



Snowshoe Hare (*Lepus americanus*) Ecology Monitoring

Gates of the Arctic National Park and Surrounding Areas

Natural Resource Data Series NPS/GAAR/NRDS—2015/783





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ON THE COVER

A snowshoe hare rests amongst browsed vegetation along Wiseman Creek in Gates of the Arctic National Park.
Photography by Donna DiFolco

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Donna L. DiFolco

National Park Service
4175 Geist Road
Fairbanks, AK 99709-3420

Julie A.K. Maier

Institute of Arctic Biology
902 N. Koyukuk Dr.
Fairbanks, AK 99775

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Contents

	Page
Figures	iv
Tables	v
Executive Summary	.vii
Acknowledgements	.vii
Introduction	1
Study Area	3
Methods	5
Annual Track Count	5
Annual Pellet Count	5
Vegetation Descriptions & Winter Cover	5
Browse Measurements and	6
Analyses	6
Heavy Metals & Mineral Salts in Soils & Heavy Metals in Browse	7
Hare Live Trapping and Collaring	8
Results	9
Annual Track Count	9
Annual Pellet Count	9
Vegetation Descriptions	10
& Winter Cover	10
Browse Measurements and Analyses	15
Heavy Metals & Mineral Salts in Soils & Heavy Metals in Browse	19
Hare Live Trapping and Collaring	23
Discussion	27
Literature Cited	31

Figures

	Page
Figure 1. Map of snowshoe hare project study area	2
Figure 2. Snowshoe hare pellet plot grids at six sites	4
Figure 3. Relative annual deposition of snowshoe hare pellets at six sites, 2007 – 2011	9
Figure 4. Graph of vegetation strata found at pellet plots in six sites	11
Figure 5. a) Absolute densities of trees and b) total tree cover at six sites	13
Figure 6. Absolute densities of shrubs at six sites	14
Figure 7. Index of winter cover at six sites	15
Figure 8. Mean diameters at point of browse at four sites.	16
Figure 9. Mean content of tannins in willows at six sites	17
Figure 10. Mean content of tannins in alders at six sites.	18
Figure 11. Mean content of tannins in poplar at six sites	18
Figure 12. Mean content of tannins in shrub birch at six sites	18
Figure 13. Nitrogen content in four browse species at six sites	19
Figure 14. Calcium content in four browse species at six sites.	20
Figure 15. Magnesium content in four browse species at six sites	21

Tables

	Page
Table 1. Average snowshoe hare track deposition per 100 m through six vegetation types, 1997 - 2011	9
Table 2. Percentage of pellet plots that lie under a particular vegetation stratum at six study sites	10
Table 3. Percentage of plots supporting forest and shrub vegetation strata at six sites	12
Table 4. Percentage of plots supporting either graminoid or forb herbaceous strata and plots with low or dwarf shrub vegetation ("food") strata at six sites	12
Table 5. Average total number of vegetative strata, forest or shrub ("cover") vegetation strata, and low/dwarf shrub or herbaceous ("food") strata at each plot at six sites	13
Table 6. Concentrations of 19 heavy metals in soil samples collected from 11 creek banks	22
Table 7. Concentrations of the mineral salts Ca, K, Na and Cl in 11 soil samples collected from 6 sites	23
Table 8. Heavy metals found in 18 browse samples collected from six sites	24
Table 9. Results from two snowshoe hare trap sessions at Slate and Jennie sites	25

Executive Summary

This report presents the data that has been collected for the snowshoe hare (*Lepus americanus*) project since the project began in 1997 through 2011. At its inception, only track counts were conducted in the Gates of the Arctic National Park & Preserve along a section of Wiseman Creek west of Nolan. At that time, hare populations in the area were moderate and growing. Over the next few years, hare densities increased dramatically and virtually all browse within reach of hares was consumed. We began recording diameters of browsed species in 1998. In conversations with long-term area residents and through our own observations, we heard about and saw how hares visited mineral soil licks during periods of high hare densities. Not all areas had licks accessible during winter, and in these areas, it appeared that hare populations did not reach such high densities nor persist as long as in areas where hares had access to mineral licks year-round. Our site in the park was one area where hares could access mineral soil throughout the year. Soils from our study area and other surrounding areas were collected for analysis of mineral salts, and later, for heavy metals also.

By 2002, the hare population had crashed in the park. Recovery since that time has been slow, but in the meantime, we expanded the study to include five additional study sites, with two more “mineral” sites where hares have year-round access to mineral soils, and three “non-mineral” sites, where hares do not have access to

mineral soils during winter. In 2006, we established pellet plot grids at each site to monitor the hare populations using annual pellet counts. (Pellet counts were determined to be a better method for monitoring hares on a long-term basis, although the annual track count continues in the park as a legacy data set.) Data on tree and shrub densities, winter cover, and vegetation strata were collected at each site. We also are monitoring the levels of tannins and important nutrients in browse plants. Once the hare population increases sufficiently, we will also be able to monitor hare densities at two of our sites (one mineral and one non-mineral) by live-trapping.

Although we attempted to select sites for their similarity, there are differences in both the vegetative cover and the hare populations inhabiting each site. In the five years of pellet counts reported here, two of the non-mineral study sites saw a real surge (followed by a decline) in their populations, while only very small increases in hare densities have been recorded at the other sites, which otherwise remain at very low densities. Traditional Ecological Knowledge tells us that hare populations in this northernmost reach of the snowshoe hare’s range tend to have longer cycles between major peak densities, occurring roughly every 20 years rather than the 10-year cycle commonly associated with snowshoe hare populations in most of their range.

There are differences in both the vegetative cover and the hare populations inhabiting each site.

Acknowledgements

This project is indebted to the many volunteers who have helped collect data throughout the years. In addition, we would like to thank K. Kielland, of the University of Alaska Fairbanks, and his former student S. Worker, for their technical expertise and field assistance in live-trapping and collaring hares, and for sharing their data on soil consumption by snowshoe hares. We are grateful also to J. Reakoff, of Wiseman, for his guidance in the development of this project and his insight into the interrelatedness of all the components of the ecosystem in which hares play an integral role.

Snowshoe hare study
area in Gates of the
Arctic National Park and
Preserve.





Snowshoe hare tracks in Gates of the Arctic's snowshoe hare study area along Wiseman Creek, March 2009.

Introduction

In 1997, Gates of the Arctic National Park and Preserve began to monitor the snowshoe hare (*Lepus americanus*) population in a small portion of the park by counting snowshoe hare tracks (DiFolco 1997). The project was developed in response to a 5-year furbearer study that discovered unusual sex and age ratios in the lynx (*Lynx canadensis*) population in the eastern area of the park. While male lynx and juveniles are generally more prone to capture, during the winters between 1988 and 1993 trappers caught more female lynx than males and a lower proportion of juveniles to adults (Swanson 1994). The relatively low number of juveniles caught may have been an indication of lower juvenile survival. This situation could possibly be the result of food stress in the lynx population.

During the first several years of monitoring, we witnessed drastic changes in vegetation during peak years when hares were abundant. Willows were severely browsed, completely stripped of bark, and many young spruce trees were killed after being denuded of needles, bark and branches by browsing hares (DiFolco 2002). We also noticed hare trails leading to exposed mineral soil in creek banks. Long-time area residents were of the opinion that hare populations using mineral licks reached greater densities, and remained at higher numbers, than hare populations to the south which did not appear to use mineral licks. This geophagy (soil consumption) may counteract the effects of plant toxins in hares, enabling them to consume highly defended plants to a greater degree (Diamond 1998, Gilardi et. al. 1999, Dominy et.

al. 2004), and extend the duration of the population peak. A recent study by Worker (2013) that used soil collected from one of our study sites suggests that geophagy may provide essential minerals that are otherwise deficient in the diet. However, hares in areas believed to use mineral licks (as around Wiseman) appear to be lethargic, especially in spring. Additionally, lynx that feed on geophagic hares undergo unusual changes in body condition, including decreased weight (despite an abundance of hares) and abnormally dark-colored muscle tissue (Reakoff pers. comm.).

The role of geophagy in hare populations and the effect that this phenomenon may have on lynx consuming geophagic hares motivated the development of the Snowshoe Hare Ecology Project. In 2004, the National Park Service (NPS) formally initiated its collaboration with University of Alaska Fairbanks (UAF) when Dr. Julie Maier joined the project (DiFolco and Maier 2004). We expanded the study area to include five additional study sites in order to monitor hare populations and levels of key nutritional elements in browse vegetation, as well as analyze soils, in both mineral and non-mineral areas. In August 2009, the collaboration with UAF expanded to include Dr. Knut Kielland and graduate student (at that time) Suzanne Worker. This alliance resulted in the initiation of a mark-recapture study of hares at mineral and non-mineral sites, and, through a grant from the National Park Foundation, using GPS collars to track hares in a mineral area.

The role of geophagy in hare populations and the effect that this phenomenon may have on lynx consuming geophagic hares motivated the development of the Snowshoe Hare Ecology Project.

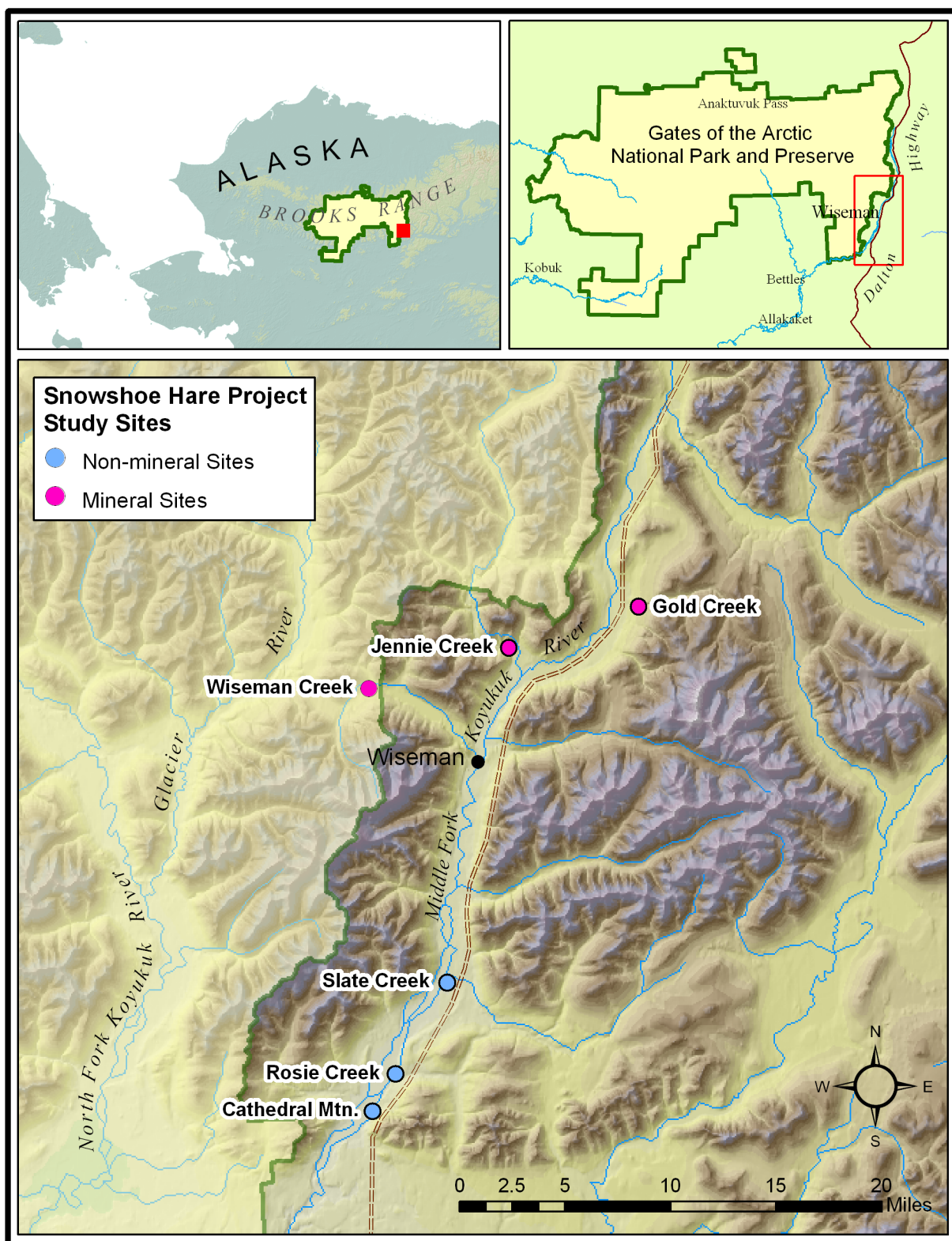


Figure 1. Gates of the Arctic National Park and Preserve lies north of the Arctic Circle in the central Brooks Range of Alaska (top left). The snowshoe hare ecology project study area is centered around the village of Wiseman, at the eastern boundary of the park (top right). The six study sites include 3 non-mineral sites south of Wiseman, and 3 mineral sites north of Wiseman.

Study Area

Gates of the Arctic National Park and Preserve is located north of the Arctic Circle (66° 33' N latitude) in the central Brooks Range, Alaska (Fig. 1, top left). Two climate zones occur in the park and preserve: the subarctic zone at lower elevations south of the continental divide and the arctic zone to the north and at high elevations. Precipitation is low within the park and preserve and yearly averages fall between 30 - 45 cm in the west and 13 - 25 cm in the north (National Park Service 1986). Snowfall averages south of the divide range between 152 - 203 cm and averages of 89 - 127 cm are typical in the north. Yearly temperatures in the south fluctuate from an average July maximum of 21° C (70° F) to an average January minimum of -34° C (-30° F). Temperatures in the north fluctuate from an average July maximum of 18° C (65° F) to an average February minimum of -23° C (-10° F) (National Park Service 1986).

