

Distance and Temperature Effects on Pika Forage

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Research need

The American pika, *Ochotona princeps*, has been referred to as a 'canary in the coal mine' when it comes to climate change. This small rabbit relative inhabits cool alpine and subalpine mountain areas and has been shown to be sensitive to higher temperatures from both physiological experiments (Smith 1974) and from past climate transitions in the late Quaternary (Grayson 2005). Two studies in the Sierra Nevada and Great Basin showed recently abandoned pika habitats possibly due to global warming and associated heat stress (Beever et al. 2010, Millar et al. 2010). A more indirect influence on long term pika success at individual sites could be through their forage base. Researchers in Colorado have shown that most pika foraging is within four meters of safe sites in talus with late summer haying occurring slightly further away (Roach et al. 2001, Huntley et al. 1986). Naturalists as far back as 1917 have noted that pika feed on "low vegetation" such as grass near talus slopes and are distributionally restricted to "rock-pile" habitats (Grinnel 1917). Changing climate conditions in temperatures and precipitation may alter the composition, extent, production and phenology of vegetation in their alpine habitat. Most pika studies have focused on behavior such as foraging distance from talus and response to avian predators or alternatively, changes in plant biomass or plant functional group (graminoid, cushion plant, forb, and woody) abundance changes with distance from talus (e.g. Roach et al. 2001, Smith and Weston 1990, Huntley et al. 1986). Few studies have attempted to measure plant species composition within the pika foraging zone or compared it with species composition outside of this zone (10+ m). Categorized as Tier III species in Utah's Wildlife Conservation Strategy, the Division of Wildlife has established studies to monitor pika occupancy across the state. Data from these studies on the La Sal Mountains in 2008 and 2011 found pika in all suitable habitat sampled, and no changes in occupancy between years. DWR personnel will redo the survey in 2014.

Aboveground herbivores that consume plant material and initiate changes in plant community structure and productivity affect belowground communities that regulate decomposition and nutrient cycling (Bardgett and Wardle 2010). This ecological linkage between aboveground and belowground communities strongly influences physical soil development and chemical properties of those soils. Foraging behavior of pika in response to predator risk appears to shift the plant community composition, changing the amount and quality of litter entering the soil and stimulating root exudation (Wardle et al. 2001). The quality of this litter and root exudation stimulates decomposition and nutrient cycling, improves nutrient inputs to these plant species, which exclude later successional species such as spruce (*Picea engelmannii*) creating a long-term feedback that maintains a habitat favorable to pika.

Both pika and its many forage plant species may respond to increasing temperatures due to global warming, but in what way? We propose to measure both soil surface temperature and plant species composition within and outside of the normal pika foraging zone in order to establish a baseline for future species composition and temperature change comparisons.

Methodology and personnel

We described growing season length in two ways: frost free days using air temperature data from the pre-Laurel weather station (Mesowest http://mesowest.utah.edu/cgi-bin/droman/meso_base.cgi?stn=Lsl) in the middle group of the La Sals, and number of snow free days from iButton temperature sensors placed on the soil surface. Archived air temperature data from the weather station was analyzed for frost free ($>0^{\circ}\text{C}$) period length, defined as the number of days from the last spring frost until the first fall frost. In addition, we collected current soil surface temperature data using iButton temperature sensors along 12 transects through pika foraging habitat at three sites where meadows were relatively narrow and adjacent to spruce-fir timberline: north Mellenthin, Gold Basin, and Dark Canyon (Fig. 1). Soil surface temperature data indicate growing season length as number of consecutive snow free days defined as lack of diurnal temperature fluctuations, under and insulated by snow, staying near 0°C for days, weeks, or months.



Figure 1. Study area map for Manti - La Sal National Forest pika foraging study. The three research sites (north Mellenthin, Gold Basin, and Dark Canyon) are centered around Mt. Mellenthin and were chosen as narrow meadows with adjacent distinct timberlines at the base of rock glaciers.

In order to measure how species composition and vegetation height changes with distance from pika safe sites, we placed transects perpendicular to pika safe sites at the edge of rock glaciers downslope through their foraging area and into spruce-fir forest. Four transects were placed at each of the three timberline research sites. Start points were directly below pika haypiles and chosen to represent the range of meadow soil moisture: two relatively wet and two relatively dry at each site. Beginning at the transect start (0 m) and at each subsequent 1 m interval until reaching timberline, we used a 20 cm x 50 cm sampling frame placed perpendicular to the transect line to measure species composition and plant height for each species. Plant height was measured to the nearest centimeter as the tallest leaf height excluding the inflorescence (flowers). This definition was necessitated by species in which the inflorescence is separated along the stem from the rest of the plant (as in some grasses and sedges). Soil surface temperature sensors were placed at the mid-point of each transect. Timberline was defined at the beginning of closed canopy forest, and at these three sites appeared to be an abrupt, dense wall of trees. Each transect was continued from timberline into the forest for 40 m. For each transect, species richness and composition was measured with 100 cm x 100 cm sampling frames placed at meadow midpoint, timberline, 20 m and 40 m forest (from timberline). Soil surface temperature sensors (iButtons) were placed at these sample points as well. The sensors recorded temperatures at 75 minute intervals to the nearest 0.5° Centigrade. The temperature sensors will allow us to track both temperature change and pika forage change through time with future re-measurements. Transects were measured during the week of July 8-12, 2013 to get plant species heights just before pika begin haying behavior, and again during the week of August 26-30, 2013 to measure the amount removed by pika during the major part of the haying season. Soil surface temperature sensors were placed during the July 2013 sampling period and removed in July 2014. Data collected at each vegetation sampling frame included all vascular plant species present, elevation, geographic coordinates, and species height. Tree density data were collected by species along a 20 meter wide belt for one entire transect at each site.

