

American pika (*Ochotona princeps*) monitoring and model development in Glacier National Park, Montana

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Abstract

American pikas (*Ochotona princeps*) are sentinels of mammalian climate change response. Populations have been disappearing from many of their lowest elevation sites in the Great Basin and recent research has linked losses to high mean summer temperatures. Pika monitoring efforts, many volunteer-centered, are being initiated across the mountain west in an effort to quantify their status range-wide. However, little is known about: pika detectability by volunteers, the status of northern pika populations, how pikas respond behaviorally to temperature, and the mechanisms by which temperature mediates site extirpations. From 2007 – 2009 we conducted a large-scale research effort in Glacier National Park (GNP), Montana, aimed at addressing each of those knowledge gaps. We found minimal observer bias among trained biotechs on numerous metrics of pika presence and density. Volunteers showed consistency at spotting pikas, for which sitting surveys were sufficient. GNP contains > 400 suitable habitat patches and > 300 site surveys revealed a relatively large pika population of roughly 1800 – 3600 individuals. Higher pika densities were predicted by higher elevations, more forbs and mosses, and surveys conducted later in the season or during mornings and evenings. Observations at eight sites for 288 hours showed that above-talus activity was more frequent during cooler temperatures and at higher elevations. The biophysical model, NicheMapper, indicated that higher activity at cooler sites may, in part, be driven by greater metabolic demands, and that lower elevations provide less available time to be active.

Keywords: Pika, *Ochotona princeps*, Citizen Science, Modeling, Temperature, Elevation

INTRODUCTION

Research by Grayson (2005) and Beever et al. (2003; 2010) has drawn attention to the American pika (*Ochotona princeps*) as an imperiled indicator of climate warming. In the Great Basin, an alarming number (7/25 or 28%) of their lowest elevation satellite populations have been extirpated in the past 60-90 years (Beever et al. 2003). In addition, the U.S. Fish and Wildlife Service recently rejected a petition to list pikas under the Endangered Species Act (USFWS 2010). They cited insufficient information on pika distributions and densities, and a dearth of mechanistic linkage between rising temperatures and site extirpations. While ostensibly a case for despair, the plight of the pikas provides an opportunity to improve our understanding of how climate warming affects animals, create predictive models that inform conservation decisions, and to engage the public. This paper presents results from: the first formal tests of pika detectability for biotechs and citizen scientists, habitat and biophysical relationships to local pika distribution that can be applied to broad spatial and temporal scales, and activity-temperature relationship observations all conducted in Glacier National Park (GNP), Montana.

Pika monitoring initiatives have sprung up throughout the mountain west and will continue to do so in coming years, thanks, in part, to a National Park Service (NPS) grant (nps.gov 2010). These initiatives primarily aim to obtain baseline distribution data, but effective monitoring for climate warming impacts will also require presence/absence and density data at sites revisited periodically. Detectability and observer bias quantifications are essential for producing high-quality data from these efforts. Pikas are among the easiest animals to detect in one visit because they are talus habitat specialists, individually territorial, diurnally active, produce distinct vocalizations, and leave conspicuous scat and hay-piles (Beever et al. 2003; Beever et al. 2008; C. Ray and E. Beever *unpubl. data*). However, formal detectability tests have not been published. This paper reports the results of biotech detectability trials.

Many of the upcoming monitoring initiatives plan to use citizen scientists for much of the data collection. What little research has been done to assess volunteer-gathered data quality relates primarily to bird and amphibian surveys (e.g. Diefenbach et al. 2003; Lotz 2007). No one has looked at the viability of citizen scientist volunteers for collection of scientifically-useful pika data.

GNP has been called “The Crown of the Continent”. Its ability to influence and inspire the public should not be overlooked. It appeals to visitors because of its unmatched scenic beauty. It appeals to biologists, in part, because of its unique biota and its position in the Northern Rockies wilderness corridor. Additionally, the retreat of GNP’s namesake alpine glaciers has been well documented and has served as a publicly recognized sign of climate warming (Hall and Fagre 2003). One union of the scientific community and the public occurs during citizen science. This paper reports the results of citizen scientist volunteer and biotech pika survey comparisons as well as volunteer sitting-survey analyses.

The case for pikas as a climate change indicator is strong but incomplete. Beever et al. (2003) found low elevation to be the most consistent predictor of site extirpations. Their data supported the negative correlation between latitude and minimum elevation of pikas within sites earlier found by Grinnell (1917). These results suggested that thermal effects may have mediated extirpations. However, they found that 6 of the 7 extirpated sites occurred in the northernmost one-third of the Basin (Figure 1). This was in contrast to expectations of greatest losses at the southern edge of a species’ geographic range, such as northward range shifts by mammals in response to warming since the last glacial maximum (Martinez-Meyer et al. 2004). While many

species have already shifted their ranges northwards in response to recent climate warming (Parmesan and Yohe 2003), montane species are more likely to make elevational shifts than latitudinal ones (Guralnick 2007). In fact, high latitude montane mammals of western North America are expected to have significant elevational responses to climate warming (Guralnick 2006).

Niche theory would suggest that the negative correlation between latitude and elevation for pika habitat is consistent with the existence of a bioclimatic envelope (or fundamental niche) appropriate for pikas. In support, Hafner (1993) showed that, contrary to assertions by Mead (1987), *O. princeps* qualifies as a biogeographic indicator of cool, mesic, rocky habitat. His regression analysis of historical and contemporary museum records and the fossil localities from the geographic range of pikas south of 46° N latitude produced an equation for pika minimum elevation:

$$E \text{ (m)} = 14,087 - 56.6 \text{ (°N)} - 82.9 \text{ (°W)}.$$

For this equation, E is the minimum elevation (in m) of *O. princeps* populations in North America, and N and W are the latitudinal and longitudinal positions (in decimal degrees) of the site.

While there is reasonable support for climate-driven extirpation of American pikas, both physiologically (MacArthur & Wang 1973; Smith 1974; Smith & Weston 1990) and ecologically (Hafner 1993), no one has produced a mechanistic model or conducted behavioral observations to test this hypothesis. Additionally, little has been done to investigate *O. princeps* north of 46° N latitude. The research presented in this paper expands pika monitoring to GNP, which is much farther north than previous studies focused in California, Colorado, and the Great Basin (e.g. Smith 1974; Beever et al. 2010). GNP sits roughly between 48 and 49° N latitude and 113 to 114° W longitude, and pika-appropriate talus habitat appears between 1050 m - 3000 m, averaging ~2100 m elevation. This provides an elevation range complementary to that of the study by Beever et al (2003), although at latitudes 5 to 12 degrees farther north.

If rising temperatures are indeed driving extirpations of American pika populations, GNP may be one of their final refugia in the U.S. Successful management of GNP's pika population will require a greater understanding of their responses to climate change. Species respond to climate change in various ways depending on the magnitude of change and their physiology and behavior. Species-specific responses range from tolerance to extinction (Figure 2). To date, only Smith (1974) documented a relationship between temperature and pika behavior. Additionally, nothing has been published on how behavioral changes lead to the reductions in fecundity that necessarily precedes site extirpations. This paper reports the results of 288 hours of activity observations in relationship to site temperatures.

Species range modeling. Thus far, efforts to identify broad principles that govern spatial and temporal distributions of mammalian populations have been largely unsuccessful. One apparent reason is that species utilize landscapes and respond to environmental change in different ways. For example, many extant mammals, whose ranges overlapped during the last glacial maximum (LGM), are no longer sympatric (Graham 1986). On broad time scales, species-specific responses to climate change drive extinction and speciation events, while on shorter time scales they influence community composition and distributions. Species range shifts under climate warming scenarios in western North America will likely have complex distributional consequences on the relationship between range size, latitude, and elevation

(Brown et al. 1996). High latitude montane systems are excellent arenas for examination of these shifts because they will likely serve as climatic refugia for cool-adapted montane mammal species (Guralnick 2007). In order to increase our ability to accurately predict range shifts in response to climate change, it is important to consider each species' response individually, with a focus on the biophysical mechanisms that limit their range in addition to correlative associations which will likely change over time. Mechanistic models are also needed given the likelihood that some future climates will lack current analogs (Williams et al. 2007). Additionally, there is a need to cross-check the species-range predictions made by regression and biophysical models.

Most models of mammal distribution are based on qualitative descriptions and evaluated empirically based on goodness of statistical fit, such as regression analysis. They are limited, however, in that their power is severely reduced when they are used to predict range expansions and shifts over long periods of time, due to extrapolation beyond the modern data set (Williams et al. 2007). In addition, correlative models are less useful for assessing mechanistic hypotheses. For example, Burns et al. (2003) conducted a study that predicted mammal species turnover in eight U.S. national parks as a function of expected vegetation shifts, in a 2.5°C climate-warming scenario. Their analysis predicted a substantial shift in mammal-species compositions. Although their work was a useful condensation of empirical facts using statistical regression, their predictions were based upon the assumption that mammals would relocate in concert with vegetation. Burns et al. (2003) concluded that scientists need to develop models that mechanistically account for the effects of climate change and mosaic habitats. As such, development of models that utilize species-specific physiological properties, in conjunction with local climate information, is crucial to achieve applicability to real-world ecological situations such as protected-areas management (Mackey & Lindenmayer 2001). Furthermore, mechanistic models can be utilized on a broader suite of species (Porter et al. 2000). Here, models that use biophysical first principles to mechanistically predict distribution will be called "biophysical" models, whereas correlative empirical models will be called "regression" models. Comparisons of biophysical and regression models should distinguish between the ecological significance of their respective predictions.

Fundamental vs. Realized Niche. There is a basic distinction between the space that an organism could inhabit and the space that it does inhabit. The fundamental niche is primarily a function of physiological performance and ecosystem constraints; whereas, the realized niche includes these constraints as well as biotic interactions and anthropogenic influences. Biophysical models can parameterize the fundamental niche, and later include competitive principles to predict the final response. Regression models, on the other hand, predict only the realized niche. For this reason, regression models are severely limited in application when environmental conditions are changing (Guisan & Theurillat 2000). Additionally, there can be significant differences in predictions of distributional changes using regression versus biophysical modeling (Kearney & Porter 2004).

Niche Mapper. To date, very few successful models have been developed to describe mammal distributions based on biophysical properties, due to demands on information (e.g. physiology, morphology, behavior, landscape, microclimate) and technical ability (e.g. engineering, computer programming). Since 1969, Dr. Warren Porter has been developing and improving a first-principles model which has been used successfully for both endotherms and ectotherms (Porter & Gates 1969; Porter 1988; Porter et al. 1994; Porter et al. 2002). In 2007, Dr. Porter's model was patented under the name "Niche Mapper". Niche Mapper calculates the fundamental niche of an animal using physiological, allometric, and life-history characteristics

(Figure 3). Mass, heat, and water-balance equations can be derived for any animal from the metabolic rate, surface properties, and basic environmental properties (e.g. air temperature, relative humidity). This method has been shown to have both high accuracy and broad taxonomic applicability (e.g., Porter et al. 2000). For example, Niche Mapper has been used successfully to predict food and water requirements and distribution limits of reptiles in Australia (Kearney & Porter 2004) and the Po'ouli on Maui (Porter et al. 2006).

Focal organism. The American pika (*Ochotona princeps princeps*; Hafner and Smith 2010) is a model organism for scrutiny of temperature effects on presence and abundance. It is a medium-sized (150 g) diurnal lagomorph that lives up to 7 years and is found in mountainous areas of western North America, from British Columbia to California and New Mexico (Smith & Weston 1990). American pikas are specific to talus or piles of rocks >0.2 m in diameter and fringed by vegetation, with a preference for the largest rocks (Brown et al. 1989; Tyser 1980). *O. princeps* defend individual home ranges of ~400 m² and larger habitat patches have a higher probability of supporting a persistent population (Smith & Weston 1990). They do not hibernate, but rather collect hay-piles during the summer and early fall to supplement their winter caloric needs (Dearing 1997).

Current pika presence or absence should reflect distributional trends for multiple generations because pikas are not proficient dispersers. Smith (1980) found that patches with perimeters >150 m had little change in occupancy over a five-year period and only ~25% of juveniles attempted to disperse. Young typically inhabit home ranges adjoining their natal one, and among those that disperse further, few travel >100 m (Smith & Weston 1990). These factors contribute to relatively isolated patches of habitat. Establishment of baseline data and subsequent annual monitoring of a large, probabilistically selected network of sites, such as across GNP, would increase our ability to predict the likelihood of individual site rescue at temporal scales relevant to pikas and contemporary climate change.

There are numerous lines of evidence suggesting pika range distribution is affected by temperature. At its highest latitudes, *O. princeps* is found at elevations ranging from 3000 m to sea level. The lower elevational limits of its range become progressively higher with decreasing latitude, as found by Grinnell (1917). At its southern limit, it is uncommon to find pikas lower than at 2500 m (Smith & Weston 1990). Pika basal metabolic rate is high (143% of predicted weight-specific value) and thermal conductance is low (101-53% of predicted values; MacArthur & Wang 1973). As a result, their body temperature is high (mean = 40.1°C) and upper lethal temperature is relatively low (mean = 43.1°C; Smith 1974). Hyperthermia and death may occur at moderate (25.5-29.4°C) ambient temperatures (MacArthur & Wang 1973; Smith 1974). Applying species-area relationships and tenets of island biogeographic theory, McDonald and Brown (1992) predicted pikas were the 4th (out of 13 modeled mammal species) most vulnerable to local extinction in Great Basin mountain ranges, given a scenario of a 3°C temperature increase.

This paper provides detailed methods and results from pika research conducted in GNP from 2007 – 2009. Research included: 1) pika detectability by biotechs and volunteers, 2) park-wide talus site identification, 3) park-wide site surveys, 4) activity observations, 5) biophysical model development, and 6) trapping.

METHODS

Pika detectability. We collected data to assess pika detectability and compare biotech and volunteer bias in three ways: 1) Biotech pika detectability trials, 2) citizen science site surveys, and 3) volunteer sitting-surveys. See table 1 for a description of terms used commonly in this paper.

Biotech pika detectability trials. Ten trained assistants (biotechs) surveyed eight sites near Snyder Lake, July 12-13, 2009 (N = 80). Sites occurred at two talus fields and were separated by rock cairns. Each observer was shown a map of the sites and their boundaries. Assistants were told to spend approximately 30 mins. surveying each site. Observers recorded only signs that occurred within their current site. For example, calls and sightings beyond the boundary of their present site were not recorded. Surveys were categorized by time of day (Daytime) according to the survey's start time: morning = before 12:00, midday = 12:01 – 17:00, and evening = after 17:00. Observers were assigned an experience level (EXP) from 1 – 3 based on how many previous surveys they had conducted: (1) = less than eleven surveys, (2) = between 11 and 30 surveys, (3) = more than 30 surveys.

Observers searched the designated area for static and transient pika signs. Static signs included scat and hay-piles. Both were easily identified. Pika scat is a small sphere approximately the size of a BB-pellet. Hay-piles are collections of local vegetation that also contain some scat. Observers also estimated visible hay-pile volume. We estimated the length, width, and depth (by sticking a pen into the hay) in inches. Transient signs included calls and pika sightings. We estimated the number of potential home ranges that contained at least one pika sign (pikaID). Since pikas are solitary central-place foragers, we considered all signs within a 20m radius of a hay-pile to belong to a single individual. A 20m-radius circle was considered one potential pika home range (HR). If pika signs were found in an area without a visible hay-pile, we assumed the hay-pile was either deep in the talus or the site was newly occupied. We estimated the center of an HR in those instances when a hay-pile was not evident. PikaID was further differentiated by those including transient signs. Observers recorded a current occupant (CO) when a PikaID included at least one transient sign. For example, an observer conducting a survey could find 15 HRs (20m-radius circles) containing at least one pika sign (pikaID = 15) and in six of those HRs the observer heard or saw a pika (CO = 6). Finally, observers recorded an end time and estimated the number of HRs at the site.

Citizen science site surveys. Biotechs and volunteers adhered to the following protocol for surveys of the same 12 sites during 2008 and 2009 (N = 22). One or more surveyors navigated to the site using a provided site description and GPS coordinates. Upon reaching the position, a survey start time was recorded. Surveys were given a Daytime according to the start time and in the same fashion as the detectability trials. Surveyors traversed the site by searching non-overlapping sections of the talus, recorded all the observed pika signs, and assigned pikaIDs as described above. Surveyors also recorded whether other small mammals (competitors, e.g. Columbian ground squirrel [*Spermophilus columbianus*]) were present during the survey. The survey end time was also recorded. Search effort was quantified using people-minutes (PMINS).
$$\text{PMINS} = (\# \text{ of active surveyors}) \times (\text{total search time}).$$

Biotechs always surveyed in pairs so their PMINS were the total search time multiplied by two. Volunteer group-size varied from one to four. For the analyses, “Observer type” meant either biotech or volunteer.

Citizen scientist sitting-surveys. Sitting-surveys were conducted by volunteers at 21 sites during 2008 and 2009 (N = 95 surveys). The volunteers sat on a rock providing a good vantage point near the designated GPS position. They recorded Daytime, pika sightings, calls, and estimated number of CO.

