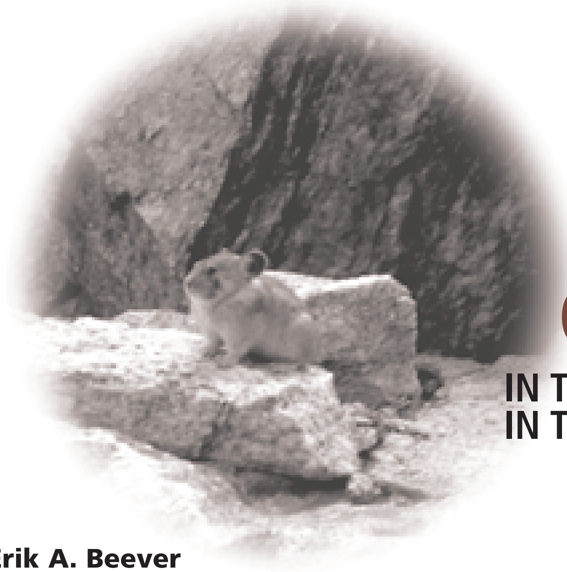

Persistence of Pikas

In Two Low-Elevation National Monuments in the Western United States

By Erik A. Beever

From the perspective of island biogeography (MacArthur and Wilson 1967), national parks act as island reserves of restricted management sprinkled within a matrix dominated by commodity production and other human uses. Nonetheless, recent research has highlighted the dramatic changes (e.g., local extirpations, invasions of exotic species) that can occur in flora and fauna even on lands where the primary management mandate is resource conservation (Svejcar and Tausch 1991, Newmark 1995). The legacy of past disturbances, influences from adjacent lands, and climate change, in addition to the isolation and relatively small size of park units may all affect persistence of species within parks. In the western United States, pikas *(Ochotona princeps)* represent a model system that may help ecologists to understand these timely and complex relationships, as well as their implications for management in at least two units of the National Park System.

RELICTS OF A COOLER TIME

Pikas are small (100-175 g [4-6 oz]) mammals typically found in talus and other rocky habitats such as lava formations and mine tailings (fig. 1). Paleoecological evidence suggests that pikas were far more widespread during the late Pleistocene in western North America than they are today (Grayson 1987). Climatic warming during the past 10,000 years led to the extirpation of most low-elevation pika populations, producing the modern-day relictual distribution of the species. In the intermountain West currently pikas generally inhabit high-elevation areas and are considered montane mammals. However, temperature appears to limit their distribution more than elevation per se (Hafner 1993). For example, high temperatures (25.5-29.4°C [47.9-54.9°F] ambient shade temperature) can be lethal to pikas in as little as six hours, if they are caged on the surface of talus and thus deprived of their behavioral mechanisms to avoid stressful temperatures (Smith 1974). Consequently, pikas may be early sentinels of biological response to global climate change such as increased temperatures, although to date little fieldwork has been done on response of terrestrial vertebrates to climatic changes. Pikas' vulnerability to high temperatures partly results from the thick fur that insulates them against severe cold, because it also inhibits evaporative cooling during warm periods. A mystery remains, however, in whether acute (i.e., short-term) thermal stress, from high maximum temperatures, or chronic thermal stress over a pika's lifetime (resulting from living in hotter, drier climates) most affects pika persistence. Furthermore, as is true for most mammals, we know little about how thermal stresses interact with other potential stresses to pika populations such as small habitat area, catastrophic fires, human disturbance, and livestock grazing.

"Climatic warming during the past 10,000 years led to the extirpation of most low-elevation pika populations...."

Figure 1. Often heard but not seen, pikas typically inhabit high-elevation talus slopes in the western United States. However, the unusual occurrence of low-elevation pika populations in two western U.S. national monuments prompted the author to investigate their persistence and to evaluate implications for management of the species.

