Annual Report Vol. 39 (2016)

Factors influencing American Pika (*Ochotona princeps*) distributions in the Beartooth Mountains and implications of a warming climate

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Abstract Over the next century, temperatures are expected to rise by 1-4°C in the Greater Yellowstone Region. This will force alpine species such as the American pika (*Ochotona princeps*) to compensate, shift in distribution, or disappear. If pika are limited by temperatures, they may disappear from warmer, lower elevation southwest-facing sites and find refuge in cooler, higher elevation northeast-facing sites. However, populations have been found across a range of elevations, suggesting they are instead limited by food or a need for large talus slopes. We explored these possibilities in the Beartooth Mountains, near Yellowstone, by surveying 31 pika populations and asking whether pika density varied with elevation, food availability, or aspect, all related to temperatures, or with talus area, which is not. Pika density was estimated by latrine density, which ranged from 14.6 to 167.4 per ha and declined slightly with elevation but was unrelated to vegetation. From a preliminary analysis of 61 sites, we estimated an occupancy probability of 0.89, with occupancy most strongly related to talus area. We will test and refine these results by predicting the locations of additional colonies, and by incorporating microclimate data into an ecophysiological model of temperature dependence in pika, with the long-term goal of predicting the fate of pika under a warming climate.

Introduction

Global climate change is expected to have profound effects on ecosystems around the world. Montane ecosystems are especially at risk from these changes, with an expected increase of 1-4°C over the next century in the Greater Yellowstone Region (Chang and Hansen, 2015). Even if species in these ecosystems can respond by shifting to higher elevations, they may simply run out of habitat on the tops of mountains and "ascend to heaven" (Calkins et al., 2012).

The American pika (*Ochotona princeps*) has become a textbook example of an alpine species at risk of extinction due to climate change (Schwalm et al., 2016). It is a lagomorph that lives on boulder fields and talus slopes throughout the western North American mountains. It is the only alpine mammal that does not hibernate, sustaining activity through the winter by feeding on haypiles collected during the growing season (Morrison and Hik, 2007). Living in this cool microhabitat, pika are sensitive to heat stress and may be unable to survive at lower elevations or on south and southwest-facing slopes at middle elevations (Beever et al., 2011). Additionally, snow insulates the talus from extreme cold during the winter, likely resulting in complex patterns of habitat suitability at higher elevations, dependent also on insulating snow cover (Millar et al., 2014). As the climate warms, pika may be extirpated at lower elevations or south-facing sites due to warmer summer temperatures or to cooler winter temperatures that result from

Figure 1. Study area in the Beartooth Mountains, with Cooke City-Silver Gate, MT and Red Lodge, MT indicated by yellow stars on the left and right, respectively. White lines indicate Highways 212 and 296 occupancy study sites are marked with red dots.

the loss of insulating winter snow (Millar et al., 2014).

Pika have a narrow thermal niche leading many scientists to believe that their distribution is limited by temperature (Beever et al., 2003, 2011; Kreuzer and Huntly, 2003). Concern was sparked by the Beever et al. (2003) report that 28% of pika colonies at low elevations in the Great Basin and Sierra Nevada Mountains had disappeared in recent years. However, more recent discoveries of populations at even lower elevations (Simpson, 2009), and evidence of thriving populations across a range of elevation gradients and mean temperatures (Millar et al., 2014), have led some to question this interpretation. The talus where pika live may in fact provide stable microrefugia, protected from extreme temperature shifts (Calkins et al., 2012). Temperatures within the talus are cooler than surface air temperatures during the warm season, and warmer during the cold season when heavy snowpack insulates the talus (Millar et al., 2014). This allows pika to avoid physiologically stressful temperatures at lower elevations and, when combined with behavioral changes such as becoming crepuscular when temperatures become too hot, they may be able to survive across a wider range of local climates (Simpson, 2009).