Data analysis. A number of variables were derived for analysis. We calculated the number of days from June 1 to the survey date (Season) as a metric of seasonality (e.g. a survey conducted on August 11 would have Season = 71). When noted, we normalized data by dividing by HR or ID as some sites were larger (greater HR) or contained more pikas (greater ID). When surveys were conducted in both 2008 and 2009, we derived a Site:Year variable to compare only surveys of the same site during the same year, thereby removing the effect of annual turnover from analyses. Significant predictors of each pika sign variable were identified by fitting the “full” linear model. Next, we used R statistical software to perform a “drop 1” F-test. This procedure calculates the Aikake’s Information Criterion (AIC) value for each user-specified set of models, which is a combination of variables that most parsimoniously describe variability in the response variable (Burnham & Anderson 2002). The significance (p-value) of each variable and the change in AIC (delta-AIC) if removed from the model are also calculated by the drop 1 procedure. Each non-significant variable ($p > 0.05$) was removed from the model and the drop 1 procedure repeated. Non-significant variables, if present, were again removed. Once the most parsimonious model was produced, we found the adjusted R-squared value for the linear regression model and the sign of correlation for each variable.

The “full” model varied for each of the three investigations presented here, as did the response variables. Analysis of the biotech pika detectability trials included a suite of response variables: HR, ID, Scat, Old Hay, and CO. We also used three derived response variables that had to be transformed to adjust for fan-shaped residuals: $\log(\text{Old Hay Volume})$, $\sqrt{\text{Sightings/ID}}$, and $\sqrt{\text{Calls/ID}}$. We used two full models because of colinearity between “name” and “EXP”. The two full models were:

$$1) y = \text{Section} + \text{Daytime} + \text{Name}$$

$$2) y = \text{Section} + \text{Daytime} + \text{EXP}$$

Citizen science site survey comparisons were conducted using the following derived response variables: ID/PMINS, CO/PMINS, CO/ID, Sightings/PMINS, Hay/PMINS, Hay/ID, and Scat/ID. We also square-root transformed Scat/PMINS to adjust for fan-shaped residuals. The full model was:

$$y = \text{Observer type} + \text{Site:Year} + \text{Season} + \text{Daytime} + \text{Competitors}$$

Citizen scientist sitting-survey analyses used the following response variables: CO/PMINS, CO, and Calls. The full model was:

$$y = \text{Site:Year} + \text{Daytime} + \text{Season} + \text{Competitors}$$

Site Identification. We identified 706 talus deposits within GNP, each with a perimeter >150 m, from a surface geology GIS layer obtained from the National Park Service (NPS). However, pilot surveys conducted during summer 2007 revealed that many of the presumed talus

deposits were in fact scree fields that contain rocks too small (<0.5 m diameter) for appropriate pika habitat. As a result, we conducted visual scans from summits and ridges in the park and identified talus deposits of at least 1000 m² on 7.5 minute USGS maps. Talus deposits were relatively easy to identify from a good vantage point, although topographic features sometimes limited viewshed. During the 2007 pilot study, we identified about 100 suitable talus patches, approximately another 200 in 2008, and 100 more in 2009. Among those 400 sites, ~300 were surveyed. Since we visually scanned the vast majority of the areas above tree-line in the park, it is likely that we identified at least 75% of the talus habitat in the park. Defining deposits as one or multiple sites was sometimes challenging. We considered deposits distinct sites if separated by: a) >100 m or b) a significant dispersal barrier, such as a cliff or river. Separations were often meadows or forest patches that did not contain appropriate talus.

The observed talus patches were digitized into ArcGIS by Megan Apple (Whitefish High School) under the direction of Richard Menicke (NPS – GNP). Next, we (Gavin Jones and I) evaluated the polygons for accuracy and labeled them using survey site identification numbers. We were also able to consolidate site numbers for multiple surveys conducted on a single continuous talus patch by navigating directly to the lat/lon coordinates.

Site Surveys. We conducted pika habitat identification and monitoring in GNP during June 12 – August 23, 2007, June 1 – September 30, 2008, and June 11 – September 17, 2009. The first surveys of each season were conducted following sufficient snowmelt. Most monitoring occurred during July - September, and less frequently at midday, when pikas are least active. Surveys begun between 11:00 and 15:00 were considered midday. Pikas are easy to detect because individuals construct and defend haypiles. Haypiles and territorial disputes are most conspicuous during late summer and early fall, during periods of elevated haying activity before winter. It is still possible, however, to identify pika sign during late June and July. Besides increasing total sample size, monitoring earlier in the season has the additional advantage of corresponding to peak vegetation times. To identify and mitigate potential sampling bias arising from variation in monitoring time (i.e. early or late summer), a sub-sample of early-monitored sites absent of pika sign were visited again in September, along with a small sub-sample of early presence sites. This effort allowed us to quantitatively assess detectability of individuals, and to what extent (if any) it varies during the snow-free season. We also re-surveyed, in 2008 and 2009, a subset of the previously surveyed sites, thus allowing us to begin tracking annual population fluctuations. Since pikas tend to be least active during midday.

Survey Datasheets. Datasheets were revised following the 2007 and 2008 field seasons to improve data collection and clarity. A sample datasheet appears in Appendix D.

Observers. For data entry, observer names were abbreviated and assigned an experience level score (EXP) based on the number of surveys the individual had previously conducted: (1) = less than eleven surveys, (2) = between 11 and 30 surveys, (3) = more than 30 surveys. Abbreviations and full names follow: LMH = Lucas Moyer-Horner, SS = Scooter Sakura, JG = Jacob Goldberg, AK = Andy Kellner, WM = Will Martens, SC = Skip Carpenter, GJ = Gavin Jones, CG = Carly Garfield, CD = Colin Donihue, HL = Han Lee, LA = Leah Alstad, ML = Marty Lea, MH = Michael Harris, SY = Sara Yeo, SR = Samantha Reuter, ZS = Zach Spector, MS = Matt Smith, SW = Susan Wheeler, AS = Andrea Snow, AD = Alex Devoe, JW = Juli Waarvik, JS = John Stuhler, ME = Mason Lantz, KL = Kate Lofgren, RR = Robin Robinson, JP = John Pye, KK = Kate Klacan, HM = Hannah Motl, AG = Ashley Gramza, JB = Jami Belt, WH = Wendee Holtcamp, SW = Scott Schweizer, RI = Rachel Irvine.

Survey Protocol. Monitoring protocol adhered closely to standards determined at the Pika Monitoring Workshop, Lava Beds National Monument, 2006 (Ray & Beever, 2007). Surveys were conducted in teams of two. Each team carried the following equipment: Garmin CSx Map GPS, >1 pens, >1 datasheets, compass, GNP map, and appropriate 7.5 minute USGS map(s). Teams split up and surveyed different areas of the talus patch in the manner deemed most efficient. Often, individuals traversed the upper and lower portions of a patch in parallel. Pika signs occur most frequently under the largest boulders and near the talus/meadow interface. Surveyors traveled in an irregular zig-zag fashion, focused on the places most likely to contain pika sign, such as the largest boulders and near the talus/meadow interface. Teams reconvened for the vegetation transect after searching for a maximum of 30 mins. Multiple 30 min surveys were conducted if the patch was too large to be adequately covered in just one. A GPS position was taken at the first identified hay-pile. If a hay-pile was not found, the GPS point was taken roughly in the center of the talus patch. All GPS points were recorded (and subsequently provided in this paper) using the NAD83 zone 12 datum. A detailed protocol appears in Appendix B.

Pika sign. We classified pika sign in several ways during site surveys, including visual and aural detection of individuals at various distances from the observer, number of fresh and old hay-piles discovered, and number of fresh and old scats discovered. We assigned a pikaID number to each sign to facilitate population size estimates. Signs judged to be from a pika previously detected were given a redundant pikaID. For example, if a pika call was observed near a previously detected haypile, the associated pikaID did not increase in value (i.e. this was not a new pika detected). In this way, the final pikaID number at each site represented a rough estimate of the number of individuals detected. However, it is important to note that fresh hay-piles are the best evidence of an ‘active’ or currently occupied territory. Even the appearance of a pika within the site cannot guarantee that the site lies within the active territory of a pika: the pika may have entered the site from an adjacent territory, perhaps in order to observe the survey crew. Similarly, fresh scat can be deposited by a pika wandering outside its territory. Old scat may have been deposited in previous years.

We estimated the number of pikas currently occupying a site by subtracting pikaIDs associated with old signs (old hay, old scat) from the final pikaID. The resultant metric, current occupancy (CO), represented the summation of fresh hay, pika calls and sightings from individual pikas. Fresh scat was not used to calculate CO due to inconsistent observer identification. Observers were often unsure whether a given scat was fresh or not, so scat was generally considered ‘old’. The pikaID method worked well in GNP as sites tended to be large and separated by great distances, thus reducing the likelihood of hearing or seeing pikas from a neighboring site. It can be challenging to associate pika calls and sightings to distinct individuals because pikas, although typically found within their 20 m home range, can and will travel farther on occasion. However, these estimates are still useful, especially during surveys in June and July when there is little active haying. Even in late summer, when hay-piles can be quite large, some are well hidden. Preliminary analyses comparing early and late summer CO estimates at the same site suggest this method is effective, even with relatively inexperienced observers.

Search techniques varied among types of sign. The detection of ‘indirect’ signs (hay-piles and scat) requires focused searches at or below the surface of the talus, while the ‘direct’ (visual or aural) detection of individuals may occur at any time during the site survey. Therefore, search effort necessarily differs between direct and indirect signs. Search effort for indirect signs was

represented by the hay/scat search time. Total search time for direct signs was recorded as the total time spent at the survey site.

Other mammal sign. Signs of other small mammals were also recorded during site surveys. Hoary Marmots (*Marmota caligata*) and Columbian Ground Squirrels (*Spermophilus columbianus*) were the most common talus co-inhabitants. Observers also recorded signs of potential predators (e.g. weasels, hawks, bears, wolverines, eagles) and other competitors (e.g. woodrats, golden-mantled ground squirrels, least chipmunks). Woodrat sign was of particular interest as they often occupy the same talus crevices and similarly collect vegetation. Woodrats typically collect larger and ‘woodier’ vegetation than pikas, and often leave a milky-white stain on the rocks. Pikas may leave similar stains due to repeated use of a particular latrine; however, their stains are typically small, whereas woodrat stains are larger than a silver dollar. Prior to data analysis, mammals were categorized as either predators or competitors (Table 1).

Weather. Effective search effort is often influenced by the weather, as animals are more active or more detectable under certain conditions. Pikas have been shown to be less active during hot, windy, and rainy weather (Smith 1974, Hayes & Huntly 2005). During surveys, estimates were made of ambient temperature, wind speed and cloud cover. Wind speed was estimated as described in Appendix B. Skies were classified according to broad classes of cloud cover. Surveys were not conducted during precipitation events.

Topography, biogeography and geology of survey sites. We recorded the minimum depth of the deepest crevices within the talus (e.g., >1.0 m) as a metric of ‘insulation’ or the potential for pikas to escape surface temperatures and predators. We also recorded maximum rock size (along its major axis) associated with each pika sign.

As estimates of habitat area and connectivity, the number of pika territories (home ranges) visible within the site was recorded, along with the visible number of discrete talus patches (i.e. separated by >20 m). During early season 2008, many crews failed to record the size of the site as it did not appear explicitly on the data sheet. Instead, many crews recorded the number of potential sites visible from the one they were surveying (e.g. on a mountainside across the valley) and number of home ranges within those sites. These mistakenly taken data, although difficult to estimate, were useful for identifying new sites. In 2009, extra attention was given to ensuring crews estimated site home ranges and number of patches.

Vegetation. Within each site, the total cover of each plant species was estimated using point-intercept sampling along line transects. The point-intercept method may be the most effective way to characterize plant cover within multiple layers of vegetation, and can be used to estimate relative plant height. We identified plants by ‘functional type’ (graminoid, forb, shrub, tree, moss, lichen). Pikas are generalist herbivores, and published studies indicate pikas make at least some use of almost any vegetation available. Conversely, studies also indicate that pikas respond to the relative availability, size, and secondary chemistry of plants (Huntly et al. 1986, Dearing 1997). Much of the variability in secondary chemistry can be captured by identifying plants according to broad classes. For example, forbs (herbaceous, flowering plants) tend to be larger and defend themselves with toxic chemicals, while graminoids (grasses, sedges and reeds) are relatively small and less toxic. Plant size can vary dramatically even within species, but size (unlike chemistry) is easily determined. Plant height was estimated in inches because that unit was most familiar to the observers.

Random sampling may not be appropriate for characterizing the vegetation available to central-place foragers like the pika, especially when the habitat contains strong gradients that may affect vegetation structure (e.g. steep slopes or patchy substrates). For these reasons, a

stratified sampling scheme should be used, with heavier sampling closer to the likely centers of pika activity (e.g. closer to hay-pile locations). However, we could not count on locating hay-piles during all surveys. When hay-piles were absent, we estimated the ‘best’ available pika habitat at the site for sampling. We selected the biggest rocks, with the deepest crevices and near at least a moderate plant density, often near the talus-meadow interface.

We sampled vegetation using a 24-meter diameter transect with its midpoint at a hay-pile, other pika sign or best available habitat. In pika habitats, the fall line (steepest average slope gradient) often captures the most dramatic vegetation gradient (Ray & Beever 2007), so we oriented transects along this line to provide a good representation of the plant diversity available. If the site was flat, the transect was oriented along the most (visually) apparent vegetation gradient. This first transect was crossed by two additional 24-m transects forming a hexagonal design (60° separations). Beginning at the central point and moving outward, a point-intercept sample was completed at each meter along each transect (i.e., at meters 0, 1, 2...12). For each sample, a long pin (or thin stick) was held vertically through the vegetation, touching the substrate (rock or soil). Each functional type touched by the pin was recorded, beginning with the tallest species and ending at the substrate. Dead litter (dead wood or other dead vegetation) intercepted by the pin, and the type of substrate, were also recorded. Living plants were identified by functional type and size as described above.

Microclimatic data. In 2008, we placed AQA 8000 Series LogTag™ data loggers (www.logtagrecorders.com) within the talus at seven sites to record ambient temperature and relative humidity at intervals of 15 minutes. These sites were chosen based on representation of the largest possible variability in elevation and site aspect. At one site (Gable Pass), two loggers were placed within 100 m of each other. The site names with elevation appear here in order of increasing elevation: Janet Lake (1512 m), Buttercup Park (1765 m), Mad Wolf (2031 m), Calf Robe (2054 m), Lower Gable Pass (2207 m), Upper Gable Pass (2272 m), Triple Divide Pass (2274 m). Loggers were placed in protected crevices 1 – 1.5 m below the talus surface near hay-piles, thus protected from direct sunlight. Fresh hay-piles were chosen preferentially for logger placement, but since most loggers were placed during June and early July, before active haying, we chose large old hay-piles under the most prominent boulders. We used plastic ‘trimmerline’ (used for weed-whackers) to secure the logger to a rock, so that it was adjacent to or hanging just above the hay-pile. Loggers were collected in September and data were downloaded to a computer. Since loggers were placed and collected at different times, their record duration varied.

The loggers placed in 2008 were also used to calculate the lapse rate for GNP. We fit a linear regression to the instantaneous morning (07:00), midday (14:00), and evening (20:00) temperatures at each of the sites to calculate a “GNP lapse rate”. We calculated this lapse rate at one-week intervals from July 28 to September 15.

In 2009, we placed two loggers at each of three different sites. At each site, one logger was placed 1 m below the talus near a hay-pile, as was done in 2008. The second logger was placed above the hay-pile, on the talus surface, exposed to the sun. The site names with elevation in order of increasing elevation appear here: Red Rock Point (1056 m), Hidden Lake (1939 m), Mt. Brown (2521 m).

We used the Red Rock Point and Mt. Brown loggers to calculate the instantaneous temperature difference between above and below the talus. The activity observation time-periods were used as points of reference. Those observations took place over ten days, from July 15 to July 24, during morning (05:15 – 08:15), midday (13:00 – 16:00), and evening (19:00 – 21:00).

For example, we found the below-talus maximum temperature for each of the ten mornings and subtracted them from each of the corresponding above-talus maximums. We then found the mean and standard deviation of the above- minus below-talus temperature for the ten mornings. We used the same procedure for midday and evening.

Site use and occupancy. Pika signs were classified in several ways during field surveys, including visual and aural detection of individuals at various distances, number of fresh and old hay-piles discovered, and number of fresh and old scats discovered. We defined occupancy based on signs of site use. We classified the site as currently occupied (by pikas) if the survey crew observed: 1) a pika (detected by sight or sound) within the site; or 2) a fresh hay hay-pile. Fresh scat could be used as an indication of current occupation, but differentiating fresh from old scats proved too inconsistent between observers.

Site occupancy varies from year-to-year and the likelihood of visual or aural pika detection may vary with season (e.g. early versus late summer) and time of day. We revisited sites between and within summers to quantify this variability.

Data analysis. The drop 1 procedure was applied to generalized linear regression models, as described above, to find the most parsimonious models using AIC and removing non-significant variables ($p > 0.05$). Many surveys were conducted without corresponding vegetation transects because one had already been conducted elsewhere in that particular patch. However, sites (rows) with missing data are excluded from regression calculations in R. Therefore, we used two “full” models, one with and one without vegetation data so as not to lose vegetation information and also utilize the larger sample size. The model without vegetation was used to maximize observations ($N = 271$). The model with vegetation was used to maximize the number of explanatory variables at the cost of a smaller sample size ($N = 193$). Three derived response variables were used for each model: ID/HR, CO/HR, and CO/ID.