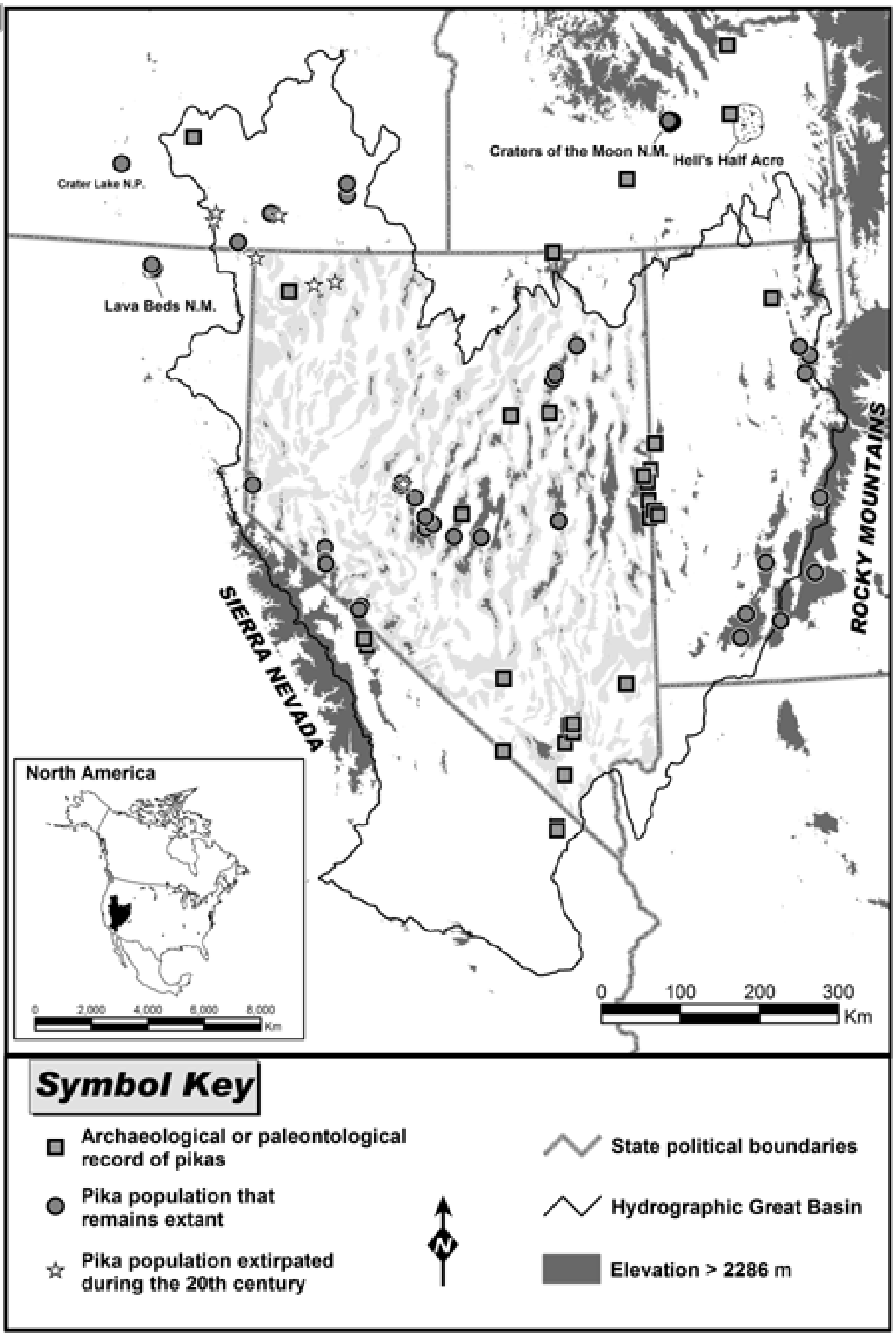

Figure 2. Pika surveys took place at 25 locations in the internally drained (interior) Great Basin; at Craters of the Moon and Lava Beds National Monuments where low-elevation populations of pikas persist; and at Hell's Half Acre, a low-elevation site near the monuments that lacks pikas but has similar habitat.