An alternative hypothesis (Yandow et al., 2015) suggests that pika are instead limited by food availability. Because their winter survival depends on building large haypiles in the summer, pika are extremely territorial central place foragers. They can range hundreds of meters for food, although they usually travel only short distances and rarely leave the talus (Huntly et al., 1986). Grasses and forbs are routinely grazed by pika, but haypiles contain a disproportionate amount of flowering stalks, forbs and tall grasses, suggesting that pika preferentially store larger and more nutritious food sources (Huntly et al., 1986). Pika may be actively selecting plant species that will provide them the energy requirements needed in the winter and their distribution may be linked to preferred food plants (Yandow et al., 2015). A third possibility is that pika persist across a patchy landscape of suitable habitat–talus–surrounded by unsuitable habitat, and that the area and connectivity of these patches are key determinants of pika persistence.

We are studying the factors that influence pika distri-

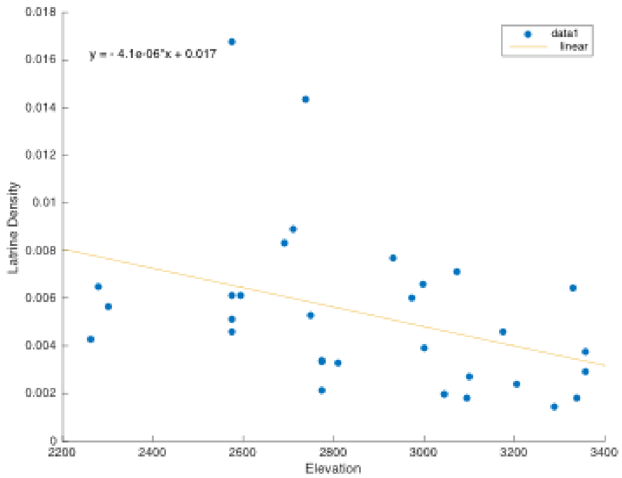

Figure 2. Pika latrine density declined with elevation across 31 sites in the Beartooth Mountains

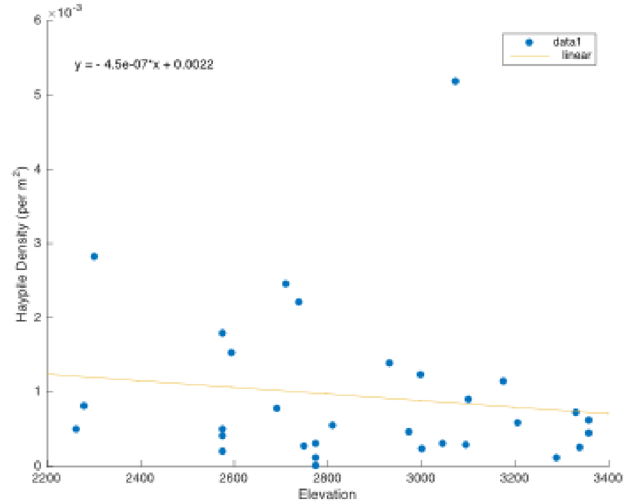

Figure 3. Density of pika haypiles did not change with elevation across 31 sites in the Beartooth Mountains

butions in the Beartooth Mountains in the northeast portion of the Greater Yellowstone Region. This area includes a vast plateau at an average elevation of 3300 m, such that the area of alpine habitat potentially available to pika actually increases with elevation (Elsen and Tingley, 2015). This topographical feature and the large area of this protected wilderness may provide a refuge for pika and other alpine species under future, warmer climates. Here we report preliminary analyses of our first year's research, as well as our plans for the future.

