what effects the proposed Darroch-Eagle Creek Timber Sale may have on wildlife. As authorized and directed by the Gallatin Land Consolidation Act, Public Law 105-267, 10/1998, this sale was 1 of about 12 similar efforts intended to generate revenue to use as a federal exchange asset to acquire 4 sections of private land elsewhere on the Gallatin Forest. Initially, the Darroch-Eagle timber sale involved 2.1 million board feet of timber and 107 ha. However, due to concerns raised during effects analysis, this was reduced to about 1.5 million board feet and 79 ha. Harvesting is scheduled for 2004 (USDA 2004).

In a broader context, 2 documents determining lynx and snowshoe hare habitat management on public lands in the intermountain west have recently been prepared. Unfortunately, very few data specific to the GYA were available to aid in assessing potential regional variation. Findings from my study may shed light on the efficacy of some of the timber management prescriptions in these documents for a portion of the GYA.

For example, in 2000 the Canada Lynx Conservation Assessment and Strategy (Ruediger et al. 2000) was provided to agencies responsible for ensuring the integrity of lynx populations and habitat. It includes conservation measures that address identified risk factors affecting lynx productivity. Programmatic and project level objectives, guidelines, and standards are detailed for all resource management issues, including timber management. Most goals involve maintaining or enhancing snowshoe hare habitat. Also, in 2004 the Northern Rockies Lynx Amendment Draft Environmental Impact Statement was made available. It proposes amendments to existing resource management plans that incorporate lynx habitat management. It would apply to 18.5 million acres of lynx habitat in Idaho, Montana, Wyoming, and Utah. Like the Conservation Strategy, it also addresses timber management practices. These documents, of necessity, apply to large landscapes. Consequently, they may miss important regional differences in snowshoe hare habitat relations.

Habitat use by snowshoe hares varies greatly across North America, but most studies have shown that snowshoe hares favor areas with dense horizontal understory cover 1 to 3m above ground level (Wolfe et al. 1982, Ferron et al. 1998, Hodges 2000). Forest understory density appears to be more important to snowshoe hares than does species composition (Pietz and Tester 1983, Litvaitis et al. 1985, Hodges 2000). Although hares seek areas with thick understory cover, Adams (1959) found that understory density could exceed levels preferred by snowshoe hares. In his study, extremely dense stands were used less than moderately dense areas. Typical hare habitat in the intermountain west consists of montane coniferous forests with well-developed understories (Hodges 2000). This combination of over and understory provides hares with protection from predators, both terrestrial and avian, and an adequate food supply.

The full effects of modern silvicultural practices on snowshoe hares are not clearly understood. Short-term effects of clearcuts and thinning are usually negative, causing an initial loss of habitat and forcing hares to disperse to other areas. However, Sullivan and Sullivan (1988) found that hare activity increased immediately after thinning due to increased amounts of cover and food piled on the ground, but use decreased 2 years later, and unthinned stands were preferred. Several studies have shown that hares prefer regenerating coniferous stands 20 to 60 years post harvest, depending on geographic location and the rate of regrowth, due to the dense understories typically found in these early successional stages (Monthey 1986, Thompson et al. 1989, Koehler 1990, Koehler 1991).

Several authors have noted increased snowshoe hare activity near edges between forest types or in areas with great habitat interspersion (Conroy et al. 1979, Wolff 1980, Giusti et al. 1992). Often these ecotones contain greater plant diversity than interior areas of a stand, making them more attractive to many species of wildlife (Yahner 1988). Edges can provide optimal foraging opportunities on one side and dense hiding cover on the other (Giusti et al. 1992).

Snowshoe hare diets vary widely across their geographic range and between seasons within a specific area. During summer months, hares typically feed on succulent herbaceous vegetation. In winter they browse on trees and shrubs (de Vos 1964, Wolff 1978). Although hares eat a wide variety of plants, including conifers and deciduous shrubs, they often show preference for certain species (de Vos 1964). These preferences vary greatly between regions and are dependent on the local plant community (Hodges 2000). Wolff (1978) and others have noted that the composition of snowshoe hare diets is greatly affected by the density and frequency of occurrence of plant species within different habitats, but several studies have shown that, where present, pines are often the preferred coniferous winter browse (de Vos 1964, Pietz and Tester 1983).

Winter plant availability is greatly influenced by snow accumulation. Typically, grasses, forbs, and small shrubs that are important components of the summer diet are unavailable to hares during winter months. High snow levels also allow hares to reach branches well above the ground that are typically unreachable during other periods of the year (De Vos 1964, Smith et al. 1988).

Although studies on snowshoe hare habitat use and diet are fairly common across North America and Montana (Adams 1959, Malloy 2000, McKelvey et al.2002, L.S. Mills, University of Montana, personal communication), relatively little work has been done within the GYA. Since substantial variation in snowshoe hare habitat use and diet exists among locations, this study represents an opportunity to determine how snowshoe hare ecology in the GYA compares to other populations in the intermountain west. This information is critical to understanding the potential of the GYA to support viable lynx populations. Because this study was located in managed forests rather than wilderness, it provides badly needed data on how current silvicultural practices, especially precommercial thinning, affect hare habitat use. Although I did not address population cycles directly, my study encompassed 5 consecutive winters and may provide base-line data relevant to investigations of hare cycles in the southern portion of their range.

During the winters of 1999- 2003, I monitored snowshoe hare habitat use and diet in an area heavily impacted by more than 50 years of silvicultural treatments, including clear-cutting, selective harvesting, and precommercial thinning. My study objectives were to:

1. Compare the relative abundance of snowshoe hares across the 8 common cover types in the study area.

2. Examine the relationship between hare abundance and distance from a forest ecotone.

3. Describe differences in hare diets among different cover types and winter months relative to food item availability.

4. Examine snowshoe hare habitat use in regenerating clear-cuts, thinned stands, and uncut mature forest stands.

STUDY AREA

This study was conducted in the Bear Creek drainage on the Gallatin National Forest northeast of Gardiner, Montana. The study area encompassed about 11.7 km^2 (1,172 ha) between Yellowstone National Park and the Absaroka-Beartooth Wilderness (Fig. 1). The western side of the study area was bounded by Bear Creek and extended to the east towards the hydrologic divide between Bear Creek and Crevice Creek. Elevation ranged from 2,100 to 2,600 m. Mountain peaks in the surrounding area exceed 3,100 m.

The study area was typically snow covered from late October until May. The average snow pack in March over the past 60 years on nearby Crevice Mountain (2,560 m) was 99 cm (USDA 2003). The snow pack on the lower portions of the study area was considerably less. Annual total precipitation in Jardine, Montana over the past 12 years averaged 38 cm, with June, May, and April being the wettest months (R. Burke, Mineral Hill Mine, personal communication). During those years, January through March averaged 7.6 cm. The average high and low temperatures in Gardiner for January through March are 3.9 and –7.8 degrees Celsius, respectively (R. Burke, Mineral Hill Mine, personal communication). Average temperature in the study area was slightly lower than that of Gardiner. During the years of my study, 1999 and 2003 had near average snowfall and temperatures, while 2000 and 2002 experienced slightly below average snowfall and higher temperatures. 2001 was abnormally dry and warm, with total snowfall that winter being approximately half the average for the past 12 years.

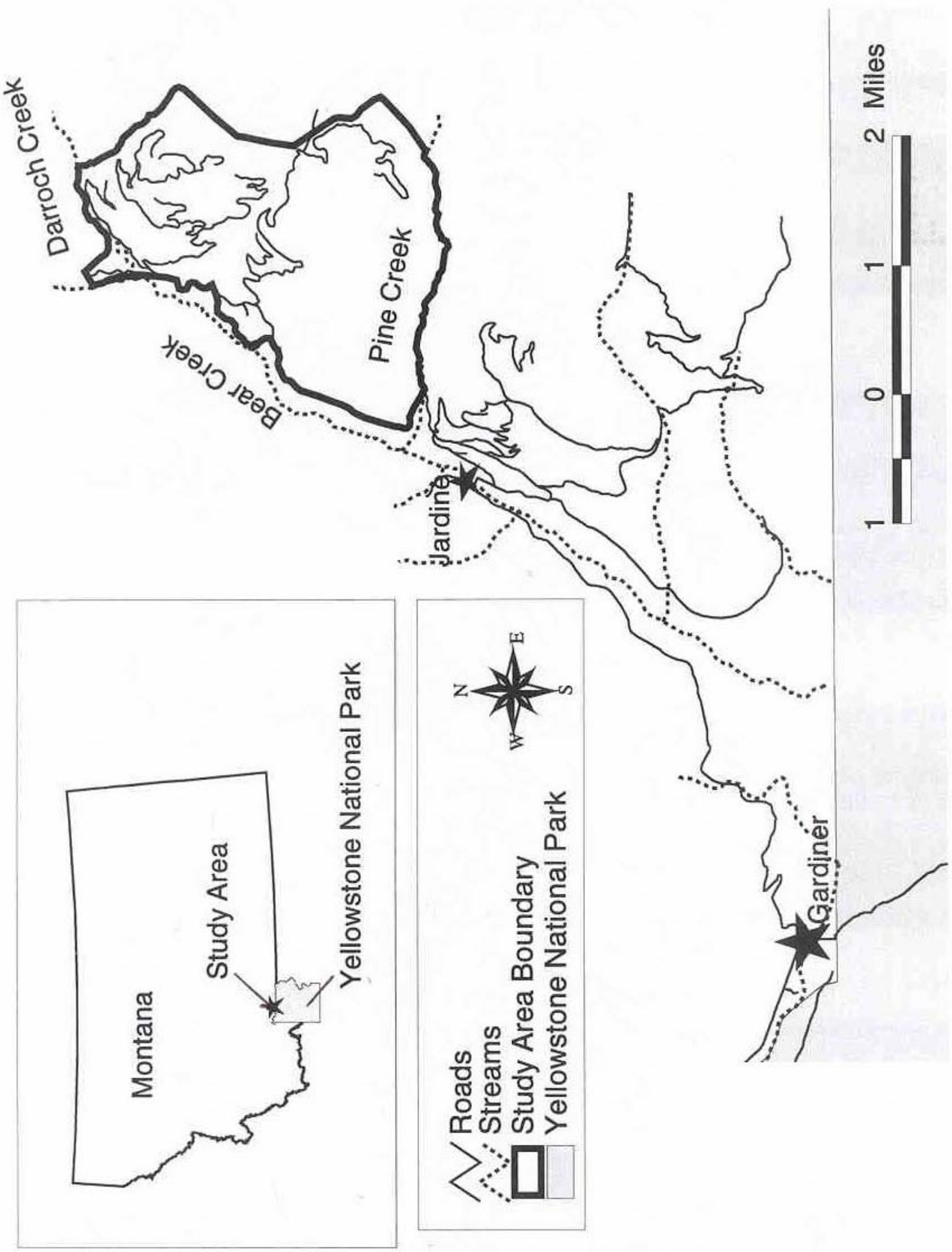

Figure 1. Location of the Bear Creek Study Area.

Coniferous forests covered the majority of the study area. Douglas fir (*Pseudotsuga menziesii*) was the dominant overstory species at lower elevations, less than 2,280 m, and covered 8% of the study area. Lodgepole pine (*Pinus contorta*) dominated higher elevations, above 2,280 m. Cover type proportions across my study area were determined from a map developed for the cumulative effects model (CEM) by the Interagency Grizzly Bear Study Team (USDA 1990). This map, routinely used by biologists in the Yellowstone Ecosystem to identify habitat types, indicated that different successional stages of lodgepole pine forests covered 62% of the study area. Other conifers in the study area included Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa)*, and whitebark pine (*Pinus albicaulis*). For this study, forests were categorized into 1 of 8 common cover types (Mattson and Despain 1985) (Table 1). I sampled hare use of these 8 types with each of my sampling methods.

The forest understory was dominated by birch-leaved spiraea (*Spiraea betulifolia*) and snowberry (*Symphoricarpos albus*) at lower elevations while higher elevations contained predominantly subalpine fir, whitebark pine, buffaloberry (*Shepherdia canadensis*) and twinberry (*Lonicera involucrata*). For this study, understory is inclusive of all vegetation within approximately 4 m of the ground including lower branches of large trees as well as small trees, shrubs, and forbs. The Bear Creek drainage has been subject to extensive timber harvesting over the past 60 years with major clear-cuts, created during the late 1940s and the mid 1970s, covering 30% of the study area (356 ha). Sanitation salvage cuts, selective harvests that remove dead or dying trees but do not remove all mature trees or destroy the understory, were made in 1986 and covered 6% of the area (75 ha) (USDA 2002). All stands that were harvested during the late 1940s were thinned 20 to 30 years after clear-cutting. A few stands cut during the 1970s were scheduled for thinning in 1999, but thinning operations were suspended because of potential negative impacts on wildlife. Another harvest of 79 ha was scheduled for 2001 but has been delayed due to litigation (USDA 2002).