Boreal forest, tundra, and shrub thicket are the major vegetation communities in the park and preserve (National Park Service 1986). The snowshoe hare study area lies in the boreal forest, which covers the southern flanks and valleys of the Brooks Range

and is composed of black spruce (*Picea mariana*), white spruce (*P. glauca*), paper birch (*Betula papyrifera*), shrub birch (*B. glandulosa*), aspen (*Populus tremuloides*), and balsam poplar (*P. balsamifera*). Willow (*Salix* spp.) and alder (*Alnus* spp.) thickets up to 3.5 m in height occur along stream channels and gravel bars. The study area lies near the eastern park boundary near Wiseman (Fig. 1, top right).

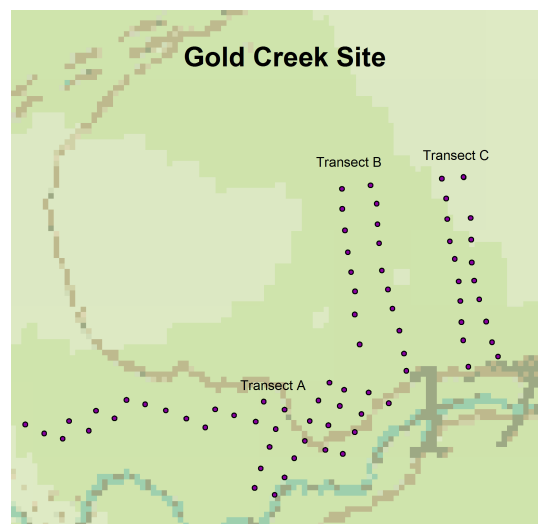
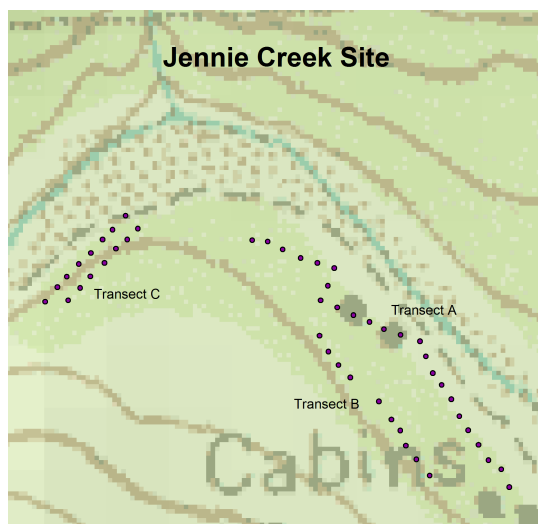
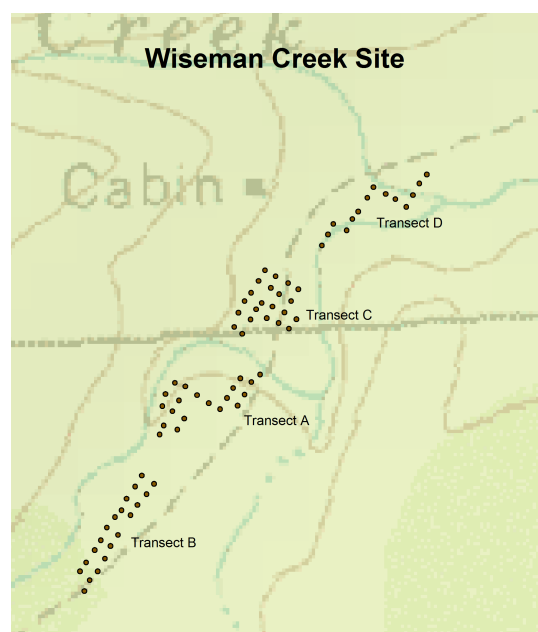
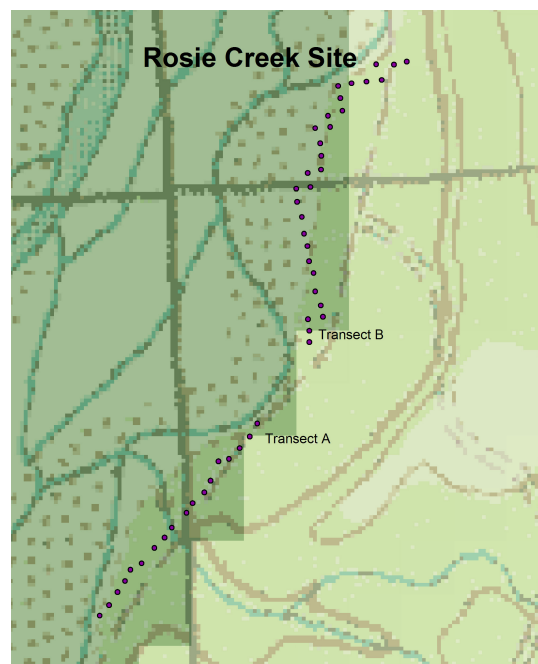
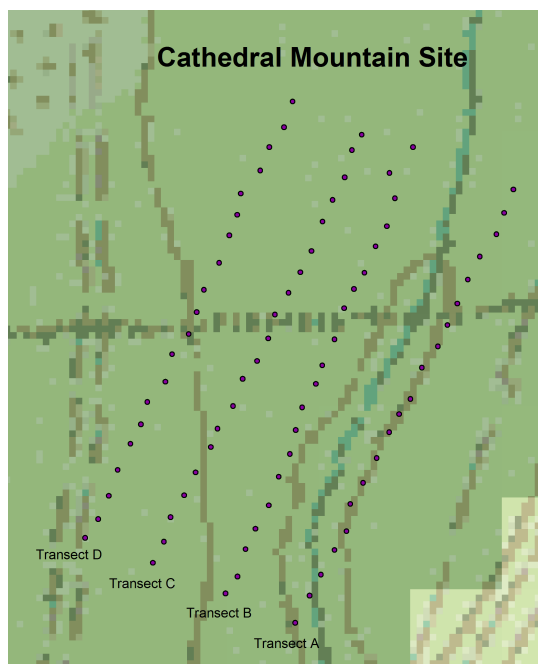
When the scope of the study expanded in 2004, we sought guidance from local area experts to help us select 5 sites in addition to the original study area in the Park. Criteria for choosing a site were based upon its history of supporting hare populations, whether its vegetation and topography were comparable to other sites, and relative ease of access. Three study sites are in areas where we believe hares do not have access to soils during the winter months ("non-mineral" areas), and three sites (including the original study area) are in areas where hares have access to soils at exposed soil banks ("mineral" areas) during winter.

Criteria for choosing a site were based upon its history of supporting hare populations, whether its vegetation and topography were comparable to other sites, and relative ease of access.



The same location as seen in June and March in the original study area along Wiseman Creek in Gates of the Arctic National Park.

Figure 2. Snowshoe hare pellet plots were established in 2006 at six sites in and near Gates of the Arctic National Park, Alaska. Plots are 25 m apart in transects that are at least 75 m apart. Grid size and shape varies with differing vegetation patterns and topography at each site.



Methods

Annual Track Count

March 2011 marked the 15th year since the initiation in 1997 of the annual snowshoe hare track count in the original study area within Gates of the Arctic National Park and Preserve. Accessing the study area partly depended on whether the Silverado Mine at Nolan was active. When it was, the Nolan road was well maintained during winter and the mine's management granted us permission to park near their airstrip at Nolan. From there, we skied or snowshoed to our study area within the park. During years when the mine was inactive and the road unplowed, we rode snowmobiles to the park boundary and then continued on skis or snowshoes into the study area. The day before the count, we brushed out all hare tracks along the route (if necessary) using leaf rakes (borrowed from a Wiseman resident). The following day, we counted all snowshoe hare tracks found along the 3.5 km survey route following the method outlined by Golden (1994). The route is comprised of six vegetation cover and composition (VCC) zones (DiFolco 1997). During years of high hare densities, we re-established 11 100-meter transects along the route (four in lightly vegetated areas, four in moderately vegetated areas, and three in densely vegetated areas). Two observers counted tracks on each side of the trail. The tallies for each side were combined into an average for each VCC.

Annual Pellet Count

In June, 2006, we established snowshoe hare pellet plots in all areas except Wiseman Creek, which we set up in July, 2006. (Suspicions that a carcass was in the area, which may have attracted a bear, persuaded us to postpone setting up the Wiseman grid for another month.) We followed the procedure outlined in Monitoring Protocols, Kluane Ecological Monitoring Project (2004 edition) for setting up snowshoe hare pellet transects. The plots are 5.08 x 305 cm (2 inches by 10 feet), covering an area of 0.155 m², oriented north-south, and marked at each end by plastic survey stakes. Plots were spaced 25 m

apart in transects that are at least 75 m apart. As the size and shape of the sites vary due to differences in topography and vegetation patterns, so the size and shape of the grids also vary (Fig. 2). The total number of plots at each site is: Cathedral: 80 plots; Rosie: 48 plots; Slate: 80 plots; Jennie: 49 plots; Gold: 75 plots; Wiseman: 76 plots. Each June since 2007 we have counted (and removed) the annual accumulation of hare pellets. We use a long band of elastic to wrap around each stake (which is 2-inches wide at the head) to define the plot boundary. A pellet must lie at least half inside the boundary to be counted. Pellets near but outside the plot boundary are tossed aside in order that they are not accidentally counted the following year. Since the number of plots per site varies, we have standardized the counts by calculating the number of pellets per plot.



Pellet plots are 2 inches wide by 10 feet long. An elastic band around the 2-inch wide stakes at each end defines the plot perimeter.

Vegetation Descriptions & Winter Cover

Vegetation strata, tree and shrub densities

We classified the vegetation strata (Viereck et. al. 1992), from canopy to ground cover, at each pellet plot in 2007. Also, in 2007 and 2008, we measured shrub and tree densities at half the plots at each site using the point-centered quarter method (Mitchell 2007). Young trees and large shrubs were considered “trees” if they were at least 3.5 cm in diameter at about 1.25 m above ground level. Confidence intervals for tree density were calculated using the formula in Mitchell (2007).

score of the four quadrants at each plot by the average distance to cover. Cover of a particular score would have a higher index if it were closer to the central point than the same cover at a greater distance. This index could then be used to compare the quality of cover at different plots and for the site overall.

Browse Measurements and Analyses

DPB measurements

We have collected diameter-at-point-of-browse (DPB) measurements since 1998, with a hiatus during the population low from 2003 to 2005 when no freshly browsed stems were observed. We began measuring

A snowshoe hare pauses within a forested area near Wiseman Creek. A modified point-centered-quarter method was used to measure winter cover for hares. Better cover received a higher rating.



Winter cover density

Winter cover density was measured in March of 2008, 2009 and 2011 using a variation of our own invention on Mitchell's (2007) point-centered quarter method. Rather than measure the distance just to the nearest tree, the distance to the nearest cover for a hare (which could be a tree or some other form of cover) was recorded in each quarter. In 2008, we described what the cover consisted of using categories, e.g. spruce tree; >1 spruce tree, poplar/birch tree, tree + brush, deadfall/snag, snow + brush, etc. If there was no cover within 5 m, the quarter was “exposed.” However, we could not quantify the quality of cover using this category system, so we devised a scoring system to measure winter cover in 2009 and 2011: 1 = cover on one quarter or overhead; 2 = cover on 2 quarters or 1 quarter + overhead; 3 = cover on 3 quarters or 2 quarters + overhead; 4 = cover on 4 quarters or 3 quarters + overhead; 5 = cover on 4 quarters + overhead (i.e. complete cover). Zero was given if there was no cover within 5 m. An index of winter cover was obtained by dividing the average

DPB again at sites where hare activity was observed beginning in 2006. DPB measurements were typically collected in a haphazard fashion while moving through a site to collect other data (e.g. winter cover data) or by moving through a site looking for signs of hares.

Nutrient & tannin analyses

To track possible changes in nutrient and tannin contents in browse plants as hare population densities change (and therefore browsing intensity) and differences in browse species between sites, we collected about 10 unbrowsed twigs from browse species including willows (*Salix* spp.), alders (*Alnus* spp.) poplar (*Populus balsamifera*) and shrub birch (*Betula glandulosa*) throughout the hare cycle. Current annual growth (CAG) <5 mm in diameter was clipped (most browse had CAG smaller than this), placed in paper bags, oven dried at 70° C, then ground in a mill with a #20 mesh sieve. In hindsight, we should have clipped browse at a uniform stem diameter, but this was

not the case, and no record was kept of the diameters of the clipped stems. In March of 2002 and 2003, prior to expanding the study area, we collected browse samples only from the Wiseman Creek site. Following the addition of the five new sites, we collected samples in June 2005 (*Salix* spp. from all sites except Rosie), March 2006 (all sites), June 2007 (only *P. balsamifera* from all but Gold), August 2007 (all sites), March 2009 (rejected stems from *Salix* spp. in Rosie, Cathedral and Wiseman sites) and March, June and August 2010 (*Salix* spp., *Alnus* spp. and *P. balsamifera* from all sites). Prior to the 2010 collections, we collected all species of willow. Since not all species were found at all sites, we did not collect certain species from each site every time. Some willow species were found only at one or two sites; therefore, in 2010 we began limiting our collections of willow to *Salix alaxensis*, a species found in all sites.

The samples collected in 2002 and 2003 were processed and analyzed for tannins and nitrogen (N) content by UAF's Dr. Rich Kedrowsky. The later samples we sent (after drying and grinding) to Washington State University's Wildlife Habitat/Nutrition Lab to obtain relative amounts of total condensed tannins, measured as the amount of

suggest that tannins may be toxic (Bryant et al. 1992). Ca is important for growth, pregnancy and lactation, while Mg is critical as a cofactor in the glycolytic cycle (Jones and Hanson 1985). Not enough Mg in the diet may lead to hypoglycemia in hares, which may lead to death.