Methods

Study Site

The Beartooth Mountains encompass a series of plateaus and mountains in south-central Montana and northwestern Wyoming. This vast wilderness rises well over 3500 m, but Beartooth Pass, the focal area for this study, peaks at 3350 m (Fig. 1). Highways 212 and 296 along with smaller roads provide access to sites along the full elevational gradients from the southwest, southeast and northeast (Anderson, 1994). The alpine habitat at the top grades into sagebrush steppe to the west and south, to a rain-shadow desert to the east, and to woodlands to the north. This wilderness area is maintained by the Custer Gallatin National Forest (most northern Montana portion), Absaroka-Beartooth Wilderness Area (Montana-Wyoming border) and Shoshone National Forest (Wyoming portion).

We visited Mount Washburn and the Beartooth Plateau in September 2015, to scout possible field sites and compare methods for detecting pika and their haypiles and latrines. We returned in May 2016, as part of a course on Rocky Mountain Field Ecology that DT has taught since 2000, with KH and KQ as Teaching Assistant and student, respectively, to learn the natural history of the region, plan the vegetation sampling and review bear and travel safety issues. KH and KQ then returned in June 2016 for 2 months of field work, with DT assisting at the start to finalize the sampling methodology and at the end to help complete the data collection. Initially, we focused on identifying potential study sites along a range of elevational gradients on the warmest, southwest-facing slopes and coolest, northwest facing slopes in the Beartooth Mountains. Similar scouting efforts on Mount Washburn were put on hold until we received research permits to work there. We then measured the elevation, aspect and area of each talus site, determined whether pika were present using standardized methods, then sampled the vegetation and pika signs (haypiles and latrines) along standard transects, all as elaborated below. At the end of the season, we placed data loggers in and on the selected talus sites to record temperatures at two hour inter-

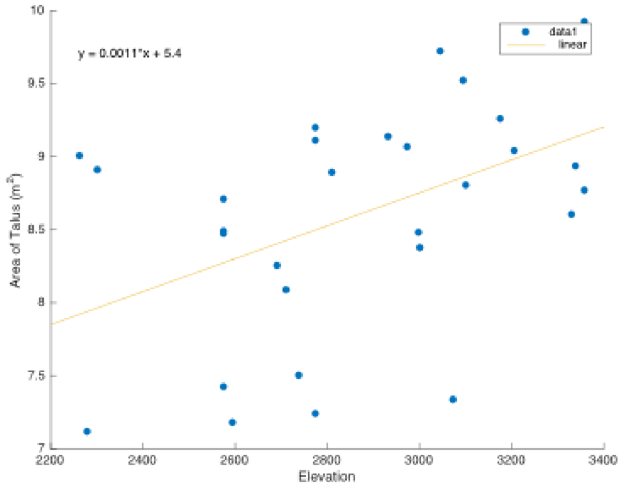

Figure 4. Talus area increased with elevation across 31 sites in the Beartooth Mountains

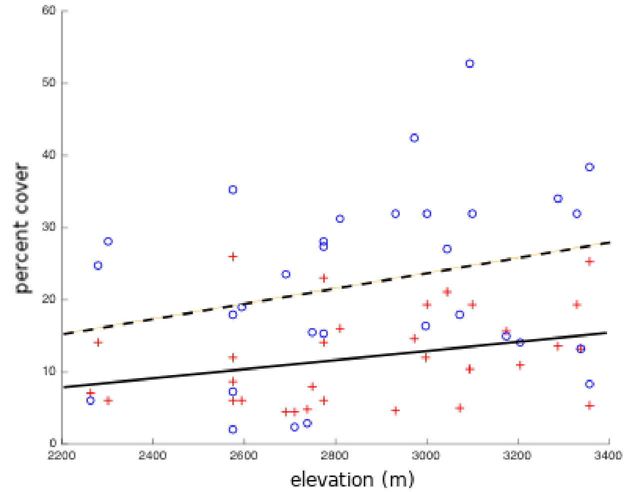

Figure 5. Percent graminoid cover (red crosses, solid line) and percent bare ground (blue circles, dashed line) both increased with elevation.

vals for the next year. We returned again in October to place additional data loggers, and to be filmed for an upcoming PBS/BBC documentary on Yellowstone called "The Great American Thaw".

