

**inferring the  
role of  
climate in  
the decline of  
the American  
pika**

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This work on the American pika was done in collaboration with Erik Beever, currently with the USGS, Phil Mote, the Washington State Climatologist, and Jennifer Wilkening, who is now my graduate student at CU Boulder. As you know, Connie presented some really neat data on the distribution of this species in different types of rock glaciers in the eastern Sierra, and found that pikas are more widespread there than previously published. Our work is sort of a counterpoint, using a formal patch occupancy study to show that the distribution of the species is shrinking in the Great Basin, and modeling this range shift as a function of climate.



First, I'll briefly review some important facts about the American pika. It's a small relative of the rabbit, about as big as your fist. One of the most important characteristics of this pika is that it's a habitat specialist, found only in taluses, and generally in certain types of talus, as Connie's poster attests.

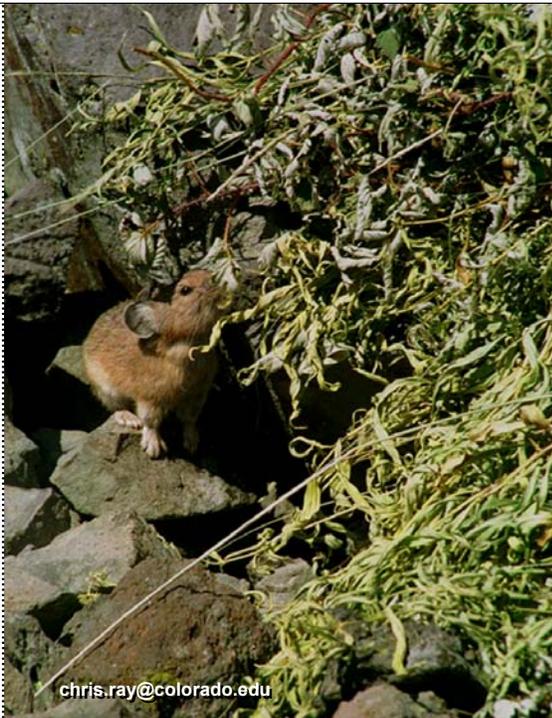
One important trait that pikas share with rabbits is that they don't hibernate during winter. And that's a problem, because they're so small that they shed heat quickly. They solve this problem by having a very high metabolic rate to keep them warm over winter, but this gets them in trouble in the summer when they can overheat easily. So, they spend lots of time under the talus

Like rabbits, they eat anything that grows, and they digest everything twice, resulting in very compact and characteristic fecal pellets, each the size of a peppercorn. These unique pellets really help with studies of patch occupancy, like ours.

Unlike rabbits, they cache food for the winter, constructing characteristic "haypiles". And each pika fiercely defends the territory around its haypile. This female in the lower corner is calling to defend her haypile, which is developing in the background. Pikas are highly vocal, and make a wide array of calls, most relating to territorial defense. They also mark territory with scent from a gland in the cheek, as this male in the upper corner is doing.

So, given the pellets, the haypiles and the territorial calls, it's hard to miss this species when it's present on a talus patch.

The species occurs throughout the western US and along the western margin of Canada, spanning a wide variety of climates—from inland to coastal, montane to lowland. But it's disappearing from some locations, and we're trying to figure out why.