In the Great Basin (where precipitation drains internally rather than to an ocean; fig. 2), persistence of pika populations during the 20th century was significantly correlated with habitat area, elevation, longitude, distance to primary roads, latitude, grazing status, and management jurisdiction (wilderness vs. non-wilderness), but not with isolation of populations from the Sierra Nevada or Rocky Mountains (Beever 1999). Island biogeography theory predicts greater rates of extinction on islands (which may be oceanic or island-like pockets within continents) that are smaller in area and more isolated from the mainland, but does not make direct predictions about the other factors. Thus, the fact that isolation from Sierra Nevada or Rocky Mountain "mainlands" is not important in pika extirpations suggests that migration of pikas between mountaintop islands is not occurring currently. Rather, it appears that extirpation of populations from montane areas across the Great Basin is occurring without any concomitant colonization events. Average temperatures generally decrease with increasing latitude and elevation, thus latitude must be accounted for when assessing persistence at different elevations. Pikas at Craters of the Moon and Lava Beds National Monuments (hereafter, "Craters" and "Lava Beds") occurred historically at elevations lower than predicted by the monuments' latitude, when compared with the latitude-elevation relationship among historic pika sites in the Great Basin (fig. 3). Pikas do not usually persist at low elevations (and consequently, high temperatures), and many of the lowest-elevation populations in the Great Basin have recently become extirpated, including seven recorded from 1925 to 1941 (see fig. 3). For these reasons I sought to determine whether pika populations that had been noted historically in Craters and Lava Beds have continued to persist. If pikas had persisted, then I also sought to explore potential mechanisms that have allowed them to persist in such apparently harsh conditions.

STUDY SITES

Craters consists of 29,000 hectares (71,659 acres) of volcanic craters, cones, 2,000- to 15,000-year-old lava flows, caves, and fissures at the interface of the Snake River Plain and the southeast edge of the high, mountainous region of central Idaho (see fig. 2). Elevations in the monument ranged from 1,590-1,990 m (5,217-6,529 ft) at the time of sampling (1995), but the November 2000 expansion of the monument incorporated areas into the monument as low as 1,280 m (4,200 ft). Lava Beds occurs in northeastern California on the north flank of the Medicine Lake shield volcano that erupted 17 times between 800 and 12,800 calendar years ago (Donnelly-Nolan et al. 1990; see fig. 2). The volcano covers about 2,000 sq km (772 sq mi) and lies about 50 km (31 mi) east-northeast of Mt. Shasta in the southern Cascade Range. The monument's 18,850 ha (46,578 acres) occupy about 10% of the area of the volcano, and encompass cinder cones,

