California's National Parks in Peril

The Threats of Climate Disruption

At stake is what makes the national parks in California the special places that Americans love.

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October 2010

A Report by the Rocky Mountain Climate Organization and the Natural Resources Defense Council

About RMCO

The Rocky Mountain Climate Organization works to keep the interior American West special by reducing climate disruption and its impacts in the region. We do this in part by spreading the word about what a disrupted climate can do to us and what we can do about it. Learn more at www.rockymountainclimate.org.

About NRDC

The Natural Resources Defense Council is a national nonprofit organization with more than 1.3 million members and online activists. Since 1970, our lawyers, scientists, and other environmental specialists have worked to protect the world's natural resources, public health, and the environment. NRDC has offices in New York City, Washington, DC, Los Angeles, San Francisco, Chicago, Livingston, MT, and Beijing. Visit NRDC on the web at www.nrdc.org.

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Acknowledgements

The principal authors would like to thank for their reviews of draft portions of this report Keith Bensen, Redwood National Park, National Park Service (NPS); Laura Castellini, Golden Gate National Recreation Area, NPS; Dan Cayan, Scripps Institution of Oceanography/University of California, San Diego, and U.S. Geological Survey (USGS); Kenneth L. Cole, Northern Arizona University; Leslie DeFalco, Western Ecological Research Center, USGS; Debra Hughson, Mojave National Preserve, NPS; Nathan L. Stephenson, Western Ecological Research Center, USGS; and Charisse Sydoriak, Sequoia/Kings Canyon national parks, NPS; for writing assistance, Todd Neff of toddneff.com; for design assistance, Maia Jourgensen; and an anonymous researcher. Cover photo © istockphoto.com/S. Greg Panosian.

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NPS

Golden Gate National Recreation Area

EXECUTIVE SUMMARY

> If we do not reduce emissions of heat-trapping emissions, a disrupted climate will harm the resources that make California's national parks so special.

This report details some of the particular threats that a changed climate poses to ten of California's national parks – Death Valley National Park, Golden Gate National Recreation Area, Joshua Tree National Park, Kings Canyon National Park, Mojave National Preserve, Muir Woods National Monument, Point Reyes National Seashore, Redwood National Park, Sequoia National Park, and Yosemite National Park.

CALIFORNIA'S ECONOMY AT RISK

The 26 units of the national park system in the state draw more than 34 million visitors a year, add $1.24 billion to the state's economy and support over 19,000 jobs. These economic benefits are at risk as climate disruption threatens the special places that yield them.

Local Economic Benefits in 2008 of California's National Parks

	Recreational Visits	Overnight Stays	Total Visitor Spending	Non-Local Visitor Spending	Jobs From Non-Local Spending
Death Valley NP	871,938	199,043	$44.5 million	$42.7 million	851
Golden Gate NRA	14,554,750	55,669	$258.6 million	$107.6 million	2,021
Joshua Tree NP	1,392,446	234,620	$37.3 million	$32.5 million	602
Mojave NPres	618,285	1,651	$13.5 million	$11.8 million	237
Muir Woods NM	838,285	0	$55.6 million	$51.8 million	974
Point Reyes NS	2,248,203	39,495	$94.0 million	$85.8 million	1,612
Redwood NP	396,899	12,951	$20.6 million	$18.7 million	376
Sequoia/Kings Canyon NPs	1,158,758	408,330	$87.8 million	$81. million	1,779
Yosemite NP	3,432,514	1,682,615	$292.4 million	$290.0 million	4,880
Subtotals	26,262,636	2,634,518	$951.1 million	$761.8 million	14,078
Other parks	8,517,823	192,319	$334.4 million	$290.4 million	5,692
Totals	**34,028,908**	**2,826,693**	**$1.239 billion**	**$1.102 billion**	**19,024**

Table ES-1. Legend: NM = National Monument; NP = National Park; NPres = National Preserve; NRA = National Recreation Area; NS = National Seashore. Totals for Sequoia and Kings Canyon NPs are combined to avoid double-counting of visitors to both.

MORE HEAT AND LESS WATER

Table ES-2 presents new projections of future temperature changes in the 10 featured national parks in California. Shown are averages of six climate-model projections, for each of two different levels of possible future emissions of heat-trapping gases.

The "lower" scenario assumes rising emissions until mid-century, then declines. In every case, the projections for this scenario are for greater than the additional 2°F that a U.S. government report says would lead, on a global scale, to "severe, widespread, and irreversible impacts."