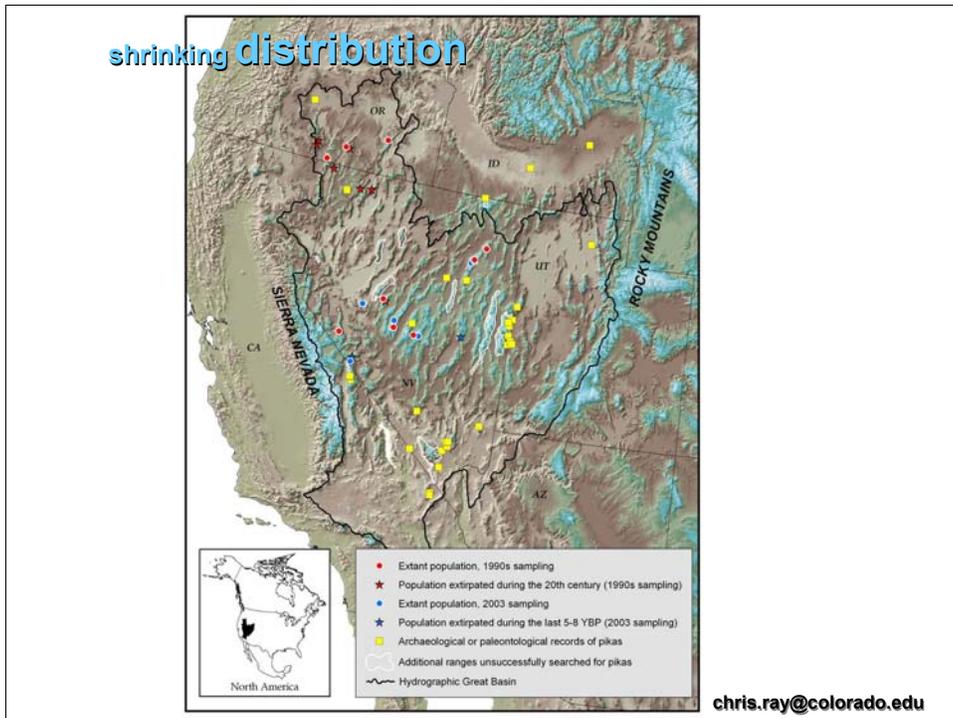
**outline**

**evidence for decline**

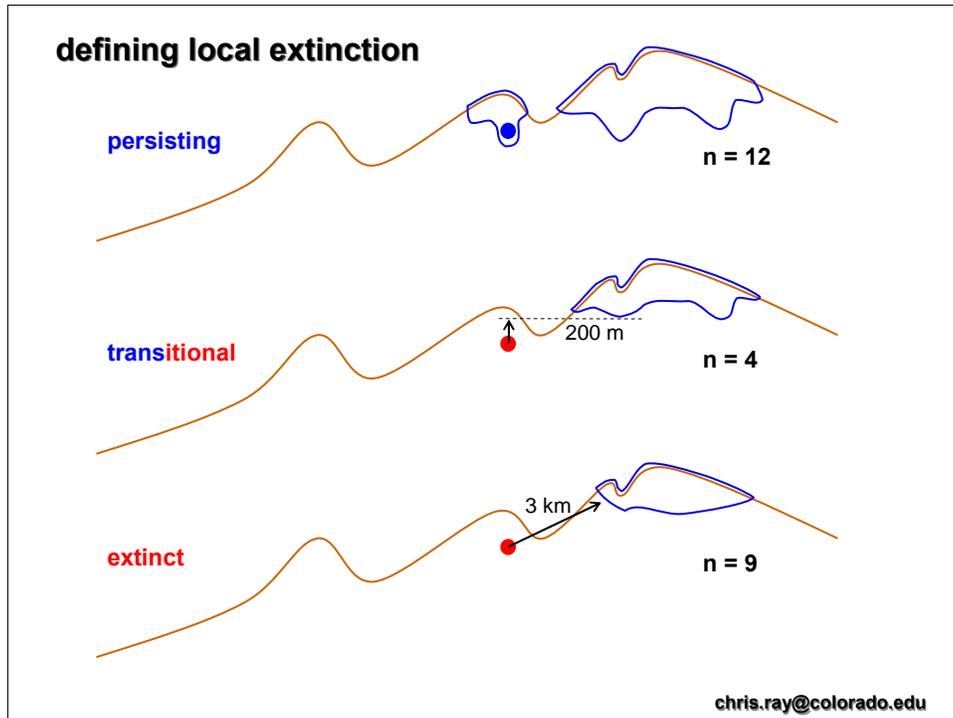
**potential climatic drivers of decline**

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I'll begin with the evidence for decline in the distribution of this species, and then show you how we were able to model these changes by assuming certain climatic drivers.



Most of the evidence for both prehistoric and very recent losses comes from the Great Basin. This map shows what's happened to the American pika in the Basin over the past 20,000 years. Everything in blue here is pika habitat and was probably occupied by pikas right after the last glacial maximum. Much of the blue area is still occupied today. Sites of pre-historic pika extinctions are indicated in yellow. Red and blue symbols indicate 25 local populations that persisted at least into the 1900's—we'll see these symbols better on the next slide.