We have identified 110 plant species in alpine/treeline habitats from previous work in the Middle Group of the La Sals. For new species encountered in the current research, voucher specimens were collected and identified by the authors, and later verified by Ron Hartman and Ernie Nelson from the Rocky Mountain Herbarium in Laramie, WY. Voucher specimens will be deposited in the USFS Herbarium in Laramie and Flagstaff. Field work and data analysis were conducted by: Jim Fowler, Research Ecologist with the Rocky Mountain Research Station in Flagstaff; Barb Smith, Wildlife Biologist with the Manti - La Sal National Forest; and Steve Overby, Soil Scientist, Rocky Mountain Research Station in Flagstaff.

Projected results

This research has specific aims focused on growing season length and plant species composition near pika safe sites. The first aim is to define growing season length and variability within potential pika foraging habitat; the second aim it to determine plant species composition of all vascular plants occurring in and near pika foraging habitat.

Actual results

Frost free ($> 0^{\circ}$ air temperature) growing season at the pre-Laurel (LSL) weather station at 3568 m (11,705 ft.) elevation ranged from 88-106 days and averaged 98 days (2007, 2009, 2011-2103). The average last frost date in the spring was June 12 with a first fall frost average date of Sept. 20 (above years plus fall 2004 and spring 2008). Although the LSL weather station has temperature records back to 1997 on the MesoWest website, missing or poor quality data prevented accurate measurement of growing season length except for the years noted above.

The number of snow free days also represents the number of potential days for pika foraging behavior. The timberline meadows ranged in elevation from 3190-3264 m, 300+ meters lower than the pre-Laurel weather station. Average meadow snow free, growing season length was fairly consistent between the three sites at 128-133 days (Table 1) while the forest habitat had a slightly shorter snow free period for the two sites with four temperature samples. Gold Basin only had one forest measurement which may not be representative. Timberline habitat had a consistently longer snow free growth period (4-5 weeks more) than the other habitats. This was an unexpected result but may have something to do with conifer branches being lower to the ground in this habitat.

Table 1. Average number of snow free days at three pika forage research sites: North Mellenthin, Gold Basin, and Dark Canyon. Four transects were placed at each site with iButton temperature sensors place at the mineral soil surface under herbaceous plants or forest floor litter in three habitats: open meadow, timberline, and spruce-fir forest. n=4 (except Gold Basin forest where n=1)			
Site	Meadow	Timberline	Forest
North Mellenthin	133	177	113
Gold Basin	128	156	187
Dark Canyon	133	172	129

Soil Carbon and Nitrogen

What we found overall was the pika-influenced meadows had lower total soil organic matter measured by total soil carbon than the adjacent spruce stands, while total soil nitrogen concentrations were comparable between spruce and meadow (Fig. 2). The edge between treeline and meadow was intermediate reflecting the plant composition with both herbaceous cover and spruce trees. We also found site differences with Mt. Mellenthin having lower values for both total carbon and nitrogen in the soil at all habitat types. This follows what we expected as the higher carbon content of the spruce litter decomposes slower due to higher proportion of carbon to the amount of nitrogen within this litter. Nitrogen in these habitats is often the most limiting nutrient. An additional factor that may influence accumulation of soil organic matter in the pika meadows is the amount and length of time that snow lays on the ground. Freppaz et al. (2012) showed that in alpine meadows soil organic matter is less under snowfields compared to adjacent meadow, and that soil organic matter decreases from edge to center of those snowfields.