The "medium-high" scenario has heat-trapping pollutants rising through the century, although slower than in recent years. In this scenario, Yosemite by 2070-2099 could become 0.3°F hotter than Sacramento historically has been. Sequoia and Kings Canyon could become hotter than the Sonoma County coast has been, and Point Reyes as hot as Santa Barbara.

How Hot California's National Parks Could Get by 2070-2099

	Lower Future Emissions	Medium-High Future Emissions	Effect of Projected Temperature With Medium-High Emissions
Death Valley NP	+ 4.9°F	+ 8.1°F	Death Valley already is the hottest place in North America.
Golden Gate NRA	+ 3.7°F	+ 6.0°F	Golden Gate would become as hot as Santa Monica pier historically has been.
Joshua Tree NP	+ 4.4°F	+ 7.4°F	Joshua Tree would become 5.1° hotter than Death Valley historically has been.
Mojave NPRES	+ 4.7°F	+ 8.0°F	Mojave would become 7.3° hotter than Death Valley historically has been.
Muir Woods NM	+ 2.9°F	+ 5.9°F	Muir Woods would become as hot as San Diego historically has been.
Point Reyes NS	+ 3.6°F	+ 6.0°F	Point Reyes would become as hot as Santa Barbara historically has been.
Redwood NP	+ 3.5°F	+ 5.7°F	Redwood would become 0.5° less hot than Santa Barbara historically has been.
Sequoia/Kings Canyon NPs	+ 4.6°F	+ 7.6°F	The parks would become 0.6° hotter than the Sonoma County coast has been.
Yosemite NP	+ 4.5°F	+ 7.5°F	Yosemite would become 0.3° hotter than Sacramento historically has been.

Table ES-2. Averages of projections from 6 climate models for 2070-2099, compared to 1961-1990 temperatures. Abbreviations as in Table ES-1. Data from World Climate Research Program and Western Regional Climate Center; analysis by the Rocky Mountain Climate Organization.

Neither of these scenarios include new policies to protect the climate. With new policies to reduce heat-trapping pollution, we can hold temperature increases below either of these projections – and avoid other impacts, too.

The effects of heat-trapping pollution on California's climate are also projected to include an overall decline in total precipitation by the middle and end of the century for southern and central California. For the northern part of the state, projections do not indicate a clear direction for precipitation. Scientists are confident that a hotter climate would lead to smaller mountain snowpacks that feed the state's major rivers and to earlier snowmelt, leading to more summer dryness.

YOSEMITE, SEQUOIA, AND KINGS CANYON

These national parks get nearly all of their precipitation in winter, so a hotter future may have more of an effect on their water cycles than on those of national parks in other regions. Scientists project that more winter precipitation will fall as rain, snowpacks built up in winter will be smaller, and snowmelt will be earlier. The result would be more water flowing into rivers in winter and less in summer, when ecosystems and wildlife need it most. Yosemite Falls, which is largely fed by snowmelt and typically goes dry by the end of summer, could be dried up earlier in the summer. More summer visitors would be deprived of one of the park's most famous sights.

In Yosemite, Sequoia, and Kings Canyon, small pine and fir trees are dying more quickly as the parks gets hotter and drier. The rate at which trees have died has nearly doubled over just the past two decades. The most plausible explanation is that hotter temperatures have created a water deficit, stressing the trees.

On the western edge of the Sierra Nevada, including in Yosemite, the lower edge of the mixed conifer forests is moving upslope, with ponderosa pines disappearing and giving way to oaks and shrubs. The changes have occurred in areas that no longer have sub-freezing winter temperatures.

Scientists with the National Park Service and U.S. Geological Survey have expressed concern that giant sequoias may not be resilient to the water stress, increased wildfire, and other effects of rapid climate change.

Projections done for the state government are consistent in pointing to increased wildfire in the region of Yosemite, Sequoia, and Kings Canyon as a result of altered climate conditions.

Mammals also have moved upslope as temperatures have increased. About half of small-mammal species in Yosemite now live at elevations different from where they were found nearly a century ago. Most have moved to higher elevations, by an average of about 500 yards.

Yosemite, Sequoia, and Kings Canyon have levels of ground-level ozone higher than federal health standards. Hotter temperatures promote formation of more ozone, so improving the parks' air quality will be more difficult in a hotter future.