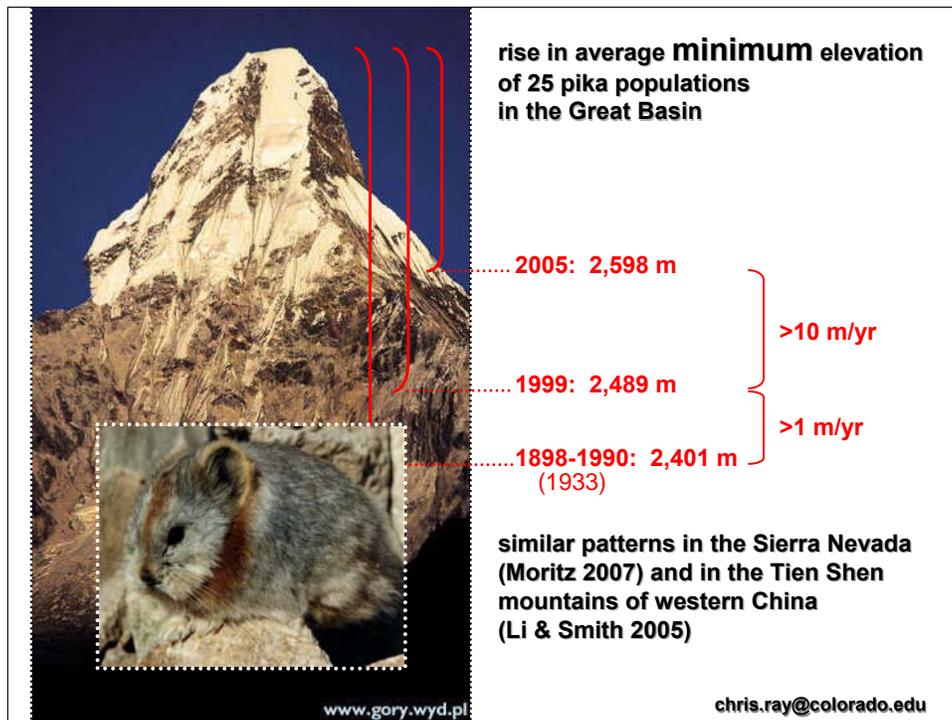
Here's how we define local extinction. We classified populations as persisting, extinct, or transitional.

For example, the cartoon at the top represents a mountain range, and the blue dot represents the location of an historical record of pikas. The blue outline represents the current distribution of pikas within the range. The population is persisting if the current distribution includes the historical location.

The population is extinct if pikas can't be found within 3 km of the historical location. To determine absence, each site was surveyed several times and by different teams over the course of two or more years, with each survey conducted for 8 hours during the cooler portions of the day, in late summer, when haying activity should be apparent.

The population is in transition if pikas can be found within 3 km, but only at elevations at least 200 m higher than the historical location.

Of the 25 historical populations, less than half are persisting in this sense, and another 4 have retracted their range uphill by at least 200 vertical meters. For the current analyses, we've included transitional populations among what we call persisting populations.



But let's look at how the range of elevations occupied by pikas has been changing within this sample. You'll recognize that this mountain is a little *bigger* than anything in the Great Basin, but just bear with me. The red bracket might represent the range of elevations occupied by pikas on a more *typical* mountain. In our historical sample, the average elevation at which pikas were recorded was about 2400 meters. This isn't a proper minimum elevation, because previous researchers weren't focused on the elevation question. This "minimum" is biased high. These historical records also span many decades, so we can't pinpoint the date of this elevation, but the average date was 1933.

By 1999, Erik had determined true minimum elevations for these populations, and the average of these minimum elevations was approaching 2500 meters. By 2005, it jumped to nearly 2600 meters.

The average rate of uphill movement during the last century was more than one meter per year, which is already high relative to other range shifts reported in the literature. Since 1999, the minimum occupied elevation has moved uphill at well over 10 meters per year.

We need to put some confidence intervals on these rates, but the implications are disturbing. In North America, we don't have any 6800-meter peaks like Ama Dablam here. The highest peak occupied by pikas in the Great Basin isn't much more than 1000 meters above this lower bound recorded in 2005. At the current rate, pikas could pop off the top of the highest peaks in the Basin within 100 years.

Other researchers are suggesting similar trends for this species in the Sierra Nevada, and for other species in Asia. This is the Ili pika, a striking species discovered by science in 1983 in the Tien Shen mountains of western China. Today, almost 60% of the populations discovered in 1983 are already extinct.



So that's our evidence for decline of the American pika. What's driving this decline?

Because pikas inhabit taluses, usually at high altitudes, they don't suffer a lot of *direct* interference from human activity. Climate change is the most obvious potential source of stress on this species. So...



How might climate cause extinction in this species?

Climate might affect pikas *directly* through thermal stress. Most attention has focused on this thermal stress because, even at rest, the body temperature of a pika is near its thermal maximum: the resting temperature is 40 deg C, but the lethal temperature is 43 deg C. They also lack heat dissipating mechanisms like panting. They've been shown to die of hyperthermia after even brief exposure to moderately high temperatures: 26 to 29 deg C.

Climate may also affect pikas *indirectly* by altering the forage available to them, by altering the density of predators or other animal species that they interact with, and by altering the distribution and prevalence of diseases that pikas have to contend with.



In developing the models that I'll discuss today, we assumed that pikas are affected by temperature directly. We attempted to predict the extinctions observed in the Great Basin using specific metrics of direct thermal stress that have been suggested in the literature. Of course, our metrics might be good predictors because of indirect effects, but it's important to note that our models were inspired by direct effects of temperature on pikas.



