State of California
Department of Fish and Wildlife

Memorandum

Date: March 5 ~~February 25,~~ 2013

To: Sonke Mastrup
Executive Director
Fish and Game Commission

From: Charlton H. Bonham
Director

Subject: **American Pika Status Evaluation**

The Department of Fish and Wildlife (Department) has prepared the attached status review for the Fish and Game Commission (Commission) regarding the proposal to list the American pika (*Ochotona princeps*) pursuant to the California Endangered Species Act (CESA; specifically Fish and Game Code section 2074.6). The Commission received the petition on August 27, 2007 (which was subsequently amended May 15, 2009, and March 31, 2011). The attached status review represents the Department's final written review of the status of the American pika and is based upon the best scientific information available to the Department. The status review contains the Department's recommendation to not list the American pika as threatened or endangered.

On November 11, 2011, the Commission published notice of its decision to accept the petition to list the American pika under CESA for further consideration. Following the Commission's determination, the Department notified affected and interested parties and solicited data and comments on the petitioned action per Fish & G. Code §2074.4 (see also Cal. Code Regs, Title 14 § 670.1(f)(2)). In addition, the Department commenced its review of the status of the species as required by Fish & G. Code §2074.4 and circulated a draft of the status review for outside peer review as required by Cal. Code Regs, Title 14 § 670.1(f)(2).

The Department finds that projected human-caused climate change as currently predicted based on climatic models and models of the future extent of habitat indicate there may be a reduction in the amount of suitable habitat for the American pika in California by the end of this century (2100). However, the best scientific information currently available indicates it is not in serious danger in the next few decades of becoming extinct throughout all or a significant portion of the species' range in the state, nor by the end of the century should the existing climate change models and predicted trajectory of suitable pika habitat come to fruition.

Yet, the Department also believes it will be imperative for our agency and the scientific community to study and monitor the distribution and abundance of American pika over the next few decades, and as climate change models become more data driven as to species specifics, to be able to better assess the foreseeable future and the need for protections under CESA.

If you have any questions or need additional information, please contact Dan Yparraguirre, Deputy Director, Wildlife and Fisheries Division at 916-653-4673 or Dr. Eric Loft, Chief, Wildlife Branch at 916-445-3555.

Attachment

STATE OF CALIFORNIA
NATURAL RESOURCES AGENCY
DEPARTMENT OF FISH AND WILDLIFE

REPORT TO THE FISH AND GAME COMMISSION

STATUS REVIEW OF THE AMERICAN PIKA (*Ochotona princeps*) IN CALIFORNIA

CHARLTON H. BONHAM, DIRECTOR
CALIFORNIA DEPARTMENT OF FISH AND WILDLIFE
February 25, 2013

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Report to the Fish and Game Commission

Status Review of the American Pika in California

February 25, 2013

Executive Summary

Pursuant to CESA, the Department has prepared this status review report and recommendation to the Fish and Game Commission to inform its decision whether to designate the American pika (*Ochotona princeps*) as an endangered or threatened species under CESA. The primary threat to the continued existence of the species is considered to be future climate change, which may reduce the area available as suitable habitat for the American pika in California. Conversely, some data suggest the American pika may be able to contend with a generally warmer and drier future climate. The species is currently widely distributed in California and is thought to occur at relatively high population numbers. Although climate change has occurred and will continue to occur, the American pika has existed in western North America for millennia, during a period characterized by repeated periods of warming and cooling, suggesting the species may be able to persist during projected future changes.

The American pika is a small mammal in the Order Lagomorpha. There are five currently-recognized subspecies of American pika; the one subspecies occurring in California *Ochotona princeps schisticeps*, also ranges into the Great Basin ranges outside California. The American pika occurs in most of the western United States and the Canadian provinces of Alberta and British Columbia. In California, it is found from the Oregon border south through the Cascade region to Tulare and Inyo counties in the Sierra Nevada. The pika inhabits the range above the mid-montane conifer belt in California's Sierra Nevada and other high elevation mountain ranges. Although often considered to be rare below 2,500 m elevation in California, American pikas have been reported at multiple locations below that elevation in the southern portion of their range, and in northeastern California they have been found as low as 1,250 m in elevation. The pika primarily lives in high-elevation patches of talus with adjacent herbaceous or shrub vegetation, as well as in old lava formations.

American pikas are predominantly diurnal, although during hot weather they may adjust their daily activity pattern to avoid excessive heat. Pikas are territorial and their populations in many locations function as metapopulations. Dispersal by pika from a population is generally believed to be more likely at high-elevation (cooler) sites than at warmer low-elevation sites.

The pika is herbivorous and engages in both feeding and haying (haypiling) while foraging. Haying is the caching of food for later consumption. The pika harvests herbaceous vegetation or tall grasses for storage in hay piles, which allows them to survive harsh winters.

American pikas behaviorally thermoregulate in response to high ambient temperatures by reducing activity on warm days or during mid-day hours. The American pika does not hibernate but remains active throughout the winter, using cover to abate the effects of extremely cold

temperatures and to access stored food. High temperature is a primary factor controlling the initial dispersal success of juveniles, primarily at low-elevation sites. In general, temperatures within the rock matrix of talus fields have been found to be lower and less variable than on the surface of the talus in the summer. Generally, winter temperatures within talus are warmer than the external air.

The population size for the American pika in California is uncertain. However, resurveys of distribution at historically-occupied pika sites have been conducted in several areas in California, as well as in the Great Basin ranges of Nevada. In California, these studies have found pikas occupying some but not all of the historical sites. A recent meta-analysis of several resurvey projects found that the amount of talus habitat in the vicinity of the historical site had the strongest ability to predict whether pikas still occupied the site. However, elevation was another significant factor, with low elevation sites more likely to have lost pikas than high elevation sites.

Because of the American pika's thermoregulatory characteristics, it has been suggested that several climate change effects could threaten the continued existence of the species, including mortality and stress associated with increasing temperatures; changes in foraging and dispersal behavior; mortality and stress associated with more extreme cold in the winter; changes in nutrient and water availability in forage plants; increased competition or predation; and combined effects of all these factors.

A number of modeling studies have projected the future climatically-suitable habitat for American pikas in California and elsewhere in its range. These studies found that temperature variables were good predictors of the current distribution of pikas and that future habitat suitability under standard climate change scenarios would be substantially reduced. Although fairly consistent in their results, these studies do not typically consider aspects of a species' ecology other than the apparent correlations of species occurrence with (typically) coarse-scale climate variables. Nor do the models consider the capacity of the species to behaviorally or physiologically adapt to different climatic conditions. Additionally, the studies do not consider changes in human adaptation that could influence the model projected climate change.

Other potential indirect effects on pikas due to climate change, such as how climate change may affect disease dynamics and predator-prey relations are unknown. Livestock grazing near talus habitat may affect pika habitat and cause pikas to change their foraging behavior. Mining may disturb or directly injure pikas. However, these potential impacts are not clearly understood.

A number of survey studies on American pikas in California and elsewhere have explored the relationships between pika occurrence and climate variables. Although climate has been implicated in recent loss of pikas from some historically-occupied sites in some studies, other studies have not found such a pattern.

Based on projections of future habitat suitability for the American pika in California, the Department considers future impacts of projected climate change to be a potentially serious threat to the continued existence of the American pika in California by the end of the century.

Other factors, such as overexploitation, predation, competition, and disease, are not considered by the Department to be a serious threat.

The Department provides this report to the Commission based upon the best scientific information available pursuant to Fish and Game Code section 2074.6. The best scientific information available indicates to the Department that the petitioned action is not warranted. Also included in this report is the Department's preliminary identification of habitat that may be essential to the continued existence of the species, and suggestions regarding management activities and other recovery actions that may benefit the species.

Report to the Fish and Game Commission

Status Review of the American Pika in California

February 25, 2013

INTRODUCTION

The status review report addresses the American pika (*Ochotona princeps*), which is the subject of a petition to list the species as endangered or threatened under the California Endangered Species Act (CESA) (Fish & G. Code, § 2050 et seq.). The petition (Wolf et al. 2007, as amended) and the Department of Fish and Wildlife (formerly Department of Fish and Game) evaluation of the petition (CDFG 2011) noted several potential threats indicating the need to list the species under CESA may be warranted. The primary threat to the continued existence of the species is considered to be future climate change, which may reduce the area available as suitable habitat for the American pika in California. Increased summer temperatures and reduced snowpack in the future would challenge the pika's ability to survive and reproduce. Climate change may adversely impact the vegetation occurring near the broken-rock habitat used by pikas for cover. And climate change may also interact with other factors to exacerbate threats from disease, competitors, predators, and human activities that may degrade pika habitat quality, although the future effects of these factors are uncertain.

Conversely, data from a long-term study site in California suggests the American pika may be able to use behavioral and physiological mechanisms to contend with a generally warmer and drier future climate (Smith 2012b). The species is currently widely distributed in California and is thought to occur at relatively high population numbers, which may provide a reservoir of adaptive capacity for the species in the future. Pursuant to CESA, the Department has prepared this status review report and recommendation to the Fish and Game Commission to inform its decision whether to designate the American pika as an endangered or threatened species under CESA.

Human-caused climate change is a scientifically accepted fact (AMS 2012), and projected climate change is recognized as a significant threat to the natural resources of California (DFG 2011). Warming of global temperatures due to increased atmospheric greenhouse gas levels has been observed and is expected to continue in the future (IPCC 2007). Such general patterns of warming also affect other climate characteristics, such as precipitation patterns (Cayan et al. 2012). The effects of human-generated greenhouse gas emissions overlay and interact with natural climate change processes, which occur on timescales of years to millennia (AMS 2012). For example, the warming of the 20th century has been attributed to a combined effect of natural climate drivers (reduction in volcanic aerosols and longer term (ca. 1,400 year) solar changes known as "Bond cycles", interacting with decadal modes such as the Pacific Decadal Oscillation); accelerated warming in the late 20th century and into the present century shows the increasing influence of anthropogenic GHG emissions (Millar and Brubaker 2006, Millar personal communication 2012). However, some of the fluctuations in temperature in western North American during the past 10,000 years have been at rates and magnitudes that exceed those projected to occur during the next several decades (Millar and Brubaker 2006).

Natural climate change in the past has dramatically affected the wildlife communities and ecosystems of western North America. The fragmented contemporary distribution of the American pika is largely the result of the warming and drying of climate that occurred at the end of the Pleistocene and early Holocene several thousand years ago (Grayson 2005). Recent and on-going climate change has also been implicated in American pika range contractions in the Great Basin in the past few decades (Beever et al. 2003, 2008, 2010, 2011). Future climate change is predicted to continue to contribute to the shifts in the geographic range of species of plants and animals (Grabherr et al. 1994, Burns et al. 2003, Breshears et al. 2008). Species occurring in montane and alpine habitats may be susceptible to extinction if suitable habitat shifts upward in elevation due to climatic changes to the point where insufficient area is available to maintain the species or where other physical factors (such as soil depth) limit the species' distribution. McDonald and Brown (1992), in their analysis of future elevation shifts of small mammals in Great Basin mountain ranges, predicted the American pika to be one of two small mammal species most likely to go extinct first in that region due to climate change.

Work by Barnosky and Kraatz (2007) on the paleontological record of mammals in western North America suggests that current rates of climate change are far too fast to influence the evolution of these species. In general, the predicted continued effects of future climate change are likely to lead in many cases to extinctions rather than adaptation or the evolution of new species. However, as a widely-distributed and relatively abundant species with the ability to change behavior to accommodate changes in the environment, the American pika may not be impacted to the degree some models would predict, and the species has weathered historical periods of abrupt global climate warming (increases of as much as 10° C over periods of 3 to 40 years (Steffenson et al. 2008)) in the past.

Determining whether the American pika is threatened with becoming endangered or extinct due to climate change requires the Department to consider model-based forecasts of unknown accuracy, which are based in part on the uncertain extent and timing of climate change effects. Further, the projected effect of climate change on the American pika is also model-based. The effects of the most negative model-based predictions suggest that the American pika may face a substantial reduction in habitat suitability in California by the end of the current century. The Department is also informed by the studied responses of organisms to past climate change events, although whether past responses are predictive of future changes is also uncertain. The American pika has existed in western North America for millennia, during a period characterized by repeated periods of warming and cooling (Millar and Brubaker 2006), suggesting that the species may be able to persist during projected future changes.

Petition History

The Center for Biological Diversity (Petitioner) submitted a petition to the Commission on August 21, 2007, to list the American pika (*Ochotona princeps*) as a threatened species, pursuant to CESA. As an alternative, the Petitioner asked that the Commission list each of the then recognized five subspecies of the American pika occurring in California as, variously, either endangered or threatened species. The Commission received the petition on August 22, 2007. The Commission referred it for evaluation to the Department on August 30, 2007.

On September 12, 2007, the Department asked the Commission to grant the Department an additional 30 days, for a total 120 days, to evaluate the petition pursuant to Fish & Game Code section 2073.5. On October 19, 2007, the Commission granted this request.

The Department evaluated the petition, using the information in that document and other relevant information available at that time, and found that the scientific information presented in the petition was insufficient to indicate that either of the petitioned actions may be warranted. That is, the Department found at the time that the petition did not provide sufficient scientific information to indicate that the following actions may be warranted: 1) State listing of the pika as a threatened species, or 2) State listing of any of the five subspecies of the pika occurring in California as, variously, either endangered or threatened species. The Department's review of additional scientific information supported these findings. The Department recommended in its December 21, 2007, evaluation report to the Commission, pursuant to Fish and Game Code section 2073.5, subdivision (a), that the Commission reject the petition.

On April 10, 2008, the Commission determined that the petition provided insufficient information to indicate the petitioned action may be warranted. On June 24, 2009, the Commission set aside its April 10, 2008 decision, and again determined that the petition did not provide sufficient information to indicate the petitioned action may be warranted. The Petitioner challenged the Commission's actions on both occasions in related litigation. As a result of the litigation, the Commission reconsidered Petitioner's petition to list the American pika as threatened or endangered under CESA, including a new submission by Petitioner dated May 15, 2009. The Commission treated the petition, including Petitioner's new submission, as an amended petition pursuant to Fish and Game Code section 2073.7, and also determined the amendment to be substantive. At its February 3, 2011 meeting, the Commission transmitted the amended petition to the Department for review.

The Petitioner submitted another comment letter to the Commission on March 31, 2011. The Commission voted at its May 4, 2011, meeting that the March 31, 2011, letter submitted by the Petitioner amounted to yet another substantive amendment of the petition. The Commission indicated in a memorandum to the Department dated May 13, 2011, that the Department's evaluation report should be submitted to the Commission on or before August 2, 2011.

On June 27, 2011, the Department requested that the Commission grant the Department an additional 30 days, for a total 120 days, to evaluate the amended petition, pursuant to Fish and Game Code section 2073.5, subdivision (b). On August 3, 2011, the Commission granted this request. The Department submitted its initial evaluation of the amended petition to the Commission on August 23, 2011, with a recommendation to reject the petition. At the October 19, 2011, Commission meeting, the Department presented a summary of its evaluation of the petition. At that meeting, the Department Director presented a new recommendation to the Commission, indicating the Commission should accept the petition, designate the American pika as a candidate species under CESA, and direct the Department to conduct a 12-month review of the status of the species in California. The Commission voted to accept the petition based on its determination that there was sufficient information to indicate that the petitioned action may be warranted. On November 11, 2011, the Commission published notice of its findings to accept the amended petition for further review under CESA, as well as notice of the

American pika's designation as a candidate species under State law (Cal. Reg. Notice Register 2001, No. 45–Z, p. 1826).

Department Status Review

Following the Commission's action to designate the American pika as a candidate species, the Department solicited the scientific community, land managers, state, federal and local governments, mining and agricultural industries, conservation organizations, and the public for relevant information, and undertook a status review of the species in California based on the best scientific information available. This report reflects the Department's scientific assessment to date of the status of the American pika in California. The Department primarily relied on published, peer-reviewed scientific papers, but also considered information presented in academic theses, information presented at scientific symposia, unpublished reports, and personal communication when information on a specific topic was not available in a published, peer-reviewed source, or to supplement information from published sources. The report has also undergone independent peer review by scientists with acknowledged expertise relevant to the status of the American pika. A list of the experts providing scientific peer review of this report and the Department's related analysis, along with the specific input provided to the Department by the individual peer reviewers are included as appendices to this Status Review report.

SPECIES DESCRIPTION

The following description of the American pika follows the Mammalian Species account prepared by Smith and Weston (1990) from original sources, with additional information from Burt and Grossenheider (1976). The American pika is a small mammal, in the Order Lagomorpha (pikas, rabbits, and hares), with a somewhat egg-shaped body and with short legs. The American pika's tail is short and not externally apparent. The round ears are small relative to rabbits and hares, originate from a point behind and below the eyes, and are haired on both surfaces. Body pelage color may be grayish, buffy, or brown. The fore and hind limbs are of similar length, and the hind feet are relatively short compared to those of rabbits and hares. The soles of the feet are densely furred except for the pads at the end of each toe. The forefeet have five toes and the hind feet have four toes. Adult body length ranges from 162 to 216 mm, hind foot length ranges from 25 to 35 mm. Average body mass is about 150 g. Males and females typically are similar in size, with males sometimes slightly larger than females.

GEOGRAPHIC RANGE AND DISTRIBUTION

The geographic range of the American pika includes all of the 11 western United States, except Arizona, and the Canadian provinces of Alberta and British Columbia (Smith and Weston 1990, see Figure 1).

In California, the American pika is found from the Oregon border south through the Cascade region to Tulare and Inyo counties in the Sierra Nevada (Bailey 1936). Generally an alpine and sub-alpine species, the pika inhabits this range above the mid-montane conifer belt in California's Sierra Nevada and other high elevation mountain ranges. In California, near the southern limit of their range, Smith and Weston (1990) state that American pikas are seldom found below about 2,500 m elevation; however, Millar and Westfall (2010) have reported multiple pika locations below that elevation, and in northeastern California American pikas have been found as low as 1,250 m in elevation (Ray and Beever 2007, Jeffress et al. in press). Minimum elevation limits for American pikas tend to decrease on a gradient from south to north and from east to west within the species' geographic range (Hafner 1993). The pika primarily lives in high-elevation patches of talus with adjacent herbaceous or shrub vegetation. The species also is found in lava formations (Beever 2002, Rodhouse et al. 2010). The pika remains in its habitat year-round. Fossil evidence from other parts of the American pika's range has been interpreted by some researchers to indicate that they were not restricted to talus and other rocky habitats during prehistoric periods with relatively cool summer temperatures (Mead 1987); however, others believe the evidence is not strong enough to support this hypothesis (Hafner 1993).

Figure 1 depicts the Department's current geographic range for the American pika as delineated using California Wildlife Habitat Relationships System methods. The Department periodically reviews and revises such range maps based on available distribution and other information for all of California's terrestrial vertebrate species. Within the large polygons depicting the pika's range, the Department expects that much of the area is not occupied by pikas due to absence of suitable landform (talus or other broken rock habitat), suitable vegetation, other conditions necessary for survival, or simply because pika populations, like other wildlife, may not occupy all suitable habitat within their range due to other factors limiting their area of occupancy. These factors may include a lag between local extinctions and recolonization of suitable patches.

Figure 2 depicts the output from a MaxEnt model (Phillips et al. (2006) prepared by the Department. The model predicts probability of occupancy of American pikas ranging from low (light blue) to high (red) probability. The model used 19 bioclimatic variables as well as elevation, aspect, and slope. The distribution of high probability areas is patchy throughout much of the geographic range of the American pika in California. Additionally, within the mapped areas pika distribution would be expected to be limited to those areas with suitable substrates (e.g. talus). Some areas known or strongly suspected to be outside the species distribution are included by the model based on suitable climatic and geographic conditions (e.g., Mount San Jacinto in southern California and the Trinity Alps in northwestern California).

TAXONOMY

The pika is a mammal in the Order Lagomorpha, which includes rabbits, hares, and pikas. The Family Ochotonidae consists of about 29 species of pika worldwide (in North America, Europe, and Asia) (Wilson and Reeder 2005). There are two species of pika in North America: the collared pika (*Ochotona collaris*), which occurs in Alaska, Yukon territory, and British Columbia, and the American pika (Smith and Weston 1990).

Until recently, the American pika was considered to consist of 36 subspecies. These subspecies have been shown to belong to five distinct evolutionary lineages (Galbreath et al. 2009, Hafner and Smith 2010), which have been designated as subspecies (Hafner and Smith 2010). The five formerly recognized California subspecies are now regarded as one subspecies, *Ochotona princeps schisticeps*, which ranges from the Sierra Nevada and southern Cascades in California and Oregon through many of the Great Basin ranges in Nevada to the Utah border. Figure 3 (from Hafner and Smith 2010) depicts the general ranges of the revised subspecies. The Department has adopted the new taxonomy for the American pika, as did the U.S. Fish and Wildlife Service in its status review of the American pika for the federal Endangered Species Act petition (USFWS 2010).

Although all five former California subspecies are now considered one subspecies, the older literature and some recent studies refer to the traditional subspecies. Distributed from north to south, the traditional subspecies in California were the Taylor pika (O. p. taylori), grayheaded pika (*O. p. schisticpes*), Yosemite pika (*O. p. muiri*), Mt. Whitney pika (*O. p. albata*), and White Mountain pika *(O. p. sheltoni*). Of these, only the Mt. Whitney pika was endemic to California. The Taylor pika ranged into Oregon, and the other three traditional subspecies ranged into Nevada (Hall 1981).

LIFE HISTORY

Territoriality and Dispersal. Mature individual American pikas are territorial and remain within their territories year round and adjacent territories are usually occupied by members of the opposite sex (Smith and Weston 1990). Pikas den and nest beneath the talus and generally do not dig burrows (Smith and Weston 1990), though Markham and Whicker (1972) documented that pikas can dig burrows while in captivity and observed that “pikas may be capable of enlarging den and nest sites by digging.”

American pikas are predominantly diurnal, although they are also known to be active at night (Smith 1974a). During hot weather, pikas may adjust their daily activity pattern to avoid excessive mid-day and late afternoon heat loads (Smith 1974a). An individual may spend up to one-half of its waking time perched on a prominent boulder for surveillance (Smith and Ivins 1984). Most activity is associated with foraging and haying, and infrequently when defending territories with aggressive behavior such as fights or chases (Smith and Ivins 1984).

Because pikas are territorial, populations are limited by available habitat. Juveniles either disperse or settle near their birth territory depending on density-related social behaviors. Due to the patchy distribution of suitable broken rock habitat, pika populations in Bodie, California (Smith and Gilpin 1997) and many other locations function as metapopulations. A metapopulation is a collection of spatially separated populations which interact through animal migrations and dispersals; and within which patches of suitable habitat experience colonizations and extinctions. Accordingly, populations are relatively stable compared to other lagomorph species (Southwick et al. 1986). Because adult pikas are relatively long-lived, vacancies in territories may occur rarely, which would force juveniles to disperse long distances. Although Tapper (1973) observed an individual ear-tagged American pika successfully move 3 km to a vacant talus patch, such long-distance dispersal is difficult due to aggressive behavior of adults already established in saturated habitat and because dispersing juveniles may encounter predators and environmental temperatures that are too high to tolerate (Smith 1974a, Smith and Ivins 1983, Smith and Gilpin 1997). Most juveniles of a small marked population that successfully established territories moved less than 50 m from their birth territory (Smith and Ivins 1983).

Generally, it is thought that long-distance dispersal is easier for pikas living at high-elevation (cooler) sites than at low-elevation (warmer) sites (Smith 1987).

Work on pika population genetic structure by Peacock (1997), Meredith (2002), and Henry and Russello (2012) in the Sierra Nevada, central Great Basin, and British Columbia, respectively, has established that American pikas can readily disperse up to 3 km between sites, with limited ability to disperse further in some cases. Henry and Russello (2012) noted no genetic exchange between sites more than 10 km apart, suggesting the limit on dispersal distance is between 5 km and 10 km.

Because pikas have specific temperature and habitat requirements, they have been considered to be confined to habitat patches in areas having short summers, long winters with most of the days below freezing temperatures, and high annual rainfall. Meredith (2002), in a genetic analysis of American pikas in two connected mountain ranges of northeastern Nevada, found considerable gene flow between all sites sampled. She characterized the pikas in her study to be excellent at dispersing between highly fragmented talus habitat, but found that low elevation habitat between mountain “islands” is a complete dispersal barrier. Peacock (1997) reconstructed the long-term (multigenerational) dispersal patterns in American pikas using both direct and indirect methods (field surveys and DNA analysis) to determine the driving forces for dispersal. Contrary to the common characterization that pikas tend to settle near their birth territory, Peacock’s genetic analyses showed that nearby individuals were not closely related. She concluded that pika dispersal is primarily driven by the competition for territories.

Foraging and Haying. The pika is strictly herbivorous and engages in two different types of foraging: feeding and haying. Haying (or haypiling) is the caching of food for later consumption. The pika harvests herbaceous vegetation or tall grasses for storage in hay piles. Storing food through haying during the summer allows pikas to survive the harsh, prolonged winters of high-elevation habitats. Pikas are generalist herbivores and consume and cache plant species according to their nutritional content, relative abundance, and proximity to talus cover. At low elevation sites, pikas have been found to select plants with higher water content (Smith and Erb 2012). Thus, haypile composition and foraging patterns vary widely between populations in different geographical areas and even between individuals within the same population (Broadbooks 1965, Conner 1983, Beever et al. 2008).

American pikas generally consume grasses where they are available and store more chemically complex plants such as forbs and shrubs for winter consumption (Huntly et al. 1986, Dearing 1997a, 1997b). This may be in part because grasses can be more nutritious when consumed immediately, while many forbs contain toxic chemicals that prohibit immediate consumption. These plant chemicals partially break down in the haypile over winter and the stored plants improve in nutritional value before they are consumed (Dearing 1997a, 1997b). Where grasses and forbs are unavailable pikas have been observed to build haypiles comprised entirely of coniferous foliage (Millar, pers. comm.).

Smith and Erb (2012) found pikas showed evidence of selecting for plants with higher nutrient content under warm temperature conditions. Additionally, they found evidence of selection for plants with higher water content at lower elevation sites.

Haying also affects the American pika's habitat. Aho et al. (1998) determined that haypiles degrade over time and form nutrient-rich soils in otherwise barren talus and scree fields. These soils had higher nitrogen and carbon levels, as well as higher nitrogen-to-carbon ratios, than non-haypile soils. Plants growing in these soils had greater biomass and, in some cases, higher nitrogen content than plants growing in non-haypile soils. Pika foraging also directly affects meadow vegetation in their habitats. Huntly and her coauthors (Huntly et al. 1986, Huntly 1987) studied the influence of pika herbivory on subalpine vegetation in Colorado. They found that as distance from the talus field increased, total vegetation removal by pikas decreased, the percent vegetation cover increased, and plant species richness increased. American pikas are considered ecosystem engineers because of their effects on soils and vegetation (Aho et al. 1998).

Vocalizations. American pikas vocalize and use scent-marking to advertise territories and perhaps to attract mates. Vocalizations are also made in response to the presence of predators. Conner (1983) found that American pikas can discriminate between vocalizations recorded from their own population versus recorded from distant populations, and that pikas were more attentive to vocalizations from their own populations. Trefry and Hik (2009) noted that collared pikas responded differently to the calls of other pikas than they did to the warning calls of marmots and ground squirrels. Vocalizations are also elicited by the presence of predators such as weasels, martens, and ravens (Smith and Ivins 1983, Millar pers. comm. 2012).

Vital Rates and Reproductive Biology. American pikas are relatively long-lived for small mammals. Adult annual survival rates for mature pikas normally exceed 50% per year. In the Bodie population , for example, Smith (1978) found that almost 10% of the population was 5 or 6 years old.

Smith and Gilpin (1997) described the reproductive capacity of American pikas as follows : "Throughout the range of the American pika, all females, including all yearlings, initiate two litters per summer breeding season and successfully wean only one of these litters (Smith 1978, Smith and Ivins 1983). Litter size (determined from embryo counts of pregnant females) is relatively small for a lagomorph and averages 3 throughout the range of the American pika (Smith and Weston 1990). Weaned young grow rapidly and reach adult size in their summer of birth. "

Thermoregulation. American pikas behaviorally thermoregulate in response to high ambient temperatures by reducing activity on particularly warm days or mid-day hours (MacArthur and Wang 1974). The species has a high body temperature, high insulation value, and low upper lethal temperature relative to other small mammals (MacArthur and Wang 1974, Smith 1974a). Individuals may seek out cool refuges, in particular talus interiors, but also rock crevices, cooled lava tubes, and caves to avoid heat stress during periods of high temperature. Smith (1974a) found that the surface activity of pikas at low elevations was minimal during midday in the summer when ambient temperatures were high, while pikas were active throughout the day at higher elevation sites and at the lower sites when temperatures were cooler. Similarly, Massing (2012) found that daily activity patterns differed between higher elevation sites and lower elevation sites. Pikas at lower elevations were more active at dusk and dawn and less active during the day than pikas at higher sites. As discussed below, curtailed daytime activity due to warming temperatures may not leave individual pikas enough time to prepare haypiles of adequate size for pikas to survive the winter in good condition, potentially leading to reduced survival and reduced reproduction (Wilkening et al. 2011). Consequently, pika populations forced to curtail daytime activity may be less able to produce young capable of dispersing successfully (Wilkening et al. 2011). However, this hypothesis has been challenged by the success of American pikas at warm low-elevation sites (Smith 1974a, 1974b).

The American pika does not hibernate but remains active throughout the winter, using cover to abate the effects of extremely cold temperatures and to access stored food. High temperature is a primary factor controlling the initial dispersal success of juveniles, primarily at low-elevation sites (Smith 1974b). At higher elevation, temperature may not be as much of a limiting factor to dispersal success. Pikas are well adapted to their cold alpine environments, with thick fur to protect them from excessive heat loss. However, this adaptation makes the species vulnerable to acute heat stress. Pikas that were experimentally caged (and thus denied the ability to retreat into talus or other cool refuges) died at ambient temperatures of 25.5° and 29.4° C (78° to 85° F) (Smith 1974a).

Millar and her coauthors (Millar and Westfall 2010, 2012a, 2012c) have used temperature recording devices to characterize the thermal environment of American pikas in and around their talus habitat in the southeastern Sierra Nevada and Great Basin. In general, they have found that internal temperatures within the rock matrix of talus fields are lower and less variable than on the surface of the talus, with summer internal temperatures tending to be cooler lower in the talus field, especially near the talus border, than at higher positions. And, generally, winter temperatures within talus matrix are warmer than the external air. All of these characteristics create a more mild thermal environment for pikas within the talus matrix than would be experienced on the surface (Millar and Westfall 2010, 2012a, Millar et al. 2012).

Millar and Westfall (2010) also demonstrated an association of American pikas in the eastern Sierra Nevada and Great Basin with rock-ice features (RIF). These features, which include rock glaciers and boulder stream landforms, have thermal characteristics that may make the interstices (spaces between rocks) used by pikas for cover even more cool than surface temperatures during the summer, and cooler than interstices in talus fields without RIFs. The authors also showed that, in some cases, talus RIF matrices are warmer than the surface during winter.

Predation. Smith and Weston (1990) summarized the information about predators of the American pika as follows: “Potential predators of American pikas include coyotes (*Canis latrans*), longtail weasels (*Mustela frenata*), shorttail weasels (*M. erminea*), and martens (*Martes americana*) (Ivins and Smith 1983)… Larger predators are less successful than weasels in their ability to capture American pikas; weasels can follow American pikas into the talus interstices where coyotes and martens cannot go (Ivins and Smith 1983). All American pika skulls found in coyote scats by Krear (1965) were juveniles, indicating young animals are vulnerable to predation and may be caught while trying to disperse between patches of talus. A variety of predatory birds occur in the habitat of American pikas, but these probably do not kill many individuals (Krear 1965, Severaid 1955).”

Forsman et al. (2004) noted the infrequent but not uncommon occurrence of American pikas in the diet of northern spotted owls (*Strix occidentalis caurina*) in portions of the owl's range where pikas occur. Rattlesnakes (*Crotalus* sp.) have also been suggested as potential predators of American pikas.

Markham and Whicker (1972) documented that pikas are most commonly found near the interface between talus fields and adjacent vegetation. Pikas presumably depend on the rocks as cover to avoid predation. The farther they travel from the rocks, the more vulnerable they likely are to predation, which would be particularly significant while juveniles are dispersing and while individuals are foraging beyond the talus-meadow interface.

HABITAT ESSENTIAL FOR THE CONTINUED EXISTENCE OF THE SPECIES

American pikas in California and elsewhere are found in close association with broken rock habitats. These include natural habitat types such as montane talus fields and old lava flows. Human-created rocky areas such as old ore-dumps at mining sites are also used (Severaid 1955, Smith 1974a, 1974b). Manning and Hagar (2011) noted that, similar to the human-made habitat for pikas found in mining ore-dumps, the creation of rock quarries, road cuts, and rip rap may also create pika habitat. Ernest et al. (2011) found pikas inhabiting construction rubble at bridge and highway sites. Other types of habitat observed in California include: eroding bedrock outcrops (e.g., tors and inselbergs), crevices and cracks in bedrock, lava cones, road and trail armaments (rip-rap) and abandoned stone houses (Millar and Westfall 2010).

Robert Klinger of the U.S. Geological Survey (pers. comm. 2012) found that pikas in the Sierra Nevada and White Mountains occurred on all but the steepest slopes and on a wide range of slope aspects. Vegetation in and around the talus patches where pikas were found varied greatly and included conifer stands (though rarely dense forest), shrub patches, meadows, and areas with a mix of different types. Millar (personal communication 2012) noted pikas in taluses adjacent to montane desert scrub in the White Mountains.

Kreuzer and Huntly (2003) studied the habitat-specific vital rates of a pika population in the Beartooth Mountains of Wyoming. Their study included both source and sink populations. Population size was consistently higher in meadow habitat (which generally occurred on slopes and with predominantly forb vegetation) than in snowbed habitat (which occurred in low-lying depressions and was usually dominated by sedges). Effective fecundity was higher in meadows than in snowbeds, and also fairly consistent over multiple years, whereas fecundity rates were more variable in snowbed habitat. Birth rates in snowbed habitat declined sharply in years when summer snowmelt occurred at later dates, whereas the date of snowmelt had no effect on birth rates in meadow habitat.

CURRENT DISTRIBUTION

Much of the current information on the distribution of the American pika in California is presented under Species Status and Population Trends below. Based on that information, the Department has revised its depiction of the geographic range of the American pika in California, primarily by excising large contiguous areas of lower elevation habitats that were included in previous range maps produced by the Department (see Figure 1 for the Department's current designated geographic range of the American pika). Although new information on the occurrence of American pikas indicates that pikas may inhabit a wider range of habitats and elevations than previously described (Millar and Westfall 2010a; but see also Wolf 2010, Millar and Westfall 2010b), inclusion of some of the very low areas on previous maps was not supported.

Analysis by the U.S. Fish and Wildlife Service (USFWS 2010) for the federal status review of the American pika determined that habitat for the subspecies (*Ochotona princeps schisticeps*) occurring in California is largely on federal land, with a majority of its habitat in the Sierra Nevada of California. Throughout its range in California, Nevada, Oregon, and Utah, more than 95% of the geographic range for the *schisticeps* subspecies is comprised of federal land, and nearly half is designated as wilderness (USFWS 2010). Approximately 64% of the *schisticeps* geographic range exists in the Sierra Nevada, with the remainder in the southern Cascades and mountain ranges of the Great Basin (Finn 2009, in USFWS 2010).

The ownership pattern within California is depicted in Figure 4. Table 1 presents area by ownership type within the revised geographic range of the American pika in California. Federally designated Wilderness is located within lands owned by the U.S. Forest Service, National Park Service or Bureau of Land Management.

Table 1. Area by ownership type within the California range of the American pika.

Ownership Type	**Km^2**	**Percent of Total Range Area**
U.S. Forest Service	36,183	58.2%
National Park Service	6,455	10.4%
Bureau of Land Management	6,411	10.3%
DFG Fee Titled Lands	335	0.5%
CA State Parks	88	0.1%
Other and Private	12,722	20.5%
Total (excluding Wilderness)	62,193	100.0%
Wilderness (subset of federal lands)	9,682	15.6%

Figure 1 also depicts all the localities for which the Department has information on American pika occurrence in California. These locations include museum specimens and reliable observation dating from the late 19th century through early 2012. These locations include information from survey work conducted in the last few years. The locations are color-coded by date of observation; that is, either prior to or after 1980. The year 1980 was chosen as a cut-off because anthropogenic climate change became prominent in many datasets after that date (Erb et al. 2011). In some cases, historically-occupied sites have been resurveyed and found to be recently unoccupied. In other cases historically-occupied sites remain occupied.

Ongoing research by the USGS has found that pikas are distributed widely throughout the alpine and subalpine zones of the Sierra Nevada, although they are somewhat more common in the southern Sierra Nevada than the central and northern Sierra (Klinger pers. comm. 2012).

The new locations from the USGS work were not available to be included in the distribution map, however it is believed they would not modify the overall distribution of pika.

In its extensive sampling, the USGS has not observed pika south of the northern border of the Golden Trout Wilderness (south of Sequoia National Park and the Mount Whitney area), which may be the southern extent of the species' distribution in the Sierra Nevada. Pikas have been detected as low as about 2,130 m (7,000 ft) near the northern end of the USGS study area (Carson-Iceburg Wilderness). Pika density was found to decline above 3,600 m (12,000 ft), which was attributed to vegetation availability rather than temperature (Klinger pers. comm. 2012). Pikas were also found extensively in the White Mountains, with, different from the Sierra Nevada, high densities between 3,600 m and 4,000m (12,000-13,000 ft) and also abundantly through middle elevations, and occupying taluses in eastside canyons to as low as 2,466 m (8,091 ft; Millar and Westfall 2010, Millar pers. comm. 2012). Klinger (pers. comm. 2012) notes that pika distribution varies greatly from area to area and from year to year.

None of the recent survey work (at both historically-occupied sites and new survey locations) has changed the Department's conclusions about the current distribution of the American pika in California. Based on information from the various recent efforts to survey for American pikas, the species appears to be well-distributed throughout its historical range in California.

SPECIES STATUS AND POPULATION TRENDS IN CALIFORNIA

There is little information on population numbers for the American pika in California. As a proxy for changes in population size, conservation biologists often use trend information in the occupancy of suitable habitat or the proportion of the geographic range occupied by a species. One example of this method is the Grinnell resurvey project in Yosemite (Moritz et al. 2008). This study was conducted to see what changes in small mammal distribution occurred during the interval of 100 years between the original surveys conducted by Joseph Grinnell and his colleagues and resurveys conducted in the 2000s. The small mammal surveys were conducted along a series of sites ranging from west to east over the Sierra crest. Several species of montane small mammals exhibited upslope range retractions in the Yosemite study, while other lowland species expanded their ranges upward. Moritz et al. suggested that warming temperatures in the study area since the early 20th century due to climate change was the cause of the range retraction˙ In the case of the American pika, which the resurvey project found to be present at most of the historical sites it had previously occupied, the loss of pikas at one low-elevation site on the west side of the Yosemite transect (Moritz et al. 2008) suggested to some that climate change is already negatively impacting the conservation status of the species. The Grinnell Yosemite transect dataset, though interesting, is insufficient to determine what mechanism caused the loss of pikas from the site, nor when it occurred. Thus, it is not possible to conclude from this one study that climate change has impacted the American pika in the Sierra Nevada.

In California, a number of other survey projects at sites where pikas were found historically and at other suitable habitat patches have shown that pikas have been lost from some sites, but remain at others. The data from five of these California pika resurvey projects have been combined in a meta-analysis, which is presented as a supplemental report in Appendix 1 (Stewart 2012). The results and conclusions of the meta-analysis project are summarized after brief descriptions of individual projects, both resurveys and surveys of new sites, in the following paragraphs.

While resurveys inform our understanding of changing pika distribution, it is difficult to extrapolate population trends from resurveys of species such as the American pika with metapopulation structure due to the dynamics of colonizations and extinctions of individual habitat patches. Between 2001 and 2010, Goehring (2011) attempted to survey all suitable talus patches on Mt. Shasta between elevations of 2,290 and 2,900 m (7,500 - 9,500 ft). Pikas were detected at 28 sites, including six of the seven locations where pikas were reported by C. Hart Merriam in 1899 in his Results of a Biological Survey of Mount Shasta, California. Elevations of the 28 occupied sites range from 2,241 to 2,918 m (7,354 to 9,575 ft).

Jeffress (Jeffress and Ray 2011, Jeffress 2012) reported early results from a National Park Service pika study at eight NPS units in the western United States. Two of the NPS units, Lava Beds National Monument (LABE) and Lassen Volcanic National Park, (LAVO), are located in California. This study involved surveys of 24 m diameter circular plots at randomly-located suitable habitat patches (i.e., not historical pika sites). At the two California park units, site-occupancy at LABE was 15% (n = 76 plots) and at LAVO was 24% (n = 101 plots). The protocol used in the NPS project relies on randomly placed survey locations, unlike historical re-survey projects and other new survey projects, which usually focus on higher-quality habitat patches. Thus, it is not surprising that the NPS surveys result in relatively low site occupancy compared to other projects.

Massing and Perrine (2011) reported on resurveys of historical Grinnell sites on the Lassen transect, plus additional sites in the area. Eleven of 17 (65%) historical pika sites were occupied; 6 of 17 (35%) additional surveyed sites were occupied. One historical site that was resurveyed twice by Massing and Perrine (2011) changed status from unoccupied in year 1 to occupied in year 2 of the study.

Stewart and Wright (2011, 2012) conducted resurveys at 19 historical sites in the Sierra Nevada. Seventeen of the sites were occupied during their study period. The authors combined their field results with climatic and other habitat information for the sites and found the amount of talus within a 1-km radius of the survey plot had a statistically significant effect on whether a site lost pikas (i.e., more talus area reduced the chance of extirpation). The small number of sites in the study limited the analysis, and elevation had a non-significant effect on occupancy although lower sites were more likely to lose pikas than higher sites.

Nichols (2009, 2011a, 2011b) reported on the results of on-going surveys in the Bodie Hills and Bodie State Historic Park in eastern California. Attention has been placed on the Bodie SHP pika population because it has been studied since the 1970s and occurs at a relatively low elevation (2,500 m, 8,200 ft). The Bodie pikas have been studied as a classic example of metapopulation dynamics because the discrete patches of rocky habitat have repeatedly undergone extirpations and recolonizations over several decades (Smith 1980, Smith and Gilpin 1997, Hanski 1998). This population is somewhat unusual in that the broken-rock habitat it occupies consists of mine ore dumps. Pikas apparently moved into the Bodie town site from the surrounding Bodie Hills after mining activity began in the late 19th century. As reported by

Nichols (2011b), Severaid (1955) described the ore-dump sites in the Bodie town site as nearly 100% occupied. By the 1970s, site-occupancy had declined to about 61%, and the southern and middle clusters of sites were completely unoccupied by 2008 and have remained unoccupied to date (Nichols, pers. comm. Smith, pers. comm.. 2012). The northern cluster of sites has exhibited a pattern of abandonment and re-occupancy since the 1970s and currently the percent occupancy is at about where it was when modern surveys began there in the 1970s (Smith 2011b).

Although the American pika population at Bodie has been studied for decades, the factors affecting the pattern of site occupancy and extirpation there are still unclear. Statistical investigations of the relationship between prior-season weather and site occupancy did not reveal any correlation (A. Smith pers. comm., J. Stewart pers. comm.). Habitat patch size and distance to nearest neighbor habitat site affect occupancy, but did not explain the pattern of extirpations within entire neighborhoods of sites (Smith and Gilpin 1997). Spatially-correlated extinction risk, as might occur with a predator that lives within a particular portion of the Bodie town site, has been shown by mathematical simulation to result in patterns of occupancy similar to those actually observed in Bodie (Clinchy et al. 2002). It is uncertain whether interactions between predation effects (causing site extirpations) and warm temperatures (impacting recolonization of extirpated sites) resulted in the current near abandonment of the southern sites at Bodie.

In the Bodie Hills around the Bodie town site, natural talus habitat occurs at greater distances from one another than the ore-dump patches in the Bodie town site. Surveys in the Bodie Hills by Nichols (2011a, 2011b) indicate high occupancy in historical times (determined by the presence of old pika sign, including fecal pellets and urine stains), but nearly complete loss of occupancy in the recent past.

To increase the power of statistical inference from the resurvey projects in California, a meta-analysis has been conducted using the results of five of these projects (Appendix 1 of this report, Stewart et al. 2012). This study analyzed the results from 53 resurveys of historical pika locations (locations where pika presence had been reliably recorded in field notes, museum specimens, literature, and other records dating from the late 1800s through year 2000). Overall, 42 sites were determined to be currently occupied by pikas, while 11 sites appeared to be extirpated. Six of the apparently extirpated sites were located in the Lassen region, three in the Sierra Nevada, and two in the Bodie Hills (natural habitat sites). Across all sites, small talus habitat area was the best predictor of site extirpation. Climate variables were also statistically significant predictors of extirpation, with warmer, drier, and lower-elevation sites more likely to be extirpated. Increased probability of pika extirpation at small talus patches would combine with reduced ability to re-colonize low elevation sites to produce the pattern seen in the meta-analysis.

Stewart et al. (2012) also noted that the lower elevation limits of sites currently occupied by pika in the Sierra Nevada were 320 - 330 m (1,050 -1,083 ft) higher than sites where old pika fecal pellets indicated pika were present in the recent past. (i.e. prior to 2001).

Millar (2011a, 2010a, 2010b) reported on a survey project at both historical and previously unsurveyed habitat in canyon systems of the eastern Sierra Nevada and adjacent ranges, including sites in the western Great Basin (California, southern Oregon, and Nevada. American pikas were found to occupy most of the available habitat and were widely distributed throughout the region. Millar and Westfall (2010a) reported on the first three years of this on-going study and found that pikas use a wide range of sites in terms of elevation and temperature. Contrary to some other published scientific literature the researchers found no consistent pattern in terms of elevation or habitat quality for sites that had lost pikas (as evidenced by old fecal pellets).

In a presentation, Millar et al. (2012) reported the elevation range occupied by pikas in the Sierra Nevada and western Great Basin mountains spans 1,780 m (5,840 ft). Additionally, Millar et al. (2012) stated the density of pikas in their study area was greater than that reported from the central Great Basin.

Another recent study (Collins and Bauman, in press) conducted in the northern Great Basin (outside of California but near the state's northeastern corner) found pikas and their recent sign at several previously undescribed low elevation sites. All of the currently-occupied sites were at elevations below 2,500 m (8,200 ft), with elevations ranging down to 1,810 m (5,940 ft) for currently occupied sites and 1,648 m (5,400 ft) for sites with old sign (dry fecal pellets, dry haypiles). Although outside California, the discovery of these sites provide additional examples of relatively low elevation pikas at latitudes near the northern border of California.

In addition to inferences about the population status of American pikas that may be made from the resurvey work, direct estimates of pika density across a large study region are now available to serve as baselines for future population monitoring work. Klinger (pers. comm. 2012) provided preliminary results from an extensive (1,177 pika observations), multi-year study being conducted in the Sierra Nevada and White Mountains. The study is examining the effects of climate change on the distribution and abundance of several focus mammal species, including the American pika. In the Sierra Nevada portion of the study area, Klinger reported that estimates of pika density from 2008 through 2010 were relatively stable at about 4 individuals per km^2) and that variability (measured by the coefficient of variation, or CV) ranged from 16% to 25%. Almost all of the variability in pika density was due to spatial variation. After the extended winter of 2010-2011 the population in the Sierra Nevada decreased to about 2 individuals per km^2, with a dramatic increase in the CV to 36%.

Klinger (pers. comm. 2012) reported that densities of American pikas in the White Mountains were greater than in the Sierra Nevada (on average about 3 to 4 times more dense) and showed the same general magnitude of spatial and temporal variability. Pika density in the White Mountains in 2008 and 2009 was around 10 individuals per km^2, but the CV was 12% in 2008 and 38% in 2009. Pika density increased almost threefold in 2010 (to 25 individuals per km^2). As in the Sierra Nevada, pika density in the White Mountains decreased after the winter of 2010-2011 (to about 4 individuals per km^2), but this was a spatially variable pattern (CV around 36%).

The relatively high density of pikas at Klinger's White Mountains study area is analogous to the relatively high densities of pikas at Smith's Bodie study area (Smith 1974a). As pointed out by Smith (pers. comm.), both these high-density sites are dry relative to the Sierra Nevada sites to which they are compared. This result is counter to the general understanding that American pikas are best adapted for cool, moist environments.

According to Klinger (pers. comm. 2012), two important points emerge from the density estimates: 1) In years when pika populations are low there are still tens of thousands of pikas in the Sierra Nevada and White Mountain ranges and in years when abundance is high there are well over 100,000 pikas between the two ranges. 2) American pikas in the Sierra Nevada and White Mountain ranges show dynamics that are very typical of many, if not most, wildlife populations. He also describes work conducted to investigate pika habitat changes in the alpine and sub-alpine zone and reports that there is no evidence for habitat degradation there. Klinger also lists the limitations on interpreting the study results at this time: the data are considered preliminary and unpublished and four years of data are insufficient to meaningfully describe trends in population size or density.

Nearest-neighbor distances (which are another way to describe density) for American pikas have been calculated in a number of studies (summarized in Smith and Weston 1990), including at Bodie and at nearby higher elevation natural habitat sites. The estimates from California (Smith 1974a) were obtained in the 1970s and could serve as a useful benchmark for on-going monitoring.

In summary, although little information on population size or trend is available for the American pika in California, concerted efforts have been conducted throughout the state to explore the current distribution of pikas, and on-going efforts should provide information on population trend in portions of the California range in the future. Losses of pika occupancy at some sites have occurred, suggesting that some reduction in population size since historical times may have occurred. But the lack of comprehensive survey data throughout the state or at representative monitoring sites at this time makes it impossible to draw firm conclusions about recent population trends.

FACTORS AFFECTING ABILITY TO SURVIVE AND REPRODUCE

It has long been recognized that the thermal environment may limit the geographic distribution of the American pika. In 1917, Joseph Grinnell (Grinnell 1917) published a general paper discussing the factors affecting the geographic ranges of species. Grinnell outlined the various factors that had been proposed as limiting the ranges of different species, then suggested field biologists could provide the necessary information to describe the particular factors affecting individual species ranges. Based on his experience observing and collecting birds and mammals in California, Grinnell discussed several examples of well-known species to illustrate his thesis. For the pika, Grinnell concluded that availability of talus cover and suitable environmental temperatures limit the lower elevation distribution of the species in California. Grinnell stated the upper elevation limiting factor(s) could not be determined, but are likely either lack of suitable vegetation or unsuitable temperature, or both (Grinnell 1917). Smith et al. (2004) were the first to suggest that pikas could be particularly susceptible to climate change impacts due to sensitivity to high temperatures and distribution in high-elevation habitats. Both of these conclusions are now commonly discussed in the scientific literature, as well as the popular press.

In addition to climate change, this report discusses several other factors that may affect the conservation status of the American pika in California. See the sections below addressing grazing, mining, disease, predation, competition, small and isolated populations, and other risk factors.

CLIMATE CHANGE

Several pathways through which climate change could be negatively impacting pikas have been identified, including:

- mortality and stress associated with increasing temperatures;
- changes in behavior as pikas attempt to adapt to increasing temperature (e.g., curtailed mid-day foraging, shifts to nocturnal foraging exposing pika to nocturnal predators);
- mortality and stress associated with cold temperatures and reduced insulation from declining snow pack;
- reduced survival of dispersing individuals due to heat stress, heat mortality, and changes in food plant availability due to changed growing seasons;
- changes in vegetation community composition at occupied pika sites;
- reduced water content in forage plants;
- changes in competitor (e.g., California ground squirrel (*Otospermophilus beecheyi*) and bushy-tailed woodrat (*Neotoma cinerea*)) and predator (e.g. rattlesnake (*Crotalus* sp.) communities at occupied pika sites; and
- the combined and interrelated effects of all of these pathways (Smith 1978, Beever et al. 2003, Morrison and Hik 2008, Nichols pers. comm. August 5, 2011).

Many authors, when defining and modeling climatically suitable pika habitat reference Andrew Smith's early experiment demonstrating mortality of two caged pikas from exposure to ambient temperatures of 25.5° to 29.4° C (78° to 85° F) (Smith 1974a). Therefore, as temperatures increase with climate change lower elevation and lower latitude sites may become too warm for the pika. Upward shifts in low elevation boundaries of montane species result in rapid losses of available habitat. For example, Wilson et al. (2005) documented apparently climate-driven upward shifts in the ranges of butterfly species in the mountains of Spain and noted that mountaintop species lost 34% of their habitat in just 30 years simply because of the smaller area of the landscape at progressively higher elevations. It is important to note Smith (1974a) concluded that pika survival is based on the pika's ability to behaviorally thermoregulate by retreating to cool spaces within talus. Therefore, ambient temperature alone may not be a reliable predictor of suitable pika habitat.

Smith (1974a) and Massing (2012) also found that on warm days pikas become less active during the day and more active at dusk and dawn at the lower edge of their elevational and latitudinal ranges. Because pikas must spend significant amounts of time foraging and haying due to their high metabolic rate and because they do not hibernate (Huntly et al. 1986, Dearing 1997b), it has been hypothesized that curtailed daytime activity due to warm temperatures may not leave them enough time to prepare haypiles of adequate size to survive the winter in good condition, potentially leading to reduced survival and reduced reproduction (Wilkening et al. 2011). Additionally, Smith (1974a) noticed that haying ceased earlier in the summer at low elevation sites in dry years when vegetation around pika sites became desiccated, which suggests climate changes resulting in drier soils may reduce availability of adequate vegetation and impair pikas' ability to prepare adequate haypiles.

Warming summer temperatures may also reduce the ability of pikas to disperse to unoccupied habitat patches. Smith (1974a) suggested that long distance dispersals lasting more than one day across non-talus habitat may be impeded by warm temperatures at low elevation sites like Bodie. Although the general relationship between warmer temperatures and reduced dispersal follows from the species' thermoregulatory biology, the magnitude of the effect is unknown, as are the relative importance of factors such as variation between populations and effects of substrate, cover, and topographic features.

A predominant effect of climate change on wildlife populations in the Sierra Nevada region will likely result from changes in vegetation communities. Plant species have been shown to generally shift upward in elevation with warming (Breshears et al. 2008). These changes will include increases in the amount of grassland and oak/pine vegetation, and a loss of conifer dominated vegetation, especially at higher elevations (e.g., red fir/lodgepole pine/subalpine conifer). However, as noted by Millar (pers. comm.), the general effect of warming temperatures on mountain ecosystems will likely be much more complicated and varied than a simple upward shift in vegetation. Cold air-pooling, downward shifts in the distribution of some plant species, and the influence of particular hydrologic and geomorphologic conditions on local temperature and vegetation could create conditions in some areas that favor the persistence of the American pika (see Connie Millar's comments on report lines 742-747 for more information).

Vegetation shifts may also be affected by changes in fire severity and frequency (PRBO 2011). As changes occur in vegetation communities, concurrent changes in the associated wildlife communities are expected. These changes are difficult to predict, as some species distributions appear to adapt to vegetation distribution changes and other species distributions appear to remain fixed (Santos et al. 2012). However, community changes could result in increased competition between pikas and other herbivorous species, increased exposure to predatory animals, and increased exposure to disease vectors.

Observed Climate Change to Date

The climate in California and western North America is known to have changed over the past century. For example, Bonfils et al. (2008) estimated average temperature trends in California over the past half century and found an increase in annual-mean average temperature between 0.36° C and 0.92° C (0.6° and 1.7° F), positive trends in daily mean and maximum temperatures for late winter and early spring, and increases in minimum daily temperature from January to September in the second half of the 20th century. These effects were attributed to human-induced climate change.

Gershunov and Cayan (2008) examined heat-wave trends in California using data from 95 weather stations collected between 1948 and 2006. Heat waves, identified from high maximum daily temperatures or high minimum daily temperatures, increased in frequency of occurrence over the study period. Two extreme nighttime heat waves occurred in 2003 and 2006. The authors noted that nighttime heat waves contribute to increased maximum daily temperature and don't provide wildlife the nighttime respite from extreme high temperatures. They concluded that the observed increase in nighttime heat waves is consistent with global climate change and can be expected to continue. The authors also found daytime heat waves to be increasing, with most of the observed increase occurring since the 1970s. The increase is more pronounced at higher elevations than lower, possibly due to decreased snowpack and earlier snowmelt, which lead to drier, hotter summers.

Kapnick and Hall (2009) analyzed snow station data and detected a trend toward earlier peak snow pack in the Sierra Nevada over the period 1930 to 2007, which has shifted 0.4 days per decade since 1930. This shift is associated with an increase in temperatures in March. The authors predict larger shifts toward earlier snowpack peaks as March temperatures continue to rise.

Ray et al. (2010) found that the western United States has warmed about 1° C (2° F) during the past 30 years. Climate stations near pika locations in the Sierra Nevada and western Great Basin and in Oregon show a statistically significant warming trend of 1° to 2.4° C (1.7° to 4.3° F) in the summer during the past 30 years. The authors also found that spring has warmed more than other seasons at many locations in the western United States. The onset of spring has come earlier, by 2-3 weeks, and snow cover, postulated to provide insulation to pikas during extreme cold snaps in the spring, is melting out earlier.

Moritz et al. (2008), in providing context for their Yosemite transect resurvey results, analyzed regional weather records for their study area. Their analysis pointed to a substantial increase in the average minimum monthly temperature of 3.7° C (6.7° F) over the past 100 years, with notable increases from 1910-1945 and from 1970-present.

Taken together, the recent research on climate change during the 20th century indicates that California is already showing increased temperatures, shifts in precipitation patterns, and reduced snowpack during the spring relative to conditions 50 to 100 years ago. However, see the comment by one of this report's reviewers suggesting warming at one low-elevation site over the past century has been minimal (Smith and Nagy 2012, Andrew Smith pers. comm.). Temperatures in western North America have repeatedly fluctuated over the past several thousand years, during which period the American pika has persisted in the region. As summarized by Millar et al (in press), several peer-reviewed studies have estimated that temperature deviations of 2° C and greater (both increases and decreases) from the mid-20th century average occurred during discrete but extended intervals starting approximately 8,000 years ago. The warm interval temperature increases were similar in magnitude to the observed and projected 20th and 21st century temperature increases. Although such increases no doubt affected the distribution and abundance of the American pika during pre-historic warm periods, the species did persist and probably expanded its range during subsequent cooler periods.

Evidence of Climate Change Impact on Pika

Morrison and Hik (2008), in a 10-year study of a Yukon population of collared pika (*Ochotona collaris*) documented a 90% reduction in population size in the period from 1998 to 2000. The decline occurred across the entire study area and did not appear to be related to biotic factors such as disease, food resources, or predation. The authors hypothesized that the decline was related to warmer winters, increased frequency of freeze-thaw events, icing following winter rains, and late winter snowfall. The population began to recover in the last few years of study, but by the publication date for the study (2008) had not returned to the levels observed at the start of the study. As of 2010, however, the population was “fully recovered” according to discussion between one of the study’s co-authors, David Hik, and a reviewer of this report (Andrew Smith, peer review).

In an unpublished manuscript, Loarie et al. (2009) presented a study of American pika extirpations throughout its range in North America. In that study, the univariate mean annual temperature was the best model to predict the loss of pikas at a site. The strongest correlation with pika extirpations was increasing mean annual temperature at pika sites.

Trook (2009) modeled pika habitat suitability using current climate data for western North America. Two climate variables, the maximum temperature of the warmest month and the annual maximum temperature, served as the primary explanatory variables in modeling current and future suitable pika habitat.

It is important to note that large-scale bioclimatic envelope models do not typically consider aspects of a species’ ecology other than the apparent correlations of species occurrence with (typically) coarse-scale climate variables. The models’ projections are inexact. For example, in the unpublished study by Loarie et al. (2009), their model depicts current suitable habitat for the American pika in Arizona, where the species does not occur (Smith pers. comm. 2011). Two variables that directly affect whether pikas may occur in a given area that are usually not considered in such models include substrate (talus or other broken rock habitat) and vegetation type. Also not considered in the models of current habitat suitability or projections of future suitability (see below) is the capacity of the species to behaviorally or physiologically adapt to different climatic conditions; although the species’ current distribution presumably represents the climatic conditions for which pika are optimally adapted. Also, when currently-unoccupied areas are included in calculations of percent decline in future habitat availability, the projected decline must necessarily be inflated because the denominator used in the calculation is greater than the actual area of occupied habitat (Smith peer review). Moreover, global climate change models project free air temperature (such as is measured at weather stations) rather than temperatures that may directly affect pikas, such as the temperatures within the talus matrix. The temperature regimes within talus do not track free air temperature and have been shown in many cases to be substantially less extreme (cooler in summer, warmer in winter) than free air temperature (Millar and Westfall 2010a).

