Winter Snowshoe Hare Habitat Use Within a Silviculturally Impacted Area

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Abstract

We used snow tracking to monitor snowshoe hare (*Lepus americanus*) habitat use during winter in the Bear Creek drainage near Gardiner, Montana, from 1999 to 2003. Of nine available cover types in our study area, we found the greatest frequency of hare trails in older regenerating stands (~50-55 yrs post-harvest) of lodgepole pine (*Pinus contorta*) that had been pre-commercially thinned. The study area also contained young unthinned stands of lodgepole pine (~25-30 yrs post-harvest) and several middle-age and mature forest types. Older lodgepole stands provided a dense understory and a well-developed overhead canopy as well as plentiful food sources. These three characteristics typically define good snowshoe hare habitat within most of the Rocky Mountain region. Some studies of snowshoe hare habitat needs in portions of the Rocky Mountains indicated that pre-commercial thinning of forest stands may reduce snowshoe hare densities and thus reduce quantity of primary prey for Canada lynx (*Lynx canadensis*). Forest management strategies on USDA Forest Service lands in the Rocky Mountains based on these studies do not allow pre-commercial thinning in areas of potential lynx habitat. Our study showed that thinning portions of regenerating stands may increase the amount of time that lodgepole stands provide suitable habitat for hares.

Key words: snowshoe hare, habitat use, *Lepus americanus*, pre-commercial thinning, silviculture, Greater Yellowstone Ecosystem, forest habitat

Introduction

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 lynx, a more complete understanding of snowshoe hare ecology has also become a priority (Ruggiero et al. 2000). Currently, biologists and managers are developing management protocols to provide and protect habitat for mid-sized carnivores and their prey. The Canada Lynx Conservation Assessment and Strategy (Ruediger et al. 2000) and the Northern Rockies Lynx Amendment Draft Environmental Impact Statement (USDA Forest Service 2004a) provide the most comprehensive conservation reports to date. They include objectives, guidelines, and standards for resource management, i.e., timber management practices, for 8.4 million ha (18.5 million ac) of occupied and potential lynx habitat in Idaho, Montana, Wyoming, and Utah. These documents, by necessity, apply to large landscapes. Consequently, they may miss important regional differences in snowshoe hare habitat relations. Our research on snowshoe hare habitat use responds to a proposal by the Gallatin National Forest (GNF) to harvest timber in potential lynx habitat. Because little was known about snowshoe hare ecology in the Greater Yellowstone Ecosystem (GYE), the GNF needed baseline data to determine what effects timber sales may have on wildlife, specifically the proposed Darroch-Eagle Creek Timber Sale (USDA 2004b).

Habitat use by snowshoe hares varies greatly across North America, but most studies report that snowshoe hares favor areas with dense understory cover 1-3 m above ground level (Wolfe et al. 1982, Ferron et al. 1998, Hodges 2000). Forest understory density appears to be more important than species composition to snowshoe hares (Pietz and Tester 1983, Litvaitis et al. 1985, Hodges 2000). Although hares seek stands with dense understories, 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 Rocky Mountains consists of montane coniferous forests with well-developed understories (Hodges 2000). This combination of over and understory provides hares with an adequate food supply and protection from both avian and terrestrial predators.

The full effects of modern silvicultural practices on snowshoe hares are not clearly understood. Short-term effects of clearcutting or thinning are usually negative, forcing hares to disperse to other areas (Bull et al. 2005, Homyack et al. 2007, Griffin and Mills 2007). Some recent studies have shown that new thinning treatments may have fewer negative effects on snowshoe hares compared to traditional pre-commercial thinning practices (Ausband and Baty 2005, Griffin and Mills 2007). Sullivan and Sullivan (1988) found that hare activity actually increased immediately after thinning due to increased amounts of cover and food piled on the ground. Use of thinned sites decreased 2 years post-thinning, and unthinned stands were preferred. Several studies reported 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 successional stages (Monthey 1986, Thompson et al. 1989, Koehler 1990, Koehler 1991).