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**summer heat stress**

- Grinnell 1917
- MacArthur & Wang 1973
- Smith 1974
- Hafner 1993
- Hafner & Sullivan 1995
- Verts & Carraway 1998
- Li et al. 2001
- Simpson 2001
- Beever 2002

**winter exposure**

- Tapper 1973
- Smith 1978

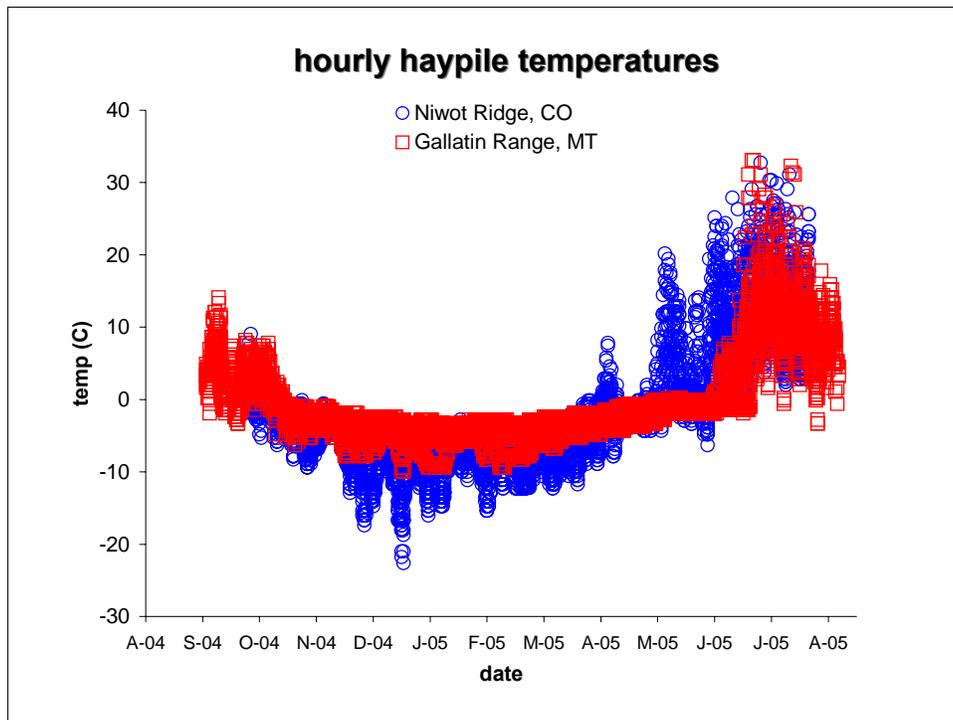


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The literature is full of studies showing that pikas can overheat (MacArthur & Wang 1973, Smith 1974a). They have a very high resting metabolic rate, relative to other animals (Li et al. 2001). Pikas are operating so close to their thermal maximum in the summertime that they need constant access to cooler microclimates like the shadow being used by this little juvenile.

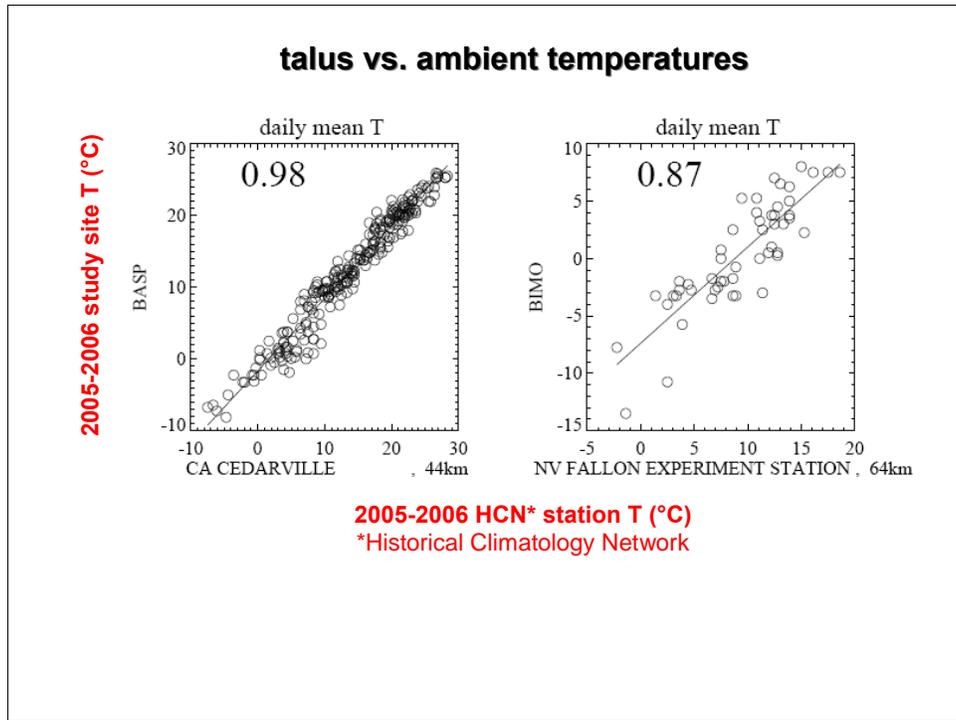
But what do pikas do when it's too cold? Here's a cold, puffed-out pika waiting for this sparse snow cover in the background to be replaced by a thick, insulating blanket. There have been a couple of studies suggesting that snow cover insulates pikas during cold winters, because survival has been shown to decline in years with less snow cover (Tapper 1973, Smith 1978).

