National Park Service
U.S. Department of the Interior

Natural Resource Program Center

# Monitoring the American pika (*Ochotona princeps*) in the Pacific West Region: Crater Lake National Park, Craters of the Moon National Monument and Preserve, Lassen Volcanic National Park, and Lava Beds National Monument

*Narrative Version 1.0*

Natural Resource Report NPS/UCBN/NRR—2011/XXX

**ON THE COVER**
American pika (*Ochotona princeps*) at Craters of the Moon NM&P
Photograph by: Douglass Owen

# Monitoring the American pika (*Ochotona princeps*) in the Pacific West Region: Crater Lake National Park, Craters of the Moon National Monument and Preserve, Lassen Volcanic National Park, and Lava Beds National Monument

*Narrative Version 1.0*

Natural Resource Report NPS/UCBN/NRR—2011/XXX

Mackenzie R. Jeffress
National Park Service
Upper Columbia Basin Network
601 Nevada Highway (Mojave Desert Network)
Boulder City, NV 89005

John Apel
National Park Service
Craters of the Moon NM&P
P.O. Box 29
Arco, ID 83213

Lisa K. Garrett
National Park Service
Upper Columbia Basin Network
105 East 2nd St. Suite #5
Moscow, ID 83843

Gregory Holm
National Park Service
Crater Lake National Park
P.O. Box 7
Crater Lake National Park, OR 97604

David Larson
National Park Service
Lava Beds National Monument
1 Indian Well Headquarters
Tulelake, CA 96134

Nancy Nordensten
National Park Service
Lassen Volcanic National Park
P.O. Box 100
Mineral, CA 96063-0100

Thomas J. Rodhouse
National Park Service
Upper Columbia Basin Network
20310 Empire Ave. Ste A100
Bend, OR 97701

January 2011

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received formal, high-level peer review based on the importance of its content, or its potentially controversial or precedent-setting nature. Peer review was conducted by highly qualified individuals with subject area technical expertise and was overseen by a peer review manager.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Upper Columbia Basin Network website (http://www.nature.nps.gov/im/units/UCBN/) and the Natural Resource Publications Management website (http://www.nature.nps.gov/publications/NRPM).

Please cite this publication as:

Jeffress, M. R., J. Apel, L. K. Garrett, G. Holm, D. Larson, N. Nordensten, and T. J. Rodhouse. 2011. Monitoring the American pika (*Ochotona princeps*) in the Pacific West Region: Crater Lake National Park, Craters of the Moon National Monument and Preserve, Lassen Volcanic National Park, and Lava Beds National Monument: Narrative Version 1.0. Natural Resource Report NPS/UCBN/NRR—2011/XXX. National Park Service, Fort Collins, Colorado.

NPS XXXXXX, January 2011

## Change History

| Original Version # | Date of Revision | Revised By | Changes | Justification | Page #'s Affected | New Version # |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

1. Version numbers increase incrementally by tenths (e.g., version 1.1, version 1.2, …etc) for minor changes. Major revisions should be designated with the next whole number (e.g., version 2.0, 3.0, 4.0 …). Record the previous version number, date of revision, author of the revision, identify paragraphs and pages where changes are made, and the reason for making the changes along with the new version number.

2. Notify the UCBN Project Lead and Data Manager of any changes to the Protocol Narrative or SOPs so that the new version number can be incorporated in the Metadata of the project database.

3. Post new versions on the internet and forward copies to all individuals with a previous version of the Protocol Narrative or SOPs. A list will be maintained in an appendix at the end of this document.

# Contents

# Contents (continued)

# Contents (continued)

# Figures

## Tables

Page

# Executive Summary

The mission of the National Park Service (NPS) is “to conserve unimpaired the natural and cultural resources and values of the national park system for the enjoyment of this and future generations” (NPS 1999). To uphold this goal, the Director of the NPS approved the Natural Resource Challenge to encourage national parks to focus on the preservation of the nation’s natural heritage through science, natural resource inventories, and expanded resource monitoring (NPS 1999). Through the Challenge, 270 parks in the national park system were organized into 32 inventory and monitoring (I&M) networks.

Four park units in the Pacific West Region, Crater Lake National Park (CRLA), Craters of the Moon National Monument and Preserve (CRMO), Lassen Volcanic National Park (LAVO), and Lava Beds National Monument (LABE) have formed a partnership with the Upper Columbia Basin Network (UCBN) to develop a long-term monitoring protocol for the American pika (*Ochotona princeps*) following common methods that support comparative analyses. Monitoring efforts for CRMO will be implemented and funded by the UCBN whereas efforts in CRLA, LABE, and LAVO will be implemented and funded at the park level. The pika is a charismatic species in all of these parks and evidence of recent localized extirpations and range contractions in some areas, particularly in the Great Basin and Sierra Nevada mountains, have led to concerns about the impacts of climate change on this heat-intolerant animal.

This protocol details the why, where, how, and when of a pika monitoring program. As recommended by Oakley et al. (2003), it consists of a protocol narrative and a set of standard operating procedures (SOPs) which detail the steps required to collect, manage, and disseminate the data representing the status and trend of pika populations in the parks. The protocol is a “living” document in the sense that it is continually updated as new information acquired through monitoring and evaluation leads to the refinement of program objectives and methodologies. Changes to the protocol are carefully documented in a revision history log. The intent of the protocol is to ensure that a scientifically credible story about the ecological condition of park pika populations can be told to park visitors and managers alike. Four years of pilot data have been collected at CRMO, 3 years at LABE, and 1 year’s worth at CRLA and LAVO. These data provide answers to preliminary questions about the current pika distribution and have been used to resolve several logistical and methodological questions for the monitoring program. Initial focus of the protocol will be to obtain additional baseline information about the distribution and occupancy status of pikas in each of the four parks. As more information becomes available, the focus will shift toward trend detection, in which changes in occurrence patterns will be compared against baseline estimates for each park, and biologically meaningful declines or increases in pika occupancy can be described. Ultimately, data from this monitoring program can contribute to the understanding of relationships between pika site occupancy patterns and park environmental conditions, which can then inform park management decisions.

## Acknowledgments

Funding for this project was provided through the National Park Service Natural Resources Preservation Program (NRPP), the Natural Resource Challenge and the Servicewide Inventory and Monitoring Program. Many people contributed their ideas and hard work toward the development and implementation of this pika monitoring effort. The list of authors is presented in alphabetical order after the protocol lead and does not imply the level of contribution. We thank the UCBN Data Manager, Gordon Dicus, and GIS Analyst, Meghan Lonneker, for their contributions to the GIS and data management ideas and procedures. UCBN Science Communication Specialist, Paulina Starkey, was helpful in producing interpretive materials, such as resource briefs, and reviewing protocol documents. We thank the park superintendents, other park resource staff and key field technicians including Emilie Blevins, Laura Hudson, Michael Magnuson, Michael Munts, Jeffrey Murphy, and Devin Stucki for their contributed thoughts and help with various phases of the project. Klamath Network (KLMN) data manager, Sean Mohren, provided GIS information for development of sampling frames in CRLA and LAVO. We appreciate the contributions of Dr. Erik Beever and Dr. Chris Ray for sharing information from their pika surveying efforts and conclusions at LABE. Dr. Kathi Irvine at Montana State University provided guidance on sampling design and data analysis. The Mojave Desert I&M Network provided office space and supplies for the protocol lead. We thank Dr. Penny Latham, NPS Pacific West Region Inventory and Monitoring Program Coordinator, for facilitating peer reviews. Finally, we thank the anonymous reviewers who provided thorough and constructive comments on this protocol.

# Background and Objectives

This document presents a protocol for monitoring the status and trend of American pika (*Ochotona princeps*) populations in 16 National Park units in the western U.S. where the species occurs. Current focus of the protocol is on Crater Lake National Park (CRLA), Craters of the Moon National Monument and Preserve (CRMO), Lassen Volcanic National Park (LAVO), and Lava Beds National Monument (LABE), although the protocol could be adapted for wider use. Monitoring efforts for CRMO will be implemented and funded by the Upper Columbia Basin Network (UCBN) whereas efforts in CRLA, LABE, and LAVO will be implemented and funded at the park level. The protocol details a sampling strategy for determining status and trend in pika occupancy patterns, a fundamental population attribute and one more readily measured than other more informative but costly metrics of abundance. Sampling design and field methods for each of these four parks are presented. Furthermore, this protocol details data management, analysis, and reporting strategies. Standardized methods for data collection and analysis will enable the UCBN and park staff to document park-specific and regional patterns of pika occupancy as well as changes in those patterns over time. The protocol demonstrates how key environmental factors influencing pika distribution and occurrence, particularly elevation, can be incorporated into occupancy models to inform evaluations of the species' status and trend within the context of global climate change. Accelerated climate change poses one of the greatest challenges for National Park Service (NPS) natural resource managers in the coming decades, and this protocol will make a substantial contribution to NPS efforts to cope with this challenge. Other ongoing monitoring efforts in these parks pertinent to climate change include high-elevation 5-needle white pine population dynamics monitoring at CRLA, CRMO, and LAVO (Murray 2010, McKinney et al. *in review*), which is also regional in scope. Each of these parks is also involved in the Department of Interior (DOI) Landscape Conservation Cooperatives (LCC) framework, which is the centerpiece infrastructure for the DOI climate change initiative. For example, in CRMO, which is included in NPS planning efforts for the Great Northern LCC, sagebrush steppe vegetation monitoring (see Yeo et al. 2009) has also been identified as a monitoring effort directly relevant to tracking ecological changes in response to climate change, and is being expanded to Grand Teton National Park (GRTE) in the Greater Yellowstone Network, where our pika monitoring protocol is currently being tested for possible adoption. Taken as an information suite, these and other park studies relevant to climate change will provide a cornerstone of natural resource information for parks to assess the ecological effects of climate change and inform the coordinated NPS climate change response strategy.

## Rationale for Monitoring Pika Populations

The American pika (*Ochotona princeps*), a small mammal related to rabbits and hares (Order Lagomorpha), inhabits rocky montane environments of western North America from British Columbia south to northern New Mexico (Hall 1981). Pikas have received increasing attention over concerns that the species is at risk of extinction due to global climate change, and several authors have proposed that it is a sensitive climate change indicator species (Smith 1974, McDonald and Brown 1992, Lawlor 1998, Beever et al. 2003, Krajick 2004, Smith et al. 2004, Grayson 2005, Beever et al. 2010). Localized extirpations of pika populations have been documented in the Great Basin (Beever et al. 2003, Grayson 2005, Beever et al. 2010). The species appears to have responded to climate change with rapid range contractions during the Holocene and over the last century (Hafner 1994, Hafner and Sullivan 1995, Beever et al. 2003, Grayson 2005, Moritz et al. 2008, Galbreath et al. 2009). Elevational range contractions in the Great Basin appear to be particularly pronounced (Beever et al. 2003, Grayson 2005). The hypothesized mechanism for these range contractions is elevated temperatures and decreased mountain snowpack resulting from accelerated climate change (Smith et al. 2004, Grayson 2005). Recent habitat models (Craighead *unpublished report*) as well as dynamic models of climate-mediated extinction (Loarie et al. *in press*) predict that pikas may disappear from up to 80% of their current range by the turn of the century. The American pika was recently considered for protection under the Endangered Species Act (USFWS 2009). At the same time, a taxonomic revision of the species (Hafner and Smith 2010) led to the aggregation of formerly recognized subspecies, including several that were endemic to NPS lands, into five large phylogenetic groupings. In its listing decision, the USFWS recognized that "climate change is a potential threat to the long-term survival of the American pika" but concluded that none of the newly recognized phylogenetic groups were in immediate risk of extinction. Notably, however, the USFWS called for further data on the status, trends, and determinants of pika distribution for future listing and management considerations (USFWS 2010).

Pikas may be directly impacted by climate change for several reasons. First, they have a relatively high metabolic rate and low thermal conductance, such that resting body temperature is only about 3°C lower than lethal body temperature (MacArthur and Wang 1973, MacArthur and Wang 1974, Smith 1974). Due to this low thermotolerance, pikas primarily thermoregulate through behavioral adaptations and strategically time activity during the hot, summer months (MacArthur and Wang 1974, Smith 1974). Pikas are locally restricted to boulder-strewn talus fields and lava flows where abundant crevices and cavities provide sufficient cover and thermal refugia (Smith and Weston 1990, Millar and Westfall 2010, Rodhouse et al. 2010). This leads to pika occurrence patterns distributed along latitudinal and elevational gradients (Hafner 1993, Hafner 1994, Rodhouse et al. 2010). In the southern and more arid portions of the species' range, such as in the Great Basin and Sierra Nevada Mountains, it is uncommon to find pikas below 2,500 m (Grinnell 1917, Smith and Weston 1990, Beever et al. 2003, Moritz et al. 2008, Beever et al. 2010, but see Millar and Westfall 2010 and Rodhouse et al. 2010), but pikas occur at elevations as low as 300 m in mesic, northern latitudes (Simpson 2009). Furthermore, since pikas do not hibernate, the snowpack serves as thermal insulation in cold winter months, which has been studied in the closely-related collared pika (*O. collaris*; Morrison and Hik 2007). Without this insulation, pikas may be exposed to freezing rain and prolonged freezing temperatures (Smith et al. 2004, Morrison and Hik 2007). Recent research suggests that pikas are being lost from sites that have higher average summer temperatures and that experience more extremely cold days, presumably due to reductions in the insulation provided by winter snowpack (Beever et al. 2010). Therefore, snowpack declines projected to occur in mountainous regions of the western United States as a result of warming temperatures and altered precipitation patterns (Wagner et al. 2003, Mote et al. 2005, Karl et al. 2009) may also increase the risk of local extinction, particularly at lower elevations (Smith et al. 2004, Morrison and Hik 2007, Beever et al. 2010).