Table 1. Dominant Cover Types in the Bear Creek Study Area.

Cover Type	Percent of Study Area	Description
DF	7.9	Old growth Douglas fir forest. Canopy is broken and the understory consists of some small to large spruce and fir.
SF	15.9	Mature spruce fir forest. Stands dominated by Engelmann spruce and subalpine fir in both overstory and understory.
MF	8.4	Mature mixed forest, late succession to climax stage. Varied structure and age class representation with lodgepole pine, subalpine fir, Engelmann spruce, Douglas fir, and whitebark pine all in the overstory.
LP0	14.8	Lodgepole pine 0-40 years post disturbance. Recently disturbed areas of seedlings and saplings before canopy closure.
LP1	15.6	Lodgepole pine 40-100 years post disturbance. Closed canopy of even-aged, usually dense, lodgepole pine (In my study area, all LP1 had been thinned).
LP2	17.6	Lodgepole pine 100-300 years post disturbance. Closed canopy dominated by lodgepole pine. Understory of small lodgepole pine, whitebark pine, Engelmann spruce and subalpine fir seedlings.
LP3	13.3	Lodgepole pine 300 plus years post disturbance. Broken canopy of mature lodgepole pine, but whitebark pine, spruce and subalpine fir also present. Understory of small to large spruce and fir saplings.
SS	6.4	Sanitation salvages (mature forest partially harvested during 1986). Broken old growth canopy with a dense regenerating understory dominated by lodgepole pine.

Within the study area, Forest Service management allowed timber harvest, motorized travel, and dispersed recreation. Winter recreational activities included cross-country skiing, snowshoeing, snowmobiling, hunting, trapping, and firewood harvest. During the 5 winters of the project, human recreation increased significantly, but I did not measure the extent of the increase. Three Forest Service roads traverse the study area and are open to vehicles in the summer and are used as snowmobile and ski trails during the winter months.

Several species of carnivores capable of killing snowshoe hares, including red fox (*Vulpes vulpes*), coyote (*Canis latrans*), gray wolf (*Canis lupis*), grizzly bear (*Ursus arctos horribilis*), black bear (*Ursus americanus*), mountain lion (*Felis concolor*), pine marten (*Martes americana*), weasel (*Mustela sp*.), wolverine (*Gulo gulo*), great gray owl (*Strix nebulosa*), and goshawk (*Accipiter gentilis*), were present in the study area. These carnivores had an array of potential prey in addition to snowshoe hares including mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), Shiras moose (*Alces alces shiras*), red squirrel (*Tamiasciurus hudsonicus*), porcupine (*Erethizon dorsatum*), and grouse (*Bonasa umbellus* and *Dendragapus sp.*), and several species of small rodents.

METHODS

Snowshoe hare habitat studies traditionally rely on a variety of methods including pellet counts, track counts, and live trapping (mark-recapture) to identify habitat use patterns (Litvaitis et al. 1985). Litvaitis et al. (1985) reported that these 3 commonly used methods provided similar information on hare habitat use in Maine. Koehler's (1990) study in north central Washington also showed a significant correlation between winter track counts and pellet plot counts. A fourth method commonly used to study snowshoe hares is radio-telemetry. Based on my study objectives, time of year, and budget constraints, I chose to use snow tracking as a primary means of collecting data. Data were collected between January 1 and March 31 each year from 1999 through 2003.

Vegetation Availability

I used standard techniques outlined for Forest Service stand exams for timber management (USDA 1986, USDA 2000) to classify species composition and density within the 8 cover types. Eighteen sites in each of the cover types were randomly selected. At each site, 2 concentric fixed-radius plots were established. The first was a 1/100-acre plot (3.6 m radius). For each live tree rooted within the circle, species, height, diameter at breast height (DBH), height to canopy, canopy ratio, and canopy class were determined. Height to canopy was measured from the ground to where the lowest live branches formed nearly a complete canopy around the tree. Canopy ratio was defined as the proportion of the total tree height that consisted of live canopy. Trees were also classified in 1 of 5 canopy classes (remnant, dominant, codominant, intermediate, or overtopped) based on how the height of each tree compared to all other trees in the area.

After all trees were classified, a 1/300-acre plot (2.07 m radius) was established from the same center point that was used for the 1/100-acre plot. This plot was divided into 2 horizontal layers, from the ground up to 1 m and from 1 m to 2 m. This provided me with estimates of plant availability in early winter (less than 1 m snow depth) and availability during the late winter months (greater than 1 m snow depth) when I monitored hare distribution. Percent canopy cover was estimated by species for all trees and shrubs that had canopy within the lower layer (0-1 m) or the upper layer (1-2 m). I did not attempt to quantify the herbaceous cover within the plots because most grasses and forbs are unavailable to hares in winter. Herbaceous plants may provide some food for hares in winter if protruding from the snow but do not provide any cover and probably do not influence hare habitat use during the winter.

Cover Type Use

Road Track-Intercept Transects

I used a fixed linear transect established along roads in the study area to determine if snowshoe hares used each cover type in proportion to its availability along the route. Proportions of cover types encountered along the transect were not representative of the proportions of cover types found across the whole study area because my route followed roads built to access cutting areas. Using aerial photos, I split the roads in the study area into sections corresponding to changes in cover type (Mattson and Despain 1985). My methods were similar to those used by Conroy et al. (1979), Monthey (1986), Thompson et al. (1989), and Tyers (2003). The availability of each cover type was determined during the summer by measuring the length of each section with a hand-operated odometer wheel.

From January through March the 18-km route was traveled via snowmobile 24 to 72 hours after each snowfall, and snowshoe hare tracks were counted in each of the 48 sections of the transect. Snowshoe hare tracks were recorded each time they crossed the road. The tracks of hares traveling along the road were recorded once. If a hare crossed the road several times in an area, it was recorded each time it crossed the road. For runways, several sets of tracks on top of each other made by several hares or by 1 hare traveling back and forth on the same path, I tried to determine the number of times it was traveled by backtracking away from the road. Often tracks would split off a short distance from the road surface. By tracking shortly after a snowfall, I never encountered extremely heavily used runways. I was able to sample the transect route between 7 and 12 times each winter from 1999 through 2003. Sampling runs varied due to frequency of new snowfall. New snow was needed to erase old tracks and create a new tracking surface (Thompson et al. 1989). For each section, the number of tracks, hours since last snowfall, and cover type were recorded. I standardized the number of tracks counted on each trip by dividing by the number of nights since the last snowfall.

Data were grouped into 11 cover type combinations and analyzed using chi-square goodness-of-fit to test the null hypothesis that each cover type was used in proportion to its availability (Neu et al.1974). Statistical significance was accepted at

$P < 0.05$. If the null hypothesis was rejected, then a Bonferroni confidence interval was calculated to determine if each type was used more, less, or in proportion to its availability.

Line Transects

During the winters of 1999 and 2000 I used a set of line transects (Conroy et al. 1979) to cover the entire study area to determine if the association between hares and cover types observed on the road transect would hold for a sampling system independent of roads. The preliminary transects in 1999 consisted of meandering lines that started at upper elevations in the study area and followed the fall line of the topography. Endpoints were not marked for these lines. Each line was traveled on snowshoes or skis, 1 to 8 days after a snowfall, once over the course of that winter. I used aerial photos to divide the lines into segments that corresponded to different cover types (Mattson and Despain 1985). For each cover type segment on a line, I classified snowshoe hare track densities into 1 of 4 categories: absent, low, medium, or high (Conroy et al. 1979) (Table 2). I chose to classify track densities into categories instead of counting actual track intercepts along each line to alleviate the problem with runways where it was impossible to decipher how many tracks were present. In all, a total of 30 lines and 198 different cover type segments were traveled and were lumped into 14 cover type categories.

Table 2. Ranking of Snowshoe Hare Activity on the Line Transects.

Rank	Description
Absent	No tracks seen along a cover type segment
Low	Occasional single sets of tracks throughout a cover type
Medium	Many trails and some runways, forms, and feeding sites
High	Many undistinguishable trails and heavily used runways; forms and feeding sites are common

During the winter of 2000, I established a repeatable set of systematic transect lines (Conroy et al. 1979) spread over the entire study (Fig 2). I divided my study area into 5 subunits based on geographic location and accessibility. In each subunit, parallel lines were established 160 m apart each with the same compass bearing that corresponded to the aspect of the slope in that subunit. The endpoints of each line were marked using a GPS unit. Overall, 51 lines of variable length were established to cover the study area. These lines covered 390 cover type segments and a total distance of 56.05 km. The system used to classify levels of hare use within the different cover type segments during 1999 was also used for this set of line transects.

For both years of the line transects, I calculated the proportion of segments traveled within each cover type where snowshoe hare tracks were present (Monthey 1986). For cover types where snowshoe hare tracks were observed, I also calculated the proportion of segments that contained low, medium, and high densities of tracks.

Edge Relationship Transects

Several studies of snowshoe hares have noted increased activity near edges between forest types (Conroy et al. 1979, Wolff 1980, Giusti et al. 1992). To investigate if this was the case in my study area, which was highly fragmented due to past logging activity, I established a series of transects that ran from 1 cover type into another. Although the width of edge effect has been described as being twice the average height of the trees along the edge (Morrison et al. 1998), roughly 50 m in my study area (Tyers 2003), I measured hare distribution over a greater distance. Transects were 200 m long

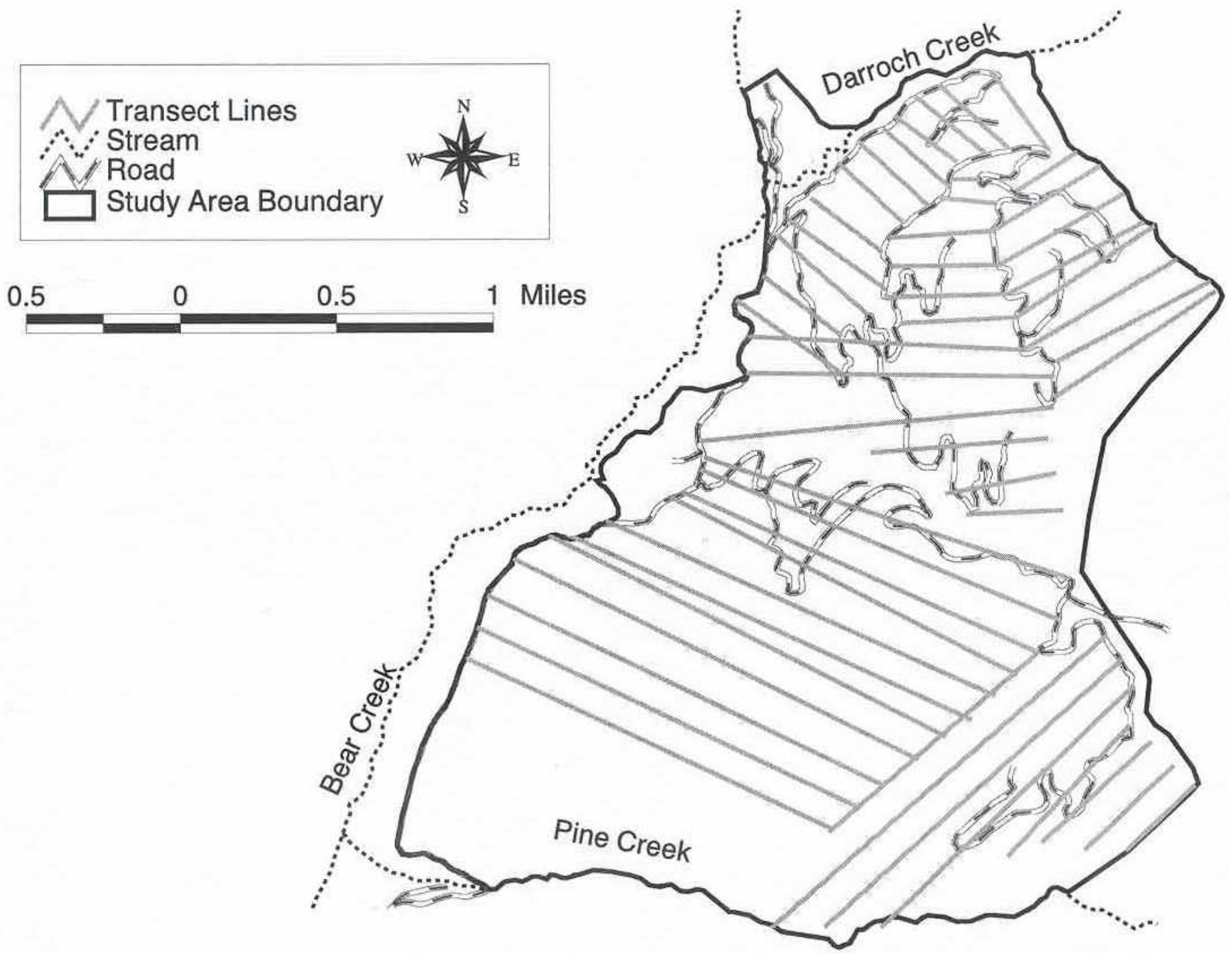

Figure 2. The location of the subunits and lines established for the systematic line transects within the Bear Creek Study Area.

and crossed an edge perpendicularly between a mature forest and a regenerating forest. Each transect ran 100 m into the cover type on either side of the edge. As I walked each line, I recorded the cover type, days since last snowfall, cover type on the other side of the edge, and the number of hare tracks in 5 m increments. Because transects were walked 1 to 8 days after a snowfall, the number of tracks was standardized by dividing by the number of nights since the last snowfall.