The full maximum observations model was:

$y = \text{Year} + \text{Season} + \text{Midday} + \text{Elevation} + \text{Total EXP} + \text{Search Time} + \text{Total Time} + \text{Aspect} + \text{Gradient} + \text{Talus Depth} + \text{\#Visible Patches} + \text{\#Visible HR} + \text{Competitors} + \text{Predators} + \text{\%Cloud Cover} + \text{Estimated Temperature} + \text{Wind Speed} + \text{Rock Size}$

The full maximum variables model included the same as above with the addition of percent cover vegetation height data as follows: Rock, Lichen Rock, Forb, Grass, Shrub, Moss, Tree, Dead Vegetation, Substrate Soil, Substrate Rock, Substrate Rocky-soil, Snow, Substrate Unknown, Mean Grass Height, Mean Forb Height, Mean Tree Height, Mean Shrub Height.

Activity observations. We observed pika activity at eight sites based on high pika densities and variation in aspect and elevation. The sites are listed here with GPS location and slope aspect in order of increasing elevation: Red Rock Point (N 48.6941, W 113.81691; 215°; 1056 m), Janet Lake (N 48.9465, W 113.9332; flat; 1445 m), Snyder Lake (N 48.6362, W 113.80128; 300°; 1607 m), Apikuni Falls (N 48.885, W 113.63794; 160°; 1713 m), Mad Wolf Mt. (N 48.5769, W 113.3825; 270°; 1962 m), Sperry Chalet (N 48.3608, W 113.47103; 232°; 2054 m), Gable Pass (N 48.9169, W 113.63983; 15°; 2176 m), Divide Mt. (N 48.6572, W 113.39508; 280°; 2228 m).

Protocol. We conducted twelve separate three-hour observation periods per site (3-hour periods * 12 observations * 8 sites = 288 observation hours). Observation intervals were as follows: morning (05:15 – 08:15), midday (13:00 – 16:00), and evening (19:00 – 22:00). All

observations occurred from July 15 – July 24, 2009. Observations were conducted over the short ten-day span to reduce the effect of seasonality. Morning observations commenced ~15 mins prior to sunrise. Evening observations concluded ~15 mins after sunset. We observed from a high vantage point and in a passive manner, as pikas pay little attention to quiet observers (Conner 1983). The observers continuously scanned the talus field and recorded the time of all visual and audible evidence of pika activity. We recorded visual events using the naked eye or 7x35 binoculars. When possible, observers also noted whether the activity occurred while the pika was exposed to direct sunlight. Observers worked in pairs but recorded data from non-overlapping areas (~40 m radius) of the same talus patch. Observers assigned individuals temporary ID numbers and sketched maps of their whereabouts to distinguish the activity of individual pikas. A single pika call or sighting was considered a “unique event”. Additional calls or sightings of the same individual within 30 secs. were recorded but not considered new unique events. In this way, we categorized brief flourishes of activity as single events. Additional site data and specific behaviors were recorded as outlined in the field instructions and data sheet (Appendix C).

Temperature data. We estimated above-talus temperatures during each observed activity using two data loggers and the standard dry adiabatic lapse rate (-9.8 C/km). First, we matched each observation time with its appropriate 15 min interval from the loggers at Red Rock Point (1056 m) and Mt. Brown (2521 m). Next, we applied the lapse rate to the measured above-talus temperature from each logger to produce two estimates of the temperature at the elevation and time of the observed activity. Finally, we used the mean of the two estimates, except for observations at Red Rock Point, for which that logger’s data were used.

Data analysis. We used the number of current occupants at each observation site to normalize the calls and sightings into calls/CO and sightings/CO. We ran ANOVAs to identify significant predictors of calls and sightings from the following possibilities: site, observation period, elevation, and above-talus temperature. Linear regressions were used to identify the sign of effects.

Biophysical model development. The pika properties used for biophysical (NicheMapper) modeling were measured directly or gleaned from the literature. We obtained a preserved pika specimen with summer pelage from the University of Wisconsin-Madison Zoology Museum that had originally been shot during the summer in Colorado. We directly measured fur length, depth, and reflectivity for the dorsal and ventral sections of the torso and legs. Allometry and mass data were retrieved from Smith and Weston (1980). Metabolic rates and temperature data were retrieved from MacArthur and Wang (1973). Climate and weather data were retrieved from the National Oceanic and Atmospheric Administration website (www.noaa.gov) for Kalispell International Airport. We ran point-simulations for GNP and modified temperatures and barometric pressures to reflect five elevations (m): 0, 750, 1500, 2250, and 3000. We used the standard dry adiabatic lapse rate (9.8 C/km) to derive mean monthly temperatures for those elevations. We also modeled two warming scenarios: 2050 ($+2.7\text{ C}$) and 2100 ($+5.5\text{ C}$) for 1500 m elevation (LLNL 2009).

NicheMapper, described in detail elsewhere (Porter & Gates 1969; Porter & Kearney 2009), derives a suite of biophysical variables. Some of them are presented in this paper, others are available upon request. Those presented include: activity time (number of hours per day the animal can be active without overheating), food requirements (grams of wet food per day required to meet metabolic demands), and evaporative water loss (grams of water lost per day). We also calculated foraging rate as food requirements divided by activity time. It is important to

note that this model allows for behavioral modification of microclimate, which corresponds to a pika seeking shelter under shade of the talus. This behavior will be automatically chosen when ambient temperature exceeds 25°C or body temperature is >43°C, producing conservative limits to activity time.

Trapping. We trapped pikas at two sites, Gable Pass and Janet Lake, for ten days each in an effort to measure their field metabolic rates. Sites were chosen due to high pika densities and elevation variation. Pikas were handled in order to: a) determine weight and body condition; b) mark individuals for re-trapping; and c) collect blood and hair samples for analysis. All trapping was conducted by me and one other trained assistant. All pika handling was done by me.

Pikas were trapped individually using wire-mesh traps (Tomahawk-brand “chipmunk” traps, approximately 16x7x7 inches). Traps were set near the center of an individual’s territory, near its haypile. Deaths during trapping and handling were mitigated by trapping during daylight hours, sheltering each trap from the elements, checking traps frequently and handling animals immediately upon discovery. Traps were open only between the hours of 06:00 and 12:00 or 16:00 and 21:00. During this time, open traps were visited every 1-3 hours, depending on weather conditions. Traps were visited more frequently when ambient temperatures were relatively high or low, and during periods of precipitation or high winds, especially when combined with lower temperatures. Wire-mesh traps were used in order to allow heat dissipation, because pikas are thermally stressed during warm days. Large stones were placed around and on top of each trap to provide protection from the weather and from predators (e.g. weasels). Traps were baited with local vegetation known to be part of the normal pika diet, and pika scats obtained at other hay-piles. Sufficient bait was included to provide sustenance for at least four hours.

Animals were processed and released at the trap site. Stress-related mortality associated with handling was minimized by anesthetizing all trapped animals. Anesthetic (Isoflurane vapor) was applied after the animal is self-transferred from the opened trap into a transparent and semi-ventilated anesthetizing chamber designed specifically for pikas (Chris Ray, CU-Boulder, *pers. comm.*). Animals were under constant observation while in the anesthetizing chamber, to prevent overdose. Pikas exhibit pronounced responses to anesthesia, allowing handlers to estimate optimal exposure time. Pikas also respond well to a sort of modified cardio-pulmonary resuscitation, and handlers were trained to provide such assistance. Additional anesthetic (20% Halothane / 80% mineral oil) was applied via a soaked cotton ball within a plastic nose cone. Handlers covered the pikas mouth and nose with the nose cone as needed if it began to regain consciousness.

Handling included determination of body condition, collection of blood samples, injection with doubly-labeled water, collection of hair samples, placement of ear tag, and determination of weight, in that order. During handling, the temperature of each animal was maintained within a reasonable range by shading the animal or by providing heat through proximity to the handler’s body. Two blood samples were collected retro-orbitally from each pika using capillary tubes. The handler’s hands and all tissue collection devices were cleaned with 70% ethanol between pikas. Each animal was released at the exact location where it was trapped.

The protocol outlined above had been applied to approximately 475 pikas over the past 15 years, resulting in just nine deaths due to exposure (n=5), anesthesia (n=3) or attempted predation (n=1; Chris Ray, CU-Boulder, *pers. comm.*). Trapping was discontinued in 2009.

RESULTS

Six categories of data are reported: GIS layers, observer bias and pika detectability, site surveys, activity observations, biophysical modeling, and trapping.

GIS layers. Unique survey locations ($N = 303$) can be found in “AllSurveys.shp”. This layer does not indicate how many times a particular site was visited. The ~400 talus patches viewed and subsequently digitized occur in “talus_seen.shp”. The file name is meant to differentiate it from the remotely-sensed talus found in the surface geology layer provided by the NPS. A comparison of the “talus seen” and surface geology talus layers reveals surprisingly little overlap. The surface geology layer nearly always identifies scree as talus. Some talus locales are correctly identified but also include surrounding scree. However, there are many instances where extremely large talus fields are completely omitted on the surface geology layer (e.g. North side of Yellow Mt.). On a few occasions, surveys were conducted at sites not identified on the topographic map. These talus patches are identified as points in the file “sitesWOpolygons.shp”.

Observer bias and pika detectability. Observer bias data from 2009 can be found in “ObserverBias09.xls”. Additional spreadsheets containing volunteer and biotech comparisons and volunteer sitting survey data are available upon request. In this section we refer to the trained pika crew as “biotechs” and the citizen scientists as “volunteers”.

Biotech pika detectability trials. We found evidence of observer bias during home range estimates, scat counts, and calls/ID (Table 2). However, when a single outlier was removed from home range estimates and calls/ID the observer name effect was no longer significant. Daytime also predicted calls/ID. Calls/ID were greatest in the morning and least during midday. Biotech experience level was a robust predictor ($p < 0.01$) of scat-piles found. The most experienced biotechs (level 3) found the most scat while the least experienced found the fewest scat piles. As expected, section was the most consistent predictor of pika signs and home range estimates. Old hay volume, pikas/ID, and calls/ID were log or square-root transformed to correct fan-shaped residuals.

Citizen science site surveys. Observer type and Site:Year were the most consistent predictors of pika-signs and the citizen science sites (Table 3). Observer type was a significant predictor of all pika-signs except CO/ID and Pikas/PMINS. When significant, volunteers found fewer signs than biotechs. Site:Year was a significant predictor of all pika signs except Hay/PMINS and Scat/ID. Season showed a positive correlation with two metrics of current occupation: CO/PMINS and CO/ID. Additionally, more Pikas/PMINS were found during the evening than at midday. Scat/PMINS was square-root transformed to correct fan-shaped residuals.

Citizen scientist sitting-surveys. Daytime was the most consistent predictor of pika signs during sitting-surveys (Table 4). A greater number of signs were observed during the evening and fewer during midday. The presence of potential competitors (e.g. *Spermophilus columbianus*) predicted greater CO/PMINS and total calls. Calls were more frequent later in the season. Total CO was predicted poorly by the linear model ($R^2 = 0.05$) and only Daytime was statistically significant. There were no significant predictors for number of pikas seen.

Site surveys. In three summers, 360 surveys were conducted: 43 in 2007, 148 in 2008, and 169 in 2009. Some of the surveys ($N=57$) were site revisits, while 303 surveys covered unique areas of potential pika habitat. Eight of the 303 unique surveys did not follow standard survey protocol, but instead constituted incidental pika sign encounters, usually while climbing up to or along a ridge-top. The complete spreadsheet of raw data (“AllData.xlsx”) contains tabs

“AllData” (all the data), “UniqueSurveys” (excludes revisits), “UniqueWOincidental (excludes revisits and non-survey pika data), “Revisits” (only site revisits), and “Stats” (descriptive statistics of selected variables).

Habitat variables. Descriptive habitat statistics were calculated from the unique surveys so that specific patches would not be double-counted (Table 4).

Search effort variables. Descriptive search effort statistics were calculated from all the surveys (including revisits; Table 5).

Pika sign variables. Descriptive pika sign variables were calculated from the unique without incidental surveys (Table 6).

Generalized linear models. Models were run to maximize either the sample size (number of observations) or number of variables. Maximum observations models are shown in Table 8, maximum variable models are shown in Table 9.

Abiatic lapse rate. Tables 10 – 12 show the results of the lapse rate measurements.

Talus temperature buffer. Table 13 displays the temperature differences measured above and below the talus surface.

Site pictures. Digital photos of most sites will be sent to the NPS.

Activity observations. Activity observation data from 2009 can be found in “ActivityObs.xlsx”. Temperature increases predicted reductions in both sightings and calls (Figures 4 and 5).

Sightings. Unique sightings per current occupant (S/CO) were influenced by site, observation period, temperature, and elevation (ANOVA, $p < 0.01$; Figure 5). Linear regressions of these variables revealed a slope of 1.5 fewer S/CO during midday than during morning or evening ($p < 0.01$). S/CO decreased as temperature increased. However, the site:temperature interaction term was non-significant ($p = 0.40$) indicating that the slopes of the temperature effect did not differ between sites. Instead, it was the y-intercept, or baseline, S/CO that differed. Higher elevation sites also had more S/CO.

Calls. Unique calls per current occupant (C/CO) were influenced by site, observation period, and temperature (ANOVA, $p < 0.01$). Linear regression revealed a slope of 14.7 fewer C/CO during midday than during morning or evening ($p < 0.01$). C/CO decreased as temperature increased (Figure 2). Although C/CO differed between sites, there was not a significant elevation effect. Data were also collected on whether calling pika were in the sun or not. Only one of 149 (0.67%) long callers was in the sun. Additionally, only 400 / 6699 (6%) short callers were in the sun. There were no significant temperature or elevation effects on the proportion of short callers exposed to the sun.

Biophysical modeling. The pika specimen’s pelt reflectivity was: dorsal = 45%, ventral = 57%. Higher elevation sites produced higher modeled metabolic rates (Figure 6), foraging rates (Figure 7), and evaporative water loss rates (Figure 8). Higher elevation sites also allowed for more available activity time (Figure 9). Future warming scenarios modeled at 1500 m elevation predicted one less hour of available daily activity time in July and September by 2050 and June – September by 2100 (Figure 10). Additional model results are available upon request.

Trapping. Trapping data can be found in “GableTraps.xls”. At Gable Pass, there were eight successful trapping events of five separate individuals. They received the following tags numbers: 125, 148, 149, 150, and 175. Although blood samples were could only be taken from three, all five were injected with doubly-labeled water. Only one of the two re-trapped pikas yielded a second blood sample. Trapping at the Janet Lake site resulted in successful trapping of only one individual, who was injected with doubly-labeled water but not tagged. The one post-

injection blood sample retrieved was not analyzed for metabolic rate estimate because the sample size was insufficient.

DISCUSSION

GIS layers. The NPS “talus” surface geology layer is largely incorrect; identifying primarily scree instead of talus. Our ridge and peak surveys for talus allowed us to see most of the basins and cliff-bottoms in GNP. It is likely that we directly observed ~75% of the potential talus land-surface in the park. There are a number of reasons we missed ~25%. A few talus patches were found in unexpected places such as surrounded by trees at low elevation (e.g. Dutch Lakes trail) or derived from man-made structures (e.g. Red Rock Point and Hwy 2 train tracks south of West Glacier). Recently burned areas (e.g. Divide Mt.) sometimes revealed previously forest-covered talus. A few areas of the park were only poorly observed because we either didn’t have enough time to gain a good vantage point or the view was obscured by clouds or smoke when the observations were made. In general, drainages on the east side of the continental divide were scanned for talus in more detail than those on the west side. The northwest and southwest corners of the park were the least observed. Talus occurs on many peaks and ridges but is difficult to confirm from afar. Peaks and ridges, especially on the west side, constitute the least explored areas of the park for talus. For example, previously unidentified talus patches were observed in the Park Creek and Ole Creek drainages during the writing of this report, and numerous pikas were heard and seen from an extensive talus patch along the western ridge of Brave Dog Mt.

Observer bias and pika detectability. Table 2 shows that a trained biotech crew can consistently identify pika signs even with minimal experience. We found an observer effect for three signs: HR, Calls/ID, and Scat. We expected HR estimates to pose a consistency challenge. Thus, it was not surprising to see an observer name effect. However, consistent HR estimates were important for park-wide surveys and accurate density measurements, so care was taken during training to follow a consistent procedure. Since analyses revealed that the name effect came entirely from one aberrant observer we can have a higher degree of confidence in the consistency of the HR estimates from the remainder of the biotechs.

On the other hand, it was surprising to find a name effect for Calls/ID. Again, one outlying observer was responsible for the effect. The individual consistently under-reported calls and may have misunderstood the instructions to record every call heard, even when coming from the same individual.

Experience played a role in the number of scat-piles found. The effect was not attributed to a single observer and followed a predictably linear pattern of more scat-piles found by the more experienced observers. Traversing talus, which can be unpredictable, unstable, sharp, and precipitous, is challenging. Experienced observers typically traverse talus quicker and more efficiently, allowing them to cover more ground than those less experienced per unit time and find scat that would otherwise go unnoticed (*pers. obs.*).