The following paragraphs summarize the results of climate change impact studies on American pikas in California and elsewhere.

Great Basin Studies. Beever and his co-authors examined the patterns of persistence and extirpations at 25 sites historically occupied by American pikas in the Great Basin (Beever et al. 2003, 2010, 2011). These sites are outside California and occur within the relatively small and isolated Great Basin mountain ranges. Although there are exceptions to the generally-observed patterns (e.g., see Beever et al. 2008), as summarized below, the results of these studies suggest that climate change has already had an impact on some populations of the *schisticeps* subspecies and provide a mechanistic framework for evaluating the potential for future climate change impacts to pikas in California.

Beever et al. (2003) found that maximum elevation of a site was an important factor in predicting whether pikas persisted at the site. The authors hypothesized that higher available elevations at a site allow pikas to retreat upwards as temperatures warm and lower elevations become unsuitable.

Beever et al. (2010) provided information from additional surveys and analysis. In addition to the data from the previous round of surveys (1994-1999), the sites were surveyed for pikas during a second period (2005-2007). In total, pikas were extirpated from 9 of the 25 sites (six sites lost pikas prior to the study, and three during the period between 1999 and 2005). Temperature loggers were deployed within talus interstices at the sites, and historical temperature profiles for the sites were hindcast back to 1945 using the relationship between observed temperatures at each site and data from the Historical Climate Network (HCN). These "hindcast" temperatures were applicable to the period between the initial observations of pikas at the sites and the first visits by Beever in the 1990s.

The authors hypothesized that three measures of temperature stress may affect pika persistence and extirpation: Chronic heat stress (mean summer temperature), acute heat stress (number of days above 28° C (82° F) during the hindcast and observed periods), and acute cold stress (number of days below two cold thresholds, 0° C (32° F) and -5° C (23° F). The authors noted that cold stress temperatures are difficult to hindcast because HCN weather stations are kept snow-free while temperature loggers within talus are subject to the insulating effect of snow cover. Presence or absence of snow cover could not be modeled using the HCN data, nor could any potential effects of other potential stressors on American pika populations.

Three periods were available for analysis: the hindcast period of 1945-1975, the hindcast and observed period of 1976-2006, and the observed period of 2005-2006. The authors examined: a) difference between the means of the two hindcast 31-year periods (as a measure of climate change); b) the average conditions over 1945-2006; and c) conditions measured by sensors during 2005-2006· Absolute values for these three periods were used, as well as the differences between the periods. The difference variable is considered a measure of climate change.

The analysis of the temperature profiles for the sites with pika persistence versus extirpation suggests acute heat stress and chronic heat stress were higher at pika-extirpated sites. Pika-extirpated sites also had more days below -5° C (23° F) than sites where pikas persisted. Information-theoretic analysis of logistic regression models indicated that chronic heat stress, acute cold stress (using the -5° C threshold), and acute heat stress were the best predictors for pika extirpations. The climate values for the recent time period were the best predictors, while the climate change (difference) values were poor predictors. Beever et al. (2011) used additional data on pika sites in the Great Basin to estimate the rate of pika extinctions and upslope range retractions during the 20th century and the last 10 years. They also looked at within-site elevations for pika occurrence, and anthropogenic factors that may affect pika extirpation or persistence.

The "drivers" of pika extirpations changed over the three periods examined: "20th Century" (historic to 1999), "Recent" (1999 to 2008), and "Overall" (historic to 2008). Using the same sites and suite of models for both periods, maximum temperature in August became the best predictor of persistence for the "Recent" interval, whereas maximum elevation was the best predictor in the "20th Century" interval. The latitude-corrected residual of maximum site elevation had the most predictive power in the "Recent" and "Overall" intervals. The authors cautioned that the change in drivers of extirpation over the intervals suggests that past patterns may not be predictive for future extirpations.

Lower elevation boundaries at ten sites where pikas were detected since the 1999 survey shifted upslope at least 145 m (475 ft). Basin-wide, the lower elevation limit of occupied pika sites retracted upslope an average of 13.2 m (43 ft) per decade during the "20th Century" period (n=25). Since the late 1990s the upslope retraction rate increased to a Basin-wide average of 145.1 m (476 ft) per decade (n = 16). These upslope range retraction rates are much faster than the average rates reported for other species in the literature. In this study, the upper elevation boundaries of pika sites did not shift, which is similar to the 18 mid- to high-elevation mammal species studied in the Yosemite transect (Moritz et al. 2008).

The average rate of site extirpation increased over the two intervals: six of the 25 sites were lost between historical period and the late 20th century surveys (an average of one loss per 10.7 years), while four additional sites were lost between 1999 and the 2000s surveys (one loss per 2.2 years). The authors note haypiles were observed at four of the six 20th century-extirpated sites, suggesting relatively recent loss of pikas at those sites.

Overall, extirpations occurred at the most thermally stressful sites, rather than the sites that had the greatest change in temperatures. In general, sites or locations where pikas were lost exhibited higher summer temperatures and lower winter temperatures than sites where pikas persisted. By PRISM (spatial climate data) estimates, pika-persistence sites received more precipitation than sites where pikas were lost (although precipitation was a poor predictor in the analysis).

Patch saturation (defined in this study as the number of individuals detected within 8 hours divided by the number of field-validated 20 m circles of talus of appropriate rock diameter searched) increased linearly with latitude. Additionally, the magnitude of declines in patch saturation between 1990s and 2000s surveys increased as latitude decreased (i.e., the more southerly the site, the more dramatic the pika decline), despite the fact that the average mountaintop elevation in the northern Great Basin is lower than the average mountaintop elevation in the central Great Basin (Beever et al. 2011).

These observed effects of climate change on American pikas in the Great Basin ranges may be very different than what has occurred or will occur in the majority of the pika's range in California. The area and configuration of habitat patches in California is different than in the relatively small and isolated Great Basin ranges, which are more likely to suffer from local extirpations and are less likely to be recolonized. Indeed, even within their Great Basin study area Beever and his co-authors cautioned that differences in the size and configuration of the mountain ranges in the northern and southern ranges may have affected their results. Further, they noted population losses in other parts of the American pika's range (including the Sierra Nevada and southern Cascades in California) "appear less extensive" than the documented Great Basin losses.

Rapid assessment-type surveys by Collins and Bauman (in press) in the northern Great Basin indicated presence of American pikas at several locations at relatively low elevations. Currently occupied sites within their study areas at the Hart Mountain National Antelope Refuge (southeastern Oregon) and Sheldon National Wildlife Refuge (northwestern Nevada) ranged from about 1,800 m (5,900 ft) to about 2,400 m (7,870 ft). Further, it has been argued that the 25 historical pika sites studied by Beever and his co-authors are not a representative sample of American pika sites in the Great Basin (Millar and Westfall 2010b). Although necessarily relying on an existing set of sites, resurvey projects generally have the limitation of non-random or non-stratified sampling. Thus, conclusions drawn from a limited set of historical sites may not be generally applicable to the Great Basin as a whole.

Wilkening et al. (2011) examined Beever et al.'s (2003) Great Basin pika data, along with information on microclimates and microhabitats from pika sites, and found that in addition to differences in summer temperatures, several aspects of vegetative cover also differed between pika persistence and extirpation sites, and relative forb cover was positively related to pika persistence, although forb cover also correlated with temperature and made it difficult to separate vegetation and temperature effects. They found strong support for recent mean summer temperature as the primary driver of extirpations, supporting the hypothesis that extirpation results from chronic heat stress during the summer months when pikas must gather and store food for the winter. In their analysis, Wilkening and her coauthors (2011) showed that sites where pikas were extirpated had a mean number of days in which the temperature rose above 28° C (82.4° F) nearly ten times greater than sites where pika persisted. However, in contrast with previous studies, they found less support for the hypothesis that extirpation results from acute cold stress during the winter months (Wilkening et al. 2011). Regarding chronic cold stress, Wilkening et al. (2011) stated:

> We would also emphasize results from this analysis and others that are in agreement with the finding of Beever et al. (2010), that exposure to low temperatures may explain extirpations. For example, the number of extremely cold days was negatively related to persistence in the single-regression models explored here. Also, the ratio of cold days to forb cover exhibited the expected relationship with persistence. Within sites, pikas persisted where there were fewer days below negative ten degrees Celsius (-10° C , 14° F) combined with relatively low-forb cover, supporting an early hypothesis (MacArthur and

> Wang, 1973) that pikas may be able to withstand cold snaps given a suitable food cache. Previous studies have documented the negative impacts of harsh winters on pika populations (Tapper 1973, Smith 1978, Smith and Ivins 1983, Simpson 2001, Morrison and Hik 2007), suggesting that snow cover acts as a thermal blanket that insulates pikas during cold winters (Tapper 1973, Smith 1978). Demographic studies have documented a steep decline in the population density of pikas following a severely cold winter with a shallow snow pack (Smith and Ivins 1983, Simpson 2001). Pikas can also be adversely affected by an increased frequency of melt-and-refreeze events, since this can result in an impenetrable barrier to food resources, or collapsed subnivean movement corridors (Morrison and Hik 2007).

Wilkening et al. (2011) found no evidence of recolonization of sites identified as extirpated by Beever et al. (2003), but did find evidence of extirpation at two additional sites.

Great Basin pika habitat is located in discrete patches on mountain ranges where pika populations are isolated from one another by surrounding low elevation, unsuitable habitat. This is different than pika habitat in the Sierra Nevada of California. Brown (1971) describes the mountain-top mammal communities of the Great Basin as relicts left at the end of the Pleistocene. Populations of small mammals are more likely to persist in large patches (large mountain ranges) than in smaller patches. The species-area curves and regression analysis of distance from mainland, elevation of intervening passes, and distance to nearest island with more species all strongly suggest that no recolonization has occurred in any of the ranges once a species experienced a local extirpation (Brown 1971). American pikas occurred on four of the mountain “islands” in the study, which was similar to other habitat specialist herbivores in the study (Brown 1971).

It has been hypothesized that connections between patches of American pika habitat within a mountain range (whether the relatively small ranges of the Great Basin or the relatively vast Sierra Nevada) may open or close over climatic periods depending on the general climate during the summer dispersal period (Millar et al. 2012, Millar et al. in press). During periods with relatively cool, moist conditions, dispersal from high elevation sites through lower elevation areas may be possible, which could connect high elevation sites and allow recolonization of extirpated sites. On the other hand, in a generally warming climate, during warm periods, formerly large, interconnected habitat areas may be both reduced in total area and isolated into small fragments of habitat at the highest elevations.

Southern Rocky Mountains Studies. In the Rocky Mountains, Erb and her coauthors (Erb et al. 2011) investigated the climate factors that may affect the distribution of the American pika in the southern Rocky Mountains. Based on resurveys at 69 historically-occupied pika sites, their data indicate that few (four of the 69 surveyed sites) populations have been extirpated within their study region in the recent past. Low annual precipitation was implicated as a factor for pika extirpation in their study. Their most recent years of data suggest pika sites with high summer temperatures are also vulnerable to extirpation (Erb et al. 2012).

The results of Erb et al. (2011) are consistent with Millar and Westfall's (2010b) survey results in the Sierra Nevada, where wetter sites were more likely to support pika populations. The Rocky Mountain extirpation sites were dry in terms of precipitation and also did not have sub-talus water. Erb and her coauthors suggest that the dry sites with recent extirpations in their study may be marginally suitable for pika under the best of circumstances. It is possible that such sites are only occupied after one or more successive years with conditions that allow pika populations to expand in numbers and geographic area occupied.

British Columbia. Henry et al. (2012) found strong genetic structuring between American pika populations in Bella Coola, British Columbia. They found no evidence of genetic mixing between low and high elevation sites, which suggests pika populations may not move readily upslope as climate warms. They found genetic differentiation patterns between sites was best explained by (in order of effect) geographic isolation, heat-to-moisture ratio, precipitation as snow, mean annual precipitation, and summer mean maximum temperature. The effects of the climate variables together implicate warming climate as a contributor to genetic isolation of pika populations. Additionally, half of the studied sites (of different elevations) showed evidence of recent population declines. These declines were correlated with increasing heat-to-moisture ratio, decreasing mean annual precipitation, decreasing precipitation as snow, and increasing summer mean maximum temperature. The authors concluded, "in the face of climate change, *O. princeps* may have to rely on local adaptations or phenotypic plasticity in order to survive the predicted magnitudes of environmental change."

California – Yosemite. Moritz et al. (2008) found in their Yosemite transect resurvey that several high-elevation species' contemporary ranges, including pika's, have contracted upslope from where they were detected in the early 20th century by Grinnell and Storer. The elevation range in which pika were detected in the period of 1914-1920 was 2,377 - 3,871 m (7,800 – 12,700 ft). The contemporary lower elevational range limit of pika was found to have shifted upslope by 153 m (502 ft).

California – Bodie State Historic Park. The American pika population at Bodie State Historic Park has been studied longer than any other population of pika, including populations of other pika species. Bodie is one of the warmest localities where pikas have been continuously studied; therefore it is relevant to this review to consider the population status over time of the pikas at Bodie.

Severaid (1955) was the first to describe the pikas at Bodie and studied them intensively from 1946 to 1949. He determined "currently every mine dump or rock pile, regardless of size, shape or height, contains therein one or more pikas, or family units, providing only that the rubble is of sufficient size to permit them a thorofare [sic] into and throughout the dump" (page 110). He later stated (page 150), "despite my earlier implication to the contrary, another impression which I consistently formulated for the Bodie colony was that the average stable population was never equal to the carrying capacity of the habitat." Severaid also trapped out some of the ore dumps and noted that they were slow to be re-colonized.

Andrew Smith began studies at Bodie in 1969, investigating them intensively from 1969 to 1973 (Smith 1974a, 1974b, 1978), and following up these investigations with a survey in 1977

(Smith 1980). Smith resumed censuses in 1989, and these have continued through to 2010, aided by Mike Gilpin, Chris Ray, Smith's students Mary Peacock (who worked at Bodie from 1988 to 1991; Peacock and Smith1997), John Nagy (1996) and Lyle Nichols, and others (Smith and Gilpin 1997; Moilanen et al. 1998; Smith and Nagy 2012).

The pika population at Bodie represents one of the best examples of a classic metapopulation system: the pikas live in spatially distinct habitat patches scattered across an open landscape, all local populations are small and have a significant risk of extinction, dispersal among patches appears to be distance-dependent, and the dynamics of local populations appear to be asynchronous. Smith identified 76 isolated ore dump patches for censusing. The study area is roughly 3 km from the north to south and is constricted in the middle, such that 39 of the ore dump patches occur in a southern constellation of habitat patches and 37 are in a northern constellation. All patches identified for the first (1972) census contained sign that they were, or had been, occupied by pikas. Percent patch occupancy was highest during the two early censuses (58.7% in 1972; 55.4% in 1977). Characteristic of a metapopulation system, the patches represented a dynamic equilibrium between extinction, which was inversely related to patch size, and re-colonization, which was inversely related to distance to other patches (Smith 1974b; 1980).

By the time censuses resumed in 1989, the pika population in the southern constellation of patches had begun to collapse. By 1991 nearly all of the southern patches were vacant; overall percent patch occupancy at Bodie dropped to 41.9% in 1989 and 43.2% in 1991 (Smith and Gilpin 1997; Moilanen et al. 1998). Overall percent patch occupancy at the Bodie ore-dump sites has remained low (average = 37.6% from 1989-2010), as the southern constellation of patches has remained largely vacant. Some animals have been located in the south since 1991, but from 2008 onward no pikas have been observed there. While showing considerable variability among years, there was no significant decline in percent occupancy for all patches combined from 1989 through 2010 (regression coefficient = –0.3277, $p = 0.264$), or percent occupancy in the northern constellation of patches from 1972 through 2010 (regression coefficient = –0.3988; $p = 0.158$). Percent occupancy in the north in 2009 (83.8%) was slightly greater than in the first 1972 census (83.3%).

The total number of pikas in annual censuses has not changed appreciably over time, in spite of the collapse of the southern constellation of patches by 1991. The number of pikas counted on all patches was 132 in 1972 and 119 in 1977, compared with 122 in 2009 and 109 in 2010, the latter two years reflecting number of pikas in the northern constellation only. Overall, between 1989 and 2010 extinction events were recorded on 114 patch populations (6.3 patch extinctions/year) and re-colonizations on 109 patches (6.1 patch re-colonizations/year) (Smith and Nagy 2012).

The high annual variability in a number of patches re-colonized or undergoing extinction events allowed Smith and Nagy (2012) to look more closely at potential dynamics between chronic and acute temperature data and these events. Tests for correlations among measures of high temperature (chronic and acute in either the same year or the previous year) with the number of re-colonization or extinction events yielded a single significant result in the opposite direction of what one would expect —the number of patch re-colonizations tended to correlate positively with August temperatures in the previous year. Thus, with the resolution available using standard climatological data, it could not be determined whether the Bodie pika metapopulation dynamics were determined by temperature.

The lack of significant correlations between temperature data and re-colonization and extinction events may indicate that standard climatological temperature data are insufficient to understand these important population processes for pikas – even though the temperature data were from on site. Even in the hottest year on record, a pika could disperse on the only cool day in that month or during the coolest part of a warm day. All time activity data available on pikas show that they are extremely adaptive and flexible (Severaid 1955, MacArthur and Wang 1974, Smith 1974b). Thus, this result enforces the need to understand pikas on their own terms with detailed observations of marked animals (see Tapper 1973; Smith and Ivins 1983, 1984) coupled with detailed micro-climatic temperature measurements in or near critical habitat elements like haypiles or deep in the talus (see Beever et al. 2010, Millar and Westfall 2010, Wilkening et al. 2011). Studies that attempt to quantify the persistence of pikas using regional temperature measurements or climatological models (see Calkins et al. 2012) are more likely to be too coarse to be informative.

The inability of pikas to fully saturate all the habitat patches at Bodie and their inability to quickly recolonize those sites experimentally trapped out by Severaid in the 1940s supports the idea that dispersal ability of pikas is restricted in environments as warm as found at Bodie. This means that extinction of pika populations on small patches may lead to a net loss in a region if the patch is sufficiently far from a source of colonists. The spatial scale at Bodie – with a southern constellation of patches within 1 or 2 km of extant patches, yet remaining largely vacant for 20 years – indicates that stochastic extinction of small isolated patches near the low range of elevation of pikas may be permanent. The resurvey project meta-analysis presented in Appendix 1 shows that most currently vacant patches in those resurveys were small (thus subject to stochastic extinction) and low in elevation – a combination that may preclude their becoming re-occupied in the foreseeable future.

The loss of pikas in the southern constellation of patches at Bodie is the first example of a metapopulation collapse, but one predicted by metapopulation theorists. It is unknown what triggered the downward spiral of occupancy in the south. Smith and Gilpin (1997) considered several possibilities, and commented that a resourceful weasel could have consumed all pikas in some key patches leading to the decline, but this is unsubstantiated. Smith and Nagy (2012) determined that pikas have not been found on 15 (20%) of patches, and these were all small and all in the southern constellation. It was not possible to excavate ore dumps to examine the suitability of the rock substrate that they contained – to determine if a pika could easily retreat deeply enough to avoid summer heat (Smith 1974b) or winter cold (Beever et al. 2010). Nevertheless, these data on lack of occupancy indicate that these patches may have over time become unsuitable for long-term occupancy by pikas. Thus, an increasingly small network of patches and the resulting inevitable stochasticity of extinctions and re-colonizations, could have amplified the tendency toward regional extinction.

Conversely, the continued high levels of occupancy in the northern constellation of patches in spite of frequent extinction of populations on individual patches demonstrates the resiliency of metapopulation systems.

It has been argued the overall lower percent patch occupancy rates at Bodie now, compared with the first comprehensive censuses in the 1970s, is not an indication of loss due to a warming climate because it seems unlikely that climate could have been responsible for the initial collapse of the southern constellation – as the northern constellation of patches, only 1 to 2 km away, remained healthy. However, failure to become re-colonized could be a feature of warm temperatures.

Smith and Nagy (2012) suggested that most climate change in the intermontane west has occurred over the past 20 to 30 years, but that there has been no significant decline in overall pika patch occupancy at Bodie during that time. To explore the relationship between several measures of high temperature and Bodie pika population dynamics, they organized Bodie temperature data by period, as follows:

1895 – 1903: corresponding to the time pikas were putatively colonizing the ore dumps,
1932 - 1950: the period during which Severaid worked at Bodie
1951 - 1972: the period between Severaid's work and the first metapopulation census by Smith
1973 – 1991: the period from the first census to that of the fourth census when the collapse of the southern constellation of patches was first evident
1992 – 2010: the period leading to the present.

For all chronic temperatures (June, July, August, annual mean maximum temperatures) and acute temperatures (number of days ≥ 25^{o} C, ≥ 28^{o} C), the most recent period has been the hottest. However, warming in the most recent period does not fully explain the observed pattern in patch occupancy over time: full occupancy in the early years of Severaid's observations; 60% patch occupancy by 1972, 40% patch occupancy by 1991, and no change in percent patch occupancy since that time.

California – Bodie Hills. Lyle Nichols provided unpublished summaries of work in the Bodie Hills and Bodie State Historic Park (Nichols 2009, 2011a, 2011b). The 2011b summary includes information from pika surveys at suitable habitat patches in the Bodie Hills starting in 2008 (n = 51 natural patches) and New York Hill (n = 1 natural patch, 16 ore-dump patches). It also summarizes ore-dump occupancy at Bodie over several years starting in 1972. Additional occupancy data from Severaid's (1955) work in 1948-49 is reported. Nichols could identify 28 of Severaid's ore-dump patches and revisited them in 2010. Occupancy is reported as the percentage of surveyed patches that were occupied each year. The following bullets summarize Nichols' reports regarding the Bodie Hills pikas:

- Ore-Dump Sites and Natural Talus Patch, New York Hill. Seven of the 17 recently surveyed patches were occupied by pikas in 2010 (41.1% patch occupancy). All 17 New York Hill patches contained pika fecal pellets showing that all had been occupied in the recent past. Elevations of New York Hill patches range from 2,513 to 2,618 m (8,245 to 8,590 ft). As noted by Millar (pers. comm.), the lack of current occupancy at all sites within a metapopulation is an expected observation, even for a healthy metapopulation system.

- Natural Talus Patches, Bodie Hills. All 51 habitat patches recently surveyed in the Bodie Hills were found to have fecal pellets indicating occupancy in the past, but none had fresh sign or pikas observed. Elevations of the Bodie Hills sites range from 2,209 to 3,112 m (7,250 to 10,210 ft).
- Rates of Extirpation. Based on his technique for aging fecal pellets (Nichols 2010), Nichols estimated the date of abandonment of sites in Bodie SHP, New York Hill, and the Bodie Hills. His Figure 3 shows the percentage of occupied sites as a function of year in these three areas since the 1940s. Large declines for all three areas are shown in the period from 1980 to the present.

Nichols (2011b, pers. comm, August 5, 2011) emphasizes the differences between the natural talus patches in the Bodie Hills versus the ore-dump patches in BSHP and New York Hill. In general, the ore-dumps are small and are separated by relatively short distances. The ore-dumps have relatively small rocks and presumably shallow cover. The natural patches in the Bodie Hills are relatively larger but more distant from one another. They are composed of generally larger rocks and likely have deeper cover than the ore-dumps. Taken together, Nichols (pers. comm., August 5, 2011) suggests these characteristics make the natural sites in the area more likely to lose pikas if climate change is a stressor affecting the pika populations, primarily because dispersal and patch re-occupancy would be limited for the more widely dispersed natural patches. He notes the percent occupancy trend for the Bodie SHP and New York Hill sites suggests possible extirpation in these areas by the end of the 21st century – a conclusion disputed by Andrew Smith (pers. comm.), who states that Bodie ore-dump occupancy rates have not had a downward trend 1989 (Smith and Nagy 2012)[97].

Millar (pers. comm. 2012) notes that pikas were present in 2012 at four sites identified as extirpated by Nichols (2011a) near New York Hill/Masonic Mountain and Benjamin Buttes.

California – Lassen Area. In the Lassen area, Massing and Perrine (2011) found that historical pika sites that lost occupancy averaged warmer than the occupied sites (overall mean temperature, summer mean temperature, and warmest 10 days temperature). There was no discernible difference in the coldest 10 days temperature.

Millar (pers. comm. 2012) searched for American pikas in the Madeleine Plain area east of Lassen National Forest. Her best estimate of the location a historical pika site reported by A.H. Howell (1924) is the Termo Buttes, which arise from the plain and range in elevation from about 1,650 to 1,700 m (5,400 to 5,600 ft). Millar was unable to find any pikas or their sign at that location, but did find sites with many pikas on the nearby Three Peaks, MacDonald Peak, and Observation Peak. These sites range from about 1,850 to 2,400 m elevation (about 6,000 to 7,800 ft). Millar considered these observations interesting, given the site's relatively low elevation and great distance to other ranges.

DEGREE AND IMMEDIACY OF CLIMATE CHANGE THREATS

Global climate models project warming over all land areas of the globe, including North America, through 2100. In the western United States, the models project summertime warming by about 2.75° C (5° F, estimates range from 1.65° to 3.85° C, 3° to 7° F), greater increases than anywhere else in North America (Ray et al. 2010). The models project winter warming, by about 1.65° C (3° F, range from 1.1° to 2.75° C, 2° to 5° F) (Ray et al. 2010).

The 2050 summer (June, July, August) temperature projections average about 3° C (5.4° F) higher than the recent climatology for most of the western United States, and for the 22 specific locations analyzed as representative of pika habitats. Due to the impacts of temperature, projections show a large decline in lower-elevation snowpack (below 8,200 ft/2,500 m) by 2050, with more modest declines at elevations above 8,200 ft where some pika populations live (Ray et al. 2010). Snow pack in the Sierra Nevada is expected to decrease 12% to 46% by the 2035-2064 time period according to a low-end warming scenario, or 26% to 40% according to a high-end warming scenario for California; by the 2070-2099 time period, snow pack could have decreased by as much as 90% according to a high-end warming scenario (Cayan et al. 2006). Additionally, Rauscher et al. (2008) used a high-resolution climate model to predict (under the A2, high-emissions scenario) early-season snowmelt runoff as much as two months earlier than present by 2100.

More recently Cayan et al. (2012) projected warming in California using six models and projected warming of about 1° C to 3° C (1.8° F to 5.4° F) by year 2050, and from 2° C to 5° C (3.6° F to 9° F) by the end of the century. When the authors downscaled models to California's mountainous terrain they found that a warming climate will have a profound influence on snow accumulation, with reductions of up to 79% and 55% at elevations of 2,000 to 3,000 m (6,562 to 9,843 ft) and 3,000 to 4,000 m (9,843 to 13,123 ft) respectively by the end of the century (Cayan et al. 2012).

Pika Habitat and Distribution Projections

Several recent studies have modeled the expected impact of projected changes in climate on the amount and distribution of suitable pika habitat. These studies utilize the concept of a "climate envelope", the geographic area with a climate suitable for pika survival. These models usually start by exploring the predictive power of habitat and climate variables (such as slope, aspect, mean annual and monthly temperatures, maximum annual and monthly temperatures, mean annual and monthly precipitation, and many other permutations of climate variables) and then focus on the variables with the greatest ability to explain the current distribution of the species. Often, just a few environmental variables provide high predictive power. For models exploring the effects of future climate change on pikas, measures of acute and chronic heat and cold stress may be used.

The "envelope" is generally expected to move up in elevation and north in latitude in the future with a warming climate. These models assume that pika populations will be able to move with the moving climate envelopes over time within a mountain range; however, in some cases pikas may not be able to follow the envelope due to gaps in suitable structural habitat. In addition, because these models use climate variables as measured at the surface rather than within talus, they do not account for the pika's observed ability to inhabit suitable microclimates within otherwise unsuitable areas, indicating that pikas could remain in existing sites even as the climate envelope shifts (see the section below entitled Pika Resilience to Climate Change Effects).

Also, when evaluating projected pika habitat distribution models one should be cognizant of the interrelated effects of climate-driven reductions on available habitat and the effects inherent to small and isolated populations (see below discussion of Population Size and Isolation). For example, Heikkinen et al. (2010, cited in Calkins et al. 2012) note that climate change presents increased risks to high elevation/montane species due to several inherent characteristics: restricted geographic ranges, low genetic diversity, narrow habitat usage, limited dispersal ability, and a tendency to occupy high-elevation or high-latitude ecosystems. A warming climate might exacerbate these effects by creating smaller mountaintop patches of habitat and greater expanses of unsuitable habitat between patches (more isolation). However, montane habitats have also been shown to have fine-scale variability in their surface microclimates (Sherrer and Koerner 2010, 2011). Such variability may ameliorate or balance climate change impacts produced by increases in free air temperature.

Finally, as pointed out by Smith (peer review 2012), these models indicate current habitat suitability in some areas:

> "that do not currently possess pika populations. What is not made explicitly clear in the S[tatus] R[eview], however, is how this plays out. These papers give summary results (independent of other aspects contained in the research) of a projection of percent decline of pika habitat under scenarios of a warming climate. Each of these percentages consists of a denominator that is derived from the "current predicted distribution" of American pikas (viz. Figure 3a in Calkins et al. 2012, and Figures 2 and 5 of the SR) and a numerator with the projected area of pika distribution in the future. A close inspection of the maps used to determine the denominator area shows pikas in Arizona (as appropriately pointed out is incorrect on page 22) – but the same modeling that led to this error also yields a modern pika distribution that far exceeds reality. Thus, percent decline in pika populations are artificially high because in 100 years the pikas will not be found in these places (the numerator) – as they are not there now! The trouble is, we do not know how much error there is in this process, thus the percent decline numbers must be viewed very conservatively."

Despite the limitations on such studies, climate envelope models provide a means of quantifying the expected impacts of projected climate change. Below are key findings from recent pika habitat projection studies.

Calkins (2010) examined the current extent of suitable habitat for 19 of the traditional 31 subspecies of American pika and then predicted the extent of suitable habitat for each subspecies under incrementally warmer climates. Predicted loss of suitable habitat of traditional subspecies ranged from 20-77% with a 2° C increase, up to 66-100% with a 6° C increase. Calkins noted that his model corroborated the USFWS finding (USFWS 2010) that all of the five currently recognized subspecies of American pika would persist, at least at some sites, under predicted climate warming scenarios.

Calkins et al. (2012) refined and extended the bioclimatic envelope-modeling of future pika habitat suitability in the western United States of Calkins (2010) by incorporating habitat variables (land-cover) to refine predictions under 1° to 7° C degree increases in range-wide temperatures, as well as spatially heterogeneous IPCC forecasts for 2050 and 2080. Calkins et al. (2012) included habitat variables to expand upon simpler bioclimatic modeling which does not incorporate non-climatic variables in species distribution modeling.

Additionally, Calkins et al. (2012) examined patterns of modeled range collapse (center vs. periphery, large vs. small island patch size, currently-defined lineages vs the 31 traditional US subspecies). Key findings from Calkins et al. (2012) include:

- The most important climate variables in the model were mean temperature of the warmest quarter, annual mean temperature, and maximum temperature of the warmest month (together contributing 85% to the model's development). Other climate variables each contributed about 2% or less to the model. Further analysis indicated mean temperature of the warmest quarter was the most useful climate variable.
- The habitat filter approach did not appreciably change the geographic patterns of range loss, but did remove between 6% and 40% of the pixels predicted to be occupied by pikas based only on climatic variables. In other words, the inclusion of land-cover type refined the model's predictions.
- Under increasing temperatures, the pika-occupied range was predicted to collapse to large, contiguous areas of suitable habitat in the Rocky Mountains, Sierra Nevada, and northern Cascades (WA).
- Of the five currently recognized subspecies (lineages), the central Utah and northern Rocky Mountain lineages were predicted to lose the most habitat, the Sierra Nevada lineage fared relatively well, but was predicted to lose 88% of occupied habitat with a 7° C increase.

A summary of the results for each of the five currently-recognized subspecies, as well as the five traditional subspecies in California, is presented in Table 2.

As with all such climate envelope model studies, the authors presented several caveats for consideration when interpreting their results: modeling did not include the potential 'rescue' of unoccupied patches once they were modeled to lose suitability, models did not consider the microclimate (sub-talus) amelioration of surface temperatures, there is some uncertainty related to use of general circulation models (GCMs), and the modeled homogeneous temperature increases over the western United States do not account for the finer scale temperature patterns exhibited by complex terrain (Calkins et al. 2012).

Figure 5 presents some of the results from the Calkins et al. (2012) models of habitat suitability for the American pika (the figure area is cropped to emphasize California). In addition to current conditions, maps of habitat suitability at general warming of 2° C, 4° C, and 7° C are presented. Warming of 2° C by the end of the current century is generally projected under "B" (moderate) greenhouse gas emission scenarios, while 4° C is a general projection for "A" (high emission) scenarios (IPCC 2007, Ray et al. 2010, Cayan et al. (2012). To date, actual emissions have generally been tracking the "A" scenarios.

Table 2. Area and percent change in area of the predicted geographic ranges of currently defined subspecies of *Ochotona princeps* (range-wide for the species) and for the five traditional subspecies of *O. princeps* in California, based on current conditions and predicted climate warming. Excerpted and simplified from Calkins et al. (2012) Table 2.

		Change in Range Area for Specified Average Warming						
Current Subspecies	**Current Area (km^2)**	**1° C**	**2° C**	**3° C**	**4° C**	**5° C**	**6° C**	**7° C**
O. p. princeps (northern Rocky Mountains)	125,800	-19%	-38%	-58%	-71%	-82%	-90%	-95%
O. p. saxatilis (southern Rocky Mountains)	43,334	-16%	-32%	-47%	-58%	-71%	-80%	-88%
O. p. uinta (central Utah)	9,391	-21%	-41%	-57%	-66%	-79%	-88%	-94%
O. p. fenisex (Cascade Range)	15,943	-13%	-27%	-41%	-53%	-69%	-82%	-91%
O. p. schisticeps (Sierra Nevada, S Cascades, Great Basin ranges of Nevada)	18,127	-18%	-35%	-51%	-63%	-74%	-82%	-88%

Traditional CA Subspecies	**Current Area (km^2)**	**1° C**	**2° C**	**3° C**	**4° C**	**5° C**	**6° C**	**7° C**
O. p. albata (southern Sierra Nevada)	2,588	-8%	-22%	-36%	-46%	-58%	-69%	-79%
O. p. muiri (Yosemite region)	8,525	-11%	-25%	-40%	-53%	-66%	-76%	-83%
O. p. schisticeps (N Sierra Nevada, NW Nevada)	770	-44%	-77%	-95%	-99%	-100%	-100%	-100%
O. p. sheltoni (White Mountains)	483	-8%	-20%	-34%	-44%	-56%	-66%	-71%
O. p. taylori (Warner Mtns, Mt Shasta, SE OR)	732	-38%	-63%	-79%	-86%	-93%	-95%	-97%

Trook (2009) examined climate change projections through 2090 and reported 81-98% decreases in predicted extent of suitable pika habitat depending on the climate projection model used. Additionally, Trook found that the average habitat patch size for *Ochotona princeps schisticeps* (the California subspecies) is only expected to shrink by 0-17% due to the contiguous nature of the Sierra Nevada. He concluded that even under the greatest warming projection model examined, habitat "possibly large enough" to maintain a pika population will persist in the Sierra Nevada out to year 2090.

Galbreath et al. (2009) examined pika genetics and determined that there is evidence that the major pika lineages have persisted through climatic oscillations in the past which offers optimism that barring complete extirpation of a major genetic lineage, the species-wide pool of genetic diversity should not be greatly diminished by ongoing climate change. However, their projections of the distribution of the American pika under simulated future climatic conditions suggests that the Sierra Nevada lineage may be at risk of extinction if anthropogenic climate change continues unabated. They found that their ecological niche model predicted nearly all patches of suitable habitat in the southwestern part of the Intermountain West will be lost if atmospheric CO^2 levels double.

Loarie et al. (2009) presents a different approach for modeling American pika persistence – climate histories. They modeled the probability of pikas at 97 known locations surviving the interval between a historical record date and a resurvey date based on the climate trajectory for that interval and site using climate data from PRISM. Mean annual temperature estimates were the strongest variable explaining pika persistence. Extirpations were predicted to be rare at sites where mean annual temperatures were at or below about 7° C, but the probability of extirpation increased rapidly at sites where mean annual temperatures reached or exceeded 8° C.

Temperature projection predictions obtained from downscaled global climate models were used to extrapolate the probability of pika persistence from 2010 to 2099. Large areas of currently mapped pika-habitable range are predicted to be extirpated by 2099, particularly (in CA): almost all areas north of South Lake Tahoe other than Mt. Shasta. Their model estimates for the worst-case scenarios examined are that 74% of Sierra Nevada pika sites have a less than 50% chance of persistence through 2099. Under the best-case scenarios examined by the authors there is a 50% chance that 15% of currently occupied sites in the west will be extirpated by 2099 (Loarie et al. 2009). According to this model, the high Sierra Nevada may still be inhabitable by pika in the future.

The USFWS, after considering the above models (with the exception of Calkins 2010 and Calkins et al. 2012, which were not completed until after the USFWS status review) concluded that increased summer temperatures as a result of climate change may have the potential to adversely affect some lower and mid-elevation pika populations of *Ochotona princeps schisticeps* in the foreseeable future (such as the Warner Mountains population in northeastern California); however adverse effects are not expected to occur to a significant portion of the suitable habitat of any of the five current subspecies. (USFWS 2010).

The use of air temperatures from global circulation models as the temperature affecting pika persistence has been criticized by some scientists (Smith peer review, Millar peer review). These pika researchers believe that temperatures within talus are more important than surface or air temperature in determining whether pikas may persist at a site. Also, one peer reviewer (Smith peer review) noted that the Calkins et al. (2012) and Loarie et al. (2009) studies apparently excluded certain low-elevation sites in creating their climate envelope models, which could incorrectly narrow the predicted range of suitable temperatures.

To summarize, and considering only California, it appears that climate warming alone is unlikely to cause the extinction of the American pika in the state by the end of the century, and that the pika will still inhabit California. Although the magnitude of habitat declines may be inflated as described above by Smith (peer review comment), by the end of the century, the climate models project there is likely to be a substantial reduction in suitable habitat area for the American pika, which in turn, would likely result in a reduction in the geographic range of the species. Further, it is likely that projected climate-driven declines in suitable habitat coupled with interrelated climate change effects on montane ecosystems and the compounding effects of population contraction and isolation will present a significant threat to the persistence of the American pika in California by 2100. Within nearer time periods, such as the next 10 to 50 years that were modeled in some cases, it seems reasonable to expect intermediate consequences and resulting distribution of pika that is between the present conditions and those projected by 2100.

Other Climate Change Impacts

Climate changes could threaten pika through less direct pathways than acute and chronic heat stress; however, there is little certainty regarding the degree and immediacy of these hypothesized threats. Higher summer temperatures could prevent individuals not only from foraging sufficiently (due to avoiding activity during the hottest part of the day) but also from accumulating enough stored vegetation in their hay piles (Smith 1974a). Additionally, under elevated atmospheric carbon dioxide levels, leaf protein content will decrease and carbon to nitrogen ratios of leaves will increase, implying a reduction in food quality for herbivores worldwide (Ehleringer et al. 2002 in Wilkening 2007). This could lead to declines in health and body mass, which would negatively influence winter survival, reproductive output, and the ability to survive dispersal attempts - exacerbating the risks associated with isolated populations (Wilkening 2007, Wilkening et al. 2011).

Climate change may also directly affect disease pathogens by increasing or decreasing the pathogen's growth rate, persistence in the environment, or ease of transmission to susceptible hosts. A recent review of this topic suggested that most wildlife-parasite systems are likely to experience more frequent or severe disease impacts with a warming climate (Harvell et al. 2002). The spread of plague has been linked to warmer temperatures, which potentially could play a role in pika extirpations (Blakemore 2007 in Wilkening 2007). Although disease has not been found to be a major threat to American pika populations to date, it has been hypothesized that pikas may become more susceptible to disease if their condition is already compromised from chronic heat stress (Wilkening et al. 2011) and they may be exposed to new or greater numbers of disease vectors between the present and 2100.

Pika Resilience to Climate Change Effects

Several recent studies suggest that American pikas may be able to inhabit a wider range of habitat types and quality, and be more resilient to climate change impacts than previously thought. Much of this work was conducted outside California, but may have relevance to the situation in California. Also, as noted above in the section discussing climate change and its potential or observed impacts on American pika populations throughout the species' range, pikas have persisted over a wide geographic range in western North America. The degree of local adaptation of pika populations to conditions in British Columbia, for example, versus those in the southern Great Basin, is unclear, as are the relative impacts of future climate change to these populations. It is unknown whether low-latitude and low-elevation populations have been pushed to their limit for temperature impacts. Likewise, it is unknown whether higher latitude/elevation populations have lost their capacity to adapt to warmer conditions. The work by Henry et al. (2012) suggests local adaptation and lack of mixing between high and low elevation populations in his study area, and if it proves to be a general pattern in pika populations, may mean that temperature changes may be more relevant than a single temperature threshold.

Millar and Westfall (2010b) surveyed for pikas from 2007 to early 2009 at 329 sites in the Sierra Nevada (SN), 67 sites in six mountain ranges in the southwestern Great Basin (swGB), 16 sites in three central Great Basin ranges, and eight sites from the central Oregon Cascades (the authors defined a site as an area < 1.0 square meters containing >= 25 pika fecal pellets or the location a pika was seen or heard). Overall, 67% of the sites were occupied by pikas, 27% had recent indirect sign of occupancy, and 6% had old sign of occupancy. The proportion of "old" sites increases from the SN (2%) eastward into GB (17% in swGB, 50% in cGB). Old sites were distributed throughout the elevation range studied, with no indication of greater occurrence at lower elevations. The authors reported the occurrence of pikas at elevations lower than previously considered the limit for the species in the Sierra Nevada and western Great Basin.

Global climate models project warming over all land areas of the globe, including North America, through 2100. These models project larger summertime warming over the western United States than elsewhere in North America. Rodhouse et al. (2010) observed that in some situations (Craters of the Moon, Idaho, Lava Beds National Monument, California) substrate features could enable pikas to persist outside their typical bioclimatic envelope and might reduce the effects of accelerated climate change. However, even at Craters of the Moon, elevation was associated with patterns of pika distribution, although the authors noted elevation also presumably influences vegetation cover. The authors cautioned that declines in pika site occupancy may lag behind declines in habitat quality. Some low elevation peripheral habitats with persistent pika populations could become particularly important refugia for the species, as well as sources of genetic and phenotypic diversity.

Beever et al. (2008) found persistence of pikas at a site in Nevada 407 m lower than the minimum elevation latitude-specific elevation modeling from the Great Basin would have predicted. The authors suggested this result challenges some of the predictions of earlier climate envelope modeling. These authors also observed pikas haying *Bromus tectorum* (cheatgrass), an invasive annual grass species, at this grazed site in Nevada. This is one of the few places cheatgrass and pika are currently known to co-occur. Whether cheatgrass will continue to expand into pika range, and the consequence to pika if it does, remains uncertain.

Two recent publications document pikas using atypical habitat in Oregon. Although outside of California, these studies suggest pikas habitat associations are more diverse than previously thought. Manning and Hagar (2011) detected pikas at 42 sites in anthropogenic substrate (rock quarries, road cuts, and rip rap) in western Oregon. The sites were at low elevations relative to those occupied in California: between 610 and 1701 m (2001 and 5581 ft). Pikas were observed colonizing a human-made field of rip-rap within 21 months of its creation. The authors also found pikas in natural talus as low as 538 m (1,765 ft) in western Oregon. Pikas were found as much as 60 km (37 mi) from the nearest alpine habitat.

Pikas have long been known to occur at low elevation sites at higher latitudes (Anthony 1928). Simpson (2009) described four low-elevation sites occupied by pika in the Columbia River Gorge between 108 and 255 m (354 and 837 ft) elevation. These sites are more than 1,100 m (3,609 ft) below the low-elevation predicted Approximate Thermal Limit (ATL, Hafner 1993) for the latitude and longitude of each site. Summer temperatures at these sites are relatively mild (well below ATL), although many days have temperatures above 25.5° C, which is the often-cited lethal temperature limit for confined pikas. The sites had little snow, no snow pack, and many fewer days below 0° C (32° F) than the ATL. The author suggested that that snowpack may not be necessary for pika at all sites, such as non-alpine sites where temperature infrequently falls below 0° C. Such sites may not be negatively affected by climate change-driven reduction in snow cover. Interestingly, the author observed nearly no haying activity by pikas at his study sites, and hypothesized that hay storage may not be necessary due to the area's mild winters.

Pikas in the Sierra Nevada and Bodie Hills breed asynchronously, presumably as an adaptation to environments where the timing of spring snowmelt and the sprouting of vegetation is unpredictable from year to year. With asynchronous breeding, some of the young pika in any given year could be born at the ideal time to take advantage of emerging vegetative forage (Smith 1978). This adaptation may also be advantageous for California pika populations adapting to changing climatic conditions.

Millar (2011b), in her comment letter on the amended petition, stated the information she provided to the Department provides evidence of the ongoing capacity of pika to occupy and use a diverse range of environments, elevations, and climatic conditions in eastern California, as well as the potential for talus habitats to serve as climatic refugia under future warming conditions. Millar summarized the information from her research (Millar and Westfall 2008, 2010a, 2010b, Millar 2011a, Millar et al. 2012a, and unpublished information) as follows:

- Talus features with unique thermal regimes and micro-climatic processes provide cool conditions for pikas in summer and are more resistant to climate warming (i.e., decoupled from regional surface air temperatures).
- For locations with topographic features (such as rock-ice features) that provide cooler than average temperatures relative to adjacent habitats, climate envelope models used for the region are inaccurate. This suggests that pikas using buffered refugia in the future may be more resistant to regional temperature increases than pikas using sites without thermal refugia within the region.
- Occupied sites had recorded surface air temperatures well above the known thermal tolerance for pika survival.

The International Union for the Conservation of Nature (IUCN) Red List account for the American pika prepared by Beever and Smith (2011) classified the species' conservation status rangewide as 'Least Concern.' The authors placed the species in this category based on:

- The relatively large area of occupied habitat.
- The only adequately documented declines are largely restricted to the Great Basin, and some areas of the Great Basin are not declining (higher elevations, some mountain ranges).
- The documented decline only represents a small fraction of species' total population.
- Even within the Great Basin, a population decline of 80-90% (required for higher IUCN ranks) has not been documented.
- The estimated total population size for the American pika is consistent with a low ranking (i.e., Least Concern) in the IUCN system.

Although much of the concern about climate change impacts to the American pika is focused on the direct effects of increased temperature on pikas, the Department considers other factors as well. For example, climate envelope models do not account for the pika's ability to behaviorally adapt to warmer climates using crepuscular (dawn and dusk) or nocturnal foraging, retreating to cooler interstitial spaces in talus during hot periods. Also, recent work indicates precipitation may be an important factor of habitat suitability for pikas in some locations (Smith and Erb 2012, Erb et al. 2011). Other contributors to resiliency include local conditions in the environment that provide favorable refuges for the pika despite general degradation in habitat quality. Although temperature plays a large role in determining where pikas can persist, they have been documented outside what was believed to be "suitable pika habitat" (Simpson 2009, Rodhouse et al. 2010, Manning and Hagar 2011; thus ecological niche modeling may overestimate future extinction risks for this species (Zgurski 2011).

Climate change would occur in combination with other threat factors, such as a small and isolated population size, predator and competitor community changes, and changes in invasive plant species composition to affect a species. The Department recognizes the threat that climate change poses to many wildlife species in California, including the American pika. Some of the losses of pikas from historical sites in California may be due to direct or indirect effects of warmer summer temperatures or more extreme cold temperatures during winter due to loss of snowpack. Some of the losses that have occurred may represent fluctuations in site occupancy by a species that occurs in patchily-distributed habitat, where local extinctions alternate with recolonizations. But the loss of pikas from some low-elevation sites found by Nichols (2011a, 2011b) in the Bodie Hills, Massing (2011) in the Lassen area, and Stewart and Wright (2011, 2012) in the central Sierra Nevada, as well as the meta-analysis of the California resurvey projects (Stewart et al. 2012, Appendix 1 of this report) is suggestive that increasing temperatures at the lower elevational range of the pika may already have had an impact on the species. The best available scientific information indicates the losses of pikas from sites in California to date are not substantial, given the pika's current occurrence throughout most of its historical range. However, given the predicted temperature increase over the next 100 years, some models suggests pika habitat suitability will substantially decrease in California in the future. However, some of these models did not accurately predict the current range and site-occupancy of pika.

Time Scales and Uncertainty for Climate Change Effects

The protection afforded listed species under CESA is driven in general terms by a Commission determination that the species' continued existence is in serious danger throughout all or a significant portion of its range (for endangered species) or that it is threatened to be in the foreseeable future (for threatened species). Anticipating the future conservation status of a species is fraught with uncertainty, especially when complex systems such as climate are involved. Because there is no statute, regulation, or policy available to guide CESA listing recommendations related to climate change impacts, the Department here provides its case-specific rationale for the American pika recommendation.

In considering what the "foreseeable" future is for climate change effects, the Department relied on climate change projections to the end of the 21st century, as described by the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007). The IPCC models and projections have been thoroughly vetted and validated in the series of Assessment Reports produced over the past 12 years. The Department considers the climate change projections to be the best available information on global climate change.

Regarding the effects of future climate change on the American pika, the Department notes that independent modeling efforts using bioclimatic variables only (Loarie et al. 2009, Trook 2009, Galbreath et al. 2009, Calkins 2010), bioclimatic variables plus land-cover variables (Calkins et al. 2012), and the climate-history approach of Loarie et al. (2009) produce similar results. These models predict the American pika in California will undergo a substantial reduction in habitat suitability, and consequent reduction in occupied range, due to projected climate change during this century, concluding in 2100. The Department concurs with the general assessments regarding climate change trends, but also recognizes the uncertainty in relying on models and considers the exact trajectory and patterns of habitat suitability in the future to be unknown. Additionally, based on some investigations, there is likely untapped resiliency in the system that may ameliorate projected climate change impacts, at least in some contexts. However, the consistent results of the climate change models that were reviewed and were conducted specifically on American pika predict that a significant reduction in suitable habitat in California will occur during this century.

The Department notes that the National Marine Fisheries Service has adopted a similar approach in recent listing decisions for the federal Endangered Species Act. Climate change projections and models of habitat impacts for the ringed seal, bearded seal, and several coral species used the end of the 21st century as the foreseeable future (Cameron et al. 2010, Kelly et al. 2010, Brainard et al. 2011).

In adopting this approach for the American pika listing recommendation, the Department acknowledges the constraints on projections of future climate impacts, as outlined by Berteaux et al. (2006). In particular, better cause-and-effect relationships are needed to complement the results from the correlative models that are currently available. Better understanding of the physical and biological factors that affect the American pika's ability to survive and reproduce will allow for better predictions of future habitat suitability in California, as well as inform adaptation planning for the species.

The uncertainty of the future status of the pika as affected by climate change, combined with the uncertainty about the actual climate conditions that will exist for pika, will be better informed as time proceeds and additional field data on American pikas is obtained. Studies and monitoring of distribution and abundance collected during the next years and decades will provide information that informs the question of accuracy of the foreseeable future as well as the immediacy of threat. Such scientific data is needed to test, or validate, the models predicting significant habitat loss during this century. While climate change can be considered to be in progress now, it may not be immediately threatening the American pika in a significant manner.

FACTORS OTHER THAN CLIMATE CHANGE

Mining

Nichols (2011a, 2011b) suggested in his unpublished report and a related presentation that gold mining in the Bodie Hills poses a threat to pikas that may persist in unsurveyed areas. Nichols reports that exploratory drilling at the abandoned Paramount Mine was conducted in 2009. An Environmental Assessment, dated May 1, 2009, briefly mentioned pikas but did not analyze potential impacts or propose mitigation measures. Additional proposals to open the Bodie Hills to gold mining are "ongoing." Nichols (2011a, 2011b) indicated that, although it is unknown whether the Paramount Mine ore-dumps are occupied by pikas, mining activity could directly impacts pikas (if they are there) or indirectly impact pikas (if nearby sites are disturbed through habitat alteration, including increased human activity). The potential for future occupation by pikas of the impacted sites could also be reduced.

Depending on the type of mining operation, it is also possible that mining could create new patches of habitat for American pikas. The ore-dump sites occupied by pikas at Bodie and nearby sites consist of excavated rock removed from shaft mines.

The report by Nichols (2011a) suggesting potential direct and indirect impacts of mining on American pikas in the Bodie Hills is plausible. However, the degree of impact from mining is unknown. It is not known whether pikas occur or occurred at the Paramount mine described by Nichols, nor does the Department currently have information on any other on-going or proposed mining activity in or near pika-occupied sites. The predominance of federal ownership within the pika's geographic range suggests that most new mining projects would be required to address potential impacts to pikas in documents prepared under the National Environmental Policy Act (NEPA). However, it is unclear to what extent potential impacts to a non-listed species like the pika would be assessed, disclosed, or mitigated. According to Nichols (2011b), the pika received only cursory treatment in the Environmental Assessment for the Paramount mine project. Moreover, on-going or renewed mining activity on federal, state, or private lands may not undergo a thorough environmental review.

The Department sent letters to the California Geological Survey, the California State Mining and Geology Board, and a mining industry group (the California Construction and Industrial Materials Association) requesting information and comments on the status of the American pika. No response was received.

On a local level, the harvest of boulders for construction and landscaping may impact pikas. Because pikas preferentially use larger sized rocks for their haypiles, selective harvest of the largest boulders from talus fields (which has been observed in some parts of the species' range), may have a disproportionate effect on pika densities in the effected areas.

Grazing

Beever et al. (2003, 2011) found evidence that livestock grazing near talus negatively impacts pika persistence in the Great Basin sites they studied. Millar (2011a, 2012) described her finding that pika haypiles in talus with adjacent livestock grazing were located farther upslope than sites where grazing did not occur. These haypiles from areas with adjacent livestock grazing were comprised of lower nutritional quality vegetation than in areas without grazing. Further, Millar (2011a) indicates the forage taken from taluses with adjacent grazing is comprised of species that preferentially grow in lithic environments. These sites have lower plant species diversity as well as lower vegetative abundance and poorer nutritive quality. A dominant lithic species, *Rubus idaeus* ssp. *strigosus*, has low biomass, above-ground tissues covered with spines, and (citations in Millar 2011a) declines in wildlife forage value as plants dry in haypiles.

Preliminary available information indicates that livestock grazing adjacent to talus may have a negative impact on pikas occupying a site. Such impacts may occur through either reduced nutritional value of available vegetation, less abundant and diverse vegetation, less-favorable microclimates, or some combination of these factors.

The Petitioner (Wolf 2011a) provided a list of federal grazing allotments in California and suggested that significant overlap of these allotments occurs with the pika's geographic range. According to Wolf (2011a), there are "at least 118 U.S Forest Service (USFS) allotments allowing cattle, sheep, and/or horse grazing and 49 Bureau of Land Management (BLM) allotments may overlap with occupied pika habitat." It appears that 82 of the USFS allotments are indicated as "Active" while the others are either indicated as "Vacant" or no status is given. No area is provided for these allotments. The Petitioner's list provides area for the BLM allotments, but does not indicate status.

While the Department recognizes the potential for adverse impacts from livestock grazing on nearby pika populations, it does not have sufficient information to assess the degree or immediacy of threat from notes that Beever et al. (2011) found in their analysis of the factors potentially driving recent pika extinctions in the Great Basin that ungulate grazing was a weaker predictor of extinctions than climate-related variables.

Millar (2011, pers. comm.) found that livestock grazing impacted pika behavior in the eastern Sierra Nevada and Great Basin. She described her observations that grazing is widely permitted in the Great Basin, and in some areas of the eastern Sierra Nevada and eastern White Mountains. Millar found that grazing was associated with foraging by pikas further upslope in or adjacent to the talus field. Pika haypiles in grazed sites consisted of plant species with apparently lower nutritional quality than haypiles in ungrazed sites. In grazed locations where pikas are present, the mean distance from lowest haypile to lower talus edge was about 30 meters. In ungrazed sites, the distance was less than 2 meters. This statistically-significant difference could also be biologically important, given that Millar's other work indicates that subsurface temperatures in talus fields are usually coolest at the lower edges of the fields (Millar and Westfall 2008, 2010a).

Table 3 lists the areas within federal grazing allotments (U.S. Forest Service and Bureau of Land Management) within the California range of the American pika. Figure 6 depicts the allotments. Although a relatively large percentage of the pika's geographic range in California has grazing authorized to occur on it, the Department believes that much of the area is in low-lying areas that are only marginally suitable for pikas.

Table 3. Area of federal grazing allotments within the California range of the American pika.

Ownership Type	Km^2	Percent of Total Range Area
U.S. Forest Service Grazing Allotments	21,537	34.6%
BLM Grazing Allotments	6,689	10.8%
Total	28,225	45.4%

The Department sent letters to the California Farm Bureau Federation, the California Cattlemen's Association, and the California Wool Growers Association requesting information and comments on the status of the American pika. The California Cattlemen's Association responded with a letter that argued against listing the American pika (see Appendix 2 for a copy of the letter).

Predation and Competition

Natural and introduced predators may affect pika populations. Li and Smith (2005) attributed some of the population decline in the Ili pika (*Ochotona iliensis*) of northwestern China to predation by domestic dogs associated kept with for the protection of free-ranging livestock.

Long-tailed weasels (*Mustela frenata*) and short-tailed weasels (*Mustela erminea*) are among the most efficient and ubiquitous native predators on the American pika (Ivins and Smith 1983, Smith and Weston 1990). It has been suggested that weasels may switch from preying predominantly on meadow voles (*Microtus* sp.) during episodic population crashes of that species to preying predominantly on pikas (C. Millar, pers. comm., July 31, 2011). It has also been suggested that weasels may be partly to blame for the loss of pikas from the middle and southern ore-dump patches at Bodie SHP (Millar 2011a, Smith 2011a).

Species with similar resource needs compete with pika for food and cover. Two rodents, the bushy-tailed woodrat (*Neotoma cinerea*) and California ground squirrel (*Otospermophilus beecheyi*) are of particular interest in this regard. Woodrats have long been recognized as a species that co-occurs with American pikas in their talus habitat. Numerous anecdotes of woodrats taking over pika haypiles as nests have been related to Department staff by pika researchers. California ground squirrels appear to be expanding their elevational range (Moritz et al. 2008, Morelli 2011) and now may be found co-occurring with pikas at some sites in California (Nichols, pers. comm., August 5, 2011).

It is unknown to what degree predation by native or introduced predators are affecting pika populations, or if recent and future circumstances will result in different predation risks to pikas. Rattlesnakes (*Crotalus* sp.) may be a newly-occurring native predator at some low-elevation sites, such as Bodie State Historic Park (Nichols, pers. comm., August 5, 2011). The potential for climate-induced changes, such as been suggested for the possibly new occurrence of rattlesnakes at Bodie (Nichols, pers. comm., August 5, 2011), does exist, however.

It is uncertain to what degree competition from other species using the same resources as pikas may be affecting the ability of pika populations to persist. It is also uncertain how climate change will impact predation risks to pikas, either by allowing additional predator species to move into areas occupied by the pika and to impact those pika populations or by negatively impacting some current predators. It is possible that climate change may affect the interactions between the pika and competing species like the bushy-tailed woodrat and California ground squirrel, however the magnitude of such possible effects is unknown.

Disease

The importance of disease, including plague, as a potential threat to pika population persistence is unknown. Li and Smith (2005) considered and rejected the hypothesis that plague negatively impacted populations of the Ili pika (*Ochotona iliensis*). Plague was reported in one American pika at Lava Beds National Monument (Bonkrude 2009, pers. comm. in USFWS 2010). Bot fly parasitism, found in six individuals in Montana and Oregon, has been rarely noted in American pikas (Baird and Smith 1979). Durette-Desset et al. (2010) describe nematodes endemic to most lineages of American pika. According to the authors, there is likely a long coevolutionary history between the nematode species and pikas and the parasites may not constitute a threat to the species. Severaid (1955) identified 66 species of ectoparasites that use American pikas as hosts.