Now let's look at the sorts of temperatures that pikas have to deal with.

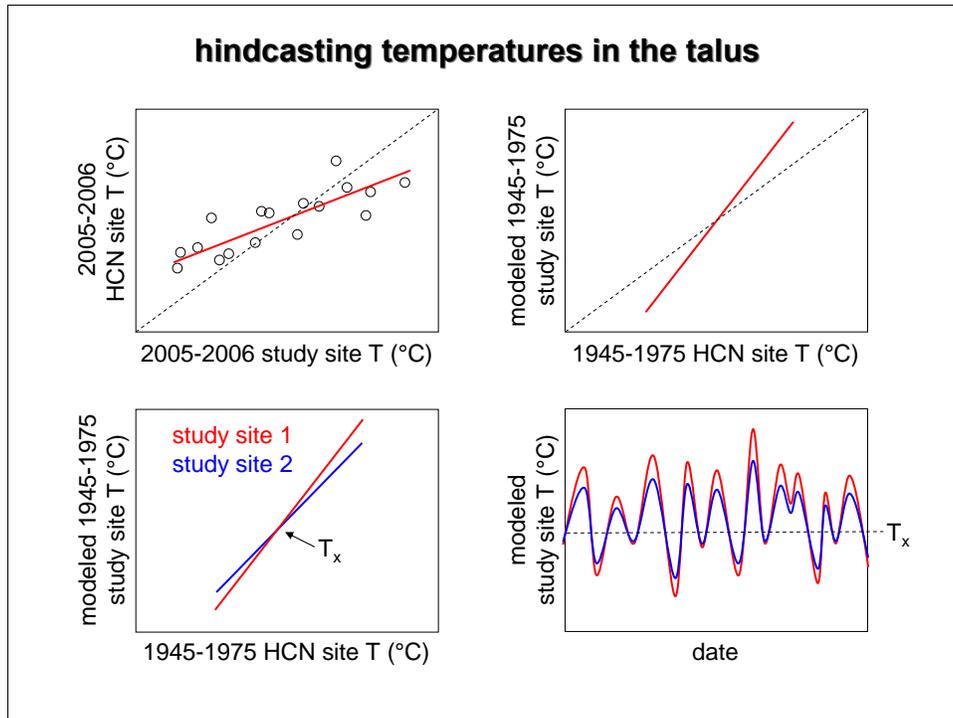


Here's what the thermal regime looks like inside a pika's haypile at a couple of my study sites. These points represent temperatures recorded every 2 hours from Sep 2004 to Aug 2005. The red squares represent temperatures in a haypile that's down in a box canyon in southern Montana. The blue circles, a haypile that's up on an exposed ridge in northern Colorado. The Colorado site is much colder in the winter, and more variable in the spring. primarily because the snow cover always blows off.

We used iButtons to record temperatures like this at several locations within the talus at each of the 25 Great Basin sites. The iButtons were in place from the summer of 2005 through the summer of 2006. We did this in order to characterize the relationship between temperatures in the talus and ambient temperatures measured at the nearest weather station in the Historical Climate Network. We then used this relationship, combined with long-term data from the weather station, to hindcast temperatures in the talus at each site over the past 60 years.