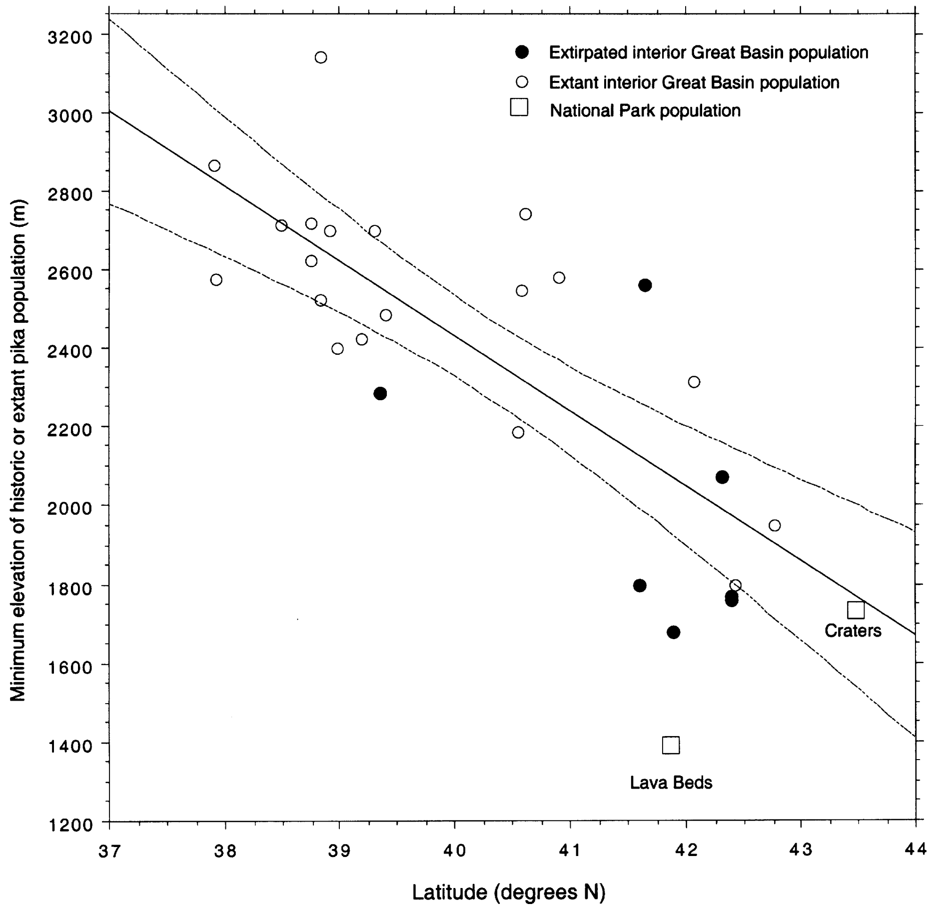

Figure 3. Persistence of pika populations during the 20th century in the intermountain West, at different elevations and latitudes. Open circles represent sites in the interior Great Basin where pikas remain extant, and closed circles represent pika populations that became extirpated in the late 20th century. Open squares represent Craters of the Moon and Lava Beds National Monuments, where pikas were recorded during the mid to late 20th century. The solid line represents the relationship between elevation and latitude among the 25 sites in the interior Great Basin at which pikas were previously recorded, and dotted lines represent 95% confidence intervals around the solid line.

spatter cones, and over 440 lava tube caves at elevations between 1,230 and 1,650 m (4,036 and 5,414 ft). Pikas are one of the more charismatic mammal species in the monuments, and are more frequently heard than seen. They are one of six lagomorph and 48 mammal species known from Craters, and one of three lagomorph and 53 mammal species known from Lava Beds.

To provide a comparison of a low-elevation area with extensive potential pika habitat that was geographically closer to the monuments than the interior Great Basin sites, I also sampled three locations in the Hell's Half Acre lava flow in south-central Idaho from 17–19 July (see fig. 2). We chose this site because it has extensive amounts of talus-like habitat, much of which occurs at large distances from primary roads; the site also has a similar range of elevations to Craters, but experiences different management. These factors played the most important roles in determining persistence of pika populations in the interior Great Basin during the 20th century. Because historic records of pikas in the vicinity of Hell's Half Acre do not exist, it would be difficult to ascribe a cause to the absence of pikas there, if we could not detect them. Ideally, other low-elevation sites outside but near either monument having historic records of pikas would have been preferable, but we were not aware of any such sites. In associated research, I also re-sampled populations of pikas recorded between 1916 and 1990 at 25 sites ranging in minimum elevation from 1,680–3,139 m (5,512–10,300 ft) throughout the interior Great Basin in summer from 1994 to 1999 (fig. 2).

METHODS

I re-visited locations in Craters from 14–17 July 1995 and in Lava Beds from 22–24 July 1995 where pikas had been observed in previous decades, and I sampled sites at Hell's Half Acre from 17–19 July 1995. Sampling occurred on lava formations for three days at each site (i.e., Lava Beds, Craters, and Hell's Half Acre), totaling between 15.5 and 18 hours of censuses per site. I chose specific sampling locations in the monuments based upon presence of precise historic records, relative accessibility, and the desire to sample broadly within each monument. Sampling at interior Great Basin sites occurred on taluses for 8 hours per site in summer between 1994 and 1999, or longer (up to 20 hr) if I could not detect pikas at the site.

During slow-walking transect surveys through lava formations, I recorded locations of pika sign (e.g., sightings, calls, and fresh hay pile sightings) using a handheld global positioning system unit without differential correction (precision ± 100 m [328 ft]). I used standardized recording criteria to avoid counting multiple types of evidence from the same individual. I also made observations on the natural history of pikas sighted within the monuments.