A potential interaction between climate change and disease is the endemic occurrence of plague in California ground squirrels (*Otospermophilus beecheyi*). California ground squirrels are documented as expanding their range to higher elevations, and are now occurring at some pika sites. It is possible that increased exposure of pikas to this plague host may increase the impacts of the disease in the future. The Department is currently co-sponsoring a baseline health assessment of pikas in California to determine disease exposure and prevalence of disease-carrying parasites in natural populations (Clifford and Foley 2011).

Habitat Degradation and Fragmentation

American pikas have difficulty crossing distances greater than 300 to 350 meters of unsuitable habitat to reach other suitable habitat patches, at least at low elevation sites like Bodie (Smith 1980). Pika site occupancy is dynamic, with ongoing colonizations, extirpations, and recolonizations. At sites such as Bodie, where habitat patches are small and discrete (i.e., separated from other patches by unsuitable habitat), changes in site occupancy may be frequent (Smith 1980). Smith (1980) found that the probability that a habitat patch in Bodie would lose pika occupancy was inversely related to the patch size, and that the probability of a patch being recolonized was inversely related to the distance to the nearest occupied patches. Such sites at lower elevations (i.e., warmer sites) may become increasingly difficult for American pikas to recolonize as the inhospitable stretches of land with little or no thermal refugia between habitat patches warm (Smith 1980).

Patch size appeared to be the most important factor governing the occurrence of pikas on the habitat patches at Bodie, an effect apparently due to the relatively low probability of extinction of populations on large patches (Smith 1980). However, Smith and Gilpin (1997) determined that the probability of a given patch of habitat being occupied is strongly influenced by the level of occupancy in the habitat patches of the surrounding “neighborhood”, not just the nearest neighbor. They considered predation a likely factor in neighborhood-scale extinctions, which could explain this result.

Population Size and Isolation

The degree and immediacy of threat of the pika’s population distribution across the landscape is uncertain. However, in general pikas are more likely to be extirpated from small, isolated patches of suitable habitat than from larger patches that occur closer together. Size of talus patches has been implicated as a factor affecting persistence of pikas (Smith 1974b, Beever et al. 2003, Stewart and Wright 2011, Stewart et al. 2012, Appendix 1 of this report). As temperatures increase, it is likely that pika subpopulations will become more isolated as conditions between patches are less suitable for dispersal.

Small, isolated populations are at increased risk of extinction due to demographic stochasticity (unpredictable changes in sex and age ratios, distribution of individuals and geographic structure of a population (Mace and Lande 1991) and genetic stochasticity (random changes in gene frequencies and fitness which are amplified in small populations) (Pimm et al. 1988).

Because the species inhabits a naturally patchy habitat type (talus) and has relatively poor dispersal ability, the American pika tends to occur as relatively small subpopulations with limited exchange between the subpopulations. Climate change could exacerbate the risks associated with small populations and isolation by decreasing habitat patch sizes, increasing the distance between patches as pika populations contract upslope, and rendering dispersal attempts less likely to succeed. Castillo and Epps (2012), found that the genetic diversity within pika populations in the western United States was greater in higher elevation populations, suggesting climate effects may already be isolating populations and affecting population genetics. Similarly, Henry et al. (2012) have detected evidence of population isolation among geographically close pika sites in British Columbia. Of particular concern is the fact that the authors determined differences in elevation effectively isolated populations from one another.

In their study of the population genetic structure of the American pika throughout its range in North America, Galbreath et al. (2010) found the distribution of genetic diversity in American pikas is highly structured across its range at both regional and local scales. The researchers found that populations that comprise the *schisticeps* subspecies are strongly isolated from other subspecies to the north and east, although evidence exists for past gene flow between the subspecies. Population genetic structure among Sierra Nevada pika populations indicates genetic exchange is ongoing or has occurred there relatively recently. There is relatively strong isolation between the Sierra Nevada pika populations and populations in the northeastern-most extent of the *schisticeps* subspecies range in central Utah, suggesting a degree of isolation even within the subspecies. This result is not surprising, given the basin-and-range topography of the Great Basin, in which pikas are found in suitable habitat in relatively small mountain ranges surrounded by expanses of unsuitable habitat.

Summary of Risk Factors other than Climate Change

The U.S. Fish and Wildlife Service identified potential threats to American pika other than climate change: livestock grazing, native plant succession, invasive plant species, fire suppression, disease, predation, roads, off-highway and off-road vehicles, trails, and recreational shooting (USFWS 2010). The Service concluded none of the identified potential threats posed a significant threat to the species or any of the identified subspecies at the time of its review or in the foreseeable future.

Similarly, for all risk factors other than climate change that were evaluated by the Department in this report (such as grazing, mining, predation, competition, disease, small population size as well as the interactions among these factors), the magnitude or effect on the American pika is uncertain.

REGULATORY STATUS

State, federal and non-governmental organizations designate “at risk” species (e.g., threatened and endangered species, Species of Special Concern, Species of Greatest Conservation Need, etc.) and assess and rank their conservation needs. Status designations for the American pika are summarized below by jurisdiction or organization:

State of California Status. The Fish and Game Commission designated the American pika a “candidate” for listing as endangered or threatened under CESA, effective November 11, 2011.

With related notice of its candidacy, the CESA prohibition against unauthorized “take” of the American pika is currently in effect. (Fish & G. Code, §§ 2080, 2085). “Take” is defined for purposes of the Fish and Game Code, including CESA as hunt, pursue, catch, capture, or kill, or to attempt to engage in any of these activities. (*Id.*, § 86.) Take of species protected by CESA, including the American pika may be authorized under certain circumstances.

“Species of Special Concern” (SSC) is a Department administrative designation intended to alert biologists, land managers, and others to a species’ declining status and to encourage them to afford these species additional management consideration. SSCs are defined as species, subspecies, or distinct populations of an animal native to California that currently satisfies one or more of the following (not necessarily mutually exclusive) criteria: is extirpated from the State or, in the case of birds, in its primary seasonal or breeding role; is listed as federally-, but not State-, threatened or endangered; meets the State definition of threatened or endangered but has not been formally listed; is experiencing, or formerly experienced, serious (noncyclical) population declines or range retractions (not reversed) that, if continued or resumed, could qualify it for State threatened or endangered status; has naturally small populations exhibiting high susceptibility to risk from any factor(s), that if realized, could lead to declines that would qualify it for State threatened or endangered status (Comrack et al. 2008).

The Mammal Species of Special Concern (MSSC) list has been in a state of ad hoc revision since the list was established in 1986 (Williams 1986). The American pika is not currently designated as an MSSC. The MSSC list is now undergoing a formal update and revision using an objective, criterion-based method developed by the Department (see Shuford and Gardali 2008 for a recent published example of the current method). As part of the update process, the American pika is being evaluated, scored, and ranked using eight criteria along with all other mammalian taxa naturally occurring in California. It is too early in the evaluation process to ascertain whether the American pika will be on the updated MSSC list. However, regardless of the outcome of the evaluation, it is important to note that the scoring criteria for the MSSC project explicitly address a time frame of approximately 20 years into the future and that the threat due to climate change impact is given very low weight in the evaluation. Additional evaluation of climate change impacts to California mammals, including the American pika, will be made in a follow-up analysis for the MSSC project.

Projects carried out on state and private lands which are funded or authorized by public agencies are subject to the provisions of CEQA (e.g., highway construction, residential and commercial development, energy projects). CEQA requires that actions which may substantially reduce the habitat, decrease the number, or restrict the range of any species which can be considered rare, threatened, or endangered (regardless of status under state or federal law) must be identified, disclosed, considered, and mitigated or justified (California Code of Regulations, Title 14, sections 15065(1), 15380). Impacts to species identified as SSCs should be carefully evaluated in CEQA planning documents.

Federal Status. The American pika is not currently listed as endangered or threatened nor is it a candidate for listing under the federal Endangered Species Act. In October 2007, the Center for Biological Diversity (CBD) petitioned the Service to list the American pika and conduct a status review of each of the recognized subspecies of American pika. The Service advised CBD that the petition could not be addressed at that time because existing court orders and settlement agreements for other listing actions required nearly all of the listing funding. Subsequently, the CBD filed a notice of intent to sue over the Service's failure to publish a petition finding. The Service then entered into a settlement agreement requiring the Service to submit a petition finding to the Federal Register by May 1, 2009, and to submit a status review finding to the Federal Register by February 1, 2010. On February 10, 2010, the Service published the results of its status review, in which it concluded that the American pika did not meet the criteria for listing under the federal Endangered Species Act (USFWS 2010). The Service acknowledged that the American pika is potentially vulnerable to the impacts of climate change in portions of its range, but that the best available scientific information indicated that the species will be able to survive despite higher temperatures and that there is enough suitable high elevation habitat to prevent the species from becoming threatened or endangered.

Status in Surrounding States. The American pika is not listed as threatened or endangered, nor does it have any other special management status in the state of Oregon. In Nevada, although the species has no special management status, it was included in the state's 2012 Wildlife Action Plan because the Nevada Department of Wildlife's Climate Vulnerability Assessment found the species to be moderately vulnerably to climate change impacts, and because populations are isolated and fragmented within the state.

Non-governmental Organization Designations. NatureServe, a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action through its network of natural heritage programs, ranked the American pika as a whole as globally secure (rank G5). However, the traditional subspecies in California were ranked as either vulnerable (rank T3, *taylori*, *schisticeps*, *muiri*, and *albata* subspecies) or critically imperiled (rank T1, *sheltoni* subspecies). NatureServe defines the term "vulnerable" as "At moderate risk of extinction or elimination due to a restricted range, relatively few populations, recent and widespread declines, or other factors" and "critically imperiled" as "at very high risk of extinction due to extreme rarity (often 5 or fewer populations), very steep declines, or other factors." (NatureServe 2012).

As mentioned above, the IUCN has designated the American pika as a 'Least Concern' species based on the latest assessment of the species range-wide.

EXISTING MANAGEMENT EFFORTS

The Department, along with other state and federal agencies, is addressing the impacts of climate change through a combination of initiatives aimed at curtailing greenhouse gas emissions of its own activities, proposed projects reviewed under the California Environmental Quality Act and National Environmental Policy Act, and adaptation planning for California's wildlife, fish, and plant species. In general, potential impacts to the American pika of proposed grazing and mining activities is and will continue to be addressed during the environmental review process for such activities. Listing of the American pika under CESA would provide more weight to such impact analysis, and ensure that impacts to pika from projects subject to CESA are minimized and fully mitigated.

Also of note, many of the areas occupied by American pikas in California are relatively free of direct habitat loss or degradation by development-related human activities. As summarized by researcher Rob Klinger (Klinger 2012 pers. comm.), "pika populations in the Sierra Nevada and White Mountain ranges occur on some of the most protected and relatively intact ecosystems remaining in North America. The vast majority of their range is in wilderness areas managed by The National Park Service or the U.S. Forest Service."

Based on recent summaries of greenhouse gas emissions, the Department has determined that global, national, and state climate change initiatives to date have not moved atmospheric greenhouse gas levels off the trajectories predicted to result in severe impacts in habitat suitability for the American pika over the next 100 years. It is possible that current and future efforts to reduce greenhouse gas emissions will reduce such impacts, but given the expected lag time between emissions reductions and changes in climate conditions, the Department expects that conditions for the American pika in California will worsen over the next several decades. Because of the expected impacts to wildlife in California, the Department, along with other state and federal agency partners, is actively engaged in adaptation planning for climate change-affected species, as well as working to reduce greenhouse gas emissions from proposed projects and its own activities.

California Pika Consortium

The Department, along with federal and academic partners, led the formation in 2009 of the California Pika Consortium (CPC). The CPC consists of pika researchers, wildlife and land management agency representatives, and non-government organization members with its major purpose of facilitating communication on issues related to the American pika and other high-elevation small mammals in California. The group has generally met once or twice a year since its first meeting in 2009 to share information, prioritize research topics, discuss standardized field techniques, and to visit natural and human-made pika sites in the eastern Sierra Nevada and western Great Basin. The CPC served as the model for the formation of the North American Pika Consortium (NAPC), which pursues similar goals throughout the geographic range of pikas in North America; CPC members are actively engaged with NAPC activities. These two organizations provide a forum for discussions of American pika biology, conservation, and adaptation planning. The Department will continue to rely on the CPC for information related to the American pika.

National Park Service

The American pika has no special status designation within the structure of the National Park Service (NPS). However, the NPS initiated a pika monitoring partnership in 2009 with the NPS's Vital Signs Monitoring Program and four National Parks. The effort resulted in the development of a pika monitoring protocol with robust, standardized field methods. The NPS also initiated the three year "Pikas in Peril" project which has expanded on the monitoring project and includes additional occupancy surveys (using the concepts of the protocol sampling design and survey methods), incorporates genetic analyses and climate projections, and will produce a vulnerability assessment for the species. NPS pika work has now expanded to include Crater Lake National Park, Craters of the Moon National Monument and Preserve (ID), Great Sand Dunes National Park and Preserve (CO), Grand Teton National Park, Lava Beds National Monument, Lassen Volcanic National Park, Rocky Mountain National Park (CO), and

Yellowstone National Park. Pikas in Peril is funded through 2013. Ongoing commitment to pika monitoring in the National Park system varies by Park and by Inventory and Monitoring network (Mackenzie Jeffress, pers. comm.).

Within California, the NPS is currently collaborating with the USGS on a large scale study examining the relationship between climatic shifts and the distribution, abundance, and habitat use of alpine mammals (including American pikas) throughout the alpine and sub-alpine zone of the Sierra Nevada and White Mountain ranges (Yosemite NP, Sequoia NP, Kings Canyon NP, and National Forest lands). The study uses downscaled climate layers for the Sierra Nevada and White Mountain ranges and other data sources to analyze temporal and spatial dynamics of pika abundance and habitat use, as well as changes in the condition and extent of alpine zone vegetation communities over the last several decades. Eventually the study will model potential shifts in range and abundance of pika under several future climate scenarios.

Additionally, Yosemite National Park has approved two pika-related research projects for the coming years. One will examine climate driven range shifts in talus-dwelling mammals and the other will investigate pika genetic diversity and gene flow across landscapes (Sarah Stock pers. comm.).

National Forest System Lands

The American pika has no special status on United States Forest Service lands in California. The American pika, as a talus-associated species, has not been considered to occur within areas of forest management, such as timber harvest and road-building, or other permitted activities, such as grazing or recreation (Macfarlane pers. comm. 2012). However, given the recent finding of an effect of livestock grazing on pika behavior, it is possible that greater scrutiny of potential impacts of grazing on the pika will be incorporated into permitting by the Forest Service (Macfarlane pers. comm. 2012). Research conducted by the USFS Pacific Southwest Research Station has been instrumental in furthering the understanding pika distribution, habitat relationships, and response to climate change and other impacts (e.g. Millar and Westfall 2008, Millar 2011).

MANAGEMENT RECOMMENDATIONS

The following list of management recommendations were generated by Department staff. Additional recommendations generated by the California Pika Consortium to prioritize conservation, research, and monitoring activities are presented in Appendix 4.

- Habitat-specific demographic information for the American pika, as per Kreuzer and Huntly (2003), should be collected by the Department and its partners. Such studies would inform conservation planning for the American pika by allowing better evaluation of habitat areas needing protection, as well as adaptation planning for climate change.
- Comprehensive genetic studies of American pika populations in California and adjacent states should be conducted to provide a better understanding of the genetic structure of the *schisticeps* subspecies. Such information is essential for conservation planning.

- Research and consider implementing management activities that would ensure that American pika populations persist despite projected climate change impacts.
- Continue and expand monitoring efforts for pika populations and their habitat as part of comprehensive climate change monitoring and adaptation planning for high-elevation small mammal communities in California.
- Assess and recommend measures to reduce potential significant impacts to American pika populations associated with activities such as mining and livestock grazing, as part of the environmental review process for such projects.
- Assess the greenhouse gas emissions associated with proposed projects and activities reviewed under the California Environmental Quality Act. Such assessments and associated recommendations should be made by the Department as part of its general approach to the issue of climate change.
- Adaptation planning for climate change impacts on California's wildlife is an on-going task of the Department. See the California Climate Change Adaptation Strategy (California Natural Resources Agency 2009 and DFG's Vision Document, DFG Climate Science Web Page) for more information. The Department, along with its diverse group of stakeholders, is also actively working to address climate change adaptation actions for fish, wildlife, and habitats across the state. Integrating climate change considerations into Department functions, management activities, and conservation planning efforts such as the state Wildlife Action Plan, are serious undertakings by the Department that have placed it on the path towards successfully addressing climate change and the many challenges it presents.
- Complete the MSSC update to determine whether the American pika should be designated as a Species of Special Concern. Conduct the follow-up climate-change analysis for the American pika and other at-risk mammal taxa currently funded by a State Wildlife Grant. Depending on the results of these analyses, the American pika may be among those species prioritized for additional research and monitoring if funding is available.
- Review recommendations from the 2009 meeting of the California Pika Consortium (see Appendix 4).

SCIENTIFIC DETERMINATIONS REGARDING THE STATUS OF THE AMERICAN PIKA IN CALIFORNIA

CESA directs the Department to prepare this report regarding the status of the American pika in California based upon the best scientific information. Key to the Department's related analyses are relevant factors highlighted in regulation. Under the pertinent regulation, a "species shall be listed as endangered or threatened ... if the Commission determines that its continued existence is in serious danger or is threatened by any one or any combination of the following factors: (1) present or threatened modification or destruction of its habitat; (2) overexploitation; (3) predation; (4) competition; (5) disease; or (6) other natural occurrences or human-related activities." (Cal. Code Regs., tit. 14, § 670.1, subd. (i)(1)(A).)

Also key from a scientific standpoint are the definitions of endangered and threatened species, respectively, in the Fish and Game Code. An endangered species under CESA, for example, is one "which is in serious danger of becoming extinct throughout all, or a significant portion, of its range due to one or more causes, including loss of habitat, change in habitat, over exploitation, predation, competition, or disease." (Fish & G. Code, § 2062.) A threatened species under CESA is one "that, although not presently threatened with extinction, is likely to become an endangered species in the foreseeable future in the absence of special protection and management efforts required by [CESA]." (*Id.*, § 2067.)

The Department's scientific determinations regarding these factors as informed by and following independent peer review are summarized below.

Present or Threatened Modification or Destruction of Habitat

Projected human-caused climate change as currently predicted based on climatic models and models of the future extent of habitat indicate there may be a reduction in the amount of suitable habitat for the American pika in California by the end of this century (2100). Alternatively, some of the reduction in climatically suitable habitat conditions for the pika in California may be ameliorated by behavioral and physiological mechanisms, and some of the models that predict pika habitat failed to predict currently occupied habitat. In summary, the best available information suggests a substantial reduction in the geographic range of the American pika in California by 2100, but the effect on the species future existence is uncertain at this time. A generally warming climate with more extreme weather conditions may have several impacts to American pika populations, including reduced opportunities for successful dispersal between habitat islands, reduced overwinter survival (reduced winter snowpack will reduce insulation cover and create harsher winter conditions or, conversely, heavier snowpack from extreme winters could delay spring emergence of forage vegetation), and these factors may interact with others to increase population impacts. There is significant uncertainty about the degree of continued warming and the effect of this continued warming on the ability of the American pika to persist in California. The Department considers future habitat impacts of projected climate change to be a potentially serious threat to the continued existence of the American pika in California by the end of the century, but not until then based on existing scientific information.

Overexploitation

The American pika in California is designated as a nongame mammal, and therefore may not be legally taken. (See, e.g., Cal. Code Regs., tit. 14, § 472.). There is no indication that pikas have been harvested for recreational or commercial purposes. A few individual pikas have been captured over the past several years for research purposes; only one mortality from these studies has occurred. To the Department's knowledge based on the best scientific information available, there is not a threat to the species' continued existence due to overexploitation.

Predation

American pikas are subject to predation by a variety of native predators and are adapted to contend with predation pressure by several characteristics, such as vigilant behavior, central-place foraging with good escape cover, and relatively moderate reproduction rate. It is possible climate change may affect the predator-prey relationships for the pika, either by allowing additional predator species to move into areas occupied by the pika or by negatively impacting some current pika predators by altering their preferred prey. Climate change may force individual pikas to contend with greater predation risk while foraging or dispersing, or may relieve them of some predation risk. The Department concludes that the effects of predation as a threat to pika populations is currently uncertain, as are any climate change change-induced effects on predation, to American pikas. There is not sufficient scientific evidence to indicate that current predation is a threat to the continued existence of the species.

Competition

The Department does not consider native competitors to the American pika in California to be a threat to the continued existence of the species. However, climate change may allow additional competitor species to move into areas occupied by the pika and to impact those pika populations. Additional or new competitors may reduce the fitness of individual pikas and reduce the viability of pika populations where the competitors invade. However, it is also possible that some native competitors will be adversely affected by climate change, thus relieving pikas of some competition from these species. The Department concludes that the effect direction and the magnitude of climate change’s effect on competing species to American pikas are unknown. There is not sufficient scientific evidence to indicate current predation is a threat to the continued existence of the American pika in California.

Disease

Diseases occur naturally in American pika populations. Health assessments of California pika populations are just beginning. As with the other factors, however, it is possible that climate change may facilitate the transmission or increase the virulence of diseases currently endemic in pika populations. The Department cannot currently determine the magnitude of the risks to pika populations from disease, nor from the interaction of climate change and disease. The best scientific information available to the Department from disease studies in other pika populations suggests this factor is not currently a threat to the continued existence of the species.

Other Natural Occurrences or Human-related Activities

The Department does not consider mining or grazing to be significant threats to the continued existence of the American pika in California. Other human-related activities contribute to global climate change (e.g. fossil fuel emissions, land use practices, agricultural practices), and therefore indirectly threaten pika populations in California through the habitat, competition, predation, and disease pathways discussed above. Most human-related (anthropogenic) contributions to global climate change are projected to increase in the future. The Department concludes that anthropogenic contributions to climate warming may pose a threat to the continued existence of pika in California, but not in the next number of decades.

Summary of Key Findings

Based on the criteria described above, the best scientific information currently available to the Department indicates the American pika is not in serious danger in the next few decades of becoming extinct throughout all or a significant portion of the species’ range in California, nor by the end of the century should the existing climate change models and predicted trajectory of suitable pika habitat come to fruition. At the present time, the species is widespread through its known range in California and the scientific uncertainty associated with current modeling efforts do not establish with scientific certainty or otherwise provide a sufficient scientific basis for the Department to know categorically or to state the actual threat climate change ultimately poses to the species at this time or through the end of this century. Even the models currently available predict a reduction in pika habitat and therefore populations, distribution, and abundance, but not extinction.

It will be imperative for the Department and for the scientific community to study and monitor the distribution and abundance of the American pika over the next few decades, and as climate change models become more data driven, to be able to better assess the foreseeable future. Such monitoring will ultimately inform scientific understanding as to whether the American pika is trending toward serious danger of extinction or not.

LISTING RECOMMENDATION

CESA directs the Department to prepare this report regarding the status of the American pika in California based upon the best scientific information available. CESA also directs the Department based on its analysis to indicate in the status report whether the petitioned action is warranted. (Fish & G. Code, § 2074.6; Cal. Code Regs., tit. 14, § 670.1, subd. (f).) The Department includes and makes its recommendation in its status report as submitted to the Commission in an advisory capacity based on the best available science. In consideration of the scientific information contained herein, the Department has determined that the petitioned action is not warranted.

PROTECTION AFFORDED BY LISTING

It is the policy of the State to conserve, protect, restore and enhance any endangered or any threatened species and its habitat. (Fish & G. Code, § 2052.) If listed as an endangered or threatened species, unauthorized "take" of the American pika will be prohibited, making the conservation, protection, and enhancement of the species and its habitat an issue of statewide concern. As noted earlier, CESA defines "take" as hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill. (*Id.*, § 86.) Any person violating the take prohibition would be punishable under State law. As to authorized take, the Fish and Game Code provides the Department with related authority under certain circumstances. (*Id.*, §§ 2081, 2081.1, 2086, 2087 and 2835.) In general, however, impacts of authorized taking of the American pika as a result of otherwise lawful activities must be minimized and fully mitigated according to state law.

Additional protection of the American pika following listing is also likely with required public agency environmental review under CEQA and its federal counter-part, the National Environmental Policy Act (NEPA). CEQA and NEPA both require affected public agencies to analyze and disclose project-related environmental effects, including potentially significant impacts on endangered, rare, and threatened special status species. Under CEQA's "substantive mandate," for example, state and local agencies in California must avoid or substantially lessen significant environmental effects to the extent feasible. With that mandate and the Department's regulatory jurisdiction generally, the Department expects related CEQA and NEPA review will likely result in increased information regarding the status of the American pika in California as a result of, among other things, updated occurrence and abundance information for individual projects. Where significant impacts are identified under CEQA, the Department expects project-specific required avoidance, minimization, and mitigation measures will also benefit the species. State listing, in this respect, and required consultation with the Department during state and local agency environmental review under CEQA, is also expected to benefit the species in terms of related impacts for individual projects that might otherwise occur absent listing.

Listing the American pika increases the likelihood that State and federal land and resource management agencies will allocate funds towards protection and recovery actions. Funding for species recovery and management is limited, and there is a growing list of threatened and endangered species.

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APPENDIX 1
Revisits of Historical Pika Locations in California

Prepared by Joseph A. E. Stewart
December 7, 2012

Abstract:

This report examines current (2005-2012) occupancy patterns at historical American pika (*Ochotona princeps*) record locations in California. Of 53 historical pika sites, 9 appeared to be extirpated, and 44 occupied. To assess the cause of these extirpations, 20 habitat and climate variables were derived via geographic information systems and modeled against pika persistence. Consistent with metapopulation theory, total talus area was the best predictor of pika occupancy, with small talus area sites more likely to be extirpated. Temperature and precipitation were also important predictors of continued site occupancy, with hotter and drier sites more likely to be extirpated. These results are consistent with recent studies in the Great Basin and Rocky Mountains and suggest that high temperatures and low precipitation have contributed to pika extirpations in California.

Introduction:

Multiple lines of evidence point to the American pika (*Ochotona princeps*) being geographically limited by climate. Physiological traits, including poor ability to dissipate heat and an upper lethal body temperature 3°C above resting body temperature, make them vulnerable to hyperthermia (MacArthur & Wang 1974; Smith & Weston 1990). The paleontological record indicates that since the last glacial maximum the distribution of pikas retreated upslope as the climate warmed (Grayson 2005). Finally, historical resurveys in the Great Basin and Southern Rocky Mountains indicate that pikas in hot, dry environments were most likely to become extirpated over the last century (Beever et al. 2011; Erb et al. 2011). In the Great Basin, repeated surveys of historical sites are suggestive that range retreat accelerated during the first decade of the 21st century, in concert with anthropogenic climate warming (Beever et al. 2011). Given evidence of climate-mediated contraction in pika distribution elsewhere in the species' range, parsimony suggests similar shifts may have occurred in California. This report investigates patterns of persistence and extirpation at historical pika record locations in California to assess whether the data are consistent with climate-mediated range retreat.

Methods:

This analysis combined the work of five separate resurvey teams and sought to include all geographically precise historical pika records in California that were resurveyed during the "current period," (2005-2011). To standardize the resurvey protocol and to confirm extirpations, sites reported to be extirpated by the original resurvey teams were resurveyed again in 2012 and all talus patches within a 1 km search radius were visited to confirm extirpation (Fig. 1). Because evidence of pika presence was robust at all occupied sites, no occupied sites were selected for additional resurvey in 2012. Methods of locating and resurveying historical pika sites followed earlier work in the northern Sierra Nevada (Stewart & Wright 2012) with minor modifications described here. In addition to historical records obtained from the literature and wildlife museums, more recent pika occurrence and resurvey data were obtained via correspondence with researchers (e.g. Chris Ray, Lyle Nichols). For some sites, historical photographs supplemented historical field notes and allowed us to precisely relocate the original record location. Following experimental evidence, "perched" fecal pellets (e.g., adherent and resting above the angle of repose) were not considered definitive evidence of current year site occupancy; pika fecal pellets that contained green or greenish matter were considered definitive evidence of current occupancy.

Twenty environmental variables (Table 4) were tested against current pika occupancy in univariate and multivariate logistic regressions. Habitat quality variables included: total habitat (talus) area within the 1 km radius, total habitat perimeter within the radius, and rock type. Talus boundaries were delineated by human aerial imagery interpretation. Perimeter was included in addition to area because pikas may preferentially utilize habitat at the margins of talus fields that is closer to vegetation (Moilanen et al. 1998). The variable "rock type" measured whether the rocks in the talus appeared to have thermal properties that might provide higher thermal buffering (e.g. vesicular igneous "lava" rocks). Twelve climate variables were included. Recent (2000-2009) climate was extracted from 4 km grain PRISM grid cells—includes: annual, summer (June, July, August), and winter (December, January, February) temperature and precipitation. Higher resolution climate was extracted from 30 arc-second (approx. 800 m) PRISM 1981-2010 climate normals—includes: annual, summer, and winter maximum precipitation and minimum temperature within the 1 km radius. Maximum/minimum climate values were selected to assess the most suitable climate available to pikas within the search radius. In the case of winter temperature the mean value was used because it was not obvious whether higher or lower values were more suitable. To explore and compare possible effects of direct (abiotic) or indirect (species interaction) effects on pikas, both maximum and minimum "pika equivalent elevation" within the 1 km radius were included. "Pika-equivalent elevation" was defined as the difference between the observed elevation (DEM derived) and a predicted lower elevation limit for pikas across western North America (Hafner 1993). Absolute maximum and minimum elevation within the 1 km radius, was also included. Finally, one variable "distance to roads" was included as an easily calculated proxy for possible human impacts on pika populations.

Forty-seven multivariate models, consisting of up to three independent variables, were tested in logistic regression against pika occupancy. Variables with high Spearman's correlations ($|r| \geq .5$) or that attempted to measure similar causal mechanisms were not included in the same model (e.g. temperature and elevation were not included in the same model). Best performing models with $\Delta AIC_c \leq 2$ were assessed with multimodel inference techniques (Burnham & Anderson 2002).

Results and Discussion:

Fifty-three resurveys of historical pika locations were conducted by five separate resurvey teams (Fig. 2). Historical records dated from as early as 1910 to as recent as 2000. John Perrine, Cody Massing, and Joseph Stewart resurveyed 16 sites in the Lassen region; David Wright and Joseph Stewart resurveyed 21 sites in the northern Sierra Nevada and Sweetwater Mountains; Jim Patton, Emily Rubidge, David Wright and Joseph Stewart resurveyed 10 locations in the Yosemite region; Ken Goehring resurveyed four locations in Shasta region; and Lyle Nichols and Joseph Stewart resurveyed two locations in the Bodie Hills. Three historical pika record locations in anthropogenic habitat (ore dumps) at Bodie State Historical Park and nearby Masonic were excluded due to difficulty delineating habitat boundaries via aerial imagery for anthropogenic sites.

Overall, 44 sites were currently occupied by pikas, while 9 sites appeared extirpated (Fig. 2). Two sites that appeared extirpated during previous resurveys were discovered to be occupied again in 2012. Most (N = 5) apparent extirpations occurred in the Lassen region. Two apparent extirpations occurred in the northern Sierra Nevada and two in the Bodie Hills. One exception to the protocol of surveying all talus patches within the 1 km radius (to confirm apparent extirpation) was made for a site with an exceptionally high number of small talus patches, “4 mi SW of McDonald Peak.” For logistical reasons, total 2012 search effort was capped after survey effort exceeded 10 hours in-talus, (29 hours total), with survey effort spatially stratified to include the highest to lowest talus fields ranging across all aspects and topographic positions and emphasizing search effort in what appeared to be the highest quality habitat. For context, previous studies indicate that 15-30 minutes of search effort is sufficient to achieve >90% pika detection probability at occupied sites (Beever et al. 2010; Rodhouse et al. 2010). Further, when this record is excluded from statistical analysis results are not substantially altered.

Univariate logistic regression supported eleven variables as statistically significant predictors of site occupancy patterns (Table 1). Talus area had the strongest statistical relationship with occupancy patterns. Sites with more talus area were more likely to be currently occupied ($p < 0.001$). This pattern is consistent with the application of metapopulation theory to pikas wherein sites with larger and more connected habitat patches are more likely to be occupied at any point in time. The second best performing independent variable was pika-equivalent maximum elevation within 1 km. Sites with higher pika-equivalent maximum elevation were more likely to be occupied ($p < 0.005$). The third best performing predictor was maximum winter precipitation within 1 km ($p < 0.01$). Eight other variables were also significant ($p < 0.05$) predictors of pika occupancy in the univariate test and all model parameters were of the expected sign (e.g., higher precipitation increased likelihood of occupancy, higher temperature decreased likelihood of occupancy, and larger distance from roads increased likelihood of occupancy).

Seven multivariate models achieved $\Delta AIC_c \leq 2$ (Table 2). Talus area and precipitation were included in all seven models and temperature was included in the top four performing models. This result is consistent with recent studies that indicate that high temperatures and low precipitation have adversely affect pika populations in the Great Basin and Rocky Mountains (Beever et al. 2010; Erb et al. 2011; Wilkening et al. 2011). Distance to roads was included in three models with $\Delta AIC_c \leq 2$. The inclusion of distance to roads in the top model set in this analysis (distance from roads increased likelihood of occupancy) is difficult to interpret, and may warrant further investigation of potential mechanisms behind this relationship. Parameter signs were all of the expected sign (e.g., lower temperature increased likelihood of occupancy). Relative variable importance rankings (Burnham & Anderson 2002) add further support to the conclusion that though high talus area was the best predictor of pika persistence, climate variables were also important (Table 3). Plotting talus area against two top performing environmental variables (recent summer temperature and pika-equivalent maximum elevation) also visually supports habitat limitation as the strongest predictor of extirpation with climate and elevation effects also apparent (Fig. 3).

These results are consistent with the hypothesis that recent climate change, over the last century, has caused the American pika's range to contract in California. However, an alternate hypothesis is that climate and elevation stressors result in metapopulation dynamics in which hotter, drier, or lower elevation sites tend to be occupied a lower proportion of time than more-favorable sites. The metapopulation dynamics hypothesis implies that the observed climate relationships in this study do not constitute permanent range contractions. Continued monitoring of these sites would enable us to test this prediction. While historical resurveys are the best tool we have for inferring changes in occupancy pattern from the historical era to the present, they do not constitute randomized sampling of the entire landscape. In order to detect potential future climate-mediated range contractions a statistically rigorous inventory and monitoring program should be established. Additional investigation of mechanisms behind pika population dynamics will be important.

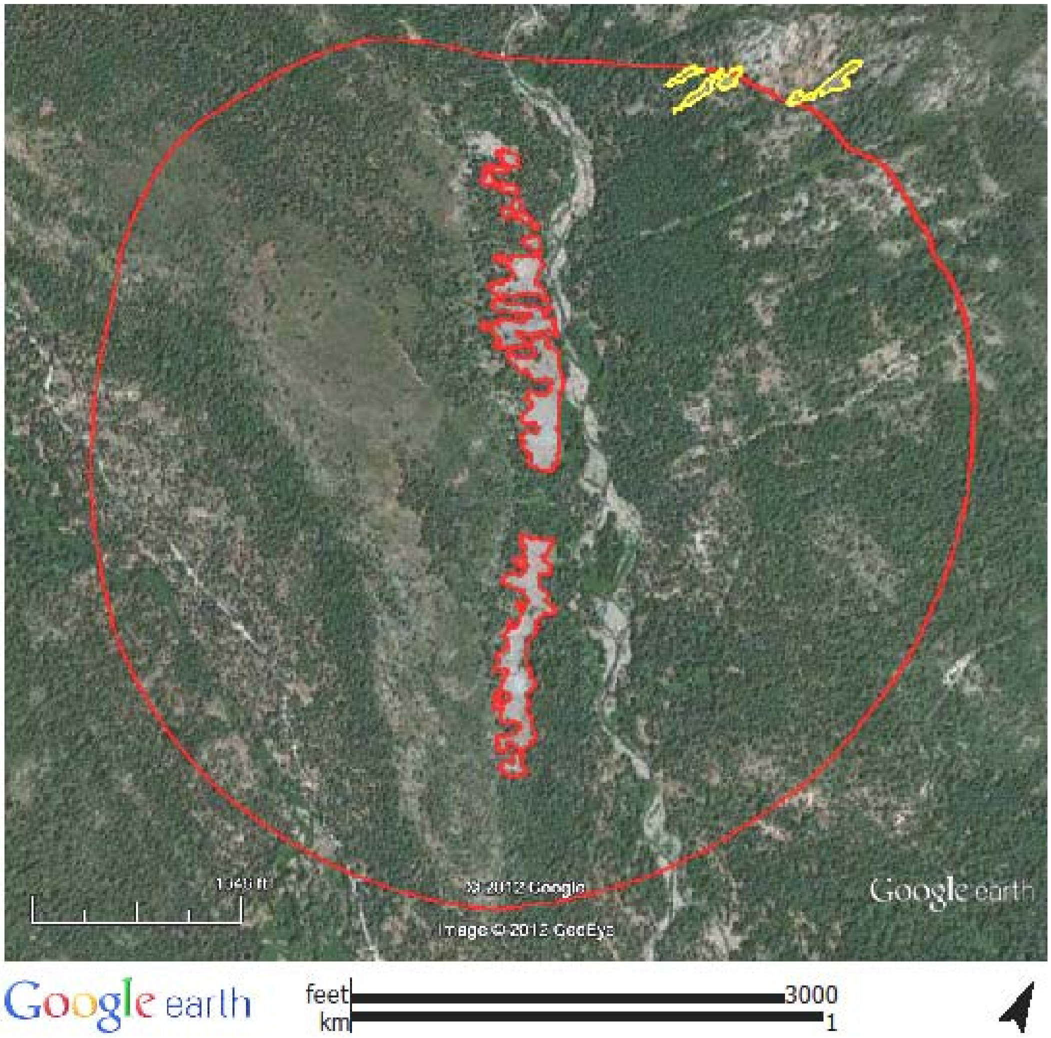

Figure 1. An example of the method used set the centroid location. Talus that plausibly met the historical record description is outlined in red. The centroid was set at the center of the minimum encompassing circle for the plausible talus. The 1 km radius around the centroid is also shown in red. Talus at least partially included in the 1 km radius that does not meet the historical record description is shown in yellow. If pikas were detected in any talus habitat within the 1 km radius, the site was scored as occupied. Pika detections outside the 1 km radius were not scored as occupancy of the historical site.

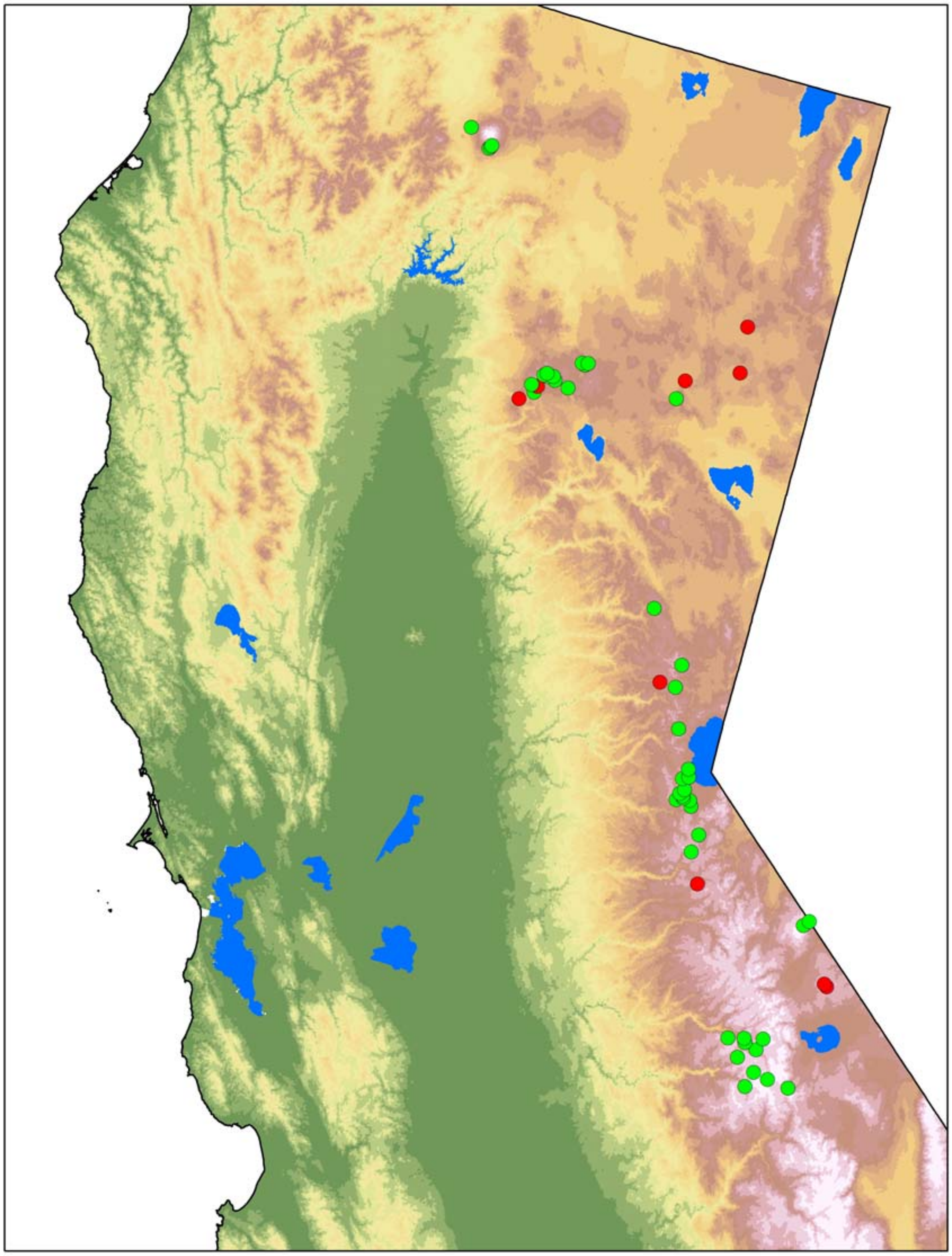

Figure 2. Location of 53 historical pika locations included in this study. Currently occupied locations (N = 44) are shown in green and apparently extirpated (N = 9) locations are shown in red. Note that the majority of extirpations (N = 5) occurred in the Lassen Region.

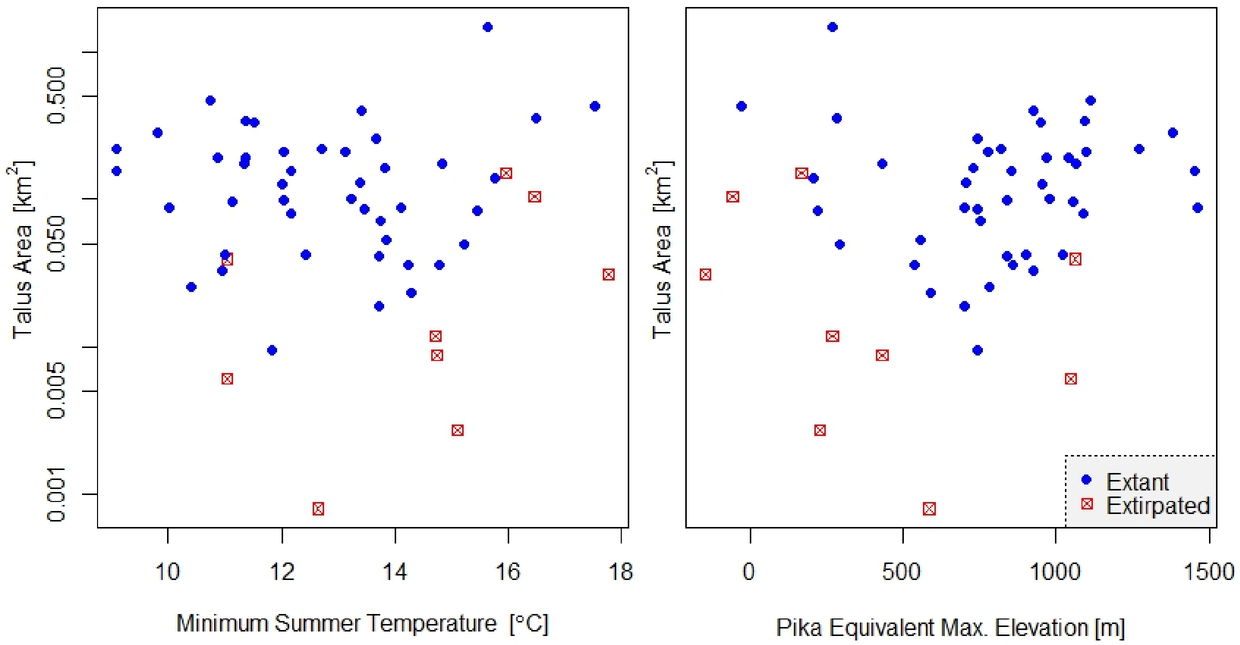

Figure 3. Current pika occupancy plotted against talus area (logarithmic scale) and minimum summer temperature (left) and pika equivalent maximum elevation (right). Though the majority of the extirpation signal appears to come from habitat limitation, climate and elevation signals are also apparent.

Table 1. Statistically significant univariate models of current pika occupancy patterns. Logistic regressions were performed in the R statistical computing program (version 2.15.1).

Model	p > ChiSq	Parameter Sign
Pika ~ TalusArea	$p < 0.001$	+
Pika ~ PikaEqMaxElev1k	$p < 0.005$	+
Pika ~ MaxWinPpt1k	$p < 0.01$	+
Pika ~ MaxElev1k	$p < 0.05$	+
Pika ~ MaxPrecip1k	$p < 0.05$	+
Pika ~ RecWinPpt	$p < 0.05$	+
Pika ~ DistRds	$p < 0.05$	+
Pika ~ RecAnnPpt	$p < 0.05$	+
Pika ~ MinSumTemp1k	$p < 0.05$	-
Pika ~ RecSumTemp	$p < 0.05$	-
Pika ~ RecSumPpt	$p < 0.05$	+

Table 2. Multivariate models with $\Delta AIC_c \leq 2$ and the null model. Variables are ordered by relative variable importance and followed by the parameter sign in parentheses. Logistic regressions and multimodel inference were performed in the R statistical computing program (version 2.15.1) using the "MuMIn" package (version 1.7.11).

Models	ΔAIC_c	Akaike Weight
Pika ~ TalusArea(+) + MaxAnnPpt1k(+) + MinSumTemp1k(-)	0.00	0.18
Pika ~ TalusArea(+) + MaxWinPpt1k(+) + MinAnnTemp1k(-)	0.02	0.18
Pika ~ TalusArea(+) + MaxAnnPpt1k(+) + MinAnnTemp1k(-)	0.12	0.17
Pika ~ TalusArea(+) + MaxWinPpt1k(+) + MinSumTemp1k(-)	0.19	0.16
Pika ~ TalusArea(+) + RecWinPpt(+) + DistRds(+)	0.58	0.13
Pika ~ TalusArea(+) + RecAnnPpt(+) + DistRds(+)	1.25	0.10
Pika ~ TalusArea(+) + MaxWinPpt1k(+) + DistRds(+)	1.60	0.08
Pika ~ Constant (null model)	23.78	0.00

Table 3. Relative variable importance weight for variables in Table 2. Computed in the R statistical computing program (version 2.15.1) using the "MuMIn" package (version 1.7.11).

Variable	**Relative Importance**
TalusArea	1.00
MaxWinPpt1k	0.42
MaxAnnPpt1k	0.35
MinAnnTemp1k	0.35
MinSumTemp1k	0.34
DistRds	0.31
RecWinPpt	0.13
RecAnnPpt	0.10

Table 4. Variable abbreviations and definitions for 20 environmental variables included in this analysis.

Variable	**Definition**
TalusArea	Total talus area within 1 km of the site centroid.
TalusPerim	Total talus perimeter within 1 km of the site centroid.
DistRds	Distance from the site centroid to the nearest road; includes mainly paved roads and some major unpaved roads.
RockType	A binary variable, describes whether rocks appear, on the ground, to have thermal properties that may provide superior thermal buffering (e.g. vesicular igneous "lava" rocks).
MaxElev1k	Maximum elevation within 1 km of the site centroid.
MinElev1k	Minimum elevation within 1 km of the site centroid.
PikaEqMaxElev1k	Adjusted maximum elevation within 1km of the site centroid; the difference between MaxElev1k and predicted lower elevation limit for pikas as derived from Latitude and Longitude (Hafner 1993).
PikaEqMinElev1k	Adjusted minimum elevation within 1km of the site centroid; the difference between MinElev1k and predicted lower elevation limit for pikas as derived from Latitude and Longitude (Hafner 1993).
RecAnnTemp	Recent (2000-2009) annual temperature as derived from 4 km PRISM grid cells.
RecSumTemp	Recent (2000-2009) mean summer (June, July, August) temperature as derived from 4 km PRISM grid cells.
RecWinTemp	Recent (Dec 1999 – Feb 2009) mean winter (December, January, February) temperature as derived from 4 km PRISM grid cells.
RecAnnPpt	Recent (2000-2009) annual precipitation as derived from 4 km PRISM grid cells.
RecSumPpt	Recent (2000-2009) summer (June, July, August) precipitation as derived from 4 km PRISM grid cells.
RecWinPpt	Recent (Dec 1999 – Feb 2009) winter (December, January, February) precipitation as derived from 4 km PRISM grid cells.
MinAnnTemp1k	Minimum mean annual temperature within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.
MinSumTemp1k	Minimum mean summer (June, July, August) temperature within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.
MeanWinTemp1k	Mean winter (December, January, February) temperature within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.
MaxAnnPpt1k	Maximum annual precipitation within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.
MaxSumPpt1k	Maximum summer (June, July, August) precipitation within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.
MaxWinPpt1k	Maximum winter (December, January, February) precipitation within 1 km of the site centroid as derived from 800 m, 1981-2010, PRISM grid cells.

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APPENDIX 2

Public Comments Received During 12-Month Review Period

Public Notice regarding the Status Review for the American Pika

The Fish and Game Commission published the attached Notice of Findings in the California Regulatory Notice Register on November 11, 2011 (Vol. 2011, No. 45-Z). The Department released the attached announcement to news media on December 30, 2011:

The Department mailed the notice of the American pika's candidacy and a request for information and comments to approximately 150 persons or offices of state and federal agencies, counties, industry, and non-governmental organizations. The complete mailing list is on file with the Department.

Summary of Comments Received

The Department received one letter in hard copy format (see letter image below). All other comment letters were received electronically via email (or in some cases, by both email and hard copy). Most of these comments were from the general public. Representatives of the Sierra Club and California Cattlemen's Association also submitted comment letters. The Petitioner submitted three comment letters during the 12-month status review period as of August 23, 2012. Researchers from the United State Geological Survey – Biological Resources Division (Robert Klinger), and USDA Forest Service – Pacific Southwest Research Station (Constance Millar) submitted preliminary information from their on-going research projects.

Not including the letters from the Petitioner and researchers, a total of 11,309 comment letters were received by the Department. Of these, 11,288 were identical (except for the date, author's name and contact information, and, rarely, a personal anecdote). One example of the "form letter" is shown below. Many of the persons submitting the form comment letter apparently sent more than one copy. The Department estimates the number of unique senders of the form letter to be about 9,600.

The remaining 21 unique public comment letters/emails are reproduced below. Sixteen of these, like the many form letters, supported the listing of the American pika. Two letters expressed the authors' belief that human-caused climate change is a hoax, and one of these included a 48-page attachment of information gathered by the author discussing natural climate cycles. Two letters expressed frustration with the Petitioner's actions in the CESA and federal ESA arenas. Two other commenters stated from personal experience recreating in pika habitat in California that they had noticed no change in pika numbers during their years of experience in the range of the American pika.

Example of form email comment letter (11,285 submittals, approximately 9,600 unique email addresses):

==

Mar 8, 2012

California Department of Fish & Game

Dear Department of Fish & Game,

I strongly support protecting the American pika under California's Endangered Species Act.

Scientific evidence shows that the pika is threatened by climate change: rising temperatures and decreasing snowpack have already been linked to significant losses of lower-elevation populations in the Great Basin. In California, pikas are disappearing from warmer, lower-elevation regions, including the Bodie Hills and Lassen areas. Scientists predict that, in this century, climate change will largely eliminate suitable habitat for the pika in California if greenhouse gas emissions are not drastically reduced.

Listing the pika in California will provide important protections that will increase its chances of survival and recovery. I urge you to take immediate action to protect this climate change-threatened species.

Sincerely,

Chris McMullen
Arroyo Grande, CA 93420-3448
===

Unique Public Comment Letters
See pages following the email transcripts (starting after page A2-15) for images of the single hard copy comment letter received, plus hard copy letter attachments to the Sierra Club, California Cattlemen's Association, and Horsting emails)

1.
From: Amber Miksza <hikeramber@gmail.com>
To: <pika@dfg.ca.gov>
Date: 1/7/2012 6:53 PM
Subject: Please protect the Pikas
Attachments: pika flower close.jpg; 12 pika on pinchot.jpg

Dear Scott Osborne,

If you have never seen a pika, or heard one, you may not understand my love of them. But if you have, then you will understand how incredibly special they are, and what a gift it is to see one. Attached a a few shots of pikas we have seen in the Sierra Nevada on the John Muir Trail.

Pikas are so tiny, and have such a limited habitat, surviving in the coldest temperatures throughout the winter, hibernating below granite boulder fields, as I am sure experts have told you. They really are quite resourceful, but do need protection as their population decreases, as their natural habitat shrinks.

Please, take action to save the pikas, so the next generation of youth (and the next after that!) can see tiny little pikas bounding across granite boulder fields will bouquets of flowers in their mouths.

From an admitted pika-lover,

Amber Miksza, Richmond, California

===
2.
From: Gabino <gabinoalonso@yahoo.com>

To: <pika@dfg.ca.gov>
Date: 1/3/2012 9:06 AM
Subject: Comments on Pika

To whom it may concern,

I have hiked most of the Sierra Nevada and Northern California areas throughout my life and I have yet to notice a decrease in population of Pikas or "whistling hare" as I call them. Granted as the average temperature does warm there is a noticeable shift north but I still do not agree there is a decrease in population. In fact I think the population is becoming more dispersed. Since these animals do not hibernate they are more able to adapt to newer areas.

What I believe may be an issue is in the way whistling hares are being monitored. Whistling hares are asocial animals and trying to take a count outside of breeding season for example is a waste of time since your data will always come up short. We need better field trained, scientific minded biologists using better instruments and methods for monitoring populations over time that take into consideration the dynamics of habitat, weather, etc.

Let's not raise a red flag until we have a better understanding of the population trends.

Regards,
Gabino Alonso
South San Francisco, CA
==

3.
From: Walter Horsting <visionar@comcast.net>
To: "pika@dfg.ca.gov" <pika@dfg.ca.gov>
Date: 1/5/2012 6:11 AM
Subject: Global Climate Change is Natural
Attachments: Global Climate Change is Natural.pdf; Part.002

Dear Pika team,

Climate is always changing and is not manmade. Earth is the coldest it has been in 65 million years. Since the ice sheets started to melt 20,000 years ago and the seas rose 500 feet; the last 10,500 years have been warmer 9,850+ years than today's relatively cool warm up from the recent Little Ice Age that ended 150 years ago.

Our money is better spent on many other things than a climate hoax underway.

Thank you,

[The attachment follows page A2-15]

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4.
From: Cal Kenney <ckenney1@yahoo.com>
To: <pika@dfg.ca.gov>

Date: 1/4/2012 2:20 PM
Subject: Mr. Pika

Dear Mr. Pika,

Man made climate change is a hoax perpetrated by socialists and liberals to redistribute wealth from producers to parasites. Do not feel threatened by it, for the Sacramento Socialists will soon be extinct.

PS: Love your furry little munchkin noses!

Cal Kenney
Irvine, CA
==
5.
From: Bill and Ramona Winegar <manolito@frontiernet.net>
To: <Pika@dfg.ca.gov>
Date: 1/10/2012 11:47 AM
Subject: American Pika

I am writing to ask you deny the petition to place the Pika on the endangered species list. This group the Center for Biological Diversity has an interesting history and it should be noted the courts denied this protection of the Pika in 2007 and since the cost of litigation is born by law students at Stanford University they just petition the law school for another class project for the senior students to prepare another suit and wear down the judicial system over time.

The goal is not to protect the Pika but to further their belief in global warming. I am attaching a link to their own site and a small quote in the body of this letter showing clearly this is not about the Pika but about global warming. "Designating the pika as endangered would help protect the species from direct harm and would also require the protection of the habitat necessary for the pika's survival and recovery. Just as importantly, the species' protected status would be a strong call to action against global warming."

I have attached the study by U.S. Fish and Wildlife indicating the Pika should not be considered for the endangered species act.

I am attaching another quote from Animal Spot a group similar in idea that the Pika should be the animal used to defend global warming and has nothing to do with is it endangered. "The American pika is a comparatively smaller and cuter relative of the lagomorph family of hares and rabbits. These innocent mountain rodents thrive best in cold climates and prefer to dwell in high altitude mountains and alpine meadows especially of the American west. Strict herbivores, these American pikas are hardworking animals that are often spotted gathering flowers and plants for storage in winters. These montane mammals are forecasted to fall victims to global warming in the near future .

I watched 117 pass in California and have watched the 30 million dollars a year spent on boondoggle after boondoggle. The problem is people listen to the words spread by these groups CUTE, CUDDLY,HELPLESS, INDICATORS OF MANS FUTURE ETC.

Scientific fact is far better understood without emotion and feeling. No person who supports the

California Department of Fish and Game IE. Hunters and fishermen want a species on earth to be lost. Knowing that helps to explain fossils a scientific fact that species became extinct long before the first fossil of man is dated.

I point to the California Antelope and the migratory waterfowl recovery. These are a direct result of action in the field by those that care. Not by a group of lawyers using the sweat and intellect of vulnerable students trying to pass a curriculum.

My last quote comes from Science clarified regarding the ice ages that have occured in the world to date and specifically the the most recent that has considerable documantation both scientific study and written historical documantation.

"Scientists know a great deal about the cycle of cooling and warming that has taken place on Earth over the last 125,000 years, the period of the last ice age cycle. They have been able to specify the centuries and decades during which ice sheets began to expand and diminish. For example, the most severe temperatures during the last ice age were recorded about 50,000 years ago. Temperatures then warmed before plunging again about 18,000 years ago.

Clear historical records are available for one of the most severe recent cooling periods, a period now known as the Little Ice Age. This period ran from about the fifteenth to the nineteenth century and caused widespread crop failure and loss of human life throughout Europe. Since the end of the Little Ice Age, temperatures have continued to move up and down. No one is quite certain whether the last ice age has ended or whether we are still living in it. "
Please find in favor of science and common sense and do not give in to a group that preys on students for their work threatening law suits.

http://www.scienceclarified.com/He-In/Ice-Ages.html
http://www.fws.gov/mountain-prairie/species/mammals/americanpika/
http://www.biologicaldiversity.org/species/mammals/American_pika/index.html
http://www.scientificamerican.com/article.cfm?id=pika-endangered-species

Respectfully,
Bill and Ramona Winegar
manolito@frontiernet.net
===

6.
From: Harold Noell <haroldnoell@att.net>
To: <pika@dfg.ca.gov>
Date: 1/1/2012 9:29 AM
Subject: american pika

since climate change is effecting the pika's evolution, then leave them alone! you always want yo play GOD. what are you going to do? go up in the mountains, capyure them, put them in a zoo? leave them alone.
===

7.
From: Pikachu Lover <pikanunu@gmail.com>
To: <pika@dfg.ca.gov>

Date: 1/5/2012 8:51 PM
Subject: Endangered Species

Dear State Agency:

Indeed we should protect the pika, an species that is representative of
California wildlife.

Regards,

Friends of the Pika
===
8.
From: Margo Parks <Margo@calcattlemen.org>
To: <pika@dfg.ca.gov>
Date: 3/15/2012 4:12 PM
Subject: American Pika Comments
Attachments: american pika.pdf

Thank you for your consideration of these comments.

Margo Parks
Associate Director of Government Relations
California Cattlemen's Association
1221 H Street
Sacramento, CA 95814
(916) 444-0845
www.calcattlemen.org <http://www.calcattlemen.org>

[The California Cattlemen's Association letter follows page A2-15]

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9.
From: Mike Sweeney <msweeney@arcofamador.org>
To: <pika@dfg.ca.gov>
Date: 3/13/2012 4:06 PM
Subject: Adding Pika to California Endangered Species List

3/13/12

Dear California Fish and Game Representatives:

It is absolutely imperative that we take the lead in California in saving the American pika. (The fact that the Federal Government will not take the lead in this matter only makes it more important that we take concrete action to save this species).