Heavy Metals & Mineral Salts in Soils & Heavy Metals in Browse

Heavy metals in soils

In early spring of 2002 and 2003, with the help of our local area expert, Jack Reakoff, we obtained ten soil samples from exposed mineral soil banks believed to be visited by hares during peak years and one sample from an exposed bank not believed to be visited by hares. These samples were collected and analyzed before we expanded the study area to its current six sites; therefore, other than the samples collected from the original study area along Wiseman Creek in the park, the soils collected were from sites outside the current study area. We sent those 11 samples to RTI International at Research Triangle Park in North Carolina for analysis of 19 heavy metals. Analyses for aluminum (Al), arsenic (As), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), manganese (Mn),



Snowshoe hares can access soil banks like this one on Gold Creek even during the winter when their need for minerals may be the highest.

proanthocyanadine in each sample (Martin and Martin 1982), and to University of Alaska Fairbanks' Palmer Research Center to determine concentrations of N, calcium (Ca), and magnesium (Mg). Percent nitrogen gives a rough measure of the protein content in the sample, while tannins may be digestion inhibitors, although recent investigations

mercury (Hg), magnesium (Mg), molybdenum (Mo), nickel (Ni), lead (Pb), selenium (Se), strontium (Sr), vanadium (V), and zinc (Zn) was performed by inductively coupled plasma mass spectrometry (ICP-MS) and inductively coupled plasma atomic emission spectrometry (ICP-AES). Mercury was determined by cold vapor atomic absorption

(CVAA) according to the Environmental Protection Agency's (EPA) Method 7473.

Mineral salts in soils

In addition to heavy metals, soil samples also were delivered to Analytica International in Fairbanks, Alaska, for analyses of the mineral salts Ca, Mg, potassium (K), sodium (Na) and chloride (Cl). EPA Method 300.0/300.0 (Solid) was used to determine Cl content; EPA Method 6010B/3050B (Solid) was used to determine the amounts of Ca, Mg, K, and Na in the samples.

Heavy metals in browse

Three dried and ground browse samples collected in August 2007 from each site (18 total) were sent to ACZ Laboratories, Inc., in Steamboat Springs, Colorado, for analysis of the same suite of heavy metals for which soils were analyzed. One sample from each site was of *Salix alaxensis*, the only major browse species common to all sites. *Betula glandulosa* from Jennie, Wiseman, Cathedral and Gold, constituted a second sample from those sites. From Slate, the second sample was *B. papyryfera*, and from Rosie, the second sample was *Populus balsamifera*. The third sample was a mixture of *Salix* species found at each site, respectively (other than *S. alaxensis*). ICP and ICP-MS methods were used for all metals except mercury, which was analyzed using CVAA.

Hare Live Trapping and Collaring

In August 2009, we established trap grids of 30 live traps each in Slate and Jennie using Tomahawk live traps, model 106 (26 x 9 x 9 inches). Traps were spaced 50 m apart, baited with alfalfa cubes and carrots, and left open for three nights. Each day we checked all traps. Captured hares were weighed, ear tags attached, hind foot measured and gender determined, and then released. After checking traps, processing and releasing captured hares on the third day, we closed all traps and propped them upright or hung them from a tree (to facilitate relocating the traps during winter). We conducted a second, four-night trap session in early June 2010.

In February 2010, five GPS collars for tracking hare movements near mineral licks were purchased using a small grant from the National Park Foundation. The 30 g Micro Mini Collars, manufactured by Telemetry Solutions, have battery power to last about a month, depending on how many fixes per day it is programmed to acquire. We programmed the collars to collect 12 fixes per day (once every 2 hours) with the expectancy that the battery would last about 20 days. We trapped four nights in late April 2010 at Jennie Creek in an effort to deploy the collars, although only one hare was captured. We attempted to locate, and retrieve if possible, the GPS collar during the early June trapping session using hand-held telemetry equipment.

NPS Volunteer and (then) UAF graduate student Suzanne Worker hauls 7 live traps to Jennie Creek site. Thirty traps were set up at each of 2 trap grids to estimate hare densities, as well as to document other population parameters such as body condition, recruitment, and survival.



Five 30-gram GPS collars for monitoring snowshoe hare movements near mineral licks were purchased with a small grant from the National Park Foundation.

Results

Annual Track Count

Since 1997, track counts along Wiseman Creek in the park have indicated wide swings in hare numbers, from moderate to high densities, followed by a crash to very low densities. Since 2003, the Wiseman Creek hare population has been low, with only a



A snowshoe hare track in fresh snow. Rarely were conditions this ideal. During peak years, we found that counting tracks became increasingly difficult as hares travelled along previously tracked snow.

Table 1. Average snowshoe hare track deposition per 100 m through six vegetation cover and composition (VCC) types, 1997 through 2011, along Wiseman Creek in Gates of the Arctic National Park, central Brooks Range, Alaska. VCC code: D=dense vegetation; M=moderate vegetation; L=light vegetation; W=willows; P=poplars; S=spruce; B=shrub birch; A=alder.

VCC	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
L-SB	0.7	12.5	4.7	0.2	6.2	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.2	0.0
L-WA	1.0	9.2	1.0	0.9	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
M-SW	3.8	28.0	31.8	10.0	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.1	2.1	0.0	0.0
M-SPW	12.7	37.0	42.9	21.8	15.1	1.9	0.2	0.0	0.0	0.0	0.0	2.0	3.0	0.3	0.0
D-WS	21.8	77.8	59.6	28.6	14.9	2.0	0.0	0.0	0.0	0.0	4.3	0.0	24.2	0.0	0.0
D-WPS	28.5	63.0	67.2	22.5	26.5	6.7	0.1	0.0	0.0	0.0	0.0	1.9	15.0	0.0	0.0
Total	68.4	227.5	207.2	83.9	82.6	10.6	0.3	0.0	0.0	0.0	4.3	4.0	44.5	0.5	0.0

slight increase in density in 2009. We recorded only a few tracks in 2003, and in 2004 through 2006, no hare tracks were observed. We began seeing signs of hares again in 2007, and by 2009, hare tracks had become more common. By March 2011, however, we again counted no tracks (Table 1).

Annual Pellet Count

The fifth annual pellet count was conducted in June 2011. The number of pellets counted at all sites increased between 2007 and 2008, most markedly at Rosie. The following year, most sites had fewer pellets, indicating a decrease in hare densities, except at Cathedral and Slate, where we counted more pellets than previously. By 2009, the 3 mineral sites (Wiseman, Gold and Jennie) had fewer pellets deposited per plot than at the 3 non-mineral sites, although Slate (a non-mineral site) had only slightly more pellets per plot than the mineral sites. In 2010,

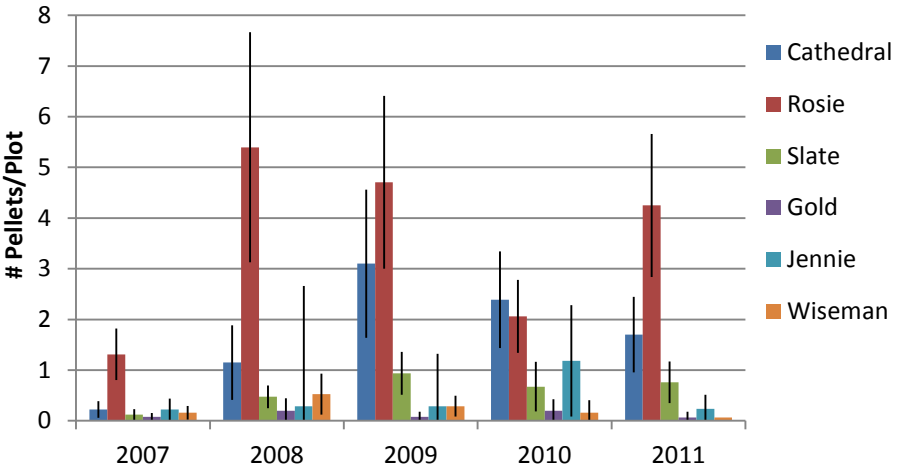


Figure 3. Relative annual deposition of snowshoe hare pellets (in number of pellets per plot, with 95% confidence intervals) at six sites, snowshoe hare project in the central Brooks Range near Wiseman, Alaska, 2007 - 2011.

Jennie saw a substantial bump in the number of pellets counted while Rosie's pellet count dropped considerably. By 2011, Rosie had rebounded somewhat, but the other sites either remained relatively the same or slightly lower (Fig. 3).

Vegetation Descriptions & Winter Cover

Vegetation strata

Vegetation strata at the six study sites fell into 27 classes: 11 classes of forests and woodlands, 7 types of scrub vegetation, 4 classes of herbaceous vegetation, a category each for mosses and lichens, and 3 categories of non-living ground cover, including litter (Table 2, Fig. 4, and Appx. 1). Not all strata were present at each site. Needleleaf and/or mixed needleleaf and broadleaf forests comprised the greatest proportion of forest or woodland strata at all six sites. Gold proved to be the most homogeneous site in regard to forest canopy, with 57.3% of plots under an open needleleaf forest and 105.3% of plots

under some kind of forest/woodland strata (5.3% were in dwarf tree scrub woodland, which lay beneath a taller forest/woodland strata). Slate supported nine of the 11 forest/woodland strata, with no one particular strata found at more than 25% of plots; however, most were classed as either open or closed mixed needleleaf and broadleaf forest, and the combined total of forest/woodland strata was 88.8% of all plots. Jennie was the least forested site, with a total of 75% of plots in eight of the 11 forest/woodland strata. Rosie was unique in that it supported more broadleaf than needleleaf forest. Cathedral and Wiseman were both heavily forested (98.8% and 97.4% total, respectively) but Cathedral was dominated more by needleleaf forest/woodland while Wiseman supported more

Table 2. Percentage of pellet plots that lie under a particular vegetation stratum at six study sites. Totals are greater than 100% due to the layering of several strata at any one location. Snowshoe hare project, central Brooks Range, near Wiseman, Alaska.

SITE	Needleleaf Forest			Broadleaf Forest			Mixed Forest			Dwarf Tree		Tall Scrub	
	Closed needleleaf forest	Open needleleaf forest	Needleleaf woodland	Closed broadleaf forest	Open broadleaf forest	Broadleaf woodland	Closed mixed forest	Open mixed forest	Mixed woodland	Open dwarf tree scrub	Dwarf tree scrub woodland	Closed tall scrub	Open tall scrub
Cathedral	8.8	32.5	11.3	0.0	2.5	0.0	11.3	30.0	0.0	2.5	0.0	40.0	56.3
Rosie	4.2	2.1	2.1	8.3	18.8	0.0	39.6	12.5	0.0	0.0	0.0	54.2	43.8
Slate	1.3	21.3	10.0	0.0	2.5	0.0	18.8	25.0	3.8	3.8	2.5	5.0	51.3
Wiseman	0.0	19.7	10.5	1.3	3.9	1.3	5.3	32.9	18.4	2.6	1.3	1.3	40.8
Jennie	0.0	12.5	18.8	2.1	2.1	4.2	0.0	20.8	10.4	0.0	4.2	14.6	45.8
Gold	5.3	57.3	26.7	0.0	0.0	0.0	1.3	9.3	0.0	0.0	5.3	0.0	25.3

SITE	Low Scrub		Dwarf Scrub			Graminoids & Forbs				Mosses & Lichens		Litter	Mineral	
	Closed low scrub	Open low scrub	Dryas dwarf scrub	Ericaceous dwarf scrub	Willow dwarf scrub	Mesic graminoid herbaceous	Wet graminoid herbaceous	Dry forb herbaceous	Mesic forb herbaceous	Mosses	Lichens	Litter	Rocks	Silt
Cathedral	51.3	41.3	2.5	70.0	5.0	13.8	0.0	0.0	62.5	77.5	5.0	26.3	0.0	0.0
Rosie	25.0	58.3	0.0	12.5	0.0	8.3	0.0	0.0	87.5	20.8	0.0	72.9	0.0	2.1
Slate	7.5	63.8	0.0	46.3	0.0	41.3	1.3	1.3	43.8	62.5	2.5	17.5	0.0	1.3
Wiseman	15.8	81.6	3.9	61.8	2.6	43.4	0.0	0.0	52.6	72.4	21.1	42.1	0.0	0.0
Jennie	39.6	41.7	8.3	83.3	2.1	22.9	4.2	0.0	12.5	66.7	8.3	22.9	2.1	0.0
Gold	12.0	80.0	13.3	90.7	5.3	28.0	0.0	0.0	22.7	58.7	54.7	0.0	0.0	20.0

mixed needleleaf and broadleaf forest/ woodland.

While forest and woodland strata varied considerably among sites, all six sites were similar in the amount of scrub (brush) found. At least 25% of plots at all sites were covered in tall (over 1.5 m) scrub and over 40% of plots lay under low scrub (Table

2). Ericaceous dwarf scrub (e.g. blueberry, Labrador tea) was dominant at most sites (the exception being Rosie, which had only 12.5% of plots under Ericaceous scrub), as was moss (again, Rosie being the outlier, with only 20.8% in moss).