To compare climatic conditions at pika sites in the interior Great Basin and in the monuments, I used PRISM data (Oregon Climate Service, Corvallis) that interpolate values between climate stations across the region, and account for factors such as elevation and aspect. These estimated climatic values represent averages from the years 1961–1990, at a resolution of 4 km (2.4 mi). I compared annual precipitation and averages of the maximum daily temperatures for the months of June, July, and August among sites in the interior Great Basin where pikas have been extirpated recently, sites in the Great Basin where they remain extant, and the three volcanic sites (Craters, Lava Beds, and Hell's Half Acre) adjacent to the Great Basin.

RESULTS

Persistence

In Lava Beds, I detected a minimum of 10 pikas (6 sightings, ≤4 calling individuals) from 9 sites, out of 16 sites visited (table 1). Pikas were detected at five of nine sites very near to where they were documented in monument records (1960–1991), and at four of eight sites more distant from historic locations. In Craters, I detected a minimum of 27 pikas (8 sightings, ≤ 18 calling individuals, and one active hay pile) at 8 of 12 sites visited. Pikas were detected at four of five historic locations (and an inactive hay pile was found at the fifth location), and at four of seven sites slightly more distant from historic locations. No pikas were detected at any of seven locations searched within Hell's Half Acre.

Climatic analyses

Loss of pika populations at study sites in the interior Great Basin occurred at sites that were on average 20% drier and 8–10% warmer than those at which populations persisted (table 2, page 28). However, the Craters and Lava Beds Monuments, where pikas persist, experience climates that are an estimated 18–24% drier annually and 5–11% warmer during the hottest months of the year than climates at areas of even *extirpated* pika populations in the interior Great Basin (table 2). Hell's Half Acre, from which pikas are not known in recent times, received an estimated average of 22–28% less precipitation annually and experienced temperatures 3–5% hotter than Craters and Lava Beds.

Natural history

Other mammals observed in Craters lava fields included chipmunks, yellow-bellied marmots, and golden-mantled ground squirrels. From my observations in Craters, pikas apparently use different parts of the volcanic landscape than chipmunks and squirrels, at least during summer. Whereas ground squirrels and chipmunks are more frequently found on flatter areas with less complex relief (usually *pahoehoe* or short *aa* lava formations or areas with extensive sagebrush vegetation), pikas appear to frequent lava tubes, caves, and valley trenches 2–5 m (6.6–16.4 ft) deep. I observed several mountain cottontails along margins of lava flows in Lava Beds, but did not observe them well within the lava flow, where pikas were often seen. Although other mammals were less plentiful at Hell's Half Acre, birds were relatively more abundant.

Although pikas in the monuments dedicated significant amounts of time to vigilance, numerous individuals were less responsive to the presence of nearby humans than were pikas at sites in the interior Great Basin. Whereas I could never approach pikas to a distance less than 13–15 m (42.6–48.2 ft) in the interior Great Basin, I came within 20 cm (8 in) of stepping on one at Craters. Furthermore, one individual on the Devil's Orchard Trail seemed so habituated to humans that it remained above the lava surface for 5–8 minutes when a group of about 25 relatively boisterous visitors approached it to within 10 m (33 ft).

DISCUSSION

Persistence of low-elevation pikas: climatic and other influences

Loss of pika populations from lower elevations and latitudes, such as the loss of nearly 30% of interior Great Basin popula-

Table 1: Locations sampled for pikas in Lava Beds and Craters of the Moon National Monuments, July 1995.

