Project Completion Report
Rocky Mountains Cooperative Ecosystem Studies Unit (RM-CESU)

Project Title: Pikas in peril: multi-regional vulnerability assessment of a climate-sensitive sentinel species

Project Code (such as UMT-72 and/or the "J" or "P" number): UCOB-74 P10AC00178 ROMN

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Project Summary: The “Pikas in peril” (PIP) project named above includes research not administered through the RM-CESU. Although the entire project is summarized here, care has been taken to delineate the research of PI Chris Ray, whose funds were administered through the RM-CESU.

PIP involved a team of National Park Service (NPS) staff and academic researchers funded through the NPS Climate Change Response Program to determine vulnerability of the American pika within eight NPS units. The American pika (*Ochotona princeps*) is generally considered climate-sensitive and perhaps vulnerable to climate change. PIP objectives were to (1) document pika occurrence patterns and predict pika distribution across the eight parks, which span the variety of habitats occupied by this species; (2) measure gene flow and model the connectivity of pika populations in five of these parks; and (3) project climate change effects on the future distribution, connectivity, and vulnerability of pika populations in each park. Data for habitat studies were to be collected from Rocky Mountain National Park (under PI Chris Ray), Great Sand Dunes National Park and Preserve (under Ray), Grand Teton National Park, Yellowstone National Park, Lassen Volcanic National Park, Lava Beds National Monument, Crater Lake National Park, and Craters of the Moon National Monument and Preserve. Data for genetic studies were to be collected from five of these parks that serve as representative study areas for most major genetic units of the species and for each major substrate it occupies (montane talus *vs.* lava beds). Due to the habitat requirements and limited dispersal ability of American pikas, it is expected that national parks may be of increasing importance as refugia for these animals. By assessing the vulnerability of this sentinel species, this research should provide park managers with insights into the expected rate and magnitude of climate-related changes in park ecosystems and information for park scenario planning and interpretive goals.

Systematic pika occupancy surveys were conducted within each park during 2010-2012. Pika fecal pellets were collected during occupancy surveys to document recent gene-flow patterns using DNA analyses. Habitat occupancy data were used to develop a hierarchical model of pika distribution within and across parks (Jeffress et al. 2013). Landscape genetic models were developed to infer pika response to landscape features in selected parks (e.g., Castillo et al. in press), and are in development for the remaining parks, including those not originally funded for genetic analyses. Based on samples from over 1000 unique individuals, genetic structure has been estimated within all eight parks. The team has finalized revisions to habitat models that will be used as the basis for modeling effects of climate change under various scenarios as part of the vulnerability assessment. PI Ray was responsible for collecting habitat occupancy data and genetic samples from two parks and for providing input during the development of habitat occupancy models and guiding the early development of landscape genetic models and the vulnerability assessment. Data acquisition and analyses are now complete and sufficient habitat and genetic modeling is complete to proceed with vulnerability analyses, which are already past the early stages of development. Projecting current and future pika occupancy in each of the eight parks is an ongoing component of the larger project and is supported by separate funding for PI Clinton Epps.

Participation in this project via the RM-CESU has allowed PI Ray to contribute to four published manuscripts, two additional manuscripts in preparation, and a variety of outreach presentations and products. One high-impact publication (Jeffress et al. 2013) reported results of the habitat occupancy study from all eight NPS units. One publication targeting NPS audiences (Garrett et al. 2011) described the rare scope of this collaborative research project, planned research methods and expected products. A technical report analyzed the potential impact of trail improvements on pikas in Grand Teton National Park (Epps et al. 2013). Ray also helped in the development of project-related publications that she did not coauthor, such as an upcoming publication reporting results of a landscape genetics analysis for Crater Lake National Park (Castillo et al. *in press*). The PI will also coauthor at least two additional manuscripts that will be submitted for peer review within the coming year: 1) a landscape genetic analysis integrating results from all eight NPS units, and 2) a vulnerability analysis using the larger landscape genetic analysis as well as recent habitat occupancy patterns and projected climates to predict effects of climate change on pikas across the study region. In an ongoing study related to the funded project, Ray continues to collect annual data on pika occurrence and hourly temperatures in 10-12 locations throughout two parks, and similar data continue to be collected in other parks by other PIP investigators funded separately.