We all know that the pika is so sensitive to heat that it can't survive for any length of time if it leaves its burrow to try and gather food and the temperature is above even 80 degrees. We know that surveys suggest that entire colonies have disappeared from the Great Basin and the Sierra Nevadas.

Obviously, pikas can move upslope in some cases but it's just as obvious that this solution will not work in the long run as they will run out of territory to move up to!

In 2009 I completed my Hika for the Pika to raise awareness of the plight of these wonderful little creatures. I hiked from my house in Sutter Creek, California to the top of Half Dome in Yosemite and I wrote about in online and in our local newspaper - The Amador Ledger Dispatch. Along the way I talked with people from Kentucky, Japan, and Europe. Everybody was intrigued with the pika and the challenges they face; but the people that were most intrigued and inspired to do something to save them were the people I met that lived right here in California. We know what the right thing to do is. We can't wait until there is only one colony left up on the west side of Mt. Whitney. (Look at the porcupine! Their numbers are dropping precipitously and it happened quickly while we weren't paying attention).

The fact that the American pika is our canary in the coal mine in regards to global warming is relevant but not the issue here. The issue is that they are endangered and need to be protected. I do not have scientific proof but I do have 40 years of hiking in the Sierras and I have firsthand knowledge that:

1. There are not as many pika colonies today as there were even 15 years ago.

2. They are found at elevations of 11,500 ft. and above now in the Sierras where I saw them at 10,000 and above when I hiked the Pacific Crest Trail in 1989.

Please let me know how I can help provide information for your decision or help to save the pika. It's the right thing to do. This can be your legacy. Our children will thank you.

Sincerely,

Mike Sweeney
Hika for the Pika 2009
209-267-5978 #24
PO Box 1843
Sutter Creek, CA 95685
===
10.

From:	Dick Ewart <dick_ewart@yahoo.com>
To:	<pika@dfg.ca.gov>
Date:	3/12/2012 10:06 PM
Subject:	Threatened status for pika

I have lived and worked in Yosemite's high country for the past 36 years, and I've noticed no change in the pika's home range or its population. Rising temperatures and reduced snowpack are the reasons cited for listing the pika as threatened or endangered. Any temperature chart or graph will show that the world's temperatures have not risen since about 1998. Also, the most recent snowpack study of the Sierra Nevada (Dr. Christy, U of Alabama-Huntsville), shows there has been no change in the snowpack for the last 100 years. Actually, because of the tremendous snowpack and cool spring temperatures of the previous 2 years, the snowpack lasted an exceptionally long time. (The pikas were probably headed downhill.)Thus, the facts do not warrant the pika being listed as threatened or endangered.

Thank you for your time and attention.

Sincerely,

Dick Ewart
P. O. Box 592
Yosemite, Ca. 95389
===

11.

From: Laurel Harkness <laurelharkness@gmail.com>
To: <pika@dfg.ca.gov>
Date: 3/14/2012 9:56 PM
Subject: RE: American pika - comments

Dear Sirs/Mesdames,

I wanted to take this opportunity to comment in support of listing the American pika as an endangered or threatened species.

The winter wildlands of California are a finite resource, and they also happens to be the habitat of the American pika. The American pika is uniquely sensitive to temperature. Their habitat is restricted to small, disconnected habitat "islands" in numerous mountain ranges. There is little to no migration between these "islands". Climate change and an overall rise in temperature is further reducing these already limited areas.

The American pika does not hibernate in winter. Rather the American pika remains active all winter, surviving on cured vegetation, as food is scare in winter in the alpine environment.

Snowlands Network is a nonprofit 501(c)(3) with over 600 members that promotes human-powered winter recreation and protects winter wildlands in California and Nevada. Founded in 2001, Snowlands Network has worked continuously and diligently with public land managers to create sustainable winter recreation policy for a healthy environment and quality access for quiet recreation.

With regards to winter recreation, human impact, and the threats to the habitat of the American pika, I would like to share a few points for consideration:

1) Winter recreation use (combined motorized and non-motorized) has doubled in the last 20 years. In California, current estimates and studies show that there are an estimated 1,700,000 winter recreation visits annually.

2) Statewide, there are four times more skier and snowshoer visits than snowmobile visits.

3) Winter recreation in the snow-covered forests depends on access from plowed trailheads; more than 80% of the official winter-recreation trailheads in California national forests are dominated by motorized recreation.

4) Local forest officials that manage California's winter wildlands liberally issue "categorical exclusions" in the case of Over Snow Vehicle (OSV) travel, as there exists an option in the 2005 Travel Management Rule for a local forest official to determine whether to manage snowmobile use. As such, there is not adequate environmental review of the impacts of OSV in public forests including areas that are prime American pika habitat.

5) In the 1990s, the development of the "powder sled" type of snowmobile vastly increased the reach of snowmobiles allowing the newer, more powerful machines to dominate terrain previously accessible only by backcountry skis or snowshoes. Many of the areas that these newer types of snowmobiles are designed to access are prime American pika habitat. These areas inhabited by the American pika were previously undisturbed by motorized recreation, however are now a playground of sorts with the growth of the "high-marking" type of snowmobile use.

I thank you for your consideration of these comments in your review of the proposal to list the American pika as an endangered or threatened species. Please do not hesitate to follow up with me if you have any further questions.

Best regards,

Laurel Harkness
Laurel Harkness, Executive Director
Snowlands Network
(530)926-3935 p
(530)859-9168 m
laurel@snowlands.org
www.snowlands.org

Snowlands Network is a 501(c)(3) Organization in Nevada and California dedicated to preserving our public lands for human-powered winter recreation and protecting our winter wildlands: sustainable winter recreation for a clean environment.
==

12.

From:	Sarah Matsumoto <sarah.matsumoto@sierraclub.org>
To:	<pika@dfg.ca.gov>
Date:	3/15/2012 4:49 PM
Subject:	Re: proposal to list the American pika
Attachments:	American Pika CA letter.pdf

Please see attached comment letter.
Thank you.

Sarah Matsumoto
Senior Representative
Sierra Club
85 Second Street, 2nd Floor
San Francisco, CA 94105
415-977-5579
sarah.matsumoto@sierraclub.org

www.sierraclub.org

[The Sierra Club letter follows page A2-15]

===
13.
From: <artunger@att.net>
To: <pika@dfg.ca.gov>
Date: 1/5/2012 10:43 AM
Subject: proposal to list the American pika as an endangered or threatened species.

Dear CDFG,

Here are my comments on listing the American pika:

About 25 years ago my son interrupted preparations for breakfast at a small lake high in a Sierra Nevada Wilderness by inviting us to the up-hill end of the lake where some "bunny-mice" were running about amid piles of small boulders. I guess the boulders were a talus slope. Seeing these pikas is one of the major thrills of my thirty eight day Sierra back-packs.

I support listing the pika because it may help it survive a warming world. People could be taught to stay away from the talus slopes, which are always dangerous. There would be one more reason to keep the house warm in summer and cool in winter, mine is at 60 degrees F. now, in order to contribute less to global warming.
Thank you for the opportunity to comment,

Arthur Unger
2815 La Cresta Drive
Bakersfield, CA 93305-1719
(661) 323 5569
artunger@att.net preferred
===
14.
From: Aileen Kaye <arkaye2@gmail.com>
To: "pika@dfg.ca.gov" <pika@dfg.ca.gov>
Date: 1/4/2012 7:56 PM
Subject: Please Save the Pika

California DFG,
Please save the Pika from the impacts of global warming.

Aileen Kaye
PO Box 1113
Turner, OR 97392
503-743-4567
arkaye2@gmail.com
===
15.

From: David Bott <dbsac67@gmail.com>
To: <pika@dfg.ca.gov>
Date: 1/20/2012 2:53 PM
Subject: Please Help the Pika

Good afternoon,

I am writing to ask that you please do whatever your agency is able to do to save the Pika in the Sierra. They are wonderful native animals and deserve our protection. Thank you for your consideration.
Sincerely,
David Bott
==
16.
From: Kids Harkness <tateandbrice@gmail.com>
To: <pika@dfg.ca.gov>
Date: 3/14/2012 9:59 PM
Subject: pikas

Dear reader,
I am only 10 so I don't know two much about pikas but I don't want them to go extinct so I think that you should put them on the endangered spicies list, in whichever category, to effect change in the way people treat California's wilderness. The most that I know about this situation is that pikas need to live in cool weather because they don't have any source of cooling their body down. So when we polute the air creating global warming, we force the pikas further up the mountains. Doing that lessens the pikas natral habitat and threatens extinction.

Sincerely,
Tate Harkness
from Mt. Shasta, CA
==
17.
From: Kathy Long <plantescape@verizon.net>
To: <pika@dfg.ca.gov>
Date: 1/8/2012 8:55 AM
Subject: Pika Listing

Put me down with those that support the listing of the pika under the Threatened and Endangered Species Act. Climate change is forcing them up and out of existence. I'd like them protected so that if we can do anything about this terrible rise in temperature then maybe we can restore some of what we once had before we so blindly forced these radical changes in our climate, including the loss of the poor pika's high mountain habitat.

Sincerely

Kathy Long
21333 Palos Verdes Blvd.
Torrance, CA
90503

==

18.

From: "johnsr@cwnet.com" <johnsr@cwnet.com>
To: <pika@dfg.ca.gov>
Date: 1/4/2012 11:02 AM
Subject: Pika Declines

Of course review the population declines more proof that humans are killing most of everything that breaths.

==

19.

From: Shane Hazleton <thespecialguest@gmail.com>
To: <pika@dfg.ca.gov>
Date: 3/8/2012 3:50 PM
Subject: Pika -choo

Mar 8, 2012

California Department of Fish & Game

Dear Department of Fish & Game,

I believe we should protect this undeniably cute creature, the Pika, under the Endangered Species Act.

If it were an ugly beast , the evidence to protect a part of the ecosystem would still stand, but hopefully with a little boost from a lovable countenance this critter can be protected.

Sincerely,

Shane Hazleton
Berkeley, CA 94708

==

20.

From: Scott Yoo
To: pika@dfg.ca.gov
Date: 12/30/2011 12:30 PM
Subject: personal comments regarding the CBD

Dear Sirs:

Rhetorical question: Why do we always take a defensive posture with the Center for Biological Diversity?? That outfit does nothing but cause DFG to use badly needed and scarce resources needed for conducting real science, in order to answer their bogus claims of harm to the environment or creature populations. Among the many deleterious actions in their past is the lawsuit that severely curtailed the planting of fish around the state.

My view of the CBD is that they are against all consumptive use of our resources and are interfering with same by the filing of frivolous actions against us in many arenas that they know we will commit manpower to answer, thereby keeping us tied up in court for years. Instead of knuckling under to these agitators, I think we should spend some significant effort in trying to discover a means to counter-threaten their operation in order to cause them to spend their resources defending their credibility. Perhaps after a few salvos they would reconsider future bogus litigation against us.

I'm not advocating this kind of counter action with all entities that wish to challenge us--far from it: an Organization with proper Checks and Balances is most likely to discharge their duties and responsibilities for the best and highest good of the Resource. However, when one organization practices sedition on another for the purpose of interfering with the lawful and righteous conduct of that operation, then the company under siege needs to protect its interests.

Those are my thoughts.

Sincerely, Scott Yoo

Scott Yoo
Wildlife Habitat Assistant
Knoxville Wildlife Area
707/966-9867 office
===

FISH AND GAME COMMISSION
NOTICE OF FINDINGS
American pika
(*Ochotona princeps*)

NOTICE IS HEREBY GIVEN that, pursuant to the provisions of Section 2074.2 of the Fish and Game Code, the California Fish and Game Commission, at its October 19, 2011, meeting in Monterey, California, accepted for consideration the petition submitted to list the American pika (*Ochotona princeps*) as a threatened species. Pursuant to subdivision (a)(2) of Section 2074.2 of the Fish and Game Code, the aforementioned species is hereby declared a candidate species as defined by Section 2068 of the Fish and Game Code.

Within one year of the date of publication of this notice of findings, the Department of Fish and Game shall submit a written report, pursuant to Section 2074.6 of the Fish and Game Code, indicating whether the petitioned action is warranted. Copies of the petition, as well as minutes of the October 19, 2011, Commission meeting, are on file and available for public review from Sonke Mastrup, Executive Director, Fish and Game Commission, 1416 Ninth Street, Box 944209, Sacramento, California 94244–2090, phone (916) 653–4899. Written comments or data related to the petitioned action should be directed to the Commission at the aforementioned address.

California Department of Fish and Game News Release

Date: December 30, 2011
Contact: Scott Osborn, Wildlife Branch, (916) 324-3564
Kirsten Macintyre, DFG Communications, (916) 322-8988

DFG Invites Public Comment Related to American Pika

The California Department of Fish and Game (DFG) is seeking public comment on a proposal to list the American pika as an endangered or threatened species.

American pikas (*Ochotona princeps*) are small lagomorphs (relatives of rabbits and hares) that inhabit broken-rock habitats such as mountain talus slopes. In California, they typically live at moderate to high-elevations in the southern Cascades, Sierra Nevada, and mountain ranges of the Great Basin. Climate change is considered to be the primary factor that may impact pikas in California, although mining, grazing, disease, and other factors may also affect pika populations.

In April 2007, the Center for Biological Diversity submitted a petition to the Fish and Game Commission to formally list the American pika as a threatened or endangered species. As part of the status review process, DFG is soliciting public comment regarding the pika's ecology, biology, life history, distribution, abundance, threats, habitat that may be essential for the species, and recommendations for management.

Comments, data and other information must be submitted in writing to:

California Department of Fish and Game
Nongame Wildlife Program
Attn: Scott Osborn
1812 9th Street
Sacramento, CA 95811

Comments may also be submitted by email to: pika@dfg.ca.gov.

All comments received by March 15, 2012 will be included in a DFG report to the Commission that will be submitted on or before the due date of October 26. Receipt of the report will be placed on the agenda for the next available meeting of the Commission after delivery. The report will be made available to the public at that time. Following the receipt of the Department's report, the Commission will allow a 30-day public comment period prior to taking any action on the Department's recommendation.

DFG's petition evaluation report for the American pika can be found at: http://www.dfg.ca.gov/wildlife/nongame/publications/.

Once a species
has gone extinct
no corrective legislation
can bring them back;
they are gone forever
Allen
Soloman

Ms. Irene Lopez
4986 Field St
San Diego
Ca 92110

Dear Mr Scott Osborn

Please be humane and place the lovely little animal called Pika on Californias Endangered Species Act before they become extinct! Climate change is affecting their habitat - Scientists predict that climate change will largely eliminate suitable habitat for the Pika in California - listing the Pika in California will provide important protections that will increase their chance of survival and recovery - Please take immediate action to protect the Pika - I would be most grateful and would appreciate a kind reply.

Sincerely

CALIFORNIA CATTLEMEN'S ASSOCIATION

1221 H STREET • SACRAMENTO, CALIFORNIA • 95814-1910

SERVING THE CATTLE
INDUSTRY SINCE 1917

PHONE: (916) 444-0845
FAX: (916) 444-2194
www.calcattlemen.org

March 15, 2012

California Department of Fish and Game
Nongame Wildlife Program
Attn: Dr. Scott D. Osborn
1812 9thStreet
Sacramento, CA 95811

Dear Dr. Osborn,

The California Cattlemen's Association (CCA) appreciates the opportunity to comment on the Department of Fish and Game's (DFG) candidacy of the American Pika for listing under the California Endangered Species Act (CESA). CCA represents California ranchers and beef producers who are committed and active stewards of our nation's natural resources and own or manage over 34 million acres of California rangelands that provide habitat to threatened and endangered wildlife.

CCA strongly opposes the listing of the American Pika or its habitat under the Endangered Species Act. We believe that the petition submitted by the Center for Biological Diversity does not demonstrate necessary evidence that the American Pika is in need of a threatened or endangered classification under the Endangered Species Act.

In general, CCA opposes the listing of species or habitat as endangered, threatened or critical under the Endangered Species Act. Cattle grazing and wildlife coexist successfully on rangelands ranchers own and manage. Likewise, many threatened or endangered species depend on grazing and infrastructure used for livestock production to survive. We believe that listing species or habitat under the Endangered Species Act only hinders a rancher's ability to manage his or her lands holistically, enhance wildlife habitat and voluntarily implement species and habitat recovery efforts.

Specific to livestock grazing, CCA strongly concurs with your analysis that insufficient data exists to attribute livestock grazing to a decline in suitable American Pika habitat. As stated in the finding, others factors, not livestock grazing, are responsible for impacts to habitat. Research cited by the petitioners to demonstrate grazing negatively impacts American Pika habitat is also questioned by the author because livestock do not typically graze in areas where American Pika are known to exist. Should you consider listing the American Pika or its habitat as endangered, threatened or critical, CCA strongly urges you to adopt a 4(d) exemption for routine ranching operations consistent with species such as the Red Legged Frog and California Tiger Salamander, both of which depend on the continued viability of California's ranching industry for their survival.

Similarly, the California Fish and Game Commission rejected a petition to list the American Pika under the California Endangered Species Act in April of 2008. The Fish and Game Commission determined that the petition did not provide sufficient cause to list the species and was unwarranted. The Fish and Wildlife Service should take this into account during this initial 90-day finding.

CCA is also concerned about listing species under the Endangered Species Act specifically related to climate change. The Endangered Species Act was adopted by Congress with the intent to identify species in peril and enact sensible recovery actions that would eventually result in a species' delisting as endangered or threatened. Recovery efforts authorized under the Endangered Species Act are not able to mitigate impacts to American Pika habitat due to climate change. Climate change is a global issue and cannot be solved by applying local or regional regulations.

Therefore, adopting recovery efforts related to climate change will prove problematic for the Fish and Wildlife Service and the Administration and will equate to no achievable or actual results. The discussion surrounding the adoption of U.S. regulatory programs to reduce greenhouse gas emissions should not be an independent policy decision made by the Administration carried out under inappropriate or unsuitable laws such as the Endangered Species Act or Clean Air Act; that is a job for Congress.

Once again, CCA appreciates the opportunity to comment on the proposed listing of the American Pika as an endangered species. Should you have any questions regarding our comments, please don't hesitate to contact me.

Sincerely,

Margo Parks

Margo Parks
Associate Director of Government Relations

SIERRA
CLUB
FOUNDED 1892

March 15, 2012

California Department of Fish and Game
Nongame Wildlife Program
Attn: Scott Osborn
1812 Ninth Street
Sacramento, CA 95811

Director Bonham:

The Sierra Club, on behalf of its 1.3 million members and supporters nationwide, urges you to protect the American pika and list it as endangered because of the impact of climate change and other threats.

The pika is a small alpine mammal that is accustomed to extremely cold conditions and can die from overheating when exposed to temperatures as low as 78 degrees for several hours. Rising temperatures are causing dramatic habitat and population losses as the pika is forced further upslope. Besides rapidly diminishing habitat, the pika also faces increased heat stress and loss of ability to gather food as well as decreased snowpack leaving individuals vulnerable to sudden cold snaps.

You have previously stated that an obstacle to pikas receiving endangered status is that while their populations have been surveyed in other parts of the nation, the same has not occurred in California. While this is true, there is little disagreement as to the science behind the projected population of the entire species. By 2050, scientists predict a 5.4 degree Fahrenheit rise in summertime temperatures in the species' current range. By the end of this century, from climate change alone, 80% of the habitat currently suitable for pika will no longer be able to sustain those populations. In separate population studies in Nevada's Great Basin mountains as well as southern Oregon, pika populations have already declined by 1/3.

On October 19, 2010, Superior Court Judge Peter Busch ordered the California Fish and Game Commission to review the available scientific data and determine whether the American pika qualifies for listing under the state endangered species law. This marks the third time that the state has been ordered to examine the potential eligibility of the species for protection.

The U.S. Fish and Wildlife Service has stated that there's "enough evidence to say that pikas are going to be among the first mammals to be adversely affected by climate change." (January 2010 Bioscience). As one of ten states in which pikas are currently found, California should set a precedent by recognizing the threat pikas face and protecting them as endangered under state law.

California has consistently led the nation on climate change legislation and administrative protection. The California Fish and Game Commission now has the opportunity, and the responsibility, to assure that California maintains its proud leadership

Thank you for considering our request; we look forward to working with you to promote California's leadership in the global campaign against the effects of climate change.

Sincerely,

Kathryn Phillips

Kathryn Phillips, Director
Sierra Club California

and

Sarah Matsumoto and Joe Fontaine
Sierra Nevada Resilient Habitats Campaign Co-Chairs
Sierra Club

Global Climate Change is Natural- Walter Horsting

The Earth has undergone dramatic climate change over its entire existence. In the past 3,000 years there have been four periods with much greater warmth than today. The Human race has only excelled in warmer periods of the Middle Ages, the Roman warming and the Minoan age. In the past 8,000 years there have only been three colder dips than we are experiencing today.

- Section 1 Hockey Stick observer in NOAA ice core data.
- http://www.c3headlines.com/temperature-charts-historical-proxies.html

The Sun's solar radiation varies on earth due to more active sun spots and the variation of the earth's orbit, tilt and wobbles. Additionally during active solar periods the solar wind forces fewer cosmic rays to strike the atmosphere and reduces cloud formation, allowing more solar heating, recent reports also indicate very high heating from the UV spectrum.

- Section 2: Linkages between solar activity, climate predictability and water Resource development
- http://wattsupwiththat.com/2010/05/05/new-paper-tropical-cyclone-response-to-solar-uv/
- **Section 3** New Little Ice Age Instead of Global Warming?
- Section 4 Milankovitch cycles
- Section 5 Cosmic Rays and Climate

Finally The Pacific Decadal Oscillation is a 20-30 year long cycle of warmer and cooler temperatures in the Pacific Ocean that has dramatic impact on the global climate.

- Section 6 The Pacific Decadal Oscillation (PDO)

Partial list of Scientists skeptical of AGW
http://www.cato.org/special/climatechange/cato_climate.pdf

Lastly, CO2 means life and without, there would be no plants and no oxygen made for Humankind to exist. More CO2 means more plant growth. Green House practice ups CO2 by 400% to promote growth.
http://alfin2100.blogspot.com/2010/05/amazing-time-lapse-video-of-co2-effect.html

In Summary it is folly for the AGW supporters to propose drastic measures in Government, Energy and lifestyle based on a time scale of 150 years when there is clear evidence we should fear a cooling planet, more than one that is failing to reach previous warming periods. Mankind should be very thankful for its current warming period. Earlier warming periods allowed us to thrive. The Human race may survive a much greater threat of an asteroid or comet impact because warmth allowed us to grow food and advance to the technical levels of today.

Section 1 Hockey Stick observer in NOAA ice core data.

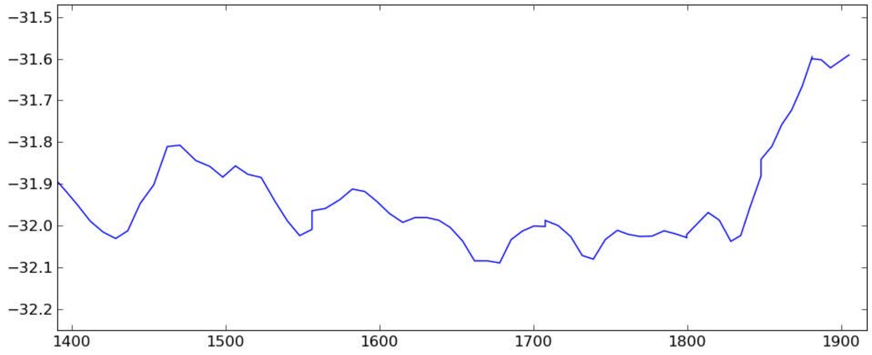
At the Foresight Institute, J. Storrs Hall had some interesting graphs made from NOAA ice core data (***Alley, R.B. 2000. The Younger Dryas cold interval as viewed from central Greenland. Quaternary Science Reviews 19:213-226.)*** It sure seems to mirror other hockey sticks this past century. Dr. Mann will be thrilled to see this I'm sure. J. Storrs Hall writes:

One thing that Climategate does is give us an opportunity to step back from the details of the AGW argument and say, maybe these are heat-of-the-moment stuff, and in the long run will look as silly as the Durants' allergy to Eisenhower. And perhaps, if we can put climate arguments in perspective, it will allow us to put the much smaller nano arguments (pun intended) into perspective too.

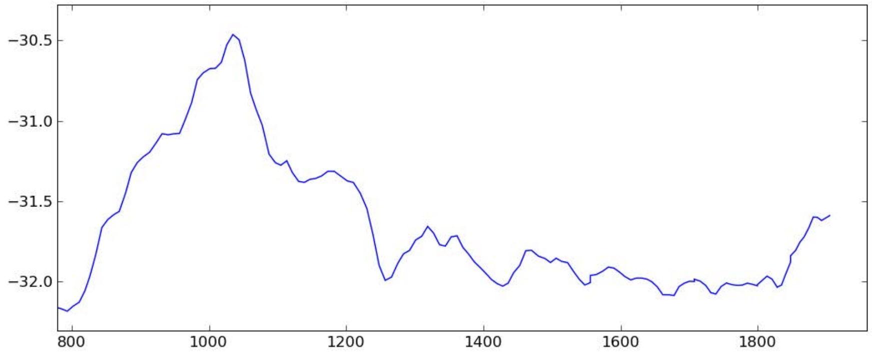
So let's look at some ice.

I'm looking at the temperature record as read from this central Greenland ice core. It gives us about as close as we can come to a direct, experimental measurement of temperature at that one spot for the past 50,000 years. As far as I know, the data are not adjusted according to any fancy computer climate model or anything else like that.

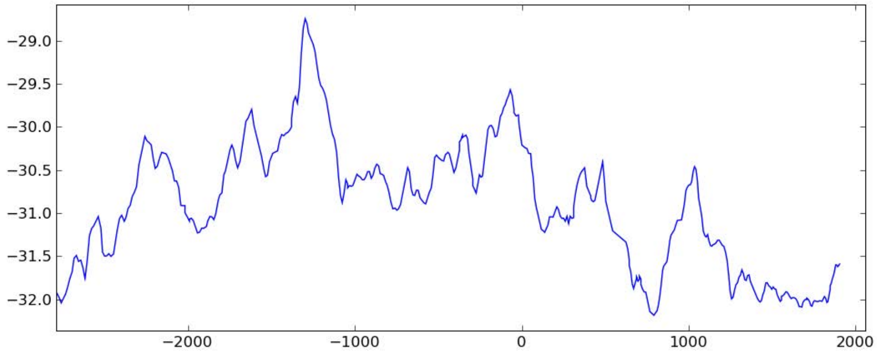
So what does it tell us about, say, the past 500 years? (the youngest datum is age=0.0951409 (thousand years before present) — perhaps younger snow doesn't work so well?):



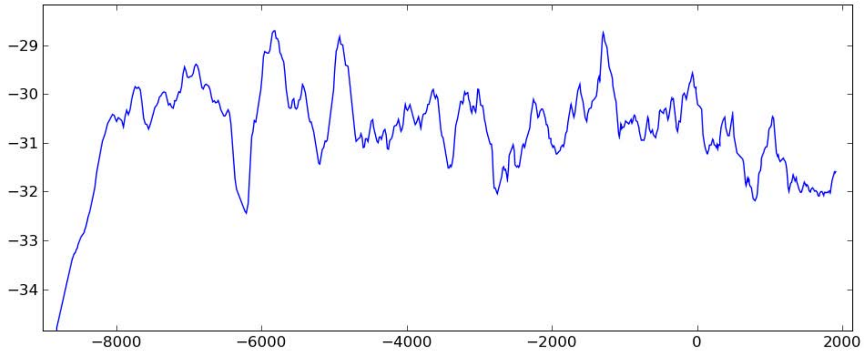
Well, whaddaya know — a hockey stick. In fact, the ―blade" continues up in the 20th century at least another half a degree. But how long is the handle? How unprecedented is the current warming trend?



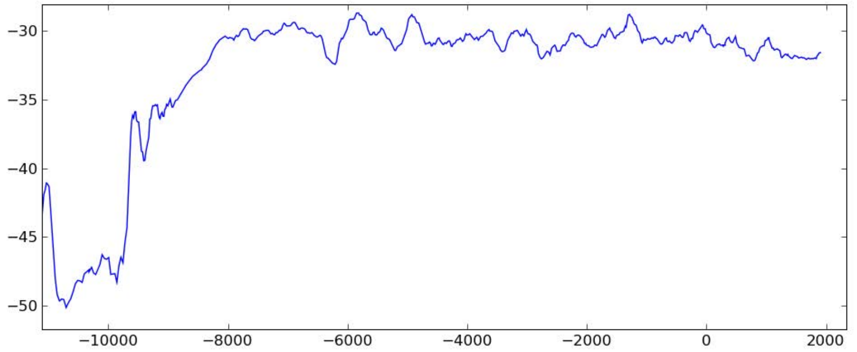
Yes, Virginia, there was a Medieval Warm Period, in central Greenland at any rate. But we knew that — that's when the Vikings were naming it Greenland, after all. And the following Little Ice Age is what killed them off, and caused widespread crop failures (and the consequent burning of witches) across Europe. But was the MWP itself unusual?



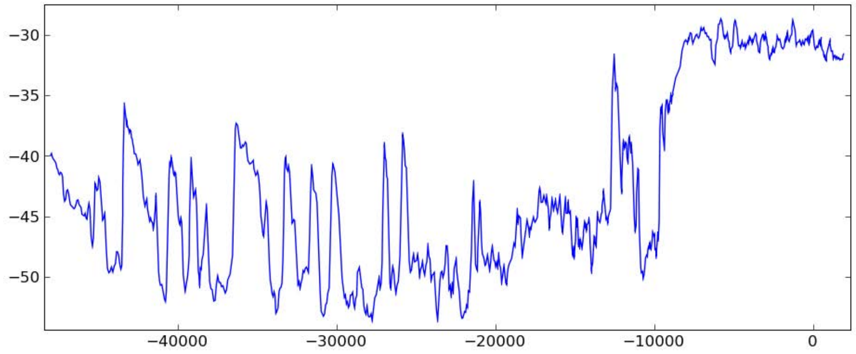
Well, no — over the period of recorded history, the average temperature was about equal to the height of the MWP. Rises not only as high, but as rapid, as the current hockey stick blade have been the rule, not the exception.



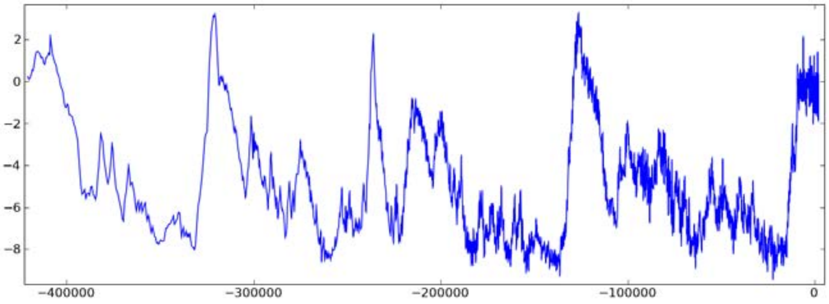
In fact for the entire Holocene — the period over which, by some odd coincidence, humanity developed agriculture and civilization — the temperature has been higher than now, and the trend over the past 4000 years is a marked decline. From this perspective, it's the LIA that was unusual, and the current warming trend simply represents a return to the mean. If it lasts.



From the perspective of the Holocene as a whole, our current hockeystick is beginning to look pretty dinky. By far the possibility I would worry about, if I were the worrying sort, would be the return to an ice age — since interglacials, over the past half million years or so, have tended to last only 10,000 years or so. And Ice ages are not conducive to agriculture.



… and ice ages have a better claim on being the natural state of Earth’s climate than interglacials. This next graph, for the longest period, we have to go to an Antarctic core (Vostok):



In other words, we’re pretty lucky to be here during this rare, warm period in climate history. But the broader lesson is, climate doesn’t stand still. It doesn’t even stay on the relatively constrained range of the last 10,000 years for more than about 10,000 years at a time.

Does this mean that CO2 isn’t a greenhouse gas? No.

Does it mean that it isn’t warming? No.

Does it mean that we shouldn’t develop clean, efficient technology that gets its energy elsewhere than burning fossil fuels? Of course not. We should do all those things for many reasons — but there’s plenty of time to do them the right way, by developing nanotech. (There’s plenty of money, too, but it’s all going to climate science at the moment. 🙂) And that will be a very good thing to have done if we do fall back into an ice age, believe me.

For climate science it means that the Hockey Team climatologists’ insistence that human-emitted CO2 is the ***only thing*** that could account for the recent warming trend is probably poppycock.

Section 2 Linkages between solar activity, climate predictability and water Resource development*

http://www.up.ac.za/dspace/bitstream/2263/5326/1/Alexander_Linkages%282007%29.pdf

VARIATIONS IN SOLAR IRRADIANCE

The sun's wobble

The distance of the sun from the SSCM isthe weighted reciprocal of the distance of the combined centre of mass of the orbiting planets. Consequently, both the sun's distance from the SSCM and its galactic velocity are continually changing. This creates a wobble in its path through space. This can be calculated given the knowledge of the masses and orbits of the four major planets. Astronomers make use of the wobbles in the trajectories of distant stars to determine whether or not they are accompanied by orbiting objects. Figure 9 shows the sun's wobble as it moved through galactic space during the period 1944 to 1958. During most of this time its orbit was below that of the SSCM in this view. While the SSCM lies within the body of the sun most of the time, there are occasions when the sun wobbles outside the SSCM. This figure provides an indication of the extent of its wobble as the sun moves through space.

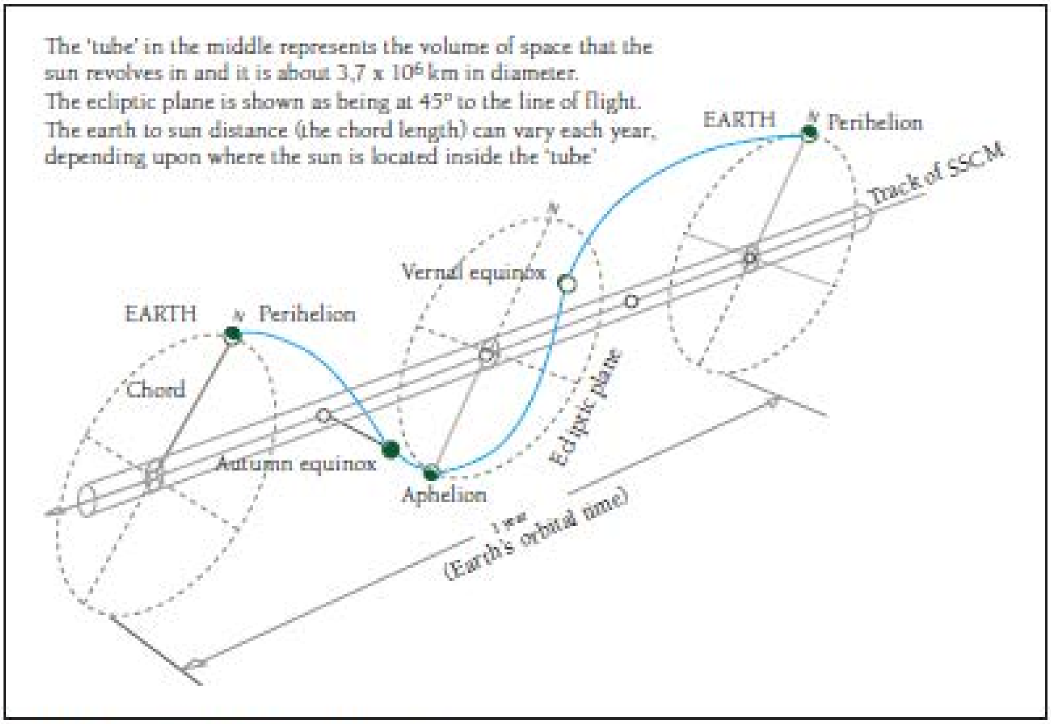
Earth to sun chord distance

As a result of the sun's wobble, the chord length between the earth and the sun and the amount of energy received by the earth will change accordingly. The next exercise is therefore to determine the corresponding changes in the distance between the earth and the sun and thereby the changes in the rate of solar energy reaching the earth. This is amenable to precise calculation. The calculation of the chord length between the earth and the sun at any particular time has two components. The first is the position of the sun relative to the SSCM at that time. The second is the elliptical path of the earth about the SSCM.

The sun's displacement from the SSCM changes relatively slowly but the ecliptic direction of the earth about the sun changes with the seasons. Figure 10 shows the displacement of the position of the sun from the SSCM during 1993 and its effect on variations in solar energy received on earth during that year.

The Intergovernmental Panel on Climate Change (IPCC) (2001) dismisses the view that solar activity has a meaningful influence on global climate. The basis for this view is that variations in the receipt of solar activity are too small to account for variations in the climatic responses. These variations were determined from satellite and other observations. What the IPCC scientists failed to appreciate is that changes in the level of solar radiation received on earth are amenable to precise calculation. The variations are well in excess of the IPCC value of +0,3 Wm–2 quoted earlier. Although the chord length is of paramount

importance on a month-by-month or year-by-year basis, whereby the actual wattage received by the earth can be determined, it does not compare with the accumulative effect of high or low wattages in a given direction on the ecliptic plane, which determines the type of weather that certain parts of the globe will experience for a given 21-year period. The cold periods that were experienced by the northern hemisphere in the 1400s, 1600s and 1800s would have been counterbalanced by opposing hot spells in the southern hemisphere. This is because of the reciprocal effect of the changes in chord length. Probably the most important shortcoming in current climate change science is the failure to appreciate that variations in received solar energy are amenable to precise calculations, instead of attempting to derive these changes from observations from orbiting satellites and other sources that are incomplete in both space and time. Furthermore, the calculated wattage changes are appreciably greater than those derived from the sources quoted in the literature. As can be seen in figure 8, these changes are not regular in time. They were relatively unchanged from 1979 to 1985, and again from 1995 to 2000. They changed rapidly from 1986 through to 1994, when they closely orbited the SSCM.



The 'tube' in the middle represents the volume of space that the sun revolves in and it is about $3{,}7 \times 10^6$ km in diameter.
The ecliptic plane is shown as being at 45° to the line of flight.
The earth to sun distance (the chord length) can vary each year, depending upon where the sun is located inside the 'tube'

Figure 7 Earth's orbital path through the galaxy

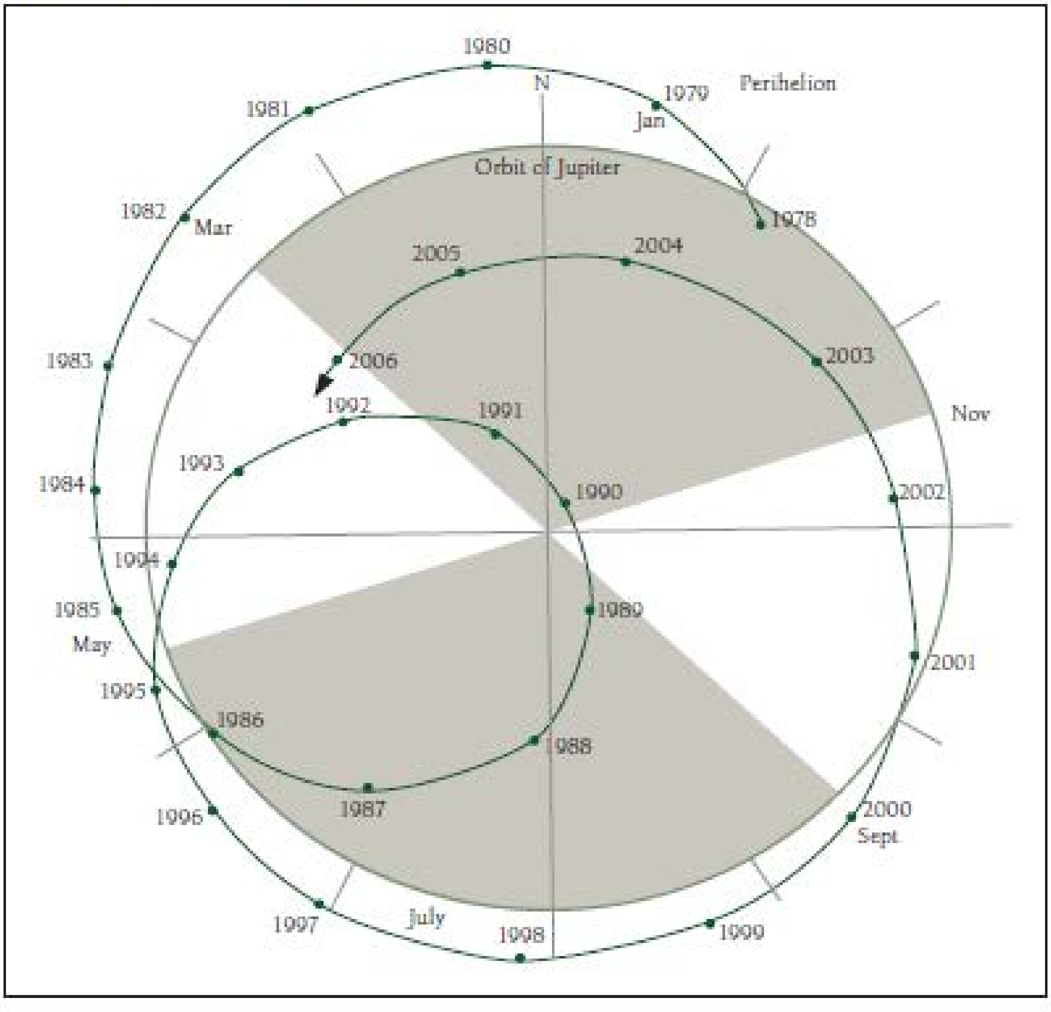


Figure 8 The orbit of the centre of mass of the four major planets about the SSCM from 1978 to 2006. The movement is towards the viewer

Table 7 Angular shift in the position of the planetary centre of mass at the time of sunspot minima for the period 1902–2006

Cycle number	Cycle period	PCM quadrant	Rotation angle (approx)	Cycle length (years)
14	1902–1913	SW	360	11
15	1913–1923	SW	270	10
16	1923–1934	NW	360	11
17	1934–1944	NW	270	10
18	1944–1954	NE	360	10
19	1954–1965	NE	270	11
20	1965–1975	SE	360	10
21	1975–1986	SE	270	11
22	1986–1996	SW	360	10
23	1996–2006	SW	270	10

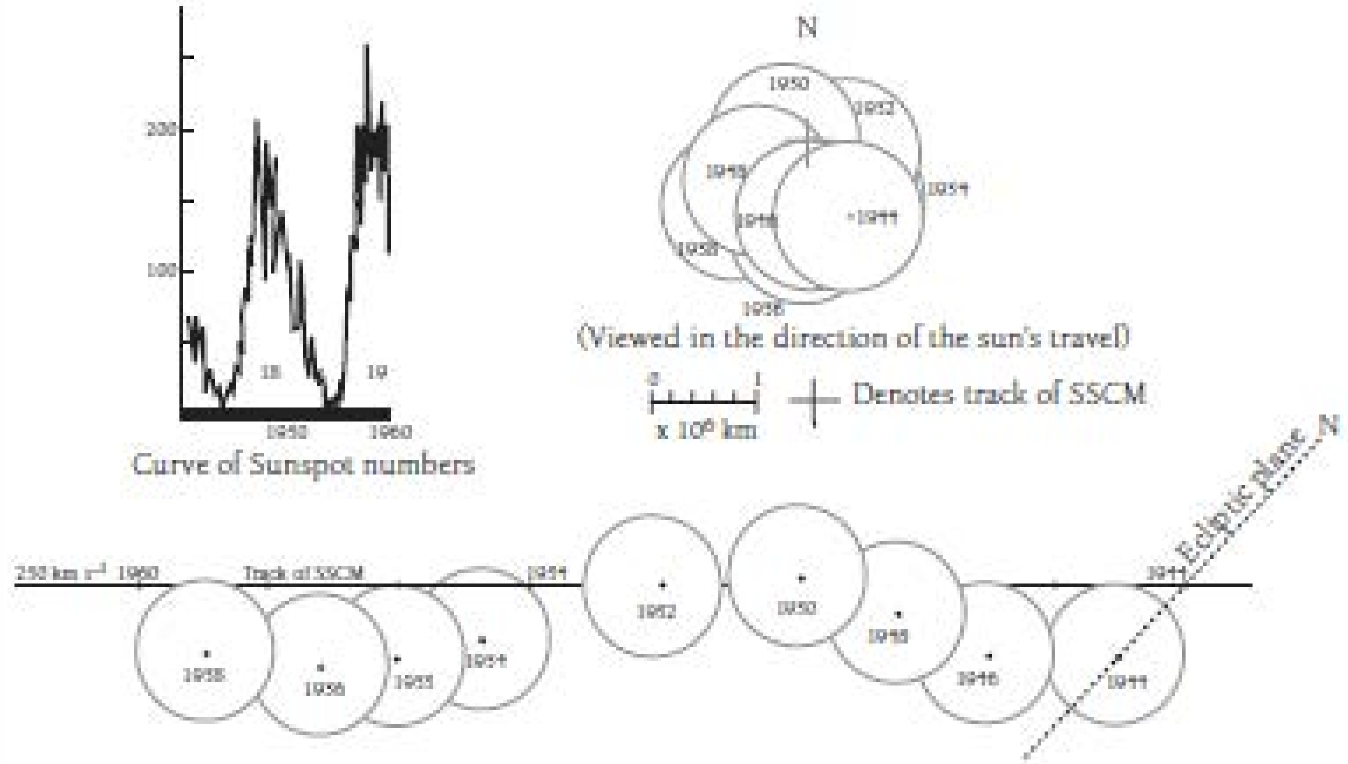


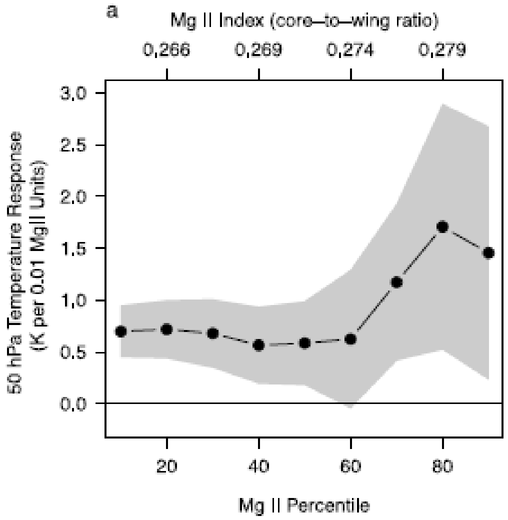
Figure 9 The location of the sun's centre of mass relative to that of the SSCM from 1944 to 1958

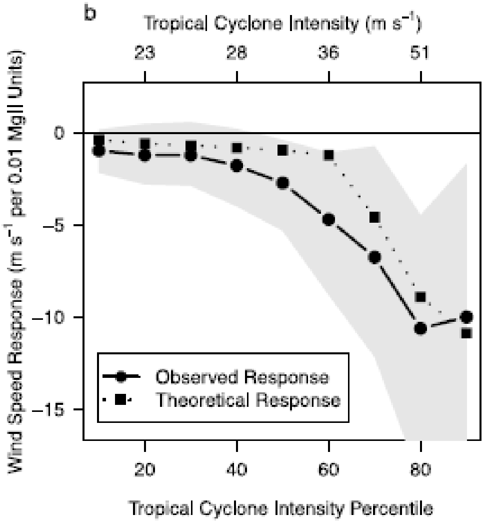
Daily tropical cyclone intensity response to solar ultraviolet radiation

J. B. Elsner, T. H. Jagger, and R. E. Hodges
GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L09701, doi:10.1029/2010GL043091, 2010

Abstract: An inverse relationship between hurricane activity over the Caribbean and the number of sunspots has recently been identified. Here we investigate this relationship using daily observations and find support for the hypothesis that changes in ultraviolet (UV) radiation rather than changes in other concomitant solar and cosmic variations are the cause.

The relationship is statistically significant after accounting for annual variation in ocean heat and the El Niño cycle. A warming response in the upper troposphere to increased solar UV forcing as measured by the Mg II index (core-to-wing ratio) decreases the atmosphere’s convective available potential energy leading to a weaker cyclone. The response amplitude at a cyclone intensity of 44 m s−1 is 6.7 ± 2.56 m s−1 per 0.01 Mg II units (s.d.), which compares with 4.6 m s−1 estimated from the heatengine theory using a temperature trend derived from observations. The increasing hurricane response sensitivity with increasing strength is found in the observations and in an application of the theory. Citation: Elsner, J. B., T. H. Jagger, and R. E. Hodges (2010), Daily tropical cyclone intensity response to solar ultraviolet radiation, Geophys. Res. Lett., 37, L09701, doi:10.1029/2010GL043091.





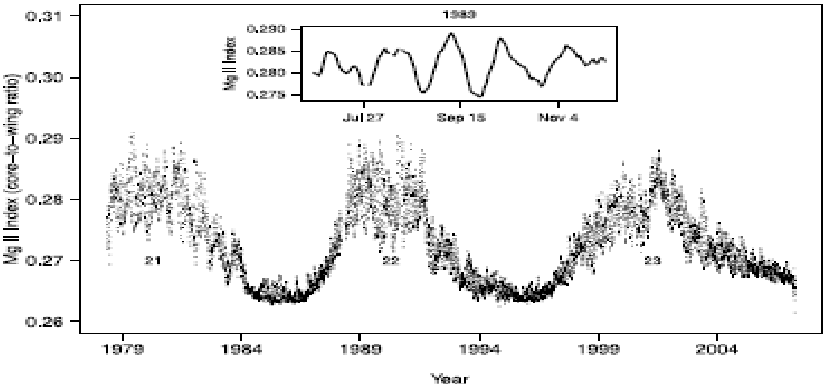


Figure 1. Time series of the daily solar Mg II index. The series begins on 7 November 1978 and ends on 14 October 2007 (10,578 days). Values are plotted as points. Values below the 11-year peaks indicate the solar cycle number. Horizontal axis is labeled on July 1st of the year. The inset graph shows the Mg II index values as a time series over the hurricane season of 1989. Values are connected as a curve. Breaks in the curve indicate missing values. There are 1331 missing values (12.6% of the days).

Figure 2. Upper air temperature and tropical cyclone intensity response to variations in solar UV radiation. (a) Change in 50 hPa temperature for a change in Mg II index given the Mg II index exceeds the given percentile. The first point to the left is the ordinary least squares regression coefficient of temperature on Mg II index using all but the lowest 10% of the Mg II values. The next point is the regression coefficient after removing the lowest 20% of the values, and so on. The point-wise one standarderror band is shown in grey and is computed using a sandwich estimator to account for the autocorrelation in the daily values. (b) Observed and theoretical response of tropical cyclone intensity to variations in solar UV radiation (Mg II index). The observed response is a change in a percentile of tropical cyclone wind speed for all values of Mg II index. The theoretical response is the change in a percentile of wind speed for a set of temperature responses to Mg II index values exceeding a given Mg II index percentile. The solid curve (circles) and the 90% confidence band is based on a bootstrap resampling of the daily data. The dotted curve (squares) is based on equation (2) with the temperature response estimated from NCEP reanalysis data.

Conclusions

Here we show compelling evidence that the relationship between hurricane intensity and solar activity on the daily time scale is physically linked to changes in atmospheric temperature near the top of the cyclone induced by UV radiation. This new finding sheds light on the problem of forecasting hurricane intensification. The overall greater sensitivity of the response found in the tropical cyclone wind data compared with the heat-engine theory and temperature data might result from the tropical cyclones themselves warming the temperature aloft and thus dampening the temperature-UV relationship [Swanson, 2008]. It is noted the theoretical results reflect a change in the maximum potential intensity of a particular tropical cyclone while the observational results reflect a change in the daily maximum wind speed over all tropical cyclones in the region. Since a tropical cyclone plays a role in moistening the stratosphere [Romps and Kuang, 2009] and since the dissipation of the cyclone’s energy occurs through ocean mixing and atmospheric transport, a tropical cyclone can act to amplify the effect on the Earth’s climate of a relatively small change in solar output. On longer time scales it is noted that a portion of the variation in tropical SST’s (0.08 ± 0.2 K) lags the Schwabe cycle by 1 to 3 years, which is roughly equal to the time required for the upper 100mlayer of the ocean to reach radiative equilibrium [White et al., 1997].

Section 3 New Little Ice Age Instead of Global Warming?

http://www.schulphysik.de/klima/landscheidt/iceage.htm

by Dr. Theodor Landscheidt �

Abstract:

Analysis of the sun's varying activity in the last two millennia indicates that contrary to the IPCC's speculation about man-made global warming as high as 5.8� C within the next hundred years, a long period of cool climate with its coldest phase around 2030 is to be expected. It is shown that minima in the 80 to 90-year Gleissberg cycle of solar activity, coinciding with periods of cool climate on Earth, are consistently linked to an 83-year cycle in the change of the rotary force driving the sun's oscillatory motion about the centre of mass of the solar system. As the future course of this cycle and its amplitudes can be computed, it can be seen that the Gleissberg minimum around 2030 and another one around 2200 will be of the Maunder minimum type accompanied by severe cooling on Earth. This forecast should prove skillful as other long-range forecasts of climate phenomena, based on cycles in the sun's orbital motion, have turned out correct as for instance the prediction of the last three El Ni�os years before the respective event.

1. Introduction

The continuing debate about man-made global warming has reached a crucial stage. The Intergovernmental Panel on Climate Change (IPCC), established by the United Nations and the World Meteorological Organisation (WMO), no longer publishes well defined �best estimate projections� of global temperature rise to the year 2100 caused by increases in greenhouse gas accumulations in the atmosphere, but publicizes �storylines� to speculate about warming as high as 5.8� C till 2100. The editors of the journal Science (2002), however, comment on the increasing number of publications that point to varying solar activity as a strong factor in climate change: �As more and more wiggles matching the waxing and waning of the sun show up in records of past climate, researchers are grudgingly taking the sun seriously as a factor in climate change. They have included solar variability in their simulations of the past century's warming. And the sun seems to have played a pivotal role in triggering droughts and cold snaps.�

Those scientists who are �grudgingly� beginning to acknowledge the sun's pivotal role in climate change are converts who had believed in the IPCC's dictum that �solar forcing is considerably smaller than the anthropogenic radiative forces� and its �level of scientific understanding is very low�, whereas forcing by well mixed greenhouse gases �continues to enjoy the highest confidence levels� as to its scientific understanding so that it is �unlikely that natural forcing can explain the warming in the latter half of the 20th century.� Actually, there had been a host of publications since the 19th century and especially in recent decades that provided evidence of strong solar-terrestrial relations in meteorology and climate ignored by proponents of man-made global warming (Koppen, 1873; Clough, 1905; Brooks; 1926; Scherhag, 1952; Bossolasco et al., 1973; Reiter, 1983; Eddy, 1976; Hoyt, 1979; Markson, 1980; Schuurmans, 1979; Landscheidt, 1981-2001; Bucha 1983; Herman and Goldberg, 1983; Neubauer 1983; Prohaska and Willett, 1983; Fairbridge and Shirley, 1987; Friis-Christensen and Lassen, 1991; Labitzke and van Loon, 1993; Haigh, 1996; Baliunas and Soon, 1995; Lassen and Friis-Christensen, 1995); Lau and Weng, 1995;

Lean et al, 1995; Hoyt and Schatten, 1997; Reid, 1997; Soon et al. 1996; Svensmark and Friis-Christensen, 1997; White et al. 1997; Cliver et al., 1998; Balachandran et al., 1999; Shindell et al., 1999; van Geel et al., 1999; Berner, 2000; Egorova et al., 2000; Palle Bago and Butler, 2000; Tinsley, 2000; Hodell et al., 2001; Neff et al., 2001; Rozelot, 2001; Udelhofen and Cess, 2001; Pang and Yau, 2002; Yu, 2002)

The IPCC's judgement that the solar factor is negligible is based on satellite observations available since 1978 which show that the Sun's total irradiance, though not being constant, changes only by about 0.1 percent during the course of the 11-year sunspot cycle. This argument, however, does not take into account that the Sun's eruptional activity (energetic flares, coronal mass ejections, eruptive prominences), heavily affecting the solar wind, as well as softer solar wind contributions by coronal holes have a much stronger effect than total irradiance. The total magnetic flux leaving the Sun, dragged out by the solar wind, has risen by a factor of 2.3 since 1901 (Lockwood et al., 1999), while global temperature on earth increased by about 0.6�C. The energy in the solar flux is transferred to the near-Earth environment by magnetic reconnection and directly into the atmosphere by charged particles. Energetic flares increase the Sun's ultraviolet radiation by at least 16 percent. Ozone in the stratosphere absorbs this excess energy which causes local warming and circulation disturbances. General circulation models developed by Haigh (1996), Shindell et al. (1999), and Balachandran et al. (1999) confirm that circulation changes, initially induced in the stratosphere, can penetrate into the troposphere and influence temperature, air pressure, Hadley circulation, and storm tracks by changing the distribution of large amounts of energy already present in the atmosphere.

2. Impact of solar eruptions on weather and climate

The strongest contributors to the intensity of the solar wind are solar eruptions which create the highest velocities in the solar wind and shock waves that compress and intensify magnetic fields in the solar wind plasma. Fig. 1 after Egorova et al. (2000) demonstrates the effect of solar eruptions on temperature and atmospheric pressure. From 1981 to 1991 Egorova, Vovk, and Troshichev observed surface temperature (lower panel) and atmospheric pressure at 10 km altitude (upper panel) at the Antarctic station Vostok. Tiny open circles indicate superimposed daily observations during the winter season. The solid line describes the 10-winter average. Fat circles mark Forbush events. These are sharp decreases in the intensity of galactic cosmic rays caused by energetic solar flares which indicate that the respective event has strongly affected the earth's environment. As can be seen from Figure 1, after Forbush events temperature nearly always rose above the mean, often reaching departures around 20� C, whereas air pressure was only in 8 out of 52 cases above the mean. These 52 experiments performed by Nature and observed by man show a clear connection between solar eruptions and a strong rise in temperature, not to mention the strong decrease in air pressure. It would be a redundant exercise to assess the statistical significance of this distinct result.

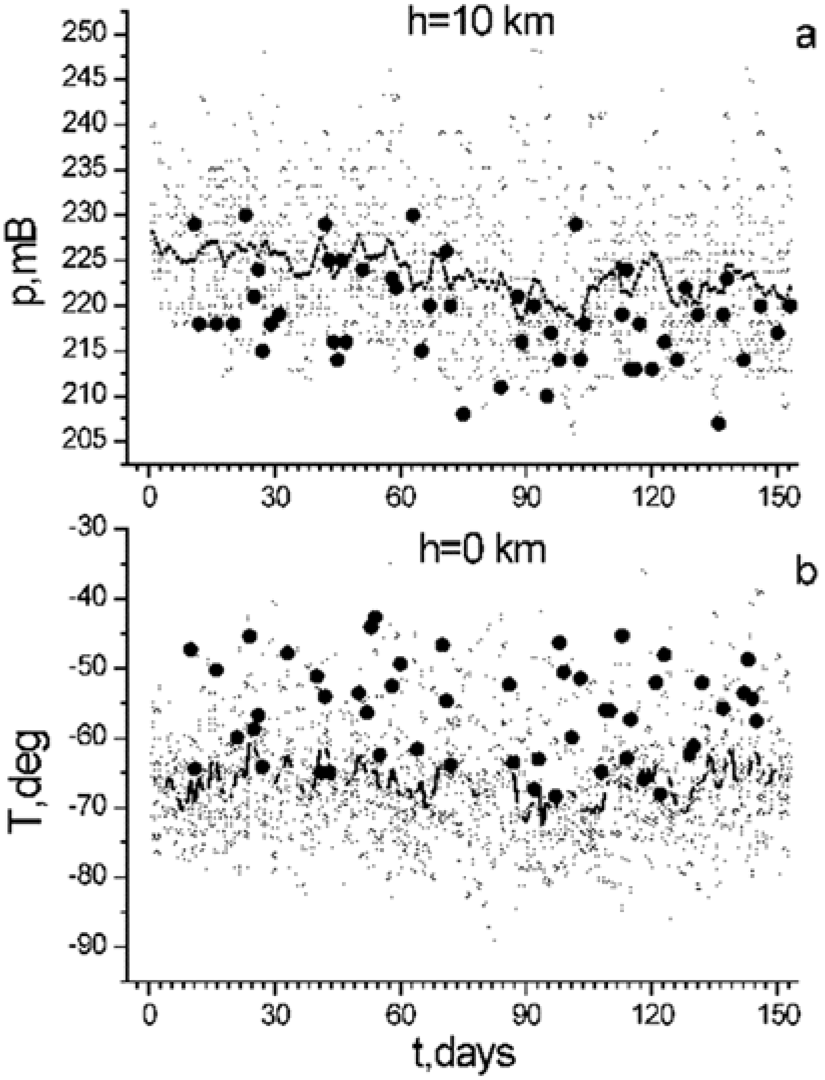


Fig. 1: Observations of surface temperature (lower panel) and atmospheric pressure at 10 km altitude (upper panel) at the Russian Antarctic station Vostok from 1981 to 1991 (From Egorova et al., 2000). Tiny open circles indicate superimposed daily observations during the winter season. The solid line describes the 10-winter average. Fat circles mark all Forbush events occurring within the observation interval. These are sharp decreases in the intensity of galactic cosmic rays caused by energetic solar eruptions. Temperature was nearly always above the mean after Forbush events, often reaching departures around 20� C, whereas air pressure was only in 8 out of 52 cases above the mean. The impact of solar eruptions on air temperature and atmospheric pressure close to the tropopause is obvious. An investigation of the statistical significance of the relationship would be redundant.

