Climate Change in the Sierra Nevada Network
A Summary of Recent Findings and Efforts to Monitor Change

The Sierra Nevada Network (SIEN) is one of 32 National Park Service inventory and monitoring networks that have implemented vital signs monitoring to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. Climate—particularly precipitation and temperature—is a primary ecosystem driver in the Sierra Nevada. It ultimately controls plant and animal distributions, and strongly influences physical drivers and resources such as fire regimes, nutrient cycling, and water availability. Atmospheric warming is resulting in an increase in the fraction of rain to snow, decreasing the maximum snowpack water content, and causing earlier melt of the snowpack.The SIEN is monitoring several vital signs that will likely reflect consequences of climate change and other stressors such as air pollution and altered fire regimes. This brief offers a summary of recent local-scale findings, as well as a summary of how SIEN monitoring provides information about change in park resources.

Recent Findings

Climate Data Show Regional Warming

Temperature has varied widely from year to year in the Sierra Nevada region since collection of instrumental weather records began in 1895, but there have been some notable trends of increasing temperatures. The average air temperature has risen since the mid-1970s, and the average minimum (nighttime) temperature has risen even more dramatically (Figure 1). The annual averages over the last 10 years approach or exceed that of any other decade on record throughout the southern Sierra. Warming temperatures cause the snow to melt earlier in the year and raise the elevation where snow melts and falls as rain; these effects decrease the total winter snow accumulation. When there is less snow accumulation over the winter, less water is available from snowmelt for plants, animals, and local communities through the summer.

Small Mammals Track Climate Change

A SIEN biological inventory project with University of California - Berkeley cooperators re-sampled a 1914–1920 survey of small mammal communities in Yosemite National Park. By re-sampling a transect across a 3,000-m elevation gradient, researchers found upward changes in elevation limits for half of 28 species inventoried, consistent with the observed ~3°C increase in minimum temperatures. Formerly low-elevation species expanded their ranges and high-elevation species contracted theirs, leading to altered community composition at mid- and high elevations (Moritz et al. 2008). Although vegetation dynamics related to changes in fire regime and other factors have likely contributed to changes at low to mid-elevation, habitat change at higher elevations is limited. These results confirm that protecting large-scale elevation gradients, like those found in SIEN parks, helps to retain diversity by allowing species to migrate in response to climate and vegetation change.

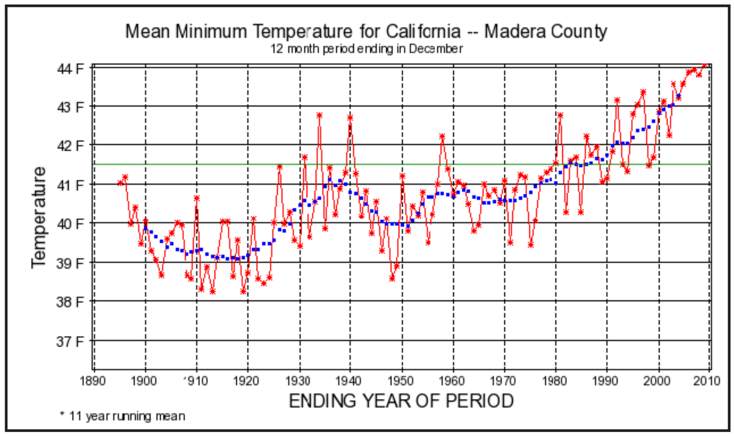

Figure 1. Madera County (Yosemite region) mean calendar year minimum temperature (1895-2009). Red: individual years. Blue: 11-year running mean. Green: 1971-2000 mean. Data from PRISM. Source: Interactive plots, WRCC/UArizona Westmap (from Edwards and Redmond 2011).

Figure 2. Alpine chipmunk (*Tamias alpinus*), a high-elevation species endemic to the Sierra Nevada, has shown contraction of its lower range. Photo: Les Chow.

Figure 3. Long-term monitoring plot in red fir forest, Sequoia National Park - one of 30 forest monitoring plots currently monitored by the USGS Sequoia-Kings Canyon Field Station. Photo: Linda Mutch.