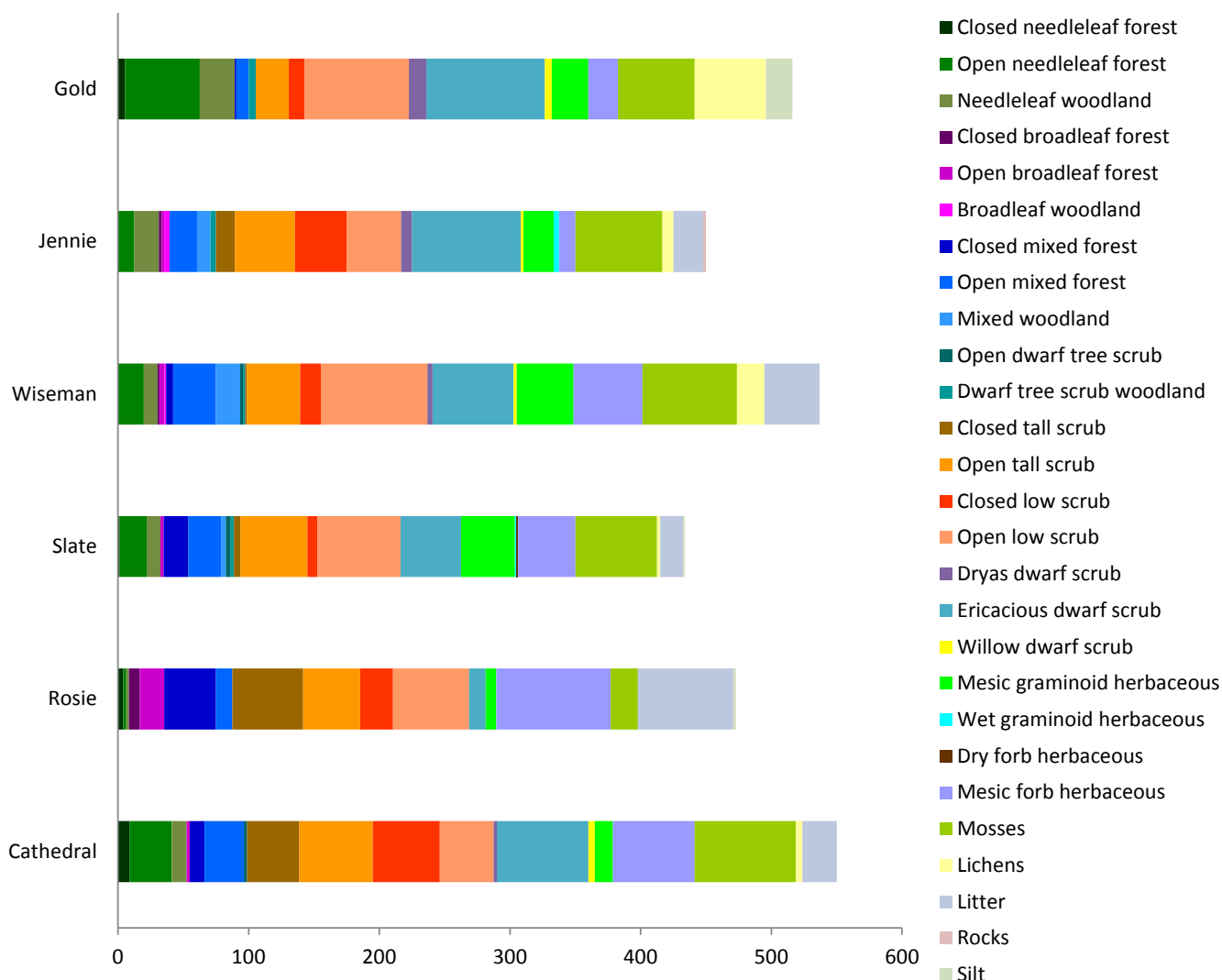


Figure 4. A graphical representation of the data in Table 2, showing the vegetation strata found at pellet plots in six sites within the snowshoe hare study area, central Brooks Range near Wiseman, Alaska. Amounts are shown as a percentage of all plots at each site (e.g., 5.3% of all plots at Gold were under closed needleleaf forest).

Focusing on strata that provide cover for snowshoe hares—trees and shrubs—we see that while Gold had 100% of its plots with some type of tree stratum, and 62% of plots were under needleleaf forest, only 6.7% of plots at Gold were under a closed forest canopy (Table 3). Rosie, which had 87.5% of plots under trees, and 52.1% of the tree canopy was of closed forest, is dominated by broadleaf forest and thus only 6.3% of its tree cover was in needleleaf forest (either open or closed). Dwarf tree, tall and low shrubs (those over 20 cm), which also provide cover for hares, varied from 191.3% of plots at Cathedral to 122.7% of plots at Gold.

Vegetation strata that provide food for hares, mainly lower stature shrubs and herbaceous plants, are summarized in Table 4. (While tall shrubs can also provide food for hares, especially during winter, these strata were not included in these calculations.) Most sites supported well over 100% of their plots

in low and/or dwarf scrub, the notable exception being Rosie. Even with the addition of herbaceous strata, Rosie supported considerably fewer of the “food” strata. Wiseman came out on top with a combined total of 261% of plots in herbaceous and lower shrub strata. Looking strictly at shrubs, Jennie, which seems to trail in most strata tallies, had the second highest percentage of lower shrub cover behind Gold.

Looking at the complexity of vegetation strata, Cathedral supported the greatest number of vegetation layers, with an average of 5.5 strata/plot, while Slate had the fewest layers at 4.3 strata/plot (Table 5). The distribution between “cover” strata and “food” strata varied between sites, with most having slightly more cover strata; Wiseman and Gold were the reverse, supporting more “food” strata than “cover” strata.

Table 3. Percentage of plots supporting forest and shrub (“cover”) vegetation strata at six study sites, snowshoe hare project, central Brooks Range near Wiseman, Alaska. Dwarf tree scrub strata were included in scrub vegetation group rather than tree strata group. Totals may be greater than 100% due to the layering of several strata at any one location.

Site	All Tree Strata	Closed Forest	Open + Closed Needleleaf	Dwarf Tree + Tall + Low Scrub
Cathedral	96.3	20.0	41.3	191.3
Rosie	87.5	52.1	6.3	181.3
Slate	82.5	20.0	22.5	133.8
Wiseman	93.4	6.6	19.7	143.4
Jennie	70.8	2.1	12.5	145.8
Gold	100.0	6.7	62.7	122.7

Table 4. Percentage of plots supporting either graminoid or forb herbaceous strata and plots with low or dwarf shrub vegetation (“food”) strata at six study sites, snowshoe hare project, central Brooks Range near Wiseman, Alaska. Totals may be greater than 100% due to the layering of several strata at any one location.

Site	Graminoid+Forb Herbaceous	Low+Dwarf Scrub	Combined Herb+ Low+Dwarf Scrub
Cathedral	76.3	170.0	246.3
Rosie	95.8	95.8	191.7
Slate	87.5	160.0	247.5
Wiseman	96.1	165.8	261.8
Jennie	39.6	175.0	214.6
Gold	50.7	201.3	252.0

Table 5. Average total number of vegetative strata, forest or shrub ("cover") vegetation strata, and low/dwarf shrub or herbaceous ("food") strata at each plot at six study sites, snowshoe hare project, central Brooks Range near Wiseman, Alaska.

Site	#Strata/Plot (Range)	#CoverStrata/Plot	#FoodStrata/Plot
Cathedral	5.5 (2-9)	2.9	2.5
Rosie	5.5 (2-9)	2.7	1.9
Slate	4.3 (1-7)	2.2	2.1
Wiseman	5.4 (3-7)	2.4	2.6
Jennie	4.5 (1-7)	2.2	2.1
Gold	5.2 (3-8)	2.2	2.5

Tree and shrub densities

Absolute density and total tree cover offer slightly different views of the forest canopy at each site (Fig. 5). For tree cover, the basal area of trees is taken into account in addition to proximity to a central point, and perhaps paints a more realistic picture of tree cover throughout the study area. While both tree density and tree cover at Rosie are roughly double that of the other sites due to the number of poplars in addition to spruce there, tree cover at Wiseman, Cathedral, Slate and Gold are quite similar, averaging just over 15 m² per hectare. Cathedral makes up for a lower tree density with its relatively larger trees, resulting in greater tree cover that surpasses that of both Slate and Gold. Jennie, as we saw in the vegetation strata data, is less forested, having about half the tree density and tree cover as most the other sites. Scatter plots showing distances to nearest trees at each of the six study sites can be found in Appx. 2.

While Rosie stood out in tree density, Cathedral proved to be the brushiest site by about double the number of shrubs per hectare as all other sites (Fig. 6). Blueberry, prickly rose and willows made up much of the bulk of shrubs at most sites (Rosie notably lacking in blueberry). Gold and Jennie were about equally brushy, but with different proportions of shrub species, followed by Rosie, Wiseman and Slate.

Hare winter cover densities

We measured winter cover using the rating system at 64% of all pellet plot locations. Rosie, which by far had the highest density of trees of all sites, also had the highest index for winter cover, although not by as great a

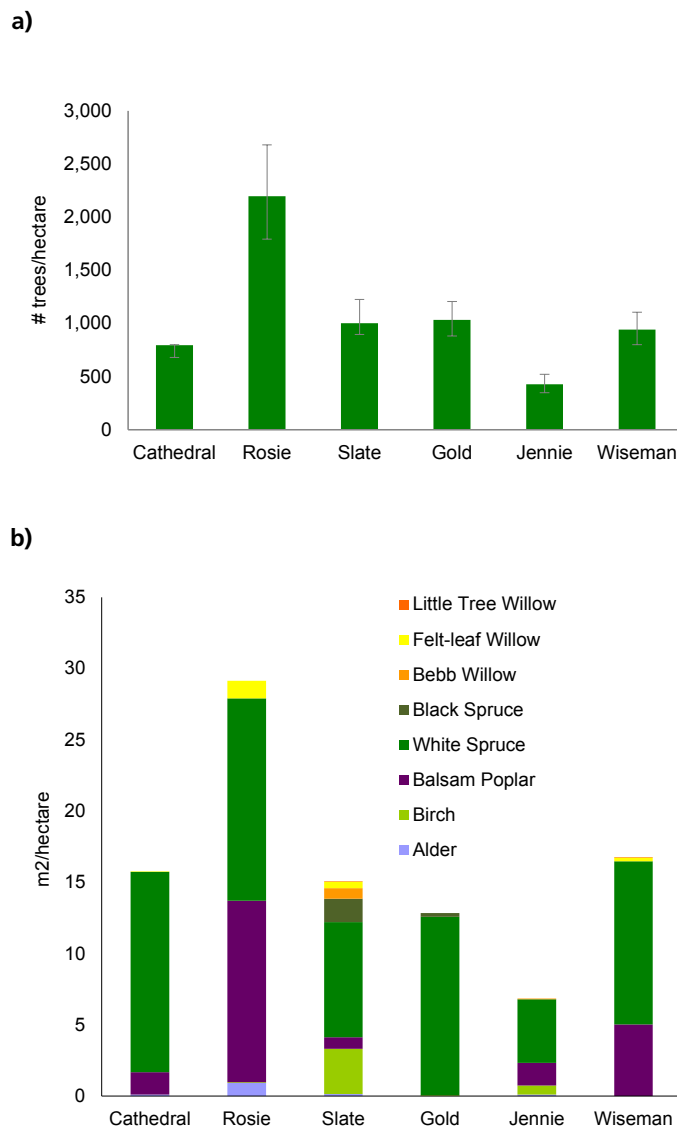


Figure 5. a) Absolute densities of trees (all species) per hectare (with 95% confidence intervals), and b) total tree cover (basal area in m²) per hectare, including tree species composition, at six sites in the snowshoe hare study area, central Brooks Range near Wiseman, Alaska.

Three vegetation strata can easily be seen in this photo taken along the trail into the Wiseman site: open needleleaf forest (bordering the trail), open low scrub and mesic graminoid herbaceous. Tree density at Wiseman was typical for most sites in the snowshoe hare study area, while shrub density was lower there than at most sites.

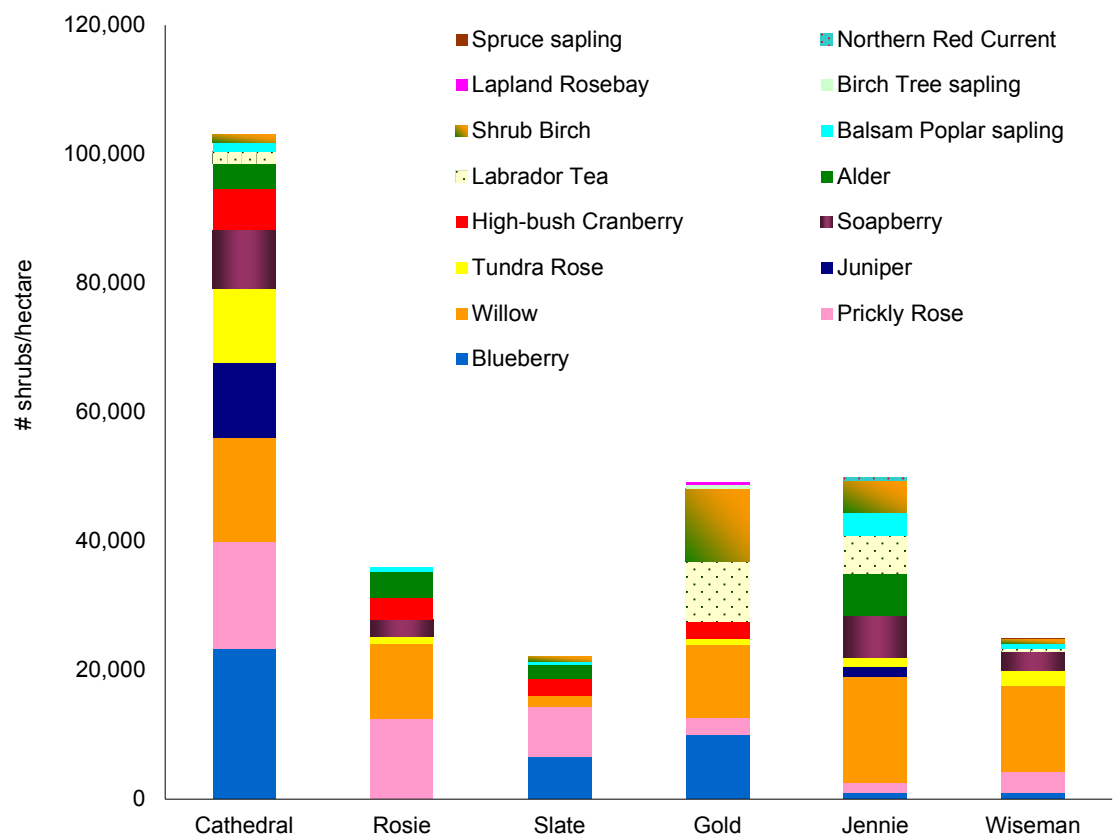


Figure 6. Absolute densities of shrubs at six sites, including shrub species composition, in the snowshoe hare study area, central Brooks Range near Wiseman, Alaska.

margin (Fig. 7). Wiseman, Cathedral, Slate, Gold, and finally Jennie were next, in descending order, with Jennie having just over half the amount of winter cover as Rosie. Since the scoring of winter cover takes into account the size of trees, thickness of brush, amount of overhead cover, and the presence or absence of cover from snow (e.g. snow

bowls under large spruce trees), results from winter cover may be a more equitable comparison of cover (at least in winter) between sites than tree density. However, cover from snow (in snow bowls or on overhanging vegetation) varies throughout the season and from year to year as the amount of snowfall varies.