POINT REYES, GOLDEN GATE, REDWOOD, AND MUIR WOODS

Scientists project that sea level along the California coast could rise by 2.0 to 4.7 feet by the end of the century. In Point Reyes, areas that could be flooded, eroded, and ultimately permanently inundated include the seashore's beaches, ecologically important wetlands, and roads, including stretches of Sir Francis Drake Boulevard and Highway 1. In Golden Gate, areas at risk include Ocean Beach, China Beach, Baker Beach, Muir Beach, Stinson Beach, Crissy Field, freshwater streams, Fort Point, Fort Mason, and portions of the Presidio of San Francisco. In Redwood, vulnerable areas include 15 miles of sandy beaches, estuaries, lagoons, stretches of Highway 101, a visitor center, campgrounds, and picnic areas. Sea-level rise also may disrupt wildlife habitat, affecting seals, shorebirds, and other animals in these parks.

Coast redwoods get nearly half of their water from coastal fog. But fog levels have declined as temperatures have increased. A continued decline in summer fog could affect future growth of the redwoods, the tallest trees anywhere.

JOSHUA TREE, DEATH VALLEY, AND MOJAVE

Joshua trees, which need winter freezes to reproduce, are projected to disappear entirely from Joshua Tree and from lower elevations of Death Valley and Mojave in a hotter future.

All three desert parks are at risk of far-reaching ecosystem changes as invasive, non-native plants move in, prompted in part by their greater adaptability to hotter and otherwise altered conditions. Joshua Tree has already experienced increased wildfire, driven at least in part by the spread of invasive grasses.

Death Valley, Joshua Tree, and Mojave also consistently exceed federal health-based standards for ground-level ozone. Hotter conditions will promote the formation of more ozone, aggravating this air-quality problem and requiring more control measures to protect people's health.

TACKLING CLIMATE DISRUPTION

New management actions are needed to identify and protect the threatened resources of these special places and to adapt to changes that now are coming. Actions are also needed to reduce heat-trapping gases to limit climate change and avoid many of its impacts. Most important are comprehensive federal actions to limit emissions of heat-trapping pollutants. Comprehensive actions by state governments also are needed – the type of actions being taken under California's pioneering climate-protection program. These actions also reduce energy costs and create new clean-energy jobs, so protecting California's national parks, along with the entire planet, can be done while achieving more economic growth.

NPS

Death Valley National Park

1 INTRODUCTION

Human-caused climate change threatens national parks that help make California a special place.

Human disruption of the climate is the greatest threat ever to America's national parks. This report details some of the threats that a changed climate poses to ten of those parks in California.

The state of California, the United States, and the whole planet all face the consequences of people's alteration of the climate. But these ten national parks deserve particular attention. What could happen to them demonstrates how the places we most love may never be the same if we do not limit our pollution of the atmosphere with heat-trapping gases.

These national parks hold much of what makes California special. Yosemite Valley, called by no less than John Muir "by far the grandest of all the special temples of Nature I was ever permitted to enter."[1] The titanic sequoias of Sequoia National Park, with trunks as wide as a city street, the largest living individual trees on Earth. The coast redwoods of Redwood National Park, the tallest trees in the world. The highest mountain in the contiguous United States – Mount Whitney, in Kings Canyon National Park – and the lowest point, in Death Valley National Park. The beaches of Golden Gate National Recreation Area, enjoyed by millions of people a year. Point Reyes National Seashore, a peninsula of rocky cliffs, sandy beaches, wetlands, and uplands, hosting some of the country's greatest biological diversity. The early spring wildflower shows of the three great desert parks, Joshua Tree, Death Valley, and Mojave.

Featured National Parks

Death Valley NP	Muir Woods NM
Golden Gate NRA	Point Reyes NS
Joshua Tree NP	Redwood NP
Kings Canyon NP	Sequoia NP
Mojave NPres	Yosemite NP

NP = National Park
NRA = National Recreation Area
NPres = National Preserve
NM = National Monument
NS = National Seashore

But much of this is threatened as people's pollution of the atmosphere makes the climate hotter and, in summer in California, drier. In a hotter and drier climate, Joshua trees are being eliminated in the national park named after them. Redwoods are in danger in Redwood National Park. Sequoias are at risk in Sequoia National Park. Yosemite Falls may dry up more often. Trees are dying sooner in the Sierra Nevada parks. Forests and mammals are moving upslope to stay ahead of higher temperatures. The natural abundance and diversity of wildlife species are at risk in all parks. A rising Pacific Ocean threatens to flood beaches, wetlands, and roads in low-lying areas in Golden Gate, Point Reyes, and Redwood.