Our approach for monitoring pika populations in NPS lands is based on repeat presence-absence surveys of circular plots (hereafter "sites") that will permit detection of changes in site occupancy patterns over time. Site occupancy is an efficient and informative measure of change in animal populations, and occupancy models can be used to examine factors affecting site occupancy and rates of turnover in site occupancy (i.e., local site "extinction" and local site “recolonization”; MacKenzie et al. 2006, Royle and Dorazio 2008). Presence-absence surveys have been successfully used to inventory the species in CRMO (Rodhouse et al. 2010) and LABE (Ray and Beever *unpublished report*), and occupancy models developed from these surveys have revealed important insights that have been useful in guiding the development of this protocol. Most recently, we successfully pilot tested this protocol in these two parks as well as in CRLA and LAVO in 2010 (Jeffress et al. *unpublished report*). These efforts have indicated that the species is readily detectable when present, particularly when direct (e.g., visual observation, calling) and indirect (e.g., scat, haypiles) signs of occupancy are used. Patterns of site occupancy appear to follow elevation gradients in some parks, most notably in CRMO (Rodhouse et al. 2010) but also in LABE (Ray and Beever *unpublished report*). These observations follow patterns of historic elevational range contractions previously noted elsewhere (Hafner 1993, Beever et al. 2003, Grayson 2005). Accordingly, we have designed the protocol explicitly within the context of elevation, which integrates climatic factors and is an efficient, stable, and more easily measured proxy for the physiological stresses caused by temperature and snowpack (Körner 2007). Other studies have found higher forb cover to have a positive influence and high graminoid cover to have a negative influence on pika site occupancy (Ray and Beever *unpublished report*. Rodhouse et al. 2010), so we are also examining vegetation cover at the sites. Site surveys will be conducted across park samples of permanent monitoring plots that are distributed along the elevational gradients that occur in each of these parks. Because the four parks share similar latitude (Figure 1), this potential source of variation will be controlled. Furthermore, we have followed a hierarchical approach to occupancy modeling (Royle and Dorazio 2008) that will enable both within- and among-park analyses to be accomplished in an efficient and robust manner. This hierarchical strategy will provide a much broader regional perspective on pika occupancy patterns and dynamics than would be achievable if analyzed on a park-by-park basis.

In 2009, during a House Committee on Natural Resources confirmation hearing for his eventual appointment as NPS director, Jon Jarvis testified that, “Climate change is potentially the most far-reaching and consequential challenge to our mission than any previously encountered in the entire history of the NPS. - Our national park units can serve as the proverbial canary in the coal mine, a place where we can monitor and document ecosystem change without many of the stressors that are found on other public lands.” This long-term pika monitoring protocol will provide invaluable data for managing pikas and will improve our understanding of the impacts of climate change on NPS lands. These parks may provide regionally significant refugia for pikas if warming over the next century occurs as predicted. Alternatively, pika populations in these parks may be moving unavoidably towards extirpation. In either case, the need for a monitoring program that establishes a baseline against which future population change can be detected is clear.

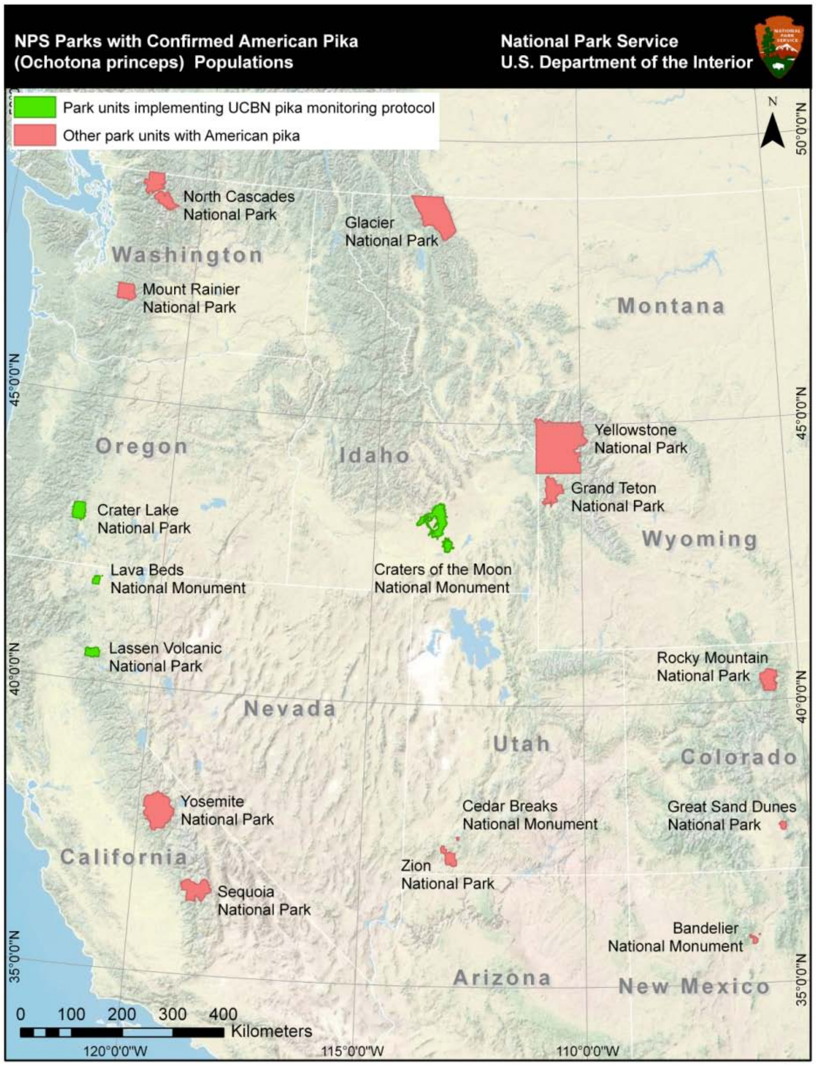


**Figure 1.** Map of the 16 park units with documented pika populations, including the four park units where the pika monitoring protocol is currently planned for implementation.

## Objectives

The overarching goal of the pika monitoring protocol is to inform park resource managers about the status and trend of pika populations within the context of elevation, a proxy for the physiological stresses directly related to climate change and implicated in pika range contractions. It will also address site occupancy dynamics as determined from rates of site turnover, which is information necessary to adequately evaluate the long-term probability of the species' persistence in the parks. This protocol will enable park managers to identify critical park areas that support pikas and to develop appropriate management strategies for those areas. Finally, this protocol will support regional syntheses of occupancy patterns and dynamics across a broad ecophysiographic range represented by the four parks that will provide an important regional perspective regarding the influence of climate change on the species. Given the lack of available ecological data on pika ecology in these parks, the following fundamental questions continue to drive much of the inquiry into pika population ecology:

- What are the current spatial patterns of pika site occupancy in the four parks?
- What are the trends in pika site occupancy patterns in the four parks?
- Does the status and trend in pika site occupancy patterns vary along the elevational gradient within and among parks?

In light of these questions, this protocol addresses the following specific measurable monitoring objectives:

1) Determine current patterns of pika site occupancy in CRLA, CRMO, LABE, and LAVO along park elevational gradients.

***Justification:*** *Pikas are territorial, conspicuous, and easily detected, making them ideal candidates for presence-absence surveys. Occupancy models can be used to identify important habitat covariates making this approach cost-effective given the vast area of potential habitat at these parks.*

2) Determine trends in pika site occupancy patterns in CRLA, CRMO, LABE, and LAVO along park elevational gradients.

***Justification****: Currently little information is known concerning the trends in pika populations at CRLA, CRMO, LABE, and LAVO. Site occupancy is a credible, cost-effective measure of change and examining the change on the proportion of sites occupied and site turnover provides insight into the patterns in site occupancy over time.*

### Management Actions

Following each survey effort the UCBN and/or park resource managers will consider the direction and magnitude of change for any annual change in occupied sites. If the proportion of occupied sites shows a decline for several years, additional investigations and expanded monitoring to better understand the nature and extent of the decline will be considered. Not only will this protocol capture changes in the proportion of sites occupied, it will be able to inform managers about where high priority habitat is found and where the change is occurring. Therefore, temporal trends in the site occupancy as well as the spatial locations of occupied and unoccupied sites and changes in these spatial patterns over time will serve as a guide for future management action. Although tools for pika population and habitat management have not yet been well developed, recent ideas focus on promoting resilience to global warming. Such ideas include protecting meadow and foraging zones adjacent to pika taluses and lava, routing trails and limiting recreational activity to avoid further fragmentation of pika habitat, using rock materials and designs to create pika habitat and corridor routes between occupiable habitats, and using attractants to lure pikas along corridors to higher elevation habitats (Hobbs et al. 2010). Since these ideas are new and have not yet been tested, our focus has been on designing a rigorous but flexible protocol that can be responsive to scientific advances and park management needs in the future as park and species climate change response strategies become developed and implemented.

# Sampling Design

## Sampling Design Rationale

Protocol objectives and sampling design were developed through a process that involved site reconnaissance, pilot data collection and analysis, and thoughtful consideration of the parks' and network's information requirements. The development team consisted of this document's authors, as well as other UCBN and park staff, in consultation with University and USGS researchers. Pilot data were collected at LABE in 2005-2006 (Ray and Beever *unpublished report*) and in 2010 (Jeffress et al. *unpublished report*), at CRMO during 2007-2009 (Rodhouse et al. 2010) and again in 2010 (Jeffress et al. *unpublished report*), and at CRLA and LAVO in 2010 (Jeffress et al. *unpublished report*).

This protocol is designed to support periodic (annual or at longer intervals) presence-absence surveys of permanent sample sites at each park. We have adopted a hierarchical occupancy modeling framework for this protocol (*sensu* Mackenzie et al. 2006, Royle and Dorazio 2008) to address questions and hypotheses pertaining to status and trends of pika site occupancy patterns at both park and regional scales. Since pikas are territorial, conspicuous, and easy to detect but relatively difficult to capture and mark (Smith 1974, British Columbia Resources Inventory Committee 1998, Smith and Gilpin 1997, Beever et al. 2003), they are well-suited for presence-absence (i.e., detection-nondetection) surveys. These presence-absence surveys will focus on direct detections of the animal as well as indirect detections of the animal's sign (Smith 1974, Beever et al. 2003, Ray and Beever *unpublished report*, Rodhouse et al. 2010). The proportion of an area occupied or used by a species is a fundamental population attribute and one more readily measured than other abundance metrics. Occupancy is a truncated measure of abundance and occupancy probabilities indicate how likely it is that a species will occur in abundance >0. Occupancy also directly reflects a species' local distribution, and knowledge about both abundance and distribution of species is central to the study of ecology and to the management of park ecosystems (Andrewartha and Birch 1954, Krebs 2001, Royle et al. 2005). Presence-absence data requires less intensive sampling than abundance data, and is therefore less costly and more likely to be implemented and sustained by research and monitoring programs. Given the vast area of potential habitat at these parks, simple presence-absence surveys are attractive for their efficiency and ease of implementation. By conducting presence-absence surveys and using hierarchical occupancy models, we can estimate the proportion of park areas occupied by pikas, probabilities of site occupancy and turnover, and trends in those probabilities along environmental gradients, such as elevation, or over time (MacKenzie et al. 2006; Royle and Dorazio 2008). Pikas are considered readily detectable when present, particularly when indirect sign is included in detection methods (Smith 1974, Smith and Gilpin 1997, Morrison and Hik 2008). Estimates of pika detection probabilities have consistently been >90% in CRMO (Rodhouse et al. 2010), LABE (Ray and Beever *unpublished report*), and elsewhere (e.g., Beever et al. 2008). We will therefore conduct only single visits to sites during each sampling period (year), allowing for much larger and more spatially-extensive sample sizes. However, our protocol can easily accommodate repeat visits, perhaps to only a subset of sites, to estimate detectability if this becomes warranted or if steep declines in pika occupancy probabilities occur in the future.

Strictly speaking, our target population includes all rocky habitat available to pika populations within each of the four parks. It is from maps of pika habitat that we have drawn samples to locate permanent plots, and these will in turn be searched for signs of pika occupancy. Park habitat maps provide the sampling frames to guide our sampling. However, we have developed spatially-restricted sampling frames that exclude substantial portions of some parks. For example, accessibility and extent of the parks makes spatially comprehensive sampling infeasible. We used historic sightings, recent survey information (Ray and Beever *unpublished report*, Rodhouse et al. 2010), and current vegetation and geologic maps to develop sampling frames, and restricted frames to areas within 1 km of roads and, in some cases, trails. Sampling frame errors arising from map inaccuracies will be addressed iteratively over the first 2 years of implementation, although pilot testing has already enabled us to improve frames considerably. Status and trend estimates will be based on model output, and inferences will be constrained by model assumptions summarized by MacKenzie (2006), MacKenzie et al. (2006), and Royle and Dorazio (2008). However, we will use a spatially-balanced sampling design within each park frame to ensure that model estimates are design-unbiased and to provide protection from model assumption failures (Thompson 2002). Simple unbiased status estimators will therefore be appropriate for within-year summaries that are computationally simple for park and network staff to perform annually without requiring statistical assistance. Each park frame has been stratified by elevation to ensure that sites adequately cover the elevational range of available habitat in the parks. Inferences to areas of potential pika habitat within park areas that are outside of sampling frames (e.g., >1 km from roads) will be applied cautiously. Because pikas are sedentary and do not disperse over large distances (Smith 1974, Smith and Ivins 1983, Smith 1987, Peacock and Smith 1997, Smith and Gilpin 1997), we do not believe our restriction of sampling to within 1 km of roads introduces a substantial bias. In most instances, park roads within our sampling frames are small, often traveled only by park visitors at low speeds, and have limited maintenance and other disturbance-generating activities along roadsides. However, as with the issue of imperfect detection, our protocol is sufficiently flexible such that it will also be effective in situations requiring larger and more spatially-extensive frames, such as in Grand Teton National Park. Backcountry travel is required in that park to obtain an adequate representative sample of available pika habitat, and our protocol has been successfully pilot tested there as well (National Park Service, Susan Wolff, Wildlife Biologist, pers. comm., 2010).