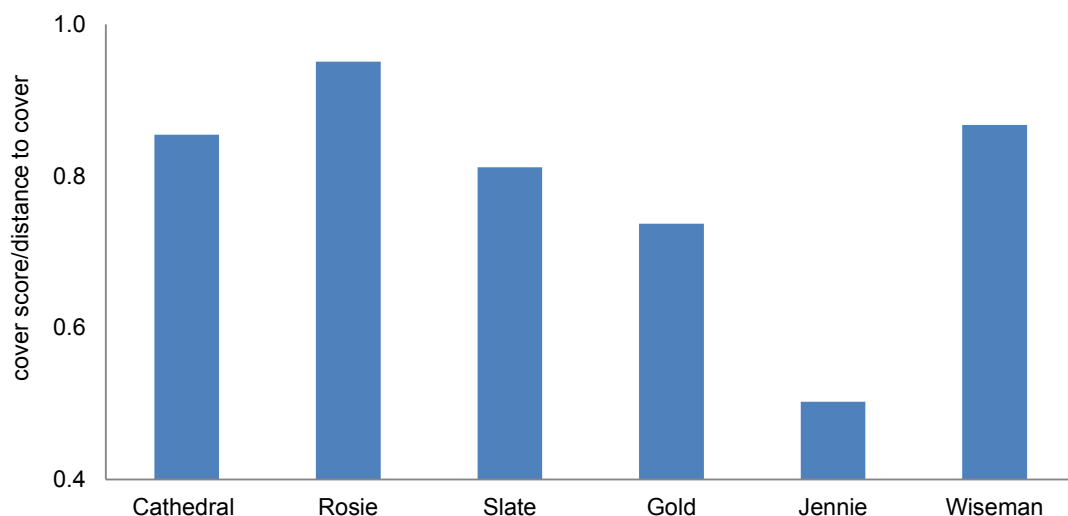


Figure 7. Index of winter cover at six sites in the snowshoe hare study area, central Brooks Range near Wiseman, Alaska. Winter cover was obtained using a variation on the point-center-quarter method of measuring density. For each point, distances to the nearest cover for hares in each of four quadrants was rated for quality of cover on a scale of 0 to 5. An index to winter cover at each point was calculated by dividing the average cover score by the average distance to cover in each quadrant. The higher the index, the better the cover for hares in that area.



Winter cover in many places is commonly comprised of mounds of snow over brush where a hare would be visually concealed from at least one direction (left). Sometimes hares may find cover under overhanging brush or deadfall where they could be completely out of site to predators (above). This sort of cover changes throughout the season and from year to year as the amount of snowfall varies.

Browse Measurements and Analyses

DPB measurements

We have measured the diameter at point of browse on 3,207 stems since 1998. From 2003 through 2005 we did not collect any dpb measurements due to lack of hare sign in the area. In 2006, two years after we expanded the study area to include the five additional study sites, we found a few willow stems to measure at Slate, but did not observe browsing the following year. In 2008, we found signs of hare browsing at all sites except Jennie; in 2009, we measured browsed stems at all but Jennie and Gold; in 2010, all sites except Gold; and in 2011, we measured stems at all sites but Wiseman and Jennie.

Among sites, willow species are the most

consistently browsed vegetation. Of the four sites where most dpb data has been collected (Fig. 8) alder, shrub or paper birch, white spruce, prickly rose and balsam poplar also have been observed browsed, but these species are not as ubiquitous as willows, nor are they browsed as consistently. During the hare population's peak years in the Wiseman site, not only willows were severely browsed, but also balsam poplar, white spruce and alder. Since then however, we have a consistent record of browsing (if any) only on willow and, to a lesser degree, alder.

Mean diameters of browsed stems in 1998 to 2002—the peak years in the snowshoe hare population—at the Wiseman site ranged from 2.2 mm for shrub birch to 6.6 mm for willows (Fig. 8). Measurements of stem diameters varied greatly. The maximum diameter recorded was a 17.0 mm willow

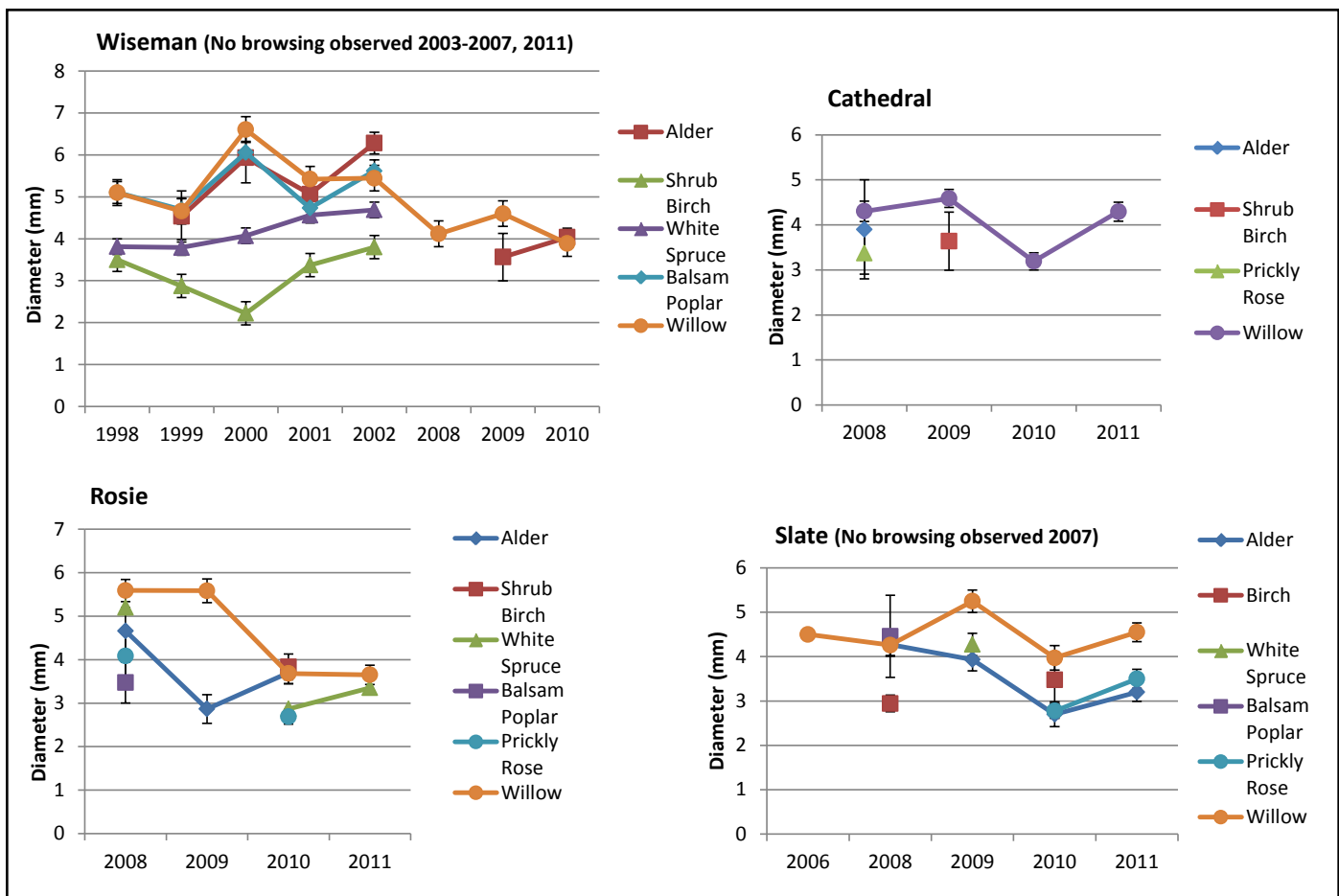


Figure 8. Mean diameters (in mm, $\pm$ standard error) at point of browse from browse species found in the original study area (Wiseman Creek) and three of the five sites added in 2004. Not included are Jennie and Gold, where we have collected little data: At Gold, mean dpb for *Salix* spp. was 3.2 ($\pm$ 0.12) mm in 2008, and 2.4 ($\pm$ 0.19) mm in 2011. At Jennie, mean dpb was 2.9 ($\pm$ 0.12) mm for *Salix* spp. and 3.2 ($\pm$ 0.20) mm for *Alnus crispa* in 2010. Snowshoe hare project, central Brooks Range near Wiseman, Alaska.



Hare-browsed stems of spruce sapling, prickly rose, downed white spruce tree and willows.

stem browsed in 2000 at the Wiseman site when browsing was extremely severe. Some measurements may under-represent the size of stems recorded during this time due to the fact that most of the bark (and some of the wood also) had been chewed off most stems. Since 2002, browsing of shrub birch, white spruce and poplar has not been observed there, and mean dpb has been 4.6 mm or less in willows and alder. Since we incorporated the additional study sites, most hare browsing in the study area has been observed in the non-mineral sites (Cathedral, Rosie and Slate) (Fig. 8).

Nutrient and tannins analyses: Tannins
 Since 2002, we have had 607 browse samples analyzed for total condensed tannins. Tannin levels in willows (*Salix* spp.) from Wiseman in March 2002 and 2003 were considerably higher than in March 2006 or March 2010, both at Wiseman and in comparison to the other sites (with the exception of Rosie in March 2010, whose confidence interval overlaps with those from the earlier Wiseman levels, Fig. 9). Willow stems collected at Wiseman in March 2003 were even higher than rejected twig tips found there and at Rosie and Cathedral

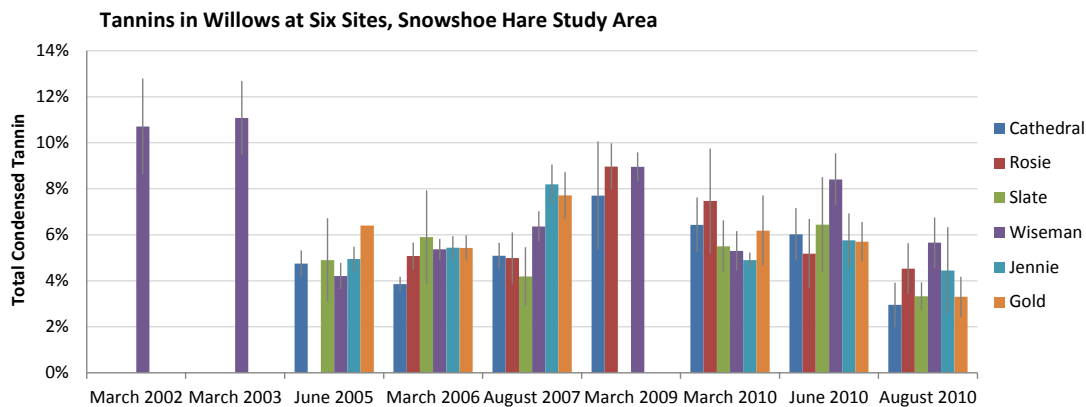


Figure 9. Mean concentrations of total condensed tannins (with 95% C.I. bars) in willow (*Salix* spp.) twigs collected from six study sites in the snowshoe hare study area near Wiseman, Alaska. Five additional study sites were added to the original study area (Wiseman) in 2004. Samples collected in March 2009 were of rejected stems.

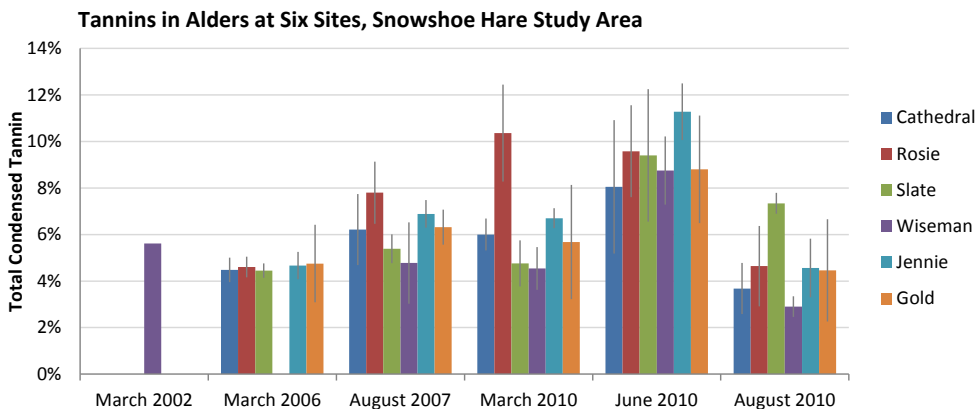


Figure 10. Mean concentrations of total condensed tannins (with 95% C.I. bars) in alder (*Alnus* spp.) twigs collected from six study sites in the snowshoe hare study area near Wiseman, Alaska. Five additional study sites were added to the original study area (Wiseman) in 2004.

during the mild increase in the hare population in March 2009. The concentrations of tannins increased at the mineral sites and at Cathedral between March 2006 and August 2007. By June 2010, tannins had increased even further in Wiseman but had dropped in Jennie and Gold. Tannin levels between June 2005 and June 2010 were about the same or slightly greater in 2010 for all sites (no samples were collected from Rosie in 2005). By August 2010, the concentrations of tannins in willows and alders had, for the most part, decreased at most sites.