Since substantial spatial variation exists in snowshoe hare habitat use, this study offered an opportunity to observe how snowshoe hare ecology in the GYE compares to other populations in the Rocky Mountains. This information is critical to understanding the potential of the GYE to support viable lynx populations. Because this study was located in managed forests rather than wilderness, it provided critically needed data on how current silvicultural practices, especially pre-commercial thinning, affect hare habitat use.

Our study objectives were to examine snowshoe hare use of nine cover types in the study area (Table 1) and to compare snowshoe hare use of unthinned regenerating clear-cuts, thinned stands, and uncut mature stands. We conducted snowshoe hare surveys in the Bear Creek Drainage, Gardiner Ranger District beginning in January 1999.

Study Area

Our study area on the Gallatin National Forest encompassed ~11.7 km^2 between Yellowstone National Park and the Absaroka-Beartooth Wilderness. Elevation ranged from 2100 to 2600 m. Mountain peaks in the surrounding area exceeded 3100 m. Snow typically covered the study area from late October until May. Average snow pack in March over the past 60 years on nearby Crevice Mountain (2560 m) was 99 cm (USDA Forest Service, Gardiner Ranger District, Gallatin National Forest, unpublished report). Snow pack at lower elevations of the study area was considerably less.

Coniferous forests covered the majority of the study area. Douglas fir (*Pseudotsuga menziesii*) was the predominant overstory species below 2280 m elevation and covered 8 percent of the study area (Table 1). Lodgepole pine (*Pinus contorta*) predominated at elevations > 2280 m. Cover type proportions across the study area were determined from a map developed for the cumulative effects model (CEM) (USDA, cumulative effects model, Interagency Grizzly Bear Study Team, Bozeman, Montana, unpublished report). This map, routinely used by biologists in the GYE to identify habitat types, indicated that different successional stages of lodgepole pine forests covered 62 percent of the study area. Other cover types in the study area included the Engelmann spruce (*Picea engelmannii*) - subalpine fir (*Abies lasiocarpa)* type and a mixed forest type, which covered 16 and 8

Table 1. Dominant (>5% of the study area) cover types in the Bear Creek Study Area.

Cover Type	Description
Douglas fir	Old growth Douglas fir forest. Canopy is broken and the understory consists of some small to large spruce and fir.
Spruce - Fir	Mature spruce fir forest. Stands dominated by Engelmann spruce and subalpine fir in both overstory and understory.
Mixed Forest	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.
Lodgepole 0	Lodgepole pine 20-30 years post disturbance. Areas of regenerating seedlings and saplings before canopy closure created by logging between 1972 and 1977.
Lodgepole 1	Lodgepole pine 45-55 years post disturbance. Closed canopy of even-aged, usually dense, lodgepole pine. Stands were clear-cut between 1947 and 1952 and thinned in the mid 1970s.
Lodgepole 2	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.
Lodgepole 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.
Sanitation Salvage	Sanitation salvages (mature forest partially harvested during 1986). Broken old growth canopy with a dense regenerating understory dominated by lodgepole pine.
Meadow	Non-forested areas supporting primarily herbaceous vegetation at climax.

percent of the study area, respectively. The Bear Creek drainage has been subjected to extensive timber harvesting over the past 60 years with major clear-cuts created during the late 1940s and mid 1970s covering 30 percent of the study area. Sanitation salvage cuts in 1986 removed dead or dying trees but did not remove all mature trees or destroy the understory; these covered 6 percent of the area (USDA Forest Service, timber treatment records, Gardiner Ranger District, Gallatin National Forest, unpublished report). All stands harvested during the late 1940s were thinned in the early to mid 1970s. Forest understories within the study area were dominated by birch-leaved spiraea (*Spiraea betulifolia*) and snowberry (*Symphoricarpos albus*) at lower elevations whereas higher-elevation stands contained predominantly subalpine fir, whitebark pine, buffaloberry (*Shepherdia canadensis*) and twinberry (*Lonicera involucrata*).