Project-related presentations by PI Ray included talks at several research conferences and research institutions as well as talks for resource management agencies and civilian groups, and even classroom lectures and a teacher-development workshop. Each publication and presentation coauthored by Ray is listed below. The landscape genetics publication by Castillo et al. (in press) can be referenced as follows: Castillo, J. A., C. W. Epps, A. R. Davis, and S. A. Cushman. *In press*. Landscape effects on gene flow for a climate-sensitive montane species, the American pika. Molecular Ecology. DOI: 10.1111/mec.12650.

Publications

Jeffress, M. R., T. J. Rodhouse, C. Ray, S. Wolff, and C. W. Epps. 2013. The idiosyncrasies of place: geographic variation in the climate-distribution relationships of the American pika. Ecological Applications 23:864-878.

Epps, C. W., D. Schwalm, J. Castillo, T. J. Rodhouse, M. Jeffress, and C. Ray. 2013. Analysis of proposed rock quarrying and trail improvement impacts on American pikas in Grand Teton National Park. Natural Resource Technical Report NPS/UCBN/NRTR—2013/756. National Park Service, Fort Collins, Colorado.

Garrett, L., M. Jeffress, M. Britten, C. Epps, C. Ray and S. Wolff. 2011. Pikas in peril: multiregional vulnerability assessment of a climate-sensitive sentinel species. Park Science 28:9–13.

Presentations

Ray, C., J. Wilkening, S. Bhattacharyya and L. Erb, 2013. Cheating climate change: can microhabitat selection save a species? University of Nevada, Reno, NV, October 17.

Wilkening, J. and C. Ray, 2013. Comparison of stress hormone levels measured in pikas across the western US. 26th International Congress for Conservation Biology. Baltimore, Maryland, July 21-25.

Wilkening, J. and C. Ray, 2013. Indicators of physiological stress in American pikas. 11th International Mammalogical Congress. Belfast, Ireland, August 11-16.

Wilkening, J. and C. Ray, 2013. Effects of environment on stress hormone metabolites measured in American pika feces. International Society of Wildlife Endocrinology 5th Annual Conference. Chicago, Illinois, October 14-16.

Ray, C., 2013. Climate and the American pika. 20th Annual Boulder County Ecosystem Symposium, *Climate Change and the Resilience of High Elevation Ecosystems*. University of Colorado, Boulder, CO, March 16.

Ray, C., 2013. Pika CPR in the Indian Peaks: status and stories of an alpine icon. Annual meeting of the Indian Peaks Wilderness Association. USDA Forest Service, Boulder, CO, March 4.

Ray, C., M. Jeffress et al., 2013. National Park Service study of pika habitats and genetics: habitat-occupancy results from eight parks and preliminary genetic results. Biodiversity and Climate Change Workshop, Continental Divide Research Learning Center's Annual Interpretation and Resource Stewardship Day. Rocky Mountain National Park, CO, February 8.

Ray, C., 2012. Climate and the American pika: in our wilderness and beyond. USDA Forest Service Wilderness Volunteer Workshop. Denver, CO, December 3-4.

Ray, C., 2012. Climate and the American pika. Fort Collins Audubon. Fort Collins, CO, November 8.

Jeffress, M., C. Ray et al., 2012. Status and trends in American pika site occupancy patterns across the western US: insights from some of the nation's "crown jewel" national park units. Symposium of the North American Congress for Conservation Biology. Oakland, CA, July 15-18.

Ray, C., 2012. A model of climate sensitivity? Lectures presented in CU Boulder upper-division/graduate courses *Mountain geography* and *Conservation biology*.

Ray, C., M. Jeffress et al., 2012. National Park Service pika habitat occupancy study: preliminary results from eight parks. 6th Biennial Rocky Mountain National Park Research Conference, Estes Park, CO, March 28-29.

