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Physical Sciences

Climate change and water supply in western national parks

By Jessica Lundquist and James Roche

Introduction

OVER THE PAST 50–60 YEARS, warming temperatures across the western United States have resulted in greater proportions of precipitation falling as rain rather than snow (Knowles et al. 2006) and in earlier snowmelt and streamflow (Mote et al. 2005; Stewart et al. 2005). The years 2004 and 2007 marked two of the earliest spring melts on record (Pagano et al. 2004), and 2007 was one of the driest years on record in California. Glaciers are disappearing across the West, and Glacier National Park (Montana) may cease to live up to its name as early as 2030 (Myrna et al. 2003). Annual precipitation amounts in the western United States have not changed significantly, and predictions of precipitation are uncertain (Dettinger 2005, 2006). However, even without changes in total precipitation amounts, warming temperatures and corresponding shifts from solid to liquid precipitation have profound implications for park water supplies and park management.

"Glaciers have provided a buffer against low flows in dry, warm summers, and their absence could result in perennial rivers becoming ephemeral streams. Streams that are already ephemeral, such as Yosemite Falls, will likely become drier on average earlier in summer."

Temperature changes will have the greatest influence in mountain parks with a Mediterranean climate such as Yosemite (California), Sequoia and Kings Canyon (California), Lassen Volcanic (California), Crater Lake (Oregon), Mount Rainier (Washington), Olympic (Washington), and North Cascades (Washington) national parks, where nearly all precipitation falls in winter, and where ecosystems and humans depend on snowmelt for water supplies throughout summer. Earlier snowmelt and a greater proportion of rain result in more water flowing into rivers in winter when it is a hazard, and less into rivers in summer when it is a resource.

Too much water in winter: Warming and flood management

Warmer temperatures increase the elevation where falling snow melts and becomes rain, thus increasing the contributing area for a given storm and the likelihood of flooding (White et al. 2002; Lundquist et al. 2008). Mountain ranges lining the Pacific coast are most at risk from "atmospheric river" or "pineapple express" storms, when winds transfer a narrow jet of warm, moisture-rich air from near Hawaii to the U.S. West Coast (Ralph et al. 2004; Ralph et al. 2006; Neiman et al. 2008). This type of storm caused floods that closed Yosemite Valley in Yosemite National Park in January 1997 and May 2005, and floods that drastically damaged roads in Mount Rainier and North Cascades national parks in November 2006. Rivers with a large proportion of total contributing area near the mean elevation of the winter 0°C (32°F) isotherm are most sensitive to increased flood risks because these areas will become unfrozen and contribute to flood runoff as temperatures warm (Bales et al. 2006).

Too little water in summer: Warming and drought management

In addition to too much water in winter, too little water in summer is a danger. Warmer temperatures will subject park water supplies to less reliable late summer streamflow. Not only will snow melt earlier (Stewart et al. 2005), but glacial meltwater will soon disappear in many western national parks (Myrna et al. 2003). Historically, glaciers have provided a buffer against low flows in dry, warm summers, and their absence could result in perennial rivers becoming ephemeral streams. Streams that are already ephemeral, such as Yosemite Falls, will likely become drier on average earlier in summer (fig. 1).

These shifts in water timing will probably have large impacts on regional ecosystems (Stephenson et al. 2006), resulting in rapid, threshold-type responses (Burkett et al. 2005). For example, earlier drying of ephemeral streams will lead to lower water tables in meadows. Once groundwater level drops below a critical depth, vegetation will change from mesic (wet meadow) to xeric (dryland) (Loheide and Gorelick 2007).

Park water supplies that depend on snow- or glacier-fed surface runoff—for example, in Tuolumne Meadows and on the South Fork of the Merced River near Wawona in Yosemite National Park (fig. 2, below)—will need management plans that consider the increased likelihood of late summer water shortages. Few sources other than surface water are available, given the lack of deep alluvial basins in many developed areas such as Wawona. This lack makes groundwater extraction for public water supplies infeasible (Borchers 1996). Management of these systems will require careful stream gauging and discharge monitoring to accurately quantify low flows and implement water rationing or other management actions.