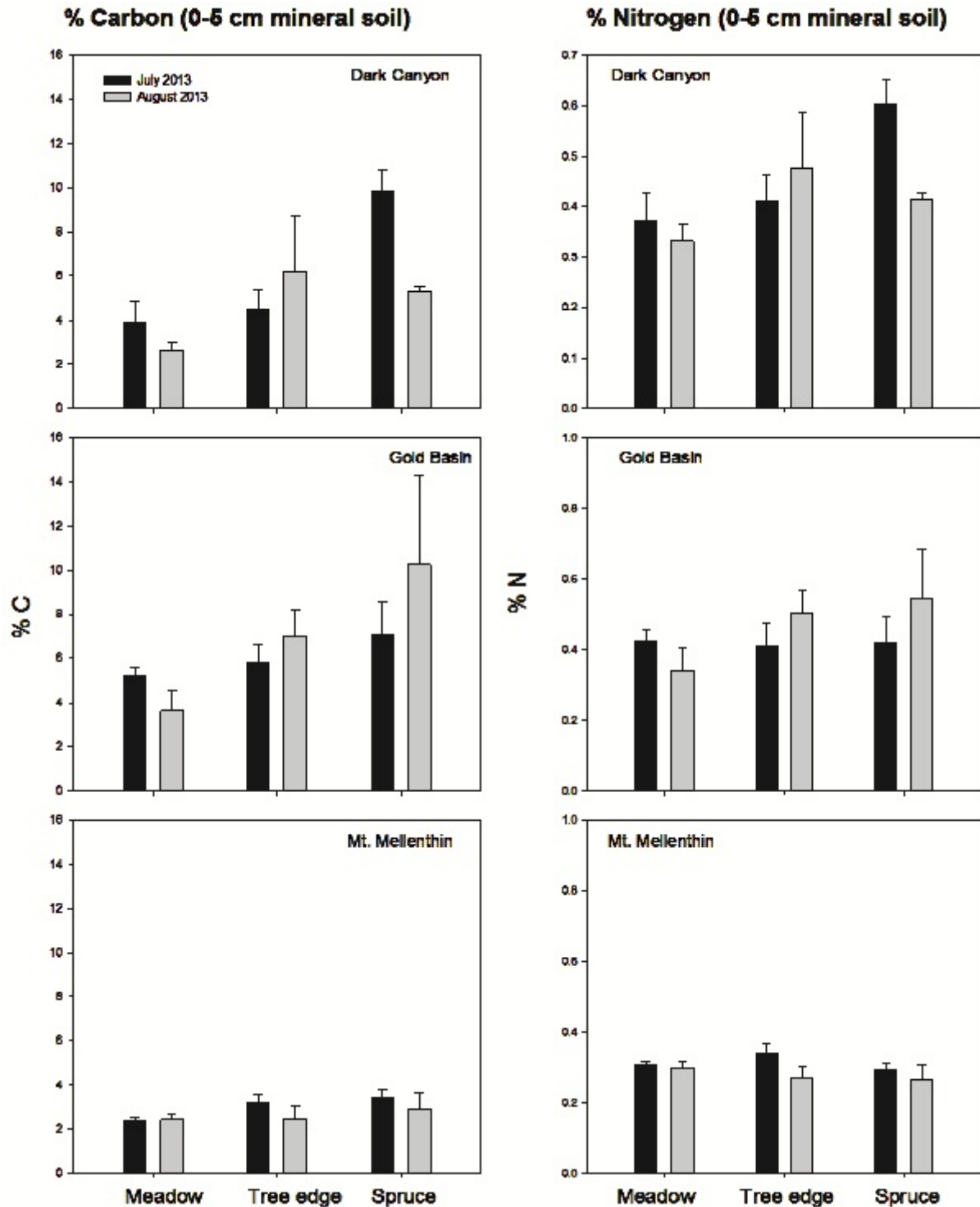


Figure 2. Total soil carbon and nitrogen concentrations (0-5 cm) at three pika influenced sites in the LaSal Mountains, Utah. The July measurements are reflective of pika haying activity; the August measurements are after haypiles have been established.

Species composition

Each of the three research sites was characterized by distinct bands of rock glacier, herbaceous vegetation, and spruce-fir forest (Fig. 3). The rock glaciers are composed of large granitic talus with a few scattered herbaceous plants and shrubs. Parallel with the lower edge of the rock glacier is a 5-15 m wide band of herbaceous meadow plants followed by a distinct timberline of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies bifolia*) further from the talus. This timberline is more abrupt than the timberline we described at the west end of Laurel Ridge (Fowler et al. 2012) since the open meadow to forest transition is only 1-2 m wide in most cases. This tree density change ranges from a three site average of 13.7 trees / m² in the spruce-fir forest to 3.67 trees / m² in the first five meters from timberline into the meadow to 0 trees / m² in the open meadow. This visual banding was also reflected in a species richness gradient with the open meadow being strikingly different than the spruce-fir forest understory. Average richness in the meadow was 15.75 species / m² compared to 4.0 species / m² in the forest understory with the short timberline transition having 10.42 species / m² (Table 2). Both the meadow and timberline habitats appeared to be densely covered in contrast to the sparse vegetative cover of the forest understory.



Figure 3. Bands of rock glacier, meadow, and spruce-fir forest at the Gold Basin timberline study site, July 8, 2013. Note the abrupt timberline adjacent to the meadow.