	Location	Elevation (m)	Search effort (hr)*	Date of historic record, if available	Pikas detected in 1995 survey?
LAVA BEDS	Heppe Ice Cave	1610	0.75	1991	No
	Catacombs parking lot	1525	2.00	1961, 1962	Yes
	Juniper Cave	1510	0.50	1960	No
	Catacomb Cave, upper Sentinel entrance	1490–1525	2.50 [3]	1963	Yes
	Maze Cave collapse	1490	1.00 [2]		No
	Merrill Ice Cave	1490	1.50	1962	Yes
	Thunderbolt Cave, upstream entrance	1490	0.25	1990	No
	Lower Sentinel entrance	1475	0.75 [3]		Yes
	Indian Well Cave	1450	0.50		Yes
	Symbol Bridge	1440	1.00 [3]	1972	Yes
	Skull Cave road	1400	1.00		No
	Fleener Chimneys area	1365	0.75	1984	Yes
	Schonchin Lava Flow	1340	1.00		No
	Trail to Black Crater; Battlefield Trail	1340	0.75		Yes
	Devil's Homestead Lava Flow	1280	0.50		No
	TOTALS (N = 15 sites, 22 searches)	Mean = 1450 m	16.0 hr		10 individuals
CRATERS OF THE MOON	North Crater Flow trail	1830	2.00	1990	Yes
	Base of North Crater	1830	1.25		Yes
	Scenic turnout near Spatter Cones parking lot	1830	1.00		No
	Highway Flow	1810	4.00 [2]		No
	Spatter Cones, trail to Big Crater	1810	2.25		Yes
	Trail to Buffalo Caves	1790	0.75		Yes
	Picnic table turnout	1780	1.00		Yes
	Base of Big Sink, Tree Molds Road	1780	0.75		Yes
	Jct of main loop road and Tree Molds road	1780	0.50	1990	No
	Caves Area Trail to Needles Cave	1760	3.25		Yes
	Devil's Orchard Trail	1750	3.25	1989, 1990	Yes
	Caves Area Trail	1750	2.25	1991	Yes
	TOTALS (N = 12 sites, 13 searches)	Mean = 1790 m	18.5 hr		27 individuals

* Number of searches (if >1) appear in brackets

tions recorded during the 20th century, is consistent with losses that have occurred over the last 14,000 years (Grayson 1993). Given the recent extirpation of pikas from low-elevation sites within 150 km (93 mi) of Lava Beds (Beever 1999; fig. 2), current persistence of pikas in Craters and Lava Beds National Monuments is noteworthy. Although population losses in the Great Basin occurred not surprisingly at sites that were drier and warmer than those at which populations persisted, estimated climates at Lava Beds and Craters were notably drier and hotter than even those locations in the Great Basin where pikas have been recently extirpated. However, the tubes, caves, and deep, complex lava formations that occur across both monuments undoubtedly provide pikas with relatively cool refugia during times of heat stress. Interestingly, though, pikas were not exclusively confined to caves and lava tubes during my July surveys, suggesting that temperature influences provide only a partial solution to the mystery of how pikas persist in these monuments. Pika behavior plays a substantial role in mediating the

Table 2. Estimated climatic conditions at areas in the interior Great Basin where pikas remained extant and where they were extirpated during the 20th century, and at two low-elevation national monuments adjacent to the Great Basin that still contain pikas.

Site(s)	Elevation range*	Average annual precipitation (cm/yr ± 1 SE [standard error])	June maximum temperatures** (°C)	July maximum temperatures (°C)	August maximum temperatures (°C)
Sites (N = 18) in the interior Great Basin with extant pika populations	1,798–3,612 m (5,900–11,850 ft)	58.9 ± 6.2	19.3 ± 0.7	24.7 ± 0.6	24.8 ± 0.5
Sites (N = 7) in the interior Great Basin with extirpated pika populations	1,680–2,877 m (5,512–8,600 ft)	47.4 ± 7.0	21.3 ± 0.5	26.6 ± 0.6	26.7 ± 0.5
Lava Beds National Monument	1,230–1,650 m (4,036–5,414 ft)	36.1	23.6	28.6	28.2
Craters of the Moon National Monument	1,590–1,990 m (5,217–6,529 ft)	38.8	23.5	29	28.1
Hell's Half Acre	1,400–1,630 m (4,593–5,348 ft)	28.1	24.4	30.1	29.0

*Represented are the lower end of talus at the lowest sites in each category (lowest elevation currently with pikas, for the lowest site with an extant population in the interior Great Basin), and the highest elevation of talus habitat within 3 km of the location of the historic record of pikas (among all sites in the group).
**Average of daily maximum temperatures for days in June (values indicate average ± 1 SE when >1 site).

effects of thermal stress, and measuring temperature regimes that pikas experience throughout the day and across seasons may provide another clue to understanding how they persist in these low-elevation areas.