Despite observer effects in the three areas discussed above, these analyses show remarkable consistency in detecting pika signs. Our findings are consistent with other, albeit largely unpublished, reports of high detectability for pikas (Beever 2003; Ray & Beever 2007; Chris Ray & Erik Beever *pers. comm.*). ID and CO were among the most important variables for determining pika density. Experience-based variation in scat-pile identification seems to have no effect on these crucial metrics. Ideally, a biotech crew would participate in detectability trials

three times during a project: 1) at the outset, 2) midway through, and 3) at the conclusion. This would allow the researcher to obtain a comprehensive grasp on intra-crew variations and tendencies. However, these results suggest that, in general, biotechs with some training and at least a few prior surveys can consistently estimate HRs, calculate ID and CO, and even estimate visible hay-pile volume.

Significantly less consistency exists between biotechs and volunteers. Table 3 shows Observer type was a significant predictor for each sign type except CO/ID and Sightings/PMINS. Additionally, biotechs consistently found more signs per unit effort (PMINS). The above observation regarding biotech experience level and talus-traversing efficiency may apply here as well. Volunteers may also feel a weaker commitment to the research and thus feel less motivated to continue searching vigorously for pika signs once a few have been identified. The lack of Observer type effect for Sightings/PMINS and CO/ID suggests that volunteers are motivated and effective at spotting pikas. Future research could explore whether volunteers experience a motivation-drop following a pika sighting.

Site:Year was a significant predictor of both CO/PMINS and Calls during the volunteer siting-surveys (Table 4). This suggests that sitting-surveys were somewhat sensitive to pika density at a particular site. However, Daytime, Competitors, and Season were also significant predictors whose effects would need to be accounted for when attempting to estimate density from sitting-surveys. Only Daytime predicted CO, and poorly ($R^2 = 0.05$). CO estimates should be normalized by PMINS or a similar search effort metric to produce interpretable results.

Daytime and Season were very important factors in pika sign identification (Tables 3 and 4). Greater numbers of CO are found later in the season and sightings are least frequent during midday. Monitoring efforts, whether volunteer- or biotech-based, should take seasonal effects into consideration and surveys should be preferentially conducted during mornings and evenings. Optimal monitoring season depends largely on the goals of the research effort. In GNP, snow-cover obscures many talus patches well into July. August and September surveys have dual benefits: 1) maximum talus accessibility and 2) high pika activity (increased hay-caching behavior). However, pika weaning occurs in early July, so that by late-August and September, many previously unoccupied and sometimes marginal territories are inhabited by young-of-the-year. Although annual turnover for pikas can average 40% (Smith and Weston 1980), death-rates for young during their first winter can be much higher and fluctuate wildly (Chris Ray, *pers. comm.*). August and September pika densities may be a poor representation of overall fecundity and density of reproductive individuals.

Our results suggest that volunteer-collected data should only be used for presence/absence purposes. Sitting-surveys should be sufficient for presence/absence surveys especially when pika GPS locations have already been determined. On the other hand, biotechs can be used to derive consistent density estimates. In some instances, volunteer surveys may inform biologists on where to send biotech crews.

Monitoring efforts should have clearly defined goals. If population-level information is desired then biotechs should be used to obtain density estimates. Volunteer-collected data may only inform us of site extirpations, and be unreliable trend indicators. Despite its potentially tenuous scientific utility, the inspirational and educational values of pika monitoring for volunteers was not measured here and should not be overlooked. Pika monitoring was the most common favorite among the volunteer participants in the GNP High Country Citizen Science program (Jami Belt, *pers. comm.*). Volunteers should be offered opportunities to engage the

research at a higher level (e.g. talus-traversing and density estimates) but they should not be expected to do so.

Site surveys. The survey data presented in Tables 5 – 7 provide a valuable and necessary baseline on which future monitoring will rely. GNP is home to a relatively large pika population. We surveyed 5065 potential home ranges and directly observed 1130 current occupants. Assuming that we surveyed 75% of the home ranges that we identified (surveyed ~300 / 400 talus patches) gives 6400 home ranges. If we next assume that 75% of the talus patches in the park were identified, that gives 8000 potential home ranges park-wide. Extrapolating our 23% CO/HR and 45% ID/HR as the lower and upper bounds gives a GNP pika population range of roughly 1800 – 3600.

Application of Hafner's (1993) equation to the GNP region shows its clear limitations at latitudes higher than °46. The equation for minimum habitable elevation works out as follows:

$$14,087 - 56.6 * (48.5) - 82.9 * (113.7) = 1916 \text{ m}$$

We found pikas as low as 1056 m at the Red Rock Point site, which is among the lowest elevations present in GNP. Although we found higher pika densities at higher elevations, there were no indications that pikas could not occur at elevations below 1000 m in this geographical region.

Season was the most consistent predictor of pika signs. Season appeared in all three maximum-observation models (Table 8) and in two of the three models that included land-cover (Table 9). Season was a particularly strong predictor of the two CO metrics (Tables 8 and 9). We know pika activity increases as the summer progresses, so it is unsurprising that we would estimate a greater number of current occupants later in the season by seeing and hearing more of them. The positive correlation with pika ID may additionally be related to the increased deposition of pika scat through the summer, increased establishment and visibility of fresh hay-piles, and establishment of new territories by young-of-the-year. Occurrence of the survey during 2007 was also a strong predictor of the two CO metrics. This may indicate a reduction in pika population from 2007 to 2008. However, these analyses did not look specifically at densities at the same sites between years, so such an interpretation would be premature.

Given the observer bias and pika detectability results presented above, it is unsurprising that fewer CO/HR were found during midday (Tables 8 and 9). However, it is puzzling that midday was also a predictor of ID/HR (Tables 8 and 9). Our biotech pika detectability trials found pika ID independent of Daytime. In our park-wide surveys, we either 1) typically explored the least densely occupied areas during midday, or 2) many of our pika IDs derived from a single call or sighting and no corresponding scat or hay. It should be noted that we attempted to minimize the number of surveys conducted during midday because we knew it was the worst time to find signs. However, the remote locations and challenging access to many of these sites did not allow us the luxury of conducting all surveys in the morning or evening.

The presence of predators had a negative impact on CO/HR and CO/ID (Tables 8 and 9). Although pikas are known to call in the presence of predators as a warning to their related neighbors (Smith & Weston 1990), our results suggest that both sightings and calls were less frequent when a predator was near. On numerous occasions, the observed predator was a short- or long-tailed weasel (*Mustela spp.*). Weasels are such efficient predators of pikas that calls may be too risky to the individual (Erik Beever, *pers. comm.*); which would explain their relative silence.

The slowest wind category (0-5 mph) predicted greater ID/HR (Table 8) and fewer CO/ID (Tables 8 and 9). Less wind means reduced convective heat loss for an animal (Porter & Gates 1969; Kearney & Porter 2009). Thus, the animal experiences an effectively higher temperature than it would with greater wind speed. Data presented in this paper and in Smith (1974) show reduced pika activity at higher temperatures. However, it is unclear why low wind speeds would increase ID/HR.

Site gradient appeared to have contradictory effects on pika signs. Steeper gradients had fewer ID/HR but more CO/ID (Tables 8 and 9). One plausible explanation is that flatter sites are more favorable as reflected in the larger ID/HR. Steep sites may be colonized primarily by young-of-the-year and displaced juveniles. If newly colonized and less likely to support over-winter survival, steep sites would contain fewer scat and hay piles, thus inflating their CO/ID ratio. Relatively flat sites generally contain thicker soil and support more vegetation growth (*pers. observation*). Additionally, flat sites are less likely to experience loss of insulating snow by wind scouring during the winter. Beever et al. (2010) found that extreme cold events during the winter were as important as chronic heat during the summer to predicting pika occupancy. A steep wind-swept slope may provide less sustenance and reduced winter insulation. For this steep site equals marginal site situation to exist (or source-sink dynamic), the best sites would have to be nearly saturated with occupants. Assuming that less than 30% of the talus in the park is not highly suitable because of lack of vegetation and the park-wide ID/HR of 0.45 (Table 7), GNP may indeed be near saturation. Future research on percent vegetation cover, hay-pile volume, snow depth, and pika survival in relation to site gradient would increase our understanding of this potential dynamic.

Higher elevation sites contained greater ID/HR (Tables 8 and 9) indicating that high elevation sites supported a higher proportion of home ranges containing at least one pika sign. Beever et al. (2003) found elevation to be the best predictor of pika presence in the Great Basin. Strangely, elevation was the strongest predictor of CO/HR when land-cover data were included in the models (Table 9) but was not significant without land-cover (Table 8). Elevation most consistently indicates temperature. Although, the standard dry adiabatic lapse rate (-9.8 C/km) can fluctuate in mountainous environments because of complex weather systems including updrafts and inversions, we found -9.8 C/km was a good predictor of temperature in GNP, especially during midday and evening, and during July and August (Tables 10 – 12). However, morning and September temperatures tended to be more even across elevations, indicative of inversions. High elevation sites may support denser pika populations because of favorably cool micro-climates. Using logistic regression, Beever et al. (2010) found that higher mean summer temperatures predicted absence of pikas. However, acute periods of high temperature did not accurately predict occupancy. Larger observed CO/HR may also be due, in part, to advanced seasonality at high elevations. Plants begin to senesce earlier at high elevations, thus pikas initiate haying earlier and become more visible to observers. In addition to increased young-of-the-year and juvenile territory establishment, this effect of seasonality on plant senescence may explain why CO/HR and CO/ID were greater later in the season (Table 9). Plant senescence and shortened growing seasons may also influence the fewer ID/HR found on north-facing slopes (Table 9). In combination with temperature and activity data presented here, these analyses suggest that higher, cooler sites support a higher pika density.

Presence of competitors increased CO/HR (Table 8). Perhaps the label “competitors” was inappropriate. Observations by Barash (1973), at Lunch Creek in GNP, indicate distinct partitioning of resources, space, and timing. Presence of other small mammals in the habitat may

primarily indicate a patch rich in resources. These other mammals may also provide enhanced safety-in-numbers from predators and may actually enhance the quality of the pikas' preferred forage by selectively harvesting competing forage.

Land-cover provides additional insight into pika habitat preference in GNP (Table 9). Greater moss and forb cover predict higher ID/HR and CO/HR. Conversely, higher grass cover predicted fewer ID/HR, indicating that pikas prefer moss and forb-covered sites over grassy sites. It could be argued that the dominant vegetation cover represents those species left-over following harvest as pika foraging does alter the local vegetative cover (Huntly 1987). However, hay-pile composition generally reflected surrounding land-cover and may actually encourage nutrient uptake by pika-preferred plants (Aho et al. 1998; *pers. obs.*). Plant defensive chemicals also play a role. Pikas prefer to forage directly on plants lowest in secondary compounds and cache those with more (Dearing 1996). Both taller forbs and grasses predicted higher CO/HR, while the former also predicted higher CO/ID. On the other hand, taller shrubs predicted lower ID/HR. Since pika densities were highest at the most well-vegetated sites, it is not surprising that greater soil substrate also predicted higher ID/HR. However, soil substrate predicted lower CO/ID which may again be attributed to recent colonization of marginal sites. Pikas have indicated cool-moist climates for thousands of years (Hafner 1993). Moist climates support greater soil deposition, as well as moss and forb growth.

Shallow talus, of a depth less than 50 cm, predicted lower ID/HR (Table 9). Talus provides a thermal refuge from hot midday temperatures. Our measurements showed below-talus temperatures were 13 – 15 C cooler than above the talus (Table 13). It should be noted that our talus-depth metric was based on the *deepest* talus at a site. Often, a site contained predominately shallow talus but one or two much deeper talus crevices. These deep crevices determined the deepest talus depth at the site. We consistently found pika signs under the biggest rocks at a site and usually in association with the deepest talus sections. Thus, to maximize our survey efficiency, we focused our attention on those sections most likely to contain signs. Although we did record the length of the longest axis of the largest rock near each sign, there was not enough variability in that metric for it to appear as a significant predictor. Our comparisons of instantaneous above- and below-talus temperatures (Table 13) are the first that have been conducted, as far as this author is aware. Future investigation into the minimum talus depth that can support pika survival and the variation in thermal protection provided is warranted.

Activity observations. As in Smith (1974), we found pika sightings were fewest during midday. However, we also found that pika activity, both calls and sightings, decreased as temperature increased (Figure 4). These data show that temperatures, even in the relatively cool range found in GNP, affect pika activity beyond a simple daily circadian rhythm. For example, evening activity at the low-elevation sites was similar or lower than midday activity at high elevation sites (Figure 5). This pattern was exemplified by the influence of site-elevation on activity. High elevation sites had higher baseline activity levels. There are a number of potential reasons for this phenomenon.

The cooler temperatures at higher elevation sites necessitate a raised field metabolic rate to maintain core temperature (Figure 6). Pikas at high elevation sites may be more active, in part, to raise their metabolism and stay in their thermo-neutral zone. This influence may be greater during the spring and fall when temperatures are particularly low. Higher metabolisms also generate greater caloric demands. Greater quantities of vegetation for direct consumption and hay-caching would be required. Lower midday temperatures reduce heat loads and allow increased activity time to meet caloric demands. Thus, low temperatures at higher elevation sites

may create a positive feedback loop that both necessitates and allows increased daily foraging and haying behavior.

Advanced seasonality may also influence higher baseline activity levels. Higher elevation sites support shorter growing seasons. Vegetation appears later and senesces earlier. The onset of senescence triggers increased haying activity. Although activity observations were conducted during a seasonally narrow 10-day window, the effective season at higher elevations may have been advanced by weeks. Exploration of these potential influences would require detailed observations of individuals throughout the summer. Observers could record the number and duration of foraging and haying trips. They could also record vegetation phenological data.

Biophysical modeling. NicheMapper models of pikas suggest that reduced available activity time is the only energetic disadvantage to occupancy of warmer sites. Pikas at higher elevation sites, which are both cooler and subject to reduced atmospheric pressure, must run a higher metabolic rate to maintain their core temperature (Figure 6). Increased metabolic demand drives the need for greater foraging rates (Figure 7) and evaporative water loss rates (Figure 8). Thus, life at higher elevation is energetically more challenging for pikas. While warmer temperatures at lower elevation sites significantly reduced available activity time (Figure 9), the simultaneously lower metabolic demand drives a reduced foraging rate. Mean monthly summer temperatures in GNP do not indicate a clear energetic advantage to higher, cooler, sites, even under future warming scenarios (Figure 10). However, the thermal refuge provided under the talus is only broadly modeled. If fully integrated into the model, these properties, as shown in Table 13, with the addition of night-time thermal insulation (available, but not presented in this paper), would provide a more accurate reflection of daily energetic expenditures.

Predation and over-winter mortality, the two major causes of pika death, are not modeled with NicheMapper. Available activity time may relate to pika densities in other ways. For example, pikas at lower elevation sites may be forced to forage primarily during dusk and dawn when vulnerability to predation is heightened. Lower elevation sites may also harbor higher predator densities because of lower predator metabolic demands and higher prey densities. Overwinter survival is difficult to predict largely because our knowledge of pika winter behavior is extremely limited. Future pika monitoring of individuals and behavior will be necessary to uncover the relationship between temperatures and survival.

Future pika monitoring. GNP's American pika population dynamics and responses to climate change will be revealed by building upon the research presented here. We identified hundreds of talus fields that have not yet been surveyed. Future researchers should use the "talus-seen" GIS layer. The associated attribute table notes whether each patch was surveyed or not. Although we scanned the majority of the park's drainages for talus, some patches were certainly missed. Still, the site survey data presented here should be a sufficient baseline for measuring population and occupancy trends. Establishment of new sites should focus on those occurring at particularly low or high elevations.

The data presented here present a unique opportunity for extensive meta-population research. Source-sink dynamics of the sites would be particularly interesting to explore as a complement to previous research (Kruezer & Huntly 2003; Smith 1980). The sites naturally vary substantially in area and isolation, and patch quality can be approximated by factors such as talus depth and vegetation cover. The intervening matrix clearly contains varying suitability, but the degree to which a steep mountain face or a sub-alpine fir forest, for example, affects pika dispersal and survival is unknown.

The effects of forest fires on pika population dynamics provide another area for future research. Fire sometimes opens up previously forested talus patches. Pikas prefer patches that allow them large view-sheds for predator surveillance (Tyser 1980). Fires stimulate grass and forb growth and may reduce predation pressure at these marginal sites and lead to site colonization, re-colonization, and increased population density. Former pika population sinks may become sources following fires.

Conclusions. This is the first pika density, distribution, and habitat characterization study approaching this level of detail and scope. The GIS layers and data presented here provide an invaluable baseline on which future monitoring will rely. Additionally, our pika detectability data will allow future monitoring efforts to be more effective and integrate volunteers appropriately. Our activity observations provide a first step towards understanding how pikas modify their behavior in response to climate change. The biophysical model results open up a previously unexamined method for predicting how pika energetics effects their survival. It is an approach that is becoming increasingly necessary in an age of rapid climate change.

OUTREACH AND IMPACTS

The “pika project”, as it became known, gained considerable public momentum through three summers of existence. Not only did I train and work with more than thirty assistants through the course of the project, but we also interacted with hundreds of park visitors, staff, and local employees. Our interactions raised awareness, in a personal way, on the impacts of climate change on the park. We also gained considerable media attention. National Geographic, Montana Public Radio, Animal Planet, The Hungry Horse News, The Flathead Beacon, and Glacier Park Magazine each wrote stories and/or took video footage of this research. A less scientific, but no less meaningful, goal developed and evolved as the research progressed. It was a pleasure to see this project inspire young people and park visitors of all ages, while raising awareness of science in the park and the effects of human activity on our beloved wildlife.