Table 2. Average number of vascular plant species present (richness) at the three pika forage research sites and at each of four habitats. n = 4 / habitat / site.				
Site / habitat	meadow	timberline	20 m into forest	40 m into forest
North Mellenthin	16.50	11.75	6.25	4.25
Gold Basin	16.25	6.50	6.00	5.75
Dark Canyon	14.5	13.00	2.25	3.50
Average	15.75	10.42	3.50	4.5

There was also a distinct difference in plant species composition between the alpine-montane meadow and the adjacent spruce-fir forest understory (Table 3). Thirty four herbaceous species occurred only in the meadow, and eight herbaceous and shrub species occurred only in the forest understory. An additional 47 species had some occurrence in mixed habitats. For the three sites combined, there were a total of 89 vascular plant species: 22 graminoid species (grasses and grass-like plants), 61 forb species (broadleaf herbaceous plants), four shrub species (woody species less than 3 m), and two tree species. Each of the three sites had a different species composition (table 3) in the meadow rather than a full set of 34 meadow species. Only four species were found at all three meadow sites: *Carex ebenea*, *Draba fladnizensis*, *Juncus drummondii*, and *Sagina saginoides*. Similarly, species composition varied between sites for the spruce-fir forest understory, but only *Polemonium pulcherrimum* occurred at all three sites. Shrubs occurred only in timberline and forest understory habitats. Both species richness and species composition change at timberline.

Table 3. Vascular plant species occurrence in vegetation samples at each timberline site by habitat: m = meadow, rock glacier to timberline, s = spruce/fir forest, or tl = timberline. Also shown are functional group assignments: g = graminoid, f = forb, sh = woody shrub, t = tree.

Species / Site	North			Pooled	Functional Group
	Mellenthin	Gold Basin	Dark Canyon		
<i>Achnatherum lettermanii</i>	m	m		m	g
<i>Agoseris aurantiaca</i>	m		m	m	f
<i>Agrostis variabilis</i>	m			m	g
<i>Antennaria rosea</i>	m		m	m	f
<i>Bistorta vivipara</i>	m			m	f
<i>Caltha leptosepala</i>			m	m	f
<i>Cardamine cordifolia</i>	m		m	m	f
<i>Carex ebenea</i>	m	m	m	m	g
<i>Carex elynoides</i>		m		m	g
<i>Carex nova</i>	m		m	m	g
<i>Deschampsia cespitosa</i>			m	m	g

<i>Draba aurea</i>		m		m	f
<i>Draba crassifolia</i>			m	m	f
<i>Draba fladnizensis</i>	m	m	m	m	f
<i>Eremagone fendleri</i>		m		m	f
<i>Geum rossii turbinatum</i>		m		m	f
<i>Helianthella quinquenervis</i>	m			m	f
<i>Juncus drummondii</i>	m	m	m	m	g
<i>Juncus mertensianus</i>	m		m	m	g
<i>Micranthes rhomboidea</i>		m		m	f
<i>Plantago tweedyi</i>		m	m	m	f
<i>Poa cusickii epilis</i>		m		m	g
<i>Podistera eastwoodiae</i>			m	m	f
<i>Potentilla diversifolia</i>		m		m	f
<i>Potentilla gracilis</i>	m			m	f
<i>Potentilla ovina decurrens</i>		m		m	f
<i>Potentilla ovina ovina</i>	m			m	f
<i>Sagina saginoides</i>	m	m	m	m	f
<i>Selaginella densa</i>		m		m	f
<i>Silene drummondii</i>			m	m	f
<i>Stellaria longipes</i>		m		m	f
<i>Stellaria umbellata</i>	m		m	m	f
<i>Trifolium dasyphyllum</i>	m	m		m	f
<i>Trisetum spicatum</i>	m		m	m	g
<i>Thalictrum fendleri</i>			tl	tl	f
<i>Allium geyeri geyeri</i>			m,tl	m,tl	f
<i>Aquilegia coerulea</i>	m	m	tl	m,tl	f
<i>Arnica cordifolia</i>	tl	m,tl	tl	m,tl	f
<i>Bistorta bistortoides</i>	m	m	m,tl	m,tl	f
<i>Carex rossii</i>	m,tl	m		m,tl	g
<i>Carex scirpoidea</i>	m,tl	m		m,tl	g
<i>Erigeron melanocephalus</i>		m	m,tl	m,tl	f
<i>Lewisia pygmaea</i>	m,tl	m	m,tl	m,tl	f
<i>Phleum alpinum</i>	m,tl	m	m,tl	m,tl	g
<i>Ranunculus alismifolius</i>	m		m,tl	m,tl	f
<i>Sibbaldia procumbens</i>	m,tl	m	m	m,tl	f
<i>Trifolium parryi</i>	m,tl	m	m,tl	m,tl	f
<i>Abies bifolia</i>	tl,s	m,tl,s	tl,s	m,tl,s	t
<i>Achillea millefolium</i>	m,tl,s	m,s	m,tl	m,tl,s	f
<i>Agoseris glauca dasycephala</i>	ms		m,tl	m,tl,s	f
<i>Androsace septentrionalis</i>	m,tl	m,s	m,s	m,tl,s	f
<i>Bromus ciliatus</i>		s	m,tl	m,tl,s	g