Ray, C., M. Jeffress et al., 2012. National Park Service pika habitat occupancy study: preliminary results from eight parks. Biodiversity and Climate Change Workshop, Continental Divide Research Learning Center's Annual Interpretation and Resource Stewardship Day, Rocky Mountain National Park, CO, February 8.

Ray, C., 2012. The American pika, a model species for studying climate sensitivity. Science Hubs Teacher Development Workshop, Colorado Springs, CO,

Ray, C., 2012. Climate and the American pika. Biology Club, University of Colorado, Boulder, CO, November 8.

Ray, C., 2011. A model of climate sensitivity? Lectures presented in CU Boulder upper-division/graduate courses *Novel ecosystems: understanding local manifestations of global change* and *Conservation biology*.

Ray, C., 2011. When tailings are habitat: hard rock mining and the American pika. Colorado Art Ranch Artposium, *Hardrock revision: re-envisioning the Ute-Ulay mine*, Lake City, CO, July 29. Sponsored by the Office of University Outreach, University of Colorado-Boulder.

Ray, C., 2011. Climate and the American pika. Pueblo Zoo, Pueblo, CO, April 7. Sponsored by the Office of University Outreach, University of Colorado-Boulder.

Ray, C. and M. Shardlow, 2010. National Park Service pika habitat occupancy study: preliminary results from eight parks. Meeting of the California Pika Consortium, Annual Conference of The Wildlife Society-Western Section. Visalia, CA, January 26-29.

Outreach materials developed by PI Ray include annual resource briefs for Rocky Mountain National Park and Great Sand Dunes National Park and Preserve for 2010, 2011 and 2012 (e.g., http://www.nps.gov/romo/parkmgmt/upload/ROMO_Pika_ResourceBrief_2012.pdf, http://www.nps.gov/romo/parkmgmt/upload/GRSA_Pika_ResourceBrief_2012.pdf). Similar annual resource briefs were developed for all eight parks. Generalized resource briefs explaining the overall project and each of the three PIP objectives were also developed with Ray's help, as was a an interpretive brief and PowerPoint presentation along with a glossary of terms to help park personnel interpret PIP for the public (all available at http://science.nature.nps.gov/im/units/ucbn/publications.cfm?tab=0).

Outreach also involved the expansion of PikaNet, a network of citizen-science programs to contribute habitat occupancy data and genetic samples from within parks as well as outside areas administered by the NPS. PI Ray was responsible for the selection, hiring and guidance of a citizen-science liaison, April Craighead, who performed the following tasks:

- Coordinated conference calls between PIP investigators and citizen-science groups, with the goal of aligning protocols to ensure data quality and similarity across projects;
- Developed a draft training manual for citizen-science programs contributing to PikaNet;
- Developed a map featuring citizen-science organizations focused on gathering pika data in the western United States;
- Helped to develop a draft protocol for the use of climate sensors in citizen-science programs associated with PikaNet;
- Solicited and archived the above materials and protocols from citizen-science groups and PIP researchers; and
- Directed interested parties to appropriate websites regarding the PIP project and related protocols.

Key products from this coordinated effort are available on-line at Craighead's web site http://www.craigheadresearch.org/pika-research.html. Citizen-science efforts associated with PikaNet include those developed by the following organizations:
Denver Zoo/Rocky Mountain Wild (http://www.pikapartners.org/),
Mountain Studies Institute (http://www.mountainstudies.org/index.php?q=content/pikanet),
Teton Science School (http://www.tetonscience.org/index.cfm?id=crc-projects-pikas),
Adventurers and Scientists for Conservation (http://www.adventureandscience.org/pika.html),
Seventh Generation Institute (http://www.seventh-generation.org/citizen_science_pika.html),
Oregon Zoo/Columbia Gorge Ecology Institute (http://www.gorgeecology.org/?p=1441), and
Glacier National Park (http://www.nps.gov/glac/naturescience/ccrlc-citizen-science_hc.htm).
The Natural Resources Ecology Laboratory developed a database to support these efforts (http://www.citsci.org/cwis438/Browse/Project/Project_Info.php?ProjectID=275&WebSiteID=7), and iNaturalist supports photo-documented pika sightings at two websites—one for the general public (http://www.inaturalist.org/taxa/43169-Ochotonidae) and one coordinated with PikaNet (http://www.inaturalist.org/projects/asc-pika-project).