### Sampling Frame and Allocation of Samples

Data will be collected at permanent sites within park sample frames stratified by elevation, and in the case of CRMO, by lava type. The criteria for delineating sampling frame boundaries was determined in consultation with park staff and included mapped existing or potential pika habitat, management boundaries, and other permanent features such as roads or topographic barriers restricting field crew access. The sampling frames cover the elevational range of potential habitat at each park, except at CRMO (see CRMO sampling frame description), which ensures adequate sampling intensity along park elevational gradients. In CRMO, following recommendations made by Rodhouse et al. (2010), we stratified the sampling frame by pahoehoe and aa lava types in addition to elevation. Access and slope were discussed with resource staff at each park to ensure that the safety of all field crews was taken into account. Accessibility was a primary constraint at all four parks so we restricted frame areas to within 1 km of roads. We also included potential habitat within 1 km of some trail segments in CRMO and LAVO. Additionally, steep slopes (>35°), identified using digital elevation models in GIS, and traversable areas isolated by these steep slopes were excluded from sampling. A 12-m buffer was placed along park boundaries to minimize problems associated with fence lines and access to non-park land.

Within each stratified sampling frame, permanent survey site locations were drawn using the generalized random-tessellation stratified (GRTS) spatially-balanced sampling design described by Stevens and Olsen (2004). A GRTS sample design is a flexible, efficient, and statistically robust approach that accommodates many of the difficulties commonly encountered in field sampling (e.g., sample frame errors, inaccessibility), allows for inclusion of new sample locations in response to these difficulties, maintains spatial balance, and, through a modified variance estimator developed for GRTS samples, increases precision of status estimates (Stevens and Olsen 2003, 2004). In order to ensure adequate representation of the available elevational gradient within each park frame, we either allocated ½ the sample to frame areas below median elevations and ½ of the sample to areas equal to or greater than the median elevation (i.e., 2 strata) or, if this proved inadequate, allocated by quantiles (i.e., 4 strata; 25$^{th}$, 50$^{th}$, and 75$^{th}$ elevation percentile breaks). This approach resulted in an unequal probability (stratified) sampling design, where inclusion probabilities differ for sample units in each of the 2 or 4 strata according to the areas of each stratum. A minimum sample size of 100 was allocated to each park frame, based on our assessment of available resources for sustaining this monitoring program within each park and to provide adequate precision of estimates. Parks stratified by median elevation received 50 samples in each stratum. Parks stratified by quantiles received 25 samples in each stratum. Oversamples of size 2*n (100; Theobald et al. 2007) were drawn for each frame in order to accommodate frame errors and site replacements or if larger sample sizes are desired.

Sample frame delineations specific to each park are as follows:

#### ***CRLA***
In order to delineate a sampling frame for CRLA a map of potential pika habitat was created using an automated process to define the boundaries of different habitat types in the park. NAIP imagery from 2007 was used as the base map. Polygons were delineated and then classified by habitat type. Those polygons containing potential pika habitat were identified and selected for inclusion in a map of potential pika habitat. As a final step, the potential pika habitat map was reviewed by a wildlife specialist at the park and edited where appropriate. The pika sampling frame for CRLA was stratified by four elevational quantiles, with spatially-balanced samples distributed equally across each stratum. The sampling frame and survey site locations are presented in Figure 2.

#### ***CRMO***
We used historic sightings, recent pilot data (Rodhouse et al. 2010), and current vegetation (Bell et al. 2009) and geologic maps to develop the CRMO sampling frames. In addition to the habitat within 1 km of roads, we also included habitat within a 1 km buffer of approximately 1.5 km sections of the northern, accessible portions of the CRMO Wilderness Trail and Tree Molds Trail to increase access to a significant amount of habitat. Given that the pilot data have found pika distribution restricted to the northern portion of the Monument above 1600 m (Monument and Huddle's Hole frames from Rodhouse et al. 2010), we combined these areas as well as additional areas within 1 km of Highway 93 and the Minidoka-Arco road into one primary sampling frame to be sampled at regular intervals. This frame captured >400 m range in elevation and was

stratified by two elevational strata, based on median elevation of the frame, and in two substrate strata (i.e., pahoehoe and aa lava). This yielded a total of four strata with spatially-balanced samples distributed equally across each stratum. The sampling frame and survey site locations are presented in Figure 3.

### *LABE*

We used a map of the black lava flows provided by the park to delineate available habitat for the LABE sampling frame. The sampling frame includes areas designated as wilderness and portions of the Callahan, Schonchin, Ross, and Devils Homestead Flows. This sampling frame also captured the majority of study area addressed by Ray and Beever (*unpublished report*). Samples were distributed across two elevational strata based on median elevation of the frame. The sampling frame and survey site locations presented in Figure 4.

### *LAVO*

In order to delineate a sampling frame for LAVO a map of potential pika habitat was created using an automated process to define the boundaries of different habitat types in the park. NAIP imagery from 2007 was used as the base map. Polygons were delineated and then classified by habitat type. Those polygons containing potential pika habitat were identified and selected for inclusion in a map of potential pika habitat. As a final step, the potential pika habitat map was reviewed by a wildlife specialist at the park and edited where appropriate. Given the remoteness of a significant amount of potential habitat, we included areas within a 1 km buffer of trail sections in addition to the habitat within 1 km of roads. Starting from the trailhead, 1 km of each trail was buffered, and in a couple instances, >1 km of trail (≤3 km of the Butte Lake trails and 2 km of the southern portion of Kings Creek Trail). The pika sampling frame for LAVO was stratified by four elevational quantiles, with spatially-balanced samples distributed equally across each stratum. The sampling frame and survey site locations are presented in Figure 5.

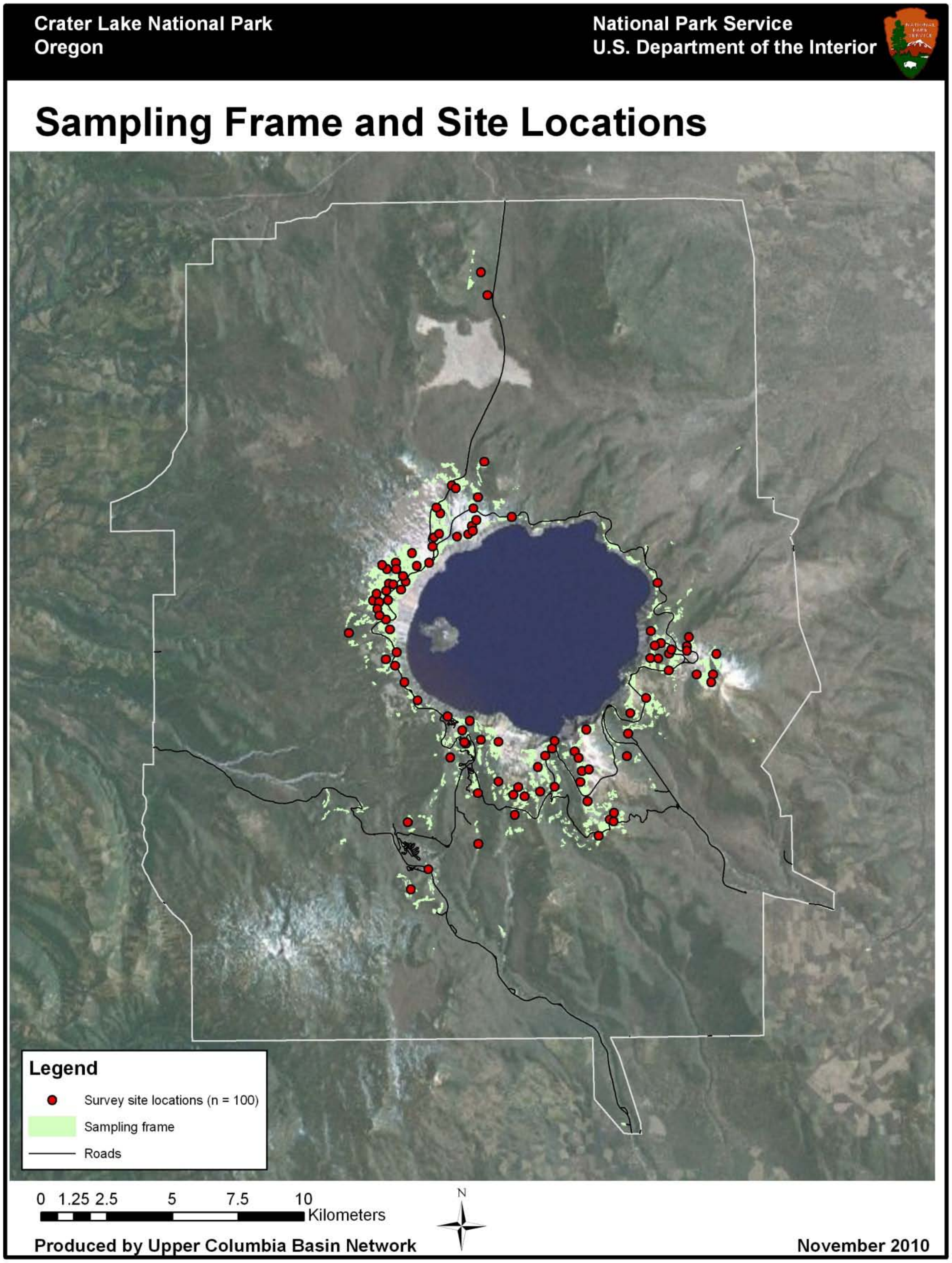


**Figure 2**. Pika sampling frame and GRTS sample of site locations for Crater Lake National Park.

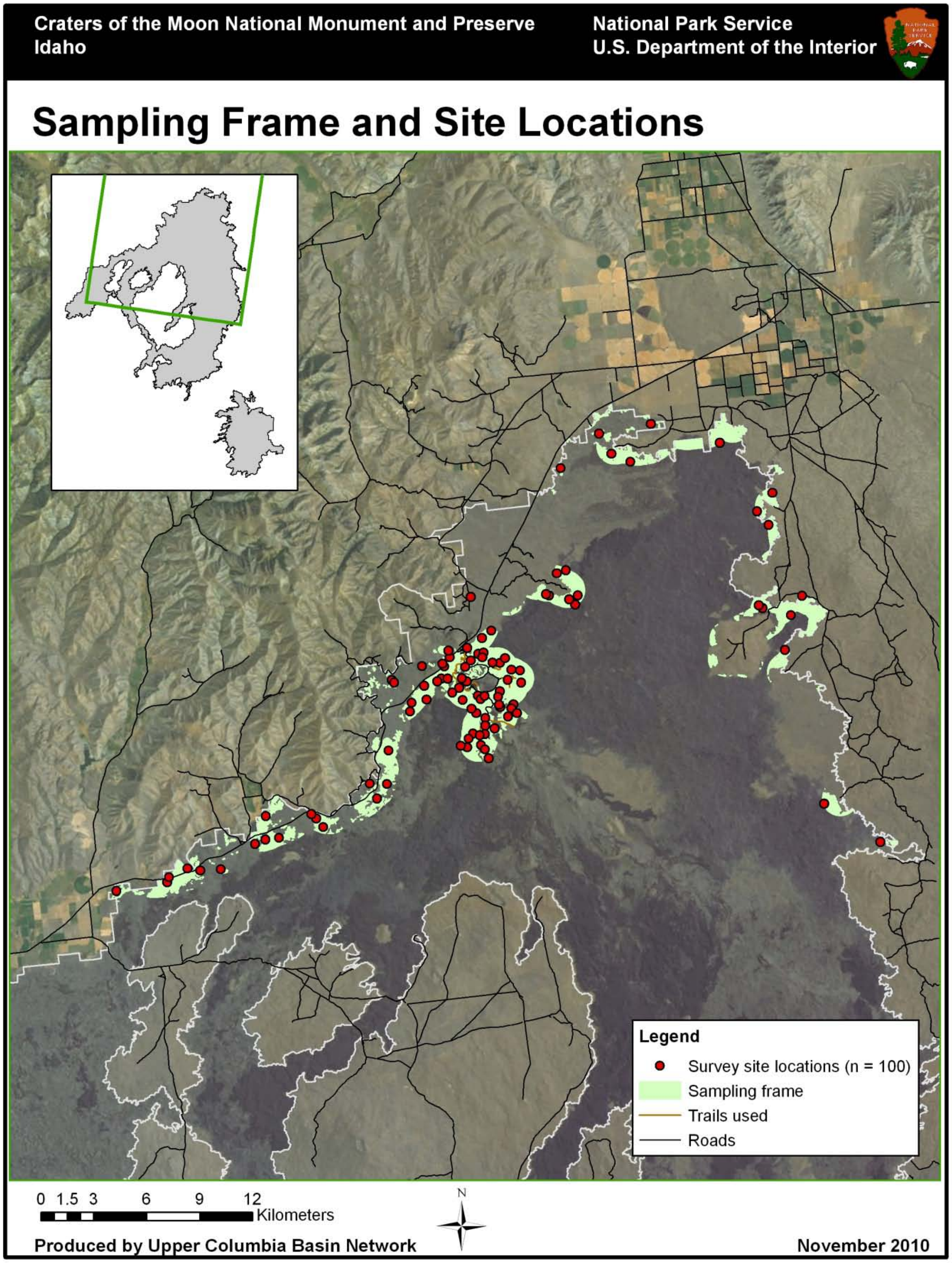


**Figure 3.** Pika sampling frame and GRTS sample of site locations for Craters of the Moon National Monument and Preserve.

