Playing by New Rules

ALTERED CLIMATES ARE AFFECTING SOME PIKAS DRAMATICALLY—AND RAPIDLY

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Credit: Yuriko Yano

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Historically, threats to mammalian wildlife were fairly easy to recognize. Species often succumbed to overharvesting, habitat destruction or degradation, invasive species, disease, or some combination of those insults. That is why it can be hard to wrap one's head around why a species that is rarely hunted, often occurs in high densities, and lives on remote mountaintops in habitats that have not physically changed in extent or distribution appears to be in need of conservation attention. Yet that's precisely the case with the American pika (*Ochotona princeps*), and the main force behind its recent decline in the interior Great Basin appears to be contemporary climate change (Beever *et al.* 2003, Beever *et al.* 2010, Beever *et al.* 2011).

It is not news to any wildlife manager that climate change demands a new approach to conservation. However, research that we've undertaken over the last two decades demonstrates phenomena that might prove more surprising: Not only are pika populations now disappearing from wilderness areas and sites with lots of apparently intact habitat, but also the factors governing whether a population survived or expired in the 20th century differ dramatically from the factors we've observed in the first decade of the 21st century (Beever *et al.* 2011). In other words, examining the dynamics of past population losses may not always help us predict the pattern of future losses. In the case of American pikas, accelerating climate change has rewritten the local-extinction "rule book."

A Climate Loser

About the size and shape of a hamster, the American pika is a generalist herbivore. Pikas create and defend hay piles, which they rely on for energy throughout the winter, when they remain active under the snow surface (Smith and Weston 1990). The species occurs in talus slopes and broken-rock formations such as lava flows, mine tailings, road-cuts, rock quarries, and occasionally even decaying foundations of old buildings (Manning and Hagar 2011, Smith and Weston 1990).

Pikas typically live at high elevations where cool, moist conditions prevail. The species' range includes portions of 10 western U.S. states and two Canadian provinces, and paleontological records show that individuals of the *Ochotona* genus have inhabited the region for the last 150,000 years. The roughly 40-million-hectare area between the Sierra Nevada and Rocky Mountains that drains internally—the hydrographic Great Basin or "the Basin"—constitutes some of the warmest and driest portions of the species' entire range. It is also the setting for our longest-running pika research.

For several key reasons, American pikas in the Basin seem predisposed to fare

Credit: Shana Weber

A talus formation along Mohawk Canyon in central Nevada's Toiyabe Range is home to a population of pikas, but the animals now occur at higher elevations than they once did, likely due to increasingly warm and dry conditions. Other sites where pikas were historically found are now entirely devoid of the species.

poorly when the climate is altered (Beever *et al.* 2010). They have high energetic requirements because they are active year-round and don't migrate or hibernate to avoid harsh winter conditions. Furthermore, compared to the enthusiastic breeding habits of rabbits and hares—pikas' closest relatives—the species has a low reproductive capacity. Additionally, pikas are often closely tied to talus formations that have a naturally patchy distribution. This, combined with the fact that they typically do not disperse over large distances, means that they may not be able to move to new habitats as the climate shifts. Finally, pikas are physiologically vulnerable to fatal overheating, due to their thick fur and the small difference between their resting and upper-lethal body temperatures, as well as to prolonged bouts of extreme cold, due to their small body size, which translates to fewer fat reserves.

In the 1990s, while a Ph.D. student at the University of Nevada-Reno, Erik Beever became interested in pikas in the Basin, which has 25 sites with museum records of pikas dating from 1898 to 1956. From 1994 to 1999, he visited each site to see if pikas still resided there. Along with then-University of Nevada-Reno master's student Jennifer Wilkening and other colleagues, Beever revisited these sites from 2003 to 2008.

To characterize the temperatures pikas experienced and would have experienced in these habitats, Wilkening placed thermal sensors in talus interstices near both active and old hay piles, respectively. Using what we know about pikas' temperature tolerance, Wilkening defined chronic heat stress as the average summer temperature, acute heat stress as the number of days in which talus-interstice temperatures rose above 28°C, and acute cold stress as the number of days below -5°C or below -10°C as tallied by the sensors (Beever *et al.* 2010).