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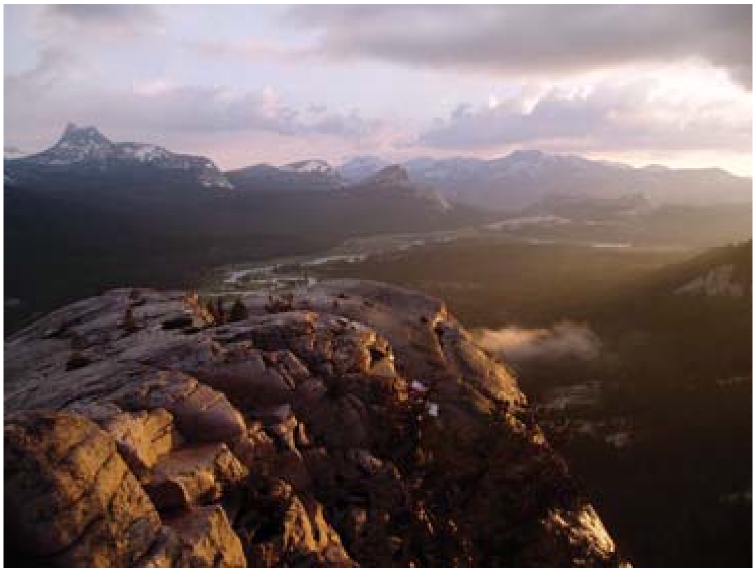
Figure 2. Run-of-the-river water supplies, as pictured here on the South Fork of the Merced River near Wawona in Yosemite National Park, are particularly vulnerable to earlier melting of snowpack.

Park management strategies

Regardless of world action plans to mitigate climate change, temperatures are likely to continue rising for the foreseeable future (Intergovernmental Panel on Climate Change 2007). Park management can best adapt to climate change by understanding which areas are likely to be most affected by warming temperatures and why. For example, Lundquist and Flint (2006) demonstrated that at midlatitudes, such as in the Sierra Nevada and Colorado Rockies, high-elevation, north-facing basins are much less sensitive to warming temperatures than their south-facing counterparts. Melt onset is delayed longer in the shadiest basins in years with early melt onset than in years with average melt timing, resulting in nonlinear differences between subbasins that are not captured by standard modeling techniques (Lundquist and Flint 2006). Also, temperatures in different locations in complex terrain respond differently to variations in atmospheric circulation. For example, because of decadal weakening of westerly winds over central California, the eastern slope of the Sierra Nevada has been warming significantly less than the western slope (Lundquist and Cayan 2007). Managers can take advantage of spatial patterns to determine which park areas would benefit most from restoration or enhanced protection.

“Park management can best adapt to climate change by understanding which areas are likely to be most affected by warming temperatures and why.”

As snowmelt becomes a less reliable source of water in late summer, summer precipitation will become increasingly important in controlling late summer soil moisture and minimum .flows in mountain streams. Hamlet et al. (2007a, b) found that modeled late-season soil moisture depends more on summer precipitation than on temperature or the spring snowpack. These studies also found that in many areas of the western United States, summer precipitation has been increasing in recent decades. For example, one large thunderstorm in late summer 2007 was sufficient to keep water levels in Wawona from falling below critical rationing levels. Thus, further monitoring and research should be devoted to understanding and predicting summer precipitation, which most often falls as spatially variable thunderstorms at high elevations (fig. 3, below).



Courtesy of Jessica Lundquist

Figure 3. Summer thunderstorms, as seen here in Tuolumne Meadows, Yosemite, California, will become increasingly important in providing late summer moisture to the western mountains and their national parks.

Conclusions

Adapting to climate change will require careful, spatially distributed monitoring to understand how different areas will respond. Parks managers will need to be prepared for the increasing likelihood of both floods and drought; this will require flexible management plans that can adapt as baselines change and new information is gleaned.

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NPS/James Roche

Figure 1. Yosemite Falls, in Yosemite National Park, is fed by snowmelt, and typically goes dry by the end of summer. Earlier snowmelt because of warmer temperatures would lead to the falls drying earlier in the season.

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