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LITERATURE CITED

- Aho, K., Huntly, N., Moen, J., & Oksanen, T. 1998. Pikas (*Ochotona princeps*: Lagomorpha) as allogenic engineers in an alpine ecosystem. *Oecologia* 114:405-409.
- Barash, D.P. 1973. Habitat utilization in three species of subalpine mammals. *Journal of Mammalogy* 54(1):247-250.
- Beever, E.A., Brussard P.F. & Berger J. 2003. Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. *Journal of Mammalogy* 84:37-54.
- Beever, E.A. & Ray, C. 2007. Distribution and abundance of the American pika (*Ochotona princeps*) within Lava Beds National Monument—final report. Document delivered to Lava Beds National Monument. 62 pp.
- Beever, E.A., Ray, C., Mote, P.W. & Wilkening, J.L. 2010. Testing alternative models of climate-mediated extirpations. *Ecological Applications* 20(1):164-178.
- Beever, E.A., Wilkening, J.L., McIvor, S., Weber, S. & Brussard, P.F. 2008. American pikas (*Ochotona princeps*) in northwestern Nevada: a newly discovered population at a low-elevation site. *Western North American Naturalist* 68:8-14.
- Brown, J.H., Stevens, G.C. & Kaufman, D.M. 1996. The geographic range: Size, shape, boundaries and internal structure. *Annual Review of Ecology and Systematics* 27: 597-623.
- Brown, R.N., Southwick, C.H. & Golian, S.C. 1989. Male-female spacing, territorial replacement, and the mating system of pikas (*Ochotona princeps*). *Journal of Mammalogy* 70:622-627.
- Burnham, K.P. & Anderson, D.R. 2002. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York.
- Burns, C.E., Johnston, K.M., & Oswald, J.S. 2003. Global climate change and mammalian species diversity in U.S. national parks. *PNAS* 100: 11474-11477.
- Dearing, M.D. 1996. Disparate determinants of summer and winter diet selection of a generalist herbivore, *Ochotona princeps*. *Oecologia* 108:467-478.
- Dearing, M.D. 1997. The function of haypiles of pikas (*Ochotona princeps*). *Journal of Mammalogy* 78(4):1156-1163.
- Diefenbach, D.R., Brauning, D.W. & Mattice, J.A. 2003. Variability in grassland bird counts related to observer differences and species detection rates. *Auk* 120:1168-1179.
- ESRI 2006. *ArcGIS/ArcView*. Redlands, CA: ESRI.
- Graham, R.W. 1986. Response of mammalian communities to environmental changes during the late quaternary. Pages 300-313, In: Diamond, J. and Case, T.J., editors. *Community Ecology*. New York: Harpers and Row Publishers.
- Grayson, D.K. 2005. A brief history of Great Basin pikas. *Journal of Biogeography* 32:2103-2111.
- Grinnell, J. 1917. Field tests of theories concerning distributional control. *American Naturalist* 51:115-128
- Guisan, A. & Theurillat, J.P. 2000. Equilibrium modelling of alpine plant distribution: how far can we go? *Phytocoenologia* 30:353-384
- Guralnick, R. 2007. Differential effects of past climate warming on mountain and flatland species distributions: a multispecies North American mammal assessment. *Global Ecology and Biogeography* 16:14-23.

- Guralnick, R. 2006. The legacy of past climate and landscape change on species' current experienced climate and elevation ranges across latitude: a multispecies study utilizing mammals in western North America. *Global Ecology and Biogeography* 15:505-518.
- Hafner, D.J. 1993. North American pika (*Ochotona princeps*) as a late Quaternary biogeographic indicator species. *Quaternary Research* 39:373-380.
- Hafner, D.J. & Smith, A.T. 2010. Revision of the subspecies of the American pika, *Ochotona princeps* (Lagomorpha: Ochotonidae). *Journal of Mammalogy* 91(2):401-417.
- Hayes, A.R. & Huntly, N.J. 2005. Effects of wind on behavior and call transmission of pikas (*Ochotona princeps*). *Journal of Mammalogy* 85:974-981.
- Huntly, N.J. 1987. Influence of refuging consumers (pikas: *Ochotona princeps*) on subalpine meadow vegetation. *Ecology* 68:274-283.
- Huntly, N.J., Smith, A.T. & Ivins, B.L. 1986. Foraging behavior of the pika, *Ochotona princeps*, with comparisons of grazing versus haying. *Journal of Mammalogy* 67:139-148.
- Hall, M.H.P. & Fagre, D.B. 2003. Modeled climate-induced glacier change in Glacier National Park, 1850-2100. *BioScience* 53:131-140.
- Kearney, M. & Porter, W.P. 2004. Mapping the fundamental niche: physiology, climate, and distribution of Australian nocturnal lizards. *Ecology* 85:3119-3131.
- Kruezer, M.P. & Huntly, N.J. 2003. Habitat-specific demography: evidence for source-sink population structure in a mammal, the pika. *Oecologia* 134:343-349.
- Lawrence Livermore National Laboratory (LLNL)/U.S. Bureau of Reclamation/Santa Clara University downscaled climate projections data derived from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project phase 3 (CMIP3) multimodel dataset, stored and served at the LLNL Green Data, http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html.
- Lotz, A. & Allen, C.R. 2007. Observer bias in anuran call surveys. *The Journal of Wildlife Management* 71(1):675-679.
- MacArthur, R.A. & Wang, L.C.H. 1973. Physiology of thermoregulation in the pika, *Ochotona princeps*. *Canadian Journal of Zoology* 51:11-16.
- Mackey, B.G. & Lindenmayer, D.B. 2001. Towards a hierarchical framework for modeling the spatial distribution of animals. *Journal of Biogeography* 28: 1147-1166.
- Martinez-Meyer, E, Peterson, A.T. & Hargrove, W.W. 2004. Ecological niches as stable distributional constraints on mammal species, with implications for Pleistocene extinctions and climate change projections for biodiversity. *Global Ecology and Biogeography* 13:305-314.
- McDonald, K.A. & Brown, J.H. 1992. Using montane mammals to model extinctions due to global change. *Conservation Biology* 6:409-415.
- Mead, J.I. 1987. Quaternary records of pika, *Ochotona*, in North America. *Boreas* 16:165-171
- NPS.gov. retr. 2010. <http://science.nature.nps.gov/im/units/ucbn/otherprojects/pikaindex.cfm>.
- Parmesan, C. & Yohe, G. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421:37-42.
- Porter, W.P. 1988. New Animal models and experiments for calculating growth potential at different elevations. *Physiological Zoology* 62:286-313.
- Porter, W.P, Budaraju, S. & Stewart W.E. 2000. Calculating climate effects on birds and mammals: impacts on biodiversity, conservation, population parameters, and global community structure. *American Zoologist* 40:597-630.

- Porter, W.P & Gates, G.M. 1969. Thermodynamic equilibria of animals with the environment. *Ecological Monographs*, 39: 227-244.
- Porter, W.P. & Kearney, M. 2009. Size, shape, and the thermal niche of endotherms. *PNAS* 106:19666-19672.
- Porter, W.P, Munger, J.C, Stewart, W.E, Budaraju, S. & Jaeger, J. 1994. Endotherm energetics: from a scalable individual-based model to ecological applications. *Australian Journal of Zoology*, 42:125-162.
- Porter, W.P, Sabo J.L, Tracy, C.R, Reichman, O.J, & Ramankutty, N. 2002. Physiology on a landscape scale: plant-animal interactions. *Integrative and Comparative Biology* 42:431-453.
- Porter, W.P., Vakharia, N.P, Klousie, W.D. & Duffy, D. 2006. Po'ouli landscape bioinformatics models predict energetics, behavior, diets and distribution on Maui. *Integrative and Comparative Biology*: 1-16. online doi:10.1093/icb/icl051
- Smith, A.T. 1974. The distribution and dispersal of pikas: influences of behavior and climate. *Ecology* 55:1368-1376.
- Smith, A.T. 1980. Temporal changes in insular populations of the pika (*Ochotona princeps*). *Ecology* 61:8-13.
- Smith, A.T. & Weston, M.L. 1990. *Ochotona princeps*. *Mammalian Species* 352:1-8
- Tyser, R.W. 1980. Use of substrate for surveillance behaviors in a community of talus slope mammals. *American Midland Naturalist* 104:32-38.
- United States Fish and Wildlife Service. 2010. Endangered and Threatened Wildlife and Plants; 12-month finding on a petition to list the American pika as threatened or endangered. *Federal Register*.
- Williams, J.W, Jackson, S.T. & Kutzbach, J.E. 2007. Projected distributions of novel and disappearing climates by 2100 AD. *Proceedings of the National Academy of Sciences* 104:5738-5742.

Appendix A: Tables and Figures

Table 1. Abbreviations and terms used throughout this report.

Term	Description
Pika Sign	Pika-identifier; scat, hay-pile, call, or sighting
Sighting	Visual observation of a pika
Call	Pika vocalization; either short (one) or long (multiple in rapid succession)
Hay-Pile	Or <i>Hay</i> is a pika's winter food cache
HR	Potential pika <i>Home Range</i> ; 20 m radius circle centered on hay-pile or other pika sign
ID	<i>Pika ID</i> is the number of HRs containing at least one pika sign
CO	<i>Current Occupant</i> is the number of HRs containing at least one call or sighting
Daytime	Time of day: morning = before 12:00, midday = 12:01 – 17:00, evening = after 17:00
Season	Measure of summer progression as the number of days from June 1 st
PMINS	<i>People-Minutes</i> are a metric of search effort, calculated by: (# of active surveyors) x (total search time)
Site:Year	Combination of a site and year used to ensure analyses compared surveys conducted at a given site only during the same year
Competitors	Non-predatory talus co-inhabitants; rodents such as marmots and squirrels (e.g. <i>M. caligata</i> , <i>S. columbianus</i> , <i>S. lateralis</i>)

Table 2. Comparison of pika signs found across eight habitat sections by each member of a trained ten-person biotech crew (N = 80) during two-day pika detectability trials. The R-squared value of the linear model is provided. Significant predictors for each sign are listed stronger above weaker; each had a $p < 0.05$, and were derived from application of the following two models: 1) Sign = Section + Daytime + Name, and 2) Sign = Section + Daytime + EXP.

Sign	Significant predictors	Adj. R-squared
HR	Name	0.38
ID	Section	0.17
Scat	EXP	0.47
Old Hay	Section	0.64
Log(Old Hay Volume)	Section	0.58
CO	Section	0.30
Sqrt(Sightings/ID)	Section	0.11
Sqrt(Calls/ID)	Daytime Name	0.24

Table 3. Comparison of pika signs found by a trained biotech crew and volunteers at 12 sites during 2008 and 2009 (N = 22). The R-squared value of the linear model is provided. Observer type = biotech or volunteer. Significant predictors are listed stronger above weaker; each had a $p < 0.05$, and were derived from application of the following linear regression model:

Sign = Observer type + Site:Year + Season + Daytime + Competitors.

Sign	Significant Predictors	Adj. R-squared
ID/PMINS	Observer type Site:Year	0.44
CO/PMINS	Site:Year Observer type Season	0.45
CO/ID	Season Site:Year	0.33
Sightings/PMINS	Site:Year Daytime	0.37
Hay/PMINS	Observer type	0.28
Hay/ID	Observer type Site:Year	0.24
Sqrt(Scat/PMINS)	Observer type Site:Year	0.44
Scat/ID	Observer type	0.21

Table 4. Significant predictors of pika signs observed by citizen scientists during sitting-surveys at 21 sites during 2008 and 2009 (N = 95). Significant predictors are listed stronger above weaker; each had a $p < 0.05$, and were derived from application of the following linear regression model: Sign = Site:Year + Daytime + Season + Competitors.

Sign	Significant predictors	Adj. R-Squared
CO/PMINS	Daytime Competitors Site:Year	0.26
CO	Daytime	0.05
Calls	Competitors Daytime Site:Year Season	0.33

Table 5. Data were collected to characterize pika habitats and weather during surveys. The mean, standard deviation, and sample size are shown for each habitat variable. Percent covers are based on a 72-point land-cover transect conducted radially in six directions from a hay-pile.

Variable	Mean	SD	N
Elevation (m)	1990.3	271.4	303
Gradient (%)	21.2	10.0	303
Visible patches	2.7	2.4	290
Cloud cover (%)	41.3	33.2	299
Temperature (C)	18.2	6.3	301
Wind speed (km/hr)	14.9	9.4	303
Rock (%)	48.6	22.3	244
Lichen rock (%)	27.5	37.5	244
Forb (%)	7.9	8.0	244
Forb height (cm)	9.3	10.3	242
Grass (%)	4.3	5.3	244
Grass height (cm)	10.3	12.1	242
Shrub (%)	3.5	4.9	244
Shrub height (cm)	55.1	253.4	242
Tree (%)	1.3	3.0	244
Tree height (cm)	91.0	357.6	242
Moss (%)	2.5	4.9	244
Dead vegetation (%)	2.2	4.2	244
Dead wood (%)	3.0	4.9	244
Substrate soil (%)	7.3	9.1	244
Substrate rocky-soil (%)	13.9	13.5	244
Substrate rock (%)	71.4	20.7	244
Substrate snow (%)	1.7	6.4	244

Table 6. Search effort data were collected during pika surveys. The mean, standard deviation and sample size are given for each search effort variable. Total time includes search time plus time spent conducting vegetation transects. Season was measured by counting the number of days from June 1 to the survey date.

Variable	Mean	SD	N
Search time (mins)	32.6	13.0	303
Total time (mins)	45.0	17.7	303
Season	53.0	29.1	303

Table 7. Pika sign data were collected during surveys. The mean, standard deviation, and sample size are shown for each pika sign variable.

Variable	Mean	SD	N
Sightings	0.84	1.71	294
Short calls	10.0	18.7	294
Long calls	0.18	0.57	294
Old hay	3.8	3.8	294
Old hay volume (cm ³)	127,177	236,366	211
Hay to veg. distance (m)	2.7	2.0	55
Fresh hay	1.2	2.4	294
Fresh hay volume (cm ³)	68,632	118,547	99
Scat	8.3	7.5	295
Total signs	24.3	29.0	295
Pika ID	7.4	5.7	295
CO	3.8	4.2	294
HR	17.0	9.5	295
Pika ID / HR	0.45	0.26	295
CO / HR	0.23	0.21	295
CO / ID	0.49	0.32	274
Rocks < 1 m	1.4	2.3	292
Rocks 1 < x < 2 m	1.9	2.5	292
Rocks > 2 m	5.5	6.5	292

Table 8. Significant predictors ($p < 0.05$) of three derived pika variables. Generalized linear model results calculated without vegetation data to maximize the number of observations ($N = 271$). The sign of the effect is given in parentheses. Daytime was separated into morning, midday, and evening for these calculations. D-AIC is the change in AIC value if that variable was removed from the model.

Sign	Predictor	D-AIC	Adj. R-Squared
ID / HR	Midday(-)	15	0.14
	Season(+)	8	
	Wind0-5(+)	4	
	Elevation(+)	3	
	Gradient(-)	3	
CO / HR	Season(+)	59	0.25
	Year(2007+)	10	
	Midday(-)	6	
	Predators(-)	6	
	Competitors(+)	3	
CO / ID	Season(+)	46	0.25
	Year(2007+)	18	
	Gradient(+)	3	
	Predators(-)	2	
	Wind0-5(-)	2	

Table 9. Significant predictor variables ($p < 0.05$) for three derived pika variables. Vegetation data were included in these generalized linear model results ($N = 193$). The sign of the effect is given in parentheses. D-AIC is the change in AIC value if that variable was removed from the model. Shallow talus had a depth of less than 50 cm.

Sign	Predictor	D-AIC	Adj. R-Squared
ID / HR	Elevation(+)	10	0.21
	Grass Height(+)	9	
	Midday(-)	9	
	North Aspect(-)	6	
	Gradient(-)	6	
	Moss(+)	5	
	Forbs(+)	5	
	Shallow Talus(-)	3	
	Grass(-)	3	
	Substrate Soil(+)	3	
	Shrub Height(-)	2	
CO / HR	Elevation(+)	17	0.35
	Total Time(+)	13	
	Season(+)	8	
	Search Time(-)	8	
	Midday(-)	7	
	Moss(+)	7	
	GrassHeight(+)	5	
	Total EXP(+)	5	
	Dead Wood(+)	5	
	Forb Height(+)	4	
	Predators(-)	4	
	Forbs(+)	3	
CO / ID	Gradient(+)	9	0.27
	Season(+)	8	
	Wind0-5(-)	8	
	Forb Height(+)	7	
	Year(2009+)	5	
	Substrate Soil(-)	4	

Table 10. Temperature(C) data from time 0700 on the dates indicated in 2008, 1 m below the talus surface at seven sites. Sites are denoted by their elevations (m). Each date was fitted with a linear regression. The slope of that line indicates the lapse rate (C/km). R-squared values are provided to show the fit of the line to the data. The mean slope for all eight dates is given.