Lost to the Heat

What we found—or rather, didn't find—was both surprising and somewhat unsettling. During surveys in the 1990s, Beever failed to find pikas at six of the 25 historically occupied sites. And though we revisited each of the 25 sites multiple times in the 2000s, our surveys not only failed to turn up any pikas at those six sites, but also identified three new site-level losses and functional extirpation of pikas from a fourth site, at which we spotted only one or two migrant individuals. It was a disquieting result, as less than a decade had passed since our last surveys at each site (Beever *et al.* 2010, Beever *et al.* 2011).

This pattern of disappearance points to climate as a culprit. Our results reveal that pikas have disappeared from the hottest and driest sites of the Basin in both the 20th and 21st centuries. In addition, where pika populations still exist but have contracted, the animals no longer occupy the hottest

Credit: Shana Weber

To understand how pikas responded to a changing climate, researchers surveyed sites in the Great Basin where populations had been found historically. Beyond actually hearing or seeing a pika (above), finding active hay piles, such as this one in Oregon's Kiger Gorge (below), can confirm pika occupancy. To build hay piles, pikas collect plants and allow them to dry in piles, which then serve as a source of winter food and bedding.

Credit: Shana Weber

patches *within* sites. Throughout the Basin, sites of pika extirpation tended both to be hotter during the summer and to dip more frequently below cold thresholds (-5°C) in the winter than sites where pikas persisted, the latter pattern reflecting a lack of an insulating blanket of snow (Beever *et al.* 2010).

Pikas in the Basin have also been on an upward march to avoid reduced snow packs and warmer summer temperatures, and the tempo of their climb has recently increased. The lowest elevation at which pikas were found rose an average of 13.2 meters per decade within sites from the time of historical surveys to our 1990s surveys. In contrast, between the 1990s and our 2000s surveys, we found that the lowest pika-occupied elevation moved upward at a rate of far more than 100 meters per decade (Beever *et al.* 2011).

Credit: Shana Weber

At a field site inside west-central Nevada's Hawthorne Army Ammunition Depot, author Erik Beever sets out a line-point transect to quantify the vegetation available to a pika that created a nearby hay pile. One way that climate change could impact pika populations indirectly is by altering the abundance or nutritional value of their forage plants.

When analyzing these data, it became clear that the factors influencing population extirpations looked much different in the 21st century than they did during the 20th. To predict the patterns of extirpation that we saw, we evaluated competing models. In contrast to our models based on data from historic records through the 1990s surveys, the models that best explained our data from the 2000s showed that climate-related variables had become even stronger predictors of the pattern of pika persistence in the 21st century. When we then tested models that included only climate-related variables against purely non-climate models and "mixed" models, we found that for both the most recent period of study and overall, the climate-only models presented plausibly the best-supported hypothesis of why the pattern of local extinctions unfolded as it did (Beever *et al.* 2011).

To say that "climate change" was the main reason for extirpations, however, is probably overly simplistic. Across all analyses of climate metrics, our results indicated that the magnitude of climate change (defined as the difference between the means of the periods 1945-1975 and 1976-2006) predicted the pattern of pika losses across the Basin very poorly compared to either the short-term (2-year) or longer-term (62-year) prevailing climate at sites. Rather, it seems that pikas in the hottest and driest regions of the Basin could not accommodate conditions that became even hotter and drier. For example, they may have run up against energetic and physiological constraints that simply could not be circumvented.

Implications Beyond Pikas

The pace and changing nature of these contemporary shifts in occupancy are striking. Before drawing sweeping conclusions about how our findings might be applied elsewhere, however, it is important to place our work in context. First, the default position of wildlife managers and researchers should be to assume that both the status and trend of wildlife species will likely vary greatly across species' ranges (Hallett *et al.* 2004, Murphy and Lovett-Doust 2007), so our observations at these 25 sites may not be indicative of pika population trends elsewhere. Similarly, because life-history strategies, physiology, and other characteristics vary so widely among species, it makes sense to assume that different species would accordingly exhibit varying responses to contemporary climate changes (Guralnick 2006, Moritz *et al.* 2008, Parmesan and Yohe 2003). Even other montane small mammals could respond to warming in a much different fashion than has been observed for Great Basin pikas.