Products for long-term monitoring: *This section focuses on Rocky Mountain NP (ROMO) and Great Sand Dunes NPP (GRSA), but similar protocols were followed for parks sampled under separate funding.* Occupancy modeling and long-term monitoring is most effective when surveyed plots are positioned in a spatially balanced, random design within the sampling frame (area to be sampled). We developed a sampling frame based on NPS Vegetation Maps (e.g., Salas et al. 2005 for ROMO and Salas et al. 2010 for GRSA) combined with a cost surface model including slopes, distances and land cover (ROMN 2008). Potential pika habitat classes were identified for sampling (e.g., Rock Alpine-Upper Subalpine, Cliff Face-Bare Soil/Rock, Rock Foothill-Lower Subalpine, etc.), and a base sample of plots were positioned within the frame according to a GRTS design (Stevens and Olsen 2004). Two experienced pika researchers independently scored each habitat class in terms of its potential to harbor target habitats (boulder-fields, taluses or other creviced rock). Averaged scores were used to apportion survey plots among habitat classes to attain a representative sample in which survey effort scaled with the putative availability of pika habitat. The base sample was reviewed by three experienced pika researchers using a high-resolution aerial image of the park to determine the accessibility as well as the potential for presence of target habitats within 100 m of each plot. Plots that appeared inaccessible or lacking target habitat were replaced by plots from an oversample (auxiliary list), following the appropriate sequence and matching habitat classes to maintain the integrity of the sampling design. Using this same procedure in both 2010 and 2011, 100 plots were targeted for survey each year. Twenty of these plots were to be revisited in both years, to allow estimates of change in occupancy and placement/retrieval of temperature sensors that would log data during the intervening year. In total, 180 plots were targeted in each park for survey over the two years. In 2010 and 2011 a field crew visited as many plots as time allowed. Of the plots visited/approached (over 150 in each park), some were dropped from the study due to lack of target habitat or problems with accessibility or safety. In ROMO, a total of 68 plots were searched in 2011 and 58 in 2010, including 20 plots surveyed in both years. In GRSA, a total of 48 plots were searched in 2011 and 49 in 2010, including 17 plots surveyed in both years. In 2012, 10-12 plots previously surveyed in each park were surveyed again and temperature data loggers were serviced at or removed from these sites.

All of our protocols, study plot locations and data have been archived in a relational database that can be used as the basis for future studies and/or long-term monitoring. Further information on long-term monitoring according to these protocols can be accessed at http://science.nature.nps.gov/im/units/ucbn/.

Number of students participating in this project: Six undergraduates and three graduate students participated under the direct supervision of PI Chris Ray. Additional students participated under the supervision of other PIP investigators funded separately.

Lessons Learned from this project: Lessons are summarized below by project objective (1 = determining pika-habitat relations, 2 = evaluating landscape connectivity from a pika's point of view, 3 = predicting pika vulnerability in a changing climate), followed by additional lessons from one application of expertise developed during the project.

Lessons from Objective 1 (from Jeffress et al. 2013): Using a Bayesian hierarchical approach, we modeled variation in local patterns of pika distribution along topographic position, vegetation cover, elevation, temperature, and precipitation gradients in each park landscape. We also accounted for annual turnover in site occupancy probabilities. Topographic position and vegetation cover influenced occurrence in all parks. After accounting for these factors, pika occurrence varied widely among parks along bioclimatic gradients. Precipitation by itself was not a particularly influential predictor. However, measures of heat stress appeared most influential in the driest parks, suggesting an interaction between the strength of climate effects and the position of parks along precipitation gradients. The combination of high elevation, cold temperatures and high precipitation lowered occurrence probabilities in some parks, suggesting an upper elevational limit for pikas in some environments. Our results demonstrate that the nature and strength of the climate–distribution relationship for the American pika varies across its range. Fine-grained, but geographically extensive, studies replicated across multiple landscapes offer insights important to assessing the impacts of climate change that otherwise may be masked at macro-ecological scales. The hierarchical approach to modeling provides a coherent conceptual and technical framework for gaining these insights.