Figure 4. American pipits breed in Sierra Nevada alpine meadows. It is uncertain how a warming climate will affect these birds, but alpine environments are among the most vulnerable to climate change impacts.

Figure 5. Weather station in the Lodgepole area, Sequoia National Park -- one of the National Weather Service COOP stations that will be used in SIEN's climate monitoring project. Photo: Kelly Redmond.

Increasing Tree Mortality Rates Coincide with Temperature-Driven Increase in Drought Index

Long-term monitoring of 21 forest plots in Sequoia and Yosemite National parks over a 22-year period (1983-2004) provided annual-resolution data on tree mortality and proximate causes of tree death. Analyses by van Mantgem and Stephenson (2007) demonstrated that tree mortality rates in two dominant taxonomic groups —pine (*Pinus*) and fir (*Abies*)— increased over this time period. The increase in overall mortality rate resulted from an increase in tree deaths attributed to stress and biotic causes, and coincided with a temperature-driven increase in an index of drought. van Mantgem and Stephenson suggest that these forests may be sensitive to temperature-driven drought stress, and may be vulnerable to dieback if future climates continue to bring rising temperatures without compensating increases in precipitation.

Monitoring Projects Track Change in Park Resources

Birds

Because they can respond quickly to changes in resource conditions, changes in landbird populations may indicate changes in the biotic or abiotic components of the environment upon which they depend. Despite being relatively mobile, birds are likely to be significantly affected by climate change, as many require existing high-elevation biomes for key portions of their life cycles. Recently, Siegel et al. (2014) did a climate change vulnerability assessment of 168 bird species that breed in the Sierra Nevada. Only one species not native to the Sierra Nevada, White-tailed Ptarmigan, received the most vulnerable rank, Extremely Vulnerable. No species ranked as Highly Vulnerable, but sixteen species scored as Moderately Vulnerable. Alpine species such as gray-crowned rosy finch and American pipit (Figure 4) may be susceptible to range shrinkage related to climate change. SIEN's bird monitoring project tracks and reports on changes in relative abundance and distribution of birds across a wide range of elevation gradients.

Climate

To monitor climate, SIEN relies upon existing weather stations, snow courses, and streamgages that provide consistent, long-term, and high-quality climate records within SIEN parks (Figure 5). We report annual and long-term trends for temperature; precipitation; snow water equivalent and snow depth; drought at the regional scale; and streamflow. Climate has a prominent influence on the following Sierra Nevada landscape components:

- Vegetation
- Hydrology
- Soils
- Landforms
- Fire regimes

Monitoring climate helps scientists and park managers understand variations in other resources and processes, and provides parks with information for future planning and visitor services.

High-elevation Forests

Whitebark and foxtail pine are five-needle white pines that occupy high-elevation Sierra Nevada treeline and subalpine habitats (Figure 6). Because these pines often occur in pure to nearly-pure stands, they can have a large influence on key ecosystem processes and community dynamics, such as regulating snowmelt and streamflow and providing habitat and food resources for birds and mammals. These pine species are currently threatened by the combined effects of *Cronartium ribicola*, a non-native fungus that causes the disease white pine blister rust, outbreaks of the endemic mountain pine beetle, and climate warming. SIEN is monitoring tree species composition, forest structure, and rates of birth, death, and growth. In addition, we monitor incidence and severity of white pine blister rust infection, mountain pine beetle infestation, dwarf mistletoe infection, canopy kill, and female cone production to better understand factors associated with tree death and reproduction.

Figure 6. Whitebark pine (*Pinus albicaulis*) in Kings Canyon National Park. Whitebark pine is showing severe declines in much of its range and the species is currently warranted for listing as a federal endangered species. Photo: Peggy Moore.