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. Three Forest Service roads traverse the study area and are open to vehicles in the summer and used as snowmobile and ski trails during winter.

Methods and Materials

Road Track-Intercept Transects

During winters 1999-2003, we determined if snowshoe hares used each cover type in proportion to its availability along transects defined by roads through the study area. Proportions of cover types encountered along the transect did not represent proportions of cover types found across the whole study area because the route followed roads built to access cutting areas; however, the road system allowed us to efficiently replicate our trail counts throughout winter among all years. Roads were split into segments corresponding to changes in cover type (Mattson and Despain 1985). Our methods similarly followed those of Conroy et al. (1979), Monthey (1986), Thompson et al. (1989), and Tyers (2003).

From January through March each year, we traveled the 18-km route via snowmobile 24-72 hrs after each snowfall and counted sets of snowshoe hare tracks, hereafter referred to as hare trails, in each of the segments of the transect. Snowshoe hare trails were recorded each time they crossed the road. If a hare crossed the road several times in an area, it was recorded each time it crossed the road. For runways, defined as multiple trails on top each other, we tried to determine the number of times it was traveled by backtracking away from the road. Often, trails would separate a short distance. We sampled the transect route between seven and 12 times each winter from 1999 through 2003. New snow was needed to erase old trails and create a new tracking surface (Thompson et al. 1989); therefore, our sample size varied annually due to frequency of new snowfall. The number of trails counted was standardized by dividing by the number of nights since the last snowfall.

We grouped data into 11 cover type combinations to account for different cover types occurring on either side of the road and analyzed them 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 (Neu et al. 1974).

Line Transects

During winters 1999 and 2000, we used systematic 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 transects would hold for a sampling system independent of roads. The 1999 transects consisted of meandering lines that started at upper elevations in the study area and followed the fall line of the topography. Lines were independent of the road network, and segment lengths for different cover types sampled were estimated based on field notes and reconstruction of transect routes on aerial photographs. We traveled each line on snowshoes soon after a snowfall once over the course of that winter. For each cover type segment on a line, we classified snowshoe hare trail frequency into one of four categories: absent, low (occasional single trails), medium (many trails and some runways, forms, and feeding sites), or high (many undistinguishable trails and heavily used runways; forms and feeding sites were common) (Conroy et al. 1979). We chose to classify trail frequency into categories instead of counting actual trail intercepts along each line to alleviate a problem with runways where deciphering number of trails was difficult. A total of 30 lines covering 21 km were surveyed.

During winter 2000, we established a set of 51 parallel transects (Conroy et al. 1979) independent of the road network and spread over the entire study area. Endpoints of each line were marked using a GPS unit. These lines covered 390 cover-type segments and a total distance of 56 km. The system used to classify levels of hare use within the different cover type segments during 1999 was also used for this set o fline transects.

For both years we calculated the proportion of segments within each cover type where snowshoe hare trails were present (Monthey 1986). For cover types where snowshoe hare trails were observed, we also calculated the proportion of segments that contained low, medium, and high amounts of trails.

Transect Method Comparison

The consistency between cover type rankings obtained from road-based and non-road-based transect sets was examined using Spearman rank-correlation tests (Zar 1999).

Results and Discussion

Road Track-Intercept Transects

When we grouped all cover type combinations along roads within the study area into 11 categories and combined data from all winters (1999-2003), chi-square analysis showed that snowshoe hares did not use cover types in proportion to availability ($\chi^2 = 1099.89$, 10 df, $P < 0.001$). Tests of individual cover types indicated that hare use of Lodgepole 1 and Lodgepole 0/Mixed Forest (lodgepole pine regrowth ~25-30 yrs of age on one side of the road and mixed forest on the other) segments was greater than expected, while the Spruce-Fir type was used as expected. All other cover types were used less than expected (Table 2).