There is cogent evidence that the Sun's eruptional activity, too, has a strong effect in the tropics. Fig. 2 after Neff et al. (2001) shows a strong correlation between solar eruptions, driving the solar wind, and tropical circulation and rainfall. The dark profile represents oxygen isotope variations (^{18}O) in a dated stalagmite from Oman. The ^{18}O record, covering more than 3000 years (9.6 to 6.1 kyr before present), serves as a proxy for change in tropical circulation and monsoon rainfall. The bright ^{14}C profile shows radiocarbon deviations derived from the analysis of dated tree rings. The level of radiocarbon production in the atmosphere depends on the changing intensity of cosmic rays. Because of the reverse relationship of cosmic rays with solar activity � strong solar wind forms a strong magnetic shield against cosmic rays whereas a weak solar wind shield reflects less cosmic rays - the radiocarbon record serves as a proxy of the Sun's activity. Most scientists think that these proxy data are related to the activity of sunspots and faculae linked to relatively weak changes in irradiance. Actually, the radiocarbon data are a proxy of the Sun' eruptional activity driving the solar wind. Energetic solar eruptions do not accumulate around the sunspot maximum. In most cycles they shun the maximum phase and can even occur close to a sunspot minimum. The upper panel in Fig. 2 covers the whole investigated interval, whereas the lower panel shows the nearly perfect synchronicity between the sun's eruptional activity and tropical circulation in detail.

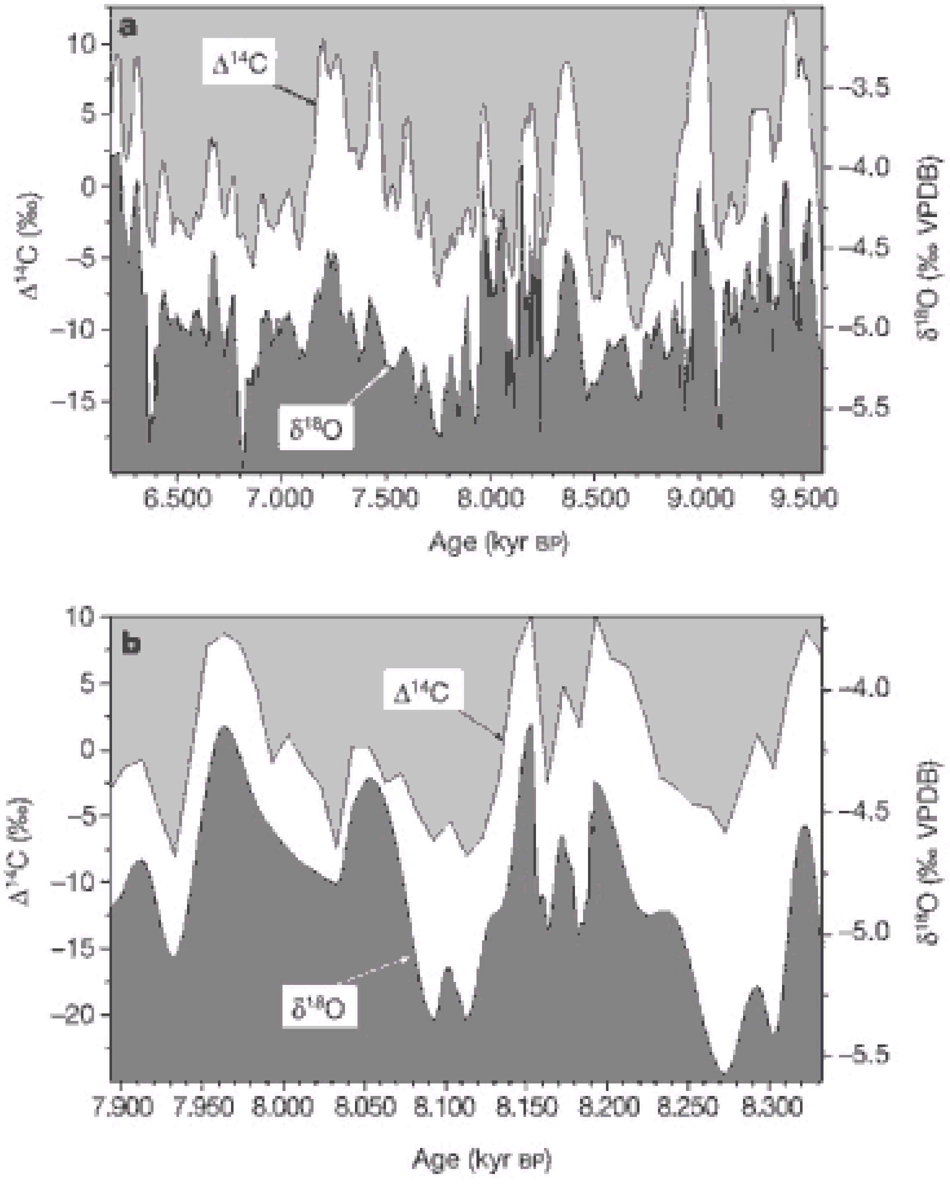


Fig. 2: Close correlation between solar eruptions, driving the solar wind, and tropical circulation and rainfall (From Neff et al., 2001). The dark profile represents oxygen isotope variations (^{18}O) in a dated stalagmite from Oman which serve as a proxy for change in circulation and Monsoon rainfall. The bright ^{14}C profile shows radiocarbon deviations derived from the analysis of dated tree rings. The level of radiocarbon production in the atmosphere depends on the changing intensity of cosmic rays. Because of the reverse relationship of cosmic rays with the sun's eruptional activity, the radiocarbon record serves as a proxy for frequency and strength of solar eruptions. The upper panel covers the whole investigated interval of more than 3000 years, while the lower panel shows the nearly perfect synchronicity between the sun's eruptional activity and tropical circulation and rainfall in detail.

Lake bottom cores from the Yukatan Peninsula show a similar correlation, covering more than 2000 years, between recurrent droughts and the radiocarbon record linked to the Sun's eruptional activity (Hodell et al., 2001). These recent results and many earlier ones (Landscheidt, 1981-2001) document the importance of the Sun's eruptional activity for climate.

3. Length of the 11-year cycle and temperature in the Nothern Hemisphere

In fact, it is quite natural to wonder whether the sun is playing a pivotal role in changing climate because the climate on earth owes its existence to the sun, as well as coal, oil, and energy of wind and moving water. If the greenhouse gas carbon dioxide (CO_2) were the dominant cause of the observed rise in global temperature, the trend of this rise would be similar to the continuously rising CO_2-trend shown in Fig. 3 after Peixoto and Oort (1992). The course of the Northern Hemisphere land air temperature, however, represented by the thick line in Fig. 4, does not follow the CO_2-trend. The increase in surface temperature from 1890 to 1940 was steeper and smoother than in the current warming phase since the early 1980s though the rate of anthropogenic emissions at that time was only 10% of the present rate. From 1940 through the late 1960s temperatures were falling in spite of the fast rise of anthropogenic CO_2-emissions.

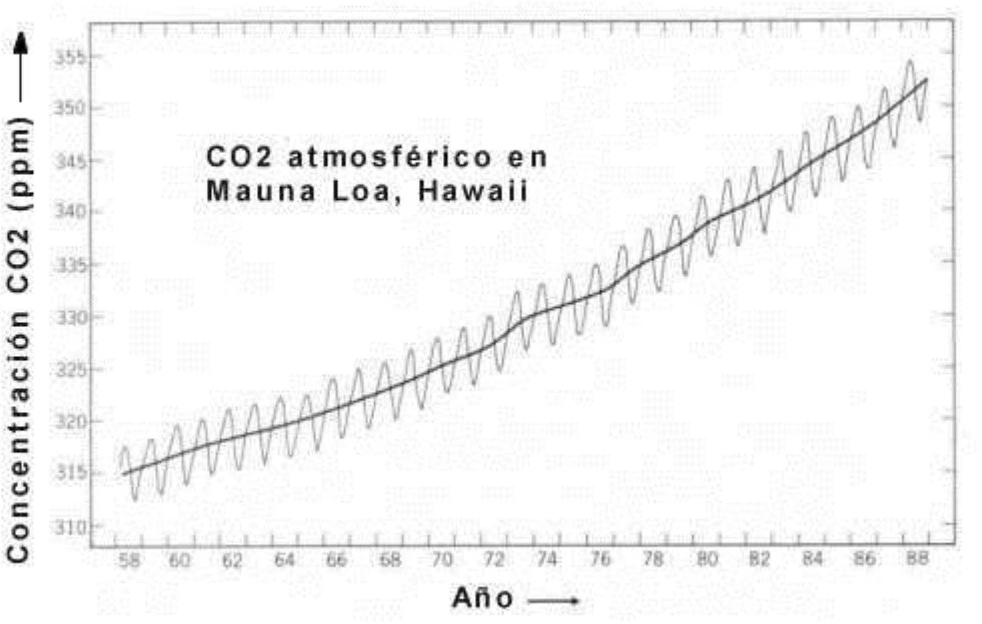


Fig. 3: Time series of the atmospheric CO_2 concentration as measured at Mauna Loa Observatory, Hawai (From Peixoto and Oort, 1992). These data are accepted to be representative for the global trend. Fig. 4 shows that the continually rising CO_2 � trend does not fit the up - and down course of observed climate.

Contrary to the CO_2-curve in Fig. 3, the thin curve in Fig. 4 after Friis-Christensen and Lassen (1991), representing the smoothed length of the 11-year sunspot cycle, follows the undulations of the observed temperature. The length of the sunspot cycle (LSC) is an indicator of the sun's eruptional activity. When Gleissberg (1958) first investigated LSC, he based his original LSC time series, going back to 300 A.D., on the number of observed aurorae which are known to be linked to strong solar eruptions. He found that short cycles go along with high sunspot maxima and strong eruptive activity, whereas long cycles are characterized by low maxima and fewer solar eruptions.

When Gleissberg smoothed his time series of LSCs, a secular cycle of 80 to 90 years emerged which modulates the amplitudes of the 11-year sunspot cycle. This secular cycle, called after Gleissberg, is indicated by the thin line in Fig. 4.

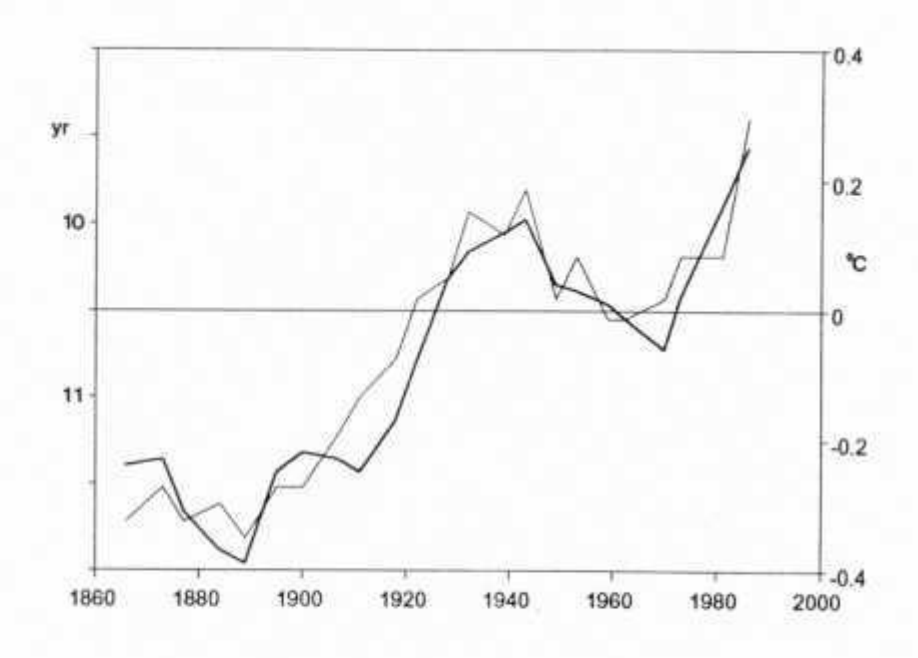


Fig. 4: Close correlation between surface land air temperature in the Northern Hemisphere (thick curve) and the changing length of the 11-year sunspot cycle (thin curve), indicating the varying intensity of the sun's eruptional activity (From Friis-Christensen and Lassen, 1991). Contrary to the curve in Fig. 3, representing the steadily increasing amount of carbon dioxide in the atmosphere, the thin solar curve covaries with the undulations of observed temperature.

A closer look shows that nearly all Gleissberg minima back to 300 A.D., as for instance around 1670 (Maunder minimum), 1810 (Dalton minimum), and 1895, coincided with cool climate in the Northern Hemisphere, whereas Gleissberg maxima went along with warm climate as for instance around 1130 (Medieval climate optimum). The degree of temperature change was proportional to the respective amplitudes in the Gleissberg cycle. During the Maunder minimum solar activity was minimal and during the Medieval Climate Optimum very high, probably even higher than in the six decades of intense solar activity before 1996. Accordingly, Friis-Christensen and Lassen (1995) have shown that the connection between the Northern Hemisphere land air temperature and varying LSC extends back to the 16th century. Butler (1996) corroborated this result for the last two centuries in Northern Ireland.

4. Predictable relationship between solar eruptions and global temperature

Fig. 5 from Adler and El�as (2000) presents an extended replication of the result in Fig. 4. LSC (filled circles), maximum ionospheric electron density in the respective 11-year cycle (plus signs), Northern Hemisphere temperature anomalies (empty triangles), and temperature anomalies measured in San Miguel de Tucuman, Argentina, (empty circles) show a statistically significant covariation. The last value in the LSC time series seems to indicate a downward movement, a switch from short cycles to longer ones, whereas the three other curves follow their upward trend.

From this divergence, Thejll and Lassen (2000) draw the conclusion that the impact of solar activity on climate, prevailing for centuries, suddenly is no longer valid. Jumping to such a conclusion is not justified. Thejll and Lassen do not take into consideration that temperature lags solar activity by several years. This can be seen in Fig. 5 around 1930.

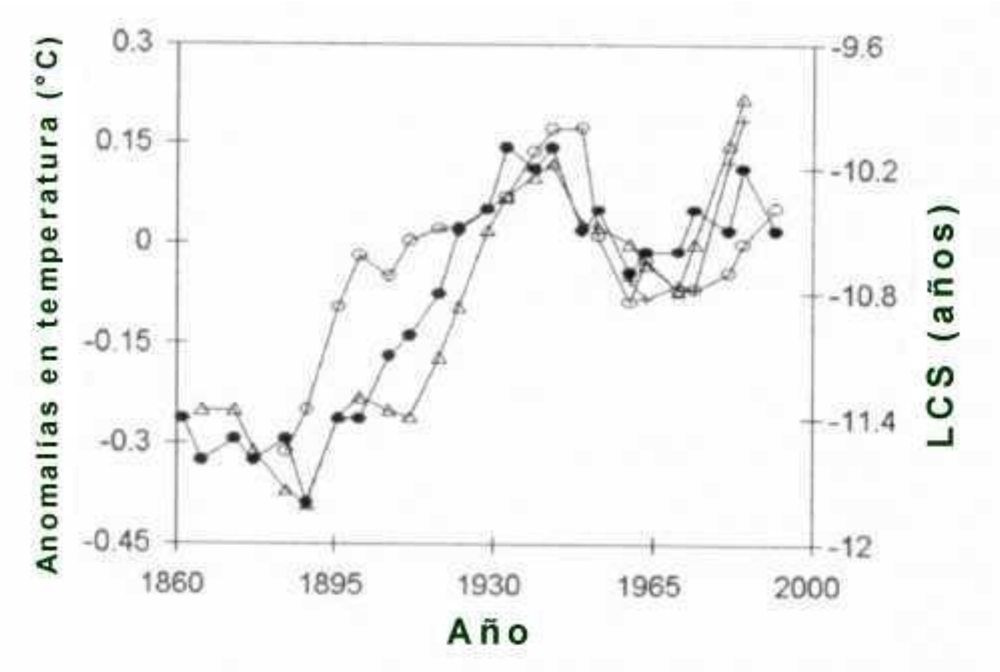


Fig. 5: Replication of the result presented in Fig. 4 (From Adler and El�as (2000). Length of solar Cycle SCL (filled circles), maximum ionospheric electron density in respective 11-year sunspot cycle (plus signs), Northern Hemisphere temperature anomalies (empty triangles), and local temperature anomalies in San Miguel de Tucuman, Argentina (empty circles) show a significant covariation. As explained in the text, the downward movement at the end of the SCL curve does not indicate that there is no longer any effect of solar activity on climate.

LSC is a coarse indicator of the Sun's eruptional activity. Indices of geomagnetic disturbances are finer indicators, especially as they measure the response to those solar eruptions that actually affect the earth. Mayaud's *aa*-index of geomagnetic activity is homogeneous and covers the long period 1868 to present. Fig. 6 from Landscheidt (2000), plotting this index, shows clearly that global land and sea surface temperature lags geomagnetic storms, caused by energetic solar eruptions. The solid curve shows the *aa*-index, the dashed curve a combination of global land air and sea surface temperature anomalies. The yearly data were subjected to repeated three point smoothing. Temperature lags *aa* by 4 to 8 years, but follows the undulations of the *aa*-curve. The connection between the leading *aa*-extrema and the following temperature extrema is highlighted by identical numbers. A disturbance of the correlation around 1940 points to exceptional internal forcing. Between 1942 and 1952 the steepest rise in volcanic activity since 1860 was observed (Simkin et al., 1981). The lag of the temperature data suggests that some of the excess energy linked to solar activity is stored and accumulated in the climate system by processes taking years. Oceans are a candidate because of their thermal inertia (Hoyt, 1979; Wigley, 1988; White et al., 1997)

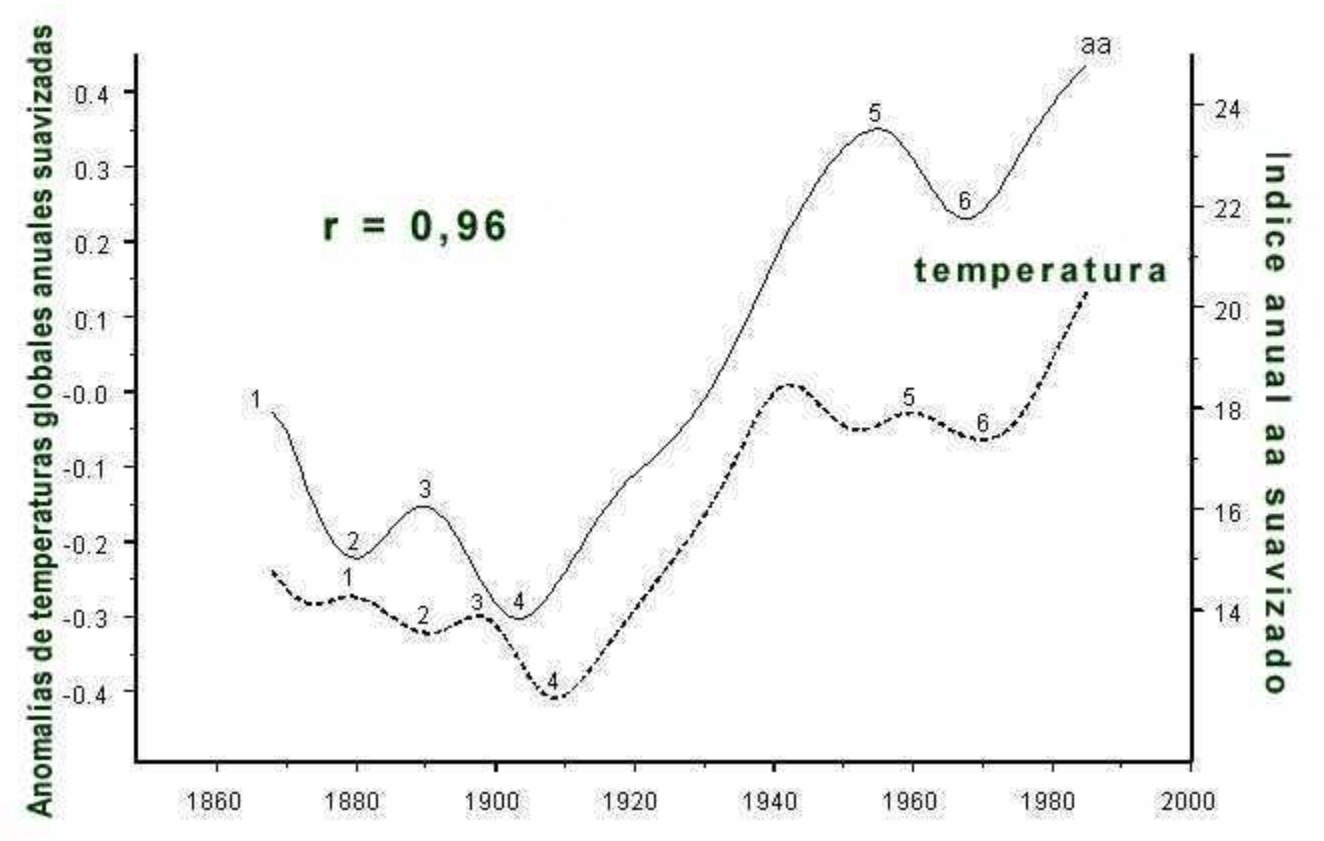


Fig. 6: The solid curve shows the *aa*-index of geomagnetic activity, reflecting the effect of energetic solar eruptions near earth. The dashed curve plots a combination of global land air and sea surface temperature anomalies. The yearly data were subjected to repeated three-point smoothing. Temperature lags *aa* by 4 to 8 years, but follows the undulations of the *aa*-curve. The connection between the leading *aa*-extrema and the following temperature maxima or minima is highlighted by identical numbers. A disturbance around 1940 points to exceptional internal forcing.

Fig. 7 from Landscheidt (2000) is an extension of the data in Fig. 6. It can be seen that the aa-curve reaches its highest maximum, marked by number 7, around 1990 and shows a steep decline afterwards. Allowing for a lag of 8 years, the highest maximum in the curve of global temperature should have occurred around 1998. This was the year with the highest surface temperature observed since the establishment of international meteorological services. The relationship in Fig. 7 points to global cooling in the years after 1998 with the exception of the period around the El Ni�o beginning in 2002, predicted more than 3 years before the event (Landscheidt, 1998, 2000, 2002). Revealingly, this forecast and the correct long-range prediction of the two preceding El Ni�os was based on special phases of solar cycles which go along with accumulations of solar eruptions (Landscheidt, 1995).

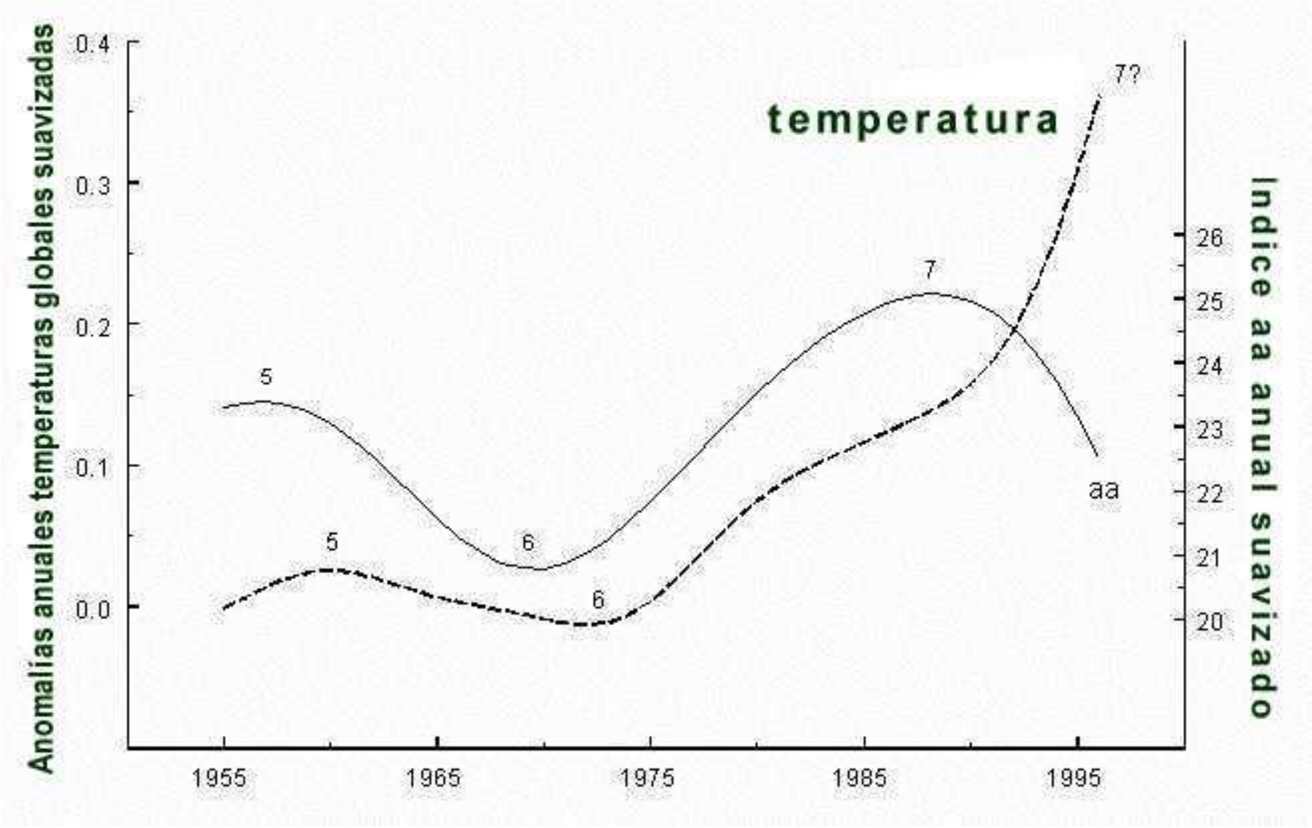


Fig. 7: Extension of the data in Fig. 6. The *aa*-curve reaches its highest maximum, marked by number 7, around 1990 and shows a steep decline afterwars. Allowing for a lag of 8 years, a maximum in the curve of global temperature should have occurred around 1998. This was the year with the highest temperature observed since the establishment of international meteorological services. This relationship points to protracted global cooling. As will be shown, solar activity is expected to decline for three decades. This contradicts the contention maintained by Thjell and Lassen (2000) and IPCC supporters that the sun's impact on climate has faded away since decades.

5. Forecast of Gleissberg cycles based on the sun's barycentric oscillations

Solar variability is recorded in cores drilled from ice sheets. The flux of cosmic rays is modulated by the solar wind, the intensity of which is linked to solar eruptions. During periods of high eruptional activity, the cosmic ray flux into the atmosphere is reduced so that the production rate of radionuclides such as ^{14}C and ^{10}Be is diminished, and vice versa. Most radionuclides are removed from the atmosphere by wet precipitation and quasi-permanently stored in ice sheets, mainly in the Polar regions. Analysis of such ice core archives reveals extended periods of exceptionally high or low solar activity which coincide with phases of rapid climate change (Beer, 2000). The annual ^{10}Be record �Dye 3� going back to 1423 is of special interest in this connection as it reflects the 80 to 90-year Gleissberg cycle and its relationship with climate (Beer et al., 1994).

Forecasts of natural phenomena are one of the most important aims of the natural sciences. As there are strong indications of a dependable connection between minima and maxima in the Gleissberg cycle and cool and warm periods in climate, we are confronted with the problem how to make long-range predictions of extrema in the Gleissberg cycle. Knowledge of its mean length is no real help in this respect as the cycle varies from 40 to 120 years. Fortunately, I have shown for decades that the sun's varying activity is linked to cycles in its irregular oscillation about the centre of mass of the solar system. As these cycles are connected with climate phenomena and can be computed for centuries, they offer a means to forecast consecutive minima and maxima in the Gleissberg cycle and covarying phases of cool and warm climate.

The solar dynamo theory developed by Babcock, the first still rudimentary theory of solar activity, starts from the premise that the dynamics of the magnetic sunspot cycle is driven by the sun's rotation. Yet this theory only takes into account the sun's spin momentum, related to its rotation on its axis, but not its orbital angular momentum linked to its very irregular oscillation about the centre of mass of the solar system (CM). Figure 8 shows this fundamental motion, described by Newton three centuries ago. It is regulated by the distribution of the masses of the giant planets Jupiter, Saturn, Uranus, and Neptune in space. The plot shows the relative ecliptic positions of the centre of mass (small circles) and the sun's centre (cross) for the years 1945 to 1995 in a heliocentric coordinate system.

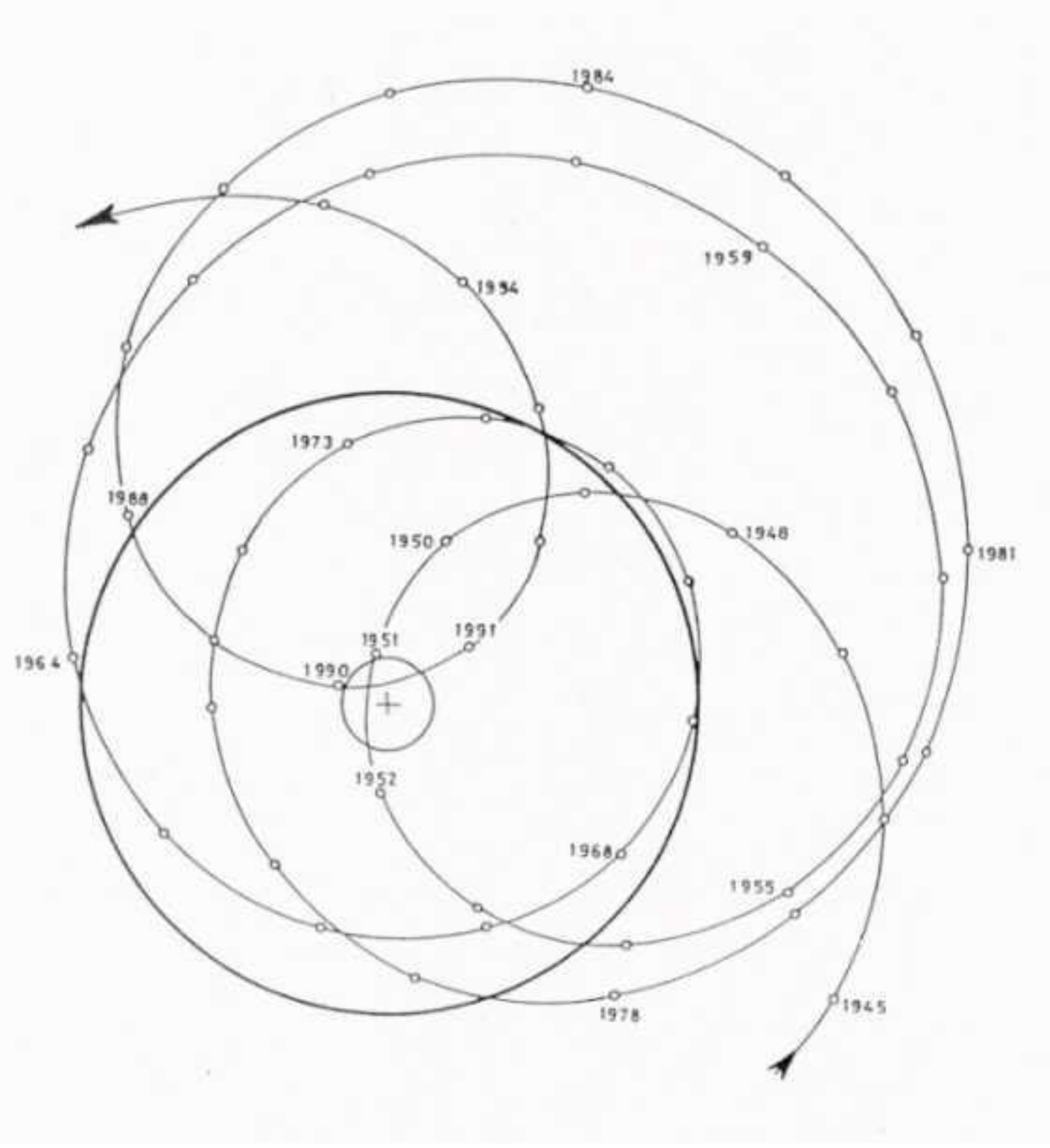


Fig. 8: Irregular oscillation of the sun about the centre of mass of the solar system in a heliocentric perspective. The sun's limb is marked by a thick circle. The position of the centre of mass relative to the sun's centre (cross) in respective years is indicated by small circles. The strong variations in the physical quantities measuring the sun's orbital motion form cycles of different length, but similar function in solar-terrestrial relations.

The large solid circle marks the sun's surface. Most of the time, the CM is to be found outside of the sun's body. Wide oscillations with distances up to 2.2 solar radii between the two centres are followed by narrow orbits which may result in close encounters of the centres as in 1951 and 1990. The contribution of the sun's orbital angular momentum to its total angular momentum is not negligible. It can reach 25 percent of the spin momentum. The orbital angular momentum varies from -0.1�10^{47} to 4.3� 10^{47} g cm^2 s^{-1}, or reversely, which is more than a forty-fold increase or decrease (Landscheidt, 1988). Thus it is conceivable that these variations are related to varying phenomena in the sun's activity, especially if it is considered that the sun's angular momentum plays an important role in the dynamo theory of the sun's magnetic activity.

Variations of more than 7% in the sun's equatorial rotational velocity, going along with variations in solar activity, were observed at irregular intervals (Landscheidt, 1976, 1984). This could be explained if there were transfer of angular momentum from the sun's orbit to the spin on its axis. I have been proposing such spin-orbit coupling for decades (Landscheidt, 1984, 1986). Part of the coupling could result from the sun's motion through its own magnetic fields. As Dicke (1964) has shown, the low corona can act as a brake on the sun's surface. The giant planets, which regulate the sun's motion about the CM, carry more than 99 percent of the angular momentum in the solar system, whereas the sun is confined to less than 1 percent. So there is a high potential of angular momentum that can be transferred from the outer planets to the revolving sun and eventually to the spinning sun.

Juckett (2000) has developed a model of spin-orbit momentum exchange which explains well established asymmetrical phenomena in the Northern and Southern Hemisphere of the sun and identifies changes in solar spin radii in the different hemispheres as a mechanism of momentum transfer. A sun-centered Coriolis acceleration could have an additional perturbing effect on the plasma flow in the sun, especially as it develops large discontinuities when the sun's centre comes close to the CM as in 1951 and 1990 (Blizard, 1987).

6. Forecasts of solar activity and climate confirm validity of solar motion cycles

These theoretical considerations have been corroborated by practical results. Predictions based on cycles in the sun's motion turned out to be correct. My long-range forecasts of precisely defined classes of energetic X-ray flares and strong geomagnetic storms, covering the period 1979 � 1985, reached an overall hit rate of 90 percent though such events show a very irregular distribution. These forecasts were checked by the Space Environment Center, Boulder, and the astronomers Gleissberg, W�hl and Pfleiderer (Landscheidt, 1986; Landscheidt and W�hl, 1986). Accumulations of strong geomagnetic storms around 1982 and 1990 were also correctly forecast several years before the events. I predicted, too, in 1984 (Landscheidt, 1986, 1987) that the sun's activity would diminish past 1990. Just this happened. Though a panel of experts (Joselyn, 1997) had predicted in 1996 and even two years later that sunspot cycle 23 would have a large amplitude similar to the preceding cycles (highest smoothed monthly sunspot number $R = 160$), the observed activity was much weaker ($R = 120$).

My climate forecasts based on solar motion cycles stood the test as well. I correctly forecast the end of the Sahelian drought three years before the event, the last four extrema in global temperature anomalies, the maximum in the Palmer drought index for U.S.A. around 1999, extreme river Po discharges around the beginning of 2001, and the last three El Ni�os as well as the course of the last La Ni�a (Landscheidt, 1983-2002). This forecast skill, solely based on cycles of solar activity, is irreconcilable with the IPCC's allegation that it is unlikely that natural forcing can explain the warming in the latter half of the 20th century.

7. 166-year cycle in variations of the rotary force driving the sun's orbital motion

The dynamics of the sun's motion about the centre of mass can be defined quantitatively by the change in its orbital angular momentum L. The time rate of change in L is measured by its first derivative $\mathrm{d}L/\mathrm{d}t$. It defines the rotary force, the torque T driving the sun's motion about the CM. Variations in the rotary force defined by the derivative $\mathrm{d}T/\mathrm{d}t$ are a key quantity in this connection as they make it possible to forecast Gleissberg extrema for hundreds of years and even millennia.

A cycle of 166 years and its second harmonic of 83 years emerge when the time rate of change in the torque $\mathrm{d}T/\mathrm{d}t$ is subjected to frequency analysis (Landscheidt, 1983). Cycles of this length, though not well known, were mentioned in the literature before. Brier (1979) found a period of just 83 years in the unsmoothed cosine transform of 2148 autocorrelations of 2628 monthly sunspot numbers. Cole (1973) confirmed this result when he investigated the power spectrum of sunspot data covering 1626 - 1968. He found a dominant peak at 84 years. Juckett (2000) derived periods of 165 and 84 years from his model of spin-orbit momentum exchange in the sun's motion. As the wave length of the Gleissberg cycle is not far from the second harmonic of the 166-year cycle, it suggests itself to see whether the Gleissberg cycle and the $\mathrm{d}T/\mathrm{d}t$-cycle have synchronized minima and maxima. This is actually the case.

Gleissberg (1958) found the cycle named after him by smoothing the length of the 11-year sunspot cycle, a parameter that is only indirectly related to the sunspot number R measuring the intensity of sunspot activity. As it could be that the smaller or greater values of the positive and negative extrema of the $\mathrm{d}T/\mathrm{d}t$ cycle have a similar parametric function, the amplitudes of these maxima and minima are taken to constitute a smoothed time series covering 2000 years. The interval is from A. D. 300 to 2300. The data were subjected to moving window Gaussian kernel smoothing (Lorczak) with a bandwidth of 60.

Figure 9 shows the result for the sub period 300 - 1200. Up to the phase reversal around 1120, indicated by an arrow, zero phases of the 166-year cycle, marked by empty circles, coincide within a relatively narrow margin with maxima in the Gleissberg cycle, indicated by filled triangles. Only close to the phase reversal the deviation of the secular maximum from the zero phase is wider. The epochs of Gleissberg minima are indicated by empty triangles. Up to the phase reversal, they consistently go along with extrema in the 166-year cycle. It makes no difference whether the extrema are positive or negative. This is reminiscent of the 11-year sunspot cycle with its exclusively positive amplitudes though the complete magnetic Hale cycle of 22 years shows positive and negative amplitudes indicating different magnetic polarities in consecutive 11-year cycles.

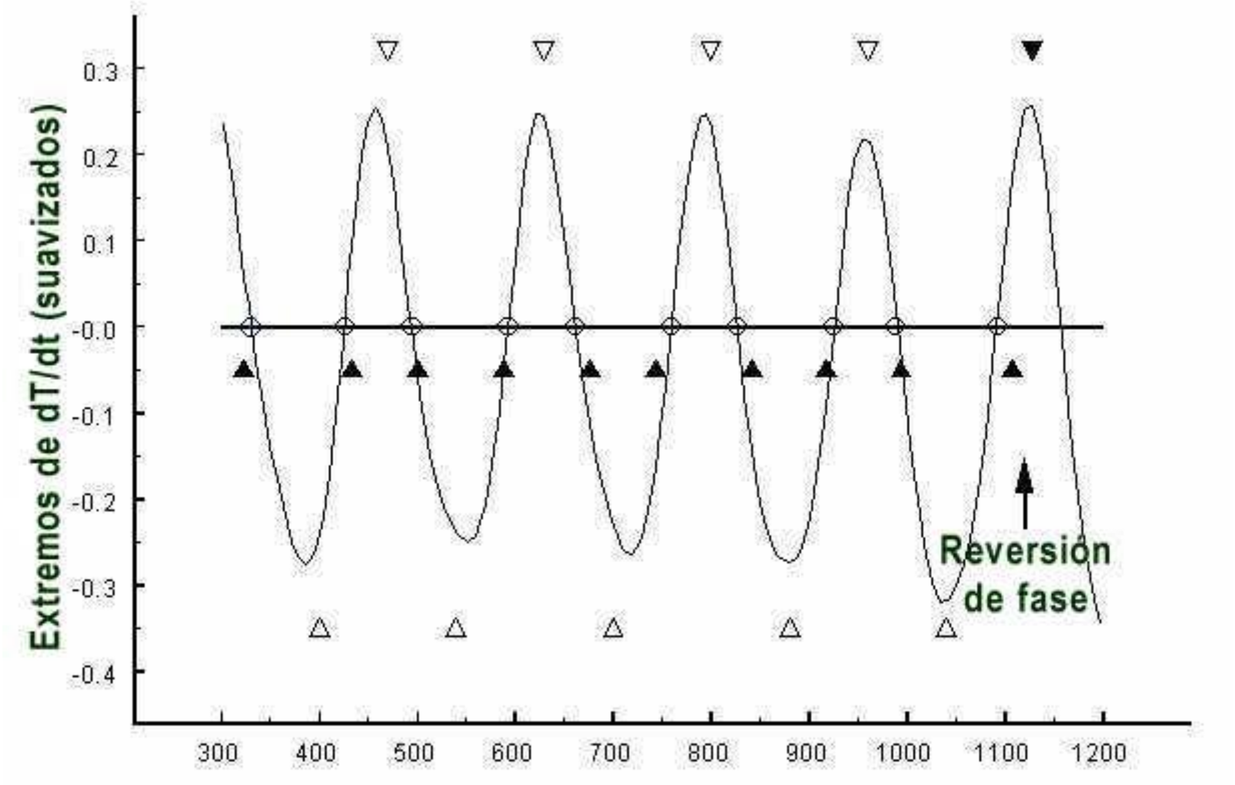


Fig. 9: Smoothed time series (A. D. 300 � 1200) of extrema in the change of the sun's orbital rotary force $\mathrm{d}T/\mathrm{d}t$ forming a cycle with a mean length of 166 years. Up to the phase reversal around 1120, set off by an arrow, zero phases in the cycle, marked by empty circles, coincide within a relatively narrow margin with observed maxima in the Gleissberg cycle indicated by filled triangles. Minima in the Gleissberg cycle, marked by empty triangles, go along with extrema in the 166-year cycle. The phase reversal explains the outstanding Medieval sunspot maximum. The secular maximum around 1100 was followed by another maximum around 1130 without an intermittent minimum. As Gleissberg maxima coincide with warm climate and minima with cool climate, the Medieval sunspot maximum was related to exceptionally warm climate.

The assessment of the epochs of minima and maxima by Gleissberg (1958) is based on data of auroral activity by Schove (1955). Hartmann (1972) has derived mean values of the epochs from data elaborated by Gleissberg, Schove, Link, and Henkel. These dates were used in Figures 9 and 10. An analysis covering 7000 years of data confirms not only the mean cycle length of 166 years, but also a mean interval of 83 years between consecutive positive and negative extrema. The phase reversal by �/2 radians around 1120 had the effect that a Gleissberg-maximum around 1100 was followed by another maximum around 1130 without an intermittent secular minimum. This explains the Medieval sunspot maximum indirectly confirmed by radiocarbon evidence (Siscoe, 1978).

Figure 10 shows the 166-year cycle in the period 900 - 2300. After the phase reversal around 1120 all Gleissberg maxima, marked by filled triangles, rather closely coincide with extrema of the curve for hundreds of years, but around 1976 the pattern changed again because of a new phase reversal by �/2 radians. After a Gleissberg maximum around 1952, a second Gleissberg maximum occurred around 1984 without an intermittent secular minimum. Only the single 11-year sunspot cycle 20 in the middle between the secular maxima showed lower sunspot activity, whereas cycles 18, 19, 21, and 22 reached very high levels of activity. The mean of the maxima of the five cycles 18 - 22 is $R = 156$, a value not directly observed before. We have to go back to the Medieval maximum, based on proxy data, to find a similar pattern. The phase reversals, indicated in Figure 10 by arrows, heuristically explain these special features occurring only twice in nearly 17 centuries. The recent Gleissberg maximum around 1984 is the first in a long sequence of maxima connected with zero phases in the 166-year cycle, four of which are marked by empty circles in Fig. 10. The following Gleissberg maxima should occur around 2069, 2159, and 2235.

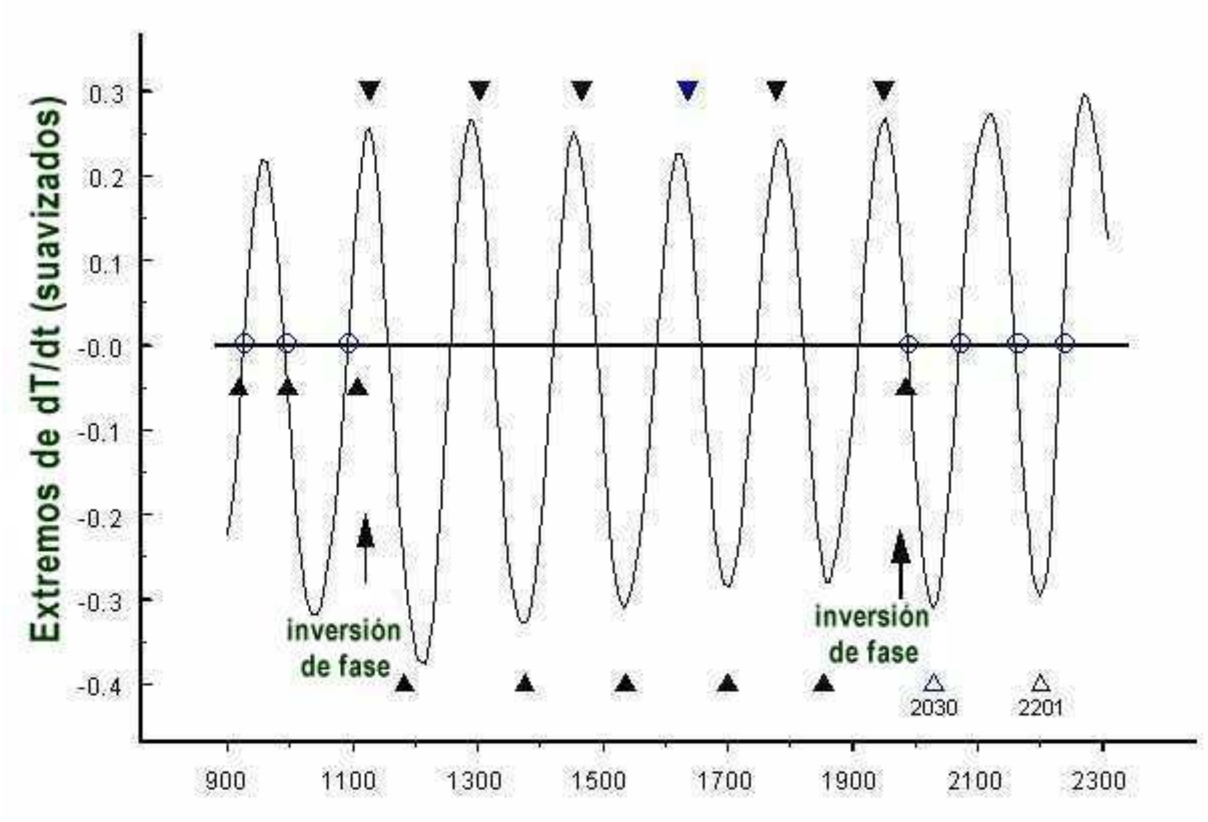


Fig. 10: Same time series as in Fig. 9 for the years 900 � 2300. After the phase reversal around 1120, maxima in the Gleissberg cycle, indicated by filled triangles, consistently go along with extrema in the 166-year cycle, whereas Gleissberg minima fall at zero phases of the cycle. Another phase reversal around 1976 changed the pattern again. After a secular sunspot maximum around 1952, a second maximum followed around 1984 without an intermittent minimum in between. The effect was a grand sunspot maximum comparable to the outstanding maximum around 1120. The phase shift around 1976 reversed the pattern created by the phase reversal around 1120. The Gleissberg maximum around 1984 is the first in a long sequence of maxima going along with zero phases in the 166-year cycle. The following maxima should occur around 2069, 2159, and 2235. After 1976, Gleissberg minima will again go along with extrema in the 166-year cycle. The next secular minimum, indicated by an empty triangle, is to be expected around 2030. The following minima should occur around 2122 and 2201. The figure shows that the Gleissberg cycle behaves like a bistable oscillator. The current phase should last at least through 2500. Because of the link between Gleissberg cycle and climate, future periods of warmer or cooler climate can be predicted for hundreds of years. The next cool phase is to be expected around 2030.

After the phase reversal around 1976, secular minima are expected to coincide with extrema in the

166-year cycle. So the next Gleissberg minimum should occur around 2030, as indicated by an empty triangle. The following minima are to be expected around 2122 and 2201. The forecast of a secular minimum around 2030 is corroborated by a different approach. S�kora et al. (2000) have found that variations in the brightness of the coronal green line are a long-range indicator of solar activity. They hold that �we are at the eve of a deep minimum of solar activity similar to that of the 19th century.�

8. Forecast of phase reversals in the 166-year cycle

The presented results indicate that the Gleissberg cycle is a bistable oscillator capable of assuming either of two states. The transition between these states seems to be triggered by special phases in the 166-year cycle which induce phase reversals. It attracts attention that the phase reversals shown in Figure 10 occur just before the deepest negative extrema relative to the respective environment. This points to quantitative thresholds which are confirmed by an additional case. The outstanding negative extremum preceding the Medieval maximum falls at A.D. 50. Just around this time the climax of the third grand sunspot maximum in the past two millenia occurred as indicated by strong ^{14}C decreases (Eddy, 1977). Revealingly, this period coincides with the Roman climate optimum, as warm or even warmer than the Medieval optimum (Sch�nwiese, 1979). There are additional arguments of a more technical nature how to foresee phase reversals in the $\mathrm{d}T/\mathrm{d}t$�cycle (Landscheidt, 1983). All indicators show that the next phase reversal will not occur before 2500. So the current pattern should continue for hundreds of years and the next Gleissberg minimum should be linked to the next zero phase in the $\mathrm{d}T/\mathrm{d}t$-cycle in 2030.

9. Forecast of deep Gleissberg minima and cold climate around 2030 and 2200

An even more difficult question is whether future Gleissberg minima will be of the regular type with moderately reduced solar activity as around 1895, of the type of very weak activity like the Dalton minimum around 1810, or of the grand minimum type with nearly extinguished activity like the nadir of the Maunder minimum around 1670, the Spoerer minimum around 1490, the Wolf minimum around 1320, and the Norman minimum around 1010 (Stuiver and Quay, 1981). Fig. 11 offers a heuristic solution. It shows the time series of unsmoothed $\mathrm{d}T/\mathrm{d}t$-extrema for the interval 1000 � 2250. A consistent regularity attracts attention. Each time when the amplitude of a negative extremum goes below a low threshold, indicated by a dashed horizontal line, this coincides with a period of exceptionally weak solar activity.

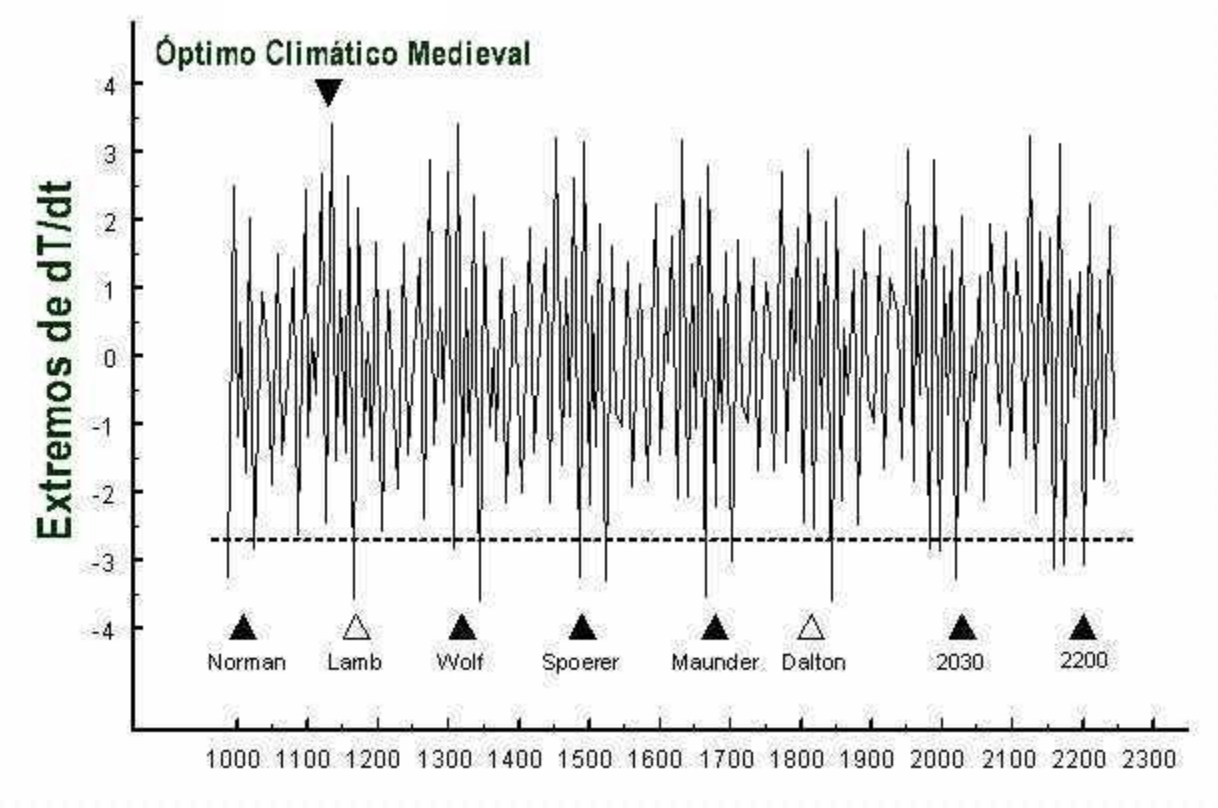


Fig. 11: Time series of the unsmoothed extrema in the change of the sun's orbital rotary force d*T*/d*t* for the years 1000 � 2250. Each time when the amplitude of a negative extremum goes below a low threshold, indicated by a dashed horizontal line, a period of exceptionally weak solar activity is observed. Two consecutive negative extrema transgressing the threshold indicate grand minima like the Maunder minimum (around 1670), the Spoerer minimum (around 1490), the Wolf minimum (around 1320), and the Norman minimum (around 1010), whereas a single extremum below the threshold goes along with events of the Dalton minimum type (around 1810 and 1170) not as severe as grand minima. So the Gleissberg minima around 2030 and 2200 should be of the Maunder minimum type. As climate is closely linked to the sun's activity, conditions around 2030 and 2200 should approach those of the nadir of the Little Ice Age around 1670. As explained in the text, the IPCC's hypothesis of man-made global warming is not in the way of this forecast exclusively based on the sun's eruptional activity. Outstanding positive extrema have a similar function as to exceptionally warm periods like the Medieval Optimum and the modern warm period.

Two consecutive negative extrema transgressing the threshold indicate grand minima of the Maunder minimum type, whereas a single extremum below the threshold goes along with an event of the Dalton minimum type. The grand minima in Fig. 11 are indicated by their names. The single negative extremum around 1170 is of the Dalton-type. At this time solar activity caved in, but this lull was not long-lasting. According to Lamb (1977), who looked at the oxygen isotope record from north Greenland provided by Dansgaard, a period of sudden cooling occurred at the end of the 12th century. So I call this deep Gleissberg minimum after him.

Fig. 11 shows that solar activity of outstanding intensity and corresponding warm periods on Earth, too, are indicated by the extrema of d*T*/d*t*. As an example, the Medieval Optimum is marked by an arrow. It should be noted that the outstanding positive amplitude around 1120 is greater than the amplitudes around 1952 and 1984 indicating the modern Gleissberg maxima linked to warming not as high as around 1120 (Sch�nwiese, 1979). More details of this relationship will be presented elsewhere.

Without exception, the outstanding negative extrema coincide with periods of exceptionally weak solar activity and vice versa. So there are good reasons to expect that the coming Gleissberg minimum around 2030 will be a deep one. As there are three consecutive extrema below the quantitative threshold, there is a high probability that the event will be of the Maunder minimum type. This is also true as to the minimum around 2201, whereas the minimum around 2122 should be of the regular type, as can be seen in Fig. 11.

It has been shown that there is a close relationship between deep Gleissberg minima and cold climate. So the probability is high that the outstanding Gleissberg minima around 2030 and 2201 will go along with periods of cold climate comparable to the nadir of the Little Ice Age. As to the minimum around 2030, there are additional indications that global cooling is to be expected instead of global warming. The Pacific Decadal Oscillation (PDO) will show negative values up to at least 2016 (Landscheidt, 2001), and La Ni�as will be more frequent and stronger than El Ni�os through 2018 (Landscheidt, 2000).

The heuristic results derived from the 166-year cycle are not yet corroborated by a detailed chain of cause and effect. Progress in this respect will be difficult as the theories of solar activity and climate change are still in a rudimentary stage of development, though there is progress as to the physical explanation of special solar-terrestrial relationships (Haigh, 1996; Tinsley and Yu, 2002).Yet the connection with solar system dynamics, the length of the involved data series covering millennia, and the skilful forecasts of solar activity and climate events based on the same foundation speak for the dependability of the forecast of the coming Gleissberg minima and their climatic impact.

10. IPCC's hypothesis of man-made warming not in the way of global cooling

I do not expect that the effects of man-made greenhouse gases will eliminate the sun's predominance. If these effects were as strong as the IPCC pretends, my diverse climate forecasts, exclusively based on solar activity, would not have had any chance to turn out correct. This all the more so as they cover recent years and decades the warming of which, according to IPCC statements, cannot be explained by natural forcing.

The IPCC's �story lines�, far from forecasts as practised in other fields of science, are nearly exclusively supported by runs of General Circulation Models (GCM). These models are based on the same type of nonlinear differential equations which induced Lorenz in 1961 to acknowledge that long-range weather predictions are impossible because of the atmosphere's extreme sensitivity to initial conditions. It is not conceivable that the �Butterfly Effect� should disappear when the prediction range of a few days is extended to decades and centuries.

Some climatologists concede that there is a problem. Sch�nwiese (1994) remarks: �Consequently we should conclude that climatic change cannot be predicted (by GCMs). It is correct that the varied and complex processes in the atmosphere cannot be predicted beyond the theoretical limit of a month via step by step calculations in circulation models, neither today, nor in the future. Yet there is the possibility of a conditioned forecast. The condition is that a special factor within the complex cause and effect relationship is so strong that it clearly dominates all other factors. In addition, the behaviour of that single dominant causal factor must be predictable with certainty, or a high degree of probability.� A look at the literature shows that these conditions are not fulfilled. In addition, there are technical and mathematical difficulties. Peixoto and Oort (1992) aptly comment: �The integration of a fully coupled model including the atmosphere, ocean, land, and cryosphere with very different internal time scales poses almost insurmountable difficulties in reaching a final solution, even if all interacting processes were completely understood.�

So it is no wonder that validated GCM-forecasts are a rare species. The IPCC-hypothesis of global warming requires that long-wave radiation to space is reduced because of the accumulating anthropogenic greenhouse gases. Actually, satellites have observed a trend of increasing tropical long-wave radiation to space over the past two decades (Wielicki et al., 2002). GCMs predict greater increase in temperature with increasing distance from the equator, but observations show no net change in the polar regions in the past four decades (Comiso, 2000; Przybylak, 2000; Venegas and Mysak, 2000). According to the most recent data, Antarctica has cooled significantly (Doran et al., 2002) instead of warming.