Lakes

Kings Canyon, Sequoia, and Yosemite National Parks have over 1,200 lakes which are critical components of the parks' ecosystems, popular visitor destinations, and habitat for aquatic and terrestrial organisms, including declining amphibian species. Climate warming may result in rapid and substantial increases in air and water temperatures; lake water temperatures have risen more than air temperatures globally, most likely related to earlier ice melt from lake surfaces. At risk are the timing and duration of ice cover, lake-mixing regimes, and seasonal hydrologic events (e.g., snowmelt), potentially altering food web interactions, species diversity, and nutrient dynamics. SIEN monitors lake level at eight lakes and water quality and temperature for a total of 78 lakes (Figure 7), as well as presence of amphibian species for park managers doing restoration projects.

Figure 7. Biological technician paddles out to collect mid-lake water temperature profiles and a water sample in Kings Canyon National Park. Photo: Lyndsay Belt.

Rivers

The SIEN parks contain the headwaters and large portions of seven major Sierra Nevada watersheds—the Tuolumne, Merced, San Joaquin, Kings, Kaweah, Kern and Tule. The distribution and movement of water and its interactions with the surrounding environment, or hydrology, will be monitored in a subset of major rivers to better understand how water dynamics change seasonally and over long time periods. Climate-related changes in snowpack and snowmelt patterns have major effects on river flow patterns. Figure 8 shows the greater variability of hydrologic patterns that are already occurring or anticipated to occur with expected temperature increases. A recent assessment of local stream gages and snow courses indicated that snowmelt is occurring earlier, and less of the total stream discharge is occurring between April and July when most of snowmelt runoff has historically occurred (Andrews 2011). Monitoring of river flow patterns helps park and water managers to better understand and predict the timing of the delivery of snow runoff as well as the effects of climate change.

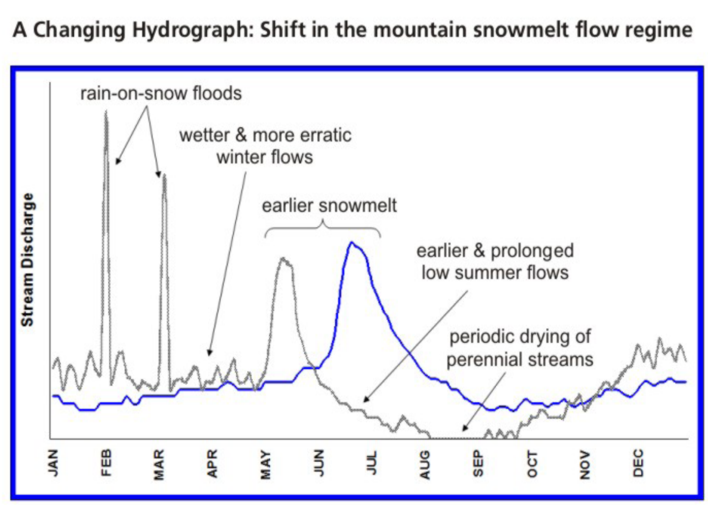

Figure 8. Developing and anticipated changes to the snow-melt flow regime in the Sierra Nevada (gray line), with a more typical historic pattern shown as the blue line. Adapted from David Herbst, Sierra Nevada Aquatic Research Lab.

Figure 9. Botanist installs a wetland monitoring plot in Devils Postpile National Monument. Photo: Linda Mutch.

Wetlands

Wetlands are biologically diverse ecosystems, and in the Sierra Nevada they support a large number of species relative to the small portion (<10%) of the landscape they occupy. Wetlands provide critical habitat for wildlife, play an important role in the life cycle of many invertebrate and amphibian species, and provide numerous ecosystem services such as flood control and sediment storage. A warming or drying climate is expected to affect the duration, depth, and timing of water in wetlands, and these hydrologic changes may alter species composition and relative abundance within plant and macroinvertebrate communities. We monitor groundwater levels, the abundance and composition of plants, and macroinvertebrate abundance and composition (Figure 9). We also quantify and compare the status and rates of change in key characteristics between two wetland types: wet meadows and fens. Analyses that integrate vegetation, water, and invertebrate data enhance our ability to understand and interpret change in wetland systems.

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