During the winters of 2000 through 2003, I sampled a total of 103 transects across 11 cover type pairs. LP0 and LP1 types were both paired with each of the 5 uncut mature forest types and the final pair was LP0 with LP1. For each pair I sampled between 6 and 16 transects. Because track intercepts were relatively uncommon in 5 m segments and data were not normally distributed, I limited analysis to 3 10 m segments in both the cut and uncut forest (0-10 m, 45-55 m, and 90-100 m) and used Kruskal-Wallis non-parametric analysis of variance to test for differences among the distance categories.

To compare hare cover type use in 7 of the 8 common cover types (all except for sanitation salvages), I calculated the average track density per 100 m line for each cover type. I then used Kruskal-Wallis analysis of variance to determine if there were any significant differences in track densities among cover types. Statistical significance was accepted at $P < 0.05$.

Food Habits

During winter months, snowshoe hares typically feed on woody vegetation and can reach stems up to 50 cm above the snow surface (de Vos 1964, Smith et al.1988).

Hares feed on woody plants by clipping twigs and needles or by removing the bark on younger trees. Several methods have been used to look at snowshoe hare diets including stomach content analysis, scat analysis, observing hares, feeding trials, tracking to locate feeding sites, and vegetation monitoring to find browsed twigs (Adams 1959, de Vos 1964, Wolff 1978, Sinclair and Smith 1984, MacCracken et al.1988, Smith et al.1988). I chose to follow tracks to locate feeding sites within each of the cover types in the study area (Smith et al.1988).

Although hares can feed on conifer needles without affecting stems, identification of these light feeding sites is difficult so I only counted bites where stems were damaged by clipping or barking. Twigs browsed by hares were cut cleanly and at an angle whereas bites by ungulates were more abrupt or torn (Telfer 1972). Only bites that were associated with fresh hare tracks were counted.

Within a cover type I would select a snowshoe hare track or trail and follow it until feeding sites were found. Since it was impossible to follow one individual hare I typically made a small loop through a stand of a particular cover type and followed any tracks that I crossed. I did not record a measure of effort spent searching for browsing in each cover type. At each feeding site that I encountered, I recorded the cover type, month and year, species of plant browsed, number of bites on that plant, total height of the plant, and snow depth. Data were collected during the winters of 2000 through 2003 and were summarized as percentages for the total diet over all years and for all years by cover type.

RESULTS

Vegetation Availability

Lodgepole pine forest was the most abundant (62%) forest type in my study area. The most common age class of lodgepole pine was LP2 (100-300 years old), which covered 18% of the area, followed by LP1 (40-100 years), LP0 (0-40 years), and LP3 (over 300 years), at 16%, 15%, and 13%, respectively. Mature spruce-fir forests (SF), Douglas fir (DF), mixed forest (MF), and sanitation salvages (SS) covered 16%, 8%, 8%, and 6% of the area, respectively. Approximately 30% of the study area had been clear-cut.

Using circular plots randomly placed in typical stands of each of the cover types, I found that LP3 stands had the highest density of trees greater than 0.1 m tall (average of 18,382 trees/ha) followed by LP2 and MF (Table 3). Douglas fir stands had the lowest density with 1,263 trees/ha. Lodgepole pine was the dominant tree species in the 2 youngest classes of lodgepole pine but became less prevalent as these stands matured.

Across all cover types, subalpine fir was the most abundant tree, making up 55% of the total trees counted. Whitebark pine, lodgepole pine, Engelmann spruce, Douglas fir, and aspen comprised 21%, 12%, 7%, 5%, and $< 0.1\%$ of the total, respectively. Although subalpine fir and whitebark pine were the most common trees counted, many were less than 1 m tall, 89% and 92%, respectively, and were unavailable to snowshoe hares during late winter (Appendix A, Table 18).

Table 3. Percent of trees greater than 0.1 m tall counted for the top 3 species in each cover type based on 18 1/100 acre plots. Cover types are defined in Table 1.

Cover Type	Total Trees >0.1 m	Average Trees >0.1 m/ha	Species 1	Percent	Species 2	Percent	Species 3	Percent
LP0	384	5,272	PICO[a]	56.3	PIAL	13.3	ABLA	13.0
LP1	304	4,173	PICO	50.3	PIAL	19.7	ABLA	19.4
LP2	710	9,747	PIAL	42.8	ABLA	33.8	PICO	20.0
LP3	1,339	18,382	ABLA	72.4	PIAL	13.1	PICO	7.4
SS	571	7,839	ABLA	53.9	PSME	13.8	PIEN	13.7
DF	92	1,263	PSME	92.4	PIAL	7.6		
SF	541	7,427	ABLA	71.7	PIEN	27.9	PIAL	0.2
MF	899	12,342	ABLA	81.1	PIEN	7.9	PIAL	5.9

[a] PICO = lodgepole pine, PIAL = whitebark pine, ABLA = subalpine fir, PSME = Douglas fir, PIEN = Engelmann spruce

LP0 stands had moderate to thick canopy near the ground and the average tree height was 3 m, but these stands provided only thin cover more than 2 m above the ground due to the triangular shape of the trees. Lower tree branches were touching those of nearby trees but there were gaps between the upper portions of trees. Lodgepole trees in LP1 stands typically ranged from 5 to 10 m tall. LP1 stands were beginning to self-prune but typically had lower branches within 2 m of the ground and a fairly dense continuous canopy. The LP2 type consisted of many small trees less than 1 m tall and many mature trees with their canopy well above the ground thus providing very little food or cover to hares during winter months. LP3 stands had their canopy well above the ground but had a more mature understory compared to LP2 stands. DF forests had very little understory cover and a broken overstory well above the ground. SS areas had a high broken canopy but had a dense understory of regenerating trees. SF stands had dense overhead canopy that often hung within 2 m of the ground but typically had little or no understory growth more than 1 m tall. MF forests were structurally similar to LP3 forests but typically had more species diversity, especially in the overstory.

To compare the understory in each cover type, I recorded species composition and canopy coverage for each shrub and tree species using 1/300-acre circular plots divided into 2 height layers. Within these 1/300-acre plots, I detected 15 species in layer 1 (within 1 m of the ground) and 12 species in layer 2 (1-2 m above the ground). In layer 1, LP0 contained the greatest number of species with 13, followed by LP1 and SS with12 each. DF stands contained the fewest with only 7 species detected (Table 4).

Table 4. Tree and shrub composition and percent canopy coverage for the 2 base layers for each cover type. The percent frequency for each species indicates the percent of plots out of 18 that contained that species. Cover types are defined in Table 1.

Cover Type	# of Species	Species 1	% Freq.	% Canopy	Species 2	% Freq.	% Canopy	Species 3	% Freq.	% Canopy
Layer	1									
SS	12	LOIN[a]	78	3.8	ABLA	72	13.3	SYAL	72	7.0
DF	7	SYAL	89	32.8	SPBE	41	2.9	JUCO	17	4.0
LP0	13	PICO	89	18.4	ABLA	61	7.2	PSME	33	3.8
LP1	12	LOIN	61	5.5	SYAL	50	2.9	PICO	41	2.4
LP2	10	PIAL	94	3.5	ABLA	78	5.8	LOIN	50	1.8
LP3	10	ABLA	100	20.7	PIAL	72	2.0	LOIN	50	3.9
SF	10	ABLA	89	11.5	LOIN	78	2.7	PIEN	72	5.5
MF	9	ABLA	100	21.7	LOIN	67	5.7	PIEN	50	6.3
Layer	2									
SS	6	PIEN	41	6.3	ABLA	41	5.9	PSME	11	3.0
DF	5	PSME	41	1.1	SPBE	6	8.0	PIAL	6	5.0
LP0	6	PICO	94	14.0	ABLA	50	7.0	PIAL	28	12.2
LP1	6	PICO	56	6.1	PIAL	17	4.5	ABLA	17	4.0
LP2	3	PIAL	28	2.7	PICO	17	2.0	ABLA	6	2.0
LP3	6	ABLA	89	5.4	PIAL	17	1.2	PIEN	11	5.0
SF	2	PIEN	44	5.8	ABLA	22	6.5			
MF	5	ABLA	78	7.0	PIEN	44	4.3	PIAL	6	5.0

[a] LOIN = twinberry, SYAL = snowberry, PICO = lodgepole pine, PIAL = whitebark pine, ABLA = subalpine fir, PIEN = Engelmann spruce, PSME = Douglas fir, SPBE = birch-leaved spiraea, JUCO = common juniper (*Juniperus communis*).

In the second layer, LP0, LP1, LP3, and SS all had 6 species present while LP2 and SF only had 3 and 2 species, respectively. Layer 1 contained both trees and shrubs, with subalpine fir and twinberry being 2 of the most common species in all cover types except for DF. The second layer contained mostly coniferous trees. Lodgepole pine was only common in the upper layer in 3 cover types LP0, LP1, and LP2. Subalpine fir was common in all types except for DF and whitebark pine in all but SS and SF. Douglas fir was only common in layer 2 in DF and SS cover types.

Cover Type Use

Road Track-Intercept Transects

During 5 winters, 1999 - 2003, I recorded snowshoe hare tracks along a fixed transect established on roads that traversed my study area. When I grouped all cover types along the route into 11 categories and combined data from all winters, chi-square analysis showed that snowshoe hares were not using cover types in proportion to their availability ($X^2 = 1,099.89$, 10 df, $P < 0.001$). Tests of individual cover types indicated that hare use of LP1 and LP0/MF stands was greater than expected, while SF stands were used as expected. All other cover types were used less than expected (Table 5).

My analysis of individual years was hampered by small sample sizes in 1999 and 2001, but general trends were apparent. Cover type use varied slightly from year to year, but LP1 was consistently used more than other types (Figure 3). The only consistent change over time occurred in the use of LP0, in which use increased each winter.

Table 5. Chi-square analysis for snowshoe hare cover type use versus availability across all years based on track counts from road track-intercept transects. $X^2 = 1099.89$; $P < 0.001$. Cover types are defined in Table 1.

Cover Type	Proportion Available	Number Expected	Number Observed	Proportion Observed	Confidence Interval	Test Result [a]
DF	0.140	259.42	22	0.012	0.005-0.019	-
LP0	0.184	341.19	242	0.130	0.108-0.153	-
LP0/LP2	0.031	57.89	22	0.012	0.005-0.019	-
LP0/LP3	0.009	17.33	7	0.004	0.000-0.007	-
LP0/MF	0.022	41.44	65	0.035	0.023-0.047	+
LP1	0.295	545.94	1,157	0.625	0.593-0.656	+
LP1/MF	0.037	68.11	24	0.013	0.006-0.021	-
LP3	0.096	178.22	135	0.073	0.056-0.090	-
Meadow	0.029	53.39	6	0.003	0.000-0.007	-
MF	0.149	276.49	165	0.089	0.070-0.108	-
SF	0.007	13.24	8	0.004	0.000-0.008	ns

[a] - = use less than expected ($P < 0.05$), + = use greater than expected, and ns = no significant difference in use and availability.