Site Elevation	Jul-28	Aug-4	Aug-11	Aug-18	Aug-25	Sep-1	Sep-8	Sep-15	
2274	9.7	6.8	4.2	18.6	12.5	-1.3	1.4	9.3	
2272	9.2	6.7	4.9	17.4	12.3	-0.2	1.9	10.3	
2207	8.9	6.3	6.3	9.6	10.0	0.4	1.7	1.5	
2054	11.1	8.7	6.5	15.7	12.3	1.3	3.9	7.1	
2031	12.0	8.8	8.2	17.6	13.7	0.2	3.3	8.3	
1765	14.0	7.4	9.4	16.3	14.8	4.1	3.3	5.8	
1512	15.7	6.3	11.6	16.8	15.0	7.7	3.7	5.0	Mean
Slope (C/km)	-8.81	0.10	-8.87	-1.37	-4.83	-10.65	-2.71	3.50	-4.21
R²	0.957	0.001	0.938	0.017	0.631	0.940	0.555	0.113	

Table 11. Temperature(C) data from time 1400 on the dates indicated in 2008 and 1 m below the talus surface at seven sites. Sites are denoted by their elevation (m). Each date was fitted with a linear regression. The slope of that line indicates the lapse rate (C/km). R-squared values are provided to show the fit of the line to the data. The mean slope for all eight dates is given.

Site Elevation	Jul-28	Aug-4	Aug-11	Aug-18	Aug-25	Sep-1	Sep-8	Sep-15	
2274	18.2	17.6	7.7	28.6	20.4	0.2	11.3	17.3	
2272	12.2	11.4	8.7	22.1	15.4	-0.1	8.8	15.3	
2207	9.9	8.1	7.9	10.9	12.1	0.9	3.1	3.2	
2054	15.2	14.1	11.5	19.4	12.6	3.3	4.1	7.1	
2031	12.6	12.4	8.9	20.1	14.3	1.1	4.5	10.0	
1765	22.7	21.9	14.5	33.6	23.5	5.1	14.4	19.7	
1512	18.1	15.4	13.3	24.3	18.4	7.8	7.7	10.5	Mean
Slope (C/km)	-9.02	-7.42	-8.31	-9.47	-6.18	-10.04	-3.07	-1.79	-6.91
R²	0.338	0.222	0.754	0.140	0.171	0.942	0.044	0.007	

Table 12. Temperature(C) data from time 2000 on the dates indicated in 2008 and 1 m below the talus surface at seven sites. Sites are denoted by their elevation (m). Each date was fitted with a linear regression. The slope of that line indicates the lapse rate (C/km). R-squared values are provided to show the fit of the line to the data. The mean slope for all eight dates is given.

Site Elevation	Jul-28	Aug-4	Aug-11	Aug-18	Aug-25	Sep-1	Sep-8	Sep-15	
2274	18.5	18.0	9.3	27.3	16.2	0.2	8.8	14.6	
2272	13.6	12.8	9.6	22.3	12.3	1.1	7.6	12.1	
2207	NA	8.6	9.1	13.3	11.0	2.0	3.1	2.7	
2054	19.8	19.9	12.6	25.2	15.4	3.9	7.6	10.5	
2031	14.9	14.5	11.2	23.9	15.4	2.2	5.6	11.1	
1765	18.9	17.7	14.2	25.9	18.9	5.8	10.3	12.9	
1512	21.6	19.6	16.5	28.0	16.8	8.4	9.5	11.8	Mean
Slope (C/km)	-9.14	-7.84	-9.58	-8.42	-6.21	-9.96	-4.56	-2.70	-7.30
R²	0.441	0.292	0.948	0.231	0.435	0.946	0.274	0.041	

Table 13. Below are the mean differences between above- and below-talus maximum and minimum temperatures (C). Temperature was recorded every 15 mins. over ten days at two sites, Red Rock Point (1056 m) and Mt. Brown (2521 m). The standard deviation for these differences is provided.

Observation Period	Mean max. temp. above - below	SD	Mean min. temp. above - below	SD
0515 – 0815	-2.62	1.69	-2.50	1.69
1300 – 1600	15.44	1.94	13.08	2.42
1900 – 2100	3.75	1.78	-2.75	1.95

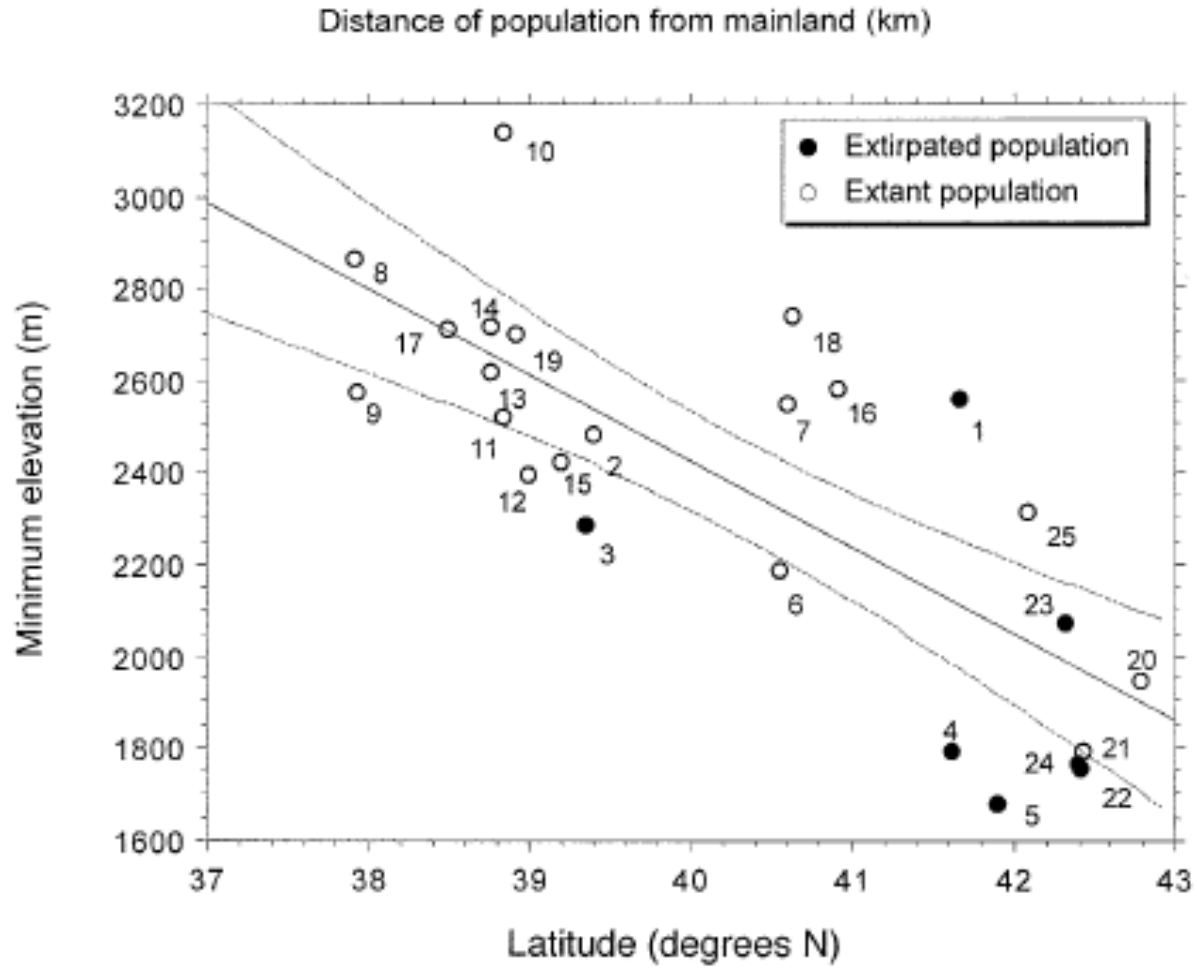


Figure 1. Relationship between minimum elevation at which pikas were encountered or (if extirpated) reported and latitude for extant (open circles) and apparently extirpated populations (closed circles) of *O. princeps* in the Great Basin. Dashed lines denote the 95% confidence interval for the linear regression and number labels refer to the site identifier (from Beever et al. 2003).

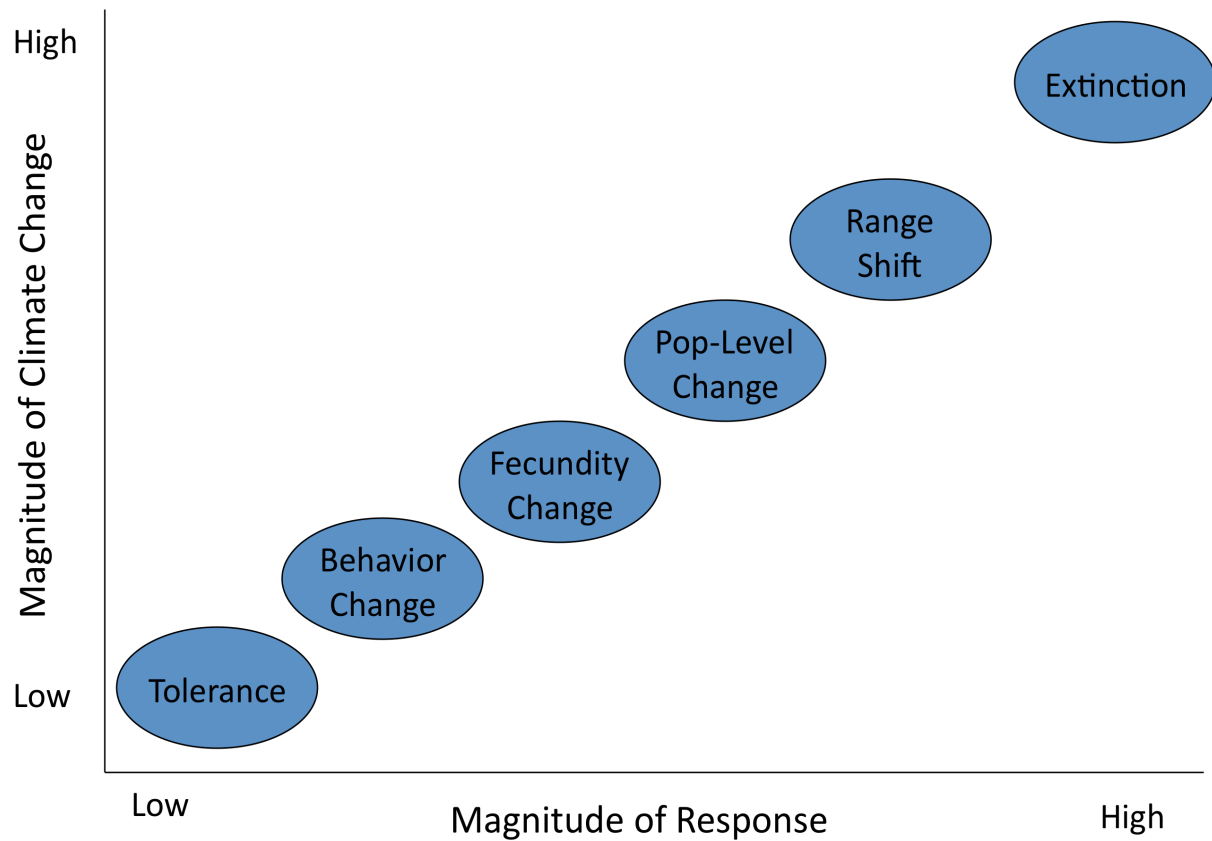


Figure 2. Simplified relationship between climate change and species-specific responses. Pika activity observations focus on identifying “tolerance” and “behavior change”.

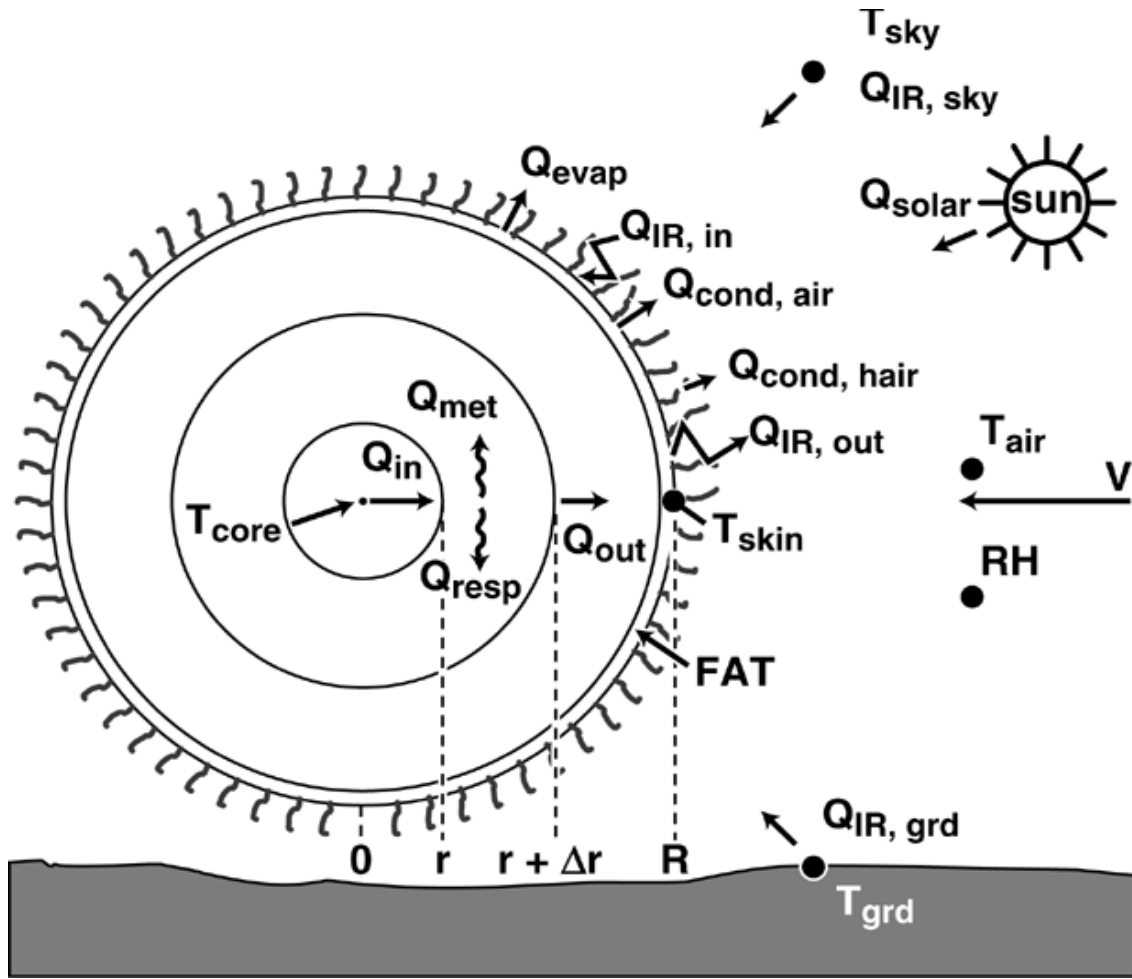


Figure 3. An example of how a mammal is modeled in Niche Mapper. Here is a cross-section of a mammal and heat fluxes, including uniform heat generation and uniform heat dissipation by respiration. T = temperature. Q = heat. r = an example radius used for integration. R = radius of the animal. RH = relative humidity. Arrows represent direction of energy flow (from Porter et al. 2000).

Above-talus Temperature vs. Calls and Sightings

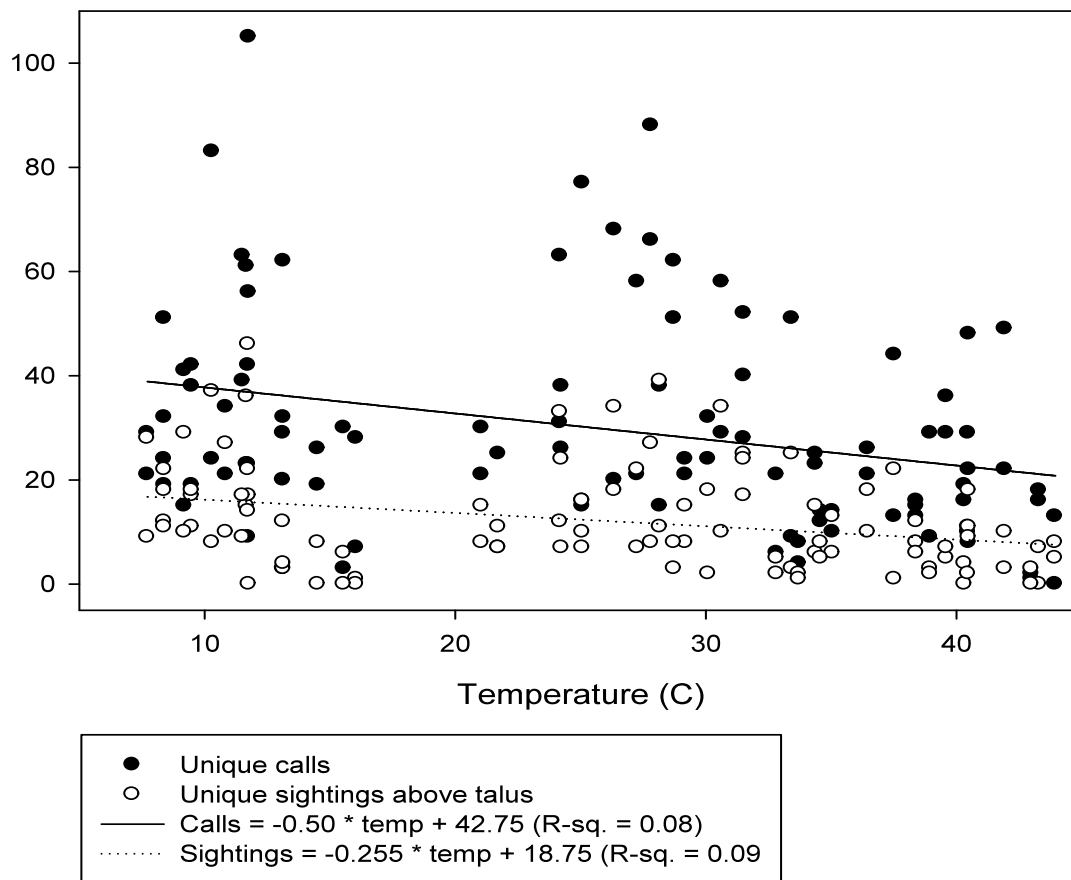


Figure 4. Mean above-talus temperature plotted against unique pika calls and sightings at eight activity observation sites with best-fit linear regressions.