Climate scientists have documented that temperatures are rising at an increasing rate (IPCC 2007), and there has been a concomitant acceleration in physical responses of Earth's systems, including contracting glaciers, receding sea ice, rising sea level, and shrinking snowpacks. In contrast, examples of accelerations in wildlife responses in the face of changing climate, as we have documented in pikas of the Basin, have been much rarer to date. Nonetheless, as the speed and drivers of population losses change, scientists should expect ecological surprises. Such surprises seem especially likely in community-level and secondary effects of climate change. For example, although warmer summers may directly affect pikas physiologically, the higher temperatures could also weaken their immune systems, reduce the nutritional value of their forage plants, or increase their risk of predation. Predation risk would undoubtedly increase if pikas avoid midday heat and instead emerge from the protected areas under the talus surface at dawn, dusk, and nighttime, when many of their predators are most active.

The use of species-distribution models, increasingly important tools for addressing climate-change effects, can help articulate alternative scenarios and possibly reduce the magnitude of these ecological surprises. Species-distribution modeling—using coarse-grained analyses of distributional shifts for tens to hundreds of species—will provide general trends and may help provide upper and lower bounds for predictions in forecasts. Finer-scale models will aid in focusing on the mechanisms underlying responses and incorporate both climatic and non-climatic factors to better inform management and conservation decisions at the local level. Combined, these models could increase our confidence when choosing areas that would be most suitable for reintroductions. For pikas, models could help us identify physically suitable talus habitat that also falls within the appropriate temperature ranges for pika survival. Such models, informed by measurements of wildlife-relevant microclimates and a solid understanding of species' behavior, physiology, and life history, could also help us identify areas that, if protected, would reap disproportionately high rewards in terms of species conservation.

Facing the Future

In this era of a new ecological rule book ushered in by contemporary climate change, there are several actions that can be taken now to better inform our actions going forward:

- Pursue robust wildlife monitoring—for instance, adding density measurements to simple occupancy monitoring—to alert us to early-warning signs of ecosystem alteration.
- Use multi-disciplinary approaches to lend insight into the mechanisms by which contemporary climate acts upon species. For example, connectivity can be better characterized if combining several types of information—such as genetic data from diverse assemblages of species, GIS analyses that identify "paths of least resistance" in current landscapes, and species-distribution forecasts—rather than relying on just one of these types of analyses.
- Identify potentially vulnerable habitats by using either data on wildlife-relevant microclimates or, if those are unavailable, well-informed proxies (Beever *et al.* 2011).
- Mitigate other factors that compromise species' ability to accommodate changes in climate. For pikas, this may include conserving landscape features that provide more-stable microclimates (e.g., cold-air drainages or large boulders that are preferentially used by pikas), acquiring or conserving habitat corridors, monitoring and managing emerging infectious diseases, and conserving genetic diversity.
- Create climatic microrefugia to provide the mosaic of habitat that species may need to sample during portions of their lifetimes. Managers could, for example, retain thicker duff layers in forests, restore structurally more-complex and -diverse forest canopies (McGraw *et al.* in review), or conserve areas of cold-air drainage.

Wildlife researchers and managers must grapple with more complexity and uncertainty in coming decades, as no single line of research will fully explain the patterns we will observe in wildlife populations and whole ecosystems (Landres 1992). For this reason, it may be more efficient in the long term to manage and restore ecosystem function and resiliency rather than focusing on individual components, such as a particular species (Mawdsley *et al.* 2009). Although not easy, we may all come to appreciate that the new rules of the game demand novel approaches to wildlife conservation and research. ■

This article has been reviewed by subject-matter experts.