Most important is a discrepancy between GMC-forecast and observation as to evaporation. Even if the IPCC's theoretical considerations were correct, CO2 alone could manage only about 0.8� C of warming within more than a century. This small amount of warming, however, would increase evaporation at the surface and raise the concentration of water vapour, by far the strongest greenhouse gas in the atmosphere. According to the climate models, this positive feedback would cause a much larger warming than CO2 and other weak greenhouse gases alone. So it is crucial for the IPCC-hypothesis of global warming that observation shows a decrease in evaporation in the Northern hemisphere over the past 50 years instead of the predicted increase (Roderick and Farquhar (2002). There are many other points, but they would go beyond the frame of this paper.

11. Outlook

We need not wait until 2030 to see whether the forecast of the next deep Gleissberg minimum is correct. A declining trend in solar activity and global temperature should become manifest long before the deepest point in the development. The current 11-year sunspot cycle 23 with its considerably weaker activity seems to be a first indication of the new trend, especially as it was predicted on the basis of solar motion cycles two decades ago. As to temperature, only El Ni�o periods should interrupt the downward trend, but even El Ni�os should become less frequent and strong. The outcome of this further long-range climate forecast solely based on solar activity may be considered to be a touchstone of the IPCC's hypothesis of man-made global warming.

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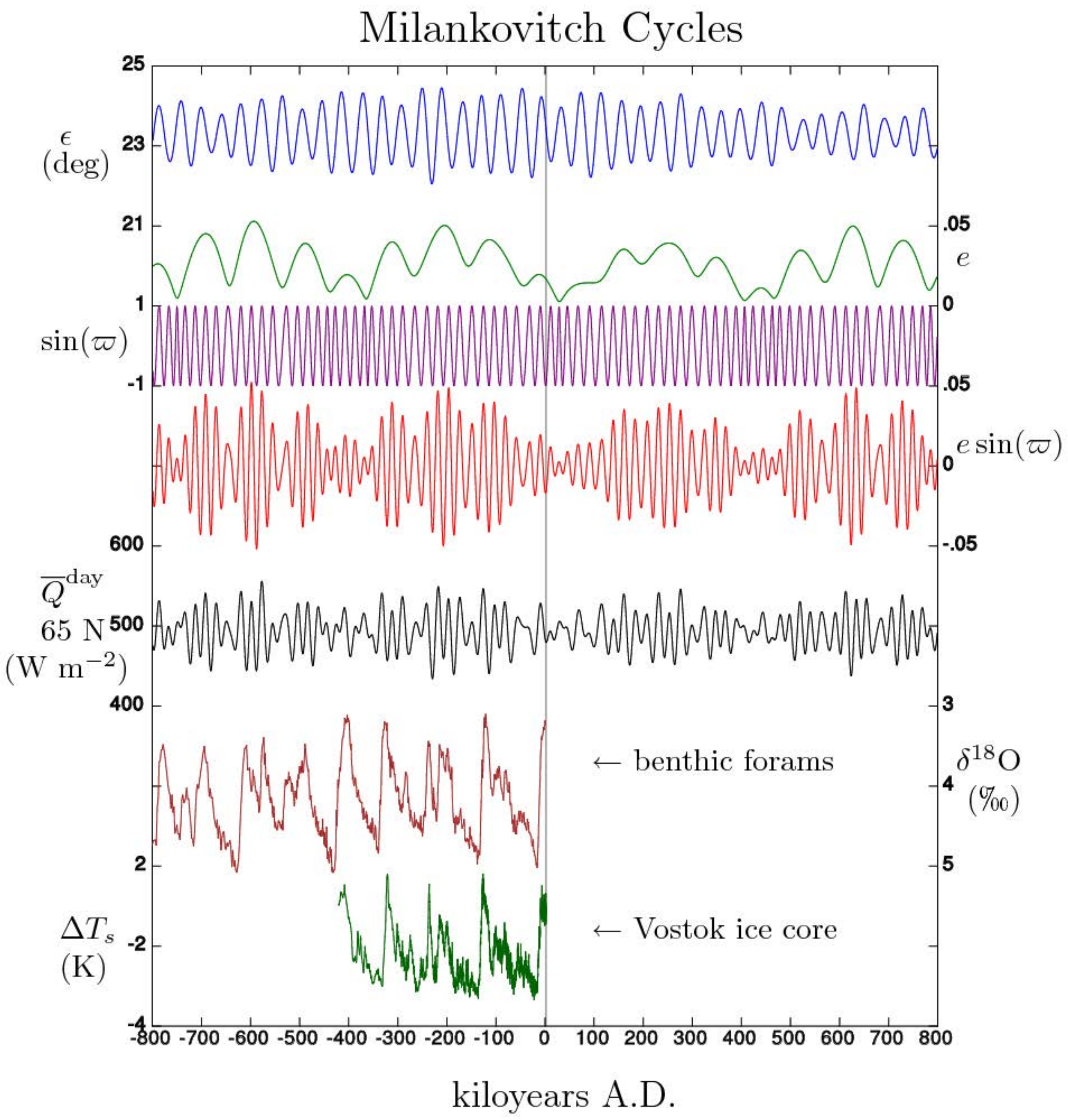
Section 4 Milankovitch cycles

From Wikipedia, the free encyclopedia



Past and future Milankovitch cycles. VSOP allows prediction of past and future orbital parameters with great accuracy. ε is obliquity (axial tilt). *e* is eccentricity. ϖ is longitude of perihelion. *e*sin(ϖ) is the **precession index**, which together with obliquity, controls the seasonal cycle of insolation. $\overline{Q}^{\text{day}}$ is the calculated daily-averaged insolation at the top of the atmosphere, on the day of the summer solstice at 65 N latitude. *Benthic forams* and *Vostok ice core* show two distinct proxies for past global sea level and temperature, from ocean sediment and Antarctic ice respectively. Vertical gray line is current conditions, at 2 ky A.D.

Milankovitch Theory describes the collective effects of changes in the Earth's movements upon its climate, named after Serbian civil engineer and mathematician Milutin Milanković, who worked on it during First World War internment. Milanković mathematically theorised that variations in eccentricity, axial tilt, and precession of the Earth's orbit determined climatic patterns on Earth.

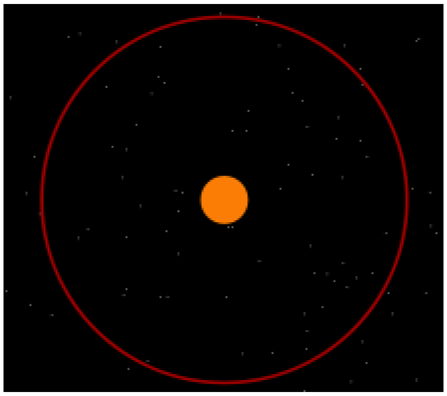
The Earth's axis completes one full cycle of precession approximately every 26,000 years. At the same time, the elliptical orbit rotates, more slowly, leading to a 21,000-year cycle between the seasons and the orbit. In addition, the angle between Earth's rotational axis and the normal to the plane of its orbit moves from 22.1 degrees to 24.5 degrees and back again on a 41,000-year cycle; currently, this angle is 23.44 degrees and is decreasing.

Other astronomical theories were advanced by Joseph Adhemar, James Croll and others, but verification was difficult due to the absence of reliably dated evidence and doubts as to exactly which periods were important. Not until the advent of deep-ocean cores and a seminal paper by Hays, Imbrie and Shackleton, "Variations in the Earth's Orbit: Pacemaker of the Ice Ages", in *Science*, 1976,[1] did the theory attain its present state.

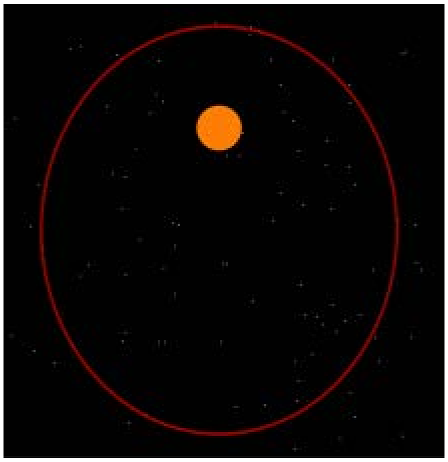
Earth's movements

As the Earth spins around its axis and orbits around the Sun, several quasi-periodic variations occur. Although the curves have a large number of sinusoidal components, a few components are dominant[1]. Milankovitch studied changes in the orbital eccentricity, obliquity, and precession of Earth's movements. Such changes in movement and orientation change the amount and location of solar radiation reaching the Earth. This is known as *solar forcing* (an example of radiative forcing). Changes near the north polar area are considered important due to the large amount of land, which reacts to such changes more quickly than the oceans do.

Orbital shape (eccentricity)



Circular orbit, no eccentricity.



Orbit with 0.5 eccentricity.

The Earth's orbit is an ellipse. The eccentricity is a measure of the departure of this ellipse from circularity. The shape of the Earth's orbit varies from being nearly circular (low eccentricity of 0.005) to being mildly elliptical (high eccentricity of 0.058) and has a mean eccentricity of 0.028. The major component of these variations occurs on a period of 413,000 years (eccentricity variation of ±0.012). A number of other terms vary between components 95,000 and 125,000 years (with a beat period 400 ka), and loosely combine into a 100,000-year cycle (variation of −0.03 to +0.02). The present eccentricity is 0.017.

If the Earth were the only planet orbiting our Sun, the eccentricity of its orbit would not vary over time. The Earth's eccentricity varies primarily due to interactions with the gravitational fields of Jupiter and Saturn. As the eccentricity of the orbit evolves, the semi-major axis of the orbital ellipse remains unchanged. From the perspective of the perturbation theory used in celestial mechanics to compute the evolution of the orbit, the semi-major axis is an adiabatic invariant. According to Kepler's third law the period of the orbit is determined by the semi-major axis. It follows that the Earth's orbital period, the length of a sidereal year, also remains unchanged as the orbit evolves. As the semi-minor axis is decreased with the eccentricity increase, the seasonal changes increase[2]. But the mean solar irradiation for the planet changes only slightly for small eccentricity, due to Kepler's second law.

The same average irradiation does not correspond to the average of corresponding temperatures (due to non-linearity of the Stefan–Boltzmann law). For an irradiation with corresponding temperature 20°C and its symmetric variation ±50% (e.g. from the seasons change[3]) we obtain asymmetric variation of corresponding temperatures with their average 16°C (i.e. deviation -4°C). And for the irradiation variation during a day (with its average corresponding also to 20°C) we obtain the average temperature (for zero thermal capacity) -113°C.

The relative increase in solar irradiation at closest approach to the Sun (perihelion) compared to the irradiation at the furthest distance (aphelion) is slightly larger than 4 times the eccentricity. For the current orbital eccentricity this amounts to a variation in incoming solar radiation of about 6.8%, while the current difference between perihelion and aphelion is only 3.4% (5.1 million km). Perihelion presently occurs around January 3, while aphelion is around July 4. When the orbit is at its most elliptical, the amount of solar radiation at perihelion will be about 23% greater than at aphelion.

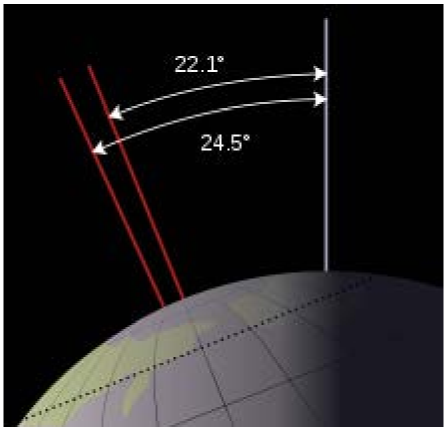
Season (Northern Hemisphere) Durations

data from United States Naval Observatory

Year	Date: GMT	Season Duration
2005 Winter Solstice	12/21/2005 18:35	88.99 days
2006 Spring Equinox	3/20/2006 18:26	92.75 days
2006 Summer Solstice	6/21/2006 12:26	93.65 days
2006 Autumn Equinox	9/23/2006 4:03	89.85 days
2006 Winter Solstice	12/22/2006 0:22	88.99 days
2007 Spring Equinox	3/21/2007 0:07	92.75 days
2007 Summer Solstice	6/21/2007 18:06	93.66 days
2007 Autumn Equinox	9/23/2007 9:51	89.85 days
2007 Winter Solstice	12/22/2007 06:08	

Orbital mechanics requires that the length of the seasons be proportional to the areas of the seasonal quadrants, so when the eccentricity is extreme, the seasons on the far side of the orbit can be substantially longer in duration. When autumn and winter occur at closest approach, as is the case currently in the northern hemisphere, the earth is moving at its maximum velocity and therefore autumn and winter are slightly shorter than spring and summer. Thus, summer in the northern hemisphere is 4.66 days longer than winter and spring is 2.9 days longer than autumn.

Axial tilt (obliquity)



22.1-24.5° range of Earth's obliquity.

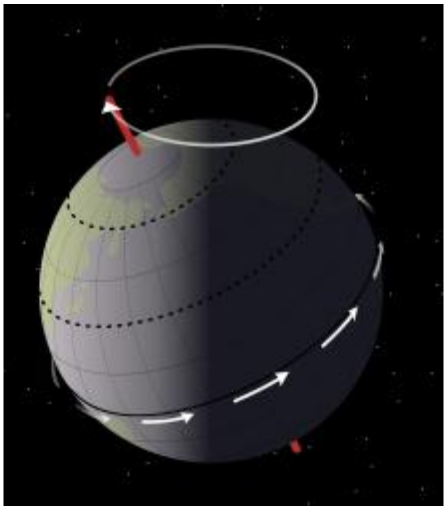
The angle of the Earth's axial tilt (obliquity) varies with respect to the plane of the Earth's orbit. These slow 2.4° obliquity variations are roughly periodic, taking approximately 41,000 years to shift between a tilt of 22.1° and 24.5° and back again. When the obliquity increases, the amplitude of the seasonal cycle in insolation (INcoming SOLar radiATION) increases, with summers in both hemispheres receiving more radiative flux from the Sun, and the winters less radiative flux.

But these changes of opposite sign in the summer and winter are not of the same magnitude. The annual mean insolation increases in high latitudes with increasing obliquity, while lower latitudes experience a reduction in insolation. Cooler summers are suspected of encouraging the start of an ice age by melting less of the previous winter's ice and snow. So it can be argued that lower obliquity favors ice ages both because of the mean insolation reduction in high latitudes as well as the additional reduction in summer insolation. However no significant climate changes are associated with extreme axial tilts.

Scientists using computer models to study more extreme tilts than those that actually occur have concluded that climate extremes at high obliquity would be particularly threatening to advanced forms of life that presently exist on Earth. They noted that high obliquity would not likely sterilize a planet completely, but would make it harder for fragile, warm-blooded land-based life to thrive as it does today. [4].

Currently the Earth is tilted at 23.44 degrees from its orbital plane, roughly half way between its extreme values. The tilt is in the decreasing phase of its cycle, and will reach its minimum value around the year 10,000 C.E.. This trend, by itself, would tend to make winters warmer and summers colder; however increases in greenhouse gases may overpower this effect.

Axial precession



Precessional movement.

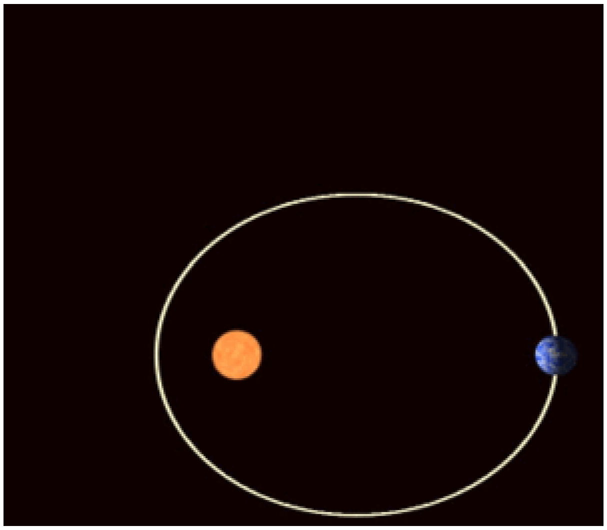
Precession is the change in the direction of the Earth's axis of rotation relative to the fixed stars, with a period of roughly 26,000 years. This gyroscopic motion is due to the tidal forces exerted by the sun and the moon on the solid Earth, associated with the fact that the Earth is an oblate spheroid shape and not a perfect sphere. The sun and moon contribute roughly equally to this effect.

When the axis is aligned so it points toward the Sun during perihelion, one polar hemisphere will have a greater difference between the seasons while the other hemisphere will have milder seasons. The hemisphere which is in summer at perihelion will receive much of the corresponding increase in solar radiation, but that same hemisphere will be in winter at aphelion and have a colder winter. The other hemisphere will have a relatively warmer winter and cooler summer.

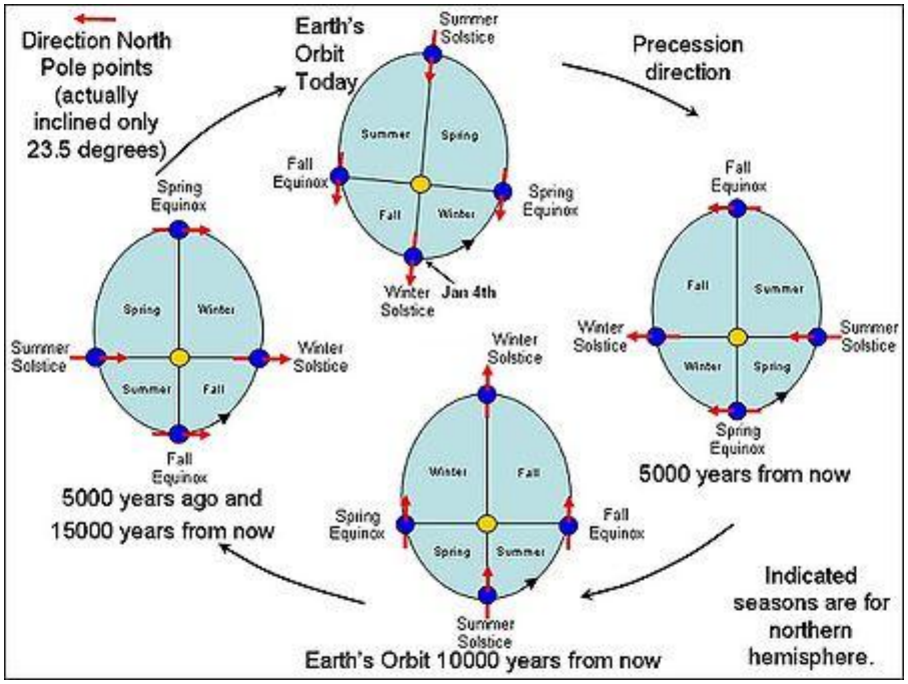
When the Earth's axis is aligned such that aphelion and perihelion occur near the equinoxes, the Northern and Southern Hemispheres will have similar contrasts in the seasons.

At present, perihelion occurs during the Southern Hemisphere's summer, and aphelion is reached during the southern winter. Thus the Southern Hemisphere seasons are somewhat more extreme than the Northern Hemisphere seasons, when other factors are equal.

Apsidal precession



Planets orbiting the Sun follow elliptical (oval) orbits that rotate gradually over time (apsidal precession). The eccentricity of this ellipse is exaggerated for visualization. Most orbits in the Solar System have a much smaller eccentricity, making them nearly circular.



Effects of apsidal precession on the seasons

In addition, the orbital ellipse itself precesses in space, primarily as a result of interactions with Jupiter and Saturn. This orbital precession is in the same sense to the gyroscopic motion of the axis of rotation, shortening the period of the precession of the equinoxes with respect to the perihelion from 25,771.5 to ~21,636 years.

The inclination of Earth's orbit drifts up and down relative to its present orbit with a cycle having a period of about 70,000 years. Milankovitch did not study this three-dimensional movement. This movement is known as "precession of the ecliptic" or "planetary precession".

More recent researchers noted this drift and that the orbit also moves relative to the orbits of the other planets. The invariable plane, the plane that represents the angular momentum of the solar system, is approximately the orbital plane of Jupiter. The inclination of the Earth's orbit has a 100,000 year cycle relative to the invariable plane; by chance, this is very similar to the 100,000 year eccentricity period. This 100,000-year cycle closely matches the 100,000-year pattern of ice ages. It has been proposed that a disk of dust and other debris exists in the invariable plane, and this affects the Earth's climate through several possible means. The Earth presently moves through this plane around January 9 and July 9, when there is an increase in radar-detected meteors and meteor-related noctilucent clouds.[2][3]

A study of the chronology of Antarctic ice cores using oxygen to nitrogen ratios in air bubbles trapped in the ice, which appear to respond directly to the local insolation, concluded that the climatic response documented in the ice cores was driven by Northern Hemisphere insolation as proposed by the Milankovitch hypothesis (Kawamura et al., Nature, 23 August 2007, vol 448, p912-917). This is an additional validation of the Milankovitch hypothesis by a relatively novel method, and is inconsistent with the "inclination" theory of the 100,000-year cycle.

Section 5 Cosmic Rays and Climate

By: Nir J. Shaviv

Article originally appeared in PhysicaPlus.

Sir William Herschel was the first to seriously consider the sun as a source of climate variations, already two centuries ago. He noted a correlation between the price of wheat, which he presumed to be a climate proxy, and the sunspot activity:

> *"The result of this review of the foregoing five periods is, that, from the price of wheat, it seems probable that some temporary scarcity or defect of vegetation has generally taken place, when the sun has been without those appearances which we surmise to be symptoms of a copious emission of light and heat."*
>
> *— Sir William Herschel, Phil. Trans. Roy. Soc. London, 91, 265 (1801)*

Herschel presumed that this link arises from variation in the luminosity of the sun. Today, various solar activity and climate variations are indeed known to have a notable correlation on various time scales. The best example is perhaps the one depicted in fig. 1, on a centennial to millennial time scale between solar activity and the tropical climate of the Indian ocean (Neff et al. 2001). Another example of a beautiful correlation exists on a somewhat longer time scale, between solar activity and the northern atlantic climate (Bond et al. 2001). Nevertheless, the relatively small luminosity variations of the sun are most likely insufficient to explain this or other links. Thus, an amplifier of solar activity is probably required to explain these observed correlations.

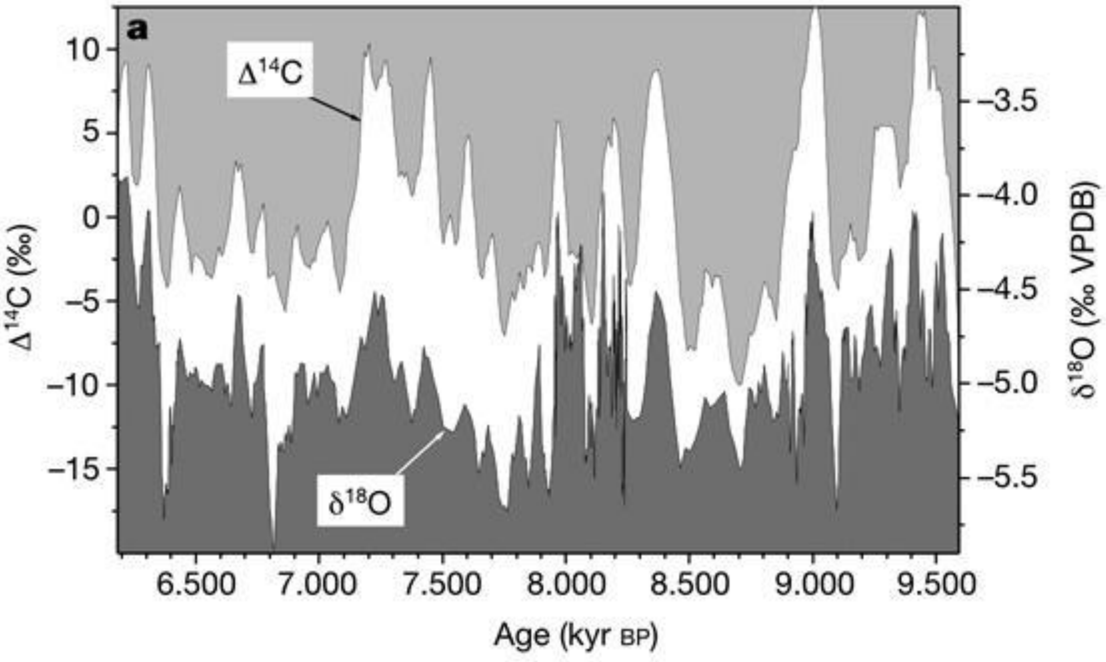


Figure 1: The correlation between solar activity—as mirrored in the ^{14}C flux, and a climate sensitivity variable, the ^{18}O/^{16}O isotope ratio from stalagmites in a cave in Oman, on a centennial to millennial time scale. The ^{14}C is reconstructed from tree rings. It is a proxy of solar activity since a more active sun has a stronger solar wind which reduces the flux of cosmic rays reaching Earth from outside the solar system. A reduced cosmic ray flux, will in turn reduce the spallation of nitrogen and oxygen and with it the formation of ^{14}C. On the other hand,

$^{18}O/^{16}O$ reflects the temperature of the Indian ocean—the source of the water that formed the stalagmites. (Graph from Neff et al., 2001, Copywrite by Nature, used with permission)

Several amplifiers were suggested. For example, UV radiation is all absorbed in the stratosphere, such that notable stratospheric changes arise with changes to the non-thermal radiation emitted by the sun. In fact, Joanna Heigh of Imperial College in London, suggested that through dynamic coupling with the troposphere, via the Hadley circulation (in which moist air ascends in the tropic and descends as dry air at a latitude of about 30°) the solar signal at the surface can be amplified. Here we are interested in what appears to be a much more indirect link between solar activity and climate.

In 1959, the late Edward Ney of the U. of Minnesota suggested that any climatic sensitivity to the density of tropospheric ions would immediately link solar activity to climate. This is because the solar wind modulates the flux of high energy particles coming from outside the solar system. These particles, the cosmic rays, are the dominant source of ionization in the troposphere. More specifically, a more active sun accelerates a stronger solar wind, which in turn implies that as cosmic rays diffuse from the outskirts of the solar system to its center, they lose more energy. Consequently, a lower tropospheric ionization rate results. Over the 11-yr solar cycle and the long term variations in solar activity, these variations correspond to typically a 10% change in this ionization rate. It now appears that there is a climatic variable sensitive to the amount of tropospheric ionization—Clouds.

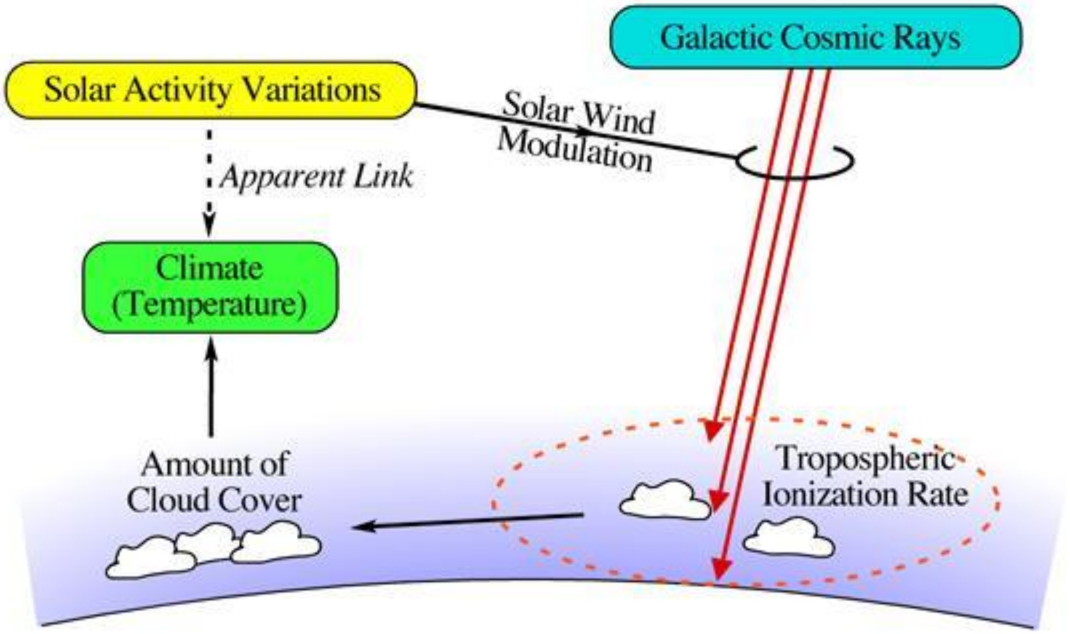


Figure 2: The cosmic ray link between solar activity and the terrestrial climate. The changing solar activity is responsible for a varying solar wind strength. A stronger wind will reduce the flux of cosmic ray reaching Earth, since a larger amount of energy is lost as they propagate up the solar wind. The cosmic rays themselves come from outside the solar system (cosmic rays with energies below the "knee" at 10^{15}eV, are most likely accelerated by supernova remnants). Since cosmic rays dominate the tropospheric ionization, an increased solar activity will translate into a reduced ionization, and empirically (as shown below), also to a reduced low altitude cloud cover. Since low altitude clouds have a net cooling effect (their "whiteness" is more important than their "blanket" effect), increased solar activity implies a warmer climate. Intrinsic cosmic ray flux variations will have a similar effect, one however, which is unrelated to solar activity variations.

Clouds have been observed from space since the beginning of the 1980's. By the mid 1990's, enough cloud data accumulated to provide empirical evidence for a solar/cloud-cover link. Without the satellite data, it hard or probably impossible to get statistically meaningful results because of the large systematic errors plaguing ground based observations. Using the satellite data, Henrik Svensmark of the Danish National Space Center in Copenhagen has shown that cloud cover varies in sync with the variable cosmic ray flux reaching the Earth. Over the relevant time scale, the largest variations arise from the 11-yr solar cycle, and indeed, this cloud cover seemed to follow the cycle and a half of cosmic ray flux modulation. Later, Henrik Svensmark and his colleague Nigel Marsh, have shown that the correlation is primarily with low altitude cloud cover. This can be seen in fig. 3.

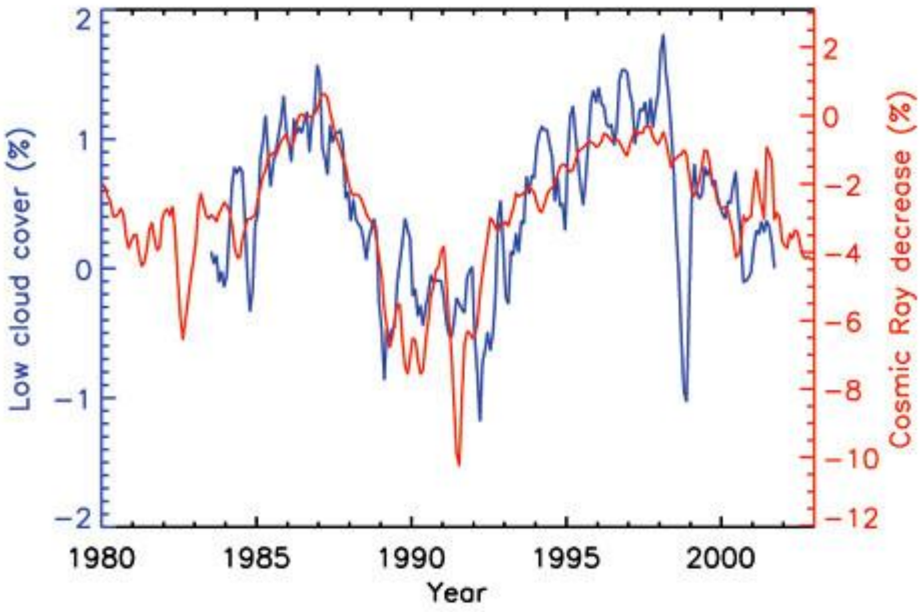


Figure 3: The correlation between cosmic ray flux (orange) as measured in Neutron count monitors in low magnetic latitudes, and the low altitude cloud cover (blue) using ISCCP satellite data set, following Marsh & Svensmark, 2003.

The solar-activity – cosmic-ray-flux – cloud-cover correlation is quite apparent. It was in fact sought for by Henrik Svensmrk, based on theoretical considerations. However, by itself it cannot be used to prove the cosmic ray climate connection. The reason is that we cannot exclude the possibility that solar activity modulates the cosmic ray flux and independently climate, without any casual link between the latter two. There is however separate proof that a casual link exists between cosmic rays and climate, and independently that cosmic rays left a fingerprint in the observed cloud cover variations.

To begin with, climate variations appear to arise also from intrinsic cosmic ray flux variations, namely, from variations that have nothing to do with solar activity modulations. This removes any doubt that the observed solar activity cloud cover correlations are coincidental or without an actual causal connection. That is to say, it removes the possibility that solar activity modulates the cosmic ray flux and independently the climate, such that we *think* that the cosmic rays and climate are related, where in fact they are not. Specifically, cosmic ray flux variations also arise from the varying environment around the solar system, as it journeys around the Milky Way. These variations appear to have left a paleoclimatic imprint in the geological records.

Cosmic Rays, at least at energies lower than 10^{15}eV, are accelerated by supernova remnants. In our galaxy, most supernovae are the result of the death of massive stars. In spiral galaxies like our own, most of the star formation takes place in the spiral arms. These are waves which revolve around the galaxy at a speed different than the stars. Each time the wave passes (or is passed through), interstellar gas is shocked and forms new stars. Massive stars that end their lives with a supernova explosion, live a relatively short life of at most 30 million years, thus, they die not far form the spiral arms where they were born. As a consequence, most cosmic rays are accelerated in the vicinity of spiral arms. The solar system, however, has a much longer life span such that it periodically crosses the spiral arms of the Milky Way. Each time it does so, it should witness an elevated level of cosmic rays. In fact, the cosmic ray flux variations arising from our galactic journey are ten times larger than the cosmic ray flux variations due to solar activity modulations, at the energies responsible for the tropospheric ionization (of order 10 GeV). If the latter is responsible for a 1°K effect, spiral arm passages should be responsible for a 10°K effect—more than enough to change the state of earth from a hothouse, with temperate climates extending to the polar regions, to an icehouse, with ice-caps on its poles, as Earth is today. In fact, it is expected to be the most dominant climate driver on the 10^8 to 10^9 yr time scale.

It was shown by the author (Shaviv 2002, 2003), that these intrinsic variation in the cosmic ray flux are clearly evident in the geological paleoclimate data. To within the determinations of the period and phase of the spiral-arm climate connection, the astronomical determinations of the relative velocity agree with the geological sedimentation record for when Earth was in a hothouse or icehouse conditions. Moreover, it was found that the cosmic ray flux can be independently reconstructed using the so called "exposure ages" of Iron meteorites. The signal, was found to agree with the astronomical predictions on one hand, and correlate well with the sedimentation record, all having a ~145 Myr period.

Figure 4: An Iron meteorite. A large sample of these meteorites can be used to reconstruct the past cosmic ray flux variations. The reconstructed signal reveals a 145 Myr periodicity. The one in the picture is part of the Sikhote Alin meteorite that fell over Siberia in the middle of the 20th century. The cosmic-ray exposure age of the meteorite implies that it broke off its parent body about 300 Million years ago.

In a later analysis, with Ján Veizer of the University of Ottawa and the Ruhr University of Bochum, it was found that the cosmic ray flux reconstruction agrees with a quantitative reconstruction of the tropical temperature (Shaviv & Veizer, 2003). In fact, the correlation is so well, it was shown that cosmic ray flux variations explain about two thirds of the variance in the reconstructed temperature signal. Thus, cosmic rays undoubtedly affect climate, and on geological time scales are the most dominant climate driver.

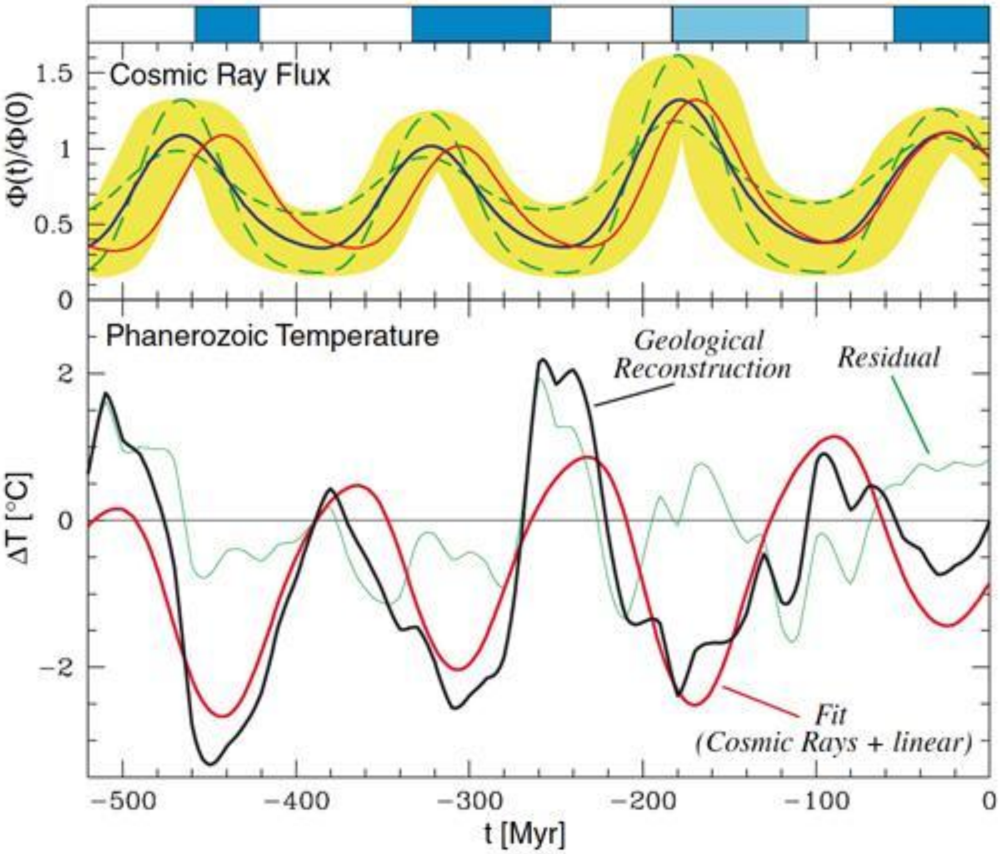


Figure 5: Correlation between the cosmic ray flux reconstruction (based on the exposure ages of Iron meteorites) and the geochemically reconstructed tropical temperature. The comparison between the two reconstructions reveals the dominant role of cosmic rays and the galactic "geography" as a climate driver over geological time scales. (Shaviv & Vezier 2003)

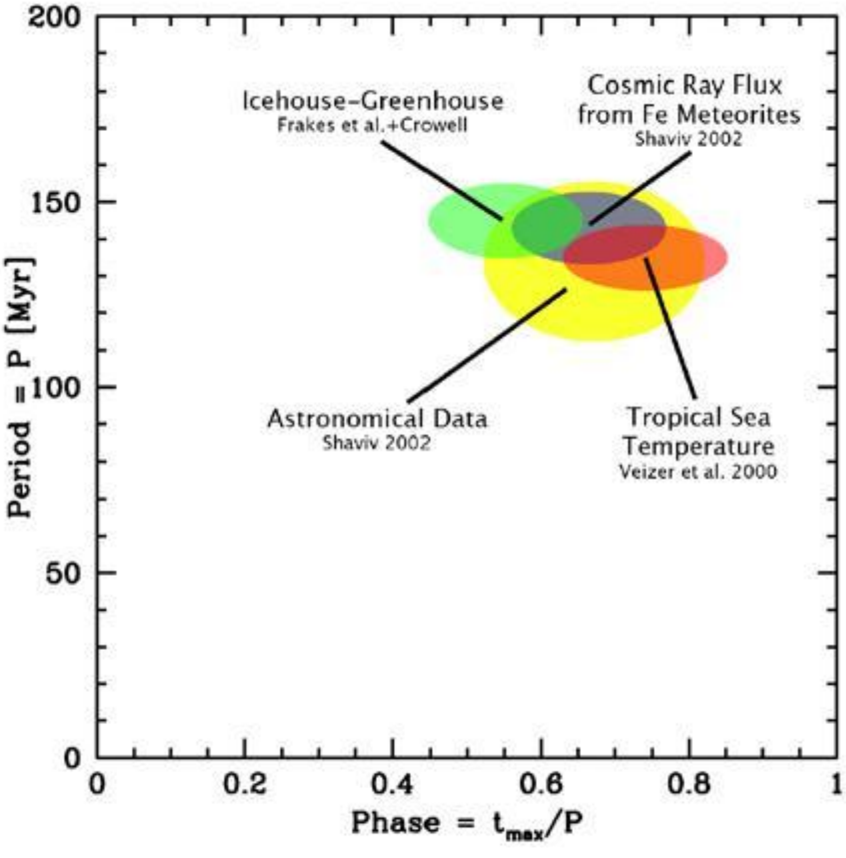


Figure 6: A summary of the 4 different signals revealing the cosmic ray flux climate link over geological time scales. Plotted are the period and phase (of expected peak coldness) of two extraterrestrial signals (astronomical determinations of the spiral arm pattern speed and cosmic ray flux reconstruction using Iron meteorites) and two paleoclimate reconstruction (based on sedimentation and geochemical records). All four signals are consistent with each other, demonstrating the robustness of the link. If any data set is excluded, a link should still exist.

Recently, it was also shown by Ilya Usoskin of the University of Oulu, Nigel Marsh of the Danish Space Research Center and their colleagues, that the variations in the amount of low altitude cloud cover follow the expectations from a cosmic-ray/cloud cover link (Usoskin et al., 2004). Specifically, it was found that the relative change in the low altitude cloud cover is proportional to the relative change in the solar-cycle induced atmospheric ionization at the given geomagnetic latitudes and at the altitude of low clouds (up to about 3 kms). Namely, at higher latitudes were the the ionization variations are about twice as large as those of low latitudes, the low altitude cloud variations are roughly twice as large as well.

Thus, it now appears that empirical evidence for a cosmic-ray/cloud-cover link is abundant. However, is there a physical mechanism to explain it? The answer is that although there are indications for how the link may arise, no firm scenario, at least one which is based on solid experimental results, is yet present.

Although above 100% saturation, the preferred phase of water is liquid, it will not be able to condense unless it has a surface to do so on. Thus, to form cloud droplets the air must have cloud condensation nuclei—small dust particles or aerosols upon which the water can condense. By changing the number density of these particles, the properties of the clouds can be varied, with more cloud condensation nuclei, the cloud droplets are more numerous but smaller, this tends to make whiter and longer living clouds. This effect was seen down stream of smoke stacks, down stream of cities, and in the oceans in the form of ship tracks in the marine cloud layer.

The suggested hypothesis, is that in regions devoid of dust (e.g., over the large ocean basins), the formation of cloud condensation nuclei takes place from the growth of small aerosol clusters, and that the formation of the latter is governed by the availability of charge, such that charged aerosol clusters are more stable and can grow while neutral clusters can more easily break apart. Several experimental results tend to support this hypothesis, but not yet prove it. For example, the group of Frank Arnold at the university of Heidelberg collected air in airborne missions and found that, as expected, charge clusters play an important role in the formation of small condensation nuclei. It is yet to be seen that the small condensation nuclei grow through accretion and not through scavenging by larger objects. If the former process is dominant, charge and therefore cosmic ray ionization would play an important role in the formation of cloud condensation nuclei.

One of the promising prospects for proving the "missing link", is the *SKY* experiment being conducted in the Danish National Space Center, where a real "cloud chamber" mimics the conditions in the atmosphere. This includes, for example, varying levels of background ionization and aerosols levels (sulpheric acid in particular). Within a few months, the experiment will hopefully shed light on the physical mechanics responsible for the apparent link between cloud cover and therefore climate in general, to cosmic rays, and through the solar wind, also to solar activity. *[Added Note (4 Oct. 2006): The experimental results indeed confirm a link]*

Figure 7: The Danish National Space Center *SKY* reaction chamber experiment. The experiment was built with the goal of pinning down the microphysics behind the cosmic ray/cloud cover link found through various empirical correlations. From left to right: Nigel Marsh, Jan Veizer, Henrik Svensmark. Behind the camera: the author.

The implications of this link are far reaching. Not only does it imply that on various time scales were solar activity variations or changes in the galactic environment prominent, if not the dominent climate drivers, it offers an explanation to at least some of the climate variability witnessed over the past century and millennium. In particular, not all of the 20th century global warming should be attributed to anthropogenic sources, since increased solar activity explains through this link more than half of the warming.

More information can be found at:

1. A general article on the cosmic ray climate link over geological time scales.
2. Henrik Svensmark's web site, including various publications on the cosmic-ray/cloud link.
3. The awaited results of the Danish *SKY* cloud experiment will be reported on their website within several months.

Notes and References:

* On solar activity /climate correlation:

1. For the first suggestion that solar variability may be affecting climate, see: William Herschel, *"Observations tending to investigate the nature of our sun, in order to find causes or symptoms of its variable emission of light and heat"*, Phil. Trans. Roy. Soc. London, 91, 265 (1801). Note that Herschel suspected that it is variations in the total output which may be affecting the climate (and with it the price of wheat).

2. Perhaps the most beautiful correlation between a solar activity and climate proxies can be found in the work of U. Neff et al., *"Strong coherence between solar variability and the monsoon in Oman between 9 and 6 kyr ago"*, Nature 411, 290 (2001).
3. Another beautiful correlation between solar activity and climate can be seen in the work of G. Bond et al., *"Persistent Solar Influence on North Atlantic Climate During the Holocene"*, Science, 294, 2130-2136, (2001).

* On cosmic ray and cloud cover correlation:

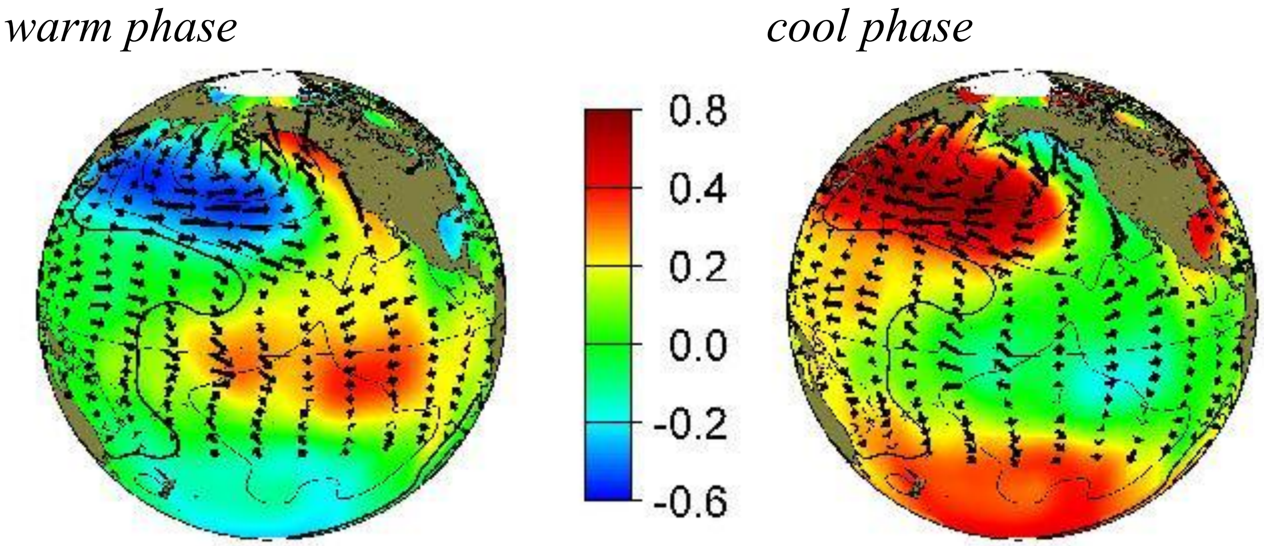
1. The paper by Henrik Svensmark, reports the correlation between cosmic ray flux variations and cloud cover changes: H. Svensmark, *"Influence of Cosmic Rays on Earth's Climate"*, Physical Review Letters 81, 5027 (1998).
2. The specific correlation with low altitude cloud cover is discussed in N. Marsh and H. Svensmark, *"Low Cloud Properties Influenced by Cosmic Rays"*, Physical Review Letters 85, 5004 (2000).
3. Further analysis including the relative role of CRF variations vs. el-niño can be found in: N. Marsh and H. Svensmark, "Galactic cosmic ray and El Niño-Southern Oscillation trends in International Satellite Cloud Climatology Project D2 low-cloud properties", J. of Geophys. Res., 108(D6), 6 (2003).
4. The analysis showing the geographic signature of the cosmic ray flux variations in the low altitude cloud cover variations can be found it: I. Usoskin et al., *"Latitudinal dependence of low cloud amount on cosmic ray induced ionization"*, Geophysical Research Letters 31, L16109 (2004).

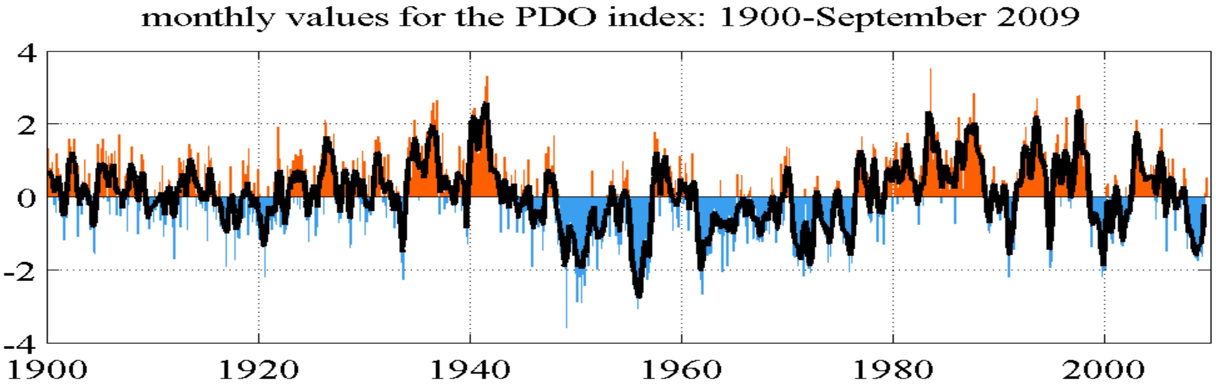
* On cosmic ray climate correlations on Geological time scales:

1. The suggestion that cosmic ray flux variations spiral arm passages could give rise to ice-age epochs is found at: N. Shaviv, *"Cosmic Ray Diffusion from the Galactic Spiral Arms, Iron Meteorites, and a Possible Climatic Connection"*, Physical Review Letters 89, 051102, (2002).
2. A highly detailed analysis, including the cosmic ray reconstruction using iron meteorites is found in: N. Shaviv, *"The spiral structure of the Milky Way, cosmic rays, and ice age epochs on Earth"*, New Astronomy 8, 39 (2003).
3. The analysis of Shaviv & Veizer demonstrates the primary importance of comic ray flux variations over geological time scales, and with it, place a limit on climate sensitivity: N. Shaviv & J. Veizer, *"A Celestial driver of Phanerozoic Climate?"*, GSA Today 13, No. 7, 4, 2003.

Section 6 The Pacific Decadal Oscillation (PDO)

Typical wintertime Sea Surface Temperature (colors), Sea Level Pressure (contours) and surface windstress (arrows) anomaly patterns during warm and cool phases of PDO




monthly values for the PDO index: 1900-September 2009

The "Pacific Decadal Oscillation" (PDO) is a long-lived El Niño-like pattern of Pacific climate variability. While the two climate oscillations have similar spatial climate fingerprints, they have very different behavior in time. Fisheries scientist Steven Hare coined the term "Pacific Decadal Oscillation" (PDO) in 1996 while researching connections between Alaska salmon production cycles and Pacific climate (his dissertation topic with advisor Robert Francis). Two main characteristics distinguish PDO from El Niño/Southern Oscillation (ENSO): first, 20th century PDO "events" persisted for 20-to-30 years, while typical ENSO events persisted for 6 to 18 months; second, the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics - the opposite is true for ENSO. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990's. Shoshiro Minobe has shown that 20th century PDO fluctuations were most energetic in two general periodicities, one from 15-to-25 years, and the other from 50-to-70 years. http://ingrid.ldeo.columbia.edu/%28/home/alexeyk/mydata/TSsvd.in%29readfile/.SST/.PDO/

Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cold PDO eras have seen the opposite north-south pattern of marine ecosystem productivity.

Causes for the PDO are not currently known. Likewise, the potential predictability for this climate oscillation are not known. Some climate simulation models produce PDO-like oscillations, although often for different reasons. The mechanisms giving rise to PDO will determine whether skillful decades-long PDO climate predictions are possible. For example, if PDO arises from air-sea interactions that require 10 year ocean adjustment times, then aspects of the phenomenon will (in theory) be predictable at lead times of up to 10 years. Even in the absence of a theoretical understanding, PDO climate information improves season-to-season and year-to-year climate forecasts for North America because of its strong tendency for multi-season and multi-year persistence. From a societal impacts perspective, recognition of PDO is important because it shows that "normal" climate conditions can vary over time periods comparable to the length of a human's lifetime.

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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

January 19, 2012

Constance I. Millar, Ph.D.
Research Paleoecologist
PSW Research Station
USDA Forest Service
800 Buchanan St.
Albany, CA 94710

Subject: American Pika Status Report Peer Review

Dear Dr. Millar:

The Department of Fish and Game (Department) is preparing a draft report on the status of the American pika (*Ochotona princeps*) in response to a petition submitted by the Center for Biological Diversity (CBD) to list this species as threatened. The report, which will make a recommendation to the Fish and Game Commission (Commission) regarding the listing of this species, will describe the results of our status review and analysis of the best available scientific information. The final status review report will be submitted to the Commission by October 26, 2012.

The Department requests your service as a peer reviewer of the draft status review report because of your expertise, publication record, and standing in the scientific community. Your comments and ideas would strengthen the scientific credibility of the report. Peer reviewers will be asked to identify changes or additions to make the draft report more accurate and complete, to discuss whether the conclusions seem logical based on the information provided, and to identify additional sources of information (literature, contacts, etc.) that may be valuable to include in the report.

The Department expects the external peer review will occur over a roughly 8-week period between late May and mid-July, 2012. We appreciate that you undoubtedly have a full schedule during this period, but hope that you can find time to participate in this important process. Please contact Dr. Scott Osborn to respond to this request or to discuss any questions you may have at the letterhead address, by email (SOsborn@dfg.ca.gov), or telephone (916-324-3564).

Thank you for your consideration of this request.

Sincerely,

Eric Loft, Ph.D., Chief
Wildlife Branch

ec: Department of Fish and Game, Wildlife Branch-Nongame Wildlife Program
Mr. Dale Steele
Dr. Scott Osborn

State of California -The Natural Resources Agency
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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

January 19, 2012

Chris Ray, Ph.D.
Research Associate
Ecology and Evolutionary Biology
University of Colorado
334 UCB
Boulder, CO 80309-0334

Subject: American Pika Status Report Peer Review

Dear Dr. Ray:

The Department of Fish and Game (Department) is preparing a draft report on the status of the American pika (*Ochotona princeps*) in response to a petition submitted by the Center for Biological Diversity (CBD) to list this species as threatened. The report, which will make a recommendation to the Fish and Game Commission (Commission) regarding the listing of this species, will describe the results of our status review and analysis of the best available scientific information. The final status review report will be submitted to the Commission by October 26, 2012.

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Sincerely,

Eric Loft, Ph.D., Chief
Wildlife Branch

ec: Department of Fish and Game, Wildlife Branch-Nongame Wildlife Program
Mr. Dale Steele
Dr. Scott Osborn

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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

January 19, 2012

Erik Beever, Ph.D.
Research Ecologist
USGS Northern Rocky Mtn. Science Center
2327 University Way, Ste. 2
Bozeman, MT 59715

Subject: American Pika Status Report Peer Review

Dear Dr. Beever:

The Department of Fish and Game (Department) is preparing a draft report on the status of the American pika (*Ochotona princeps*) in response to a petition submitted by the Center for Biological Diversity (CBD) to list this species as threatened. The report, which will make a recommendation to the Fish and Game Commission (Commission) regarding the listing of this species, will describe the results of our status review and analysis of the best available scientific information. The final status review report will be submitted to the Commission by October 26, 2012.

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Sincerely,

Eric Loft, Ph.D., Chief
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ec: Department of Fish and Game, Wildlife Branch-Nongame Wildlife Program
Mr. Dale Steele
Dr. Scott Osborn

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EDMUND G. BROWN JR., Governor
CHARLTON H. BONHAM, Director

January 19, 2012

Andrew T. Smith, Ph.D.
Professor
School of Life Sciences
Arizona State University
Tempe, AZ 85287-4501

Subject: American Pika Status Report Peer Review

Dear Dr. Smith:

The Department of Fish and Game (Department) is preparing a draft report on the status of the American pika (*Ochotona princeps*) in response to a petition submitted by the Center for Biological Diversity (CBD) to list this species as threatened. The report, which will make a recommendation to the Fish and Game Commission (Commission) regarding the listing of this species, will describe the results of our status review and analysis of the best available scientific information. The final status review report will be submitted to the Commission by October 26, 2012.

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Thank you for your consideration of this request.

Sincerely,

Eric Loft, Ph.D., Chief
Wildlife Branch

ec: Department of Fish and Game, Wildlife Branch-Nongame Wildlife Program
Mr. Dale Steele
Dr. Scott Osborn

APPENDIX 4

Notes from the 2009 CPC Priority-Setting Session

The California Pika Consortium's first meeting in 2009 included a discussion of management and research needs for the American pika in California. The group generated a list of recommended actions, then prioritized the list. The following summarizes the results of the effort. Although progress has been made on some of the high-priority actions identified by the CPC members, the list remains relevant.

Priority Setting List Categories: Research, Monitoring, Conservation

Process:

1) A list of priorities for each category was compiled by having each participant verbally list their priorities. The facilitator solicited input from all participants by going around the room 3 or 4 times until participants felt that suggestions had been sufficiently exhausted.

2) The lists were briefly discussed by the group as a whole, then each participate voted for their top 3 research priorities, and their top monitoring and conservation priorities.

3) Results of the prioritization process were summarized and discussed by the group as a whole.