Lessons from Objective 2: The first published results from Objective 2 come from a landscape genetic analysis of pika gene flow in Crater Lake NP. Using partial Mantel tests in a causal modeling framework, and spatially-explicit simulations to evaluate methods of model optimization, Castillo et al. (*in press*) found that gene flow was primarily restricted by topographic relief, water, and west-facing aspects. Results suggest that physical restrictions related to the pika's small body size and mode of locomotion, as well as exposure to relatively high temperatures, limit pika dispersal in this alpine habitat. Model optimization successfully identified landscape features influencing resistance in the simulated data for this landscape, but underestimated the magnitude of resistance. This was the first landscape genetic study to address the fundamental question of what limits dispersal and gene flow in the American pika.

Similar studies for all eight parks are in progress, based on the data summarized in Table 1. Although not reported in Table 1, there are suitable sample sizes (after omitting all samples with missing data) to characterize genetic diversity and genetic structure within every park. Preliminary analyses have revealed significant genetic structure within every park. Maximum dispersal distances have also been apparent in data from each park, as the genetic distance between individuals rises sharply at a given distance threshold for each park analyzed to date. Such analyses offer clear guidelines for evaluating the isolation of pikas in particular habitat patches and for assessing the impact of habitat change on connectivity of pika populations. In Craters of the Moon NP, elevation and topographic complexity were identified as influencing gene flow. In Lassen Volcanic NP, streams and elevation impacted gene flow. Park-specific connectivity models are a key component of the vulnerability analysis (Objective 3).

Table 1. Summary of samples collected for each park (CRLA = Crater Lake, CRMO = Craters of the Moon, GRSA = Great Sand Dunes, GRTE = Grand Teton, LABE = Lava Beds, LAVO = Lassen Volcanic, ROMO = Rocky Mountain, YELL = Yellowstone). Numbers in parentheses are percentage of the number of samples extracted. In some cases there were more than two identical genotypes and all but one were excluded, therefore the sums do not equal the number extracted.

Park	Collected	Extracted	Contaminated	Failed	Duplicate	Unique
CRLA	369	210	38 (18)	14 (7)	28 (13)	147 (70)
CRMO	238	137	25 (18)	30 (22)	28 (20)	60 (44)
GRSA	154	78	16 (21)	8 (10)	0	54 (69)
GRTE	384	300	25 (8)	59 (20)	23 (8)	196 (65)
LABE	151	85	3 (4)	6 (7)	13 (15)	51 (60)
LAVO	425	231	66 (29)	28 (12)	58 (25)	103 (45)
ROMO	437	354	47 (13)	66 (19)	26 (7)	230 (65)
YELL	100	60	9 (15)	24 (40)	2 (3)	26 (43)
Total	2258	1455	229 (16)	235 (16)	178 (12)	867 (60)

Lessons from Objective 3: We have begun combining the distribution, habitat, connectivity and climate data to conduct a quantitative vulnerability assessment that explicitly predicts pika response to climate change in each park. A distribution model for the current time-step has been produced for each park, as presented at the Pacific Northwest Climate Science conference in September 2013; these models will form the foundation for modeling climate change impacts at three future time-steps.