On a seasonal basis, tannins in alders (*Alnus* spp.) were roughly the same at all six sites (Fig. 10). The exception was at Rosie where tannin levels jumped in March 2010 following two years of relatively high hare numbers (refer to Fig. 3). By June 2010, tannin levels in alders at all sites had increased to similar levels, but then (with the exception of alders at Slate) decreased significantly by August that same year.

The amount of tannins in balsam poplar (*Populus balsamifera*) often varied widely (Fig. 11). At Wiseman, tannin levels have increased since the post-peak period of 2002-2003. Tannin levels at Cathedral also have increased since we first collected poplar samples there in June 2007.

Percent tannin in shrub birch (*Betula glandulosa*) was about the same in August 2007 at Wiseman as it was post-peak in March 2002 (Fig. 12). While tannin levels in shrub birch appear to be variable during March 2006, they were fairly consistent between sites in August 2007.

Nutrient and tannins analyses: Nitrogen, calcium & magnesium

Concentrations of nitrogen (N) in willows and alders shifted seasonally, being highest in June, lowest in March, and intermediate in August (Fig. 13). Poplar also exhibited seasonal shifts, although we had greater variability among samples, result-

Figure 11. Mean concentrations of total condensed tannins (with 95% C.I. bars) in poplar (*Populus balsamifera*) twigs collected from six study sites in the snowshoe hare study area near Wiseman, Alaska. Five additional study sites were added to the original study area (Wiseman) in 2004.

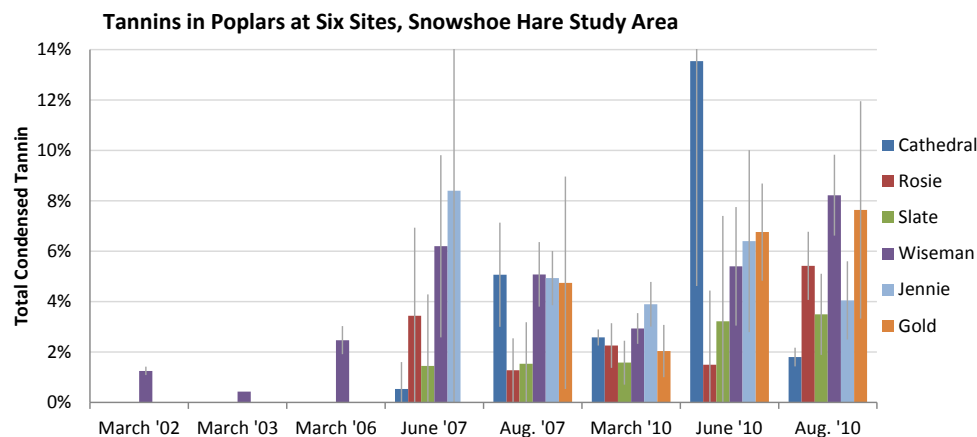
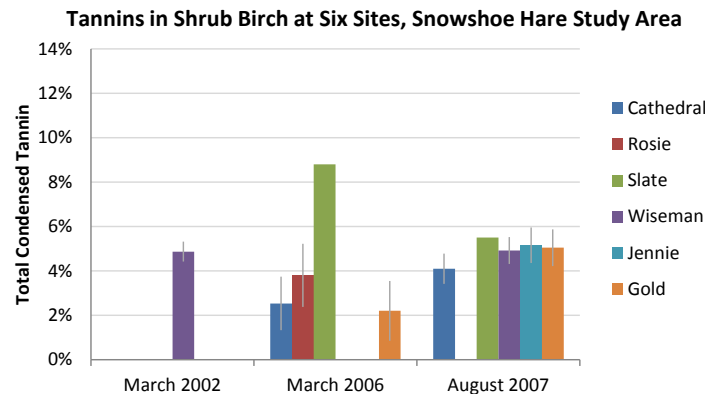


Figure 12. Mean concentrations of total condensed tannins (with 95% C.I. bars) in shrub birch (*Betula glandulosa*) twigs collected from six study sites in the snowshoe hare study area near Wiseman, Alaska. Five additional study sites were added to the original study area (Wiseman) in 2004.



ing in overlapping confidence intervals in some sites between seasons. While we had only two seasons of shrub birch collections analyzed for N, concentrations followed the same pattern as other species, having higher concentrations of N in August than in March at all sites.

Seasonal trends were also noted in calcium (Ca) (Fig. 14), although they were not as clearly defined as for N. The highest concentrations of Ca in willows were in August, the lowest in March; Ca levels in willows in June overlapped at some sites with either the March or August levels. Poplar and alder had greater variability than willow both within the species and among sites each sea-

son. Ca values for shrub birch August 2007 were lower than for other species that same time.

Values for magnesium (Mg) also were lowest in March (Fig. 15). Mg levels were higher in June and August, although we had overlapping confidence intervals between these two seasons at most sites.

There are no consistent differences between sites in N, Ca, or Mg, with the possible exceptions of relatively higher N concentrations in poplars at Slate during June and August 2010, and higher concentrations of Mg at Gold in willows in August 2007 and alder in August 2010.

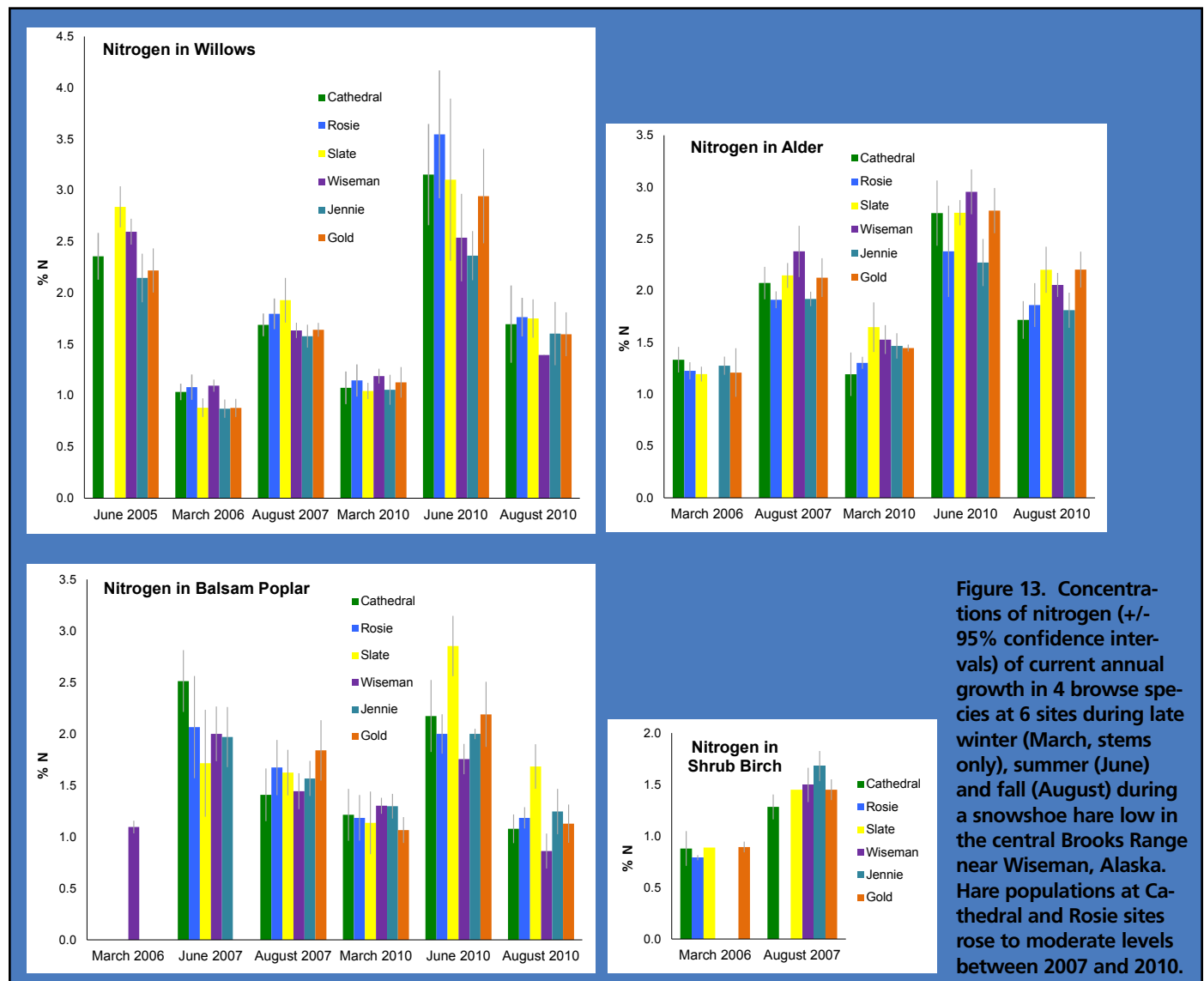


Figure 13. Concentrations of nitrogen (+/- 95% confidence intervals) of current annual growth in 4 browse species at 6 sites during late winter (March, stems only), summer (June) and fall (August) during a snowshoe hare low in the central Brooks Range near Wiseman, Alaska. Hare populations at Cathedral and Rosie sites rose to moderate levels between 2007 and 2010.

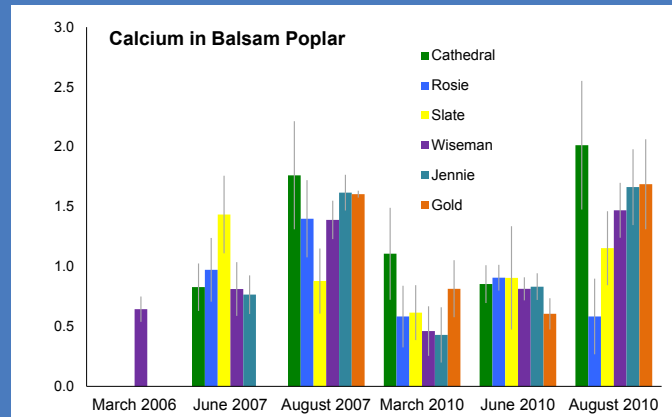
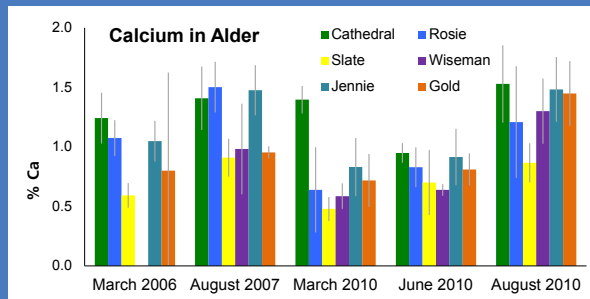
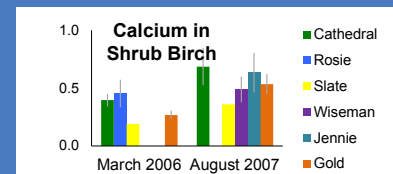
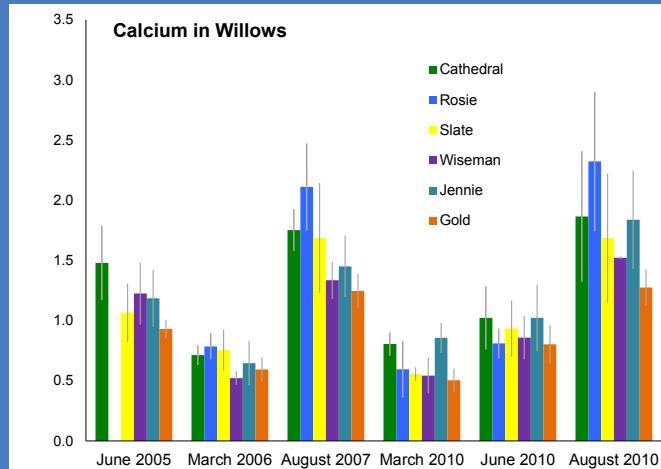


Figure 14. Concentrations of calcium (+/- 95% confidence intervals) of current annual growth in 4 browse species at 6 sites during late winter (March, stems only), summer (June) and fall (August) during a snowshoe hare low in the central Brooks Range near Wiseman, Alaska. Hare populations at Cathedral and Rosie sites rose to moderate levels between 2007 and 2010.



Clipping browse for analysis in March.