COMPREHENSIVE LISTS

Research

- Establish baseline health and disease program for pika populations
- Physical adaptive capacity
- Lower elevation boundary across distribution
- Impacts to habitat other than climate change
- Hindcasting for model evaluation
- Evaluate talus thermal characteristics
- Identify microhabitat use
- Relate individual mortality to microclimate
- Evaluating interspecific interactions
- Calculate effective population size
- Factors affecting persistence in marginal habitats
- Robust remote-sensing of potential habitat
- Limiting mechanisms affecting persistence
- Metapopulation dynamics and persistence – stability of site-level occupancy and overall size
- Paleo records and persistence
- Characterize source-sink dynamics at dispersal scale
- Social tolerance and food storing
- How to age pellets and other sign across the range (elevational and geographic)
- Investigate low-frequency climate effects

- Barriers to dispersal
- Community-level interactions: new predators, vegetation changes
- Coordinating research efforts
- Mining of the historical record
- Explore new modeling techniques for future climate projections
- Effect of rare events on distribution at various scales
- Diet diversity and habitat change
- Mapping landscape connectivity
- Investigate survey/monitoring methods using audio playback
- Cold-season behavior
- Genetic structure of California subspecies
- More data for detectability
- Balance intensive and extensive
- Pelage and rock-type and color

Monitoring

- Assess distribution in new areas
- Centralized database
- Continue monitoring climatic and land-use factors
- Demographic and density monitoring along niche gradients
- Genetic monitoring of fecundity and dispersal
- New sites for time-series, long-term monitoring
- Establish citizen monitoring
- Long-term monitoring: identify most important co-variates and standardized techniques
- Proximate causes of death and reproductive failure: disease, predation
- Establish monitoring protocols, standardization of guidelines (handling, sampling)
- Coordinate monitoring efforts
- Characterize snowpack
- Use paleo data to identify refugia
- Balance intensive and extensive

Conservation

- Incorporate the pika into other multi-species studies and monitoring
- Establish working groups: Expand and identify leadership
- Education and public outreach: emission reduction to protect pika
- Develop conservation strategies including refugia
- Determine necessary habitat protection
- PVA – prediction extinction model at appropriate scales
- Using predictive models for landscape conservation strategies
- Designate as Mammal Species of Concern for additional funding
- Cultivate powerful partners

- Costs/benefits of mitigation and adaptation strategies
- Translocation/reintroduction as a tool
- Involve Canada
- Out-of-the-box options for conservation options
- Develop conservation strategies in lieu of listing: include multiple spp
- ESA and CESA listing
- HCPs
- Suitability of current conservation areas to sustain populations
- Focus assessments on non-wilderness, non-protected areas

PRIORITIES THAT EMERGED FROM PRE-VOTE DISCUSSIONS:

- Metapopulation/source-sink dynamics at different scales (from species to group)
- Mapping talus habitat and water relations – fundamental to developing effective monitoring
- strategies (remote sensing)
- Leverage networks of other groups monitoring climate over mountain regions (coordination) characterizing snow pack.
- Integration of behavioral ecology and physiology adaptive capacity
- Health issues
- Understanding distributional limits
- Multi-species strategies and incorporated into multi-species studies: conservation strategies
- 5-7 umbrella efforts: field surveys, metapopulation analyses, climate data and modeling, physiology and health, behavior ecology, physical environment, biotic environment

RESULTS OF PRIORITY-SETTING PROCESS

RESEARCH (3 votes/person; total votes received shown for each item)

(11) Metapopulations and persistence, overall metapopulation size, stability of sites, source-sink dynamics
(10) Establish pika health program
(9) Remote sensing of potential habitat
(6) Map landscape connectivity
(5) Physiological adaptive capacity
(5) Barriers to dispersal
(4) Evaluate talus thermal characteristics
(4) Explore new modeling techniques
(3) Paleo data to identify refugia
(3) Aging of pellets and other sign
(2) Mine historical records
(2) Identify microhabitat use

(2)	Cold season behavior
(2)	Disease fecundity

MONITORING (1 vote/person; total votes received shown for each item)

(10)	Standardize protocols
(4)	Establish Centralized database
(4)	Demographics and density monitoring
(2)	Assess distribution in new areas
(2)	Longitudinal studies/time-series monitoring

CONSERVATION (1 vote/person; total votes received shown for each item)

(9)	Incorporate pika into multi-species studies
(5)	Establish working groups and leadership
(3)	PVA at appropriate scales
(2)	Education and outreach
(2)	ESA listing, conservation and outreach

APPENDIX 5
Peer Review Comments

A preliminary draft of the Department's status review report for the American pika was reviewed by the following persons:

Michael Anderson, Ph.D., P.E.
California Department of Water Resources

Erik Beever, Ph.D.
USGS Northern Rocky Mountain Science Center

Constance I. Millar, Ph.D.
USDA Forest Service, Pacific Southwest Research Station

Chris Ray, Ph.D.
University of Colorado

Andrew T. Smith, Ph.D.
Arizona State University

The comments provided by the peer reviewers are included in the following pages.

From: "Anderson, Michael L.@DWR" <Michael.L.Anderson@water.ca.gov>
To: Scott Osborn <SOSBORN@dfg.ca.gov>
Date: 11/9/2012 10:09 AM
Subject: RE: Peer Review of DFG's Pika Status Report

Hello Scott,

My apologies for losing track of the email explaining how I am to submit my comments on the Pika listing report. I have read through the report and noted some minor editorial comments not related to the climate change science element of it. If you want, I will share those with you in a separate correspondence. I do not have the Ray et al 2010 paper on the NOAA Rapid-Response Climate Assessment to inform.... I don't know that I need it to be able to comment on my part of this report. The climate change references are appropriate and current and reflect the current state of knowledge of climate change. The information to my knowledge was used appropriately in the assessment of temperature impacts. The specifics of the thresholds for the Pika and consequences of threshold exceedences are beyond my knowledge to comment upon. If you need further information from me please let me know. I am traveling for work the next week, but should have email access in the evenings.

Mike

Michael Anderson, Ph.D., P.E.
State Climatologist
California Department of Water Resources
Division of Flood Management
Hydrology and Flood Operations Office
Hydrology Branch
3310 El Camino Ave Rm 200
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From: Erik Beever <ebeever10@gmail.com>
To: Scott Osborn <SOSBORN@dfg.ca.gov>, Eric Loft <ELOFT@dfg.ca.gov>, DanielA...
Date: 11/30/2012 11:21 AM
Subject: reflections on the Report ...
Attachments: STATE OF CALIFORNIA_EABreview_COMMENTS.docx; STATE OF CALIFORNIA_EABline#s.
docx

Hi again, Scott, Eric, and Daniel:
I've been sick since the 16th (and on vacation during 12-19 Nov), so I apologize for the delay. I'm thankfully now down to just 1 infection ... upper-respiratory. Attached are some quick reflections on the Report. If any reviews ever come up again, thanks for providing line numbers, which I have done to simplify the review process. I have thus attached the doc that I used for the line numbering (i.e., the unaltered version you sent me, except that line #s were added). You'll see that I've provided all types of comments. Some relate to needing to provide a better context for the reader, some relate to interpretation of existing work, etc. I have indicated the sections that I did not review, in the midst of the Comments.

Great work, gentlemen ... by you and all the other DFG contributors to this effort. I recognize what a massive drain on resources that this has been.

Warmly,
Erik

Erik Beever

Lines 153-155 – Note that this assertion has been contested. Some argue that the bones were carried to locations far from talus patches by predators, and that fecal pellets may have washed downhill over the course of centuries and millennia. Let me know if you'd like citations, but Hafner's work in 1993 or 1994 comes to mind.

Lines 156-159 – Research that is currently in review (after initial revisions) casts some doubt about the ability of habitat to predict pika abundance, at least in the Great Basin. Take-home message is that for at least some regions, pikas will need continued empirical monitoring, to assess trend over time as climate changes.

Lines 181-182 – Note that never does Galbreath et al. (2009) use the term "subspecies"; they only call them "lineages". Otherwise, however, I liked how you presented this section. Who knows … this may change again, as amount of the genome sequenced changes, we get many more specimens, or analytical approaches change.

I did not review lines 197-285.

Line 298 – I think that more commonly, the plural of pika is "pikas".

Lines 434-438 – Being more consistent with your use of terms such as "site" would make these results clearer. Further, I would describe the nature (i.e., research design behind selection) and extent (i.e., 24-m circle) of the latter "site".
Line 445 – Neither of these citations is in the Lit. Cited. Upon further inspection, I see that these ARE in fact in the Lit. Cited. To reduce this confusion, I would suggest merging all the citations, and then just clarifying which ones ARE NOT typical references. It's more confusing, otherwise.

Line 467 –I'm not sure how this squares with Lyle Nichols' most-recent data from the northern constellation. You mention them in bullets later, but it would be valuable to mention them, here, too.

Line 499 – I think that it would provide greater logical consistency for the reader if you were able to clarify the distinction in definitions of "Great Basin" of Millar and mine. Both are valid, but they're dramatically different, and calling them the same thing gives confusing impressions that aren't really that true.

Lines 594-598 – Maybe I'm missing something, but why not supplement the butterfly example with a pika example of retraction of the lower-elevation boundary (Beever et al. 2011)? I see that you mention it later, though, instead. Either way is fine.

Line 674 – Should be "study's", not "studies".

Line 715 and elsewhere – It may be clearer for some readers to see degree signs (°).

Lines 716-718 – For readers not intimately familiar with our approach, this sentence needs a bit more explanation to be clear. You haven't described that we correlated the two data series to hindcast temperatures at the iButton locations, nor that we produced annual estimates for each year during 1945-2006. Because of this, it's not clear that the difficulty arises from the divergence in variability in a HCN weather station (explicitly designed to NOT be covered by snow) and iButtons down in the talus interstices.

Lines 720-723 – The periods that we used for the analysis were those, but the metrics that we used in models were different: a) difference between the means of the two hindcasted 31-year periods ("climate change"); b) the average conditions over 1945-2006 (again from hindcasts); and c) conditions measured by sensors during 2005-2006.

Lines 735-736 – The three periods were historic to 1999 ("20th-Century"), 1999 to 2008 ("Recent"), and historic to 2008 ("Overall"). I think that the description would be clearer if you added "Using the same sites and suite of models for both periods," before "maximum temperature in August …" on line 736.

Lines 743-746 – Consider using the definitions I provided in my comment immediately above, so that you have consistency in how you're defining each of the three intervals. Consider adding that these rates of upslope retraction were *Basin-wide averages*, and that they were retraction of the *lower-elevation boundary* (stated only once, and it's not clear that it applies to the whole paragraph). 13.2 m/decade during the "20th-Century", and 145.1 m/decade during the Recent period.

Line 761 – I would replace "Pika abundance (as Patch saturation)" with "Patch saturation (defined as number of individuals detected within 8 hrs divided by the number of field-validated 20-m-circles of talus of appropriate rock diameter for pikas)". I have analyses of abundance in a MS currently in review for *Ecology*.

Lines 764-765 – Taking this out of context of the paper, I feel that this statement is misleading. This statement referred in particular to the derivation of the residual measure (i.e., dashed green lines in Fig. 4). It would be more accurate if you could clarify this.

Line 801 – I think that "eight additional sites" is wrong. Wasn't it 8, total? I.e., 2 more than in the 2003 MS?

Line 810 – There are additional citations that could be added to this statement, most of these are much more recent.

Lines 813-820 – I haven't yet read this MS, but I don't know that this assertion was founded on GB data, was it? Maybe move it elsewhere? Time scales between the last 3 paragraphs go from years to decades to millennia, which have very different conservation and management implications.

Lines 821 vs. 835 – Consider making headings consistent: "studies" or not. Lines 828-829 also agree with results of Beever et al. (2010) comparisons of PRISM estimates at occupied vs. extirpated sites.

Lines 931-937 – This paragraph should go somewhere else; it doesn't really relate to the Lassen area. I don't know whether they analyzed it or not, but the sites of extirpation are also much drier than sites at which pikas persisted … right?

Lines 964-984 – I would also add that we don't know whether all pika populations have the same tolerance for warming climates, or whether there is an unvarying bioclimatic envelope for the entire species (*sensu* Beever et al. 2010, but for the whole geographic range).

Line 1116 – I would use "previously" rather than "generally".

Lines 1119-1126 – It is important to note that each individual constituted a "site". Connie also characterized her sampling in terms of demes and points >3 km (or something close to that threshold). Readers might think that Connie has sampled 20x more sites than some other studies. A figure of what constituted the SN, sw GB and cGB would be illustrative.

Line 1139 – add “from the Great Basin” before “would have”.

Line 1145-1152 – I don’t think that you are interpreting this quite correctly. Historical (early 20th Century) accounts from the specific region of the Manning and Hagar (2011) study reported pikas occurring down to 400’ or 900’ elevation (I forget which). Given this, current reported distribution represents significant upslope retraction, rather than great breadth (though use of atypical habitats remains important).

Lines 1199-1208 – Although unpublished (and thus still not completely peer-reviewed), results in review at *Ecology* (2nd round) suggest that measures of climatic water balance are also quite important for distribution and density of pikas, at least in the Great Basin. I’ll let you know, if and when this gets published.

Line 1253 – I would add “, at least in some contexts” to the end of the sentence. My assessment is that they seem to have resiliency in some contexts, but not in others.

I did not review lines 1347-1539.

Lines 1686-1701 – Because pikas preferentially use larger-sized rocks for their haypiles, selective harvest of the largest boulders from talus fields, observed in some parts of the species’ range for construction and road-building purposes, may have disproportionate effects of pika densities in areas experiencing such large-rock harvest.

Line 1749 – “pika”, not “pike”.

Overall, I found the Report to be thorough, pretty reasonably accurate (with some exceptions listed above), and a useful compilation of data and unpublished observations and opinions. The Manning and Hagar (2011) interpretation is a key point; the historical data (Anthony 1924, off the top of my head) lead to an arguably opposite conclusion of that stated in the Report. It is clear that much thoughtful deliberation has gone into the creation of this report. I would caution the Department to note that some of the latter statements in the document are less well-supported than information from published studies, which leads to the need for appropriately characterizing the relative certainty of the statements. There obviously remains much that we don’t know, and my experience over the last 19 years suggests that status, trend, determinants of distribution, and degree of plasticity seem to vary dramatically across the species’ geographic range. Great work, and thanks for the opportunity to provide some reflections.

From: "Millar, Connie -FS" <cmillar@fs.fed.us>
To: "sosborn@dfg.ca.gov" <sosborn@dfg.ca.gov>
CC: "eloft@dfg.ca.gov" <eloft@dfg.ca.gov>, "Millar, Connie -FS" <cmillar@fs....
Date: 11/16/2012 2:00 PM
Subject: Science-consistency Review: American pika
Attachments: AmPika_LineNumbers.doc; AmPika_PeerReview_Millar.docx

Dear Scott,

Please find attached my review comments to your evaluation of the petition for American pika. As I noted before, I have also compiled a folder of pdfs and other related material for your use. I will next transfer them to a DropBox file and send the DB invitation to you (both). You will see that I am including in the DB folder two documents that are materials in prep for manuscripts I am drafting. To the extent you have any interest to use these, I ask that you do not distribute the documents beyond internal Department use.

I do not have comments on the appendices.

I am also attaching here the unedited document with continuous line numbers added - these numbers are what I reference in my review.

If anything is unclear, don't hesitate to contact me.

Kudos to you, Daniel, and all the others who clearly have worked very hard to develop this important document!

Connie

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Science Consistency Review:
"Status Review of the American Pika (*Ochotona princeps*) in California"

Constance Millar, Senior Research Scientist, USDA Forest Service, Pacific Southwest Research Station, Albany, California, cmillar@fs.fed.us, 510-559-6435
November 16, 2012

Abbreviations used
AP = American pika
GB = Great Basin
NC = *Neotoma cinerea*
SN = Sierra Nevada; ESN = eastern Sierra Nevada

Attachments

In a Dropbox folder labeled "Pika Review Millar" I have included many (but not all) articles I reference in my review.

I am also including in that folder a draft manuscript in prep that I refer to in my review as: "Millar et al. 2012b (radiocarbon mss)". I request that this incomplete mss not be distributed beyond use of the core CDFG review team and not included in publically disseminated documents. I hope to submit it to *Ecological Applications* in late December. Further I have added a set of slides in powerpoint that include thermochron temperature data from four years data of eight intensively studied pika-occupied taluses in the central eastern Sierra Nevada. I request also that you do not distribute these (in prep for another mss).

General Comments

Regarding the scientific basis of the document, I believe a thorough job has been done to bring forth the relevant scientific information, published and not, and to assess this large body of knowledge against the petition's charge. I commend the authors and associated Department staff for a comprehensive effort to gather and analyze the cumulative scientific information. The presentation here as a whole represents a valid and credible use of available scientific information, and I accept the overall assessment and believe the final decision is reasonable and logical given the data available and understanding at present.

I've noted a few consistent limitations below (in the specific comments) that I summarize here:

-I found the scope of scientific material you are reviewing unclearly defined. Initially I thought this report would consider only material new since the last CDFG review of pika, but I realize it is much larger than this. Please clarify.

-Similarly, I was unclear on your standards for accepting information. Obviously peer-reviewed and published scientific literature is a standard, but in that you accepted other forms of unpublished and informal input, I suggest you clarify the way you handled this for quality control beyond the current peer review.

-In many situations I thought the review/assessment of scientific input was too much of a simple listing of bullet points. For a review/assessment such as this, it is best when caveats, assumptions, and clarifications – either as stated in the paper, gleaned from other literature, or representing the assessment of the Department – are included in the same or subsequent paragraphs as the summary of work being presented. In many cases the format seemed to be a series of short statements such as: "John Doe (1999) found x, y, z" with no discussion or assessment. A less informed reader would assume that the conclusions are accepted as summarized (i.e., conditioning statements are not necessary) by the scientific community and by the Department. Almost always, however, conditioning statements are necessary.

-A topic missing (or inadequately considered) from the review that I believe is important is the role of paleoclimates: natural historic variation and response of pikas and other relevant montane animals to this. As explained in more detail below, we have much to learn about how species such as AP will respond to future climates from studies of past dynamics.

-As noted below, the importance and implications of meta-population behavior often seem to be lost in the review of literature in the report and assessment of papers making conclusions about population trends in pikas. A healthy meta-population species such as American pika is expected to exhibit shifting patch vacancies and occupancies with proportions varying in relation to patch sizes and metapopulation area as well as dispersal distance between patches and metapopulations. This has been shown to be the case in the only longitudinal study of pikas in CA (Smith's Bodie data). Thus, I find in this report, for instance, implications that pika are in long-term decline where a finding of only a proportion of patches is occupied yet all patches show evidence of prior occupancy. The latter is what we expect from a meta-population species; an overall trend can only be determined through repeated and long-term monitoring.

A must-read book (and not just for the pika chapter by Smith & Gilpin), old but still relevant: "Metapopulation Biology Ecology, Genetics, and Evolution", IA Hanski and ME Gilpin, Eds, 1997, Academic Press.

-Also noted below, and the report does address this in many but not all cases, we must keep in clear focus the fact that climate, vegetation, and wildlife projections for the future do not have the capacity yet to incorporate micro- and meso-climatic processes. We know these are important to pikas, such as thermal regimes of taluses, and we have indications that they are at least partially decoupled from synoptic patterns in important ways. Climate envelope models are thus more severely limited for species such as pika than for species whose habitat are more exposed to regional climate trends (e.g., cushion plant species inhabiting mountain summits).

Specific Comments (reference continuous line numbering on text provided)

Cover: Approval to use photo needs to be requested from the photographer, and credit added, assuming approval is granted. Contact: Andrey Shcerbina, ashcherbina@apl.washington.edu

160-161: This sentence is true as written but insufficient to give an overview of climate drivers, of which human-causes are but one among a suite of natural drivers. Thus, human-caused climate change is superimposed on the many natural forces that drive climate change and climate variability. This is important for several reasons: 1) native species such as AP have been exposed to millennia of natural climate change, including and not limited to, warm intervals such as the Medieval climate anomaly and the Mid-Holocene climatic optimum, and thus have evolved in the presence of climate change, 2) we can learn by studying historic response to climate change how they might respond in the future.
For a brief overview on natural climate variability and effects on biota/management, see: Millar and Brubaker, 2006.

162-163: Continuing above, the warming of the 20th century is a combined effect of natural climate drivers (reduction in volcanic aerosols, longer term solar changes [Bond effects], interacting with decadal modes such as the Pacific Decadal Oscillation); accelerated warming in the late 20th century and into present century shows the increasing influence of anthropogenic GHG emissions, but these still will always interact with natural drivers.

170: Grayson (2005) implicates changes during Holocene climate (i.e., not just Pleistocene) as being significant to present distribution of AP in the Great Basin.

175-177: Other literature suggests, by contrast, that montane species do not move only upslope in response to warming. For instance, some species move down (see: Crimmins et al. 2008; Lenoir et al. 2006, where, despite their title and abstract, 53 of 171 showed significant downslope movements) and some move into resilient micro- and meso-climatic environments, which can be up, down, or around (e.g., Scherrer and Koerner 2009; 2011).

179: Suggest: "McDonald and Brown (1992)…*speculate* that AP is one of two…"

185-187: The suggestion that climate change may be too rapid for biota to respond adaptively, and the comment about pika ("…may not be impacted to the degree…") can be defended by reference to abrupt and extreme natural climate changes of the past, such as the termination of the Pleistocene (e.g., Younger Dryas boundary), wherein major re-organizations of the climate system occurred within years to a few decades and many small mammal species, including AP, survived, despite that megafauna did not. (e.g., Taylor et al. 1997 [AGU Fall meeting abstract]; Steffenson et al. 2008: abrupt 4°C increases in mean temperature during 1-3 yr intervals; cumulative 15°C warming over 40 yrs).

188-193: I would think the Department would indicate here that their evaluation of pika response to future climate is also (in addition to climate projections of the future) assisted by understanding of responses to past climate changes, with their own uncertainties.

191-192: Model projections are based on global and regional atmospheric circulation dynamics and do not take into account local to micro-habitat thermal regimes of pikas (these processes are not yet well-enough understood at a systems level to incorporate into climate or ecosystem models). The assumption is that these micro- and meso-scale processes are tightly coupled to air temperatures, which we have reason to believe is not the case (see later comments).

249-250: It would help to clearly indicate here whether the current report attempts to be a scientific review of all available and relevant scientific literature or an update based on scientific material made available since the last petition review.

Also, some indication of what criterion you used to include or reject information (e.g., accountability) might be important here. In that you accepted personal communications, for instance, and not only information from peer-reviewed literature, how did you quality-control the former sources and content?

259: Suggest you add: "related to rabbits and hares" and "Order Lagomorpha" in this section – many people still think pikas are rodents…(I do see that you have this info later, but it seems relevant here)

In regard to "somewhat egg-shape", I think that shape better describes pikas' cold-behavior posture (Chris Ray calls this 'spud-shaped"), which pikas adopt to conserve heat in cold temperature conditions (fluffing out their fur and protecting their sensitive belly). The opposite extreme is an elongate "rat-like" shape, which pikas adopt when temperatures are warm – i.e., they splay their bodies out to dissipate heat. At moderate temperatures, pikas seem neither to be shaped like eggs or rats…just little mammals.

269: "all of the 11 western United States" is unclear (one wonders, "Which 11?": does this include Alaska or Hawaii, and, without consulting a map, we forget how many states are in the lower West. Either add a footnote and name them, include a map of the entire species range (I vote for this), or somehow make it clearer.

273-274: Terminology a bit mixed here. First off, "alpine" technically refers to areas above upper treeline in mountain regions (temperate or polar); second, much of AP's elevational distribution is below treeline, so it's not correct to call it an alpine species.

Further, it is not correct to indicate that "the pika inhabits this range [i.e., "alpine"] above the fir-tree belt in California's Sierra Nevada." In the mountains of California, treeline is made up of various pine (*Pinus*) species (primarily *P. albicaulis* in the SN, Shasta, Warner, SW GB ranges in CA; P. *longaeva/P. flexilis* in the White Mtns and P. *albicaulis/flexilis/ balfouriana*) in the southern Sierra Nevada, not firs (*Abies*). Further, firs in CA are mid-montane, so "above" them is still forest, not alpine. If in fact you meant the "fir zone", you should indicate which species as *A. concolor* exists at a lower elevation belt than *A. magnifica* (but then, there is no fir in the White Mtns, so there is no fir zone there). Most importantly, I don't believe it is accurate to indicate the lower elevation to be either fir or the upper subalpine pines. Even to indicate "Generally…" as you start the sentence in L 273, it is more accurate to indicate pikas as extending from the mid-montane forests (varying by east/west slope) even including the pinyon/juniper woodland zones of GB ranges (e.g., Bodie Mtns, White Mtns, Madeline Plains – Observation Pk,/McDonald Pk). "Generally" is a slippery term, of course, as we now have documented many active sites that extend below the montane conifer belt and even below the pinyon woodlands – as you indicate later.

In sum, I think it is important to recognize that "alpine" refers specifically to environments above treeline, not just any high mountain environments, to correctly attribute upper treeline if you indeed mean to reference it, and to acknowledge that AP's range in California is not accurately defined as alpine.

275: 2500 m at what latitude? Some mention of the latitude-dependence of elevation/climate would be appropriate here – either a qualitative statement or the equation used by Hafner and others.

279-280: A conclusion ("not restricted to talus…") challenged by Hafner 1993.

291: I assume this probability is about a geographic region (i.e., the outer perimeter) of suitable bioclimate, which does not portray the geography of potential habitat. The latter would require an overlay with geomorphology to identify adequate talus zones within these polygons. If this is correct, it needs clarification in the text and Fig 2 caption.

307: Add reference to Fig 3 after H&S 2010 citation? I see you have it a few lines later, but seems appropriate here.

322: In the "Life History" section somewhere (probably the first sub-section), I believe there should be a discussion on the literature and significance for AP exhibiting meta-population behavior.

323: Edit: "Individual *mature* American pikas…"

337: How does the implication of relative stability for AP compared to other lagomorphs relate to the species' meta-population behavior, which predicts high dynamism with extirpation and re-colonization? Furthermore the theoretic projection is corroborated empirically for AP in the Bodie work of A. Smith.

341-342: Risk to dispersing juveniles is not just from high temperatures but exposure to predators (no hiding places).

357: I suggest deleting "complete" in this sentence. Perhaps in context it referred to the location of Peacock's study and the animals she investigated, but I think this is over-extending the interpretation. Mountain "islands" are difficult to generalize anyway, if one is implying a "complete dispersal barrier".

363: This may be too esoteric, and may be related only to *O. collaris*, but Andrew Smith told me once of David Hik's studies of collared pikas routinely eating bird brains on isolated nunatak islands in the Arctic! I don't know if there is a citation to this, but it suggests that even pikas can be carnivorous when pushed…It's an amazing story.

364: Need to clarify that the term “haying” doesn’t refer to collection of graminoids only.

365: Grasses are also herbaceous vegetation so the line needs to be edited (“herbaceous vegetation or tall grasses”). Note also that pikas harvest short grasses as well as tall.

368: Re: caching relative to abundance: Edit to “relative abundance *near talus borders*”.

372: This paragraph needs to be edited regarding consumption of graminoids compared to other vegetation. When grasses are present, they are taken preferentially, but often they are not present and haypiles comprise no grasses. Commonly where no broadleaf vegetation occurs close to taluses, haypiles comprise entirely coniferous foliage (pines, hemlock).

388: Edit: “…total grazing *influence* by pikas decreased…” or “effects”. I.e., what constitutes “damage”?

392: Consider: “APs vocalize…to *defend* territories…”?

402: Re: “Adult survival normally exceeds 50% per year”, this needs some conditioning statement, otherwise there could be pikas thousands of years old out there. Maybe “…exceeds 50% for 2-3 years after reaching maturity…”?

412: Consider: “…temperatures by *reducing inactivity* on …”

415: Suggested edit: “Individuals seek cool refuges, in particular talus interiors but also rock crevices, lava tubes, and caves…”

426-427: “Snow tunnels” are more likely for accessing the surface during winter. In winter talus matrices (interiors) at even shallow depth are snowfree, (as shown by our winter thermochron data from many locations and hundreds of talus plots; Millar & Westfall 2012a, and ppts presented at CPC, AGU, and elsewhere; see contributed ppt graphs Millar & Westfall 2012c).

427-430: Do you have a citation for this? To our experience no one has monitored the thermal regime of AP’s dispersal environment. In summer 2012 we began a study on just this aspect of pika life history, placing thermochrons in dispersal areas (between inhabited taluses) at 30 locations in the eastern Sierra and White Mtns where we also have taluses and haypile sites measured for surface and matrix temperatures. The first data will be forthcoming summer 2013. What citation indicates that temperature (and *high* temperature) is more important during dispersal than exposure to predation (e.g., see your discussion on predation, which follows, and the implication of Krear 1965 about pika skulls in coyote scat)? I might also think (but don’t have citations) that acute cold exposure during dispersal might be lethal. How long does it take dispersing animals to find new talus? Maybe they have to cope for days at a time in the “dispersal zone”, where there likely would be limited protection from night minimum temperatures…

435: Millar and Westfall 2010, 2012a (QI paper), 2012c (ppt graphs from intensive talus study). See references therein, and for summary of work on talus thermal regimes: Harris and Pederson 1998, Juliussen and Humlum 2008, Zacharada et al. 2007.

439: Edit: "Matrix (internal) temperatures tend to be cooler lower in the talus field, especially near the talus border, than at higher positions". Consider adding: "Summer talus surfaces temperatures of occupied low-elevation taluses typically exceed 30°C and occasionally reach 40°C."

440: "And, generally, winter temperatures within the talus matrix as well as near the surface where haypiles are located are warmer than external air.

443: M&W 2010 and M&W 2012a

448: "…in some cases RIF matrices are warmer than the surface during winter."

470-471: Other types of habitat in CA (M&W 2010) include: (native) eroding bedrock outcrops (e.g., tors and inselbergs), crevices/cracks in bedrock, and lava cones (not just flows; e.g., Mono Craters); (anthropogenic sites) road- (e.g., SR 120) and trail- (many high Sierra locations) armaments and abandoned stone house foundations (e.g., Bodie Mtns).

477: "…shrub patches, *including dry montane desert scrub at low elevations such as along the Wyman Cyn Rd, where pikas occupy the many taluses to at least as low as Roberts Ranch (2478 m)*, meadows…" Millar, pers. comm. summer 2012 (I believe I sent you this note in July).

484-485: Clarify the relationship of fecundity and snowmelt date: did rates decline with earlier or later snowmelt (I can imagine reasons for both)?

512: Why do you limit info on distribution to 2010? Didn't some of us share reliable location information subsequently?

521: I suggest conditioning the statement about relative abundance south vs. central & northern by a caveat that there hasn't, however, been an evaluation of how this relates to available habitat – e.g., steeper slopes, greater area at high elevation, extensive glaciation increase to the south in the Sierra, making available more pika habitat. So we don't know if there is greater abundance per available talus area in the different regions.

530-531: "…high densities between 3600 m and 4000 m and also extending abundantly through middle elevations and occupying taluses in low eastside canyons (to at least 2466 m)." M&W 2010, pers comm 2012.

533: Daniel Pritchett (White Mtn Research Center, Bishop, staff scientist) noted to me that in 2004 he had observed pikas in the Inyo Mtns, a range in which you have no data. He wrote in reply to an email I sent inquiring of this (Nov 2012): "…We are pretty sure we saw them on the ~9500' plateau just east of the Inyo range summit, between Waucoba Canyon and Lead

Canyon. This would have been on a trip in 2004. In fact … we may have taken a slide and/or noted it in our journal, but it will take some time to track this down."

541: A caveat would be important to add somewhere in this section that detecting population numbers using the proxy of repeat surveys is challenging for a metapopulation species. If only 1 repeat survey is made, there is little understanding of the background extirpation/recolonization rate; an empty talus might not indicate reduction in long term populations but just part of regular flux (e.g., Smith's longitudinal monitoring at Bodie, Massing and Perrine's 2011 change in status from year to year, and my finding occupied sites in the N Bodie Mtns noted earlier by Nichol's as un-occupied).

605-606: Re native habitat at Bodie. I don't believe the statement about "larger patch areas" relative to ore dumps is defensible. In that there are some very large ore dumps at Bodie mines (in the "mainland" area) and that the native talus is poor quality (mostly eroding bedrock and few classic talus slopes), a more accurate statement about native habitat might be: "…natural habitat is of low quality, relatively small patches, and widely scattered." I am including a manuscript in prep (radiocarbon mss, Millar et al. 2012b) where this is discussed in the Discussion section.

610-618: Very good and important analysis. Great job!

616: Re "low talus habitat area": I think you mean "small" as in small amount, not "low" as in elevation, right? Given that elevation might readily be mis-interpreted, this should be clarified. Further, I believe the interpretation is not just of small talus areas, but large distances between talus, which together create small talus area (both factors are shown important, I believe).

624: "…(California, *southern Oregon*, and Nevada)."

665: You might find a way to weave in the information in Grayson 1991 about pika remains recovered from prehistoric (late Holocene) alpine village sites in the White Mtns.

690: Re "Smith …were the first to suggest … pikas…susceptible to climate change…": you are ignoring the small but important body of early research on Quaternary responses (climatically driven) of pikas in WNA – this began (if I am correct) in the late 1980s (Meade 1987), continued with Hafner's work and more from Meade (Meade and Grady 1996) in the 1990s. This section is an example (as I indicated in an early comment) where information about pikas' response to naturally occurring climate change can be (and has been, Grayson 2005, 2006) used to interpret responses to future warming.

730: The comment about reduced length of time for haying due to less time diurnally at favorable temperatures needs to be balanced by a similar consequence that would have been the norm for centuries prior to warming temperatures of the 20th C: that is, heavier (than present) snowpacks with late snowmelt and early snowfall dates (a trend we have seen reversing in recent decades) implies short times for haying also. Apparently, however, pikas were surviving well under these conditions, as researchers such as Grinnell, Hall, Verts, etc. document from late 1800s and early 1900s observations.

738-741: A similar argument as above (730) could be made in regard to heavier winter snowpacks (early 1900s, and centuries prior during the Little Ice Age): later snowmelt and earlier snowfall shorten the active season, reducing opportunities for dispersal…

740-741: Earlier you implied it was known that dispersal success was influenced by temperature.

742-747: Despite some literature on climate and ecosystems projections I find this paragraph unbalanced of the literature in regard to the assumption that warming global and regional climates will translate to systematic shifts upward in vegetation (and impact pikas through loss of forage). The growing literature on mountain microclimates (e.g., Chris Daly, Jessica Lundquist, David Whiteman), the paleoecologic evidence on mountain ecosystems under diverse historic climates, and the increasing understanding of biotic exploitation of mountain patchiness (Scherrer & Koerner 2009, 2011) document that plant species in mountains are presented with heterogeneous environments that afford adjustment opportunities in addition to moving **up** under warming regional temperatures. A significant example is the process of cold-air-pooling, which is understood as a common and landscape-wide phenomenon in mountains (e.g., Daly et al. 2007, 2009, Pepin et al. 2011: Pepin, N., C. Daly, and J. D. Lundquist, 2011. The Influence of Surface/Free-Air Decoupling on Temperature Trend Patterns in the Western U.S., *Journal of Geophysical Research - Atmospheres,* 116 (D10), D10109, doi:10.1029/2010JD014769.). This is not limited to large basins or rare in occurrence, and potentially may increase under projected future changes in atmospheric conditions with the net effect that local temperatures may get cooler at lower elevations. This literature also emphasizes the relatively few locations in mountains (e.g., highest mountain summits) that actually DO reflect the regional synoptic conditions (this is why the international GLORIA program puts plots on mountain summits around the world – to monitor local changes in response to climate but global scale).

Literature cited above in regard to treeline also addresses this issue of mountain mosaicism in respect to vegetation response to future climates. In our region, several papers indicate either movement down (e.g., Crimmins et al. 2011), or infilling at treeline (e.g., Dolanc et al. 2012) without movement upslope (both of which we are also documenting in an ongoing study in the Sierra Nevada and western Great Basin mountains).

Another important aspect of mountain patchiness is local hydrology and its effects on vegetation response to climate. Certain geomorphic contexts (topographic, aspect, slope, permafrost-related, rock-ice landforms) are recognized as more stable in water/ice-holding capacity than upland slopes, and likely to lag in response to warming (Millar & Westfall 2008, 2012, Clow et al. 2003, and references therein). Taluses and rock-glaciers are recognized for their high water-holding capacities, serving as persistent sources of springs that support diverse herbaceous vegetation communities. These are expected to serve as refugia for such plant species in the future (Millar & Westfall 2008, 2012, Leopold et al. 2011). Thus the lag in hydrologic response to warming may translate to a lag in vegetation response in talus forefields such that these areas are important climate refugia for plants as well as pikas (and other mountain mammals such as marmots). Assuming vegetation will shift lock-step upwards following a rarely-encountered synoptic lapse rate reflects lack of comprehensive understanding of how mountain systems work.

754: I believe it is relevant to assess current and anticipated climate change within reasonable historic climate context, rather than just a 20th century baseline. This relates to my comments prior that understanding how pikas responded to historic natural temperature changes sheds light on projections of future responses. In Table 6 of Millar et al. 2012b (in prep, radiocarbon mss) see references and estimated temperature deviations (relative to mid-20th C) for Sierra Nevada environments during climate anomalies of the Holocene.

812-814: Re the substrate, make more explicit here the potentially decoupled thermal regimes of talus from free air dynamics.

817-824: Here and relevant throughout the section would be a more explicit and detailed discussion of the Nevada (GB) ecoregion (geography and climate), how it differs from California pika mountainous regions, and what the implications for pika impacts are beyond the GB region. For instance lines an assessment of these differences might challenge the implication of lines 823-824. In other words, I find adequate evidence to suspect that differences between the regions are great enough for pika to exhibit quite different trends (e.g., Hafner's 1993 and 1994 papers, and see references in the Intro and Discussion of Millar et al. 2012b in prep (radiocarbon mss). These important factors are hinted at in the discussion at Lines 891-892.

829 ff: In addition to the comments about the extension of results from the Great Basin to CA mountains above, I find the re-survey work and analyses on the 25 historic populations further limited in their wider application due to the non-representative nature of the 25 sites. See pg 494 in Millar & Westfall 2010b (reply to Wolf, AAAR) for a discussion of this. Briefly these 25 sites are not a systematic set of sites from pika distribution in NV, nor do they represent a cross-section of pika habitats relative to elevation, climatic zones, mountain ranges, talus settings. Thus extensions to population trends across the range of pika sites in NV, let alone CA, are limited.

938-945: This information is addressed in the draft manuscript in prep, Millar & Westfall 2012b in prep (radiocarbon mss).

973-978: For sake of disclosure, I think the limited number of sites in the Grinnell study – and their locations – should be indicated (Jim Patton stressed in our CPC meetings, and noted in Moritz et al Suppl: "Data insufficient to analyze with occupancy Models"), especially as this is only the second point in a "time-series" analysis (viz the metapopulation-problem discussed above). Further, Millar and Westfall 2010 (and database updates since) document lower and occupied elevation pika sites in the same regions as the Grinnell sites. From our CPC notes you should be able to find Jim Patton's (UCB MVZ) discussion about how the resurvey did not reveal compelling evidence for an upward shift in pikas' range.

1025: The suggestion of attrition at a site, here exemplified by the Serita Mine, NY Hill observations of Nichols, is an example of not rectifying implications of a meta-population study as demonstrated by Smith's long-term re-surveys. That pellets are found at all patches is expected in a healthy metapopulation, as is the expectation that not all patches will be fully occupied all the time, and that patches will extirpate and re-colonize, as Nichols (and I also) find at the NY Hill metapopulation.

1052: I believe I sent you a description of active pika sites in the Madeline Plain area north of Honey Lk (I can re-send the coordinates if desired). Briefly: I searched for pika sign where I thought the 1920s report of Hall indicated (5400' in the Madeline Plain; the record is not specific). The most likely historic site is the very small and isolated Termo Buttes, in the middle of the Plain near Termo. I found no evidence of pikas there at all. However, in the peaks northeast (MacDonald Pk) and southeast (Observation Pk) of the Plain, there were abundant pika sites from 6062' to 7910' (1848-2411 m). I found this quite unusual, in that this is not within a mountain range, relatively low elevation, and although there is abundant lava habitat in this region, there is not high connectivity to any of the areas we recognize as regional pika 'mainland' – e.g., Warner Range or the northern SN or Lassen.

1060-1062: I agree with Hafner that the important taluses for pikas resulted from freeze-thaw processes. In regard to their longevity, however, many talus features in the Sierra Nevada and Great Basin ranges currently used by pikas appear to have formed during the Pleistocene, do not presently contain ice, and are unlikely to be undergoing freeze-thaw (in other words they are relict but long persisting). In some cases there is evidence for neo-glacial reactivation, but at low elevations, this is considered unlikely. Citations to these phenomena in general are in the periglacial literature. For our region: Doug Clark and colleagues' work for the SN, Forrest Wilkerson in the White Mtns, Jim Piegat and Jerry Osborn in the Great Basin.

1092: Re "these models" (i.e., climate envelope models, CEM). I urge more discussion be put here on what – and what not – is included in the envelope development. Mentioned at the end of the paragraph are comments about pikas' micro-climate, but given the importance of these I feel the limitations of the climate envelope approaches should be emphasized. This relates to the inability to adequately incorporate (because we don't yet fully understand them) micro- and meso-climate processes, which appear to be at least partially decoupled from regional atmospheric circulation (as discussed in comments above). The discussion of CEM and their limitations, as I recall, was quite thorough and balanced in the US FWS final report on the rangewide pika petition. You might adopt some of their language.

1103-1109: The geometry issue of mountains (declining area toward height of a cone) is balanced by micro-site heterogeneity and refugial capacity of the mosaic of environments (sensu Sherrer & Koerner (2009, 2011).

1149-1155: These significant "caveats" make me wary of the usefulness of these and following several pages of model results to pikas.

1233-1235: Do these models take into account that "warming climate" will likely include not just gradual warming but increased interannual variability and more extreme events (Bonfils et al 2008, Gershunov and Cayan 2008)? For instance, has there been consideration in the disease assessments if more frequent occurrences of extreme and opposite winter conditions as 2010-2011 and 2011-2012 ensue and/or summer heat waves? I have no idea how these situations would affect disease organisms and/or pre-dispose wildlife to them, but they seem important to an assessment

1301: Millar et al. 2012a includes info relevant to pika habitat.

1405-1414: Re mining impacts. At lines 584 ff of your report, you summarize, "Pikas apparently moved into the Bodie town site from the surrounding Bodie Hills after mining activity began in the late 19th century. As reported by Nichols (2011b), Severaid (1955) described the ore-dump sites in the Bodie town site as nearly 100% occupied." Thus, evidence suggests that active mining (and whatever associated factors, such as increase in habitat, predator reduction or??) can increase pika presence in an area and improve their chances for persistence. This needs to be reconciled with the concerns from Nichols' reports and/or how the Department assesses mining as a threat. Maybe it is, by contrast, a conservation strategy to protect pikas! Obviously type of mining makes an enormous difference; for that reason, "mining" should be qualified.

1436: Further, Millar 2011 indicates that the forage taken from the taluses where grazing is adjacent comprises species that grow (preferably) in lithic environments, and that there is lower species diversity as well as lower vegetative abundance and poorer nutritive quality. A dominant lithic species, *Rubus idaeus* ssp. *strigosus*, has low biomass, above-ground tissues covered with spines, and (citations in Millar 2011) declines in wildlife forage value as plants dry (e.g., in haypiles).

1438-1439: Continuing from above: "…impacts may occur through reduced nutritional value of available vegetation, *less abundant and diverse vegetation, and/or* less-favorable microclimates."

1453: Re: "but not in pika habitats in the Sierra Nevada". I believe Millar 2011 conditioned this by saying not on the Inyo National Forest portion of the ESN – there are, however, active allotments on the portions of the Humboldt-Toiyabe NF that are in the ESN, these (e.g., Burt Cyn and Molybdenite Cyn) are adjacent to occupied pika taluses. I included several of these in my study and found them to have similar consequences as other grazed sites. The Inyo NF also has active allotments in the eastern White Mtns – although I had not included these canyons in my study, I have since visited them and found similar conditions with pika haypiles in taluses adjacent to heavily grazed forefields there.

1580-1582: I agree with your assessment conclusion about non-climate factors, and feel that you have reasonably and adequately considered the available scientific information, except perhaps we need to re-think the role of mining.

1658: Edit: "However, ~~of~~ the traditional *sub*species in California…"?

1746-1787: Except perhaps for the bullet about reducing "…significant impacts to AP populations associated with mining and livestock grazing…", I don't find any of the bulleted statements on pg 46 to be "management recommendations". They are either research or monitoring actions or administrative actions ("Complete the MSSC update.."). I am often asked by public lands managers, "What could we do for pikas?" I am usually at a loss for practical suggestions, other than things like increasing connectivity by placing trails between pika taluses and using rock armaments along the trail in hope they will be used for pika dispersal. Some suggestions such as are included in the CPC 2009 list might be nice to bring in the text here to add a few tangible management recommendations for this section.

On an apparently unrelated and far-flung topic, I’ve recently been in conversation with a Montana wildlife colleague about wolverine use of taluses (among other locations) for caching food and the “refrigerator hypothesis” about such environments limiting wolverine range extent (see: Inman et al. 2012). In discussing this with colleagues on the USFWS SN Bighorn Sheep Recovery Science Team (of which I am a member), a comment came up that wolverine re-introduction into the SN might impact SN bighorn sheep (as a prey species). I had the thought that if wolverines do use taluses for caching they might also, if successfully re-introduced to the SN, become a new predator threat for APs as well. Something to consider for assessment and management recommendations as we consider wolverine re-introductions.

1818-1822: I don’t fully agree that scientific evidence makes clear all of these conclusions (“A generally warming climate will…”). As noted above, I do not find convincing evidence in the literature that we know enough about dispersal to indicate that warming will be limiting (i.e., it may open new areas for dispersing when snowcover otherwise would prohibit it – do pikas disperse at night? Maybe high temps don’t matter). Further, from empirical but anecdotal observations, several of us (Klinger, Massing, Smith, myself) have conferred on our observations of pika status following the extreme cold/high snowpack winter of 2010-2011 followed by extreme low snowpack winter of 2011-2012. Converse to what is implied in these lines, we observed notable reduction in pikas following the heavy snowpack year (potentially: do they die under the snow, not enough haypile collected? Many forefield areas never became snowfree in the summer – not enough summer forage?). The past summer, however, following the light snowpack year (and a challenging summer prior), pika had seemingly rebounded in locations we know and revisit. This is anecdotal, but I believe Klinger’s group has numbers on this.

1837: Consider: “…good escape over, and a relatively high reproduction rate *and longevity*.”

1846: The interaction of *Neotoma cinerea* (NC) and AP is one I wonder about but find limited information available. NC significantly overlaps AP habitat (talus) and elevation range, with more overlap in the lower elevations, where we suspect AP is more vulnerable. In my years of observing situations where evidence suggests both species are present I find that AP do not put their haypiles near NC dens, and that the latter are often more abundant in a talus. Could there be an interaction between these species that limits AP use of a talus or forage? The results of Mortiz et al. 2008 on NC significant population crash indicates the existing active range to be exactly in this critical elevation zone of AP – evidence that NC is apparently persisting in these elevations.

Chris Ray

My comments appear below by page, usually preceded by a quote from the status review.

P. iii

"Historic" should generally read "historical" throughout, especially in the title of Appendix 1. "Historic" is best used to connote "of great importance".

P. 6

"The current distribution and status of the American pika is largely the result of the warming and drying of climate that occurred at the end of the Pleistocene several thousand years ago." Although this warming and drying increased the fragmentation of the species' distribution, it doesn't explain all aspects of the distribution and status. For example, it doesn't explain the range, and it's not clear (at this point in the document) how it explains the "status".

P. 7

"The Commission twice rejected the petition and adopted findings indicating there is not sufficient information to indicate the petitioned action may be warranted. The Petitioner challenged the Commission's actions on both occasions in related litigation." These two sentences are the only portion of the "Petition History" that I do not completely understand. I think these statements would be easier to follow if dates and venues were associated with these two rejections.

P. 9

"The ears are relatively large, originate from a point behind and below the eyes, and are haired on both surfaces. Body pelage color may be grayish, buffy, or brown. The fore and hind limbs are of similar length, and the hind feet are relatively short compared to those of rabbits and hares." There are two awkward points within this section. First, it isn't meaningful to state that pika "ears are relatively large" without reference to a specific taxonomic group. The only specific group referenced in this section is lagomorphs, but certainly pika ears are not large relative to those of other lagomorphs, and perhaps not even relative to mammals in general. Although I believe this statement about the ears is drawn almost verbatim from one of the cited sources, it doesn't make sense presented as it is here. Second, the final sentence implies there should be a natural comparison between the American pika and "rabbits and hares", so the taxonomic relationship between pikas and other lagomorphs should be introduced prior to this statement (instead of two pages later).

"Body length ranges from 162 to 216 mm, hind foot length ranges from 25 to 35 mm. Average body mass is about 150 g." These statements apply only to adult pikas (>4 months of age). Younger (smaller) individuals are commonly encountered during spring, summer and fall.

"Elsewhere in California, American pikas were found above about 2,500 meters in elevation." We found pikas in Lava Beds National Monument at elevations ranging 1248-1804 m in 2005-2006 (Ray and Beever 2007 report to USFWS) and again as low as 1259 m in 2010-2011 (Jeffress et al. in press). In 2010-2011 pikas occurred below 1800 m in Lassen Volcanic NP (Jeffress et al. in press).

Phillips et al. 2006 doesn't appear in the reference list.

P. 11

"American pikas generally consume grasses and store more chemically complex plants such as forbs and shrubs for winter consumption (Huntly et al. 1986, Dearing 1997a, 1997b). This may be in part because grasses can be more nutritious when consumed immediately, but many forbs contain toxic chemicals that prohibit immediate consumption." The latter statement only makes sense if you replace "but" with "and".

P. 12

"In the Bodie population, for example, Smith (1978) found that almost 10% of the population was 5 or 6 years old." The Bodie site hasen't been mentioned before this. It would be better to either replace "Bodie" with "one" or give a more precise location/definition here.

"Individuals may seek out cool refuges, such as crevices, tubes, and caves, to avoid heat stress during periods of high temperature." The reference to "tubes" would be more clear as "inactive lava tubes".

"As discussed below, curtailed daytime activity due to warming temperatures may not leave individual pika enough time to prepare haypiles of adequate size to survive the winter in good condition, potentially leading to reduced survival, reduced reproduction, and reduced dispersal ability (Wilkening et al. 2011)." We did not specifically suggest reduced dispersal ability in Wilkening et al. (2011). We wrote, "Higher summer temperatures could reduce foraging activity and the amount of vegetation stored in haypiles. This could lead to declines in health and body mass, which would negatively influence over-winter survival as well as female fecundity and successful recruitment of offspring in the following spring."

P. 13

"The American pika does not hibernate but remains active throughout the winter, using snow tunnels to abate the effects of extremely cold temperatures and to access stored food. High temperature is a primary factor controlling the initial dispersal success of juveniles, primarily at low-elevation sites. At higher elevation, temperature is not as much of a limiting factor to dispersal success." Are there references for these statements?

"[RIFs], which include rock glaciers and boulder stream landforms, have thermal characteristics that may make the interstices (spaces between rocks) used by pikas for cover even more cool than surface temperatures during the summer than talus fields without RIFs." Awkward phrasing.

"Pikas depend on the rocks as cover to avoid predation. The farther they travel from the rocks, the more vulnerable they are to predation, which is particularly significant while juveniles are dispersing and while individuals are foraging beyond the talus-meadow interface." Although these hypotheses makes perfect sense, I don't know of any data available to support them.

P. 14

"...human-created rocky areas such as the old ore-dumps at the Bodie mine sites." The Bodie site hasen't been mentioned before this, so it would be better to give a more precise location/definition here, especially since it is referred to again in the next sentence.

Contact/association info for Klinger is not listed among the references.

P. 16

"The year 1980 was chosen as a cut-off because relatively recent climate change effects on pika persistence have been found in other studies (e.g., Beever et al. 2010, 2011)." We did not find "climate change effects on pika persistence." In fact, our metrics of "climate change" were not supported among the better predictors of local extinction; instead, number of cold days in the preceding 60 years and average summer temperature in the preceding 2 years were the climatic predictors with best support, and neither of these metrics was related to a 1980 cut-off. It would be better to cite Erb et al. 2011, in which we chose 1980 as a cutoff between "historically" and "recently" occupied sites because anthropogenic climate change became prominent in many datasets after 1980. To quote from Erb et al. (2011), "Historically occupied sites were defined as those with documented pika presence prior to 1980, after which anthropogenic climate change became prominent in many datasets (IPCC 2007)."

P. 17

"Stewart et al. (2012) also noted that the lower elevation limits of sites currently occupied by pika in the Sierra Nevada were 320-330m (1,050-1,083 feet) higher than sites where old pika fecal pellets indicated pika were present in the recent past." This is an important point that should be clarified by defining or re-phrasing "recent past".

P. 18

"If this apparent pattern of wide distribution were to be found in other parts of the American pika's range in California, it would increase the uncertainty regarding the impacts of climate change." Except that Millar and Westfall (2010) found pikas mainly in association with RIFs which, like glaciers, are likely to decline in occurrence and extent as the climate changes.

"Additionally, Millar et al. (2012) found the density of pikas in their study area to be greater than that reported from the central Great Basin." I'm not aware of any viable estimates of pika density from the Great Basin that has been reported in the published literature.

P. 19-20

"Several pathways through which climate change could be negatively impacting pikas have been identified, including:" You cite Smith and Erb (2012) which also suggest (in addition to the factors you list) that a decline in the water content of available forage may reduce pika fitness.

P. 20

"Smith (1974a) also found that on warm days pikas become less active during the day and more active at dusk and dawn at the lower edge of their elevational and latitudinal ranges." Smith's studies don't include multiple sites representative of "the lower edge of their elevational and latitudinal ranges," so it would be better to include another citation of Massing's work here.

"Because pikas must spend significant amounts of time foraging and haying due to their high metabolic rate and because they do not hibernate (Huntly et al. 1986, Dearing 1997b), curtailed daytime activity due to warm temperatures may not leave them enough time to prepare haypiles of adequate size to survive the winter in good condition, potentially leading to reduced survival, reduced reproduction, and reduced dispersal ability (Wilkening et al. 2011)." As mentioned above, we did not specifically suggest reduced dispersal ability in Wilkening et al. (2011).

P. 22

"Also not considered in the models of current habitat suitability or projections of future suitability (see below) is the capacity of the species to behaviorally or physiologically adapt to different climatic conditions." My personal reflection on this is that pikas have had a very long time to adapt to different climatic conditions (there is always that opportunity, all around them), yet they still only occur in a very limited range of microclimates.

P. 23

"Temperature loggers were deployed at the sites and historical temperature profiles for the sites starting in 1945 were predicted using the observed temperatures at the sites and data from the Historical Climate Network (HCN)." It would be more clear if you stated that our temperature profiles "were hindcast using the relationship between observed temperatures at each site and data from the Historical Climate Network (HCN)."

"The authors hypothesized that three measures of temperature stress may affect pika persistence and extirpation: Chronic heat stress (mean summer temperature), acute heat stress (number of days above 28 C (82 F) during the hindcast and observed periods), and acute cold stress (number of days below two cold thresholds, 0 C (32 F) and -5 C (23 F))." This implies that acute heat stress is the only stress metric we calculated in two ways ("during the hindcast and observed periods"). Instead, we calculated every one of the three stress metrics in three ways: 1) using our short-term data on observed sub-surface temperatures from 2005-2006, 2) using modeled data from the previous 60 years (including our model of sub-surface temperatures during 2005-2006 plus the hindcast represented by the rest of the modeled data), and 3) using the 60 years of modeled data to estimate change in the metric between the first and second 30-year periods.

"Presence or absence of snow cover could not be modeled using the HCN data, nor could any potential effects of other stressors on American pika populations." The latter half of the sentence isn't really true. We just didn't know of any other stressors that we could or should model, at that point.

"Three periods were available for analysis: the hindcast period of 1945-1975, the hindcast and observed period of 1976-2006, and the observed period of 2005-2006. Absolute values for these three periods were used, as well as the differences between the periods." Actually, we only examined the difference between 1945-1975 and 1976-2006.

P. 24

"Lower elevation boundaries at ten sites where pikas were detected since the 1999 survey shifted at least 145 m (475 feet)." For clarity, it would be best to state "shifted upslope" rather than just "shifted".

P. 25

"Within sites, pikas persisted where there were fewer days below 10 C combined with relatively low-forb cover, supporting an early hypothesis (MacArthur and Wang, 1973) that pikas may be able to withstand cold snaps given a suitable food cache." Not 10 C but -10 C (negative 10 C).

"Wilkening et al. (2011) found no evidence of recolonization of sites identified as extirpated by Beever et al. (2003), but did find evidence of extirpation at eight additional sites." Not eight additional sites, but at least 2 additional sites, such that we found eight total local extinctions among the 25 historical sites studied.

P. 26

"They found genetic differentiation patterns between sites was best explained by (in order of effect) geographic isolation, heat-to-moisture ratio, precipitation as snow, mean annual precipitation, and summer mean maximum temperature. The effects of the climate variables together implicate warming climate as a contributor to genetic isolation of pika populations. Additionally, half of the studied sites (of different elevations) showed evidence of recent population declines. These declines were correlated with heat-to-moisture ratio, mean annual precipitation, precipitation as snow, and summer mean maximum temperature." It would be best to include the direction of each effect.

P. 28

"Another potential impact of climate change on American pikas is through effects on the freeze-thaw processes resulting in talus formation. Hafner (1994) notes that all extant records of American pikas in the southern Rocky Mountain region are within 20 km of the estimated distribution of alpine permafrost. The role of freezing in creating and maintaining talus implies a very long term effect of warming on pika habitat availability. It is possible that talus in warmer sites will cease forming or moving and will fill in with debris and vegetation on a time scale of perhaps hundreds to thousands of years." Another rational hypothesis deriving from Hafner's observations, as well as those of Millar and Westfall (2010), is that areas with permafrost or at least seasonal sub-surface ice support pika source (productive) populations, and areas without are more likely to support only sink (receptive) populations. If so, loss of sub-surface ice features should cause pika declines on a shorter time scale.

P. 32

"Loarie et al. (2009) presents a different approach for modeling American pika persistence – climate histories. They modeled the probability of pikas at 438 known locations surviving the interval between a historic record date and a resurvey date based on the climate trajectory for that interval and site..." Actually, the model was based on 97 locations at which records of pika presence/absence were available at two separate times. The number of total pika records/sites used to model the current pika distribution was 438, but only 97 of these locations were associated with pika records from different periods that could inform our study of pika persistence.

"Extirpations were predicted to be rare at sites with mean annual temperature increases up to about 7 C, but the probability of extirpation increased rapidly at sites with mean annual temperature increases above 8 C." This phrasing is misleading because "increases" implies that mean annual temperature must increase by 7 or 8 C for these extinctions to occur. Actually, we found that extinctions had occurred mainly where mean annual temperature HAD BEEN above 8 degrees C sometime during the period between pika surveys. Thus, our model predicts a high probability of pika extinction at locations where mean annual temperature is at least sometimes above 8 C. These locations will become more abundant with any rise in mean annual temperature; rises of 8 C are not necessary for these predicted extinctions to occur.

"The authors reported the occurrence of pikas at elevations lower than previously considered the limit for the species." It's not useful to perpetuate this poorly supported statement from Millar and Westfall (2010). Since Grinnell's time it's been understood that the lower elevation limit of species' distribution falls toward the west and north, and there are pika populations in New Mexico that occur at much lower elevations than expected due to habitat anomalies, such that it's unreasonable to think anyone placed much importance on any scale-independent number describing the lower elevational limit for the species.

P. 35

"...climate envelope models do not account for the pika's ability to behaviorally adapt to warmer climates using crepuscular (dawn and dusk) or nocturnal foraging, retreating to cooler interstitial spaces in talus during hot periods." If pikas are capable of adapting in these ways, why have they not expanded their range previously?

"Although temperature plays a large role in determining where pikas can persist, they have been documented outside what was believed to be "suitable pika habitat"..." Is there a reference for this? Where pikas persist below Hafner's (1993) elevational threshold, we find microhabitats that probably create a suitable microclimate (e.g., lava beds). It is not useful to pretend that pikas will be popping up in unexpected locations unless you expect those locations to gain favorable microclimates with climate change.

P. 36

"...some models suggests pika habitat suitability will substantially decrease in California in the future. However, some of these models did not accurately predict the current range and site-occupancy of pika." It would be useful to address the direction in which these models failed.

P. 38

"While the Department recognizes the potential for adverse impacts from livestock grazing on nearby pika populations, it does not have sufficient information to assess the degree or immediacy of threat from grazing." See Beever et al. (2011) for an assessment of support for grazing (relative to other factors) as a predictor of pika extinction in the Great Basin. Grazing was not among the best predictors in our analysis.

P. 39

"Long-tailed weasels (Mustela frenata) are among the most efficient and ubiquitous native predators on the American pika." Is there a reference for this?

P. 40

"Li and Smith (2005) found plague to be one of several factors likely causing the population decline of the Ili pika (Ochotona iliensis), although the authors concluded that Ili pikas did not serve as a reservoir for plague in the studied population (Li and Smith 2005)." Reservoir species do not generally decline in response to the pathogen; if they did, they would not be a good reservoir for the pathogen. The phrasing here should be altered; because the Ili pika is susceptible to plague and is not a reservoir for Yersina pestis, it is reasonable to suspect that plague could cause declines in populations of this host.

P. 44

"The group has generally met twice a year since its first meeting in 2009 to share information, prioritize research topics..." Really? I'm a member and haven't received information about meeting twice each year.

P. 45

"The effort resulted in the development of a pika monitoring protocol with robust, standardized field methods. The project has now expanded to include Crater Lake National Park, Craters of the Moon National Monument and Preserve (ID), Great Sand Dunes National Park and Preserve (CO), Grand Teton

National Park, Lava Beds National Monument, Lassen Volcanic National Park, Rocky Mountain National Park (CO), and Yellowstone National Park. Now known as the Pikas in Peril Project..." PIP is not a monitoring project, as implied in the above. It is a one-time research project with funding only through 2013.

Figures

Fig. 2

References cited are not included among those listed in main document.