NPS

Death Valley National Park

"I believe climate change is fundamentally the greatest threat to the integrity of our national parks that we have ever experienced."

Jon Jarvis, Director,
National Park Service[2]

At stake are not just the spectacular resources and values of these national parks but also an important contribution to California's economy. The national parks in California add $1.24 billion a year to the state's economy and support over 19,000 jobs in the state. These economic benefits, though, depend on the continued attractiveness to visitors of the natural and cultural resources of the parks, including those threatened by climate change. Risks to those resources are also risks to the state's economy.

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Point Reyes National Seashore

This report summarizes the impacts, now and in the future, on the featured parks of climate disruption caused by human emissions of heat-trapping pollutants. Information is drawn from government and scientific reports, journal articles, and other publications, and from the national parks themselves, including from National Park Service and U.S. Geological Survey scientists and other professionals who work in and study them.

Also in this report are new local projections from climate models on how much temperatures may go up in those parks. Projections are included for two different possible futures. One, which the California Climate Change Center calls a “lower” emissions scenario, has a continuing rise in the global annual rate of emissions until mid-century, followed by a gradual decline. The other, called a “medium-high” scenario, has emissions continuing to rise throughout the century. The projections from these different scenarios illustrate that the climate will be changed more if we continue with high levels of heat-trapping pollution and will be changed less if we bring emissions down.

Scientists tell us that because of the long-lasting effect of heat-trapping gases we can do more to protect the climate if we reduce emissions now, not down the road when the pace of climate disruption has accelerated even further.

In short, what we do matters – in these national parks and everywhere else.

Fortunately, it is possible to head off the worst of the possible effects on California's national parks by taking decisive actions to reduce the heat-trapping pollution that is changing the climate.

The state of California is beginning to do its share by taking far-reaching actions under its 2006 landmark climate-protection law, the Global Warming Solutions Act (still more widely known by its legislative title, Assembly Bill 32). Actions under this state law not only will reduce climate change but also, studies consistently show, actually strengthen the state's economy by reducing energy costs and creating clean-energy jobs.

With similar actions by others across the country and around the world modeled after this kind of approach, we can protect our environment – globally and in California's most special places – and secure a better future for ourselves and our children.

“Sizable early cuts in emissions would significantly reduce the pace and the overall amount of climate change. Earlier cuts in emissions would have a greater effect in reducing climate change than comparable reductions made later.”

U.S. Global Change Research Program[3]

2 California's Economy at Stake

National parks add $1.24 billion to California's economy. But a disrupted climate threatens the jobs that come from that spending.

California's national parks are a significant contributor to the state's economy. The 26 units of the national park system in the state draw more than 34 million visitors a year. Their spending adds $1.24 billion to the state's economy and supports over 19,000 jobs. These economic benefits are at risk as climate change threatens the special places that yield them.

For years, a Michigan State University team has been analyzing the local economic contributions of national parks. The latest such report covers 2008.[4] Since visitation to the national parks in California was 3 percent higher in 2009, and has continued so far in 2010 above the 2008 level, more up-to-date tabulations, if they were available, would show even higher current benefits.[5]

Local Economic Benefits in 2008 of California's National Parks

	Recreational Visits	Overnight Stays	Total Visitor Spending	Non-Local Visitor Spending	Jobs From Non-Local Spending
Death Valley NP	871,938	199,043	$44.5 million	$42.7 million	851
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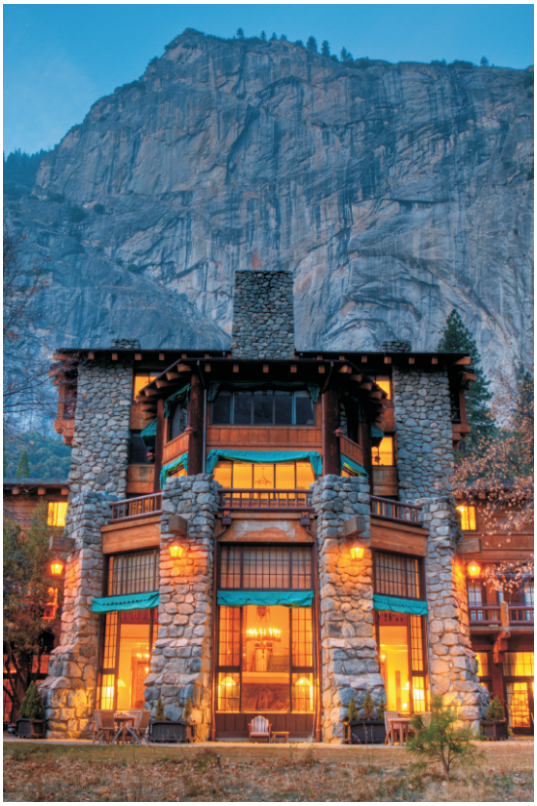
Totals	**34,028,908**	**2,826,693**	**$1.239 billion**	**$1.102 billion**	**19,024**