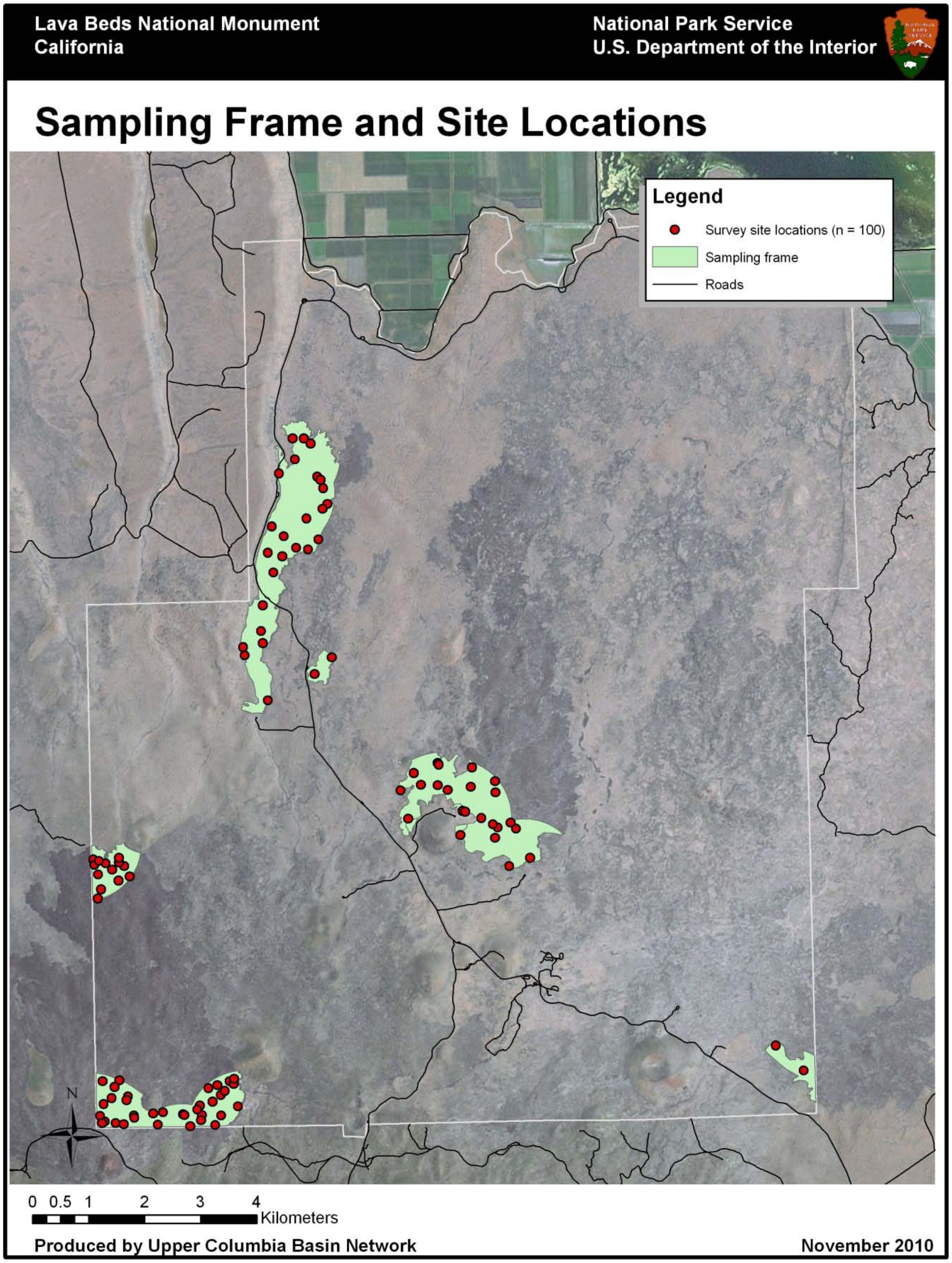


**Figure 4.** Pika sampling frame and GRTS sample of site locations for Lava Beds National Monument.

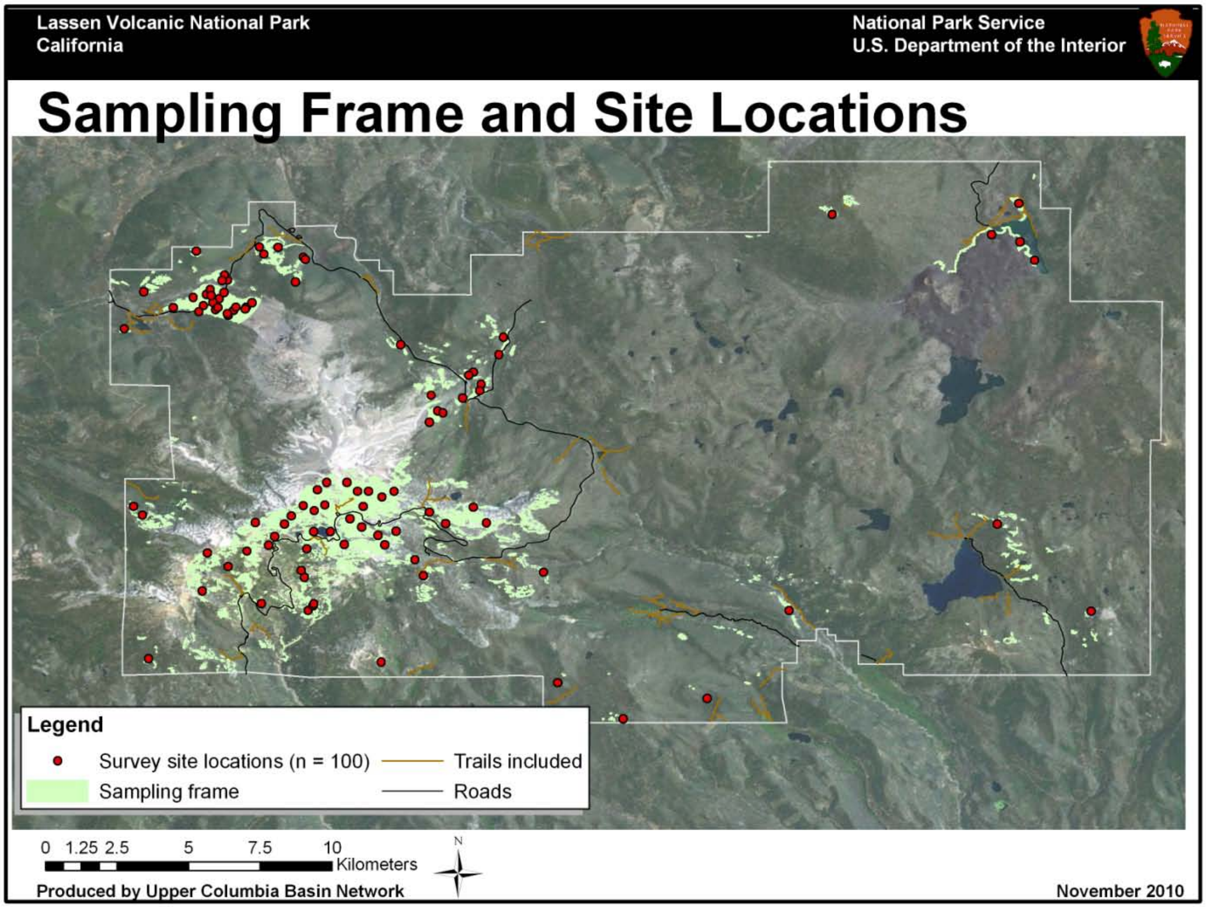


**Figure 5.** Pika sampling frame and GRTS sample of site locations for Lassen Volcanic National Park.

## Survey Frequency and Timing

Sampling will occur annually within the first 3 years of implementation to gain an understanding of variation in occupancy estimates. After this baseline is established we predict sampling will occur every 1 to 3 years, although this decision may change once we begin to understand the nature of variation. If inter-annual variability is low and the precision of each year's sampling is high, then we will initiate a less frequent revisit strategy (i.e., every 2 to 3 years). Because we have emphasized a relatively simple and efficient monitoring strategy, we are confident that an annual survey schedule in each park is sustainable were it deemed necessary.

Pikas are vocal during the breeding season, which typically runs from late April to early July (Johnson 1967, Millar 1972, Smith and Ivins 1984). A post-partum estrus is possible and two litters are commonly conceived each year (Millar 1972, Millar 1973, Millar 1974, Smith 1978). Haying occurs in the summer months following the breeding season and spatial overlap between adults is lowest in late summer to early autumn (Conner 1983, Smith and Ivins 1983, Huntly et al. 1986). Territorial behavior during late summer and fall also results in an increase in calling frequency and haypile detectability increases in July and peaks in September as accumulations of plant material grow. Both Ray and Beever (*unpublished report*) and Rodhouse et al. (2010) found adequate high pika detectability from June through September. Given this, and the need for flexible scheduling, surveys should be conducted after snow melt but no earlier than July 1 until early October or before the first snowfall, whichever comes first. However, given the later seasons in the higher elevation parks (CRLA and LAVO), which can hold snow into and throughout the summer months, July 1 is likely too early to be able to schedule sampling and a more probable season start date is August 1. Once an optimal survey season has been established for each park (following first 2 years of implementation), it is ideal that the survey date of each individual site remain relatively constant across years, in order to control for potential effects of season on detectability.

Single visit surveys will be conducted at each permanent site during each sampling season. Pikas are highly detectable and results from the pilot efforts and past studies have documented detection probabilities of 0.90 to 0.97 (Ray and Beever *unpublished report*, Beever et al. 2008, Beever et al. 2010, Rodhouse et al. 2010, Jeffress et al., *unpublished data*), so we chose to conduct single visit surveys. Furthermore, two observers will search each site, removing the likelihood of observer influence on detectability and further improving the capacity to detect sign during surveys. If lower detection probabilities become a concern (e.g., a rapid decline in detections from one year to the next), our protocol could easily be modified so that two surveys are conducted per season in order to explicitly account for detection probabilities. In the event of a marked downward trend, we recommend instituting a subset of repeat surveys in order to confirm that site occupancy is actually declining rather than the detection probability. However, little, if any, bias in occupancy estimates occurs when detection probabilities are >0.9 (MacKenzie and Royle 2005, Rodhouse et al. 2010, Royle and Dorazio 2008).

## Response Design

Following an approach developed by Ray and Beever (*unpublished report*) and implemented successfully at CRMO (Rodhouse et al. 2010), detections will be based on both direct (aural and visual) and indirect (scat and hay piles) signs of site use in fixed area plots (referred to as “sites”). Sites are 12-m radius circles, centered on GRTS sample coordinates, and encompass

452 $m^2$. Sites will be classified as occupied (alternatively "used") if pikas are detected directly through visual or aural cues, or indirectly through sign of fresh scat (and urine) or fresh hay within a 12-m radius circular area around the sample point. Old haypiles and old scat will be interpreted as past use of the site but not used to reflect current site occupancy. The 12-m radius plot was chosen after consideration of typical pika territory size (approx. 400-700 $m^2$; Kawamichi 1976, Svendsen 1979, Smith and Ivins 1986) and what would be a reasonable search effort. This plot size was originally developed for pika surveys at LABE and was successfully implemented over 3 years at CRMO (Ray and Beever *unpublished report*, Rodhouse et al. 2010).

## Sample Size and Power Analysis

Given the recent extirpations of pikas from some parts of its range and concerns about population declines in response to climate change, we have approached the question of sample size from the perspective of acquiring precise annual estimates of occupancy, and on detecting declines rather than increases in occupancy, although our protocol will support change detection in both directions. Also, we have carefully considered the practical limitations facing the four parks and network that ultimately determine how many sites can be surveyed in a given year. For status we used a simple status estimator formula, $n = z^2 (\Psi*(1-\Psi))/d^2$ (Elzinga et al. 1998), to determine the sample size required for a specific margin of error (confidence interval half-width) for estimates of Ψ, the proportion of sites occupied (alternatively notated as p in Elzinga et al. 1998). In this equation, z is the confidence interval multiplier taken from the standard normal distribution, and we used $z = 1.64$ for 90% confidence. The equation also requires input of a desired margin of error, denoted by d, which is found by multiplying the z multiplier (in this case 1.64) by the standard error of the sample mean, Ψ. As it turns out, setting Ψ equal to 0.5 provides the most conservative estimate of necessary sample size. Therefore, a sample size of 50 will provide an estimate of Ψ with a standard error of 0.07 when the proportion of sites occupied is 50%. Precision will improve under any scenario when site occupancy differs from 50%. Under the same scenario, a sample size of 100 will yield a standard error of $\leq$0.05. These results are matched by an analogous equation provided by MacKenzie et al. (2006).

We have also considered power to detect 25% occupancy declines for fixed sample sizes using 2-year comparisons ("step-trend") of annual estimates of Ψ with an equation from Ramsey and Schafer (1997). Give the concern over detecting a decline, we used a conservative starting proportion (0.5) and a Type I error (α or false-change error) of 0.1, thus minimizing preservationist's risk (as opposed to 0.05, for example; Irwin 2006, Morrison 2007). We used a 25% practically significant difference criterion, following Ramsey and Schafer (1997) , recognizing that pikas appear to have relatively high inherent year-to-year variability of 15% or more resulting from mortality (Johnson 1967, Smith 1978, Smith and Ivins 1984, Smith and Gilpin 1997, Rodhouse et al. 2010). For this level of change, the Ramsey and Schafer (1997) exercise suggested that a sample size of 85 would be sufficient.

Given these two analyses, a consideration of practical constraints, and recognition that increased model complexity (e.g., with elevation and year covariates) will require larger sample sizes, we have chosen to sample a minimum of 100 permanent sites in each park sampling frame during each survey period, revisited annually during the initial 3-year implementation period, and annually or less frequently thereafter. Additional power calculations to consider more complex long-term scenarios have not been taken, largely due to the uncertainty concerning how multi-season hierarchical occupancy models should be parameterized to estimate power (MacKenzie et al. 2006, Royle and Dorazio 2008). We note, however, that MacKenzie et al. (2006) showed that the power to detect trend using a simple "implicit-dynamics" occupancy model, as measured by the coefficient of variation of Ψ, differed markedly among sample sizes of 50, 100, and 200 during the first 4 years of study, but converged rapidly after 4 years, and were identical after 8 years.

### Summary of the Benefits of the Selected Design

- This sampling design allows estimation of the status and trend in pika occupancy across expansive park landscapes while requiring few personnel for surveys over a short period of time.

- With proper training, the field techniques are straight-forward to implement, allowing for the use of observers from diverse backgrounds, including trained volunteers and seasonal technicians, for data collection.

- The use of GPS technology provides an objective approach to locating sample locations.