Habitat variables

To measure vegetation on the talus slopes, we modified the point-intercept method from Yandow et al. (2015) using 50 m transects. The first transect was parallel to and 10 m from the bottom of the talus edge. The next transect was parallel to and 10 m upslope of the first transect and this was continued for up to six transects, depending on the patch size. Along each transect, the vegetation type was recorded in 1 m intervals. Forbs, shrubs, and trees were classified to the species level whereas grasses, rushes and sedges were grouped collectively into graminoids. When present, mosses, lichens, and bryophytes were not classified to the species level but were recorded in their respective categories.

Latrine densities

Starting 15 m into the talus and walking the length of the patch, latrines were identified within 15 m of transects that were the length of the patch. Each transect was 30 m apart so that latrines were not counted multiple times (Erb et al., 2014). In addition to latrines, fresh haypiles were recorded along the same transects. Haypiles and fresh latrines are the most consistent available signs for current pika activity (Yandow et al., 2015). Latrines have been known to persist in the environment and provide a more stable record of presence and habitat use than visual observations of pika.

Occupancy study

In addition to the habitat variables and latrine densities collected at 31 sites, 30 additional sites were opportunistically chosen along Highway 212 for an occupancy study. At each site, two researchers looked for signs of pika (haypiles, scat, latrines, calls) for at least 20 minutes along transects within the slopes. Pika are diurnal, territorial, use calls to warn of predators, and are visible while collecting hay. Therefore these visual surveys have been used in many studies throughout the pika's distribution (Beever et al., 2003, 2011; Erb et al., 2014; Yandow et al., 2015). GPS location, elevation, slope and aspect were also recorded for each site. Sites were visited up to five different times and data were analyzed using PRESENCE software developed by James Hines at the Patuxent Wildlife Research Center (https://www.mbr-pwrc.usgs.gov/software/presence.html). Covariates including a standardization of talus area (calculated in a method similar to z-scores), elevation, aspect

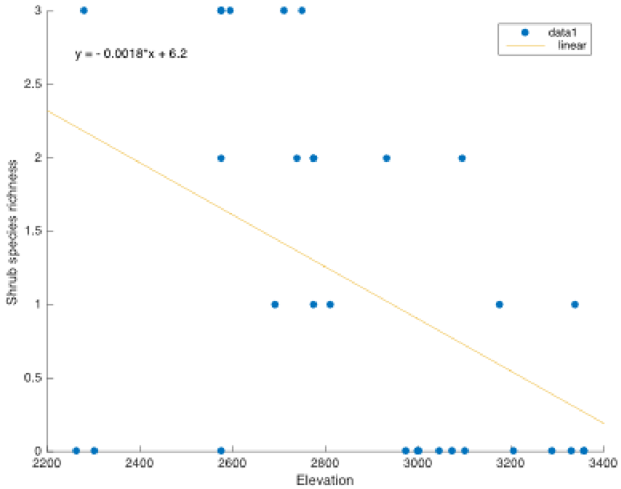

Figure 6. Shrub species richness declined with elevation.

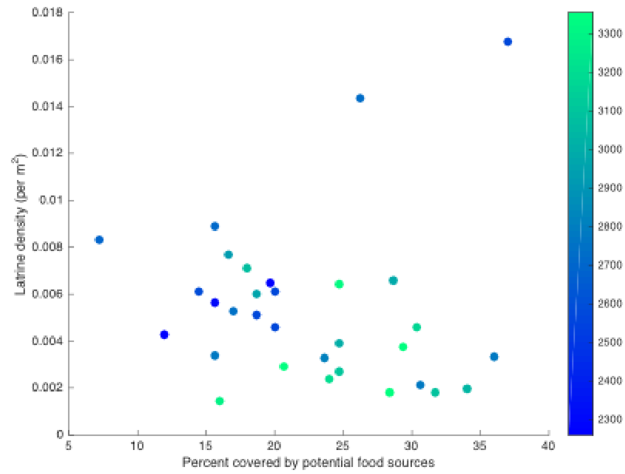

Figure 7. Latrine density declined with increased cover by potential food sources. Points are colored by elevation (see scale at right).