Table 1. Data source: Stynes (2009).[6] Legend: NM = National Monument; NP = National Park; NPres = National Preserve; NRA = National Recreation Area; NS = National Seashore. Totals for Sequoia and Kings Canyon NPs are combined to avoid double-counting of visitors to both.

Table 1 on the previous page identifies the local economic benefits in 2008 of the 10 national parks in California featured in this report, with a single combined entry covering other parks in the state. (This report often refers to all units of the national park system as national parks, whether they are titled national parks, monuments, recreation areas, or seashores – just as the National Park Service [NPS] does.)

Little research has yet been done on how the impacts of climate change could affect future visitation levels in national parks. One study focused on Rocky Mountain National Park in Colorado.[7] Like Yosemite, Sequoia, and Kings Canyon national parks, Rocky Mountain is a high-elevation, relatively cool park near major metropolitan areas which also draws visitors from afar, and has much higher visitation levels in summer. That study included an analysis of how visitation levels correspond with weather, and showed that visitor numbers generally go up with warmer temperatures. However, the increases slowed as temperatures got hotter and hotter, and visitation even declined by 7.5 percent during one summer of very high temperatures (with 60 days over 80°F).



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Yosemite National Park

Surveys of visitors to Rocky Mountain showed that moderate increases in temperature could lead to increased visitation, by perhaps 10 to 14 percent. But in a very hot future, visitation could decline, by perhaps 9 percent compared to current levels, with a comparable drop in local tourism-related jobs. These results make intuitive sense. Up to a point, more people may go to a cooler, mountain park to escape higher temperatures. But as temperatures get too hot, outdoor recreation even in the mountains becomes less pleasant, and people may find other ways to get a break from the heat. A similar pattern could possibly also hold for visitation to beaches (such as Point Reyes and Golden Gate) as the future gets hotter.

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Yosemite National Park

Research in Canada has involved surveys of visitors to that country's national parks to judge how future conditions of park resources might affect visitation.[8] Visitors were asked if they would return more often, less often, or as often if conditions were changed in the ways expected to result from an altered climate. Descriptions were given to visitors of changes in plant communities, changes in the mammal species present, increases in wildfire, and loss of fishing – all of which also are impacts that could occur in national parks in California. The results of the surveys suggest that climate-change effects could cause future visitation to the Canadian parks to drop, perhaps sharply. When given descriptions of severe changes,19 percent of current visitors said they would not visit the parks again, and 38 percent said they would visit less often. However, whether that kind of pattern would hold if climate-change impacts are showing up everywhere, not just in national parks, is of course unknown.

3 More Heat and Less Water

Climate projections show that national parks in California will get much hotter in this century. California's climate also is expected to get drier.

Human activities, principally the burning of fossil fuels, have led to large increases in heat-trapping gases over the last century. That pollution is already changing the climate, and will continue to do so, driving significant changes in California's national parks as well as elsewhere.

Perhaps the clearest overall statement yet of the current scientific understanding of human-caused climate change is in a 2009 report of the U.S. government's Global Change Research Program (USGCRP), *Global Climate Change Impacts in the United States*.[9] This national-assessment report begins:

> Observations show that warming of the climate is unequivocal. The global warming observed over the past 50 years is due primarily to human-induced emissions of heat-trapping pollutants.[10]

This supports the central conclusions reached two years earlier by the United Nations-led Intergovernmental Panel on Climate Change (IPCC), which declared that there is more than a 90-percent likelihood that human emissions have caused most of the temperature increases over the last 50 years.[11] In fact, according to both the USGCRP and the IPCC, without the effects of heat-trapping pollution, the factors causing natural climate variability likely would have made the world cooler since 1950, instead of markedly hotter.[12]