- The GRTS spatially balanced sample design provides the ability to add new sample locations without affecting the spatial balance of the sample and minimizes the effects of spatial autocorrelation relative to other sampling schemes.

- The sample size is large enough to estimate status precisely and to detect trends after 4 years, but also feasible for parks to implement. One team should be able to survey approximately eight sites a day, keeping well within a 4-week timeframe for most annual surveys within the parks.

- The large sample sizes and extensive coverage of samples across the parks will help inform managers not only of changes in the proportion of sites occupied, but where high priority habitat is and where change is occurring.

# Field Methods

## Field Season Preparations and Field Schedule

The first step in field preparation is to revise procedures based on the experiences and results from the previous year. After any revisions are completed, preparation involves determining which sites will be sampled for the season, gathering equipment, and fulfilling permitting and compliance requirements. All study areas are NPS units, and permits will be provided through the NPS research permit and reporting system (http://science.nature.nps.gov/research/ac/ResearchIndex). These preparations should begin in January preceding each sampling occasion. If necessary, hiring and scheduling of field personnel should also be initiated no later than January. Field surveys require a minimum of two people for four weeks. Student Conservation Association (SCA) interns and citizen scientists can be used to implement this protocol, provided they are properly trained. Field training should be conducted the week preceding initiation of field surveys. The field team will be able to practice survey techniques and pika sign identification in similar conditions to what will be encountered during surveys. Complete descriptions of pre-season preparation and training are in SOP # 1 and SOP # 2.

## Locating, Establishing, and Surveying Sites

Driving directions to park study areas are included in SOP # 4. Travel times can be substantial and should be carefully planned. Once on site, access to survey areas will require hiking across rugged terrain. Though surveys should not be conducted during rain or snow events for both safety and detectability concerns, weather can be unpredictable and surveyors must be prepared to encounter extreme and often unexpected weather conditions, including severe heat, cold, rain, and snow. Each surveyor should maintain a supply of warm clothes and rain gear, sun hats, and plenty of water. Safety procedures outlined in SOP # 7 should be adhered to, including conducting surveys in teams and maintaining close communication with office-based park points-of-contact regarding field schedules and check-in/check-out times. Park hazards, including emerging threats such as extreme weather or fire hazards, should be discussed with park staff and/or the Project Lead during a briefing prior to initiation of field work and throughout the duration of surveying, as necessary. First aid and other safety equipment must be kept in project vehicles and easily available at all times. Before the start of each field session, survey site locations should be organized into convenient and efficient routes through the study area according to the sample layout and topography. Each park has obstacles and barriers that may interrupt travel between the sample locations. These routes will be illustrated on hard copy maps, developed and annotated during close-out of the previous season, drawing on accumulated field experience.

Permanent survey sites will be located using a GPS unit, following procedures outlined in SOP # 3. This protocol is designed for two observers to conduct surveys. Once the site marker (or waypoint) is found, the observers will lay out two tape measures running perpendicular to each other, each measuring 24 m with the 12-m mark centered at the waypoint. Each sample unit will consist of a 12-m radius circular plot (see Figure 6).

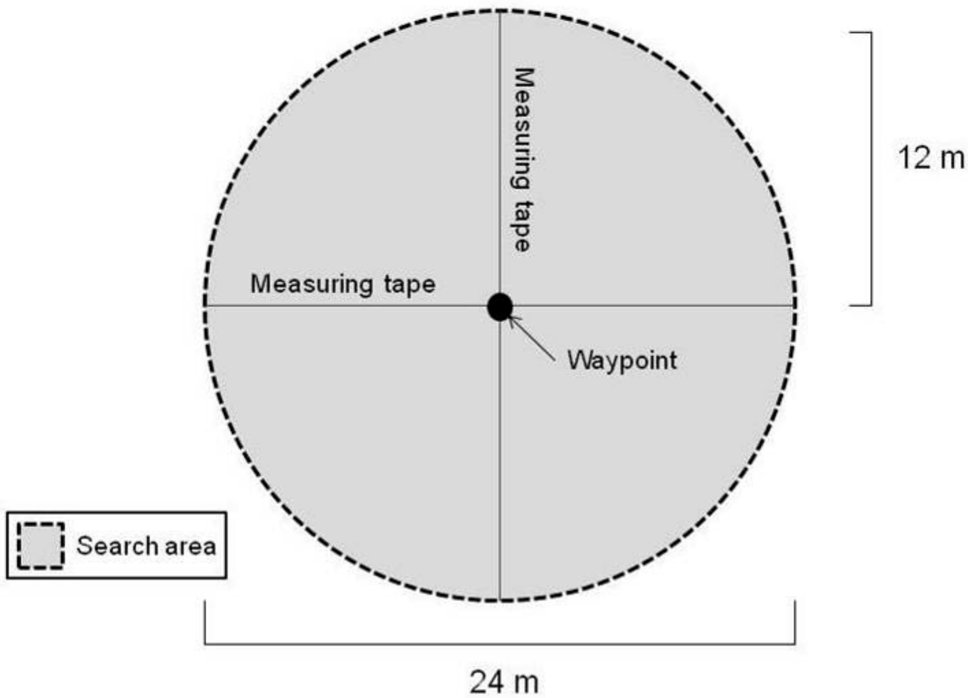


**Figure 6**. Diagram of the 12-m radius plot used for pika monitoring. Any evidence of recent pika activity found within the search area indicates the site is occupied.

Once the site is established, the basic field sampling procedure involves (1) listening and watching for pika activity within the plot for 2 minutes, (2) searching the site for pikas and their sign, (3) collecting site attribute information (i.e., vegetation cover), (4) entering and reviewing data entries on the data form, and (5) selecting and navigating to the next survey site. Percentage vegetation cover will be estimated visually within the plot in six habitat categories using a modified Daubenmire scale. Further details of survey procedures can be found in SOP # 4. Field training will be conducted at the start of each season. Training is detailed in SOP # 2 and will include a review of pika sign identification and similar species subject to misidentification.

### Data Entry and Management

Pilot pika data in 2007-2010 were collected with paper forms. Paper data sheets make it much easier to prevent data loss and their use facilitates participation by volunteers and technicians who may be not have sufficient experience using advanced technology such as mobile computers or personal digital assistants (PDAs). Therefore, this protocol version is designed around the use of paper data sheets.

Paper data entry is relatively straightforward, and a data sheet template is included in the SOP # 8. The basic structure involves a document with discrete choices for observers to record evidence of pika activity. Data sheets will be prepared for each team prior to entry into the field. Extra data sheets will also be provided.

The preferred order of field operations and data entry steps are as follows:

1. Locate survey site marker (or if no marker, site waypoint) using GPS
2. Set up measuring tapes to identify boundaries of 12-m plot

3. Enter site ID number, observers, date, and arrival time on the data sheet
4. Sit silent while listening for pika call and looking for pika visuals within the site.
5. Survey the site and record information about pikas and pika sign encountered
6. Measure and record vegetation cover data
7. Take photos of the site and if necessary, place a site marker
8. Add any necessary comments in the "notes" section
9. Review data entry before moving to the next survey site location

Data sheets will be inspected at the end of each field day as a key step in the quality assurance and quality control process (QA/QC). Data entry from paper forms into the working copy of the pika protocol database (a Microsoft Access database, described in detail in SOP # 5) will be performed by trained staff in an office setting after completion of field work, and will also be treated as an additional opportunity to conduct QA/QC. Validation rules programmed into the database will help detect logical inconsistencies, such as out of range data.

Paper data sheets, stored by the UCBN for CRMO and park staff for CRLA, LABE, and LAVO, will remain available for reference in resolving any QA/QC issues that may be discovered in the master database. After 5 years, the paper data sheets will be transferred to the appropriate park or regional museum staff for official archiving. The UCBN will maintain the master database for all four parks as the official record of protocol data, following procedures established in the UCBN Data Management Plan (Dicus and Garrett 2007) to ensure the master database is properly archived and remains compatible with applicable software.

### After the Field Season

Following field work, all equipment should be stored in labeled bins. Equipment will be stored at UCBN headquarters for CRMO. CLRA, LABE, and LAVO should identify a proper equipment storage area, likely at the Resource Managers' office. Electronic equipment should have batteries removed during winter months to prevent corrosion and leaking. Waypoints can be deleted at the end of each field season prior to storage but this is not necessary. Data entry into the project database will begin as soon as possible after data collection in order to address outstanding QA/QC problems before memories fade and personnel change.

# Data Handling, Analysis, and Reporting

The following section outlines procedures for pika data handling, analysis, and report development. A park's status and trend analyses will be conducted and reported on by the Project Lead. Consequently four annual monitoring reports will be produced each year. However, CRLA, LABE, and LAVO park staff are interested in and hope to collaborate with the UCBN on multi-park trend analyses. The parks and UCBN will explore funding opportunities for a task agreement with a university or an interagency agreement to accomplish an analysis after 5 years of data collection. Additional details and context for this chapter may be found in SOP #5 and SOP #6 (data management SOP and data summary, analysis, and reporting SOP, respectively) and in the UCBN Data Management Plan (Dicus and Garrett 2007), which describes the overall information management strategy for the Network. The UCBN monitoring plan also provides a good overview of the network's information management and reporting plan (Garrett et al. 2007).

## Overview of Database Design

A customized relational database application, implemented in Microsoft Access, has been designed to store and manipulate the data associated with this project. The design of this database is consistent with NPS I&M Natural Resource Database Template version 3.2 and UCBN standards (http://science.nature.nps.gov/im/apps/template/index.cfm; Dicus and Garrett 2008). The database will continue to undergo revisions, which will be reflected in both this protocol narrative and the data management SOP # 5. The general database strategy is to use a blank version of the protocol database (a "working copy") to import, error-check, and validate a given season's data, then migrate those data to the read-only "master version" of the protocol database. This strategy protects validated data from corruption, and the master version will facilitate multi-year analyses. The underlying data structure (tables, fields, and relationships) will always remain the same in both versions, and they will have very similar user-interface functions (data forms, queries, etc., accessed through a user-friendly "switchboard") to facilitate data exploration and export (Figure 7). The user-interface of the working copy database will serve data import, quality control, and validation needs. The user-interface of the master database application will serve analysis and summarization needs, including specific reporting and exporting format needs. Details of the database, including a description of core and peripheral tables and a logical model of table relationships, are presented in SOP # 5.


**Figure 7**. View of UCBN pika monitoring database user-interface.

### Data Entry

A blank version of the database will be provided by the UCBN to each of the Project Leads before each field season. Entry of data from paper field sheets to the database will be accomplished each season shortly after completion of field work. The database's data entry form will resemble the layout of the paper field sheet, and will have built-in quality assurance components such as pick lists and validation rules to test for missing data or illogical combinations. Data entry should be viewed as an important step in the overall QA/QC process, and care should be taken to review both the input from the paper forms and the resulting entries in the database.

### Quality Review

After the data have been entered and processed, they will be reviewed by the Project Lead for that park for quality, completeness, and logical consistency. The working database application will facilitate this process by showing the results of pre-built queries that check for data integrity, data outliers and missing values, and illogical values. The user may then fix these problems and document the fixes. If all errors and inconsistencies cannot be fixed, the resulting errors will be documented and included in the metadata and certification report.

### Metadata Procedures

Data documentation is a critical step toward ensuring that datasets are useable for their intended purposes well into the future. This involves the development of metadata, which can be defined as structured information about the content, quality, and condition of data. Additionally, metadata provide the means to catalog datasets within intranet and internet systems, making data available to a broad range of potential users. Metadata for all monitoring data will conform to Federal Geographic Data Committee (FGDC) and NPS guidelines and will contain all components of supporting information such that the data may be confidently manipulated, analyzed, and synthesized. For long-term projects such as this one, metadata creation is most time consuming the first time it is developed – after which most information remains static from one year to the next. Metadata records in subsequent years then only need to be updated to reflect current publications, references, taxonomic conventions, contact information, data disposition and quality, and to describe any changes in collection methods, analysis approaches or quality assurance for the project.

Specific procedures for metadata development and posting are outlined in the I&M network data management plans, such as the UCBN Data Management Plan (Dicus and Garrett 2008). In general, the Project Lead and the Data Manager (or Data Technician) will work together to create and update an FGDC- and NPS-compliant metadata record in XML format. The Project Lead should update the metadata content as changes to the protocol are made, and each year as additional data are accumulated. Edits within the document should be tracked so that any changes are obvious to those who will use it to update the XML metadata file. At the conclusion of the field season, the Project Lead will be responsible for providing a completed, up-to-date metadata summary in an XML metadata file or in a metadata questionnaire document to the Data Manager. The Data Manager will facilitate metadata development by creating and parsing metadata records, and by posting such records to national clearinghouses as described below.

## Sensitive Information

Part of metadata development includes determining whether or not the data include any sensitive information, which includes specific locations of rare, threatened, or endangered species. Prior to completing metadata, the Project Lead and Park Resource Manager (if not one in the same) should work together to identify any sensitive information in the data. Their findings should be documented in the metadata summary and communicated to the Data Manager. At this time, we do not anticipate that information collected in the pika monitoring program will be considered sensitive.

## Data Certification and Delivery

Data certification is a benchmark in the project information management process that indicates that 1) the data are complete for the period of record; 2) they have undergone and passed the quality assurance checks; and 3) that they are appropriately documented and in a condition for archiving, posting, and distribution. Certification is not intended to imply that the data are completely free of errors or inconsistencies which may not have been detected during quality assurance reviews.

To ensure that only data of the highest possible quality are included in reports and other project deliverables, the data certification step is an annual requirement for all tabular and spatial data. The Project Leads are primarily responsible for completing certification. The certified data and updated metadata should be delivered to the identified Data Manager for the park as well as the UCBN Data Manager according to the timeline in Table 3 in the Operational Requirements section. Additional details of the certification and delivery processes, including a season close-out form, are described in SOP # 5.