We identified 21 climatic and topographic variables (Table 2), representing four hypothesized drivers of pika occupancy (heat stress, cold stress, growing season and habitat connectivity) These variables have been used as training data when developing models of current pika occupancy. Current occupancy models represent the baseline from which subsequent projections are derived. Projections will be based on the most up to date climate projections (e.g., CMIP 5) and the 'best case' and 'worst case' climatic forcing scenarios (RCP4.5 and RCP8.5, respectively). For each park, four sub-models were developed, each based on one of the four hypothesized drivers. Models were ranked via DIC, and a model-averaging approach will be applied to capture multi-driver influences on pika occupancy. We have included novel parameters in this analysis, including metrics of patch isolation based on park-specific estimates of pika dispersal developed from our genetic data (Table 2).

Variables related to pika occupancy vary between parks (Table 3, Figure 1), and the effect of individual variables is not always consistent among parks (Figure 1). Variables associated with temperature and precipitation are present in the final models for all parks, but differences in the identity and direction of variables included indicate idiosyncrasies in seasonal influences between parks. In Crater Lake, pika occupancy is negatively related to potential snow accumulation (avesnow), but in Great Sand Dunes and Lava Beds, potential snow accumulation is positively related to pika occupancy. This may reflect differences in the duration of snow pack, with pika populations in Crater Lake experiencing higher snow accumulation and prolonged snow melt-off compared to populations elsewhere, resulting in reduced survival when pika food stores proved insufficient. Differences in the directionality of a given variable may indicate variation in the way pikas experience extremes within a given season. For example, minimum temperature during the coldest quarter (meantcq) is positively related to pika occupancy in Crater Lake, Grand Teton and Rocky Mountain, but negatively related to occupancy in Craters of the Moon and Lassen Volcanic, indicating greater sensitivity to temperature extremes in the latter parks. Finally, our results indicate that habitat connectivity plays a large role in predicting pika occupancy in some but not all parks. Model predictive power is low to moderate overall, potentially reflecting either 1) discordance between the spatial resolution of input data and the scale at which pika experience microclimate influences or 2) temporal misalignment between the 30-year averaged climate data used in model building and inter-annual variation in pika occupancy. To assess the potential of the latter, we are testing model performance using annual climate data, as opposed to 30-year averages, and will adjust future modeling approaches based on the findings of these tests.

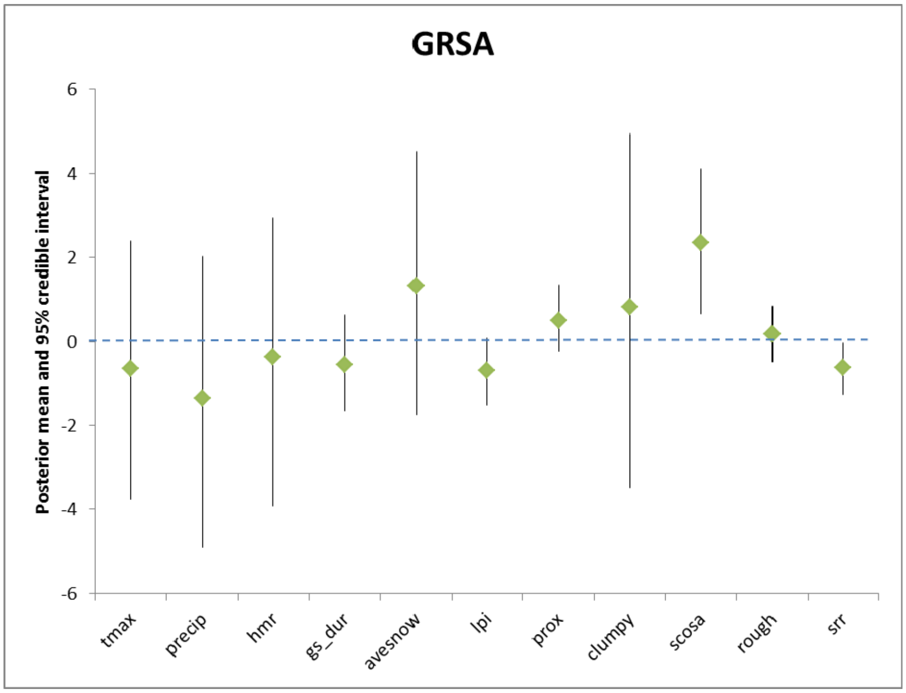
Table 2. Variable description and source. Fragstats variables were calculated using a moving window with a radius defined by the genetic distance specific to each park.