ASU
ARIZONA STATE UNIVERSITY

5 November 2012

Dr. Eric Loft
Chief, Wildlife Branch
California Department of Fish and Game
1812 Ninth Street
Sacramento, CA 95814

Dear Dr. Loft:

Thank you for the opportunity to serve as a scientific peer reviewer on the Status Review of the American Pika (Ochotona princeps) in California (17 October 2012). I have conducted research on the American pika in California since 1969, as well as on other species of pika throughout Asia since 1984. I have published 28 original articles on the American pika, 23 original articles on Asian pikas, and 16 over-arching reviews on pikas (including systematic treatments of the genus). I serve as Chair of the IUCN Species Survival Commission Lagomorph Specialist Group (a position I have had since 1991), and in this capacity have been responsible for determining the quantitative IUCN Red List status of all lagomorphs, including the American pika. I have been a Professor of Conservation Biology at Arizona State University since 1978. I consider that I have a strong understanding of the biology of the American pika, as well as the context for the potential listing of this species as Endangered under the California Endangered Species Act. I firmly accept available data showing the magnitude of global warming due to climate-change, and understand the severe consequences of climate-change on biological diversity. I also believe that it is very important to get the science right, so that those who challenge these concepts do not have overreaching targets to undermine the fact of climate-change.

This Status Review represents a notable opportunity to bring together and assess what is known about the biology of the American pika in the context of its potential for persistence in California. Your staff has done an excellent job in reviewing and summarizing this information. Also, the public comments generated on behalf of the Status Review highlight exceptional interest in the pika, a response that warms my heart as a long-time pika researcher. I do lament the lack of knowledge of natural history of pikas in these responses, but overcoming this hurdle is beyond the scope of this review.

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Per your instructions, I have attempted to package my comments together by subject and with reference to specific pages or topics (see attachment). As might be expected in a broad document such as this, some sections are stronger than others. In particular, I found the discussion of Erik Beever's work (pages 22-25) excellent, as well as the data presentation by Joseph Stewart in Appendix I. Throughout I focus on the science involved, but also include my interpretation of the science where in some places I felt not all the dots were appropriately connected. Overall, I was pleased with the end result of each discussion and the overall recommendation. Thus my comments are designed to further enhance arguments being made and to strengthen the final product of the Status Review.

Please let me know if I can be of any further assistance in this process.

Sincerely,

Andrew T. Smith
President's Professor
Parents Association Professor
Chair, IUCN/SSC Lagomorph Specialist Group

cc: Dr. Scott Osborn
att: Smith Technical Comments
Smith Technical Comments data (PP)

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TECHNICAL COMMENTS
Status Review [SR] of the American Pika (*Ochotona princeps*)
[17 October 2012]

Andrew T. Smith
School of Life Sciences
Arizona State University
[16 November 2012]

Note: these comments are bundled, wherever possible, by topic; the order of comments does not reflect any priority-setting on my behalf.

Vegetation, Foraging and Haying Analysis [Introduction page 6, paragraph 1; pages 11-12; page 20 bullet-points 2 and 3; page 27, paragraph 1; page 33, paragraph 2]

The SR frequently claims [page 6] that “climate change may adversely impact the vegetation occurring near the broken-rock habitat used by pikas for cover.” It is also claimed [page 20; see also page 33] that “curtailed daytime activity due to warm temperatures may not leave them [pikas] enough time to prepare haypiles of adequate size to survive the winter in good condition, potentially leading to reduced survival, reduced reproduction…(Wilkening et al. 2011).” It is also noted that pikas cease haying at a warm locality (Bodie) earlier in the summer … which “suggests climate changes resulting in drier soils may reduce availability of adequate vegetation and impair pikas’ ability to prepare adequate haypiles.” Also [page 27; see also page 33] it is stated “Conceivably this constraint on foraging radius could result in nutritional stress, smaller haypiles, and decreased probability of survival over winter for low elevation pika[s].”

What data bear on this issue? First, pikas may not have to forage as far from the talus edge at low elevation sites where the primary plants being utilized are shrubs (*Purshia tridentata*, *Artemisia tridentata*, *Chrysothamnus* spp.; Severaid 1955, Smith 1974a), thus representing a three-dimensional resource. The claim that pika haypiles may be smaller at low elevation is false – some of the haypiles at Bodie are gigantic (whereas others are totally tucked under the talus, reflecting the variability in this behavior across the range of the species). Most important, we have solid demographic (life table) and reproductive data on the pikas at a low-elevation site (Bodie) that are directly comparable to pikas occupying high elevation sites in the Rocky Mountains of Alberta and Colorado and the nearby High Sierra (Smith 1978). Bodie pikas have higher adult survivorship than the three high altitude sites, and the average litter size at Bodie is the largest of any population that has been studied throughout the range of the American pika. These data directly contradict the hypothesis of Wilkening et al. (2011; who presented no data on survivorship or reproduction), that pikas would have “reduced survival, reduced reproduction” at sites with warm temperatures. Thus, all available evidence is that pikas are resilient and that their life history features are not compromised in warm settings. In the SR the claim by Wilkening et al. (2011) should be presented as a hypothesis, and the test (demographic and reproductive data presented by Smith 1978) of the hypothesis should be made clear: it is falsified.

Pikas are correctly identified as generalist herbivores and highly selective of the plants they chose to hay and eat at any given locality [page 11; see also comprehensive summary in Smith 1974a and on pages 4-5 in Smith and Weston 1990]. The first robust test of pika selectivity throughout their range by Smith and Erb (2012) found that pikas chose plants with higher water content at lower elevation sites [page 11]. Erb et al. (2011) also found pika populations to be more vulnerable at drier sites [page 26]. Thus, there is a disconnect between the success pikas have had at some very dry sites and/or sites characterized by Great Basin Sage vegetation (Bodie [Severaid 1955; Smith 1974a]; the White Mountains [Klinger 2012; Millar and Westfall 2010a]; northwestern Great Basin [Millar and Westfall 2010a; Collins and Bauman In Press; reference given below]), with mesic alpine sites. Additional range-wide work on pika foraging is needed.

Disease [page 33 paragraph 3; page 40; page 48]

The SR correctly in my estimation eliminates disease as a factor threatening continued existence of American pikas [page 48]. The SR also correctly references Li and Smith (2005) who concluded upon evaluation that Ili pikas (*O. iliensis*) have not been negatively impacted by plague [page 40]; although the SR statement would be more accurate if it said something like: "Li and Smith (2005) considered and rejected the hypothesis that plague negatively impacted populations of the Ili pika…" Thus it is a bit perplexing that when disease is first introduced in the SR [page 33] credence is given to the claims of Wilkening (2007; which is not found in the literature cited) and Wilkening et al. (2011) that plague could play a role in pika extirpations. First, the citation to "Blakemore 2007 in Wilkening 2007" is very weak. Art Blakemore is a reporter who did a story on pikas and who has no expertise on pikas (I too was interviewed by him for his story – for which he knew the outcome before our interview). Second, Wilkening et al. (2011) cite two studies to corroborate their claim that plague may play a role in pika extirpations. First they cite Biggins and Kosoy (2001) claiming that these authors state: "…plague…is often closely linked with Asian pika populations." In their paper Biggins and Kosoy give no such evidence, they present one very weak sentence in which *Ochotona* is mentioned in connection with mammals that carry plague in Asia that begins: "Such combinations in other areas of Asia may be…" followed by a list of mammals that could potentially be considered as plague vectors. Wilkening et al. (2011) then state "Plague causes mortality in pikas and has been implicated in the recent and dramatic decline of one Asian pika species (Li and Smith 2005)." What Li and Smith (2005) actually said was: "Disease, particularly plague, is one possible cause of the decline. There has been considerable activity by Chinese research teams in the region, concentrating on the occurrence of plague in a sympatric species, the gray marmot *Marmota baibacina*. These investigations ruled out any possibility that the Ili pika has served as a reservoir for plague in the region..." Thus Wilkening et al. (2011) present no evidence to support their claim; instead they entirely mis-represented the available literature and their contentions should not be given standing in the SR.

Climate-change Modeling [multiple pages, identified below in text]

The SR evaluates various attempts to examine future persistence of American pikas from climate-change models, and correctly concludes that: there is uncertainty in future projections of climate change in the range of the species, with continued climate-change (warming) the amount of suitable habitat may be reduced in the future, pika resilience (via facultative changes in behavior and physiology) pikas may continue to live in warm areas, and thus projected climate change is a potentially serious threat to pika populations in the future. The SR also notes that some models fail to predict accurately currently occupied habitat [pages 6, 36, 47], and that they also map current suitable habitat for the pika in places where the species does not occur (and in some places where it has never occurred [pages 9, 22; Figure 2].

Let me first comment on data quality and references. Two of the model studies detailed in the SR have been published in a peer-reviewed journal (Galbreath et al. 2009; Calkins et al. 2012). One study was prepared by the Department (Phillips et al. 2006)[page 9; Figure 2]. One (Trook 2009) is an unpublished MS thesis. And another, Loarie et al. 2009, does not officially exist currently. This manuscript is inaccurately attributed to being "in press" on the Pikas in Peril website (http://science.nature.nps.gov/im/units/ucbn/monitor/pika/pika_peril/index.cfm); it has been so listed for several years under the title: "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". Beever does not list this ms on his CV; Ray's CV lists the paper as "in submission" to PLoS One; Loarie's CV is not available on the web. The SR clarifies where the work of others (Nichols, Klinger, etc.) is not peer-reviewed, but this paper – presented in the References without any tangible reference – is given considerable attention [pages 22, 32] but without a similar caveat. I was not a reviewer of the submission of this manuscript to PNAS, but have been shown a copy of an early draft of the manuscript by investigators at the University of Colorado (thus I am aware of its contents through this medium). This manuscript has played an important role, not only in the SR but in the petition – thus it is important to validate its credibility. Ethics aside of attributing a paper as being "in press" when it was not, this manuscript has clearly been circulating for some time (at least since 2009), and apparently has been rejected (by PNAS); thus I would question whether CADFG wants to rely heavily on its conclusions (see also below).

Each of the climate-change models suffers from the same problem that must be inherent in the use of MaxEnt as it portrays suitable habitat for pikas. As highlighted above [pages 9, 22; Figure 2], areas are portrayed that do not currently possess pika populations. What is not made explicitly clear in the SR, however, is how this plays out. These papers give summary results (independent of other aspects contained in the research) of a projection of percent decline of pika habitat under scenarios of a warming climate. Each of these percentages consists of a denominator that is derived from the "current predicted distribution" of American pikas (viz. Figure 3a in Calkins et al. 2012, and Figures 2 and 5 of the SR) and a numerator with the projected area of pika distribution in the future. A close inspection of the maps used to determine the denominator area shows pikas in Arizona (as appropriately pointed out is incorrect on page 22) – but the same modeling that led to this error also yields a modern pika distribution that far exceeds reality. Thus, percent decline in pika populations are artificially high because in 100 years the pikas will not be found in these places (the numerator) – as they are not there now! The trouble is, we do not know how much error there is in this process, thus the percent decline numbers must be viewed very conservatively.

Another problem with these modeling exercises, is that it is impossible to determine what temperature thresholds are being used to project future distributions; changes in projected temperatures are given, but not the actual baseline temperature. Standard meteorological temperatures are one potential baseline (for example, temperature thresholds in Smith 1974a), but similar absolute values, such as the in-situ (0.5 – 1.0 m deep in talus, where it is cooler than a standard meteorological reading) temperatures of Beever et al. 2010; Millar and Westfall 2010; Wilkening et al. 2011, represent a different metric altogether especially with regard to the ability of a pika to thermoregulate. To highlight the difficulties in these projections, Calkins et al. (2011) apparently use a baseline temperature that does not even include all current pika populations, as they state: "our models, do not predict any suitable habitat for the traditional subspecies *O. p. goldmani*, …, because it occurs in a warmer macroclimate than those where the species is typically found." Loarie et al. (2009) similarly avoid outliers; they exclude a site where pikas are known to exist (Lava Beds National Monument) simply because this site has mean annual temperatures higher than expected. But, if the point of climatic-envelope modeling is to determine how a species responds to warming temperatures – in a spatially explicit way, what use is it to ignore temperatures where they currently live? This procedure can lead to very large biases in projecting future scenarios for pika populations, as it fails to account for where pikas currently exist.

With regard to climate-change in the range of the American pika at Bodie, California [see page 21, last full paragraph], I attach temperature records for average monthly highs for full June, July and Augusts, and acute temperatures as number of days ≥ 25° C and ≥ 28° C within a year, for 84 years (eliminating years without complete data) from 1895-2010 (see attached Powerpoint data slides). There is remarkable scatter in all plots, and there is only a significant increase in average monthly high temperatures in July ($p = 0.038$), and a weak correlation ($p = 0.041$) between year and number of days above 25° C.

With regard to the decline in the Yukon of collared pikas (*O. collaris*) as chronicled by Morrison and Hik (2008)[page 22], the population has now fully recovered (per discussion with David Hik, summer 2010, at the International Congress for Conservation Biology in Edmonton) – showing the resilience of this population.

Non-government organization designations [page 43]

I would have thought that the IUCN Red List status for the American pika [page 35] would belong with similar status listings on page 43 under the heading "Non-governmental Organization Designations."

Dispersal dynamics [pages 11, 13, 20, 25, 40, 41]

The SR correctly identifies the dispersal dynamics of pikas as an important ingredient in their ecology, particularly with regard to persistence of populations. However, while the important message that dispersal ability of pikas is temperature, thus elevation, dependent, this relationship is often not made clear. Dispersal is first introduced on page 11. Here the SR should reference the major review paper on pika dispersal = Smith, A. T. 1987. Population structure of pikas: dispersal versus philopatry. Pp. 128-142. *In*: Mammalian dispersal patterns: the effects of social structure on population genetics. B. D. Chepko-Sade and Z. T. Halpin, editors. University of Chicago Press: Chicago. This summary should also include the observation of Tapper (1973) who observed an ear-tagged pika move 3 km (and across significant rivers!) to colonize an isolated talus patch that Tapper had trapped out. The general model, as stated correctly on page 13, should be introduced here. There is a gradient in the ability of a pika to disperse – with great difficulty at low elevation to less difficulty at higher cooler sites. There is the additional issue that pika dispersal can be frustrated even at high elevation sites, if they are saturated, due to social dynamics (Smith and Ivins 1983) – but this is of little concern in a conservation context, as if the sites are saturated, then no problem! However, on page 20 (paragraph near the bottom) and page 25 and 40 (first sentence under the heading "Habitat degradation and fragmentation") – it should be made clear that these statements refer to my studies at the hot low-altitude site of Bodie.

If we extrapolate the limited ability of pikas to disperse in warm environments, then there is a clear explanation to the data presented by Stewart in Appendix I (his Figure 3). Stewart's statistics highlight that talus area has the greatest explanatory power in predicting vacant historical pika sites – but much more is made in the CR that these are low warm sites. Figure 3 shows that the majority of extirpations occurred on very small patches (thus the highest relative importance to talus area in his model). If these sites became extinct due to some form of stochastic process, simply because of their size, then the inability of pikas to re-colonize the sites because they are at low elevation would be the primary reason for their being vacant of pikas – temperature not causing extinction, but prohibiting any rescue effect (sensu Brown and Kodric-Brown 1977). While the inability of pikas to re-colonize vacant sites at low elevation is mentioned throughout the CR – it would be most powerful to explicitly connect the dots with regard to this specific observation.

Nearest-neighbor distances [pages 19, 26, 27]

This metric is brought up in three places. Correctly it is mentioned on page 19 that I found n-n distances between centers of territories (haypile localities) to be shorter at the warm low site at Bodie versus in the High Sierra – but it is unclear what monitoring this pattern will elucidate (the text should be made explicit). It does seem to me that the higher density found by Klinger in the White Mountains [page 18] (a similarly dry environment) would also be due to smaller n-n distances; a very interesting parallel.

But what is troublesome is the interpretation that the smaller n-n distances at Bodie are an indication of "how a warming climate could impact the American pika." [page 26]. This passage goes on to say [page 27] that the reduced foraging radius could result in nutritional stress (no evidence of this), smaller haypiles (some of the haypiles at Bodie are the largest I have seen anywhere), and decreased probability of survival over winter for low elevation pikas (directly the opposite of the comprehensive comparative demography of American pikas in Smith 1978; adult pikas at Bodie had higher over winter survivorship than sites in the Sierra Nevada, Colorado Rockies and Alberta Rockies).

[Also, on page 26 – the long-distance movements I observed were forays, not foraging trips!]

Habitat [top page 14]

Kristina Ernest, Raychel Parks and Patricia Garvey-Darda presented a poster at the 2011 91st Annual Meeting of the American Society of Mammalogists: "Pika habitats in a fragmented landscape: natural and anthropogenic patches" – in which they document numerous pikas having colonized bridge and highway rubble. The mention of Bodie should contain a citation (viz. Severaid 1955; Smith 1974a or b).

Predation [pages 19, 21, 39, 47]

It is mentioned that climate change could shift pikas to nocturnal foraging which would expose them to nocturnal predators [page 19]. Trouble is, their main predator, the weasel (two species at Bodie, a warm site where pikas have been observed foraging at night) is also active during the day (see Ivins and Smith 1983; this reference should be included on page 39 as well). On page 21 it is stated that community changes could lead to increased exposure to predators. Well, Bodie has eight species of mammalian predator (Smith, A. T. 1979. High local species richness of mammals at Bodie, California. The Southwestern Naturalist 24:553-555) – so pikas seemingly can persist in the presence of a variety of predators (in addition, I have seen great horned owls, prairie and peregrine falcons, golden eagles, hawks, etc. there).

The "domestic dogs" mentioned on page 39 as potential predators of the Ili pika, are Tibetan mastiffs who are maintained by pastoralists to ward off the wolves (they are given no dog food, so forage extensively on native wildlife). I do not know of a counterpart in the American west.

One statement in the Predation section on page 47 says “and a relatively high reproduction rate.” Throughout their range most mother pikas successfully wean, at best, two young per year – this is hardly a high rate of reproduction (see Smith 1978 for review).

The conclusion [page 48] that it is unlikely for increased predation to jeopardize pika populations given climate change seems correct, but the arguments against this proposition could have been made more directly and with clarity.

Competition [pages 20, 21, 39, 48]

One potential factor mentioned that could negatively influence pikas due to climate change is “changes in competitor[s]” [page 20; see also page 21]. However, pikas have proven that they can coexist with a variety of different species of mammals. In addition to pikas, 27 small mammal species occur at Bodie (Smith 1979) – including kangaroo rats and pocket mice, to voles, to marmots, to bushy-tailed woodrats and two species of ground squirrel. The species richness of lagomorphs at Bodie, five species, may be the greatest of any locality on earth. The conclusion reached by the SR [page 48] that native competitors are not a threat to pikas is correct, given available data, but the arguments against this proposition could have been made more directly and with clarity.

Species status [beginning top page 16]

[page 16, paragraph 3]. This paragraph is in reference to the Pikas in Peril NPS project. Site occupancy percentages are given (they are fairly low compared with other PIP sites, but there is a huge problem with between-year and between-site inter-observer reliability), but no context is set. The protocol, as made clear to me by Jeffress (as I have been very skeptical of this procedure), is designed specifically to have null sites (sites with no pikas); she claims that they cannot do the modeling without null sites! So, it should be made clear that these low percentages do not reflect anything actually about the status of pikas in either of these parks – it will take many years before the noise can be separated out to see what, if anything, these data mean.

[paragraphs 4 and 5]. I think that the Massing and Perrine, and Stewart and Wright, references and results, as outlined here, should also include a reference to Stewart’s Appendix 1 data – as they overlap greatly and the appendix appears to be more up-to-date and comprehensive. We have to jump to page 17, paragraph 4 to get to the Stewart Appendix 1 material; these could be integrated better. In that paragraph it is stated: “Across all sites, low talus habitat area was the best predictor…” Because the world “low” implies elevation also, it might be better to say “small talus habitat area” to avoid confusion.

There is a new manuscript (now in press and available on-line) that highlights numerous pika sites in the region of NW Nevada and SE Oregon – all very close to the triangle where Beever et al. 2010, 2011 documented most of their pika extirpations: Gail H. Collins and Bradley T. Bauman. (in press). Distribution of low-elevation American pika populations in the northern Great Basin. *Journal of Fish and Wildlife Management*. Naturally these sites are very close to NE California. They conclude: “This and other recent discoveries suggest that pikas may be more common at low elevations in portions of the northern Great Basin than previously suspected (i.e. <2,500 m).” The elevational range of their extant sites was 1,648-2,357 m.

I found the data of Klinger (personal communication 2012) very relevant. Interestingly the SR goes out of its way to say that this is unpublished, etc., while nothing was made of the Loarie et al. (2009) unpublished reference.

I know that the above seems to be in reference to Status in California (maybe this should be made clear in the heading). But, there are other pika status statements in the SR. On page 25 Erb's work in the southern Rocky Mountains is presented; in her paper in *Ecology*, 4 of 69 surveyed sites were found to be extirpated. Interestingly, two of these had been recolonized by the next year, and then one of these lost the next…I do not have all the details, but this is apparently a very fluid system. What I find most intriguing is the relationship of these sites to low annual precipitation, compared to the sites at Bodie and the White Mountains, which are very xeric in appearance, yet have high density populations. What is going on?

A similar disjuncture is found when comparing the British Columbia sites [page 26] studied by Henry et al. (2012). Compare the climate in BC to the xeric sites in the White Mountains, Bodie, and many of the low-elevation sites discovered by Millar and Westfall (2010a). Having lived in Alberta for a winter, and currently living in southern Arizona, I am well aware that what Canadians think is warm is relative. The questions become: 1) if pikas can persist in some warm regions, why is there any relationship to climatic features in the cooler more mesic part of their range?; 2) if pikas can adapt (or become facultatively resilient) to an environment like Bodie and be successful, why cannot BC pikas similarly adapt (maybe they have not yet been pushed hard enough?); or 3) what do BC studies tell us about California pikas, and vice versa?

Also appearing on page 26 is reference to the Grinnell transect by Moritz et al. (2008), with reference to pikas. I am very surprised to see this repeated here. First, the number of pika extirpated sites in this study was 1 – a sample size that clearly cannot lead to any form of generalization. Second, CDFG knows that the Supporting Online Material provided by *Science* for this paper declares, on the data page devoted to the American pika: "Data insufficient to analyze with occupancy models." And third, I am aware that one of the co-authors of this paper (Jim Patton) has gone on record with CADFG with regard to a previous petition regarding the status of the American pika in California with a very clear and well-argued statement as to why this study does not show that pikas are or are not at risk in the Sierra Nevada: "We, in the Yosemite study, are a long way from even believing, much less documenting, that the pika is under any threat any place in California. Every population we've encountered in Yosemite is seemingly healthy." "It is not correct that 'in California, pika populations have been lost from multiple low-elevation sites in Yosemite National Park.' We failed to find the pika at only one of the historical sites where [the 1911-1920 researchers] had observed and/or collected the species. [This] is but one data point for range retraction, and the cited degree of retraction could result simply from the elevational spacing of the sites. It is impossible to conclude when in the past 90 years that event occurred. It could have just as easily been in 1916 as any year hence. Use of the word 'recent' is unjustified."

Bodie [pages 16-17; 26-28]

Long-term studies at Bodie represent the longest investigation of any pika species, and most to the point of the petition, also represent one of the warmest localities where pikas have been investigated. Thus it is important to get this story right. The CR bounces around and makes some of the important observations from this work, but other statements are incorrect: 1)on page 17 it says that there has been re-occupancy of the southern constellation of patches at Bodie since 2008 – it is the reverse, no pikas have been found there since 2008; 2) on page 28 it says there have been large declines at Bodie since 1980 – declines noted in 1989/1991 from 1977, no comprehensive data between those years, and no decline since 1991; and 3) the claim of Nichols that there is an occupancy trend for Bodie SHP leading to extirpation by end of 21st century is not supported by data showing no decline in percent occupancy at Bodie since 1989). Let me below take a stab at replacement text for the work on pikas at the Bodie State Historical Park (the anthropogenic ore dump site); this is separate from observations by Nichols at natural talus habitat across the Bodie plateau (I am sure that Connie Millar can better address issues in this region). I can add, however, that I spent considerable time in summer 1970 attempting to census pikas in the natural rock outcrops across the Bodie plateau – largely proximate to the road between Bodie and Masonic. I found old pika scats, but no evidence even at that time of any current occupancy. One more thing: I also found and sampled pikas at Aurora, Nevada (Smith 1974a), another anthropogenic mining site – yet it appears that this population may have gone extinct (Connie Millar has retraced my footsteps there without finding any pikas).

Also, regarding referencing: I organized the American pika symposium at the recent (summer 2012) North American Congress for Conservation Biology, and I prepared and provided to CADFG a document with all the abstracts of papers and posters presented at this meeting. Many of these (8) are cited in the SR, but not my summary of the Bodie pika metapopulation! Below, my presentation is referenced as Smith and Nagy (2012), and I attach a Powerpoint file with each of the data slides from this presentation (to support relevant statements below)… My suggested summary of this information:

"The pika population at Bodie State Historical Park has been studied for longer than any pika species, and it represents one of the warmest localities where pikas have been continuously studied. Therefore it is directly relevant to this review to consider the status over time of this population. Severaid (1955) "discovered" the pikas at Bodie and studied them intensively from 1946-1949. He determined: "Currently every mine dump or rock pile, regardless of size, shape or height, contains therein one or more pikas, or family units, providing only that the rubble is of sufficient size to permit them a thorofare into and throughout the dump" (page 110). He later stated (page 150), "Despite my earlier implication to the contrary, another impression which I consistently formulated for the Bodie colony was that the average stable population was never equal to the carrying capacity of the habitat." Severaid also trapped out some of the ore dumps and noted that they were slow to be re-colonized. Andrew Smith began studies at Bodie in 1969, investigating them intensively from 1969-1973 (Smith 1974a, 1974b, 1978), and following up these investigations with a survey in 1977 (Smith 1980). Smith resumed censuses in 1989, and these have continued through to 2010, aided by Mike Gilpin, Chris Ray, Smith's students Mary Peacock (who worked at Bodie 1988 – 1991; Peacock and Smith1997), John Nagy (1996) and Lyle Nichols, and others (Smith and Gilpin 1997; Moilanen et al. 1998; Smith and Nagy 2012).

The pika population at Bodie represents one of the best examples of a classic metapopulation system: the pikas live in spatially distinct habitat patches scattered across an open landscape, all local populations are small and have a significant risk of extinction, dispersal among patches appears to be distance-dependent, and the dynamics of local populations appear to be asynchronous. Smith identified 76 isolated ore dump patches (39 in a southern constellation and 37 in a northern constellation; the study area, roughly 3 km south to north is constricted in the middle) for censusing. All patches identified for the first (1972) census contained sign that they had been occupied by pikas due to presence of their characteristic sign (small round scats, haypile remains). Percent patch occupancy was highest during the two early censuses (58.7% in 1972; 55.4% in 1977), and characteristic of a metapopulation system the patches represented a dynamic equilibrium between extinction (which was inversely related to patch size) and re-colonization (which was inversely related to degree of patch isolation)(Smith 1974b; 1980). By the time censuses resumed in 1989, the pika population in the southern constellation of patches had begun to collapse, and by 1991 nearly all of the southern patches were vacant; overall percent patch occupancy at Bodie dropped to 41.9% in 1989 and 43.2% in 1991 (Smith and Gilpin 1997; Moilanen et al. 1998). Percent patch occupancy has remained low (average = 37.6% from 1989-2010), as the southern constellation of patches has remained largely vacant. Some animals have been located in the south since 1991, but from 2008 onward no pikas have been observed there. While showing considerable variability among years, there was no significant decline in percent occupancy for all patches from 1989-2010 (regression coefficient = –0.3277, p = 0.264), or percent occupancy in the northern constellation of patches from 1972-2010 (regression coefficient = –0.3988; p = 0.158). Percent occupancy in the north in 2009 (83.8%) was slightly greater than in the first 1972 census (83.3%). The total number of pikas in annual censuses has not changed appreciably over time, in spite of the collapse of the southern constellation of patches by 1991. The number of pikas counted on all patches was 132 in 1972 and 119 in 1977, compared with 122 in 2009 and 109 in 2010, the latter two years reflecting number of pikas in the northern constellation only. Overall, between 1989 and 2010 extinction events were recorded on 114 patch populations (6.3/year) and re-colonizations on 109 patches (6.1/year) (Smith and Nagy 2012). The high annual variability in number of patches re-colonized and undergoing extinction events allowed Smith and Nagy (2012) to look more closely at potential dynamics between chronic and acute temperature data and these events. 20 correlations between high temperatures (chronic and acute in either the same year or the previous year) with number of re-colonization or extinction events yielded a single significant result in the opposite direction of what one would expect —number of patch re-colonizations tended to correlate positively with August temperatures in the previous year. Thus, within this power of resolution (daily maximum and monthly average maximum standard climatological temperatures), it could not be determined whether or not the metapopulation dynamics, as driven by reduced dispersal between patches or extinction of populations on patches, was determined by temperature.

What do these data tell us with regard to the status of pikas at Bodie?:

- The inability of pikas to fully saturate all the habitat patches at Bodie (and even their inability to recolonize quickly those sites experimentally trapped out by Severaid back in the 1940s) corroborates that dispersal ability of pikas is restricted in environments as warm as found at Bodie. Indeed, this is a metapopulation system because not all the patches were occupied at any given time, due to the inability of pikas to fully saturate available habitat via dispersal. This means that extinction of pika populations on small patches (for whatever reason) may lead to a net loss in a region if the patch is sufficiently far from a source of colonists. The spatial scale at Bodie – with a southern constellation of patches within 1-2 km of extant patches, yet remaining largely vacant for 20 years – indicates that stochastic extinction of small isolated patches near the low range of elevation of pikas (thus hotter sites) may be permanent. Data in Appendix 1 show that most vacant patches were small (thus subject to stochastic extinction) and low in elevation – a combination that may preclude their becoming occupied in the foreseeable future.
- The lack, however, of any significant correlations between temperature data and key elements of the dynamics of the metapopulation system (re-colonization and extinction events), is seemingly unsatisfying. This result illustrates that standard climatological temperature data may be insufficient to understand these important population processes for pikas – even though the temperature data were from on site. Even in the hottest year on record, a pika could make the decision to disperse on the only cool day in that month, or during the coolest part of a warm day. All time activity data available on pikas show that they are extremely adaptive and flexible (Severaid 1955, MacArthur and Wang 1974, Smith 1974b). Thus, this result enforces the need to understand pikas on their own terms with detailed observations of marked animals (see Tapper 1973; Smith and Ivins 1983, 1984) coupled with detailed micro-climatic temperature measurements in or near critical habitat elements like haypiles or deep in the talus (see Beever et al. 2010, Millar and Westfall 2010, Wilkening et al. 2011). Studies that attempt to quantify the persistence of pikas utilizing regional temperature measurements or climatological models (see Calkins et al. 2012), are much more likely to be too blunt to be informative.

- Metapopulation systems may be fragile; the loss of pikas in the southern constellation of patches at Bodie is the first example of a metapopulation collapse, but one predicted by metapopulation theorists. It is unknown what triggered the downward spiral of occupancy in the south. Smith and Gilpin (1997) considered several possibilities, and commented that a resourceful weasel could have knocked out some key patches leading to the decline, but this is unsubstantiated. Smith and Nagy (2012) determined that pikas have not been found on 15 (20%) of patches, and these were all small and all in the south. It was not possible to excavate ore dumps to examine the suitability of the rock substrate that they contained – to determine if a pika could easily retreat deeply enough to avoid summer heat (Smith 1974b) or winter cold (Beever et al. 2010). Nevertheless these data on lack of occupancy strongly indicate that these patches may have over time become unsuitable for long-term occupancy by pikas. Thus, an increasingly small network of patches and the resulting inevitable stochasticity of extinctions and re-colonizations, could have amplified the tendency toward regional extinction.
- Metapopulation systems may be resilient; the continued occupancy (high levels of occupancy) in the northern constellation of patches in spite of frequent extinction of populations on individual patches demonstrates the positive dynamics of metapopulation systems.
- The overall lower percent patch occupancy rates at Bodie now, compared with the first comprehensive censuses in the 1970s, is not an indication of loss due to a warming climate. First, it is difficult to conceive that climate could have been responsible for the initial collapse of the southern constellation – as the northern constellation of patches, only 1-2 km away, remained healthy. [Failure to become re-colonized could be a feature of warm temperatures; see above]. Also, most climate change in the intermontane west has occurred over the past 20-30 years, yet there has been no significant decline in overall patch occupancy rate during that time. Critical temperature data were organized by period in the phenology of pikas at Bodie beginning with temperatures at the time pikas were putatively colonizing the ore dumps (1895-1903), through 1932-1950 corresponding to the period during which Severaid worked at Bodie, to 1951-1972 the period between Severaid's work and the first metapopulation census by Smith, to 1973-1991 the period from the 1st census to that of the 4th census when the collapse of the southern constellation of patches was first evident, to 1992-2010 the period leading to the present. For all chronic temperatures (June, July, August, annual mean maximum temperatures) and acute temperatures (number of days $\geq 25^{o}$ C, $\geq 28^{o}$ C), the most recent period has been the hottest. Nevertheless, there is no clear pattern by block of time that could explain full occupancy in the early years of Severaid's observations, versus 60% patch occupancy by 1972, 40% patch occupancy by 1991, and no change in percent patch occupancy since that time."

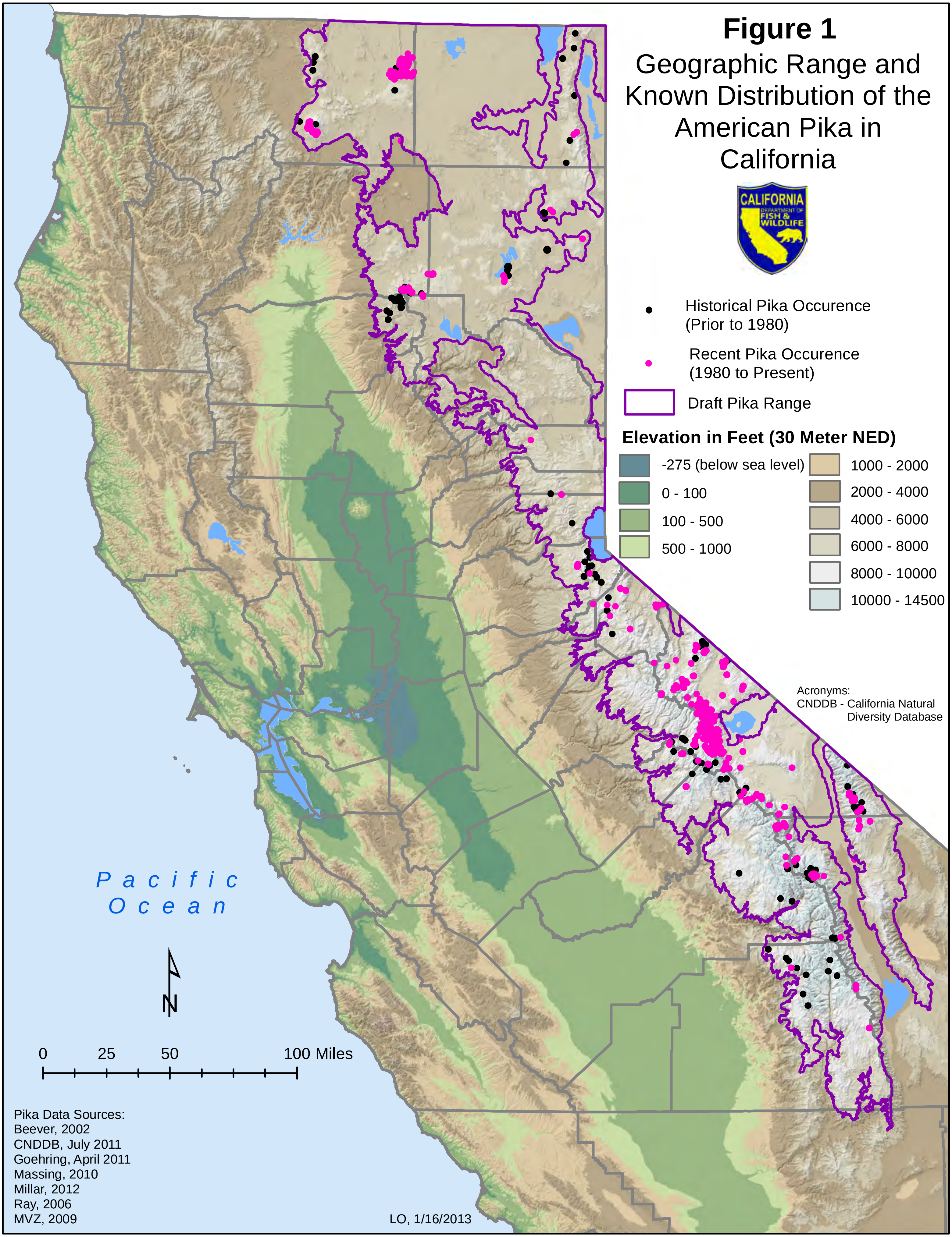


Figure 1
Geographic Range and Known Distribution of the American Pika in California

Acronyms:
CNDDB - California Natural Diversity Database

Pika Data Sources:
Beever, 2002
CNDDB, July 2011
Goehring, April 2011
Massing, 2010
Millar, 2012
Ray, 2006
MVZ, 2009

LO, 1/16/2013

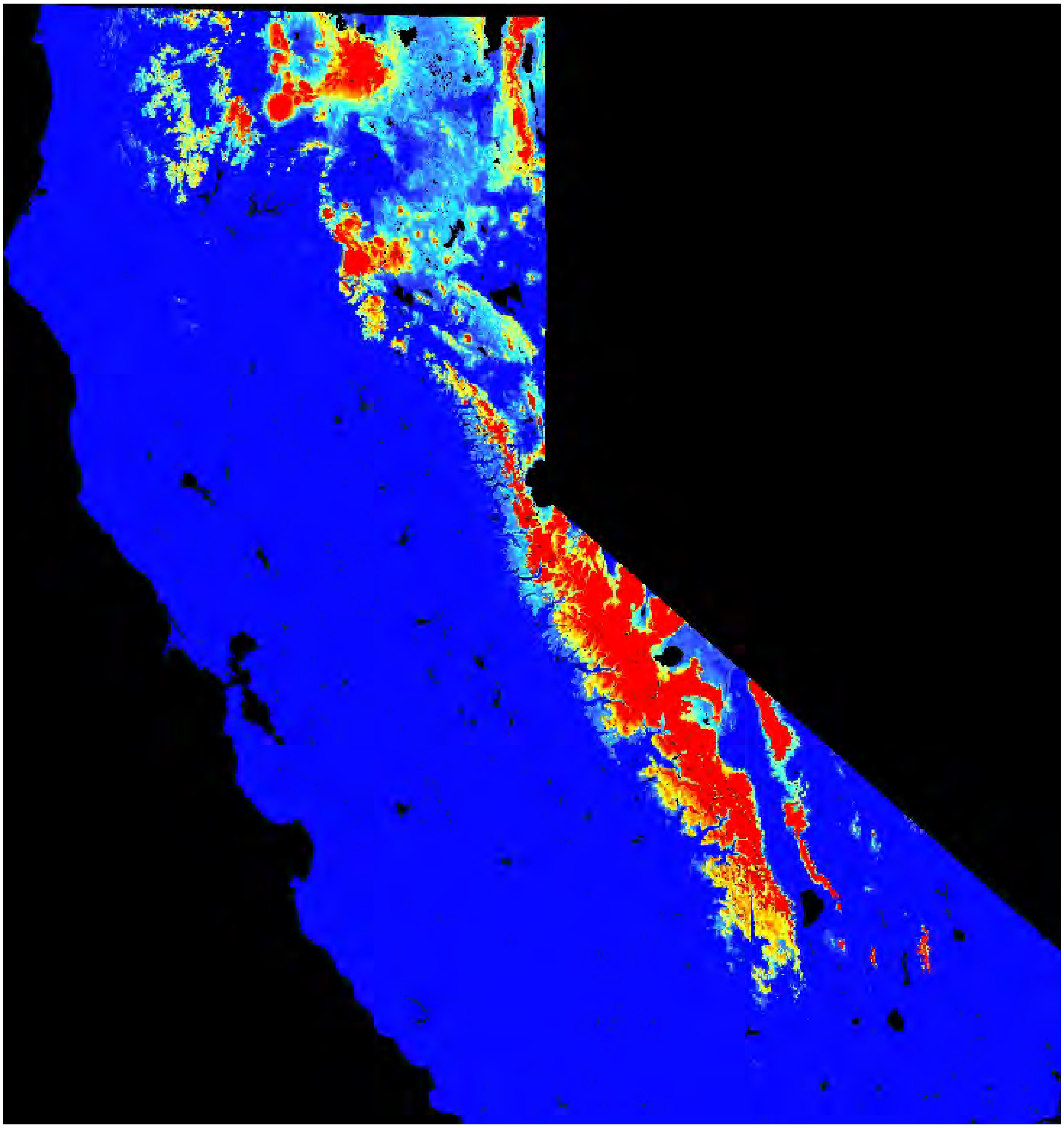


Figure 2. Predicted distribution of suitable American pika habitat within California from a MaxEnt (Phillips et al. 2006) model incorporating 19 bioclimatic variables (Hijmans et al. 2005), as well as elevation, aspect, and slope from USGS National Elevation Data to illustrate the patchy distribution of suitable habitat within the bounds of the species range. Probability of occupancy by pika varies from high (red) to low (light blue). Some areas known to be outside the species distribution are included by the model based on suitable climatic and geographic conditions (e.g. Mount San Jacinto in southern California and the Trinity Alps in northwestern California).

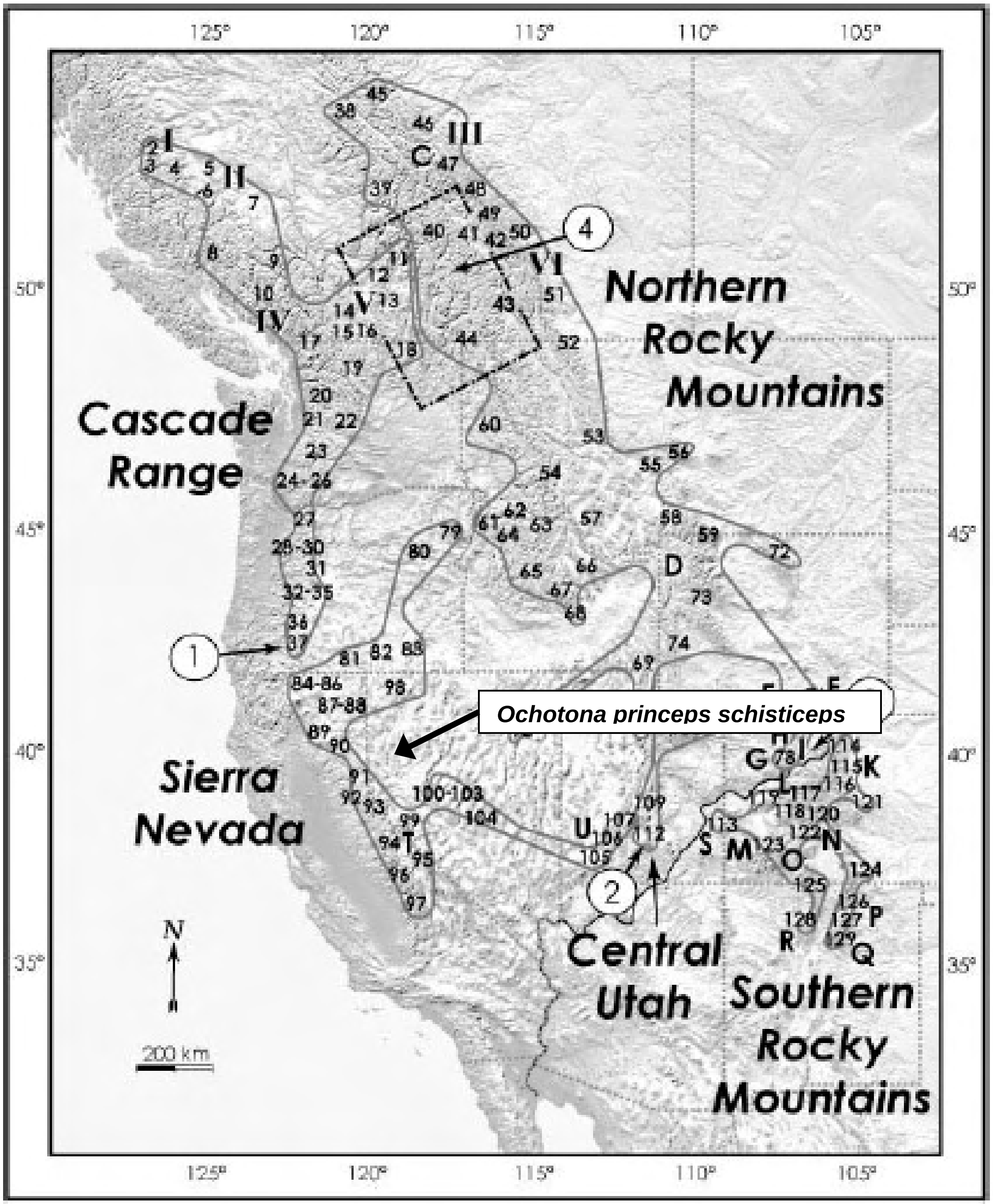


Figure 3. Map from Hafner and Smith (2010) depicting the sample locations used to determine the phylogenetic relationships of the five lineages that comprise the currently-recognized subspecies of the American pika. The geographic ranges of the subspecies are approximated by the polygons surrounding the sample locations. The subspecies of pika that occurs in California (*Ochotona princeps schisticeps*, indicated by the arrow) ranges from the Sierra Nevada north into the Cascades and east into the Great Basin ranges.

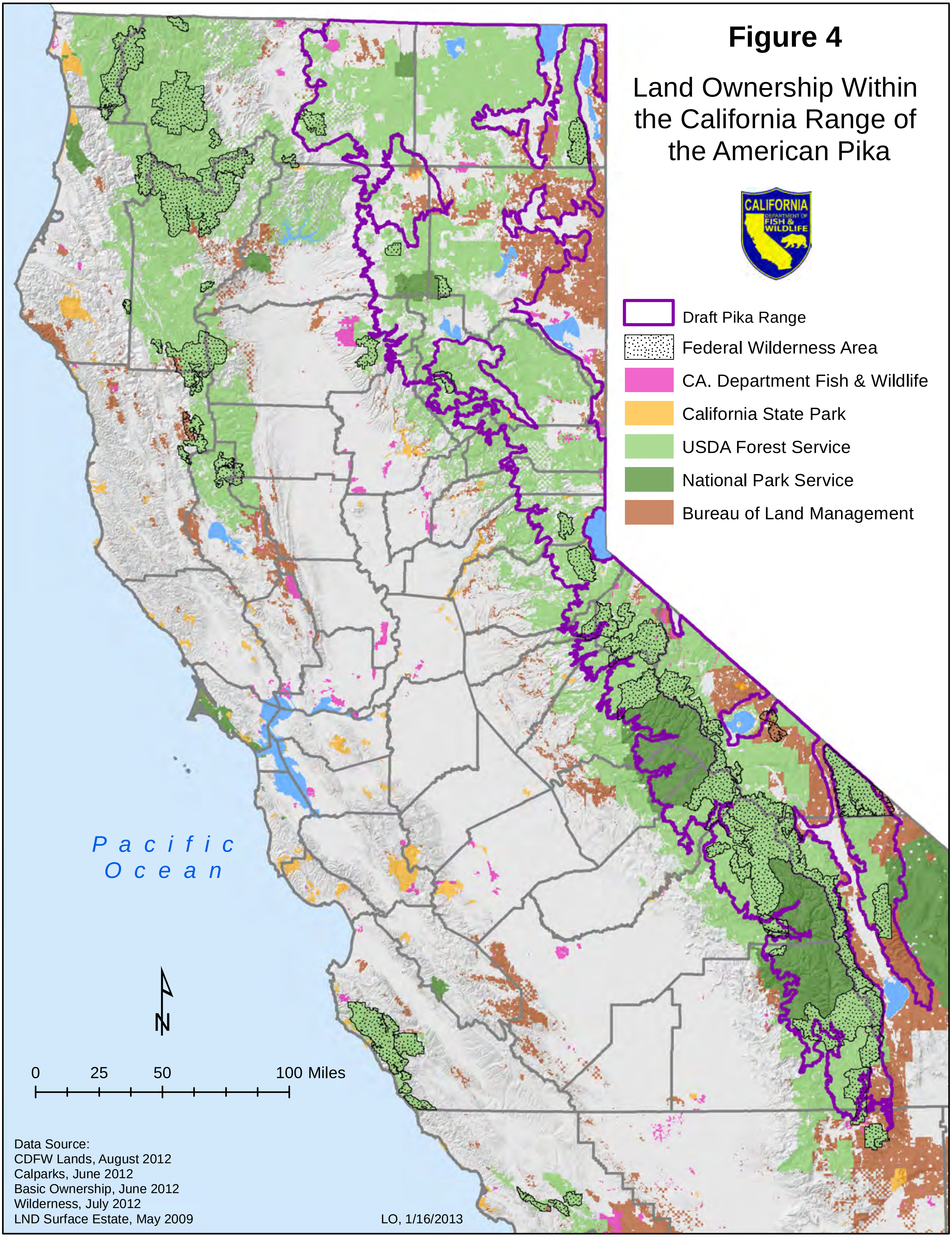
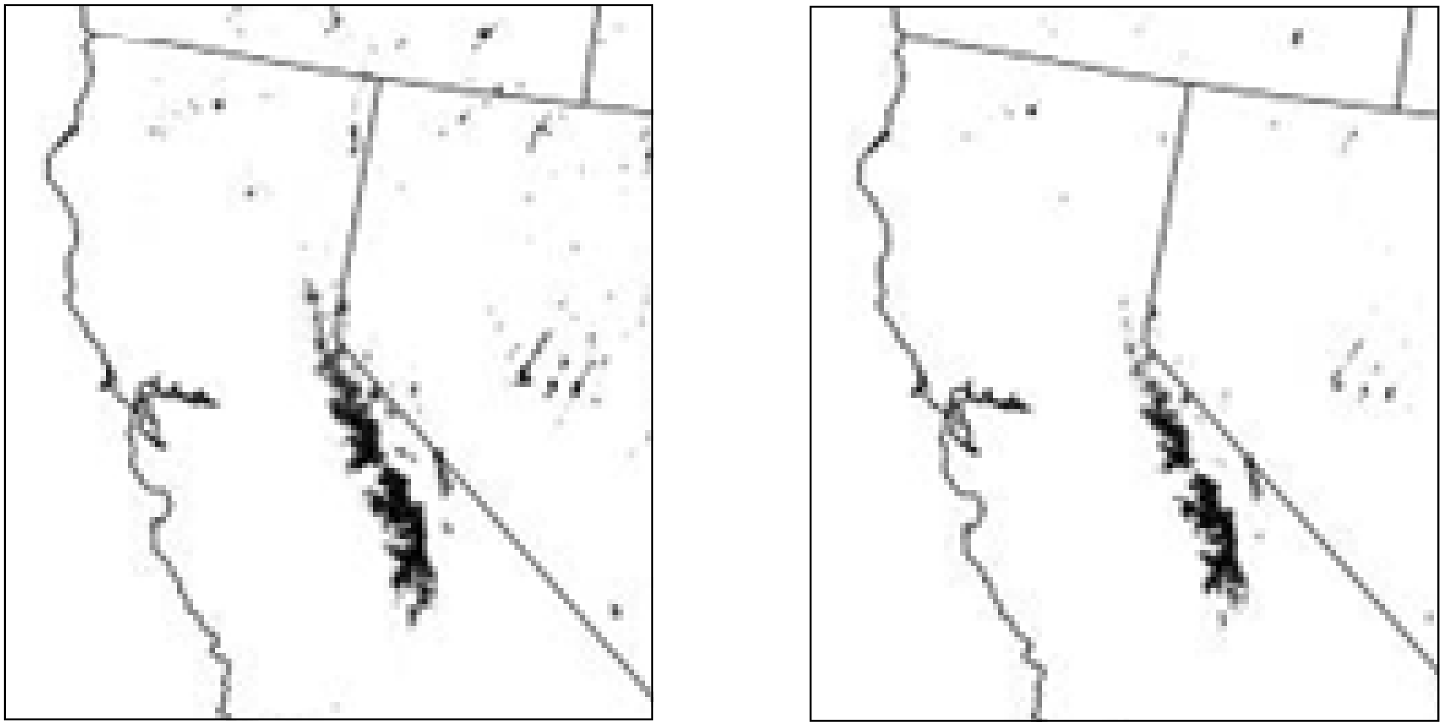


Figure 4

Land Ownership Within the California Range of the American Pika

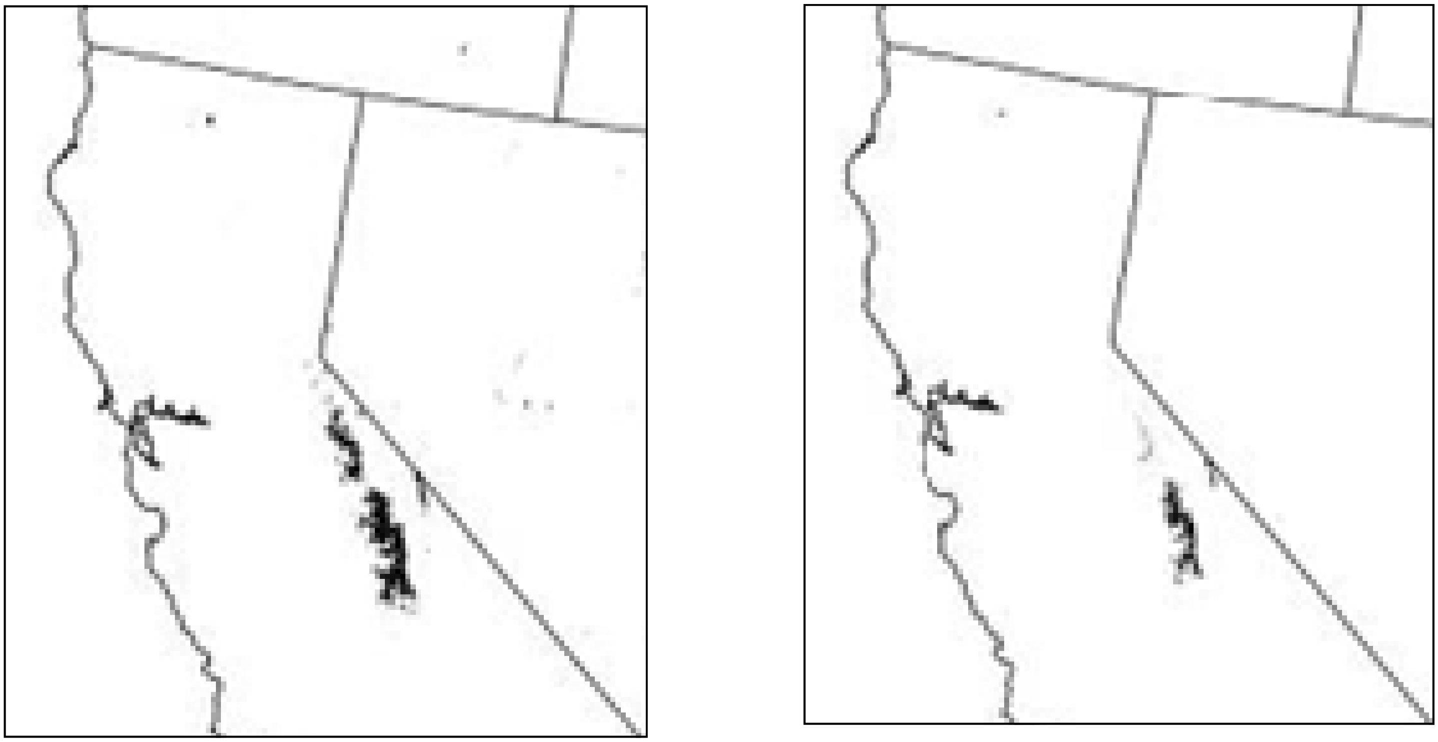
Data Source:
CDFW Lands, August 2012
Calparks, June 2012
Basic Ownership, June 2012
Wilderness, July 2012
LND Surface Estate, May 2009

LO, 1/16/2013



a. Current conditions

b. 2 C warming



c. 4 C warming

d. 7 C warming

Figure 5. American pika predicted distribution, as determined through bioclimatic envelope modeling and land cover type, modeled by Calkins et al. (2012) for (a) current conditions and general warming conditions of (b) 2 C, (c) 4 C, and (d) 7 C.

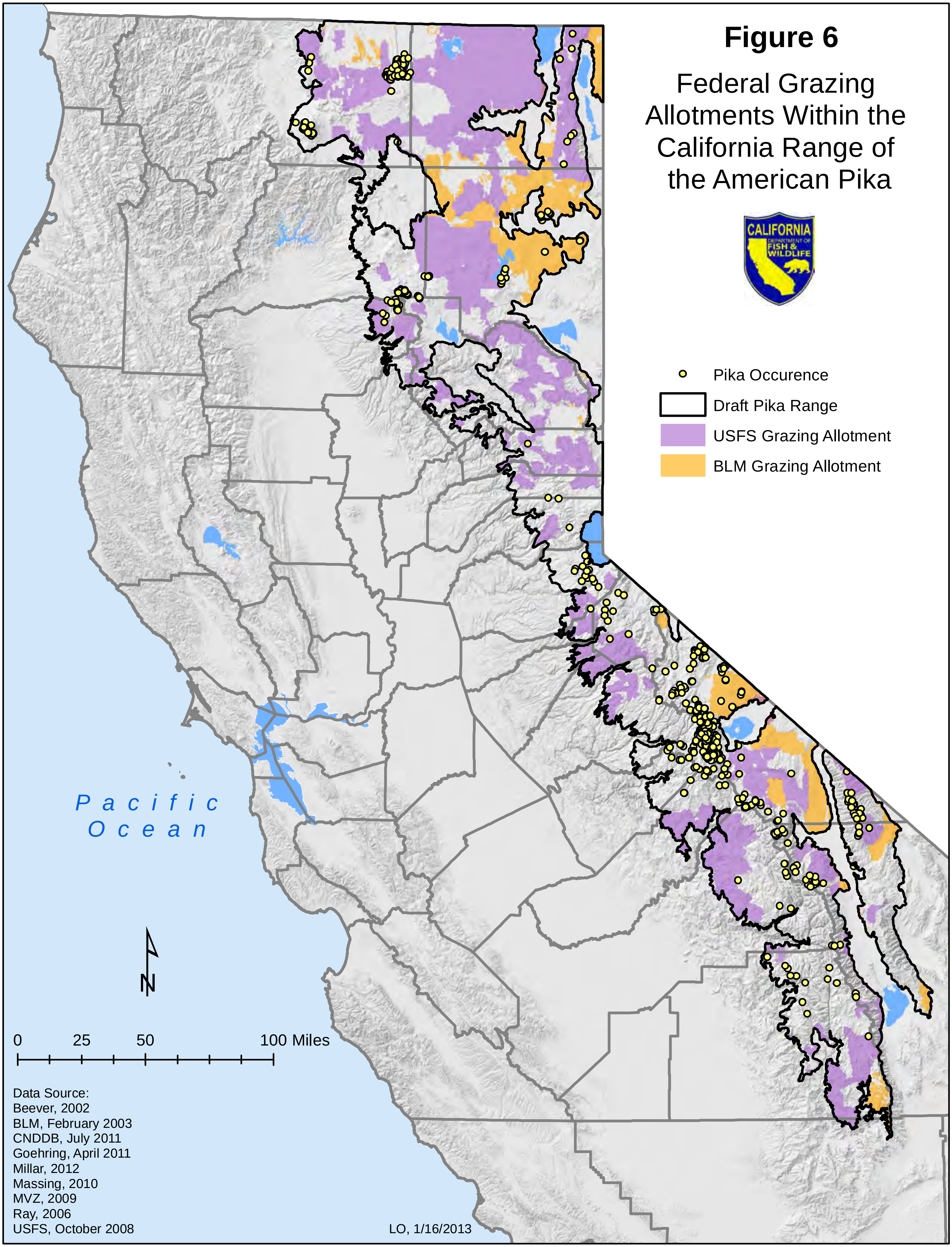


Figure 6

Federal Grazing Allotments Within the California Range of the American Pika

Data Source:
Beever, 2002
BLM, February 2003
CNDDB, July 2011
Goehring, April 2011
Millar, 2012
Massing, 2010
MVZ, 2009
Ray, 2006
USFS, October 2008

LO, 1/16/2013