## Data Analysis

### *Annual Status Analysis*

Status results for a park will be summarized by the park's Project Lead after each year of data collection. SOP # 6 presents the computational details required to accomplish annual summaries. Standard summary information will be presented for each sampling frame at each park with content similar to that shown in Table 1, and will include the number of sites surveyed, number of occupied sites, and proportion of sites occupied. The primary status metric of interest will be estimates of the proportion of sites occupied, or $\Psi$ for each park. Estimation of $\Psi$ and its standard error are straightforward and easily accomplished promptly at the end of each survey period using standard design-unbiased estimators for stratified random samples (Thompson 2002). Use of the "local" GRTS variance estimator (Stevens and Olsen 2003) can be used to take advantage of the spatially-balanced sampling design and obtain more precise estimates of uncertainty. In addition, site turnover from the previous year and the direction of turnover, in terms of site extinction and site colonization, will also be summarized by simply calculating the percentage of sites that changed occupancy status from the previous year (e.g., from occupied to unoccupied, or vice versa). Hierarchical occupancy models (MacKenzie et al. 2006, Royle and Dorazio 2008) will be employed to establish baseline relationships of occupancy patterns along the elevational gradients both within and among the four parks. For example, Figure 8 illustrates the modeled relationship between site occupancy probabilities ($\Psi$) and elevation observed at CRMO, by lava type. This type of approach will be modified to address occupancy-elevation trends among parks, rather than as shown here for lava type. These models can easily be modified to estimate detection probabilities in the event that becomes of interest.

**Table 1.** Hypothetical example of annual summary information for the pika populations at each park.

| Annual Pika Survey Results – Crater Lake | 2010 |
|---|---|
| Number of Sites Surveyed | 85 |
| Number of Occupied Sites | 55 |
| Proportion of Sites Occupied (Ψ) | 0.65 |
| Site Turnover (% from 2009 to 2010) | 15 |

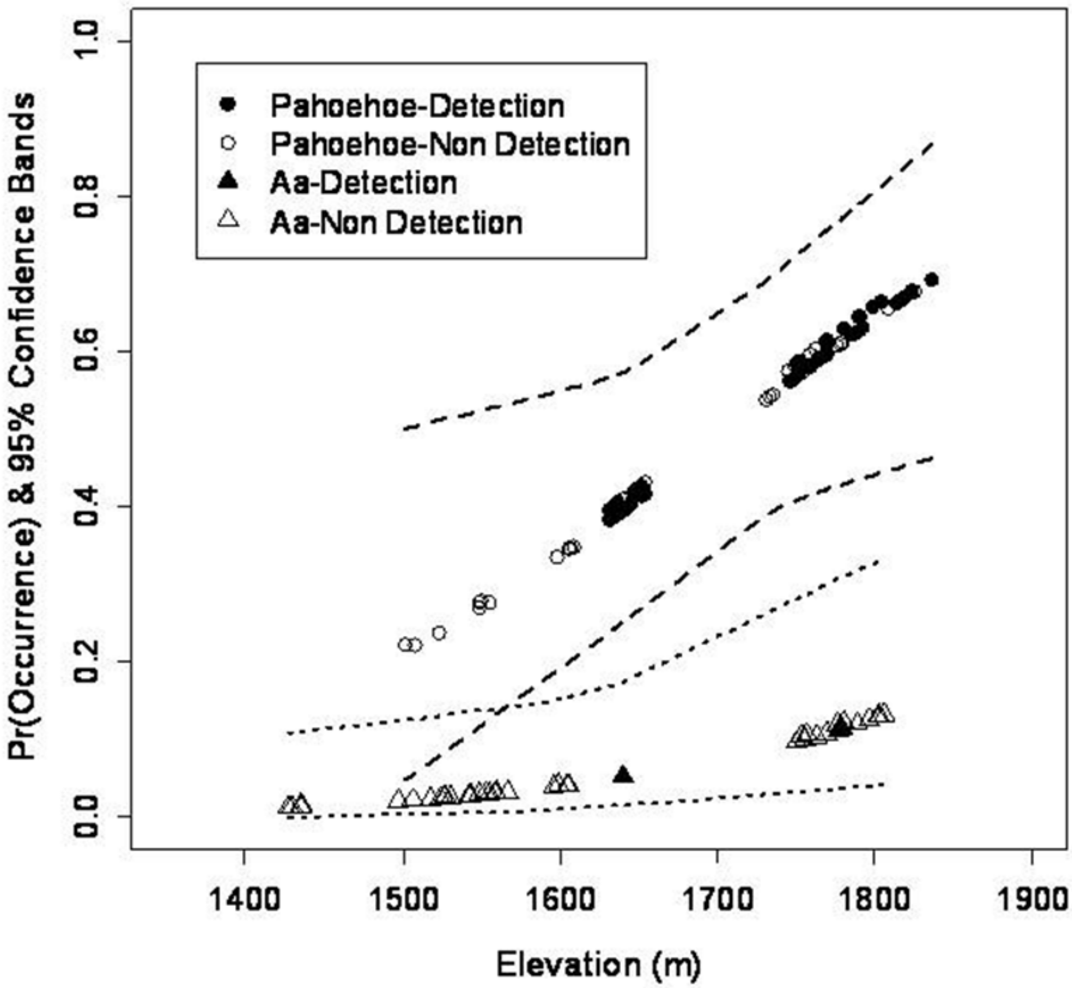


**Figure 8.** Modeled site occupancy probabilities (Ψ) and 95% confidence intervals for those estimated probabilities as they were observed along the CRMO elevational gradient. Probabilities were classed by lava type ("aa" and "pahoehoe", see glossary) and color coded by observed detection status. Data were obtained from the 2007-2009 pika inventory conducted by the UCBN (Rodhouse et al. 2010).

### *Change Detection and Trend Analysis*

Analysis and reporting of change detection will begin after 2 years of protocol implementation. Details are presented in SOP # 6. Simple graphical tools will be used to display changes in pika site occupancy over time. For example, a simple line graph of annual occupancy (Ψ) estimates can be effective, as is illustrated in Figure 9.


**Figure 9.** A simulated 25% decline in pika site occupancy over 20 years, with a stochastic component introduced by drawing from a binomial error distribution, provides a realistic illustration of how pika observation data may be presented over time. A locally-weighted scatterplot-smoothing line ("lowess" line) is also shown as a dashed line to provide a non-parametric estimate of trend.

Simple estimates of change in the proportion of sites occupied between any 2 years ("step trend") will be accomplished by comparing the two proportions, following an approach described by Ramsey and Schafer (1997) and which was employed in the Sample Size and Power Analysis section. Parameters that estimate the magnitude of change in occupancy patterns and dynamics over time will be estimated with multi-season hierarchical occupancy models, which will support estimates both within and among parks, following methods outlined by MacKenzie et al. (2006) and Royle and Dorazio (2008). For example, our basic logistic regression model takes the form

$$\hat{\Psi}_{itk} = \frac{\exp(\beta_{0_{ik}} + \beta_{1_k} * elevation + \beta_{2_{ik}} * year_t)}{1 + \exp(\beta_{0_{ik}} + \beta_{1_k} * elevation + \beta_{2_{ik}} * year_t)},$$

where *i* indexes the site, *t* indexes year, and *k* indexes the park. Here the estimated trend for the occupancy parameter Ψ will be allowed to vary linearly along the elevational gradient and among parks. This model can be decomposed into several hierarchical levels which address the probability distribution of possible values for each observation (i.e., “occupied” or “unoccupied”), and for each parameter estimate (β), which are themselves composed of park-specific and overall probability distributions, enabling estimates of regional and park-specific trends. Figure 10 illustrates graphically how this scenario might actually be presented in the future. Referring to the model above, each of these trends would be estimated from the back-transformed (“exponentiated”) $\beta_2$ parameter estimates, interpreted as the annual effect on site occupancy probabilities, after accounting for elevation.

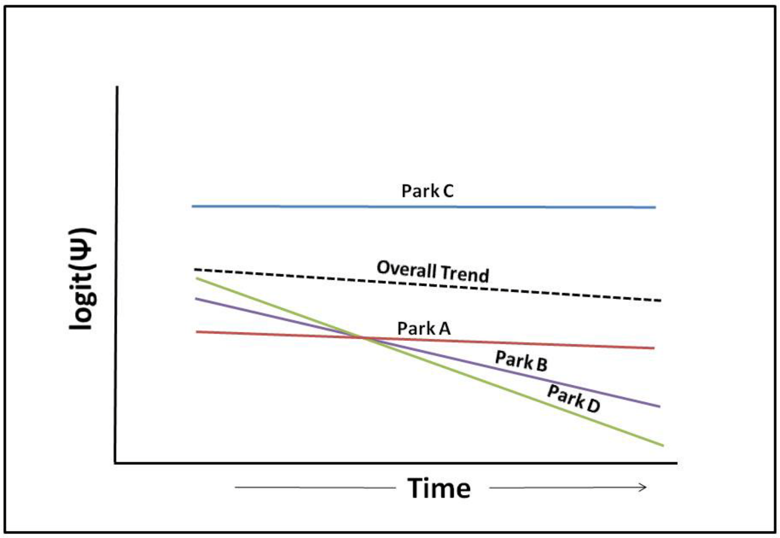


**Figure 10.** A hypothetical hierarchy of trend estimates in the proportion of sites occupied by pikas within and among parks.

Additional parameters of interest will also be estimated from occupancy models, following methods described by MacKenzie et al. (2006) and Royle and Dorazio (2008). In particular, the occupancy dynamics parameters for turnover (local site extinction and site recolonization) will become estimable after 3 years of data have been collected. These parameters will be estimated within the context of covariate effects in the same logistic regression framework as was presented for occupancy. Local extinction is defined as the probability that a site previously occupied becomes unoccupied. Conversely, colonization is the probability that a site previously unoccupied becomes occupied. These parameters estimate occupancy state “transitions”, and will provide insights into the occupancy dynamics occurring within and among parks over time. Site turnover itself, defined as the probability that an occupied site is a newly occupied site, can also be recursively derived from occupancy model output, as was shown by Nichols et al. (1998) and Royle and Dorazio (2008). Note that this “explicit-dynamics” multi-season occupancy model assumes a first-order Markovian relationship between site occupancy and time, rather than as a linear trend as presented in the previous equation. Given the year-to-year turnover reported for pikas (Southwick et al. 1986, Peacock and Smith 1997, Rodhouse et al. 2010), this may be a more appropriate model to describe occupancy dynamics, at least during the first few years of monitoring before long-term trends emerge. Additional details on how these parameters are estimated are presented in SOP # 6.

## Reporting

A summary report for each park will be produced by that park's Project Lead after each year of data collection, with a more detailed status and trend report produced every 5 years. The annual report will:

- List project personnel and their roles.
- Provide a summary history of the surveys conducted during each year of the study, tabulating survey numbers for each sampling frame and showing these locations on maps of the parks.
- Provide summary status statistics and interpretation of the results.
- Evaluate data quality and identify any data quality concerns and/or deviations from protocols that affect data quality and interpretability.
- Evaluate and identify suggested or required changes to the protocol.

An annual report should be produced by the park's Project Lead every fall after completion of the field surveys. A 1-2 page resource brief should also be prepared from this annual report that will be provided to superintendents, park interpretive staff, and resource managers. A template for the resource brief is included in SOP # 6. An NPS template for producing maps with ESRI ArcGIS or ArcView software is available at http://imgis.nps.gov/templates.html.

A more in-depth trend report will be produced by the Project Lead every 5 years. This report will provide greater analytical and interpretive detail, and will evaluate the relevance of findings to long-term management. The report will also evaluate operational aspects of the monitoring program, such as whether sample frame boundaries need to be changed or whether the sampling period remains appropriate (the optimal sampling season could conceivably change over time in response to climate change). The report will also evaluate the monitoring protocol. For instance, does it appear that detectability is lower than expected and should repeat surveys be conducted, are there new management concerns that might dictate some reallocation of effort or additions to the indicator metrics that are routinely examined annually, is the sampling time still appropriate, etc.

Annual reports will use the NPS Natural Resource Publications Natural Resource Data Series (NRDS) template and 5-year analyses of status and trend will use the Natural Resource Technical Report (NRTR) template; both are pre-formatted Microsoft Word template documents based on current NPS formatting standards. Template guidelines and documentation of the NPS publication standards are available at the following address: http://www.nature.nps.gov/publications/NRPM/index.cfm.
Current versions of the protocol, resource briefs, and annual and 5-year technical reports will be made available on the UCBN website (http://science.nature.nps.gov/im/units/UCBN/index.cfm) and/or the individual park websites. The protocol and published technical reports will also be available from the national NRPM website (http://www.nature.nps.gov/publications/nrpm/nrr.cfm). All NPS protocols are available from (http://science.nature.nps.gov/im/monitor/protocoldb.cfm).

## Data Archival Procedures

Paper data sheets will be stored by the UCBN for CRMO and park staff for CRLA, LABE, and LAVO to facilitate resolution of any QA/QC issues that may be discovered in the master database. After 5 years, the paper data sheets will be transferred to the appropriate park or regional museum staff for official archiving. The UCBN will maintain the master database for all four parks as the official record of protocol data, following procedures established in the UCBN Data Management Plan (Dicus and Garrett 2007) to ensure the master database is properly archived and remains compatible with applicable software.

Once the annual data certification has been completed, the Pika database and related reports will be archived on the UCBN and/or park server, posted to the UCBN and/or park website, and posted to the national web-accessible secure Natural Resource Information Portal (NRInfo) application hosted by the NPS Washington Areas Support Office (WASO) or National I&M program. The NRInfo application incorporates functionality previously handled by separate databases into a single web interface that comprises:

- The master database for natural resource bibliographic references
- The master database for biodiversity information including species occurrences and physical or written evidence for the occurrence (i.e., references, vouchers, observations)
- A centralized data repository with a graphical search interface

Resource management staff from CRLA, LABE, and LAVO will be responsible for following data archival procedures described for each individual park unit.