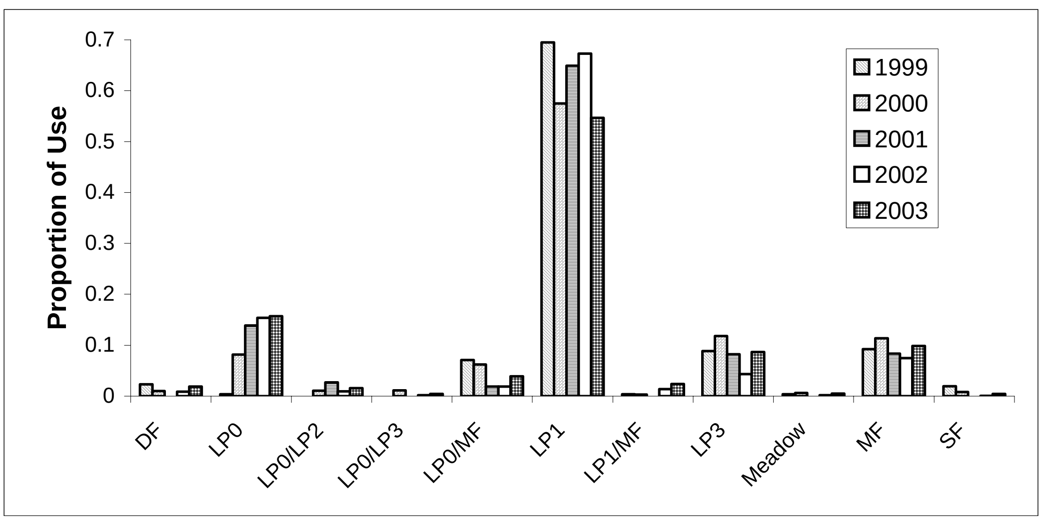

Figure 3. Snowshoe hare cover type use among all years.

Tests of use versus availability in individual years showed that LP1 was always used more than expected and DF and meadows were always used less than expected (Table 6; Appendix B, Tables 19-23). All other cover types were used either less than or as much as expected, except for LP0/MF stands which were used more than or as much as expected. Only 2 cover types showed possible temporal changes in use. In the first 2 years of the study, LP0 stands were used less than expected. They were used in proportion to availability the last 3 years. Also, MF stands were used as expected the first 3 years but less than expected the last 2 years.

Table 6. Comparison of snowshoe hare cover type use with availability among all years and months. Cover types are defined in Table 1.

Cover Type	Proportion Available	All	1999	2000	2001	2002	2003	Jan	Feb	Mar
DF	0.140	- [a]	-	-		-	-	-	-	-
LP0	0.184	-	-	-	ns	ns	ns	ns	-	-
LP0/LP2	0.031	-		-	ns	-	ns	-	ns	-
LP0/LP3	0.009	-		ns		-	ns	ns		ns
LP0/MF	0.022	+	ns	+	ns	ns	ns	ns	ns	+
LP1	0.295	+	+	+	+	+	+	+	+	+
LP1/MF	0.037	-	-	-		-	ns	-	-	-
LP3	0.096	-	ns	ns	ns	-	ns	-	ns	-
Meadow	0.029	-	-	-		-	-	-	-	-
MF	0.149	-	ns	ns	ns	-	-	-	-	-
SF	0.007	ns	ns	ns		-	ns	ns	ns	-

[a] - = use less than expected ($P < 0.05$), + = use greater than expected, and ns = no significant difference in use and availability.

When comparing use among the different months, hares used LP1 more often than expected and DF, meadow, LP1/MF, and MF less than expected during all 3 winter months (Figure 4; Table 6; Appendix B, Tables 24-26). The remaining 6 types did not exhibit consistent patterns during all months. Possible changes in use among months occurred in LP0 and LP0/MF stands. Hares used LP0 stands less than was expected during February and March but used them in proportion to their availability in January.

In LP0/MF, hares use was proportional to availability in January and February, but was greater than expected in March.

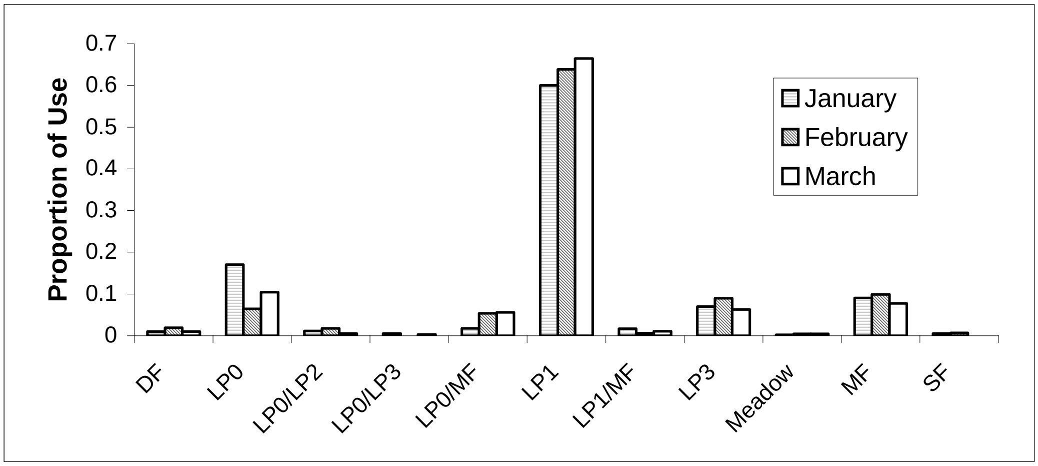

Figure 4. Snowshoe hare cover type use among months for all years combined.

I counted nearly 3 times as many tracks in each of the last 2 years than in each of the first 3 years (Table 7; Figure 5). I observed the fewest tracks per km (0.79) in 2001, while 2003 had the highest average with 3.80/km. Comparing hare track densities among the 3 months also showed that the January average was more than twice that of February or March (Table 7).

Table 7. Summary of the snowshoe hare track index based on the track-intercept transect.

Year or Month	Total km Traveled	Mean Tracks per km	Standard Deviation
1999	147.4	0.96	1.20
2000	217.7	1.41	1.81
2001	133.9	0.79	0.96
2002	298.9	2.75	2.81
2003	125.7	3.80	2.72
January	308.0	3.19	3.02
February	303.3	1.36	1.61
March	312.0	1.47	1.63

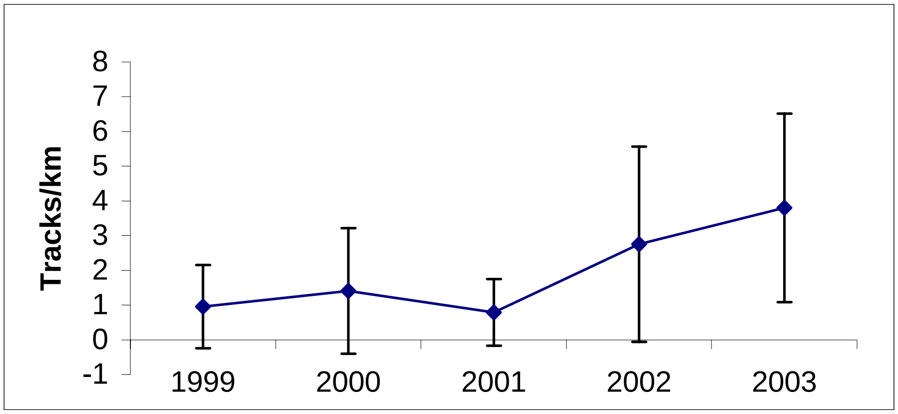

Figure 5. Temporal trend for average snowshoe hare track counts for the winters 1999 – 2003. Error bars are 1 standard deviation.

Line Transects

Since the cover types sampled using the road track-intercept transect were not representative of the distribution of cover types in the study area and were closely associated with roads, I used a system of line transects covering the entire area to see if both methods gave comparable results. These line-based transects closely mirrored the proportions of each cover type in the area and did not follow roads (Table 8). Rather than counting tracks, I calculated the proportion of segments in which hare tracks were present. During 1999, I monitored 198 cover type segments, of which 82 (41.4%) contained snowshoe hare tracks. In 2000, of the 390 segments traveled, 193 (49.5%) contained tracks. All cover types, except meadows, contained some snowshoe hare tracks during both years. In 1999, mature SF stands had the highest proportion of segments with tracks at 63.4% followed by LP1 with 57.1%. Meadows, LP0, and DF types contained the lowest proportions with 0%, 4.8%, and 12.5%, respectively (Table 9).

Table 8. Proportions of the cover types sampled using the 2 tracking methods compared to the true proportions of each cover type in the study area based on the CEM map. Cover types are defined in Table 1 plus WB is mature whitebark pine.

Road Track-intercept		2000 Line Transects		CEM Map	
Cover Type	Proportion	Cover Type	Proportion	Cover Type	Proportion
Meadow	0.03	Meadow	0.04	Meadow	0.04
DF	0.14	DF	0.10	DF	0.08
LP0	0.18	LP0	0.20	LP0	0.15
LP0/LP2	0.03	WB	0.03	WB	0.01
LP0/LP3	0.01				
LP0/MF	0.02				
LP1	0.29	LP1	0.15	LP1	0.16
LP1/MF	0.04	LP2	0.13	LP2	0.17
LP3	0.10	LP3	0.09	LP3	0.13
MF	0.15	MF	0.16	MF	0.11
SF	0.01	SF	0.10	SF	0.15

Table 9. Percent of segments containing snowshoe hare tracks for each cover type during 1999 and 2000. Cover types are defined in Table 1 plus WB is mature whitebark and SF1 is 40 to 100 year old spruce-fir.

	1999			2000		
Cover Type	Number of Segments	Number with Tracks	Percent with Tracks	Number of Segments	Number with Tracks	Percent with Tracks
Meadow	9	0	0.0	21	0	0.0
DF	8	1	12.5	23	5	21.7
LP0	21	1	4.8	51	13	25.5
LP1	28	16	57.1	43	33	76.7
LP2	25	9	36.0	48	21	43.8
LP3	18	6	33.3	41	23	56.1
SF1				23	12	52.2
SF	41	26	63.4	52	38	73.1
WB				14	9	64.3
MF	48	23	47.9	68	39	57.4
Total	198	82	41.4	390	193	49.5

In 2000, the cover type with the highest percentage of segments with tracks was LP1 with 76.7% followed by mature SF with 73.1%. Cover types with the lowest percentage of segments with tracks were meadow, DF, and LP0 with 0%, 21.7%, and 25.5%, respectively. When comparing the 2 years, 2000 had a higher proportion of segments with tracks overall and within each cover type.

Within each cover type segment that contained hare tracks, I estimated the density of tracks as low, medium, or high. In 1999, across all cover types, most of the segments were classified as low density (Table 10). Only 2 cover types contained segments with high densities, LP1 and mature SF. In 1999 my sample size was much smaller compared to 2000, but percentages of segments containing low, medium, and high densities were comparable for all cover types between the 2 years. The LP0 type changed the most between years, but my 1999 sample of LP0 segments with tracks was very small.

Table 10. Percent of segments in each density category for segments containing tracks during 1999 and 2000. Cover types are defined in Tables 1 and 9.

	1999				2000			
Cover Type	Segments with Tracks	Percent with Low	Percent with Medium	Percent with High	Segments with Tracks	Percent with Low	Percent with Medium	Percent with High
Meadow	0	0.0	0.0	0.0	0	0.0	0.0	0.0
DF	1	100.0	0.0	0.0	5	60.0	40.0	0.0
LP0	1	0.0	100.0	0.0	13	69.2	30.8	0.0
LP1	16	87.5	6.3	6.3	33	63.6	30.3	6.1
LP2	9	88.9	11.1	0.0	21	81.0	19.1	0.0
LP3	6	83.3	16.7	0.0	23	82.6	17.4	0.0
SF1					12	66.7	25.0	8.3
SF	26	69.2	26.9	3.8	38	42.1	55.3	2.6
WB					9	66.7	22.2	11.1
MF	23	60.9	39.1	0.0	39	66.7	33.3	0.0

In 2000, all cover types except for SF had the majority of their segments with tracks in the low category. In SF stands, 55% of segments with tracks were classified as medium density. Only 4 cover types had segments that were classified as high density. They were WB with 11% followed by SF1, LP1, and SF with 8%, 6%, and 3%, respectively.

Edge Relationship Transects

Counts of snowshoe hare tracks at different distances from cover type edges did not show any clear trends across all cover type pairs. When I combined the data for all cover types and analyzed for differences in track densities among 3 distance categories (0-10 m, 45-55 m, 90-100 m) from cover type edge, I did not find significant differences ($H = 4.5649$, $P = 0.1021$). When looking at each pair of edge types separately, only 2 of 11 pairs showed a significant difference in track counts among the 3 distance categories (Table 11). For both of those pairs, LP0/LP2 and LP1/DF, only 1 side of the edge showed a significant difference. For LP0/LP2, the uncut side was significant while for LP1/DF the cut side had the significant difference. The other 9 cover type pairs showed insignificant differences among distance categories on both sides of the edge.