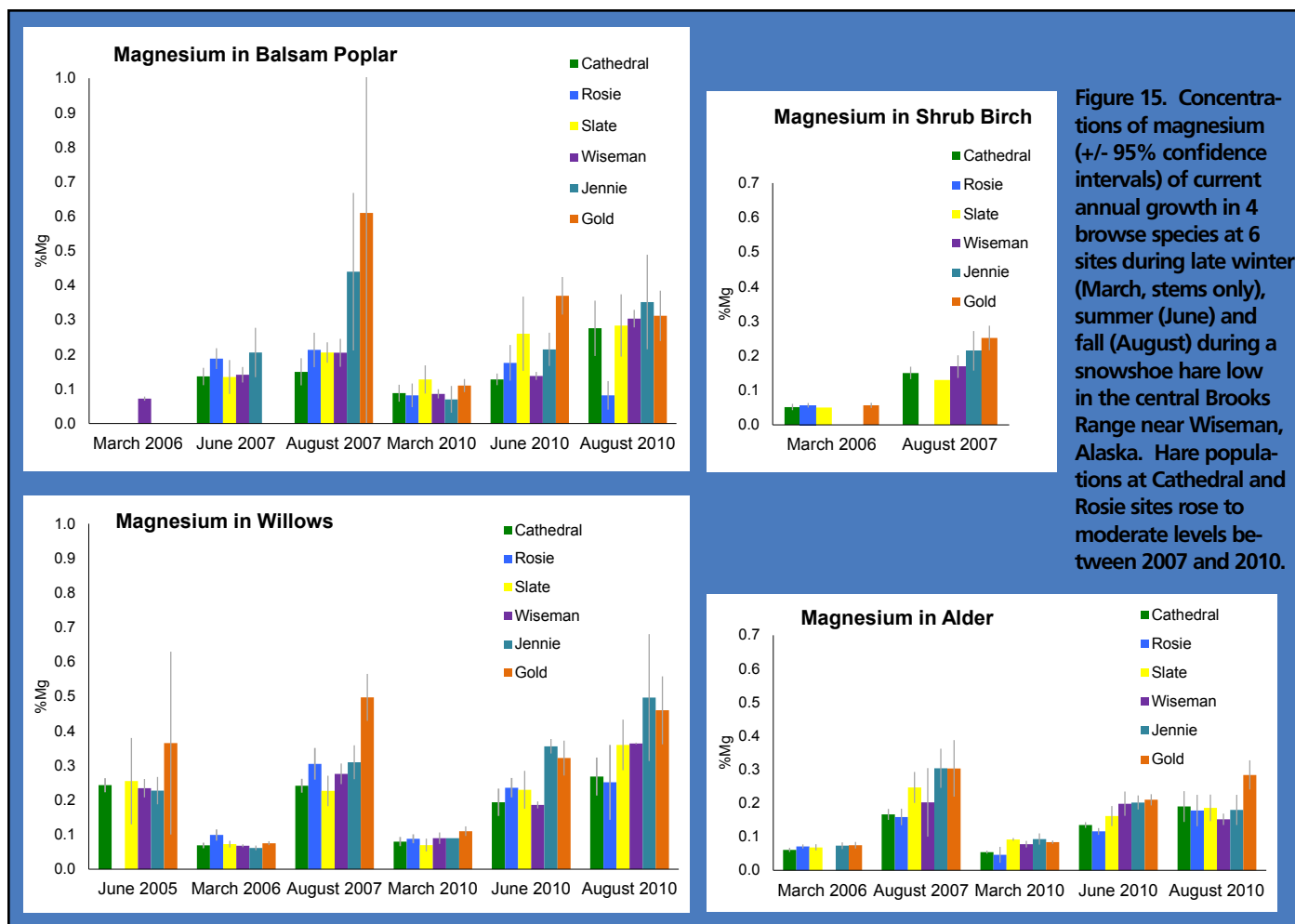


Figure 15. Concentrations of magnesium (+/- 95% confidence intervals) of current annual growth in 4 browse species at 6 sites during late winter (March, stems only), summer (June) and fall (August) during a snowshoe hare low in the central Brooks Range near Wiseman, Alaska. Hare populations at Cathedral and Rosie sites rose to moderate levels between 2007 and 2010.

Heavy Metals & Mineral Salts in Soils & Heavy Metals in Browse

Heavy metals in soils

Of the 19 heavy metals for which soil samples were analyzed, iron comprised the greatest amount, followed by magnesium and aluminum, with manganese being the fourth most abundant metal (Table 6). Five heavy metals—copper, nickel, strontium, vanadium, and zinc—were found in relatively moderate abundance in our soil samples,

mostly at concentrations between 20-100 ug/g (Table 6). Nine were present in small amounts (mostly under 20 ug/g) in at least some of the samples: arsenic, boron, barium, beryllium, cadmium, chromium, mercury, molybdenum, and lead (Table 6). Mercury was found in four of the 11 samples, molybdenum was found in three samples, and beryllium was found in just one sample. Only one of the 19 metals, selenium, was not detected in any of the samples analyzed (Table 6).

Table 6. Concentrations (ug/g) of 19 heavy metals in soil samples collected from 11 creek banks in and near the snowshoe hare study area near Wiseman, Alaska. All samples except Marion Creek were collected in areas considered “mineral” areas, where hares consume mineral soils during peak population densities. MDL = minimum detection level.

Element	MDL	Wiseman Creek 1	Wiseman Creek 2	Jennie Creek	Buckeye Gulch	Vermont Creek	Canyon Creek
Al aluminum	50.00	11,058.33	6,640.60	9,322.38	2,898.26	12,600.04	13,877.26
As arsenic	0.50	12.69	13.82	27.11	3.31	18.86	12.23
B boron	2.00	3.76	3.04	5.38	7.12	7.59	4.66
Ba barium	0.50	11.92	11.55	15.15	34.03	6.05	5.01
Be beryllium	0.10	<MDL	<MDL	<MDL	0.16	<MDL	<MDL
Cd cadmium	0.20	2.19	1.69	2.84	1.79	2.60	2.93
Cr chromium	0.50	11.49	6.47	9.82	1.71	7.21	8.56
Cu copper	0.50	31.60	29.45	57.21	17.33	44.04	48.36
Fe iron	25.00	26,506.63	18,817.55	31,806.67	17,246.62	33,052.83	41,412.92
Hg mercury	0.02	0.32	<MDL	0.02	0.06	<MDL	<MDL
Mg magnesium	25.00	8,548.46	5,316.44	8,790.60	6,101.40	19,869.42	15,226.09
Mn manganese	1.00	635.70	492.96	2,070.46	1,333.73	1,951.56	1,449.34
Mo molybdenum	0.50	0.51	<MDL	0.52	<MDL	<MDL	<MDL
Ni nickel	0.50	31.95	26.98	33.88	36.83	31.20	29.79
Pb lead	0.50	6.38	7.33	11.12	1.97	8.54	6.99
Se selenium	0.50	<MDL	<MDL	<MDL	<MDL	<MDL	<MDL
Sr strontium	0.50	65.25	99.96	133.11	34.27	85.59	105.19
V vanadium	0.50	28.08	17.10	21.83	8.31	20.36	24.54
Zn zinc	1.00	65.17	46.42	74.85	49.98	63.37	70.59

Table 6, cont’d.

Element	MDL	Hammond Canyon	Washington Creek 1	Washington Creek 2	Washington Creek 3	Marion Creek
Al aluminum	50.00	4,320.56	15,035.03	15,402.45	6,043.06	9,158.02
As arsenic	0.50	6.58	11.26	8.10	8.99	13.06
B boron	2.00	5.80	7.26	5.28	<MDL	4.04
Ba barium	0.50	0.87	18.26	5.18	10.10	10.77
Be beryllium	0.10	<MDL	<MDL	<MDL	<MDL	<MDL
Cd cadmium	0.20	2.09	3.17	2.98	1.81	2.25
Cr chromium	0.50	<MDL	14.20	11.56	2.26	10.46
Cu copper	0.50	22.44	42.47	32.79	36.85	31.16
Fe iron	25.00	27,864.95	43,329.98	42,276.98	26,525.25	30,050.77
Hg mercury	0.02	<MDL	0.02	<MDL	<MDL	<MDL
Mg magnesium	25.00	22,008.00	10,737.57	10,325.15	5,813.30	4,759.68
Mn manganese	1.00	772.35	1,015.93	966.68	1,474.84	323.31
Mo molybdenum	0.50	<MDL	<MDL	<MDL	<MDL	0.68
Ni nickel	0.50	23.89	31.67	29.34	24.25	31.99
Pb lead	0.50	3.03	8.87	6.11	7.11	6.57
Se selenium	0.50	<MDL	<MDL	<MDL	<MDL	<MDL
Sr strontium	0.50	104.99	31.03	15.58	34.40	6.31
V vanadium	0.50	19.09	28.00	25.63	9.73	19.26
Zn zinc	1.00	51.98	77.62	76.52	42.78	85.51



A local area expert says that hares utilize this large Hammond River bluff near Jennie Creek during their population peak. While hares likely receive nutritional benefits from by supplementing their diets with essential minerals found in lick soils, exactly how this complex matrix affects hare health is not yet fully understood.

Mineral salts in soils

Ten soil samples were analyzed for five mineral salts: sodium (Na), Ca, Mg, potassium (K) and chloride (Cl). In all samples, Na, K and Cl were generally found in lower quantities relative to Ca and Mg, which frequently had concentrations several orders of magnitude greater (Table 7).

Heavy metals in browse

Of the 19 heavy metals for which browse samples were analyzed, concentrations of Mg were by far the greatest. Manganese concentrations varied widely, from 20.8 - 1,010 mg/km, but in general was found in concentrations greater than most other

metals, as was zinc (Table 8). Metals found in moderate abundance in browse were iron, strontium, barium, boron, aluminum, nickel and copper (Table 8). Cadmium had the greatest concentrations of the more rare heavy metals in browse, with lead, molybdenum, chromium and selenium being even less abundant. Chromium and cadmium were detected in 17 of 18 samples; molybdenum and selenium were detected in six out of 18 samples (Table 8). Four heavy metals—arsenic, beryllium, mercury and vanadium—were not detected in any of the samples.

Table 7. Concentrations (ug/g) of the mineral salts calcium, potassium, magnesium, sodium and chloride found in 11 soil samples collected from 6 sites in the snowshoe hare study area in the central Brooks Range near Wiseman, Alaska. MRL = minimum recording level.

Location	Calcium	Potassium	Magnesium	Sodium	Chloride
Slate forest	1,900	1,400	7,300	<MRL	19.5
Slate creek bank	2,000	1,000	6,700	<MRL	15.4
Rosie forest floor	13,000	880	9,700	260	no data
Rosie creek bank	4,600	570	6,300	130	no data
Cathedral slough	62,000	1,100	12,000	<MRL	21.8
Cathedral forest	21,000	1,400	12,000	<MRL	18.3
Gold top terrace	32,000	700	7,900	<MRL	14.6
Jennie big bluff	3,980	1,010	12,000	253.0	22.7
Wiseman Poplar transect	28,800	566	9,660	26.1	10.3
Wiseman Dense transect	22,500	482	8,890	22.1	14.2
Wiseman Brush ck bank	6,800	940	9,300	<MRL	16.2



Salix alaxensis is a favored browse species of snowshoe hares found at every site in the study area. Hares can obtain most of their mineral needs from browse. Some heavy metals are also found in browse.

Table 8. Heavy metals found in 18 browse samples collected from six sites in the snowshoe hare study area in the central Brooks Range near Wiseman, Alaska. Samples labelled #1 are *Betula glandulosa* for Cathedral, Gold, Jennie and Wiseman; #1 is *Populus balsamifera* for Rosie and *B. papyrifera* for Slate. Samples #2 are *Salix alaxensis*. Samples #3 are mixed *Salix* species found at each site other than *S. alaxensis*. Arsenic, beryllium, mercury and vanadium were also included in the analysis but were not detected in any of the samples. MDL = minimum detection level.

	Aluminum	Barium	Boron	Cadmium	Chromium	Copper	Iron	Lead
(MDL)	(3)	(0.3)	(1)	(0.05)	(0.05)	(0.3)	(2)	(0.05)
Cathedral #1	6	48.1	14	0.21	0.11	4.3	35	0.19
Cathedral #2	20	3.3	15	2.00	0.23	5.1	98	0.25
Cathedral #3	8	3.3	11	0.73	0.12	3.4	36	0.34
Gold #1	8	4.5	15	0.06	0.09	3.5	31	0.16
Gold #2	10	0.8	18	0.40	0.17	4.8	48	0.37
Gold #3	11	1.1	19	0.83	0.15	5.6	56	0.37
Jennie #1	8	13.1	9	0.07	0.08	4.5	41	0.15
Jennie #2	7	1.7	22	2.65	0.10	5.0	38	0.68
Jennie #3	10	3.5	16	1.69	0.10	4.0	41	0.30
Rosie #1	13	3.9	7	0.94	0.10	6.7	49	0.19
Rosie #2	14	5.1	8	0.97	0.10	4.0	65	0.29
Rosie #3	8	17.9	9	0.47	0.06	3.2	39	0.24
Slate #1	27	59.1	7	0.46	0.13	9.0	107	0.23
Slate #2	17	9.0	9	1.93	0.08	3.5	57	0.34
Slate #3	27	17.4	5	1.62	0.07	3.4	61	0.21
Wiseman #1	4	3.2	6	<MDL	<MDL	3.1	17	0.08
Wiseman #2	5	1.5	9	0.81	0.09	2.9	31	0.36
Wiseman #3	5	2.5	10	1.37	0.10	3.0	27	0.54

Table 8, cont'd.

	Magnesium	Manganese	Molybdenum	Nickel	Selenium	Strontium	Zinc
(MDL)	(20)	(0.5)	(0.3)	(0.3)	(0.05)	(1)	(1)
Cathedral #1	2,630	411.0	<MDL	1.3	0.09	26	254
Cathedral #2	2,940	115.0	0.6	1.1	0.07	45	157
Cathedral #3	2,270	20.8	0.3	1.1	<MDL	41	120
Gold #1	2,540	120.0	<MDL	2.7	<MDL	18	145
Gold #2	4,460	44.4	<MDL	1.6	<MDL	31	117
Gold #3	5,150	94.0	0.3	4.7	<MDL	34	146
Jennie #1	1,730	261.0	<MDL	6.5	<MDL	13	94
Jennie #2	3,030	120.0	0.4	1.2	<MDL	39	501
Jennie #3	3,360	114.0	0.4	1.4	0.05	43	222
Rosie #1	940	28.0	<MDL	2.0	<MDL	25	202
Rosie #2	1,930	22.9	<MDL	1.4	0.23	35	83
Rosie #3	2,550	22.7	0.6	1.1	<MDL	44	76
Slate #1	2,180	1,010.0	<MDL	18.6	<MDL	18	154
Slate #2	2,180	64.9	<MDL	4.4	<MDL	27	168
Slate #3	1,320	359.0	<MDL	5.9	<MDL	19	166
Wiseman #1	1,010	55.0	<MDL	2.3	<MDL	10	78
Wiseman #2	2,860	60.3	<MDL	2.3	0.08	37	46
Wiseman #3	2,430	48.2	<MDL	6.2	0.21	50	66

Hare Live Trapping and Collaring

In August 2009, we captured nine individuals during three trap nights at Slate; two of these were recaptured. Since there were so few recaptures, no reliable estimate of hare density could be made (Table 9). During the June 2010 trapping session, only one hare was caught at Slate.