## Protocol Testing and Revisions

Data was collected in all parks in 2010 and will continue in 2011 using the draft version 1.0 of this protocol. Updated methods and data management strategies, including revised data forms, will be implemented during this time. Over time, revisions to both the protocol narrative and specific SOPs are expected. Careful documentation of any changes to the protocol and a library of previous protocol versions are essential for maintaining consistency in data collection and for appropriate summary analyses. The database for each monitoring component will contain a field that identifies which version of the protocol was used when the data were collected. The parks plan to work with the UCBN on any revisions to the protocol or database.

The protocol narrative is a general overview of the protocol that gives the history and justification for doing the work and an overview of the sampling methods, but that does not provide the methodological details. The protocol narrative will only be revised if major changes are made to the protocol.

The SOPs, in contrast, are specific, step-by-step instructions for performing tasks. They are expected to be revised more frequently. It will only rarely be necessary to revise the protocol narrative to reflect specific changes in an SOP. All versions of the protocol and SOPs will be archived in a pika project digital library on the network or park servers or other storage hardware such that the files are regularly backed up and secure. Current versions will be available through the UCBN website and other network or park websites as appropriate and through the national I&M protocol database. Resource management staff from CRLA, LABE, and LAVO will be responsible for following data archival procedures described for each individual park unit.

The steps for changing the protocol (either the narrative or an SOP) are given in SOP # 9, “Revising the Protocol”. Each SOP contains a change log that should be filled out each time an SOP is revised to explain why the change was made and to assign a new version number to the revised SOP. The new version of the SOP or Protocol Narrative should be archived in the project library under the appropriate folder. A revision history log in SOP # 9 will also document revisions over time.

# Personnel Requirements and Training

## Personnel Requirements

This monitoring project requires leadership from a Project Lead and a Data Manager (one person may serve both roles) for each park. Two field surveyors per park (could include Project Lead and Data Manager) are required to complete this protocol but additional surveyors would be useful to accomplish more surveys over a shorter-time period. The roles and responsibilities outlined in Table 2 can be provided by these individuals. However, additional assistance from park staff and/or volunteers will ease the annual workload generated by this effort and ensure a high quality information product.

The field team will consist of the Project Lead and any of the following: biological technicians, seasonal Student Conservation Association (SCA) interns, volunteers, or others wishing to participate after receiving proper training. Field assistants must be able to work outdoors, learn GPS and data entry, and identify pikas and their sign. During several years of pilot work conducted during the development of this protocol, we successfully trained and utilized SCA's and citizen scientists to collect field data. A capable Project Lead for each park is required and will train the surveyors, oversee their work, and verify, summarize, analyze, and interpret data each year. The Project Lead may also serve in other roles, such as part of the field team or Data Manager. Table 2 provides a general outline for the roles and responsibilities of personnel involved in this monitoring protocol. The Data Manager must be able to handle the described GPS/GIS and database tasks. The Project Lead and/or Data Manager must be able to conduct the described annual summaries, power analyses, and trend analyses.

Experience during the surveys at CRMO provided a good estimate of staff time required for field sampling. In 2007, observers averaged 8 surveys/day. Therefore, 2 surveyors (1 team) completing approximately 8 surveys per day (40 per week) will enable the completion of protocol objectives for 1 park each year. Giving our sample size of 100, this protocol requires at least two field surveyors be able to devote approximately 4 weeks per park specifically to field surveys. This number provides ample time to accommodate travel, foul weather, and unanticipated contingencies.

## Roles and Responsibilities

**Table 2.** Roles and responsibilities for implementing the pika monitoring program.

| Role | Responsibilities | Name / Position |
|---|---|---|
| Project Lead (one for each park) | • Project oversight and administration<br>  o Track project objectives, budget, requirements, and progress toward meeting objectives<br>• Coordinate and ratify changes to protocol<br>• Plan and execute field surveys<br>  o Train field team<br>  o Acquired and maintain field equipment<br>• Work with Data Manager to:<br>  o Oversee data collection and entry<br>  o Perform data summaries and analyses<br>  o Complete reports, metadata, and other products according to schedule | CRLA: Terrestrial Ecologist/Wildlife Biologist<br>CRMO: UCBN Research Associate<br>LABE: Chief of Resources<br>LAVO: Wildlife Biologist |
| Field Technicians | • Collect, record, enter and verify data | CRLA: Biological technicians<br>CRMO: UCBN seasonal technicians<br>LABE: Biological technicians and/or SCA interns<br>LAVO: Biological technicians |
| Data Manager | • Consult on data management activities<br>• Consult on GPS use<br>• Maintain and archive project records<br>  o Access database<br>  o GIS data<br>• Certify each season's data for quality and completeness<br>• Work with Project Lead to:<br>  o Oversee data collection and entry<br>  o Perform data summaries and analyses<br>  o Complete reports, metadata, and other products according to schedule | CRLA: Project Lead and/or designated field technician<br>CRMO: UCBN Data Manager<br>LABE: Project Lead and/or designated field technician<br>LAVO: Project Lead and/or designated field technician |

## Qualifications, Training and Collaboration

All surveyors for a park should train together. At the start of each field season, the Project Lead should schedule a training day where he/she can calibrate procedures across surveyors in the field. Each surveyor will practice locating, establishing and surveying a site. An easily accessible training site (located away from any actual survey locations) where pika sign is likely to be found should be identified before training. Surveyors should be exposed to pikas and pika sign in a variety of locations in order to develop a proper "search image". Training should also include time to calibrate surveyor measurements of habitat, such as vegetation cover, and other ancillary variables.

# Operational Requirements

## Annual Workload and Schedule

The annual workload of this monitoring program is outlined in Table 2 of the preceding section on Roles and Responsibilities. Table 3 provides a good overview of the general roles and tasks (responsibilities) required to complete all aspects of this program following rigorous and comprehensive information management practices, such as those outlined in the UCBN Data Management Plan (Dicus and Garrett 2007). The budget in Table 5 demonstrates that adequate resources have been allocated to data management, analysis, and reporting activities. The SOPs provided a comprehensive step-by-step description of the annual workload and tasks required for completion, including data management tasks and product delivery. The annual round for pika monitoring begins with field planning in January. At this time, final reporting, review and close-out activities are proceeding for the previous year. An evaluation of the protocol and any necessary changes must be made by April. Field work many start as early as July and as late as October (before snowfall), and data entry and QA/QC procedures should begin immediately after field data collection. Table 3 provides additional details of the annual schedule.

**Table 3**. Annual schedule of major tasks and events for the pika monitoring protocol.

| Month | Administration | Field | Data Management/Reporting |
|---|---|---|---|
| January | Begin recruiting and hiring seasonal personnel (if necessary) | Begin recruiting volunteers and scheduling field surveys (i.e., housing and vehicles) | |
| February-July | | Prepare maps, field data sheets, and GPS equipment, provide GPS and other training to staff | |
| July-October | | Conduct training first and then field surveys | Data entry and verification, metadata production, quality review (following field surveys) |
| October-November | | Field season report complete | Preliminary analysis of current year's results, prepare annual resource brief, data certification complete, data archival and posting |
| December-January | | | Analysis, reporting, and close-out |

### *Partnerships*

The ideas and methods in this protocol are being shared, considered for implementation, and adopted by other researchers and programs such as the Greater Yellowstone Network, Rocky Mountain Network, Grand Teton National Park, University of Idaho, Oregon State University, University of Colorado - Boulder, the North American Pika Consortium, and the California Pika Consortium. Some partnerships are through formal Cooperative Ecosystem Studies Unit (CESU) agreements but most focus primarily on data and information sharing (i.e., no funds exchanged). Additionally, the protocol has provided the core methods being used in a 3-year study of pika distribution, population connectivity, and climate change vulnerability in eight park units across the West, currently concluding its first year of implementation. The project, entitled "Pikas in Peril", involves multiple agency and university partners listed previously.

## Equipment Needs

This protocol required only a modest set of equipment which will be provided by the individual parks for CRLA, LABE, and LAVO and by the UCBN for CRMO (Table 4; a more detailed list is provided in SOP # 1). GPS units need to be maintained and replaced, if necessary, during the late winter/early spring well in advance of the field season. Vehicles for travel to and from survey locations need to be secured in January/February and housing for technicians (if necessary) should also be reserved at this time.

**Table 4**. Equipment required for pika sampling. Items in italics are not necessary but suggested and may have to be supplied by the observers rather than the park or UCBN.

| **Equipment** |
|---|
| GPS units |
| Compasses |
| Clipboards and data sheets (incl. extras) |
| GPS unit batteries |
| Mechanical pencils |
| First aid kits |
| Hard copies of SOPs and necessary maps |
| 2-way radios |
| Flashlights |
| Site markers and marking supplies |
| Digital camera |
| Leather gloves |
| *Water bottle, sun, and rain protection* |
| *Day packs* |

## Budget

An example budget for annual protocol implementation for a single park is presented in Table 5. Equipment costs have been excluded from this budget as most of the items are non-recurring expenses.

**Table 5.** Estimated annual budget for pika monitoring implementation in one park.

| UCBN Pika Monitoring Budget | Time allotted | % of time spent on DM* | Cost in dollars DM* | Cost in Dollars (2010) |
|---|---|---|---|---|
| *Personnel* | | | | |
| Project Lead (GS 11) | 1 week prep for field surveys, 2 weeks for field surveys (supervising), and 1 week data analysis, reporting, and close-out | 25% | $1,400 | $5,600 |
| Data Manager (GS11) | 1 week database management and archiving | 100% | $1,700 | $1,700 |
| BioTech (GS-5 STEP 1) 2 positions needed | 1 week for training, 4 weeks for field surveys, and 1 week wrap-up, data input and QA/QC | 25% | $2,400 | $9,600 (or less if interns are used) |
| *Vehicle* | | | | |
| GSA vehicle | 1 month | - | - | $500 |
| TOTAL | | | $5,500** | $16,900 |

*DM = Data management

**More than 32% of the pika protocol budget is dedicated to data management, analysis, and reporting activities.

## Literature Cited

Andrewartha, H. G., and L. C. Birch. 1954. The distribution and abundance of animals. The University of Chicago Press, Chicago, IL.

Beever, E. A., C. Ray, P. W. Mote, and J. L. Wilkening. 2010. Testing alternative models of climate-mediated extirpations. Ecological Applications 20:164-178.

Beever, E. A., J. L. Wilkening, D. E. McIvor, S. S. Weber, and P. F. Brussard. 2008. American pikas (*Ochotona princeps*) in northwestern Nevada: a newly discovered population at a low-elevation site. Western North American Naturalist 68:8-14.

Beever, E. A., P. E. Brussard, and J. Berger. 2003. Patterns of apparent extirpation among isolated populations of pikas (*Ochotona princeps*) in the Great Basin. Journal of Mammalogy 84:37-54.

Bell, J., D. Cogan, J. Erixson, and J. Von Loh. 2009. Vegetation inventory project report, Craters of the Moon National Monument and Preserve. Natural Resource Technical Report NPS/UCBN/NRTR-2009/277. National Park Service, Fort Collins, CO.

British Columbia Resources Inventory Committee. 1998. Inventory methods for pikas and sciurids. Standards for Components of British Columbia’s Biodiversity No. 29. Version 2.0.

Conner, D. A. 1983. Seasonal changes in activity patterns and the adaptive value of haying in pikas (*Ochotona princeps*). Canadian Journal of Zoology 61:411-416.

Craighead, A. *unpublished report*. Utilizing habitat suitability models to predict the effects of global climate change on three different species of pika (family Ochotonidae). Final report to Alcoa Foundation (2008).

Dicus, G. H., and L. K. Garrett. 2008. Upper Columbia Basin Network data management plan. Natural Resource Report NPS/UCBN/NRR-2007/020. National Park Service, Ft. Collins, CO.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Appendix 12 *in* Measuring and Monitoring Plant Populations. US Department of Interior, Bureau of Land Management, Denver, CO.

Galbreath, K. E., D. J. Hafner, and K. Zamudio. 2009. When cold is better: climate-driven elevation shifts yield complex patterns of diversification and demography in an alpine specialist (American pika, *Ochotona princeps*). Evolution 63:2848-2863.

Garrett, L. K., T. J. Rodhouse, G. H. Dicus, C. C. Caudill, and M. R. Shardlow. 2007. Upper Columbia Basin Network vital signs monitoring plan. Natural Resource Report NPS/UCBN/NRR—2007/002. National Park Service, Fort Collins, CO.

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. The American Naturalist 51:115-128.

Hafner, D. J. 1993. North American pika (*Ochotona princeps*) as a late Quaternary biogeographic indicator species. Quaternary Research 39:373–380.

Hafner, D. J. 1994. Pikas and permafrost: Post-Wisconsin zoogeography of *Ochotona* in the southern Rocky Mountains, USA. Arctic and Alpine Research 26:375–382.

Hafner, D. J., and R. M. Sullivan 1995. Historical and ecological biogeography of nearctic pikas (Lagomorpha: Ochotonidae). Journal of Mammalogy 76:302-321.

Hafner, D. J., and A. T. Smith. 2010. Revision of the subspecies of the American pika, *Ochotona princeps* (Lagomorpha: Ochotonidae). Journal of Mammalogy 91:401-417.

Hall, E. R. 1981. The mammals of North America. John Wiley & Sons, New York, NY.

Hobbs, R. J., D. N. Cole, L. Yung, E. S. Zavaleta, G. H. Aplet, F. S. Chapin III, P. B. Landres, D. J. Parsons, N. L. Stephenson, P. S. White, and others. 2010. Guiding concepts for park and wilderness stewardship in an era of global environmental change. Frontiers in Ecology and the Environment 8:483-490.

Huntly, N. J., A. T. Smith, and B. L. Ivins. 1986. Foraging behavior of the pika (*Ochotona princeps*), with comparisons of grazing versus haying. Journal of Mammalogy 67:139-148.

Irwin, R. J. 2006. Draft park B lite (just the basics) QA/QC review checklist for aquatic vital sign monitoring protocols and SOPs. National Park Service, Water Resources Division. Fort Collins, CO. Online. (http://www.nature.nps.gov/water/Vital_Signs_Guidance/Guidance_Documents/PartBLite.pdf).