"Pika behavior plays a substantial role in mediating the effects of thermal stress...."

In both monuments, pikas apparently use habitats that fulfill three requirements. First, pikas generally inhabit large, contiguous areas of (rocky) volcanic habitat, as opposed to isolated pockets of lava formations. Second, although pikas were not always located near edges of lava flows, areas with pikas possessed average or greater amounts of vegetation accessible within distances comparable to dimensions of home ranges. Finally, pikas appeared to be associated at the fine scale with microtopography characterized by rocks large enough to provide space for subsurface movement and tunneling (as is found in *aa* and block lava flows), as opposed to the smooth *pahoehoe* lava flows that have little relief. Because collapsed lava tubes, lava flow margins, cave entrances, fault scarps, fault cracks, and internal talus zones all provide talus-like areas that pikas may inhabit, geologic mapping of the monuments may provide additional insight into pika distribution.

In contrast to our relatively clear understanding of the climatic effects on pika distribution, the exact extent to which human-related activities such as livestock grazing, altered fire regimes, clear-cutting of adjacent forest cover, and other influences on lava habitats affect pika population dynamics remains in need of clarification. While the systems of caves and lava tubes have undoubtedly facilitated persistence of pikas in the monuments, other factors that may contribute to their persistence in these low-elevation areas include: extensiveness and connectivity of lava habitats, relatively close proximity (30–80 km [18.6–49.7 mi]) to other known pika strongholds (Hafner 1994; J. Villegas, 2001, personal communication), physical complexity of lava formations, relative inaccessibility for humans, and wilderness management. Although Hell's Half Acre possesses extensive lava flows, amounts of vegetation comparable to that of Craters, proximity (<130 km [80.7 mi]) to three other pika populations, and is relatively inaccessible over much of its area, it has fewer caves and lava tubes, a less convoluted lava structure, and a hotter, drier climate than Craters; and it is managed as a multiple-use recreational area.

This research does not allow conclusive understanding of to what degree the effects of wilderness management, habitat extent, and physical structure of habitats have contributed to persistence of monument populations of pikas while other low-elevation (interior Great Basin) populations have suffered extirpation. Although manipulative experiments, which provide stronger inference about cause-effect relationships, are not feasible within the monuments, two avenues of observational research may prove fruitful. Broad sampling for pikas in numerous caves and tubes within and around the monuments would afford greater understanding of the range of conditions (with respect to temperature, humidity, cave size and habitat extent, isolation from other populations, and human activity) that support pika populations. During sampling, collection of tissue samples from individual pikas would allow comparison of genetic differences among known pika populations and would suggest relative rates of gene flow among them. Correlation of genetic results with potentially isolating features (e.g., roads, surrounding non-talus habitat, different systems of lava tubes) and management actions (livestock grazing, fire frequency) would provide a basis for generating hypotheses as to which factors, if any, have constrained pika distribution.

MANAGEMENT IMPLICATIONS

Persistence of pikas, at least in the interior Great Basin, appears to be a function of extent of habitat, distance to primary roads, and maximum elevation of habitat to which pikas can migrate (which should dictate pikas' ability to respond to climate change) (Beever 1999; Beever et al. forthcoming). Additionally, pika population size relates to the presence of livestock grazing in some cases (Beever 1999; Beever et al. forthcoming). Therefore, management actions may hold great importance for pika persistence. For most species, persistence depends critically on the amount, spatial distribution, and quality of appropriate habitat. Although removal or physical degradation of lava and talus habitats are not likely over ecological time scales, habitat quality for pikas may be compromised by the following: consistently higher ambient temperatures (e.g., due to climate change); altered composition of forbs and grasses in and adjacent to lava flows (e.g., because of altered fire regimes, exotic species, or uncharacteristically intense levels of grazing at flow margins); and significant fragmentation of lava habitats (e.g., road construction). Pika persistence at low-elevation sites may also be affected by disturbance or alteration of pika habitats by humans or livestock (e.g., nutrient deposition by livestock in large caves [J. Villegas, 2001, personal communication], human disturbance of hay piles). Because human disturbance of lava flows to this point has been confined primarily to areas near roads or trails during warmer months, these latter influences probably have been minimal.