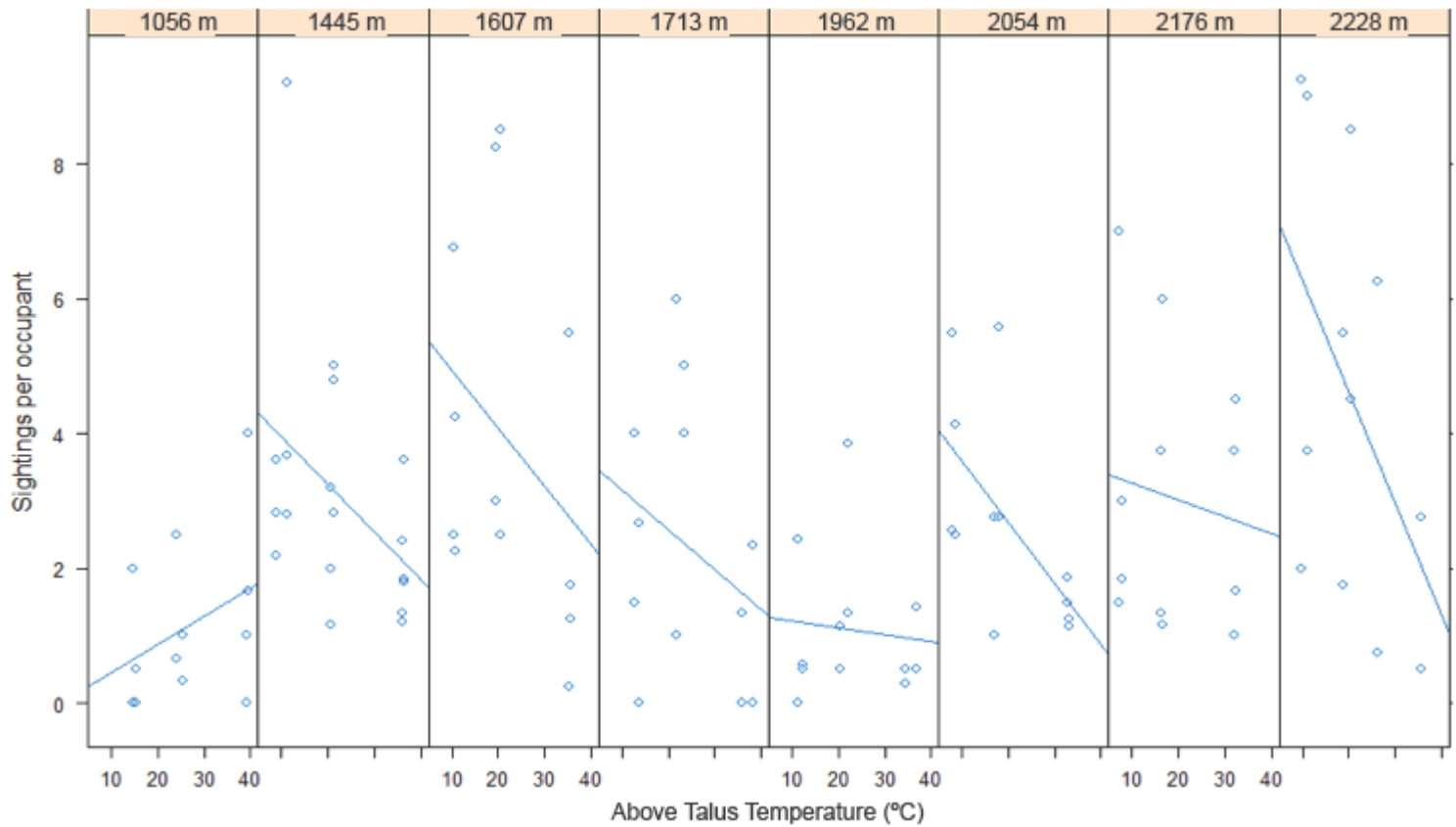


Figure 5. Above-talus temperature plotted against number of pika sightings per occupant at eight sites denoted by their elevation. Trend lines are included for each site. Trend line slopes do not differ significantly but their y-intercepts do.

Metabolic Rate

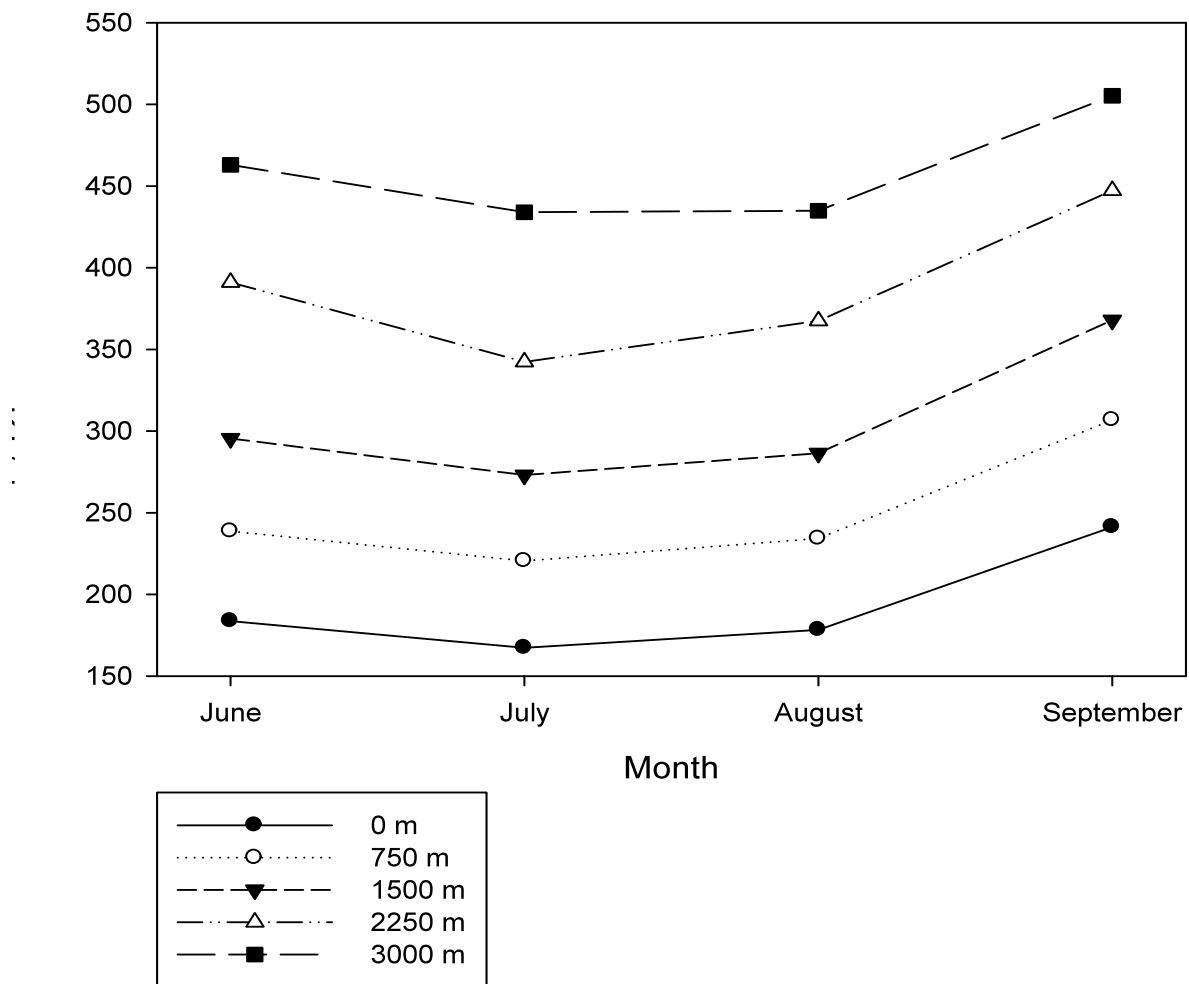


Figure 6. North American pika metabolic rate modeled at five elevations during its active season.

Foraging Rate

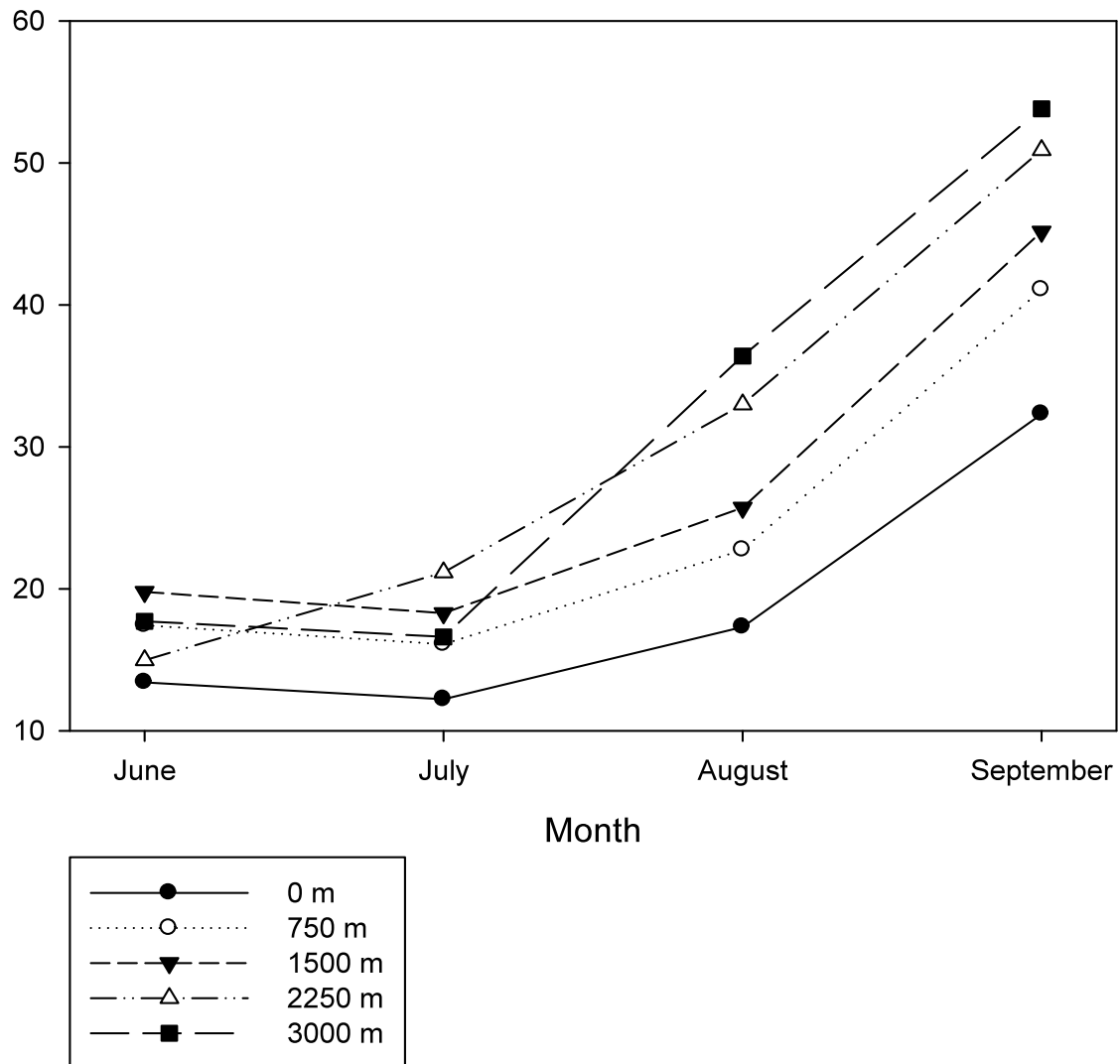


Figure 7. This figure shows the required daily foraging rate (g/hr) for a North American pika modeled in GNP at five elevations during the active season. Foraging rates were calculated by dividing the minimum daily wet food requirements (g/day) by the available activity hours.

Evaporative Water Loss

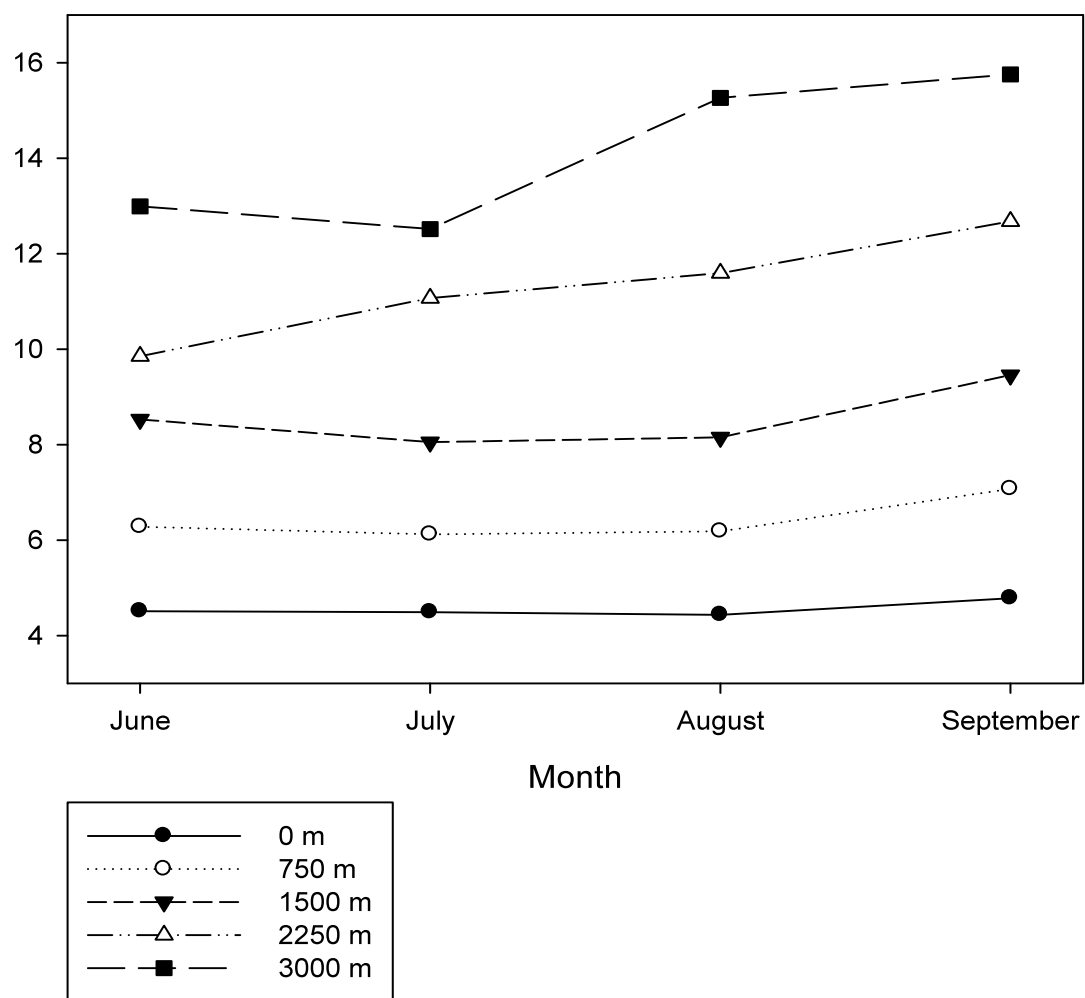


Figure 8. This figure shows evaporative water loss (g/day) of a North American pika modeled at five elevations in GNP during the active season.