Jeffress, M. R., M. Britten, C. W. Epps, L. K. Garrett, C. Ray, S. Wolff. *unpublished report*. Pikas in peril: Multi-regional vulnerability assessment of a climate-sensitive sentinel species. Project accomplishment report to NPS Climate Change Response Program (2010).

Johnson, D. R. 1967. Diet and reproduction of Colorado pikas (genus *Ochotona*). Journal of Mammalogy 48:311-315.

Karl, T., T. Peterson, J. Melillo, and S. J. Hassol. 2009. Global climate change impacts in the United States. Cambridge University Press.

Kawamichi, T. 1976. Hay territory and dominance rank of pikas (*Ochotona princeps*). Journal of Mammalogy 57:133-148.

Körner, C. 2007. The use of 'altitude' in ecological research. Trends in Ecology and Evolution 22:569-574.

Krajick, K. 2004. All down hill from here? Science 303:1600-1602.

Krebs, C. J. 2001. Ecology: The experimental analysis of distribution and abundance. 5th edition. Benjamin Cummings, Menlo Park, CA.

Lawlor, T. E. 1998. Biogeography of Great Basin mammals: Paradigm lost? Journal of Mammalogy 79:1111-1130.

Loarie, S. R., C. B. Field, C. Ray, E. A. Beever, P. B. Duffy, K. Hayhoe, J. L. Wilkening and J. S. Clark. *in press*. Climate threats to the American pika: modeling historical persistence for 21st century projections. Proceedings of the National Academy of Sciences.

MacArthur, R. A., and L. C. H. Wang. 1973. Physiology of thermoregulation in the pika, *Ochotona princeps*. Canadian Journal of Zoology 51:11-16.

MacArthur, R. A., and L. C. H. Wang. 1974. Behavioral thermoregulation in the pika *Ochotona princeps*: a field study using radiotelemetry. Canadian Journal of Zoology 52:353-358.

MacKenzie, D. I. 2006. Modeling the probability of resource use: The effect of, and dealing with, detecting a species imperfectly. Journal of Wildlife Management 70:367-374.

MacKenzie, D. I., and J. A. Royle. 2005. Designing occupancy studies: general advice and allocating survey effort. Journal of Applied Ecology 42:1105-1114.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2006. Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. Elsevier, London, England.

McDonald, K. A., and J. J. Brown. 1992. Using montane mammals to model extinctions due to global change. Conservation Biology 6:409-415.

McKinney, S. T, T. Rodhouse, L. Chow, G. Dicus, L. Garrett, K. Irvine, S. Mohren, D. Odion, D. Sarr, and L. A. Starcevich. *in review*. Monitoring white pine (*Pinus albicaulis, P. balfouriana, P. flexilis*) population dynamics in the Pacific West Region: Klamath, Sierra Nevada, and Upper Columbia Basin Networks. Narrative version 1.0. Natural Resource Report NPS/PWR/NRR-2011/XXX. National Park Service, Fort Collins, CO.

Millar, C. I., and R. D. Westfall. 2010. Distribution and climatic relationships of the American pika (*Ochotona princeps*) in the Sierra Nevada and Western Great Basin, U.S.A.; Periglacial landforms as refugia in warming climates. Arctic, Antarctic, and Alpine Research 42:76-88.

Millar, J. S. 1972. Timing of breeding of pikas in southwestern Alberta. Canadian Journal of Zoology 50:665-669.

Millar, J. S. 1973. Evolution of litter size in the pika, *Ochotona princeps* (Richardson). Evolution 27:134-143.

Millar, J. S. 1974. Success of reproduction in pikas, *Ochotona princeps* (Richardson). Journal of Mammalogy 55:527-542.

Moilanen, A., A. T. Smith, and I. Hanski. 1998. Long-term dynamics in a metapopulation of the American pika. The American Naturalist 152:530-542.

Moritz, C., J. L. Patton, C. J. Conroy, J. L. Parra, G. C. White, and S. R. Beissinger. 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, USA. Science 322:261-264.

Morrison, L. W. 2007. Assessing the reliability of ecological monitoring data: Power analysis and alternative approaches. Natural Areas Journal 27:83-91.

Morrison, S. F., and D. S. Hik. 2007. Demographic analysis of a declining pika *Ochotona collaris* population: Linking survival to broad-scale climate patterns via spring snowmelt patterns. Journal of Animal Ecology 76:899-907.

Morrison, S. F., and D. S. Hik. 2008. When? Where? And for how long? Census design considerations for an alpine lagomorph, the collared pika (*Ochotona collaris*). Pages 103-113 *in* P. C. Alves, N. Ferrand, and K. Hacklander, editors. Lagomorph biology: Evolution, ecology, and conservation. Springer-Verlag, Berlin.

Mote, P. W., A. F. Hamlet, M. P. Clark, and D. P. Lettenmaier. 2005. Declining mountain snowpack in western North America. Bulletin of the American Meteorological Society 86:39-49.

Murray, M. 2010. Will whitebark pine not fade away? Insight from Crater Lake National Park. Park Science 27:64-67.

National Park Service. 1999. Natural resource challenge: the National Park Service's action plan for preserving natural resources. US Department of the Interior National Park Service, Washington D.C. Online. (http://www.nature.nps.gov/challengedoc.html).

Nichols, J. D., T. Boulinier, J. E. Hines, K. H. Pollock, and J. R. Sauer. 1998. Estimating rates of local species extinction, colonization, and turnover in animal communities. Ecological Applications 8:1213-1225.

Oakley, K. L., L. P. Thomas, and S. G. Fancy. 2003. Guidelines for long-term monitoring protocols. Wildlife Society Bulletin 31:1000-1003.

Owen, D. 2008. Geology of Craters of the Moon. Craters of the Moon Natural History Association. Online. (http://www.nps.gov/crmo/naturescience/upload/2008%20Geo-Long.pdf).

Peacock, M. M., and A. T. Smith. 1997. The effect of habitat fragmentation on dispersal patterns, mating behavior, and genetic variation in a pika (*Ochotona princeps*) metapopulation. Oecologia 112:524-533.

Ramsey, F. L., and D. W. Schafer. 1997. The statistical sleuth: A course in methods of data analysis. Duxbury Press, New York, NY.

Ray, C., and E. Beever. *unpublished report*. Distribution and abundance of the American pika (*Ochotona princeps*) within Lava Beds National Monument. Report to NPS (2007).

Rodhouse, T. J., E. A. Beever, L. K. Garrett, K. M. Irvine, M. R. Jeffress, M. Munts, and C. Ray. 2010. Distribution of American pikas in a low-elevation lava landscape: Conservation implications from the range periphery. Journal of Mammalogy 91:1287-1299.

Royle, J. A, J. D. Nichols, and M. Kery. 2005. Modelling occurrence and abundance of species when detection is imperfect. Oikos 110:353-359.

Royle, J. A., and R. M. Dorazio. 2008. Hierarchical modeling and inference in ecology: The analysis of data from populations, metapopulations and communities. Academic Press, San Diego, CA.

Simpson, W. G. 2009. American pikas inhabit low-elevation sites outside the species' previously described bioclimatic envelope. Western North American Naturalist 69:243-250.

Smith, A. T. 1974. The distribution and dispersal of pikas: Influences of behavior and climate. Ecology 55:1368-1376.

Smith, A. T. 1978. Comparative demography of pikas (Ochotona): Effect of spatial and temporal age-specific mortality. Ecology 59:133-139.

Smith, A. T. 1987. Population structure of pikas: dispersal versus philopatry. Pages 128-142 *in* B. D. Chepko-Sade, and Z. T. Halpin, editors. Mammalian dispersal patterns: The effects of social structure on population genetics. The University of Chicago Press, Chicago, IL.

Smith, A. T., and B. L. Ivins. 1983. Colonization in a pika population: Dispersal vs philopatry. Behavioral Ecology and Sociobiology 13:37-47.

Smith, A. T., and B. L. Ivins. 1984. Spatial relationships and social organization in adult pikas: A facultatively monogamous mammal. Z. Tierpsychol. 66:289-308.

Smith, A. T., and B. L. Ivins. 1986. Territorial intrusions by pikas (*Ochotona princeps*) as a function of occupant activity. Animal Behaviour 34:392-397.

Smith, A. T., and M. Gilpin. 1997. Spatially correlated dynamics in a pika metapopulation. Pages 407-428 *in* Metapopulation biology: Ecology, genetics, and evolution. Hanski, I. A., and M. E. Gilpin, editors. Academic Press.

Smith, A. T., and M. L. Weston. 1990. Ochotona princeps. Mammalian Species 352:1-8.

Smith, A. T., W. Li, and D. Hik. 2004. Pikas as harbingers of global warming. Species 41:4-5.

Southwick, C. H., S. C. Golian, M. R. Whitworth, J. C. Halfpenny, and R. Brown. 1986. Population density and fluctuations of pikas (*Ochotona princeps*) in Colorado. Journal of Mammalogy 67:149-153.

Stevens, D. L., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. EnvironMetrics 14:593-610.

Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99: 262–278.

Svendsen, G. E. 1979. Territoriality and behavior in a population of pikas (*Ochotona princeps*). Journal of Mammalogy 60:324-330.

Theobald, D. M., D. L. Stevens, Jr., D. White, N. S. Urquhart, A. R. Olsen, and J. B. Norman. 2007. Using GIS to generate spatially balanced random survey designs for natural resource applications. Journal of Environmental Management 40:134-146.

Thompson, W. L. 2002. Towards reliable bird surveys: Accounting for individuals present but not detected. The Auk 119:18-25.

U.S. Fish and Wildlife Service. 2009. 90-Day finding on a petition to list the American pika as threatened or endangered with critical habitat. Federal Register 74:21301-21310.

U.S. Fish and Wildlife Service. 2010. 12-month finding on a petition to list the American pika as threatened or endangered. Federal Register 75:6438-6471.

Wagner, F. H., R. Angell, M. Hahn, T. Lawlor, R. Tausch, and D. Toweill. 2003. Natural ecosystems III. The Great Basin. Pages 207-240 *in* F. H. Wagner, editor. Rocky Mountain/Great Basin regional climate-change assessment. Report for the US global change research program. Utah State University, Logan, UT.

Yeo, J. J., T. J. Rodhouse, G. H. Dicus, K. M. Irvine, and L. K. Garrett. 2009. Sagebrush steppe vegetation monitoring protocol. Upper Columbia Basin Network. Version 1.0. Natural Resource Report NPS/UCBN/NRR—2009/142. National Park Service, Fort Collins, CO.

## Glossary of Terms

**Detectability** refers to the possibility that even if a species is present at a survey site, it may not always be detected. The **detection probability** is the probability of detecting a species at a site, given it is present.

**Lava** is rock that in its molten form came from volcanoes and is described by its physical appearance which can affected by its composition, temperature, fluid and crystal content, and the surface and slope it encounters. **Aa** lava is basalt rock that has a "rough, jagged, or clinker surface" while **pahoehoe** lava is basalt rock that has a "smooth, ropy, or billowy surface" (Owen 2008). These lava types form differently and have different structural attributes that may influence pika habitat use and occupancy patterns.

**Local site colonization** refers to a previously unoccupied site changing state to become occupied by at least one individual of a species. Local site colonization is one of two key occupancy dynamics parameters that can be estimated in terms of the probability that a previously unoccupied site will become occupied, notated as $\gamma$. For our purposes, a site is defined as a randomly-selected 12-m radius circular plot in potential pika habitat.

**Local site extinction** refers to the loss of all individuals from a site, such that the site is no longer occupied. Site extinction is frequently qualified as "local" extinction to differentiate from global extinction of a species. Local site extinction is one of two key occupancy dynamics parameters that can be estimated in terms of the probability that a previously occupied site will become extinct, notated as $\varepsilon$. For our purposes, a site is defined as a randomly-selected 12-m radius circular plot in potential pika habitat.

**Occupancy ($\Psi$)** is the probability that a randomly selected site or sampling unit in an area of interest is occupied by a species (i.e., the site contains at least one individual of the species; MacKenzie et al. 2006). For our purposed, we define an **occupied site** (12-m radius circular plot) as a site where pikas (visual or aural) and/or fresh pika sign (scat or haypile) are detected. Also, occupancy can refer to the proportion of sites within a sample that are occupied, and which is used as an estimate of $\Psi$ when no site covariates are included that otherwise adjust site occupancy probabilities.

**Power analysis**: The **power** of a statistical test is the probability that the test will reject a false null hypothesis, or in other words that it will not make a Type II error. As power increases, the chances of a Type II error decrease, and vice versa. The probability of a Type II error is referred to as $\beta$. Therefore power is equal to $1 - \beta$. Power is a function of effect size or minimum detectable change, variance of the parameter (e.g. standard error of the mean), and sample size. A power analysis determines the probability of correctly rejecting a false null hypothesis given fixed values of effect size, variance, and sample size.

**Site turnover** refers to a change in site occupancy state from one season to the next. Site turnover is a reflection of both local site extinction and local site colonization.

**Status** is a measure of a current attribute, condition, or state, and is typically measured with population means.

**Talus** is rock debris often found at the base of a cliff or slope. Talus can have different particle sizes, which may influence pika habitat use and occupancy patterns.

**Temporal variation** is variation in a population parameter, such as mean, over time. For our purposes this typically refers to variation seasonally or annual.

**Trend** is a measure of directional change over time and can occur in some population parameter, such as a mean (net trend), or in an individual member or unit of a population (gross trend).

**Vital Signs** are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

# Appendix. Index of Standard Operating Procedures

**(Bound as a separate document)**

SOP 1: Preparation for the Field Season
SOP 2: Training Observers
SOP 3: Finding GPS Waypoints
SOP 4: Locating, Establishing, and Surveying Sites
SOP 5: Data Management
SOP 6: Data Summary, Analysis, and Reporting
SOP 7: Field Safety
SOP 8: Field Reference Manual
SOP 9: Revising the Protocol

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS XXXXXX, January 2011

**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Program Center**
1201 Oakridge Drive, Suite 150
Fort Collins, CO 80525

www.nature.nps.gov

**EXPERIENCE YOUR AMERICA** ™