I also used this data set as a third means of assessing snowshoe hare cover type use. For this I calculated the average number of tracks per 100 m line and tested for differences among the 7 cover types. Using the Kruskal-Wallis analysis of variance by ranks test I found that there was a significant difference among the cover types ($H = 35.887$, $P < 0.001$) (Table 12).

Table 11. Average number of hare tracks per 10 m increment at 3 different distances from a forest/clearcut edge. Samples were taken from 3 distances in both the forest and the clearcut for each pair of mature and cut forest types. Cover types are defined in Table 1. Statistical significance of the Kruskal-Wallis test was accepted at P<0.05.

Cover Type 1	Lines per Pair	90-100 m	45-55 m	0-10 m	P-value	Cover Type 2	0-10 m	45-55 m	90-100 m	P-value
LP0	11	0.00	0.00	0.03	0.37	LP1	0.34	0.10	0.06	0.13
LP0	10	0.00	0.03	0.06	0.33	LP2	0.10	0.01	0.00	0.04
LP0	16	0.05	0.02	0.02	0.79	LP3	0.05	0.12	0.10	0.12
LP0	8	0.00	0.01	0.00	0.37	DF	0.03	0.02	0.06	0.83
LP0	6	0.00	0.00	0.08	0.37	SF	0.17	0.19	0.00	0.18
LP0	10	0.00	0.10	0.10	0.37	MF	0.11	0.00	0.05	0.33
LP1	7	0.24	0.00	0.00	0.12	LP2	0.14	0.07	0.00	0.59
LP1	7	0.18	0.13	0.09	0.93	LP3	0.05	0.14	0.05	0.32
LP1	7	0.00	0.00	0.21	0.04	DF	0.07	0.00	0.00	0.37
LP1	10	0.11	0.18	0.18	0.91	SF	0.08	0.17	0.00	0.16
LP1	11	0.05	0.14	0.06	0.49	MF	0.08	0.13	0.10	0.96

Table 12. Average number of snowshoe hare tracks per 100 m for each cover type. Cover types are defined in Table 1.

Cover Type	Sample Size	Tracks/100 m	Density Class
LP0	61	0.28	Low
LP1	53	1.06	High
LP2	18	0.32	Low
LP3	23	0.73	Medium
DF	16	0.33	Low
SF	16	1.01	High
MF	21	0.73	Medium

Comparison of Differences in Cover Type Use Among Methods

Collecting data on snowshoe hare habitat use with 3 different methods allowed me to ascertain how sensitive results were to methodologies. When I compared the proportions of segments in each cover type that contained at least 1 set of hare tracks using a Spearman rank correlation, the road track-intercept transect and line transect methods were significantly correlated (Rs = 0.714, P = 0.047) and LP1 had the highest percentage of segments with tracks for both methods (Table 13). Also, both of these methods agreed that DF and meadow were the least used by hares. Ranking of cover types with intermediate levels of use were not consistent. The biggest discrepancies between methods were for LP0, SF, and LP3. SF results for the road track-intercept transect were based on 1 short segment that was bordered on 1 side by a meadow. The SF segments in the line transects were more representative of SF stands across the study area.

Table 13. Comparison of percentage of segments with tracks for each cover type obtained from the 3 tracking methods. Spearman rank correlation results for road track-intercept versus line transects, Rs = 0.714, P = 0.047; road track-intercept versus edge, Rs = 0.571, P = 0.139; line transects versus edge, Rs = 0.762, P = 0.028. Cover types are defined in Table 1.

	Road Track-Intercept All Years			Line Transect Both Years			Edge Transect		
Cover Type	Number of Sections	Percent with Tracks	Rank	Number of Sections	Percent with Tracks	Rank	Number of Sections	Percent with Tracks	Rank
LP0	433	28.2	4	72	19.4	6	61	41.0	7
LP1	556	51.4	1	71	69.0	1	53	75.5	4
LP2	96	21.9	5	73	41.1	5	18	50.0	5
LP3	245	35.9	2	59	49.2	4	23	87.0	1
SF	57	14.0	6	93	68.8	2	16	81.3	2
MF	403	29.5	3	116	53.5	3	21	76.2	3
DF	177	8.5	7	31	19.4	7	16	43.8	6
Meadow	154	4.6	8	30	0.0	8	0	0.0	8

The Spearman rank correlation test also showed a significant relationship between the line transect and edge transect methods (Rs = 0.762, P = 0.028) but not between the road track-intercept and edge transect methods (Rs = .571, P = 0.139) (Table 13). The edge transect method indicated that LP3 had the highest frequency of occurrence of tracks and LP1 was the fourth highest. Other cover types were ranked similarly with the other 2 methods.

When I compared the number of tracks counted in the 2 methods that used track counts, road track-intercept transect and edge transects, the Spearman rank correlation among cover types was not significant (Rs = 0.464, P = 0.294). Both methods did show that LP1 stands contained the highest density of tracks and that LP2 had the sixth highest densities, but all other cover types were ranked differently by the 2 methods(Table 14).

Table 14. Comparison of track densities from the road track-intercept and edge transect methods. Rs = 0.464, P = 0.294. Cover types are defined in Table 1.

Road Track-Intercept All Years			Edge Transects		
Cover Type	Tracks/km	Rank	Cover Type	Tracks/km	Rank
LP0	1.59	3	LP0	2.84	7
LP1	4.10	1	LP1	10.64	1
LP2	0.82	6	LP2	3.23	6
LP3	1.23	4	LP3	7.34	3
DF	2.56	2	DF	3.33	5
SF	1.18	5	SF	10.12	2
MF	0.17	7	MF	7.33	4

Overall, edge transects showed a much higher density of tracks per km than did the track-intercept transect. The edge method had an average of 6.4 tracks per km while the track-intercept method had an average of 2.2 tracks per km. When comparing the frequency of occurrence of hare tracks with the density of hare tracks calculated from the edge transect method, LP1 ranked first in density but fourth in frequency. LP3 also changed from third in density to first in frequency. All other cover types were ranked similarly by both calculations from the edge method.

Food Habits

Tracking snowshoe hares to locate feeding sites enabled me to study their winter diet in my study area without disturbing them. I counted nearly 5,000 bites and found browsing on 18 different plant species. Hares typically clipped off the end of small branches or fed on needles and buds. Occasionally branch tips were cut off but left uneaten lying on top of the snow. Very rarely did I find branches that had been barked. Approximately 83% of the total bites were taken from 3 species. Nearly 60% of bites were on lodgepole pine, followed by Douglas fir and subalpine fir with 12% and 11%, respectively. Six species made up between 1% and 4% of the diet and each of the remaining 9 species comprised less than 1% of the total diet (Table 15). Hares browsed predominately on coniferous trees, 88% of the total diet, but also fed on several shrubs and forbs, 12% of the total, the most common of which were juniper, annual composites (*Compositea*), alder (*Alnus* sp.), and buffaloberry.

As might be expected, snowshoe hare diet differed among cover types. Within LP1 stands, 59% of the bites I observed were on lodgepole pine, followed by Douglas fir and subalpine fir (Table 16). Lodgepole was the most browsed species in all cover types except for DF and LP3. In DF stands, Douglas fir was browsed more than any other species and subalpine fir was browsed most often in LP3 stands. When comparing the percentage of browsing on lodgepole pine in the 4 successional stages of lodgepole forests, I found that use decreased from 92% in LP0 stands to 27% in LP3 stands.

Table 15. Plant species on which snowshoe hare browsing occurred and the percentage of the total number of bites recorded.

Scientific Name	Common Name	Percentage of Total Bites
Abies lasiocarpa	Subalpine fir	11.3
Alnus sp.	Alder	2.1
Berberis repens	Oregon grape	0.0
Ceanothus velutinus	Evergreen ceanothus	0.0
Compositae	Annual composites	2.3
Heracleum lanatum	Cow parsnip	0.5
Juniperus communis	Common juniper	3.7
Lonicera involucrata	Twinberry	0.2
Pinus albicaulis	Whitebark pine	3.2
Pinus contorta	Lodgepole pine	59.4
Picea engelmanii	Engelmann spruce	2.1
Pseudotsuga menziesii	Douglas fir	12.2
Ribes sp.	Gooseberry	0.6
Salix sp.	Willow	0.6
Sambucus racemosa	Elderberry	0.4
Shepherdia canadensis	Buffaloberry	1.0
Symphoricarpus albus	Snowberry	0.4
Vaccinium globulare	Huckleberry	0.2

Table 16. Three species with the most browsing by snowshoe hares in each cover type expressed as the percent of the total bites for that cover type. Acronyms are defined in Tables 1 and 3.

Cover Type	# of Bites	Species 1	Percent	Species 2	Percent	Species 3	Percent
LP0	698	PICO	92.3	ABLA	2.4	PIAL	1.9
LP1	3,266	PICO	59.2	PSME	13.7	ABLA	12.0
LP2	141	PICO	43.3	PSME	32.6	PIAL	17.7
LP3	173	ABLA	32.4	PICO	26.6	PSME	24.9
DF	25	PSME	92.0	ABLA	8.0		
MF	188	PICO	46.8	ABLA	17.6	Composites	10.1
SF	440	PICO	36.1	PIEN	19.8	Alnus sp.	15.9

The diet of snowshoe hares also differed among winter months. I recorded bites on 18 species during January but only 9 in both February and March. At each plant that I observed browsing, I also measured snow depth next to that plant. Calculating average snow depth for each month showed that January averaged 45.2 cm while February and March averaged 69.6 cm and 95.7 cm, respectively.

Although I did not have direct information on plant availability where I collected dietary data, I was able to assess the relative availability and use by assuming that the combination of the two layers from the 1/300-acre vegetation plots was representative of plant availability. I compared the percentage of the diet for the 4 most commonly browsed species with the availability (percent canopy coverage) of those species for each cover type using a Spearman correlation matrix (Table 17). The Spearman test showed that there was a significant correlation between diet and availability in only the LP0 cover type ($R_s = 1.0$, $P = 0.000$). The other 6 cover types showed non-significant results.

The plants snowshoe hares were feeding on varied in size as well as species. Plants bitten by hares ranged in size from a few centimeters tall to 21 m tall, but 61% of the total bites were taken from plants less than 2 m tall. It was common to find hares feeding on plants that were barely sticking above the snow, but they also fed on the low branches of tall trees that drooped down to the snow level and formed a canopy they could hide under. These low branches provided 28% of the total bites.

I never observed hares digging in the snow to uncover food, but I found many hares utilizing fallen branches that had broken from the tops of mature trees or had been cut down by squirrels that were harvesting cones. Approximately 11% of the total bites I counted were on fallen branches. Hares fed on these branches in the same manner as a branch attached to a tree by clipping the end or by consuming the buds and needles.

Table 17. Comparison of the 4 most common species used in the hare diet with the availability of those species for each cover type. Availability is based on the percent canopy coverage from both layers combined from the 1/300 acre vegetation plots. Acronyms are defined in Tables 1 and 4.

Cover Type	Rs	P-Value	Species	Percent of Diet	Percent Canopy Coverage
LP0	1.00	0.00	PICO	92.3	29.5
			ABLA	2.4	7.9
			PIAL	1.9	5.6
			Ribes	1.2	0.2
LP1	0.40	0.60	PICO	59.2	4.3
			PSME	13.7	0.2
			ABLA	12.0	2.4
			JUCO	4.6	1.6
LP2	-0.60	0.40	PICO	43.3	0.6
			PSME	32.6	0.5
			PIAL	17.7	4.1
			ABLA	5.7	3.8
LP3	0.20	0.80	ABLA	32.4	25.5
			PICO	29.6	0.1
			PSME	24.9	0.9
			PIAL	10.4	1.6
DF	0.82	0.18	PSME	92.0	0.7
			ABLA	8.0	0.0
MF	-0.21	0.79	PICO	46.8	0.0
			ABLA	17.6	27.1
			Composites	10.1	0.0
			JUCO	5.9	0.8
SF	-0.80	0.20	PICO	36.1	0.0
			PIEN	19.8	6.6
			Alder	15.9	0.3
			ABLA	11.1	11.7

Mature DF and LP2 stands had the highest percentage of their bites on fallen branches, both at nearly 80%. LP3, MF, and SF stands had between 20% and 30% of their bites on fallen branches. LP0 and LP1 had 0.5% and 5.7% of their bites taken from fallen branches, respectively. Overall, most fallen branches that were eaten by hares were lodgepole pine, whitebark pine, and Douglas fir.