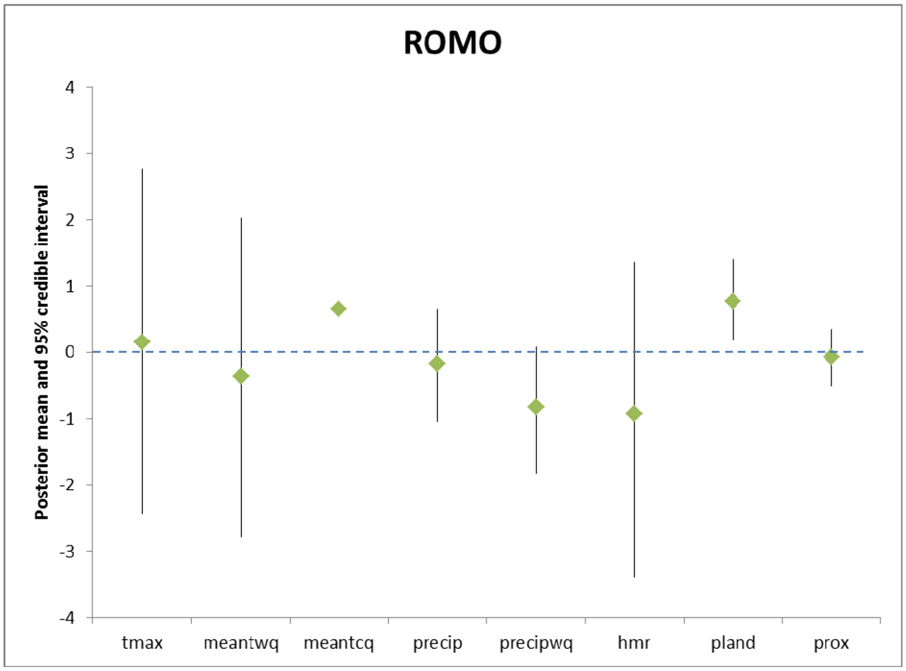
Variable	Definition and source	Hypothesized relationship to pika occupancy
Tmax	Ave max temp, July (Prism)	Acute heat stress
Tmin	Ave min temp, January (Prism)	Acute cold stress
Meantwq	Mean temperature warmest quarter (Bioclim #10)	Chronic heat stress
Meantcq	Mean temperature coldest quarter (Biolclim #11)	Chronic cold stress
Tempseas	Temperature seasonality (SD*100, Bioclim #4)	Extremity of seasonal differences in temp
Precip	Annual precipitation (Bioclim #12)	Previous research.
Precipwq	Precipitation, warmest quarter (Bioclim #18)	Forage availability and quality
Precipcq	Precipitation, coldest quarter (Bioclim #19)	If ave temp<0, then measures potential snow accumulation; if ave temp>0, then measures cold/damp stress
Precseas	Precipitation seasonality (CV, Bioclim #15)	Extremity of seasonal differences in precip
Hmr	[Mean temp May –Sep]/[(sum of monthly precip May – Sep)*(1000)]; from Henry et al. 2012.	Influences heat stress and forage growth; demonstrated relationship with genetic connectivity
GS_dur	Duration of growing season; # months with temp >0C (calculated per pixel)	Available time for veg growth and haypiling activity
GSP	Summed growing season precipitation for months with mean min temp >0C; calculated by pixel rather than across the entire raster	Forage availability and quality; influences body condition prior to onset of winter as well
AveSnow	Summed monthly precipitation for pixels with an average temp ≤ 0; measures potential snow accumulation from the onset of freeze to the end of freeze. Used in the absence of modeled snow data.	Potential subnivian insulation
Scosa	Potential solar insolation; as in Jeffress et al. 2013. Calculated in ArcGIS.	Solar/heat exposure
Resid	Pika-adjusted elevation; as in Jeffress et al. 2013. Calculated in ArcGIS.	Previous research
Clumpy	Measure of habitat aggregation. Ranges from 1 (max aggregation) to -1(max disaggregation) (Fragstats)	Spatial aggregation influences colonization
Lpi	Largest habitat patch index (Fragstats)	Large patches may serve as source populations
Pland	Percent of the landscape that is pika habitat (Fragstats)	Influences pop size and habitat connectivity within the dispersal radius
Prox	Proximity index; size and proximity of all habitat patches (Fragstats)	Size and proximity of habitat on the landscape influences colonization
Srr	Surface relief ratio, a measure of surface rugosity. Calculated on 10m LiDAR data, in ArcGIS, for CRLA and GRSA only.	Site traversability
Rough	Roughness; a measure of surface roughness. Calculated on 10m LiDAR data, in ArcGIS, for CRLA and GRSA only.	Site traversability