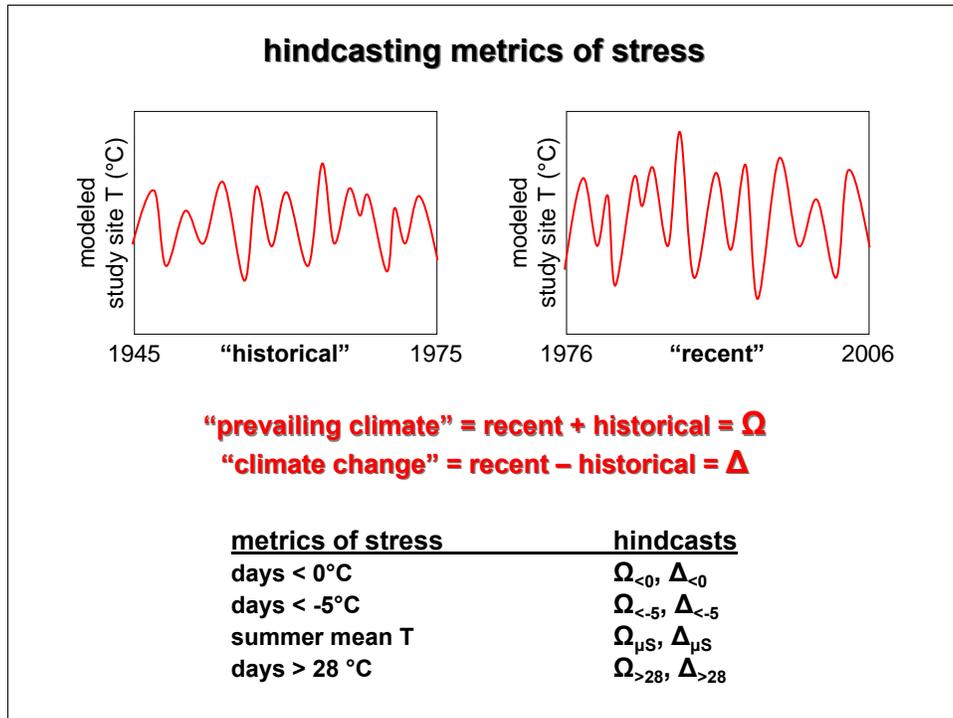
Here are two examples of the relationships we found between temperatures in the talus and those measured at weather stations within the Historical Climate Network: the best relationship daily mean temperature, and the very worst.



So, we began with a scatterplot like this of temperatures measured in the talus at a study site vs. ambient temperatures measured at the nearest HCN station over the same period. We were then able to model temperatures as the study site from 1945 through 2006 using this simple, linear model.

Unfortunately, there aren't a lot of HCN stations out there, so sometimes we were forced to use the same HCN station to model temperatures at 2 or more study sites. But that doesn't mean that different study sites ended up with the same hindcast. Instead, temperatures differed between study sites, so the relationships with temperatures at the HCN site differed between study sites, resulting in different models for different study sites. Using each model and the time series of temperatures from the HCN station, we could hindcast the time series of temperatures at each study site.

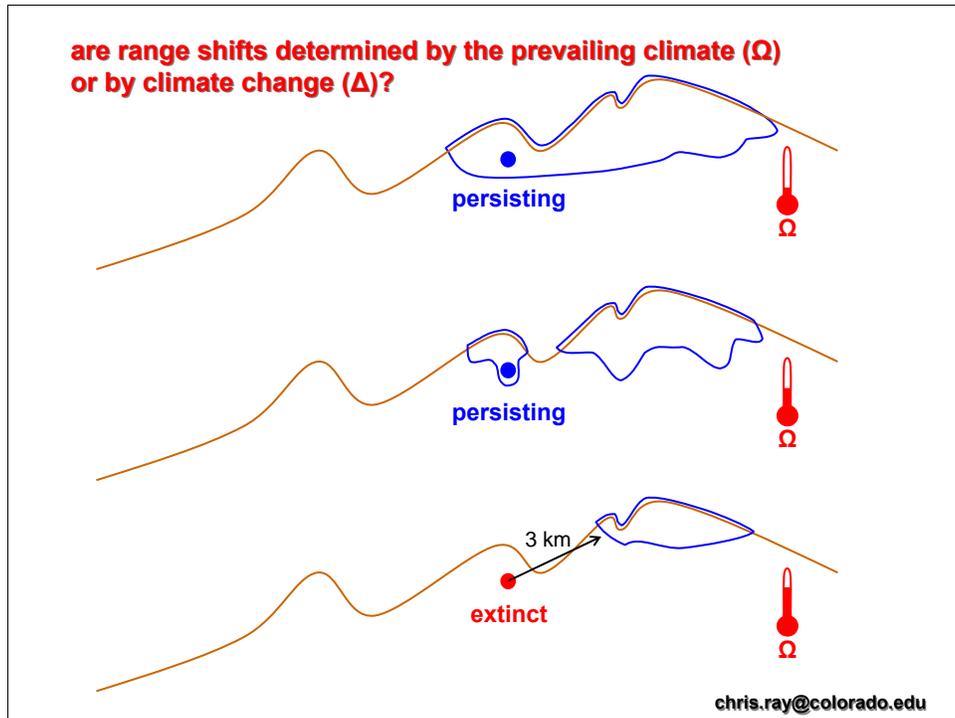
So, if the metric of stress that we're interested in were days above 26 degrees Celsius, we might estimate a lot more of these days at study site 1 than at study site 2, even if we were forced to use the same HCN station to model temperatures at both sites.