DISCUSSION

Snowshoe Hare Habitat Use

All 3 tracking methods for studying hare habitat use that I employed indicated that thinned LP1 stands, lodgepole pine 50 to 60 years post-harvest, contained comparatively high levels of snowshoe hare use. These LP1 stands had a combination of dense overhead canopy and dense understory branches forming a closed canopy within 2 m of the ground and included a high representation of species that were common in the hares' diet. Of the 8 cover types common in my study area, thinned LP1 best fits the description of preferred snowshoe hare winter habitat most frequently noted in the literature (Hodges 2000), due to its thick understory between 2 and 4 m above the ground and abundant food.

MF and LP3 stands also had a combination of thick overstory and understory but had less dense cover between 1 and 4 m above the ground compared to LP1. SF stands provided moderately dense over and understory cover as well, but preferred food species were less abundant in these stands. LP0 stands offered abundant food but lacked dense cover more than 2 m above the ground.

The pattern of snowshoe hare habitat use I observed in my study area is consistent with other studies in North America (Wolff 1980, Wolfe et al. 1982, Hodges 2000). Hares can be found in many forest types from pine to spruce to deciduous stands, but hare densities appear to be greatest in areas with thick understory cover (Adams 1959, Wolff 1980, Litvaitis et al. 1985).

I was able to compare hare use among different mature forests types, but differences in use appear to be more related to stand structure than to species composition. Density of forest understory appears to be more important in determining good habitat for hares than does species composition (Litvaitis et al. 1985, Hodges 2000). In my study area, most regenerating stands were dominated by lodgepole pine. If I had been able to adequately sample regenerating Douglas fir or spruce-fir stands similar in age to the LP stands, hare use could well have been comparable to that seen in regenerating LP stands. When comparing the 4 ages of lodgepole stands in my study area, LP1 had the thickest understory cover between 1 and 4 m. LP3 and LP0 were next with thick understories within 1 m of the ground but less cover from 1 to 4 m. LP2 stands provided very little cover within 6 m of the ground.

Snowshoe hares in the Bear Creek Drainage used older regenerating stands more than mature forests or young regenerating forests. The youngest regenerating stands showed low to moderate levels of use depending on the tracking method that was used and time of year. Snowshoe hare use of these youngest stands declined as the winter progressed probably due to loss of available cover as the vegetation near the ground was buried under snow. Use of older regenerating stands increased as the winter progressed. While both ages of regenerating stands provided plentiful food and thick cover near the ground, the younger stands lacked thick cover more than 2 m above the ground thus offering only thin overhead cover during the late winter when snow depths exceeded 1 m. Mature stands with moderate to very dense understories (MF, SF, and LP3) had moderate to high levels of use while open middle age and mature stands (DF and LP2) received very little use. Meadows were seldom used by hares due to a lack of food and cover during the winter.

There are several possible explanations to why hare use of LP1 stands was so much greater than in LP0 stands in my study area. LP0 stands contained higher stem densities than LP1 stands and had fairly dense cover near the ground. However, these stands typically were not uniform in density or height and often contained small pockets of shorter trees and lower stem densities. I believe that hares preferred LP1 to LP0 stands due to the more uniform and continuous overhead cover found in the LP1 stands. As a regenerating forest ages, stem density becomes more uniform across the stand compared to earlier seral stages (Kashian 2002). This stand uniformity, combined with the more dense cover between 2 and 4 m above ground in the LP1 stands, may be the reason that hares preferred LP1 stands over LP0 stands during winter months. Although the LP0 stands received low levels of use during the winter, they may provide good habitat for hares during summer months.

Buskirk et al. (2000) suggested that hares prefer both early and late successional forest types, but that late successional stages may provide optimal cover for hares over a longer period of time. Regenerating stands provide optimal cover for hares, but only for a relatively short period of time (approximately 20 to 30 years in my study area). Understory density in a lodgepole forest changes as the stand ages. After a disturbance, the understory (low branches as well as shrubs) continues to develop and thicken until a certain age when the overstory closes and the understory begins to die and the trees self-prune. During this self-pruning stage, the lower edge of the canopy moves progressively higher, but there is very little regrowth in the understory of later successional species of trees or shrubs. Eventually, the uniform canopy begins to break apart allowing more understory growth of trees and shrubs to take place, which will once again lead to a thick understory that also offers good habitat for hares.

Several studies have shown snowshoe hares prefer regenerating forest stands to mature forest types (Koehler et al. 1979, Wolff 1980, Bittner and Rongstad 1982, Monthey 1986, Koehler 1991). These second growth stands typically provide very dense understory cover that is important to hares for a certain period of time. Exactly when and how long regenerating stands provide suitable habitat for hares will be different between regions due to variable tree growth rates or climate differences. In Washington, Koehler (1991) compared snowshoe hare use among 6 cover types, lodgepole pine stands that were 20-years-old, 43-years-old, and more than 82-years-old, mature Engelmann spruce/subalpine fir, Douglas fir/larch/aspen, and meadow. He found the highest levels of hare use in 20-year-old lodgepole stands followed by 43-year-old lodgepole, 82-year-old lodgepole, mature spruce/fir, Douglas fir, and meadow. Stem densities were highest in the youngest aged stands in his study (Koehler 1990). Koehler et al. (1979) also found the greatest density of hares in lodgepole stands 67 years post-fire compared to open young lodgepole stands, mature spruce-fir, and mature pine-Douglas fir stands in Montana. These 67-year-old stands contained the densest understory cover.

Comparing snowshoe hare habitat use studies involving different ages of regenerating stands is difficult due to variability in stand growth rates among regions. For example, Koehler (1991) found that 20-year-old lodgepole stands in Washington had high levels of use by hares, but 25-year-old stands in my study showed low levels of use by hares compared to other available cover types. Although these forests were of similar age post-disturbance, they likely had different stand characteristics due to climatic variation. Also, caution is needed in interpreting these cover type use results in that my study and Koehler's (1979, 1991) efforts compared hare use of a small number of cover types within a specific study area. In areas with a greater variety of stand types and ages, hares may demonstrate different stand selection patterns than either Koehler or I observed. However, I believe regenerating stands do provide good habitat for hares for a discrete time frame regardless of regional context or cover type availability.

During the 5 winters of my study, I hoped to monitor snowshoe hare use of each cover type, especially in the regenerating stands, to see how use compared year to year. My tracking methods indicated increasing levels of hare use over the course of the study, potentially due to higher hare densities. For example, hare track counts in LP0 stands increased during the study. Presumably, these stands were also becoming better habitat as they matured, thus favoring more use, but the increase in use may have also represented the movement of hares into inferior habitats as population densities increased. Hares typically inhabit optimum forest types when population densities are low but will occupy sub-optimal habitats as well when densities increase (Wolff 1980).

Snowshoe Hare Food Habits

I observed hare browsing on a variety of plants (18 species), but the majority of browsing was on coniferous trees (88%) with lodgepole pine being utilized far more than any other species. Lodgepole pine was a common understory species in only 3 cover types. Whitebark pine was the fifth most commonly browsed species and was 1 of the 3 most abundant understory species in 5 of the 8 cover types. Engelmann spruce was the eighth most common species in the hare diet (2% of total diet) even though it was common in the understory of 4 cover types. Of the bites taken from spruce trees, the majority were taken from the upper branches on trees more than 5 m tall that were bent over under the weight of snow. Only a few bites were taken from spruce trees less than 2 m tall even though 1 to 2 m tall spruce trees were abundant in the study area. The amount of snowshoe hare browsing on subalpine fir and Douglas fir was very similar in my study even though subalpine fir was much more common across the study area than was Douglas fir. When comparing the diets of hares within the 4 age classes of lodgepole pine in my study, I found that use of lodgepole pine decreased substantially as the stands matured. This is not surprising because my vegetation sampling showed that the density of lodgepole trees also declined as lodgepole forests matured.

My findings are consistent with what others have observed. Other studies have also shown that snowshoe hares utilize a wide variety of species during the winter but show preferences for certain species (de Vos 1964, Wolff 1980, Hodges 2000). Although preferences for specific species vary from place to place, winter hare diets typically consist of coniferous trees, shrubs, and some forbs (Wolff 1978). Where available, pine species are often a preferred winter browse for hares (de Vos 1964). In some areas, typically in Canada where there is an absence of pines, spruce trees may be heavily utilized (Wolff 1978, Smith et al.1988). Smith et al. (1988) noticed hares avoiding juvenile spruce branches but found hares using mature side branches during periods of deep snow. Adams' (1959) study in Northwestern Montana found that hares fed heavily on Douglas fir during the winter and ponderosa pine was moderately used. De Vos (1964) also found heavy browsing on pine species, while balsam fir was used very little. Use of subalpine fir is seldom mentioned in literature on snowshoe hare.

Hares in my study also consumed several species of shrubs and forbs (12% of total diet) including common juniper, annual composites, and alder. Several shrub species in my study area were relatively abundant, but all shrubs experienced low levels of use by hares. Availability of these species was typically much lower compared to coniferous trees due to accumulating snow. Overall, the number of species used declined as the winter progressed. This was probably due to decreasing availability of many species as snow depths increased.

Other studies have also noted the use of shrubs and forbs by hares in winter (Smith et al.1988, Hodges 2000). Smith et al. (1988) observed hares browsing predominantly on deciduous shrubs, but his study area (Kluane, Yukon) had an abundance of shrub species while spruce was the only common conifer. Adams (1959) observed heavy utilization of *Berberis repens* in northwest Montana. I only noticed browsing on this species on 1 occasion, probably because it was buried under snow for most of the winter.

Hares typically feed by clipping the ends off of small twigs, but also may remove the bark of young trees (de Vos 1964). In my study, I observed barking on just a few occasions and only on small twigs of coniferous trees, never on the trunks of trees or on deciduous shrubs. Barking in my study area was infrequent probably due to the relatively low to moderate density of hares using the area. Barking can be detrimental to young stands of trees by girdling and killing them. This problem is most often associated with very high densities of hares (de Vos 1964, Hodges 2000). Under very high densities, hares can remove a majority of the available twigs as well as consume the bark of trees and shrubs.

Besides clipping the ends off of small twigs, hares in my study area browsed on fallen branches lying on top of the snow pack quite regularly. Use of these fallen branches was most common in LP2 and DF cover types. These types also had the lowest amount of available cover and browse within 5 m of the ground. Due to the lack of available browse growing in these stands, hares appeared to be taking advantage of this additional food source. Also, these fallen branches may have made these inferior habitats tolerable to hares during winter. The use of fallen branches by hares was never cited in other studies on snowshoe hare diet.

Impacts of Silvicultural Practices

Although I identified LP1 stands as the preferred habitat for snowshoe hares, lodgepole pine trees in these stands were beginning to self-prune above the snow pack. These stands were logged 50-60 years ago and subsequently were pre-commercially thinned to enhance tree growth. Although they provided hares the best habitat among the available cover types, these favorable conditions are temporally limited. For example, due to self-pruning, I believe LP1 stands will no longer have lower branches within 5 m of the ground within the next 10-20 years. Without these low branches, hare use will decrease substantially (60 to 70 years post harvest). In contrast, LP0 stands (25 years post-harvest at the start of my study) were just beginning to develop a closed canopy over 2 m from the ground. Based on these observations, lodgepole pine stands in the northern portion of the GYA provide the best habitat for hares between 30 and 70 years post-harvest. Optimum habitat conditions will vary depending on whether or not pre-commercial thinning was implemented. The best habitat conditions for hares will occur later within that time frame if stands are thinned and earlier if they are not.

The full effects of precommercial thinning on hare and lynx habitat are still not clearly understood. Although short-term effects of thinning are negative due to reduced stem densities and a more open canopy (Sullivan and Sullivan 1988), I believe that thinning delays the self-pruning process, thus keeping understory branches intact longer. Lodgepole pine self-prunes because lower limbs do not receive sufficient sunlight for photosynthesis. The more dense a stand is, the sooner it will begin to self-prune. Therefore, in the short-term, thinning a young stand decreases overhead cover and accessible winter food for hares and thereby reduces the desirability of the stand. However, in the long-term it will again develop a dense canopy and understory. Adams (1959) also suggested the use of light thinning in very dense stands to allow more light to penetrate to the ground to promote more growth of ground cover plants.

LP0 stands in my study area were created by logging between 1972 and 1976 and had not been thinned. Hare use in these stands apparently increased throughout my study. If they were thinned now, hare densities would likely remain low for another 10 or more years. However, thinning would create good hare habitat until approximately 70 years post-harvest. If they are not thinned, hare use would presumably continue to increase, but these stands would self-prune sooner and fail to provide sufficient understory cover for hares by 50 years post-harvest instead of 70 years. Whether thinning is employed or not, hares may only use these regenerating stands for approximately 25 years. Therefore, having multi-aged stands and a mix of thinned and unthinned stands in an area may provide suitable hare habitat over a longer period of time compared to an area that has been uniformly treated. Thinning portions of a logged area in juxtaposition to unthinned stands may provide hares with additional suitable habitat once the unthinned stands self-prune and no longer provide sufficient cover for hares. This may be especially beneficial for hares in areas that lack mature forests with dense understories.