(using folding of the aspect about the northeast-southwest line so northeast is zero degrees) and a representative measure of heat load (using the third equation in McCune and Keon, 2002, which is dependent on latitude, aspect, and slope) were incorporated into models to determine which variables best explained occupancy rates.

Microclimates

During the early fall trip, we placed temperature-recording data loggers at 22 of the 31 sites used in the vegetation study. We were also able to place data loggers at 4 sites on Mount Washburn, but due to weather conditions we were unable to gather vegetation data or latrine data at those sites. At each selected site, two data loggers were deployed in small chicken wire cages. One was placed at the edge of the talus but in shade to protect the data logger from direct solar radiation and the second was placed at a depth of at least one meter within the talus. These data loggers were placed relatively near a haypile or latrine, but far enough away to leave the haypiles undisturbed (Yandow et al., 2015). Loggers were set to record temperature every two hours for a year and were deployed to collect a full year's worth of data from each site. The Mount Washburn sites provide parallel temperature data for comparison with the Beartooth sites, as they are relatively nearby to the southwest, and likely experience a similar climate.

Preliminary Results

Preliminary analyses revealed that latrine density declined with increasing elevation (Fig. 2) but haypile density neither increased nor decreased with elevation (Fig. 3). This difference may reflect the fact that haypiles can be more difficult to find than latrines. Many herbivores will raid pika haypiles on the surface so pika tend to hide their haypiles under rocks or deeper within the talus, making them more difficult to find (personal observation). Interestingly, talus area increased with elevation (Fig. 4), suggesting that pika may be able to move upslope under future climate change.

Vegetation cover ranged from 10% to 51.2% and did not vary with elevation nor did it appear to influence pika densities. Both graminoid percent cover and area of bare ground increased with elevation (Fig. 5). Shrub coverage showed no relationship with elevation but species richness declined with elevation (Fig. 6). Surprisingly, latrine density decreased with increasing coverage by potential food sources (including forbs, graminoids, shrubs and cushion plants). This may be due to correlated variables such as elevation or aspect (Fig. 7).

Model	AIC	deltaAIC	AIC wat	Model Likelihood	No. Par.	-2* Log Likelihood
Psi(stand_area)	259.20	0.00	0.513	1.000	3	253.20
Psi(stand_area & heat load)	261.17	1.97	0.192	0.373	4	253.17
Psi(stand_area & elevation)	261.17	1.97	0.192	0.373	4	253.17
Psi(heat load)	263.08	3.88	0.069	0.144	3	257.08
Psi(elevation, heat load, & stand_area)	263.14	3.94	0.072	0.140	5	253.14
Psi(elevation)	267.00	7.8	0.010	0.020	3	261.00
Saturated model	268.12	8.92	0.006	0.0116	6	256.12
Psi(heat load & elevation)	268.83	9.63	0.004	0.008	4	260.83
Psi(latitude)	271.68	12.48	0.001	0.002	3	265.68

Table 1. The top eight models from the occupancy analysis in PRESENCE. Models based solely on latitude, longitude, folded aspect, slope and all combined variables were the weakest (not listed). The standardized form of area of talus was the strongest model and both heat load and elevation showed marginal strength.

Occupancy Analysis

An initial analysis using a saturated occupancy model (N = 61, seventh best model) found that the probability that a site was occupied (psi) was 0.89, a high estimate if pika populations followed standard metapopulation dynamics. The strongest covariate was the standardized area of talus habitat, which was included in the three best models. A model with standardized talus area and heat load was the second best and a model with standardized talus area and elevation was the third best model (Table 1). The strength of area effect suggests that habitat size and connectivity may be key factors influencing current pika distributions in the Beartooths.