<i>Castilleja sulfurea</i>	m,tl			m,tl,s	f
<i>Cymopterus lemmonii</i>	m,tl,s	m,tl,s	m,tl	m,tl,s	f
<i>Draba abajoensis</i>	m,tl,s	m,s	m,tl	m,tl,s	f
<i>Elymus trachycaulus</i>	m,tl,s	m	m,tl	m,tl,s	g
<i>Erigeron glacialis</i>	m	m,s	m,tl	m,tl,s	f
<i>Erigeron grandiflorus</i>	m,tl,s		tl	m,tl,s	f
<i>Festuca brachyphylla</i>	m	m,s	m,tl	m,tl,s	g
<i>Fragaria virginiana</i>	m,tl,s	m	m,tl	m,tl,s	f
<i>Gentiana parryi</i>	m,tl,s	m	m	m,tl,s	f
<i>Geranium caespitosum</i>		s	m,tl	m,tl,s	f
<i>Hymenoxys hoopesii</i>	m,tl,s	m,s	m,tl	m,tl,s	f
<i>Mertensia ciliata</i>	m	m,s	m,tl,s	m,tl,s	f
<i>Picea engelmannii</i>	m,tl,s	m,tl,s	tl,s	m,tl,s	t
<i>Poa glauca glauca</i>	m,tl,s		m	m,tl,s	g
<i>Poa reflexa</i>	m,tl	m,s	m,tl	m,tl,s	g
<i>Senecio crassulus</i>	ms	ms	tl	m,tl,s	f
<i>Solidago multiradiata</i>	m,tl,s	m		m,tl,s	f
<i>Taraxacum officinale</i>	m,tl,s	m	m,tl	m,tl,s	f
<i>Vaccinium murtillus</i>	s	m,tl		m,tl,s	sh
<i>Veronica wormskjoldii</i>	m,tl,s	m	m	m,tl,s	f
<i>Zigadenus elegans</i>	m,tl,s	m	m,tl	m,tl,s	f
<i>Calamagrostis stricta</i>	m,s	m		m,s	g
<i>Danthonia intermedia</i>	m,s		m	m,s	g
<i>Delphinium barbeyi</i>	m	s		m,s	f
<i>Noccaea fendleri</i>	m,s			m,s	f
<i>Carex geyeri</i>		s	tl	tl,s	g
<i>Osmorhiza depauperata</i>		s	tl,s	tl,s	f
<i>Pedicularis racemosa</i>	tl,s	tl	tl	tl,s	f
<i>Ribes montigenum</i>	s	s	tl,s	tl,s	sh
<i>Heracleum lanatum</i>			s	s	f
<i>Lonicera involucrata</i>			s	s	sh
<i>Luzula parviflora</i>		s		s	g
<i>Moneses uniflora</i>			s	s	f
<i>Orthilia secunda</i>			s	s	f
<i>Pedicularis bracteosa</i>		s		s	f
<i>Polemonium pulcherrimum</i>	s	s	s	s	f
<i>Sambucus racemosa</i>			s	s	sh

Sensitive plants

Draba abajoensis is a Manti-La Sal National Forest Sensitive plant species and is known to be somewhat restricted to upper spruce-fir forest, timberline, and lower alpine habitats. It occurred in 19% of the meadow, timberline, and forest sampling frames from the three research sites combined. *Podistera eastwoodiae*, *Erigeron melanocephalus* and *Draba fladnizensis* are species of interest due to their global and/or state conservation status. *Podistera eastwoodiae* occurred only at the Dark Canyon research site (Table 2) where it occurred in 68% of the meadow sampling frames and appeared to be heavily used by pika. *Erigeron melanocephalus* was common in the meadows at Gold Basin and Dark Canyon, and *Draba fladnizensis* occurred at all of the study sites.

Herbaceous plant heights

Average plant height changed with distance from pika safe sites in the talus, rock glacier habitat but not necessarily as hypothesized from reading the pika forage literature. There was strong difference between sites and to a lesser extent a pattern difference between months for each site. At the north Mellenthin site, average plant height declined with distance for both July and August. In July when pika were just starting to harvest forage for their winter haypiles, there was an abundance of tall vegetation with a species average of over 20 cm (8 inches) at the rock glacier edge where it transitions to meadow (fig. 2). The tallest plant species were *Calamagrostis stricta* at 43-74 cm, *Elymus trachycaulis* at 40 cm, *Delphinium barbeyi* at 30 cm, and *Carex nova* at 35 cm. This height dropped off to a general declining meadow height of 10-6 cm from near the rock glacier to the timberline (fig. 3). The August average heights, when numerous haypiles were present in the talus, were lower and appear to be somewhat parallel to the July heights (fig. 3). Linear regression statistical analysis of the July-August difference in species heights show that pika removed significantly more forage near the rock glacier (4.5 cm species average) and less near the timberline (1 cm species average) (fig. 4). Thus the harvested amount declined with distance from pika safe sites for the north Mel research site.