I agree with Buskirk's (2000) contention that hares and lynx may both benefit most from the preservation of large expanses of late successional or mature forests. Mature forests provide more stable, long-term habitat for hares as well as for red squirrels, another important prey item of lynx, in addition to providing an abundance of denning habitat for lynx (Buskirk et al. 2000). Mature forest types with dense understories in my study area also showed moderate to high levels of use by hares. However, in areas where logging has and will continue to take place, managing early successional forests based on the habitat requirements of hares and lynx should continue to be a top priority. But, I do not advocate the cutting of mature stands to provide more regenerating stands for hares.

Currently, Forest Service management objectives in areas of potential lynx habitat call for the maintenance or improvement of the vegetative structure for lynx and their prey (Ruediger et al. 2000). Specifically, management practices must address several items concerning lynx and hare habitat including, the retention of live and dead trees and woody debris, size and shape of harvest units, maintenance of high stem densities, and landscape patterns (amount and arrangement of mature coniferous forests) (Ruediger et al. 2000). My findings suggest that management should further emphasize the maintenance of high stem densities and dense vegetative cover within 4 m of the ground. Data I collected do not give any insight on beneficial harvest unit size, shape, or arrangement.

In areas of potential lynx habitat, current Forest Service standards only allow thinning in stands that have self pruned well above the ground and no longer provide suitable hare habitat (Ruediger et al. 2000). Also, the proposed management alternative in the current draft of the environmental impact statement for the Northern Rockies Lynx Amendment would only allow precommercial thinning within 200 feet of administrative sites or in stands that no longer provide suitable habitat for snowshoe hares (USDA 2004). I believe implementing these thinning standards, at least in the northern portion of the GYA, will reduce the amount of time regenerating stands could provide beneficial habitat for hares. I recommend a combination of thinned and unthinned stands to provide suitable habitat within regenerating stands over a longer period of time.

The results and conclusions in my study are based on what I observed within an area impacted by silvicultural practices. Caution is needed when comparing my conclusions to areas that were impacted by other types of disturbance, such as fire. Regenerating forests created by other disturbance types may be structurally dissimilar, thereby resulting in different snowshoe hare habitat use patterns than what I observed.

Further Studies and Recommendations

I found some inconsistencies in results among methods when I compared snowshoe hare cover type use using 3 different tracking methods. The systematic line transect method presumably had the fewest biases because it involved sampling across the entire study area and it was the most representative sample of the cover types in the study area but it was the most difficult technique to replicate.

The track-intercept method did not sample the cover types in the area in proportion to availability, but it allowed easy replication over time. Track-intercepts along roads could have underestimated hare use if hares exercised any avoidance of road corridors. Also, this method over sampled areas that have been logged and under sampled areas near drainage bottoms, where the SF cover type was most prevalent, because the roads lead to cut areas and avoided creek bottoms.

Track counts based on edges between cover types may have overestimated hare use because samples were taken from a portion of a cover type located near forest ecotones. Although I did not find a significant increase in hare tracks near edges, track densities were often slightly higher near the ecotones.

Since there are several problems and biases associated with track counts, further research should be conducted using direct estimates of use from mark-recapture or telemetry methods. One problem associated with track counts is that they are influenced by hare activity levels, which may be different among cover types. Therefore, studying cover type use through track indices, may be indicating that hares are more active in one cover type rather than showing differences in hare density among cover types. Track counts also provide weak inference towards population density and are limited to a relatively short portion of the year in which there is an adequate tracking substrate. Nonetheless, track counts can provide valuable indices about hare populations and tend to be highly correlated with other methods used for monitoring snowshoe hare populations (Litvaitis et al. 1985, Koehler 1990, Hodges 2000).

The U.S. Forest Service began annual spring pellet plot counts in my study area in the spring 2002 to facilitate long-term monitoring of snowshoe hare habitat use and population trends (D. Tyers, U.S. Forest Service, personal communication). This approach will avoid many of the shortcomings of track counts on snow. These pellet plots could also provide information on snowshoe hare habitat use during summer months as well as winter months, if they were visited twice each year (June for winter and October for summer). Also, future research should address potential seasonal shifts in hare habitat use. In addition to using pellet plots for monitoring long-term population trends, I also recommend further research that would address population density within the study area.

I believe that stand structure, rather than species composition drives snowshoe hare use, but I was only able to sample lodgepole forest types adequately. My study should be repeated in an area that contained stands of regenerating spruce-fir and

Douglas fir, to confirm that structure is the driving force in hare habitat selection the Greater Yellowstone Ecosystem.

Ruediger et al. (2000) call for more information to determine if and when thinning could benefit snowshoe hares. Using the LP0 stands (25 to 30-years-old) in my study area, I would recommend conducting experiments that thinned some of those stands. After thinning, monitoring of those stands should continue to see when and how long hares use both the thinned and unthinned stands as they mature and eventually self-prune. Additionally, more work could be done testing different thinning prescriptions, to see what spacing standards would most benefit hares.

REFERENCES CITED

Adams, L. 1959. An analysis of a population of snowshoe hares in Northwestern Montana. Ecological Monographs 29:141-170.

Bittner, S. L. and O. J. Rongstad. 1982. Snowshoe Hare and Allies. Pages 146-163 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild Mammals of North America. The Johns Hopkins University Press.

Buskirk, S. W., L. F. Ruggiero, K. B. Aubry, D. E. Pearson, J. R. Squires, and K. S. McKelvey. 2000. Comparative ecology of lynx in North America. Pages 397-417 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, J. R. Squires, editors. Ecology and conservation of lynx in the United States. University Press of Colorado and United States Department of Agriculture, Rocky Mountain Research Station, Denver, Colorado.

Conroy, M. J., L. W. Gysel, and G. R. Dudderar. 1979. Habitat components of clear-cut areas for snowshoe hares in Michigan. Journal of Wildlife Management 43:680-690.

De Vos, A. 1964. Food utilization of snowshoe hares on Manitoulin Island, Ontario. Journal of Forestry 62:238-244.

Ferron, J., F. Potvin, and C. Dussault. 1998. Short-term effects of logging on snowshoe hares in the boreal forest. Canadian Journal of Forest Research 28:1335-1343.

Giusti, G. A., R. H. Schmidt, R. M. Timm, J. E. Borrecco, and T. P. Sullivan. 1992. The Lagomorphs: rabbits, hares, and pika. Pages 289-307 *in* H. C. Black, editor. Silvicultural approaches to animal damage, Management in the Pacific Northwest. U.S. Department of Agriculture, Forest Service General Technical Report PNW-GTR-287.

Hodges, K. E. 2000. The ecology of snowshoe hares in northern boreal forests. Pages 117-161 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, J. R. Squires, editors. Ecology and conservation of lynx in the United States. University Press of Colorado and United States Department of Agriculture, Rocky Mountain Research Station, Denver, Colorado.

_____. 2000. Ecology of snowshoe hares in southern boreal and montane forests. Pages 163-206 *in* L. F. Ruggiero, K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, J. R. Squires, editors. Ecology and conservation of lynx in the United States. University Press of Colorado and United States Department of Agriculture, Rocky Mountain Research Station, Denver, Colorado.

Kashian, D. M. 2002. Landscape variability and convergence in forest structure and function following large fires in Yellowstone National Park. Ph.D. Dissertation, University of Wisconsin, Madison, Wisconsin.

Koehler, G. M., M. G. Hornocker, and H. S. Hash. 1979. Lynx movements and habitat use in Montana. Canadian Field-Naturalist 93:441-442.

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

_____. 1991. Snowshoe hare, *Lepus americanus,* use of forest successional stages and population changes during 1985-1989 in north-central Washington. Canadian Field-Naturalist 105:291-293.

Litvaitis, J. A., J. A. Sherburne, and J. A. Bissonette. 1985. A comparison of methods used to examine snowshoe hare habitat use. Journal of Wildlife Management 49:693-695.

_____, _____, and _____. 1985. Influence of understory characteristics on snowshoe hare habitat use and density. Journal of Wildlife Management 49:866-873.

MacCracken, J. G., W. D. Steigers, and P. V. Mayer. 1988. Winter and early spring habitat use by snowshoe hares, *Lepus americanus*, in south-central Alaska. Canadian Field-Naturalist 102:25-30.

Malloy, J. C. 2000. Snowshoe hare, *Lepus americanus*, fecal pellet fluctuations in western Montana. Canadian Field-Naturalist 114:409-412.

Mattson, D. J., and D. G. Despain. 1985. Grizzly bear habitat component mapping handbook for the Yellowstone Ecosystem. National Park Service and U.S. Forest Service.

McKelvey, K. S., G. W. McDaniel, L. S. Mills, and P. C. Griffin. 2002. Effects of plot size and shape on pellet density estimates for snowshoe hares. Wildlife Society Bulletin 30:1-5.

Monthey, R. W. 1986. Responses of snowshoe hares, *Lepus americanus*, to timber harvesting in northern Maine. Canadian Field-Naturalist 100:568-570.

Morrison, M. L., B. G. Marcot, R. W. Mannan. 1998. Wildlife habitat relationships: Concepts and applications. Second Edition, University of Wisconsin Press, Madison Wisconsin.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. Journal of Wildlife Management 38:541-545.

Pietz, P. J. and J. R. Tester. Habitat selection by snowshoe hares in north central Minnesota. Journal of Wildlife Management 47:686-696.

Ruediger, B., J. Claar, S. Gniadek, B. Holt, L. Lewis, S. Mighton, B. Naney, G. Patton, T. Rinaldi, J. Trick, A. Vandehey, F. Wahl, N. Warren, D. Wenger, A. Willamson. 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, Montana.

Ruggiero L. F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, J. R. Squires. 2000. Ecology and conservation of lynx in the United States. University Press of Colorado and United States Department of Agriculture, Rocky Mountain Research Station, Denver, Colorado.

Sinclair, A. R. E. and J. N. M. Smith. 1984. Do secondary compounds determine feeding preferences of snowshoe hares? Oecologia 61:403-410.

Smith, J. N. M., C. J. Krebs, A. R. E. Sinclair, and R. Boonstra. 1988. Population biology of snowshoe hares. Interactions with winter food plants. Journal of Animal Ecology 57:269-286.

Sullivan, T. P. and D. S. Sullivan. 1988. Influence of stand thinning on snowshoe hare population dynamics and feeding damage in lodgepole pine forest. Journal of Applied Ecology 25:791-805.

Telfer, E. S. 1972. Browse selection by deer and hares. Journal of Wildlife Management 36:1344-1349.

Thompson, I. D., I. J. Davidson, S. O'Donnell, and F. Brazeau. 1989. Use of track transects to measure the relative occurrence of some boreal mammals in uncut forest and regeneration stands. Canadian Journal of Zoology 67:1816-1823.

Tyers, D. B. 2003. Winter ecology of moose on the northern Yellowstone winter range. Ph.D. Dissertation, Montana State University, Bozeman, Montana.

U.S. Department of Agriculture, Forest Service. 1986. Field Instructions for Stand Examination. Timber Management Data Handbook FSH 2409.h Region 1 Chapter 400. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, Montana.

U.S. Department of Agriculture, Forest Service. 1990. CEM – a model for assessing effects on grizzly bears. U.S. Department of Agriculture, Forest Service, Missoula, Montana. Unpublished Report.

U.S. Department of Agriculture, Forest Service. 2000. Common stand exam user guide. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, Montana.

U.S. Department of Agriculture, Forest Service. 2002. Silvicultural treatment records – timber compartments 305 and 306. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, Montana. Unpublished Report.

U.S. Department of Agriculture, Forest Service. 2003. Crevice Mountain Snow Course. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, Montana. Unpublished Report.

U.S. Department of Agriculture, Forest Service and U.S. Department of Interior, Bureau of Land Management. 2004. Draft environmental impact statement for the Northern Rockies Lynx Amendment. Prepared by U.S. Department of Agriculture, Forest Service Regions 1, 2, and 4 and U.S. Department of Interior, Bureau of Land Management state offices in Idaho and Utah.

U.S. Department of Agriculture, Forest Service. 2004. Environmental Assessment for the Darroch-Eagle Creek Timber Sale. Prepared by the U.S. Department of Agriculture, Forest Service. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, Montana.

Wolfe, M. L., N. V. Debyle, C. S. Winchell, and T. R. McCabe. 1982. Snowshoe hare cover relationships in northern Utah. Journal of Wildlife Management 46:662-670.