Conclusions

Based on our preliminary findings, vegetation may not be a strong predictor of pika distributions, which instead seem to be driven by talus area. Because talus patches increase in size with elevation in the Beartooth Mountains, pika may find ample refugia in this region under a warmer climate due to the abundant talus on the plateau. Talus area was also the strongest covariate in the occupancy model, suggesting that size and connectivity of talus patches may be important indicators of pika presence. However, pika densities as measured from latrine densities were lower at higher elevation sites. They may require larger territories at higher elevations despite the similar vegetation cover because of the shorter growing season or because they may require more hay for a longer, cooler winter. Temperature data from deployed loggers will facilitate future work addressing these questions.

Future Work

We will continue to analyze the results from the first field season. The next step is to create a regression model to predict latrine density based on the habitat and other variables collected at each site. We will develop this model in ArcGIS and use it to predict the occurrence of other pika populations in the Beartooths; subsequent fieldwork will allow us to test the efficacy of the predictive model. In addition, we are developing an individual based model of pika ecophysiology to explore whether pika can adapt their behavior and use of microclimates to compensate for changes in local climate (Sears et al., 2011). This model relies on pika shape, physiology, thermal niche and use of different microclimates to investigate their ability to adapt to warmer, potentially life threatening temperatures.

Temperature from deployed data loggers will eventually be incorporated into both the ecophysiological and regression models once we have at least a full year of data for each site.

We will revisit sites and survey new sites for populations predicted by our model. Specifically, we would like to revisit all the sites to record if pika densities have increased, stayed the same, or decreased, and determine whether differences among sites relate to environmental variables such as microclimate, vegetation, etc. We may find that some populations have disappeared entirely, indicating metapopulation dynamics. Additionally, we would like to measure reproductive success but have had difficulty determining an effective measure for this. When juveniles emerged from the talus towards the end of the summer we were able to classify young at a small subset of our sites. But identifying them or confirming their numbers proved to be difficult. Ultimately we did not schedule enough time at each site to fully investigate the presence of young. We were able to confirm that when the juveniles emerge, they are visible and vocal in a similar manner to adults but spend less time above the talus (personal observation).

We also hope to use an unmanned aerial vehicle (UAV) to take high-resolution photos that would allow us to record more information about each site in a short amount of time and at minimal risk to the researchers. Data collected would include a high-resolution digital elevation model and vegetation information such as growth and ground cover.

We are exploring the possibility of using acoustic recorders to monitor pika calls, and therefore activity levels, remotely and with greater efficiency. The acoustic data could be synced with the temperature data to further explore the dependence of pika on local temperatures. Additionally, calls can be used to identify individual pika, which would help identify population size directly, replacing the latrine density proxy (Trefry and Hik, 2010).

In addition to continuing our research in the Beartooths, we hope to expand south into the Teton Range and explore how the change in latitude effects pika distributions. Schwalm et al. (2016) predicted expansion of pika populations under future climate conditions in the Teton Range but those predictions were based on large spatial scale data. Instead of plateaus like those found in the Beartooths, the Tetons have sharp peaks with steep slopes, topography that may in fact limit pika distributions due to the reduction in potential habitat with increasing elevation. We plan to work in the Tetons in the early summer while the Beartooths still have snow on the ground, expanding our field season by a few weeks. We have noticed that pika in the Beartooths do not start showing increased activity levels and haying behavior until late June at lower elevation sites and early to mid July at higher elevation sites. This difference will allow us to get most of our work in the Tetons done before pika get active in the Beartooths. Ultimately, it is important to understand how pika distributions are changing, as they can be an indicator of the health of alpine ecosystem under a changing climate (Erb et al., 2014). We hope the expansions of this project will help us understand how pika will respond to changing climate.

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