Small sample sizes hampered our analysis for individual years in 1999 and 2001, but general trends were apparent. Cover type use varied slightly from year to year, but Lodgepole 1 was consistently used more than other types (Fig. 1). The only consistent change over time occurred in the use of Lodgepole 0, which increased each winter from 1999 through 2003. In the first 2 years of the study, Lodgepole 0 stands were used less than expected. They were used in proportion to availability the last 3 years.

We counted hare trails in January, February, and March. Over all winters (1999- 2003), Lodgepole 1 and Lodgepole 0 contained a majority of use by hares, but use of Lodgepole 1 increased as the winter progressed; however, hare use of Lodgepole 0 stands was highest in January after which it decreased (Fig. 2).

Line Transects

Transects ran independent of the road system closely mirrored proportions of each cover type in the area based on the CEM map. During 1999 we monitored 198 cover type segments of which 82 (41%) contained snowshoe hare trails. In 2000, 193 of 390 (49%) traveled segments contained trails. All cover types except meadows contained some snowshoe hare trails during both years. In 1999, the Spruce-Fir cover type had the highest proportion of segments with trails (63% of segments) followed by Lodgepole 1 (57%), and Mixed Forest (48%). Meadows had the lowest proportion of segments with trails (0%) followed by Lodgepole 0 (5%) and Douglas fir (12%).

In 2000, the cover type with the highest percentage of segments with trails was Lodgepole 1 (77%) followed by Spruce-Fir (73%), and Mixed Forest (57%). The few segments in which whitebark pine dominated also had a high incidence of hare trails (64%). The lowest proportions of segments with trails occurred in the Meadow (0%), Douglas fir (22%), and Lodgepole 0 (26%) cover types.

Method Comparison

When we compared proportions of segments in each cover type that contained at least one hare trail using a Spearman rank correlation, the road track-intercept transect and line transect methods were correlated

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

Cover Type	Proportion Available	Number Expected	Number Observed	Proportion Observed	Confidence Interval	Test Result[a]
Douglas fir	0.140	259.42	22	0.012	0.005-0.019	-
Lodgepole 0	0.184	341.19	242	0.130	0.108-0.153	-
Lodgepole 0/1	0.031	57.89	22	0.012	0.005-0.019	-
Lodgepole 0/3	0.009	17.33	7	0.004	0.000-0.007	-
Lodgepole 0/Mixed Forest	0.022	41.44	65	0.035	0.023-0.047	+
Lodgepole 1	0.295	545.94	1,157	0.625	0.593-0.656	+
Lodgepole 1/Mixed Forest	0.037	68.11	24	0.013	0.006-0.021	-
Lodgepole 3	0.096	178.22	135	0.073	0.056-0.090	-
Meadow	0.029	53.39	6	0.003	0.000-0.007	-
Mixed Forest	0.149	276.49	165	0.089	0.070-0.108	-
Spruce - Fir	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 1. Snowshoe hare cover type use among all years.