Wolff, J. O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. Ecological Monographs 50:111-130.

_____. 1978. Food habits of snowshoe hares in interior Alaska. Journal of Wildlife Management 42:148-153.

Yahner, R. H. 1988. Changes in wildlife communities near edges. Conservation Biology 2:333-339.

Zielinski, W. J. and T. E. Kucera. 1995. American marten, fisher, lynx, and wolverine: Survey methods for their detection. General Technical Report PSW-GTR-157. Pacific Southwest Research Station, U.S. Department of Agriculture, Forest Service, Albany, California. 163 pp.

APPENDICES

APPENDIX A

VEGETATION COMPOSITION FOR EACH COVER TYPE

Table 18. Vegetation composition for each cover type. OV stands for over topped trees less than 1m tall, INT = intermediate height trees, and DOM = dominant mature trees in the canopy. ABLA is subalpine fir, PIAL is whitebark pine, PICO is lodgepole pine, PIEN is Engelmann spruce, POTR is quaking aspen, and PSME is Douglas fir. Cover types are defined in Table 1.

Cover Type	Species Present	Total Trees	Percent	Average DBH(cm)	Average Height(m)	Average Height to Crown (m)	Percent OV	Percent INT	Percent DOM
DF	PIAL	7	7.45	2.18	2.61	1.06	85.71	14.29	0.00
DF	PSME	87	92.55	22.95	15.23	7.52	6.90	24.14	68.97
LP0	ABLA	58	13.27	3.59	1.91	0.10	31.03	36.21	32.76
LP0	PIAL	62	14.19	2.29	1.26	0.11	38.71	56.45	4.84
LP0	PICO	235	53.78	5.56	3.00	0.49	21.70	27.23	51.06
LP0	PIEN	47	10.75	1.95	1.13	0.12	61.70	34.04	4.26
LP0	PSME	35	8.01	2.76	1.76	0.38	51.43	34.29	14.29
SS	ABLA	459	58.55	0.89	1.06	0.26	90.63	7.19	2.18
SS	PIAL	51	6.50	1.10	1.31	0.60	86.27	11.76	1.96
SS	PICO	83	10.59	7.91	7.02	3.92	53.01	13.25	33.73
SS	PIEN	86	10.97	5.14	3.69	0.91	55.81	27.91	16.28
SS	POTR	2	0.25	5.08	2.74	0.61	0.00	100.00	0.00
SS	PSME	103	13.14	1.63	1.52	0.82	75.73	22.33	1.94
LP1	ABLA	144	31.24	0.60	0.67	0.05	89.56	9.03	1.39
LP1	PIAL	62	13.45	2.46	1.51	0.31	48.39	51.61	0.00
LP1	PICO	201	43.60	7.51	4.60	1.29	39.30	22.89	37.81
LP1	PIEN	33	7.16	0.31	0.63	0.08	93.94	6.06	0.00
LP1	POTR	1	0.22	0.00	0.91	0.31	100.00	0.00	0.00
LP1	PSME	20	4.34	0.76	1.00	0.18	85.00	15.00	0.00

Table 18 continued.

Cover Type	Species Present	Total Trees	Percent	Average DBH(cm)	Average Height(m)	Average Height to Crown (m)	Percent OV	Percent INT	Percent DOM
LP2	ABLA	369	26.26	0.03	0.65	0.02	99.46	0.54	0.00
LP2	PIAL	869	61.85	0.13	0.49	0.05	98.62	1.15	0.23
LP2	PICO	142	10.11	16.67	13.59	8.87	4.23	31.69	64.08
LP2	PIEN	3	0.21	0.00	0.66	0.00	100.00	0.00	0.00
LP2	PSME	22	1.57	0.23	0.95	0.06	94.45	0.00	4.55
LP3	ABLA	1366	72.66	0.47	0.90	0.09	92.61	6.96	0.44
LP3	PIAL	296	15.75	0.31	0.67	0.06	96.28	3.72	0.00
LP3	PICO	104	5.53	20.52	15.35	9.20	6.73	18.27	75.00
LP3	PIEN	57	3.03	0.80	1.18	0.07	91.23	7.02	1.75
LP3	PSME	57	3.03	1.07	1.27	0.51	85.96	14.04	0.00
SF	ABLA	446	73.84	1.94	2.05	0.67	83.86	11.43	4.71
SF	PIAL	2	0.33	0.00	0.53	0.00	100.00	0.00	0.00
SF	PICO	1	0.17	40.64	25.60	7.62	0.00	0.00	100.00
SF	PIEN	155	25.66	7.31	5.65	1.65	50.32	30.97	18.71
MF	ABLA	838	81.20	1.05	1.36	0.19	86.16	12.29	1.55
MF	PIAL	69	6.69	5.45	4.14	20.7	71.01	11.59	17.39
MF	PICO	20	1.94	25.40	19.48	13.07	0.00	10.00	90.00
MF	PIEN	79	7.65	7.39	5.36	1.12	58.23	21.52	20.25
MF	PSME	26	2.52	24.62	14.53	6.87	15.38	23.08	61.54

APPENDIX B

CHI-SQUARE (X^2) SUMMARIES FOR SNOWSHOE HARE COVER TYPE USE VERSUS AVAILABILITY

Table 19. Chi-square analysis for snowshoe hare cover type use in 1999. Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	19.74	3.25	0.023	0.000-0.058	-
LP0	0.184	25.97	0.50	0.004	0.037-0.018	-
LP0/LP2	0.031	4.41	0.00	0.000	0.000-0.000	
LP0/LP3	0.009	1.32	0.00	0.000	0.000-0.000	
LP0/MF	0.022	3.15	10.00	0.071	0.010-0.132	ns
LP1	0.295	41.55	98.00	0.695	0.585-0.805	+
LP1/MF	0.037	5.18	0.50	0.004	0.000-0.018	-
LP3	0.096	13.56	12.50	0.089	0.021-0.156	ns
Meadow	0.029	4.06	0.50	0.004	0.000-0.018	-
MF	0.149	21.04	13.00	0.092	0.023-0.161	ns
SF	0.007	1.01	2.75	0.020	0.000-0.052	ns

Table 20. Chi-square analysis for snowshoe hare cover type use in 2000. Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	42.92	3.00	0.010	0.000-0.026	-
LP0	0.184	56.45	25.00	0.082	0.037-0.126	-
LP0/LP2	0.031	9.58	3.25	0.011	0.000-0.027	-
LP0/LP3	0.009	2.87	3.50	0.011	0.000-0.029	ns
LP0/MF	0.022	6.86	19.00	0.062	0.023-0.101	+
LP1	0.295	90.32	176.25	0.575	0.495-0.655	+
LP1/MF	0.037	11.27	1.00	0.003	0.000-0.012	-
LP3	0.096	29.48	36.25	0.118	0.066-0.170	ns
Meadow	0.029	8.83	2.00	0.007	0.000-0.020	-
MF	0.149	45.74	34.75	0.113	0.062-0.165	ns
SF	0.007	2.19	2.50	0.008	0.000-0.023	ns

Table 21. Chi-square analysis for snowshoe hare cover type use in 2001. Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	14.77	0.00	0.000	0.000-0.000	
LP0	0.184	19.43	14.67	0.139	0.044-0.234	ns
LP0/LP2	0.031	3.30	2.83	0.027	0.000-0.071	ns
LP0/LP3	0.009	0.99	0.00	0.000	0.000-0.000	
LP0/MF	0.022	2.36	2.00	0.019	0.000-0.057	ns
LP1	0.295	31.09	68.50	0.649	0.518-0.781	+
LP1/MF	0.037	3.88	0.00	0.000	0.000-0.000	
LP3	0.096	10.15	8.67	0.082	0.007-0.158	ns
Meadow	0.029	3.04	0.00	0.000	0.000-0.000	
MF	0.149	15.74	8.83	0.084	0.007-0.160	ns
SF	0.007	0.75	0.00	0.000	0.000-0.000	

Table 22. Chi-square analysis for snowshoe hare cover type use in 2002. Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	115.12	7.17	0.009	0.000-0.018	-
LP0	0.184	151.41	126.50	0.154	0.118-0.189	ns
LP0/LP2	0.031	25.69	8.00	0.010	0.000-0.019	-
LP0/LP3	0.009	7.69	1.50	0.002	0.000-0.006	-
LP0/MF	0.022	18.39	15.33	0.019	0.005-0.032	ns
LP1	0.295	242.27	553.50	0.673	0.627-0.720	+
LP1/MF	0.037	30.23	11.17	0.014	0.002-0.025	-
LP3	0.096	79.09	35.67	0.043	0.023-0.063	-
Meadow	0.029	23.69	1.33	0.002	0.000-0.006	-
MF	0.149	122.70	61.50	0.075	0.049-0.101	-
SF	0.007	5.88	0.50	0.001	0.000-0.003	-

Table 23. Chi-square analysis for snowshoe hare cover type use in 2003. Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	66.86	9.00	0.019	0.001-0.036	-
LP0	0.184	87.94	75.00	0.157	0.110-0.204	ns
LP0/LP2	0.031	14.92	7.50	0.016	0.000-0.032	ns
LP0/LP3	0.009	4.47	2.00	0.004	0.000-0.013	ns
LP0/MF	0.022	10.68	18.50	0.039	0.014-0.064	ns
LP1	0.295	140.71	261.00	0.547	0.482-0.611	+
LP1/MF	0.037	17.55	11.50	0.024	0.004-0.044	ns
LP3	0.096	45.93	41.50	0.087	0.050-0.123	ns
Meadow	0.029	13.76	2.50	0.005	0.000-0.015	-
MF	0.149	71.26	47.00	0.098	0.060-0.137	-
SF	0.007	3.41	2.00	0.004	0.000-0.013	ns

Table 24. Chi-square analysis for snowshoe hare cover type use for all January data (1999 – 2003). Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	137.55	10.00	0.010	0.001-0.019	-
LP0	0.184	180.91	167.33	0.170	0.136-0.204	ns
LP0/LP2	0.031	30.70	11.67	0.012	0.002-0.022	-
LP0/LP3	0.009	9.19	5.50	0.006	0.000-0.012	ns
LP0/MF	0.022	21.97	17.00	0.017	0.006-0.029	ns
LP1	0.295	289.47	589.33	0.600	0.556-0.644	+
LP1/MF	0.037	36.11	16.67	0.017	0.005-0.029	-
LP3	0.096	94.50	68.67	0.070	0.047-0.093	-
Meadow	0.029	28.31	2.33	0.002	0.000-0.007	-
MF	0.149	146.60	88.83	0.090	0.065-0.116	-
SF	0.007	7.02	5.00	0.005	0.000-0.011	ns

Table 25. Chi-square analysis for snowshoe hare cover type use for all February data (1999 – 2003). Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	57.67	7.92	0.019	0.000-0.038	-
LP0	0.184	75.84	26.50	0.064	0.030-0.099	-
LP0/LP2	0.031	12.87	7.33	0.018	0.001-0.036	ns
LP0/LP3	0.009	3.85	0.00	0.000	0.000-0.000	-
LP0/MF	0.022	9.21	22.00	0.053	0.022-0.085	ns
LP1	0.295	121.36	263.00	0.639	0.572-0.706	+
LP1/MF	0.037	15.14	2.50	0.006	0.005-0.017	-
LP3	0.096	39.62	37.00	0.090	0.050-0.130	ns
Meadow	0.029	11.87	2.00	0.005	0.005-0.015	-
MF	0.149	61.46	40.83	0.099	0.057-0.141	-
SF	0.007	2.94	2.75	0.007	0.000-0.018	ns

Table 26. Chi-square analysis for snowshoe hare cover type use for all March data (1999 – 2003). Cover types are defined in Table 1.

Cover Type	Percent Available	Number Expected	Number Observed	Percent Observed	Confidence Interval	Test Result
DF	0.140	64.20	4.50	0.010	0.000-0.023	-
LP0	0.184	84.44	47.83	0.104	0.064-0.145	-
LP0/LP2	0.031	14.33	2.58	0.006	0.000-0.016	-
LP0/LP3	0.009	4.29	1.50	0.003	0.000-0.011	ns
LP0/MF	0.022	10.26	25.83	0.056	0.026-0.087	+
LP1	0.295	135.11	304.92	0.665	0.603-0.727	+
LP1/MF	0.037	16.86	5.00	0.011	0.000-0.025	-
LP3	0.096	44.11	28.92	0.063	0.031-0.095	-
Meadow	0.029	13.21	2.00	0.004	0.000-0.013	-
MF	0.149	68.43	35.42	0.077	0.042-0.113	-
SF	0.007	3.28	0.00	0.000	0.000-0.000	-