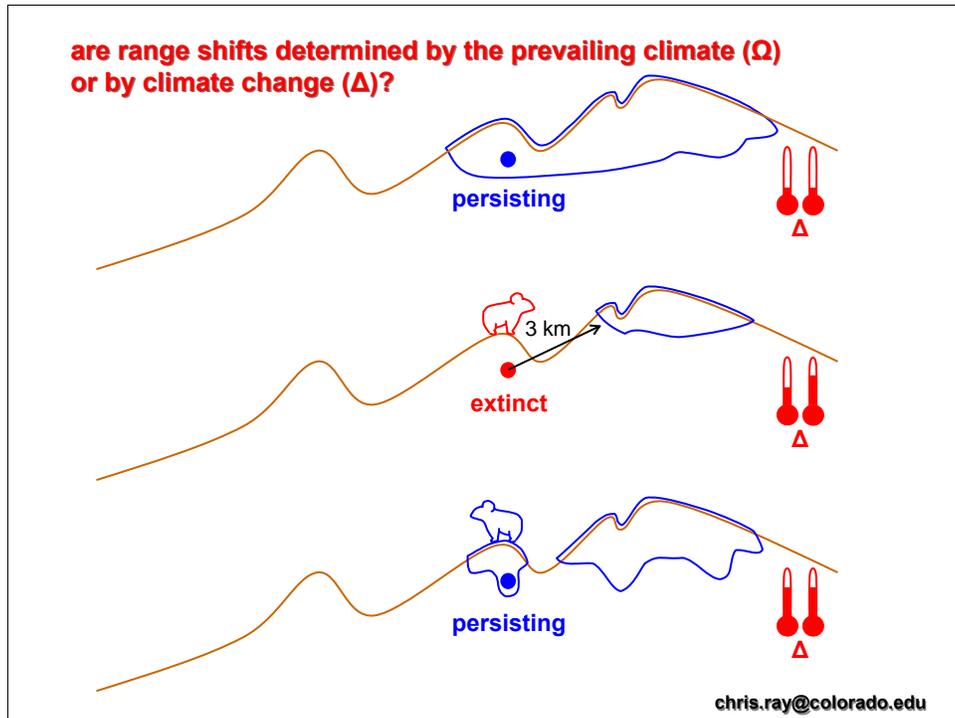
We split our hindcast for each site into two periods: 1945 to 1975, and 1976 to 2006. This allowed us to characterize what we call the prevailing or long-term climate, as opposed to climate change between these two periods. From here on, I’ll use omega to symbolize metrics of stress based on the prevailing climate, and delta to symbolize metrics of stress related to climate change.

By metrics of stress, we mean climate statistics that capture the sorts of cold stress and heat stress that pikas are supposed to suffer, given results in the literature. For example, survival declines in winters with lower snow cover, and snow cover tends to keep ground temperatures from falling far below zero, so we guessed that temperatures in the talus that were below zero or negative 5 degrees Celsius might be stressful to pikas. For each of these thresholds, we estimated both the cumulative number of days below threshold, and the change in number of days below threshold.

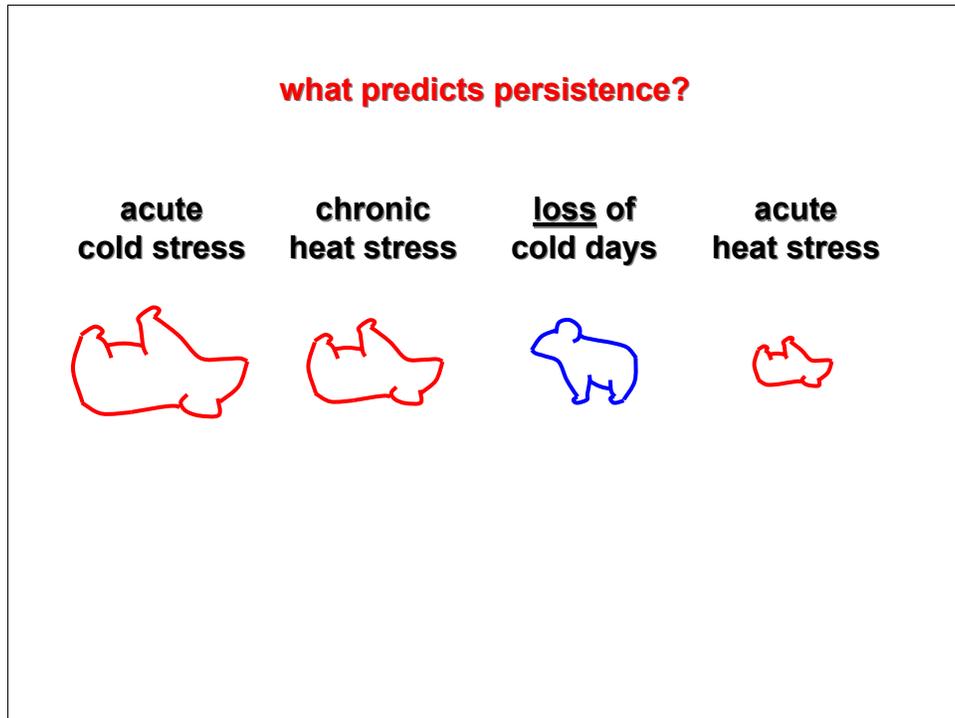
For heat stress, we hypothesized effects of chronic stress, represented by the mean temperature in June, July and August, as well as effects of acute heat stress, represented by days in which the temperature rose above 28 degrees Celsius.