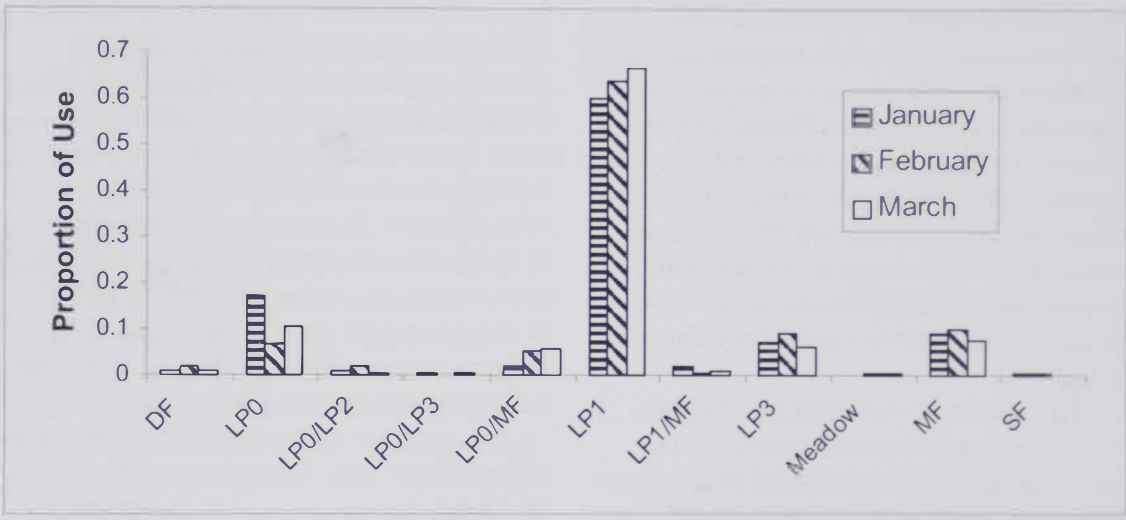

Figure 2. Snowshoe hare cover type use among months for all yers combined.

(Rs = 0.714, $P = 0.047$). Lodgepole 1 had the highest percentage of segments with trails for both methods (Table 3). Both transect types indicated that Douglas fir and Meadow were cover types least frequently used by hares. Ranking of cover types with intermediate levels of use were not consistent. The biggest discrepancy between methods was for Spruce-Fir which was probably an artifact of small sample size. The Spruce-Fir results for the road track-intercept transect were based on one short segment that was bordered on one side by a meadow. Spruce-Fir segments in the line transects were more representative of stands across the study area.

Although our experimental design precluded a definitive test of stand age and thinning vs. non-thinning as treatments (age and silvicultural treatment were confounded), both road transects and line transects indicated that Lodgepole 1 stands, which had been clear-cut ~50-55 yrs prior to our sampling and thinned 20-25 yrs after the cut, contained comparatively high levels of snowshoe hare use during winter months. These stands typically had a closed canopy within 2 m of the snow surface formed by lower limbs on regenerating lodgepole pine and abundant food in the form of accessible lodgepole limbs and palatable shrubs of other species (Zimmer 2004). Cover types

Table 3. Comparison of percentage of segments with tracks for each cover type obtained from the 2 tracking methods. Spearman rank correlation results for road track-intercept versus line transects, Rs = 0.714, P = 0.047. Cover types are defined in Table 1.

	Road Track-Intercept All Years			Line Transect Both Years		
Cover Type	Number of Sections	Percent with Tracks	Rank	Number of Sections	Percent with Tracks	Rank
Lodgepole 0	433	28.2	4	72	19.4	6
Lodgepole 1	556	51.4	1	71	69.0	1
Lodgepole 2	96	21.9	5	73	41.1	5
Lodgepole 3	245	35.9	2	59	49.2	4
Spruce – Fir	57	14.0	6	93	68.8	2
Mixed Forest	403	29.5	3	116	53.5	3
Douglas fir	177	8.5	7	31	19.4	7
Meadow	154	4.6	8	30	0.0	8

in our study area without this combination of cover and food were less heavily used by hares. Mixed Forest and Lodgepole 3 cover types had a developed overhead canopy and understory, but canopy cover between 1 and 4 m above the ground was low compared to Lodgepole 1 (Zimmer 2004. Spruce-Fir stands provided moderately dense over and understory cover, but food species frequently consumed by snowshoe hares in our study area were not abundant. Lodgepole 0 stands offered abundant food but lacked dense cover > 2 m above the ground.

The pattern of snowshoe hare habitat use we observed was 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).