Activity Hours

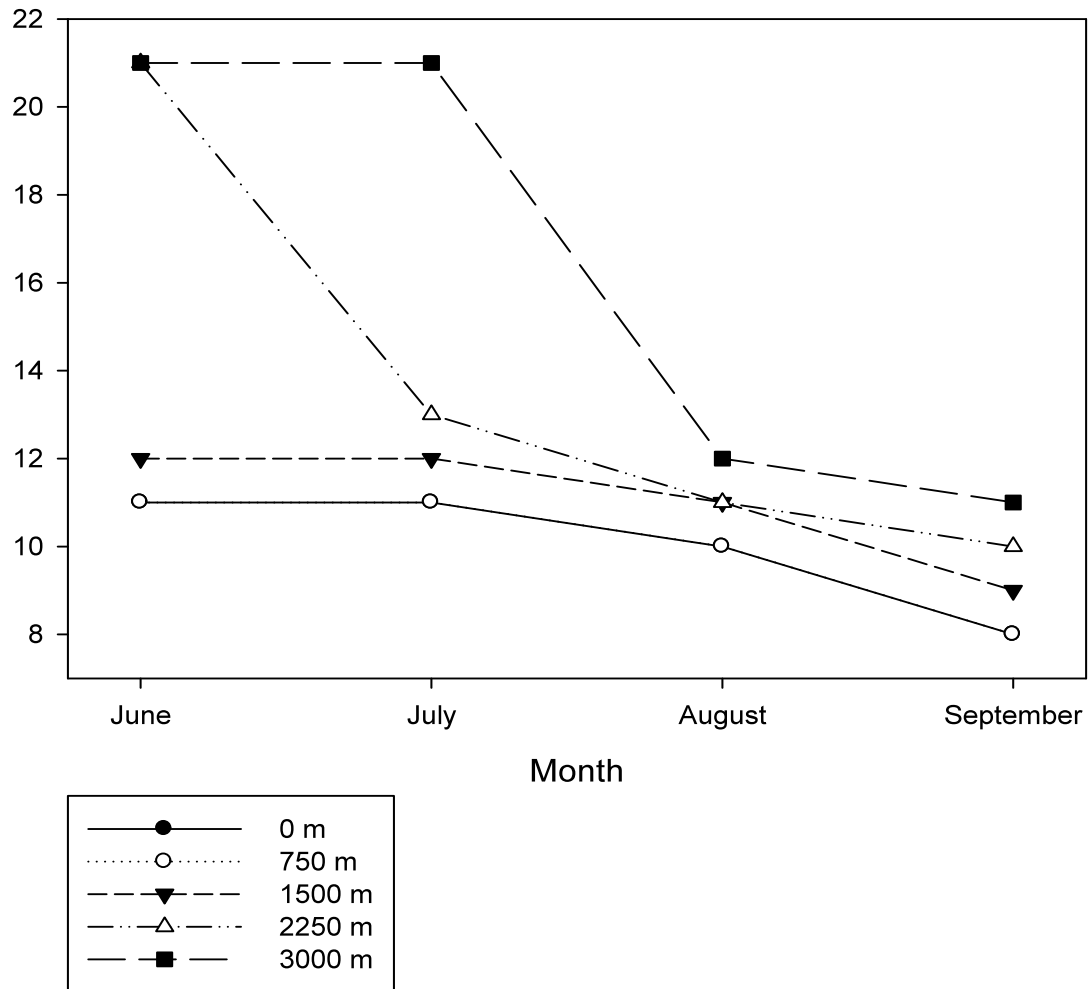


Figure 9. This figure shows the available above-talus activity time (hrs/day) of a North American pika modeled at five elevations in GNP during the active season. Available activity time is calculated as the number of hours a pika can be above the talus in its thermo-neutral zone. The sea-level (0 m) line completely overlaps the 750 m line.

Projected Activity Hours (1500 m)

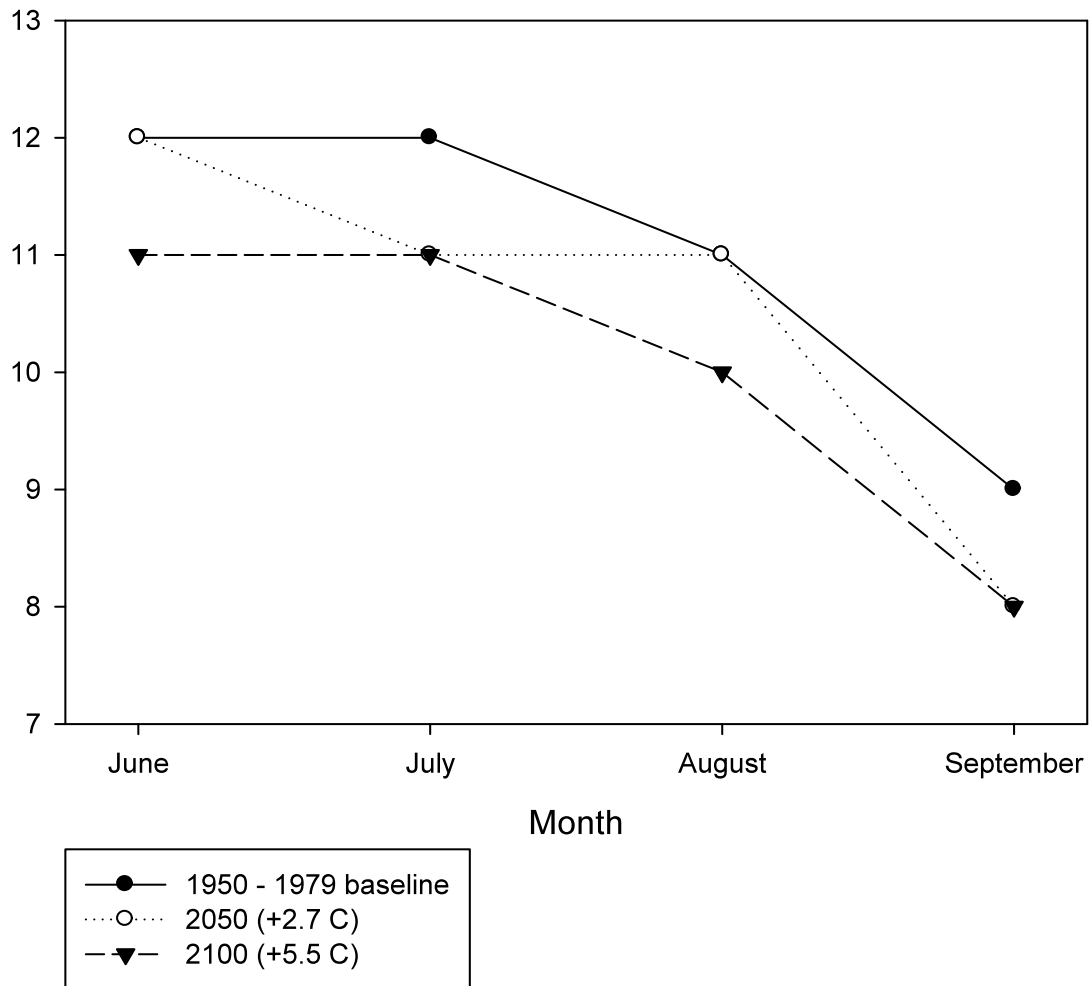


Figure 10. This figure shows available activity hours for a North American pika modeled in GNP during the active season at 1500 m elevation. Mean 1950 – 1979 monthly temperatures are compared to temperatures projected for 2050 and 2100 (LLNL 2009).

Appendix B: Survey protocol for 2009 (adapted from Beever & Ray, 2007)

Data recorded during site surveys (each item refers to a field on the data sheet):

1. **Site number** (initially GPS point number, changed to Excel row number after data entry)
2. **Name** of survey crew (initials fine)
3. **Date** of survey
4. **Times of day** that bracket the survey period
 - a. record the start time first, and record end times as you come to these portions of the data sheet (e.g. record data on pika sign first, then record the end time of the pika-sign search before taking additional data at the site)
 - b. if you choose to conduct a vegetation transect before finishing the survey, write down start and end times of that transect before continuing the survey (e.g. write “veg time” on edge of data sheet, then the start and end times)
 - c. use military time (00:00 – 24:00)
 - d. total time (start time – end site survey time) should reflect time spent at the site within distance of pikas and pika calls
5. **Before recording auxiliary site data, search for pika sign**
 - a. record details for each pika sign
 - i. the **location** where the sign was encountered (only for signs of particular interest, otherwise the site GPS position is fine)
 - ii. the exact **time** when the sign was encountered
 - iii. the **type of sign**, using the categories given on the data sheet; note that “fresh” hay or scat would contain at least some visible chlorophyll—some green tint—and plasticity, while “old” hay or scat would be brittle; in cases where this judgment is difficult to make, explain the problem in the note field and opt for “old”; multiple simultaneous signs for the same pika should be entered in the same box
 - iv. the **number of pikas detected so far (PikaID)** such that the last number entered represents the estimated number of pikas occupying the site; for example,
 1. if you find scat and later hear a pika <20m away from that spot, enter the same PikaID # for the call as the scat; you enter the previous number again because the pika you heard is likely the source of the scat
 2. if you see or hear two pikas within a short period of time, give each a new PikaID, only if you don’t believe that one (moving) pika could be responsible for both sightings/calls; keep in mind that pikas can easily move 20 m within 5 seconds in some landscapes
 3. if you discover two distinct haypiles >10 m apart, with no haypiles in between, consider giving each a unique PikaID; use your best judgment; a single pika may establish multiple haypiles, but all of the piles belonging to one pika will tend to be within 10 m of each other
 4. old scat cannot be used to infer multiple pikas
 - v. if you see or hear a pika, record your best estimate of the **distance between you and the pika**; this field would not be filled in for haypiles or scat, which you should investigate up close
 - vi. for any sign encountered, record the size (largest dimension) of the **largest rock** nearby (within about 1 m); for example,

1. if you saw a moving pika, record the size of the largest rock that the pika passed within one meter of
2. if you encountered a hay- or scat-pile, record the size of the largest rock that shelters this sign
- vii. estimate the **slope aspect and gradient** within about two meters of the sign only if it differs significantly from the overall site aspect and gradient
- viii. estimate the **maximum distance between the site center and the sign**; this may be different than the distance between you and the sign
- ix. estimate **haypile volumes**; record the dimensions of fresh and old hay separately in inches with depth as the last number (e.g. 12 x 10 x 2); you should stick a pen or twig in the hay at multiple positions as depth will vary; if there are multiple haypiles within 10 m of one another, record each of them (e.g. 5 x 15 x 2 + 2 x 8 x 1); do not attempt to guess at the volume of hay that is not visible, but do make a note if you have reason to believe there is more hay buried deeper under the talus
6. **End-time for the hay/scat search**, after searching the site completely for hay and scat; do not end the search until you've looked under every big surface rock (>0.5 m in largest dimension), especially the largest ones; note also that you may continue to see or hear pikas after this time, and you should continue to record details of pika sightings and calls
7. **Presence/number of signs of other mammals**; use tick-marks to tally the number of signs, if multiple signs are encountered, but do not attempt to exhaustively search for each type of mammal sign
8. **Site notes**; describe the location of the site relative to nearby landmarks and any other noteworthy features
9. **Site weather** during the survey, including qualitative information about the skies (% cloud cover, e.g. 50-75), temperature (carry a thermometer, if possible, e.g. >75), and wind levels (use the following wind mph estimators: 0-5 no breeze noticed; 5-15 wind felt on face, leaves rustle, loose paper raised; 15-30 small trees and large branches in motion; >30 inconvenience felt walking against the wind)
10. **Slope aspect**; standing near the site center, record aspect to the nearest 5 degrees; if the site aspect varies significantly (e.g. horseshoe shaped) record the average
11. **Slope gradient (degrees)**; standing near the site center, determine the average "fall line" of the slope through this point; this is the vertical (rise) distance divided by the horizontal (run) distance.
12. **Deepest talus (m)** – minimum depth (e.g. >1.5 m) of the deepest cracks/crevices available at the site
13. **Minimum number of discrete talus/habitat patches** visible from the site center; stand at the highest point within the site and count all visible patches separated from other patches by > 20 m and <100 m; patches separated by > 100 m should be considered separate sites
14. **Minimum number of home ranges** (each 20 m in diameter) within the contiguous talus/habitat patch; stand at the highest point within the site and estimate the minimum number of home ranges visible (e.g. >30)
15. **Take digital pictures** of the site and record the numbers/subject of these pictures
16. **Sample vegetation** within a 12m radius of the first haypile encountered
 - a. if no haypiles are found conduct the transects near the first pika seen/heard; if these signs were not found then use the first scat pile; if no pika signs were encountered conduct

transects from the 'best' potential habitat (usually largest boulder near vegetation at patch edge)

- b. establish 6 transects of 12 m each, emanating from the sign (or 'best' habitat) location; azimuth 0 is a straight line up the "fall line" (steepest uphill), 180 is down slope continuous with this transect; 60 and 300 can be estimated by facing 0 azimuth and stretching out your arms like you're preparing to give a wide hug (forming roughly a 120° angle between your arms); azimuths 120 and 240 can be estimated in the same way by facing 180
- c. if the site is flat, substitute the fall-line transect with a transect oriented along the maximum average vegetational gradient; e.g., from least vegetation to most vegetation within 12 m of transect center
- d. at each meter along each transect, complete a point-intercept sample of the vegetation
- e. for each sample, touch the ground (rock, soil, or lower level of vegetation) with a long pin (e.g. thin stick) held vertically
 - i. if plants are to be identified to true species, generate a list of two-letter species codes to facilitate data entry; otherwise identify genus or 'functional type' (e.g. forb, graminoid, tree, shrub, moss, lichen)
 - ii. record each 'species' touched by the pin, beginning with the tallest species and ending with the shortest (each field in the data sheet is large, to accommodate a short list of species intersected)
 1. if the species is <10 cm in height, note that it is "small" by adding "/S" after the species name
 2. if >50 cm, add "/L"
 3. if species height lies between 10 and 50 cm, don't bother noting species size
 - iii. include species that nearly touch the pin by establishing (and recording) the 'area of influence' of the pin (e.g., 0.5 cm to either side of the pin); disregard area of influence if using a stick >1 cm diameter
 - iv. after recording all growing species intersected by the pin, record any dead "litter" intercepted (e.g. dead wood [DW] or other dead vegetation [DV]) and, finally, record the type of substrate (rock [R], soil [SL], or rocky soil [RS]); if the pin intercepts lichen on a rock, record "lichen rock" [LR]
 - v. continue sampling for 12 m out from the central point along each transect
17. Record a short list of the **dominant plant species** occurring within the site, just in case any dominant species are missed by the above vegetation transects
18. **End-time for site survey**; this time minus the beginning time is the total amount of time that the crew was available to detect pika sightings and calls

Other data to determine for each site (these data can be obtained in the lab):

19. Year of most recent previous pika record at the site, if any
20. Predicted high temperature for the day of the site survey (or even better, actual high if available)
21. Distance (km) to the nearest road and to the nearest non 4WD road
22. Metric of intensity of human visitation or disturbance
23. Number of talus fields near the site and distance between them (determined via GIS)

Appendix C: Field instructions and data sheet for activity observations in 2009

Pika Behavioral Observations

Record before each observation:

- 1.) Observer
- 2.) Time
- 3.) Weather (as described on talus survey)
 - a. Temperature
 - b. Wind
 - c. Cloud cover

Record once:

- 1.) Site description
- 2.) Latitude
- 3.) Longitude
- 4.) Elevation
- 5.) Home ranges (in your observation area)
- 6.) Waypoint
- 7.) GPS number
- 8.) PikaID (in your observation area)
- 9.) Current occupants

Before 1st observation period:

- 1.) Survey entire site thoroughly
 - 2.) Pick an area from which you can observe home ranges where you found a high density of signs; especially calls and sightings
 - 3.) Record PikaID and potential home ranges in your site area
- Set your observation area with a radius of 30-40 meters. Calls heard outside this area should be ignored
 - By the end of the second observation you should have a very good idea of how many pikas exist in your area, this = current occupants
 - Observe each site twice during these times per observer
 - 5:15- 8:15
 - 13:00- 16:00
 - 19:00- 22:00

Record the following behaviors:

- F = Feeding
- H = Haying
- V = Vigilant
- MS = moving slow
- MF = moving fast

- SC = short call
- LC = long call

For each behavior record the time, individual, and if the behavior is in the sun or not
 Assume SC and LC are below talus unless you believe otherwise and denote with a * if above talus

<u>Time</u>	<u>Behavior</u>	<u>Individual</u>	<u>Sun?</u>
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Appendix D: Field datasheet for 2009

Site:		GPS:		Crew:		Date:		HRs in site:				
Lat:		Lon:		Elevation:		Start time:						
Pika sign (types = Pika, Long Call, Short Call, Fresh Haypile, Old Haypile, Fresh Scat, Old Scat)								End hay/scat search:				
GPS pt name	Sign type (P, LC, SC, FH, OH, FS, OS)	Time	PikaID	Det. Dist.(m)	Largest rock w/in 1m (m)	Slope ° aspect	Slope% gradient	FH Volume LxWxH (inches)	OH Volume LxWxH (inches)			
Pictures:		Notes:		Other mammal sign: <u>Hoary marmot</u> <u>Col. Gr. Squirrel</u> <u>other:</u>			Weather: Skies (% clouds): 0-25 25-50 50-75 75-100 Temp (F): <40 40-60 60-75 >75 Wind (mph): 0-5 5-15 15-30 >30					
Site aspect (°):		Maximum talus depth (m):		# of discrete habitat patches (isolated by > 20m) visible from site:								
Site gradient (%):		<0.5 <1.0 <1.5 >1.5		# of potential home ranges (HR diameter = 20m) visible from site: 1-10 10-30 >30								
Vegetation transects (6 point-intercept transects, 12m each, originating at site, 0° = up the steepest slope, 180° = down steepest slope)												
Azimuth	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m	11m	12m
0°												
60°												
120°												
180°												
240°												
300°												
Dominant plant spp.:								End site survey:				