The attempt to deploy the five GPS collars at Jennie in late April 2010 was minimally successful in that only one hare was captured. This was the same individual that had been caught during the previous trap session in August 2009. However, when we returned in early June to retrieve the collar, the radio receiver could not pick up a signal from the collar and neither hare nor collar was retrieved. Due to continuing low hare densi-



Then UAF graduate student Suzanne Worker releases a snowshoe hare at Slate in August 2009 after marking it with ear tags.

ties at Jennie Creek, we have suspended live-trapping activities until the hare population has recovered sufficiently before attempting to deploy more collars.

Table 9. Results from two snowshoe hare trap sessions at Slate and Jennie sites, 27-29 August 2009 and 4-7 June 2010, snowshoe hare project in central Brooks Range near Wiseman, Alaska.

Date	Site	#Captures	#Recaptures	Pop. Size	S.E.
Aug. '09	Slate	11	2	16	0.4
Aug. '09	Jennie	1	0	-	-
June '10	Slate	1	0	-	-
June '10	Jennie	0	0	-	-

Discussion

This report presents the data collected on the snowshoe hare populations and their habitats in the eastern border area of Gates of the Arctic National Park and Preserve near the village of Wiseman from 1997 through 2011. The project continues to be ongoing at the time of this writing. In addition to monitoring the local hare populations in different areas, much of the data collected—vegetation strata, tree and shrub densities, winter cover, soil and browse analyses—has been to compare and contrast the six study sites. Of course, every site is unique in its own way, but a better understanding of the differences may help explain some of the variation we find in the hare populations at each site.

The track count conducted in the park during the early years of the study was supplemented by pellet counts when the study area was expanded. The decision to use pellet counts at the new sites rather than additional track counts was due to the fact that track counts, while adequate for monitoring hare populations at low densities, seemed to grossly underestimate the number of hares in an area when hare densities peaked. This is due to the fact that hares tend to follow trails so that after a few passes it is impossible to tell exactly how many hares have passed by. Also, the snow becomes very hard once disturbed and lighter animals like hares leave very little imprint.

The long low period we are currently witnessing in our area of the central Brooks Range has been observed here before by long-time Wiseman resident Jack Reakoff (pers. commun.), who testifies that the snowshoe hare cycle between large peaks in the Wiseman area tends to be 18-20 years rather than the 10-year period typically observed in more southerly snowshoe hare populations (Keith 1983; Powel et. al. 2013). Our data are confirming that observation, although there did appear to be a mid-point, roughly 10-year increase in population densities in some areas, which may be interpreted as a minor “peak” in hare density.

Monitoring hare populations through pellet counts in six different areas since 2007 has shown us how variable local hare populations can be. Like at the Wiseman site in the park, hare populations at the other mineral sites, Jennie and Gold, also have remained very low, although Jennie, too, saw a brief “blip” in its pellet count in 2010. On the other hand, pellet counts in the two most southern sites, Cathedral and Rosie, both non-mineral sites, indicated notable increases in hare numbers relative to the other four sites since pellet counts began. Rosie in particular has had many times the number of pellets/plot as the mineral sites and the other non-mineral site, Slate, which has seen some gains relative to the near zero levels observed at the mineral sites, but has remained well below the level of pellets/plot counted at Rosie and Cathedral. Since we did not initiate pellet counts until after the hare populations in these areas had crashed following the last major peak, we have no data from an earlier peak density period with which to compare. Hare density data from other areas, however, suggest that the densities of hares found in our study area during

Every site is unique in its own way, but a better understanding of the differences may help explain some of the variation we find in hare populations.



the portion of the study reported here have been comparable to areas with less dense hare populations. In the Northwest Territories, Canada, hare densities in 13 areas from 1988 to 2011 (converted from pellet data using Krebs’ 2001 log-log regression formula) range in “peak” years from about 1.5 hares/ha to over 5 hares/ha. Using the

Co-author Dr. Julie Maier searches for snowshoe hare pellets in a plot at Gold.

same formula, the density of hares at Rosie in 2008 was only 1.34 hares/ha, which is similar to that found at Kluane, Yukon Territory, during the last “peak” there in 2006 (Krebs et. al 2013). This comparison assumes that Krebs’s (2001) formula used in Yukon and NWT is appropriate to use for hare populations in the Brooks Range. Bear in mind that hare population “high” or “peak” is a relative term. At Bonanza Creek outside Fairbanks, the hare population reached densities of about 5 to 6 hares per hectare during the last peak phase in 2008-2009 (Kielland et. al. 2010), whereas the concurrent population “peak” in Tetlin Wildlife Refuge was less than 1 hare per hectare (Krebs et. al. 2013).

Our attempt to determine hare density more accurately through live-capture mark and recapture was thwarted by the decline (rather than increase) in hare densities after 2009. However, now that the logistical obstacles of obtaining live traps and transporting them into the study area are done, we are prepared to re-establish live-trapping grids once the hare population rebounds.



The “dead zone” can be easily seen as a strip of bare gray trunks and branches between the live green vegetation near Wiseman Creek in June 2004 following a substantial snowshoe hare peak in that area.

An extra-long, 18-20-year period between major hare population peak densities in the Brooks Range may be at least partially explained by the condition of browse and/or the amount of cover available coupled with the timing of an increase in predatory pressure. Even after seven years of very low hare densities, hares along Wiseman Creek were rejecting willows containing relatively high levels of total condensed tannins. In the Tanana and Chena river valleys in interior

Alaska, Bryant et. al. (1985) recorded only a 2-3 year time lag following the reversion of *Salix alaxensis* twigs to juvenile form, during which time twigs were unpalatable to hares, before relaxing to an adult form twig, which hares favor. In 2009—at the same time as the partial recovery of hare populations at most of our sites—lynx began returning to the area, arriving from the south where hare populations were more abundant, and hunting in areas where hare populations were rebuilding (J. Reakoff, Wiseman trapper, pers. commun.). For the hares, unpalatable food (as indicated by rejected browse tips), combined with increased predation, and perhaps exacerbated by inadequate cover in some areas, may have presented too great an obstacle for the small hare populations at our mineral sites to overcome, causing a return to very low densities.

The lack of tree cover at Jennie Creek may partially explain why the small “bump” in the hare population there in 2010 quickly disappeared when lynx arrived in the area that winter (J. Reakoff, Wiseman trapper, pers. commun.). While Jennie supports the least amount of tree cover of any of the sites and has only a moderate cover of shrubs, this apparently sub-optimal habitat experienced extremely high hare densities during the last major peak in hare densities in the area in 1998-2001, as evidenced by the abundant remains of hare-killed spruce saplings. The area likely was used heavily only when hare populations in neighboring habitats with better cover became too crowded and over-browsed. It was during this period of intense browsing that Reakoff (pers. commun.), who traps in the area, noticed snowshoe hare trails leading directly to large bluffs along the Hammond River where hares apparently were consuming the exposed soils.

At the non-mineral sites, hares at Rosie and Cathedral maintained relatively moderate numbers (compared to the other sites) through 2011 following their modest peaks in 2008 (at Rosie) and 2009 (at Cathedral) despite the presence of lynx, and despite the higher levels of tannins in the browse. (However, our methods may have yielded

inaccurate results due to the fact that we did not record the diameter at which browse samples were collected. Since tannins concentrate in the bark, a smaller stem would have a proportionally greater concentration of tannins than a larger stem. Without a record of stem diameter, we cannot be sure that what we measured was more a factor of stem diameter rather than actual differences in tannin content. This dilemma is addressed in a subsequent paragraph.) Tree density and tree cover at Rosie is nearly double that at any of the other sites (Fig. 5), which may prevent lynx and other predators from hunting hares as successfully as in other areas. At Cathedral, the density of shrubs is at least double the shrub densities at any other site (Fig. 6), which may provide hares with not only additional cover, but also a greater variety of food choices from which to choose the most palatable diet during the winter months. And although neither of these sites is considered a “mineral” site, a hare pellet found at Rosie in June 2010 looked as if it was composed entirely of mineral soil. A slough running through Cathedral may, depending on snow cover, possibly provide hares with needed minerals in winter. These two sites in particular, therefore, may have conditions allowing hares to supplement their diet with minerals at least during the snow-free season, which may help them counter the effects of tannins or other plant secondary metabolites, or may provide minerals that otherwise are lacking in browse.

Worker (2013) conducted feeding trials using captive snowshoe hares to examine whether there were any physiological benefits to hares engaged in geophagy, and which soil constituents might be therapeutic. The soil used in these trials was collected from the exposed bank along the Hammond River at our study site at Jennie Creek. The trials revealed that hares will ingest soils when it’s accessible, and that this behavior allows them to consume more forage and maintain their weight better than hares without access to soil. Results showed that, during summer when hares feed primarily on deciduous leaves, sodium (Na) was a likely driver of



A snowshoe hare sits among some heavily browsed vegetation in 2000 during the last large peak in hare densities in Gates of the Arctic National Park.

hare geophagy, but that the excessive amount of calcium in the lick soil resulted in reduced phosphorus (P) retention, which lead to weight loss. However, during winter when hares feed on dormant twigs, an increased intake of CaCO_3 , which is also found in the lick soil, seemed to improve both Na nutrition and Ca:P ratios (Worker 2013). Bhattacharya and Warner (1968) reported that rabbits fed a supplement of calcium hydroxide (Ca(OH)_2) increased their intake of a complete rabbit diet and grew faster. While more has yet to be done in order to fully understand the effects of geophagy in hares, there does seem to be a net benefit for hares with access to mineral soil. For this study, rather than just determine mineral content, we should find out how much of the mineral contained in the soils (and browse) at each site is available to hares. And while we have seen that the mineral content of soils in the area is highly variable, we do not know whether hares target particular soils for consumption at one site over another or if they visit areas based more on accessibility. This question we hope to address as the study continues using motion sensing cameras placed at various licks within the study area.

In regard to potential heavy metal toxicosis, Worker (2013) concluded it was unlikely

that hares were ingesting enough mineral for toxicosis to occur. However, this does not address the possibility of lynx suffering from the effects of heavy metals due to a bioaccumulation of metals by consuming geophagic hares. The question remains then, if snowshoe hares consume mineral soil during times of peak population densities, thereby aiding in maintaining their weight (and, presumably, their health), does this geophagy affect lynx health? Reakoff (pers. commun.) observed that lynx caught in areas where hares were consuming soil appeared thin and had unusually dark, purplish-colored meat. Purplish meat in lynx may be the result of various factors. One possibility is that

While more has yet to be done in order to fully understand the effects of geophagy in hares, there does seem to be a net benefit for hares with access to mineral soil.

lynx feeding on geophagic hares may be, in effect, ingesting a dietary supplement of magnesium. All our soil samples had high Mg content, especially the ones collected along the Hammond River where Reakoff has harvested lynx. Worker (2013) reported that the soft white precipitate found on the Jennie Creek bluff contained very high concentrations of Mg. Mancini and Hunt (2005) report that “fortifying swine diets with magnesium...tended to darken loin color.” Depending on the form of magnesium, pork loin color was darker after only one or two days of supplements. But while a supplement of Mg may be causing a darker flesh color, it may be unrelated to weight loss. It is not uncommon to hear of thin lynx during periods of peak hare densities; however, the cause of this condition is still not clearly understood. This issue we hope to address in another study that will more closely monitor lynx movements and health in and around our study area.

Improvements in the methods used for the measurement, collection, and analysis of browse samples are planned for the remainder of this study in order to obtain more useful information about the browse in our study area. In regard to tracking fluctuations in plant secondary metabolites (PSM), we will continue to monitor tannin content post growing season in *Salix alaxensis*, a favored browse species found at all sites. However, since PSM are concentrated in the bark, we will cut twigs at a uniform diameter (e.g. at

4 mm) instead of taking all current annual growth, which may vary in diameter. Rather than monitor tannins also in poplar, alder and shrub birch, we will instead monitor papyrific acid (PA) in shrub birch (*Betula glandulosa*), as PA is the main anti-herbivore defense in birch. In the interest of budget constraints, we will narrow our nutrient analysis to N content (dropping Mg and Ca) post growing season. Since we have verified that all the sites follow roughly the same seasonal patterns in nutrient fluctuations and are not significantly different from one another, we can conclude this part of the analysis. In addition to diameter-at-point-of-browse, we could also measure the base diameter of the current annual growth of the twig browsed. We could then estimate the amount of growth that was consumed by hares.

According to traditional ecological knowledge, we expect the hare population in our study area to begin its build phase in 2015, with the population reaching peak densities around 2018-2020 (J. Reakoff, pers. commun.). The pellet and track counts will continue as we merge into this next phase, as will monitoring levels of plant secondary metabolites in favored browse species. Methods used in browse monitoring however, will be adjusted to acquire better information about the browse in our study area, including the way we collect data, what species are monitored, and what analyses are performed. In addition, we also hope to record visual data on hares visiting licks to determine whether hares target specific soils at licks. If adequate funding becomes available, we would like to monitor hare movements using GPS collars in and around licks to determine the frequency of visits and the distances travelled by individual hares to visit licks. We look forward to the continuation of this study and what we may learn about snowshoe hares and how they interact with their environment in this northernmost portion of their range.

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Snowshoe hare tracks cross an open area following a dusting of fresh snow in Gates of the Arctic National Park.