From a silvicultural perspective, snowshoe hares in the Bear Creek drainage used older regenerating stands more than mature or young regenerating forests. The youngest regenerating stands showed low to moderate levels of use. Snowshoe hare use of the youngest stands declined as winter progressed possibly due to a loss of available cover as vegetation near the ground became buried under snow. Such a condition perhaps decreased availability of food or directly reduced snowshoe hare density due to over-winter mortality. Use of older regenerating stands increased as the winter progressed. Although both ages of regenerating stands provided plentiful food and thick cover near the snow surface, younger stands lacked thick cover > 2 m above the ground and thus offered only thin overhead cover during late winter when snow depths exceeded 1 m. Mature stands with moderate to very dense understories (Mixed Forest, Spruce-Fir, and Lodgepole 3) had moderate to high levels of use while open middle age and mature stands (Douglas fir and Lodgepole 2) received very little use. Meadows were seldom used by hares during winter due to a lack of food and cover.

Stand uniformity also likely influenced desirability of specific cover types as winter hare habitat in our study area. In general, Lodgepole 0 stands contained higher stem densities and greater ground cover than Lodgepole 1 stands. However, Lodgepole 0 stands typically were not uniform in density or height and often contained small pockets of shorter trees and lower stem densities. Hare use of Lodgepole 1 could be greater due to the more uniform and continuous overhead canopy (Kashain 2002) and to the characteristic of dense cover between 2 and 4 m above ground. We should note that Lodgepole 0 stands 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 late successional stages may provide optimal cover for hares over a longer period of time. Our data suggested that regenerating stands provide optimal cover for hares but only for ~20-30 years. Understory density in a lodgepole forest changes as the stand ages. After a disturbance the understory (low branches as well as shrubs) continue to develop and thicken until 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 very little regrowth occurs in the understory among 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 create a thick understory that also offers good habitat for hares.

Several studies have shown snowshoe hares prefer regenerating forest stands to mature forest types (Wolff 1980, Bittner and Rongstad 1982, Monthey 1986, Koehler 1991, Sullivan et al. 2007). These second-growth stands typically provide very dense understory cover important to hares, but the dense understory eventually opens. Exactly when and how long regenerating stands provide suitable habitat for hares will differ among regions due to variable tree growth rates or climate differences. Thinning patterns may also influence the suitability of stands for hares (Bull et al. 2005, Griffin and Mills 2007, Sullivan et al. 2007). Koehler (1991) found that 20-year-old lodgepole stands in Washington had high levels of use by hares; however, Lodgepole 0 stands in our study showed low levels of use by hares compared to other available cover types. Although these forests were of similar age post-disturbance, climatic variation likely influenced different stand characteristics . Also, we encourage caution in interpreting these cover type use results in that our efforts and those of Koehler et al. (1979) and Koehler (1991) compared hare use of a small number of available 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 what either Koehler or we observed.

In commercial forests, thinning will likely occur despite negative short-term effects on winter habitat for snowshoe hare. e.g., reduced stem densities and a more open canopy (Sullivan and Sullivan 1988). When viewed from a long-term perspective, thinning delays the self-pruning process, thus keeping understory branches intact longer. Adams (1959) suggested using light thinning in very dense stands to allow more light penetration to promote more growth of ground cover.

Logging during 1972-1976 created Lodgepole 0 stands in our study area that had not been thinned. Hare use in these stands apparently increased throughout our study. If they were thinned now, hare densities may likely remain low for another ≥10 years. However, thinning may create good hare habitat until ~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. Hares may only use these regenerating stands for ~ 25 to 30 years whether or not thinning is employed.

Conclusions

We 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 stable, long-term habitat for hares as well as for red squirrels, another important prey item of lynx; these stands also provide an abundance of denning habitat for lynx (Buskirk et al. 2000). Mature forest types with dense understories in our study area also showed moderate-to-high levels of use by hares. However, in areas where logging has and will continue to occur, managing early successional forests based on the habitat requirements of hares and lynx should continue to be a top priority. We do not advocate cutting mature stands to provide more regenerating stands for hares.