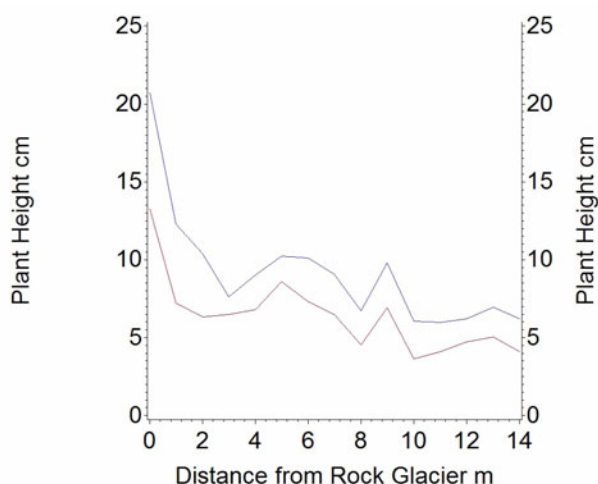


Figure 3. Average plant heights for pika foraging at the north Mellenthin timberline site. The upper line is based on July measurements just as pika starting haying activity; the lower line is based on August measurements after haypiles were well established.

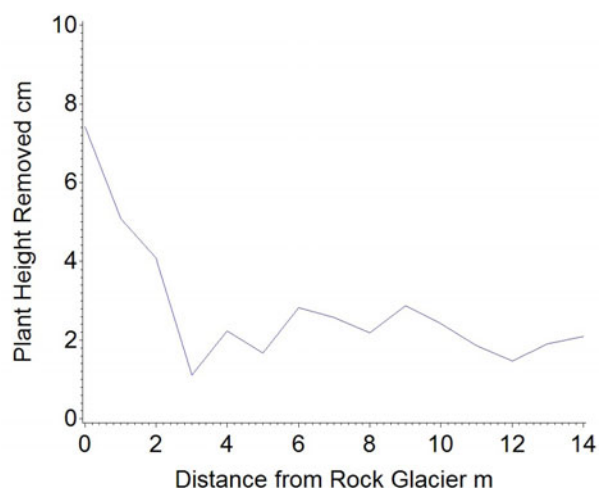


Figure 4. Average plant height removed by pika during haying at the north Mellenthin timberline site between the July and August measurements.

At the Dark Canyon site, the opposite pattern emerges, both for plant height with distance and the amount of forage harvested by pikas. Both the July and the August species average plant heights increased with distance from pika safe sites (fig. 5). The July species average plant heights were shorter near the rock glacier, averaging 5.5 cm (2.2 in), and taller near the timberline, averaging 14.5 cm (5.7 in). The tallest plant species near the rock glacier edge transition to meadow habitat were *Mertensia ciliata* at 18 cm, *Stellaria umbellata* at 33 cm, *Cardamine cordifolia* at 16 cm, and *Festuca brachyphylla* at 5-7 cm, shorter than at north Mellenthin. The August average heights were lower and again appeared to parallel across the meadow with distance from the rock glacier (fig. 5). However, in contrast to the north Mellenthin site, linear regression showed that the amount harvested at Dark Canyon actually increased with distance from pika safe sites; that is, about 3 cm average height removed at the rock glacier and about 6 cm removed at timberline (fig. 6). The mean August plant height next to the rock glacier was less than 2 cm, yet was a lush green color.

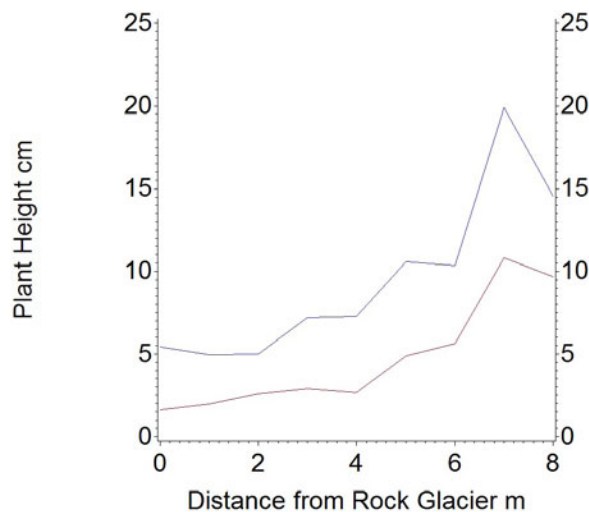


Figure 5. Average plant heights for pika foraging at the Dark Canyon timberline site. The upper line is based on July measurements just as pika starting haying activity; the lower line is based on August measurements after haypiles were well established.