By establishing two distinct predictors based on each metric of climatic stress, we're able to address this question: was this range shift caused by the prevailing climate, or by climate change? Populations may persist where the prevailing climate puts them well within the bioclimatic envelope for the species, but populations at the edge of the bioclimatic envelope may occasionally be lost. These extinctions should occur eventually—with or without significant climate change—because these populations are in marginal habitat. So, are recent extinctions just a result of this sort of extinction debt?

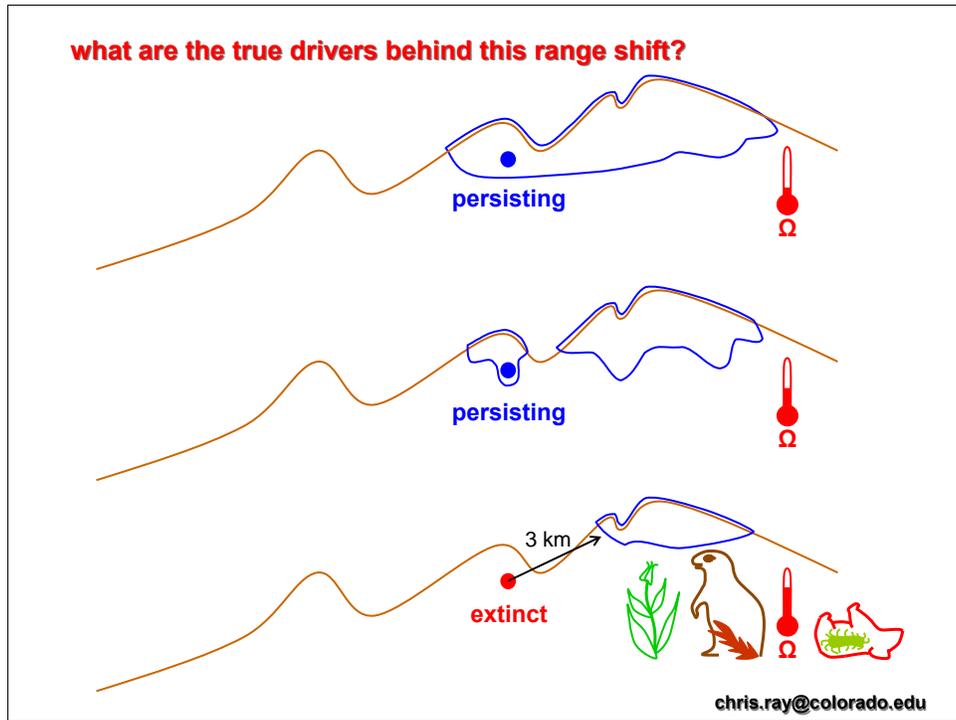


Or, are populations being lost where there's been the greatest climate change? In this case, an interesting possibility is that geographically intermediate habitats could experience the greatest climate change, leading to extinctions right in the middle of what was once suitable range. If some changes were very gradual, pikas may have had time to adapt, whereas rapid changes may cause extinction.



What predicts persistence? These were the predictors with good support...and these pikas represent the relative support for each of these predictors. Acute cold stress had a strong negative effect in models, chronic heat stress had slightly less of a negative effect. Loss of cold days—the only climate-change metric with good support—had a modest effect. And acute heat stress had a minor negative effect on persistence.

A final caveat is that...Although our stress metrics and thresholds were based on numbers in the literature regarding direct effects of temperature on pikas...



We're not arguing that direct thermal stress is the cause of this range shift. Although the prevailing climate is a good predictor of extinction, extinction may be driven indirectly by effects of climate on the abundance or phenology of forage plants, other animal species or disease agents.