Isolation of Great Basin pika populations from the Sierra Nevada or Rocky Mountains is one of few variables that does not predict persistence in the Great Basin. This phenomenon probably occurs because talus habitats in the Great Basin are separated by vast areas of non-talus habitat that usually lie at low elevation, and pikas are unlikely to traverse these areas under current climatic conditions. In contrast, the recent ninefold expansion of Craters' area creates the possibility for promoting pika persistence across the more continuous lava habitats along the Great Rift, to the extent that the monument explicitly manages for vertebrate conservation. Although connectivity among volcanic habitats may not change with monument expansion, changes in management in the area may alter *effective* connectivity. Thus, although Newmark (1995) concluded that national parks in western North America are too small to support viable populations of large mammals, actions such as monument expansion and others described earlier may help prevent loss of noteworthy pika populations from these low-elevation monuments.

ACKNOWLEDGMENTS

Special thanks are due to Chuck Barat and Bernard Stoffel, Chiefs of Resource Management at Lava Beds National Monument, for their facilitation and sharing of pika locations. Natalene Cummings, Vicki Snitzler-Neeck, and Mike Munts, Resource Management Specialists, provided similar assistance at Craters of the Moon. Anna Knipps and Suzette Tay, SCA volunteers at Craters, assisted with sampling. Thanks are also due to the superintendents of Craters (Jim Morris) and Lava Beds (Craig Dorman) for approving scientific collecting permits. Joel Berger of the University of Nevada, Reno, provided helpful discussions on mammalian persistence. The Biological Resources Research Center (BRRC) at the University of Nevada, Reno, provided funding during idea development. Brian McMenamy (of BRRC) prepared the GIS-based figure 2. C. Ray, D. Grayson, and J. Donnelly-Nolan commented on earlier drafts.

LITERATURE CITED

Beever, E. A. 1999. Species- and community-level responses to disturbance imposed by feral horse grazing and other management practices. Ph.D. dissertation, University of Nevada, Reno.

Beever, E. A., P. F. Brussard, and J. Berger. Forthcoming. Patterns of extirpation among isolated populations of pikas *(Ochotona princeps)* in the Great Basin. Journal of Mammalogy.

Donnelly-Nolan, J. M., D. E. Champion, C. D. Miller, T. L. Grove, and D. A. Trimble. 1990. Post-11,000-year volcanism at Medicine Lake Volcano, Cascade Range, northern California. Journal of Geophysical Research 95:19693–704.

Grayson, K. D. 1987. The biogeographic history of small mammals in the Great Basin: observations on the last 20,000 years. Journal of Mammalogy 68:359–75.

Grayson, K. D. 1993. The desert's past: a natural history of the Great Basin. Smithsonian Institution Press, Washington, D.C.

Hafner, D. J. 1993. North American pika *(Ochotona princeps)* as a late Quaternary biogeographic indicator species. Quaternary Research, 39:373–80.

Hafner, D. J. 1994. Pikas and permafrost: post-Wisconsin historical zoogeography of *Ochotona* in the southern Rocky Mountains, U.S.A. Arctic and Alpine Research 26:375–82.

MacArthur, R. H., and E. O. Wilson. 1967. The theory of island biogeography—Monographs in population biology No. 1, Princeton University Press, Princeton, New Jersey.

Newmark, W. D. 1995. Extinction of mammal populations in western North American national parks. Conservation Biology 9:512–26.

Smith, A. T. 1974. The distribution and dispersal of pikas: influences of behavior and climate. Ecology 55:1368–76.

Svejcar, T., and R. Tausch. 1991. Anaho Island, Nevada: a relict area dominated by annual invader species. Rangelands 13:322–26.

ABOUT THE AUTHOR

Erik A. Beever, Ph.D., is an Ecologist with the U.S. Geological Survey, Forest and Rangeland Ecosystem Science Center, 3200 SW Jefferson Way, Corvallis, OR 97331. He can be reached at 541-758-7785 or by e-mail: erik_beever@usgs.gov.