Table 3. Final models for each park and associated area under the curve (AUC) measure of predictive power

Park	Final Model	AUC
CRLA	meantcq, precip, precipwq, hmr, avesnow, gsp, clumpy, srr, rough, scosa, resid.elev	0.43
CRMO	tmax, meantcq, precip, precipcq, precipwq, hmr, scosa	0.72
GRSA	tmax, precip, hmr, gs_dur, avesnow, lip, prox, clumpy, scosa, rough, srr	0.71
GRTE	tmin, precip, meantcq, meantwq, avesnow, gsp, lip, resid.elev	0.63
LABE	tmin,precipcq,precipwq,pland,precip,avesnow,empseas,gsp,scosa,prox,clump,resid.elev	0.54
LAVO	meantcq, precseas, meantwq, precipwq, gs_dur, tmin, precip, lpi, prox, precip	0.61
ROMO	tmax, meantwq, meantcq, precip, precipwq, pland, prox	0.58
YELL	tmin, precip, tempseas, hmr, gsp, avesnow, lip, prox, resid.elev	0.66

Fig. 1. Posterior mean probability values and 95% credible intervals for variables included in Great Sand Dunes (GRSA) and Rocky Mountain (ROMO). Indices were generated using 2-3 years of pika occupancy survey data included in three replicate runs of a Bayesian auto-logistic model with 1000 "burn-in" iterations and 5000 total iterations. Mean values above (or below) zero indicate a positive (or negative) relationship between the associated variable and pika occupancy. Credible intervals represent the dispersion of 95% of the potential mean values for the variable.





Lessons from an application (Epps et al. 2013): We assessed the potential impacts on pikas in Grand Teton NP (GRTE) from a proposed trail improvement and rock removal effort near Jenny Lake. Using PIP data collected in GRTE during 2010-2012, we considered a specific scenario that was under consideration during winter 2012/2013 for removing rock from select locations to the west of Jenny Lake. Under the proposed scenario, our results did not suggest that the proposed rock removal areas would threaten pika populations locally or park-wide. However, we perceived a need for careful monitoring if the quarrying proceeds, given that 1) the impacts of such disturbance on pikas are not well understood; 2) the pikas in the area exhibit a unique genetic signature; 3) the area shows signs of isolation from other pika habitat; and 4) the affected area represents high quality habitat in an important, low elevation setting. We therefore encouraged managers to minimize the intensity, duration and area of disturbance. We further recommended that the rate of territory abandonment and changes in population density be tracked as the quarrying proceeds. If feasible, it would also be useful to assess mortality rates during rock removal, as well as patterns of territory reestablishment for surviving pikas. Monitoring of pikas in GRTE using the PIP protocol would provide this information over time. Ideally, pika surveys will be conducted in advance of quarrying to guide the final decisions about where quarrying should occur. Areas of particularly high concentrations of pika activity should be avoided.

Other RM-CESU agencies or research partners who participated in this project: Rocky Mountain National Park, Great Sand Dunes National Park and Preserve, Grand Teton Nation Park and Yellowstone National Park.