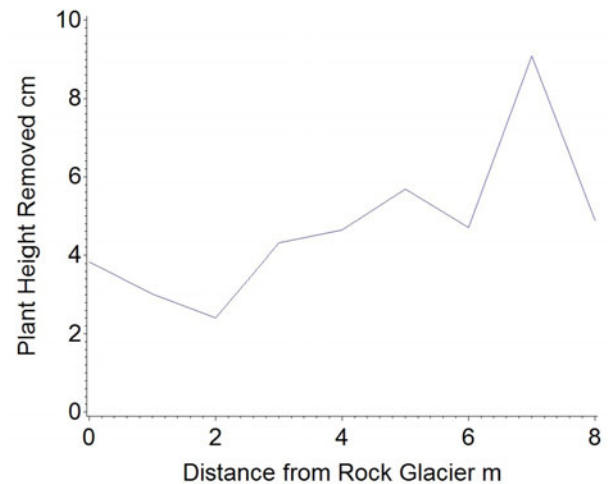


Figure 6. Average plant height removed by pika during haying at the Dark Canyon timberline site between the July and August measurements.

At the Gold Basin site, only the July average plant height changed significantly with distance and, similar to Dark Canyon, increased in height closer to timberline (fig. 7). The tallest plant species next to the rock glacier were *Arnica cordifolia* (6-20 cm), *Zigadenus elegans* (30 cm), *Veronica wormskjoldii* (13 cm), and *Taraxacum officinale* (13 cm). The August species average heights were relatively uniform with an average height of 2.6 cm (1 inch); that is, height did not significantly change with distance. The July and August average plant heights are not parallel but clearly diverge close to timberline (fig. 7). Similar to Dark Canyon, linear regression of the amount harvested by pika increased with distance, averaging 1-2 cm at the rock glacier edge to 3-5 cm near timberline (fig. 8).

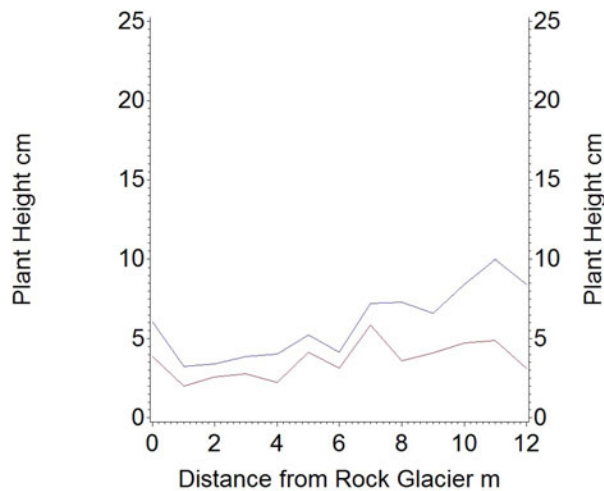


Figure 7. Average plant heights for pika foraging at the Gold Basin timberline site. The upper line is based on July measurements just as pika starting haying activity; the lower line is based on August measurements after haypiles were well established.

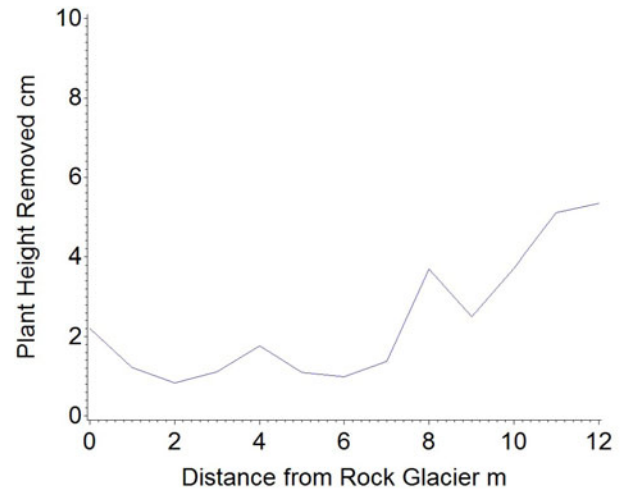


Figure 8. Average plant height removed by pika during haying at the Gold Basin timberline site between the July and August measurements.

Pika foraging habits are often presented as a preference for certain functional groups. At these sites there were more forb species (61) than graminoids (19). The average height removed between our July and August measurements was slightly higher for forbs (3.2 cm) than for graminoids (2.5 cm) but that difference between the two functional groups was not statistically significant.

Haypiles

Examination of species composition for haypiles at these sites showed 40 vascular species present plus an unidentified moss and a fungal basidiocarp (Table 4). About 35-40% of the vascular plant species found at each site were found in pika haypiles. Comparatively, one third of the “meadow only” species and none of the “forest only” species in Table 1 were found in the haypiles. At the Gold Basin site we found two small (2-3 cm height) *Abies bifolia* (Fig. 9) in a haypile and similar height seedlings of *A. bifolia* and *Picea engelmannii* growing at the rock glacier edge (outside our sampling frames). In terms of plant functional groups, 63% of the graminoid species and 44% of the forb species were found in pika haypiles.