Although we identified Lodgepole 1 stands as most used by snowshoe hares, trees in this cover type were beginning to self-prune above the snow pack. These stands were logged 50-55 years prior to our study and were subsequently pre-commercially thinned to enhance tree growth. Although they received the greatest use by hares among available cover types, favorable conditions are temporally limited. For example, Lodgepole 1 stands, due to self-pruning, may no longer have lower branches ≤ 5 m of the ground within the following 10-20 years. Without these low branches, hare use will decrease substantially (~ 60 to 70 years post harvest). In contrast, Lodgepole 0 stands (~25 yrs post-harvest at the start of this study) were just beginning to develop a closed canopy > 2 m above the ground. Thus, lodgepole pine stands near our study area provide the best habitat for hares between 30 and 70 years post-harvest. 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 pre-commercial thinning within 200 ft of administrative sites or in stands that no longer provide suitable habitat for snowshoe hares (USDA 2004a). Implementing these thinning standards, at least in locations near our study area, may reduce the amount of time regenerating stands could provide beneficial habitat for hares.

We recommend a combination of thinned and unthinned stands to provide suitable habitat within regenerating forests over a longer period of time. 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 a uniform treatment. Thinning portions of a logged area juxtaposed to unthinned stands may provide hares with additional suitable habitat once the unthinned stands self-prune and no longer provide sufficient cover. This may be especially beneficial for hares in areas that lack mature forests with dense understories.

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Literature Cited

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

Ausband, D.E. and G.R. Baty. 2005. Effects of pre-commercial thinning on snowshoe hare habitat use during winter in low-elevation montane forests. Canadian Journal of Forest Research 35:206-210.

Bittner, S. L. and O. J. Rongstad. 1982. Snowshoe hare and allies. Pp. 146-163 *in* J. A. Chapman and G. A. Feldhamer, editors. Wild mammals of North America. The Johns Hopkins University Press.

Bull, E. L., T. W. Heater, A. A. Clark, J. F. Shepherd, and A. K. Blumton. 2005. Influence of precommercial thinning on snowshoe hares. Research Paper PNW-RP-562. Pacific Northwest Research Station, USDA Forest Service, Portland, OR. 16p.

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. Pp. 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 ofl ynx in the United States. University Press of Colorado and, USDA Rocky Mountain Research Station, Denver, CO.

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.

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.

Griffin, P. C. and L. S. Mills. 2007. Pre-commercial thinning reduces snowshoe hare abundance in the short term. Journal of Wildlife Management 71:559-564.

Hodges, K. E. 2000. The ecology of snowshoe hares in southern boreal and montane forests. Pp. 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 USDA Forest Service, Rocky Mountain Research Station, Denver, CO.

Homyack, J. A., D. J. Harrison, and W. B. Krohn. 2007. Effects of precommercial thinning on snowshoe hares in Maine. Journal of Wildlife Management 71:4-13.

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.

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

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

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

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

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

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. 1983. 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, and 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. USDA Forest Service Publication #R1-00-53, Missoula, MT.

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 USDA Rocky Mountain Research Station, Denver, CO.

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.

Sullivan, T. P., D. S. Sullivan, P. M. F. Lindgren, D. B. Ransome. 2007. Long-term responses of ecosystem components to stand thinning in young lodgepole pine forest: Relative habitat use by mammalian herbivores. Forest Ecology and Management 240:32-41.

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.

USDA Forest Service and USDI Bureau of Land Management. 2004a. Draft environmental impact statement for the Northern Rockies Lynx Amendment. Prepared by USDA Forest Service Regions 1, 2, and 4 and USDI Bureau of Land Management state offices in Idaho and Utah.

USDA Forest Service. 2004b. Environmental Assessment for the Darroch-Eagle Creek Timber Sale. Prepared by the USDA Forest Service. On file at Gardiner Ranger District, Gallatin National Forest, Gardiner, MT.

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.

Zar, J. H. 1999. Biostatistical Analysis. Fourth Ed. Prentice Hall Inc., Upper Saddle River, NJ. 663 pp.

Zimmer, J. P. 2004. Winter habitat use and diet of snowshoe hares in the Gardiner, Montana area. M.S. Thesis, Montana State University, Bozeman.

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