Table 4. Species richness is shown for pika haypiles at the three timberline study sites with comparable total richness in parentheses to show proportions actually hayed at each site and habitat. Species in neither habitat refers to haypile species we did not encounter during vegetation sampling but were collected by pikas.

Habitat / Sites	North mellenthin	Gold Basin	Dark Canyon	Pooled
Haypile species richness	20 (57)	23 (56)	21 (60)	42 (89)
Meadow only species	8 (25)	11 (34)	10 (22)	12 (34)
Forest only species	0 (5)	0 (10)	0 (15)	0 (8)
Species in mixed habitats	12 (27)	10 (12)	11 (23)	27 (47)
Species in neither habitat	0	3	0	3



Figure 9. Two *Abies bifolia* seedlings placed in front of other hayed plants from one pika haypile from the Gold Basin timberline site, August 27, 2013. The large forb in the background is *Hymenoxys hoopesii* along with a partial fungal basidiocarp and scattered *Vaccinium* leaves.

Conclusions

1. There is a sharp change in vascular plant species richness and composition between meadows where pika forage and adjacent spruce-fir forest understory with a short 1-2 meter timberline transition. Interpretive examples: meadow has 15.75 species / m² whereas timberline has 10.42 species / m² and forest understory has 4.0 species / m²; out of 87 total species in the study, there were 31 meadow only species compared to 9 forest understory only species.
2. Plant species composition was quite different between the meadow/timberline/forest habitats at the three sites: north Mellenthin, Gold Basin, and Dark Canyon. Interpretive examples: only four of 31 species occurred in the meadows of all three sites (*Carex ebenea*, *Draba fladnizensis*, *Juncus drummondii*, and *Sagina saginoides*); only *Polemonium pulcherrimum* occurred in all forest understory sites; woody shrub species such as *Ribes montigenum* occurred in forest and timberline habitats but not in meadows where pika foraged; *Podistera eastwoodiae* occurred only in the meadow at the Dark Canyon site.
3. One Manti - La Sal National Forest Sensitive plant species occurred at these study sites: *Draba abajoensis*. Interpretive example: *D. abajoensis* was common at all sites and occurred on all habitats.
4. Pika hay tree seedlings as well as herbaceous plants. Interpretive examples: seedlings (2-4 cm tall) of the forest conifers *Picea engelmannii* and *Abies bifolia* were found in the meadow near rock glaciers and in pika haypiles, but trees of the same species were near timberline and forest habitats. Interpretation: pika may be haying all species in the meadow: i.e., tree and shrub seedlings along with herbaceous plants.
5. There was no consistent pattern between sites for vegetation height changes with distance from rock glaciers for either the July (early haying) or the August (numerous haypile) measurements. Interpretive examples: at north Mellenthin more vegetation height was removed by pika haying next to the rock glacier but more was removed near timberline at Gold Basin and Dark Canyon. Interpretation: pika appear to remove the most vegetation for their haypiles from areas in the meadow where plant height was greatest at the onset of haying behavior, regardless of distance from safe sites.
6. Pika haypiles contained 35-40% of the meadow herbaceous plant species but no forest understory herbaceous plant species. Interpretive examples: 63% of the meadow grass and sedge species were found in pika haypiles and 44% of the meadow forb species. Interpretation: there is no evidence for pika foraging beyond timberline.
7. Timberline habitat had a consistently longer snow free growth period (4-5 weeks more) than the other habitats. Average meadow snow free, growing season length was fairly consistent between the three sites at 128-133 days while the forest habitat had a slightly shorter snow free period. The number of snow free days also represents the number of potential days for pika

foraging behavior.

8. There were distinct differences for soil carbon and nitrogen by site, as was also the case with vegetation. Mt. Mellenthin site had lower total concentrations of carbon and nitrogen in the soil, but trends for all sites were trees > timberline > meadows. Interpretation: Pika may modify their habitat through foraging and haying to create and maintain meadow, which provides more labile organic matter that is microbially decomposed much faster and also increases the rate of nutrient cycling. This faster metabolism of the belowground system is often reflected in a much more complex food web with greater diversity of organisms within the soil. There is a strong biotic interaction between aboveground and belowground organisms that create feedbacks that maintains the distinct pika habitat.

9. Overall for these sites with narrow meadows adjacent to timberline, pika appear to indiscriminately hay all vascular plant species within the meadow regardless of distance from safe sites in talus and thus maintain timberline position by removal of conifer seedlings in the meadow.

Research needs

Primarily we need a more systematic analysis of haypile species composition to validate conclusion 9, especially for conifer seedling abundance in haypiles compared to the abundance of available conifer seedlings in the meadow. Other research needs are to use our methodology to compare these sites with adjacent timberlines to similar sites but without nearby timberlines, i.e. where spruce-fir forest is 10's of meters away. A more behavioral ecology question is whether pika forage / hay at night and if so at what distance?

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