Further temperature increases in the next few decades are now a foregone conclusion, the product of the continuing effects of past and present emissions of heat-trapping gases, which can persist in the atmosphere for a century or longer. After that, though, the extent of further change will depend in large part on what we humans do – whether we continue emitting heat-trapping gases at high levels, or take actions to reduce emissions.[13]

> *Choices made now will influence the amount of future warming. Lower levels of heat-trapping emissions will yield less future warming, while higher levels will result in more warming, and more severe impacts on society and the natural world.*
>
> U.S. Global Change Research Program[14]

RMCO TEMPERATURE PROJECTIONS

To illustrate both how climate change may affect California's national parks and how the extent of that change depends on the levels of future emissions, this report presents new projections of temperature change in ten national parks in California. The projections include so-called "downscaled" local results from six climate models for both a lower and a medium-high scenario of future emissions of heat-trapping gases.

In the lower scenario, emissions continue rising until mid-century then gradually decline. The medium-high scenario has emissions rising through the century, although slower than in recent years. (For more on emissions scenarios, including a graphic illustration of differences among them, see pages 7-8.)

Table 2 on the following page shows for each park the average of the projections from the six models for each scenario. To see the range of individual projections from the lowest projected increase to the highest for each park in each scenario, see tables 3, 4, and 5 on pages 9, 14, and 18.

These projections are generally consistent with those in a 2009 report from the California Climate

How Much Hotter California's National Parks Could Get by 2070-2099			
	Lower Future Emissions	Medium-High Future Emissions	Effect of Projected Temperature With Medium-High Emissions
Death Valley NP	+ 4.9°F	+ 8.1°F	Death Valley already is the hottest place in North America.
Golden Gate NRA	+ 3.7°F	+ 6.0°F	Golden Gate would become as hot as Santa Monica pier historically has been.
Joshua Tree NP	+ 4.4°F	+ 7.4°F	Joshua Tree would become 5.1° hotter than Death Valley historically has been.
Mojave NPRES	+ 4.7°F	+ 8.0°F	Mojave would become 7.3° hotter than Death Valley historically has been.
Muir Woods NM	+ 2.9°F	+ 5.9°F	Muir Woods would become as hot as San Diego historically has been.
Point Reyes NS	+ 3.6°F	+ 6.0°F	Point Reyes would become as hot as Santa Barbara historically has been.
Redwood NP	+ 3.5°F	+ 5.7°F	Redwood would become 0.5° less hot than Santa Barbara historically has been.
Sequoia/Kings Canyon NPs	+ 4.6°F	+ 7.6°F	The parks would become 0.6° hotter than the Sonoma County coast has been.
Yosemite NP	+ 4.5°F	+ 7.5°F	Yosemite would become 0.3° hotter than Sacramento historically has been.

Table 2. Averages of projections from 6 climate models for 2070-2099, compared to 1961-1990 temperatures. Abbreviations as in Table 1 on page 3. Data from World Climate Research Program and Western Regional Climate Center; analysis by the Rocky Mountain Climate Organization.[15]

Change Center. It included projections that statewide average temperatures could increase by 3.6 to 9.0°F by 2070-2099, compared to 1961-1990, with greater increases inland and smaller increases along the coast.[16]

In the lower-emissions scenario, the average projection for the national parks would have each get hotter by more than the additional 2°F that the U.S. government's national assessment says would lead, on a global scale, to "severe, widespread, and irreversible impacts."[17]

In the medium-high scenario, the average projections are for the parks to get even hotter – from 5.7°F hotter (for Redwood National Park) to 8.1°F hotter (for Death Valley National Park).

The right-hand column of Table 2 puts these projections in perspective. In the medium-high emissions future, Yosemite would be hotter before the end of the century than Sacramento was in 1961-1990. Sequoia and Kings Canyon would be hotter than the Sonoma County coast, Point Reyes as hot as Santa Barbara.

The temperature increases could be even larger. In recent years, levels of heat-trapping gases have actually been going up faster than assumed not only in this medium-high emissions scenario but also in all other emissions scenarios currently being used by scientists to estimate future pollution levels.[18] So if we do not take action to reduce heat-trapping emissions, these parks could get hotter in this century by even more than the amounts shown in Table 2.

On the other hand, we can head off even the lesser climate changes projected in the lower-emissions scenario. It does not assume new policies to reduce heat-trapping gases, and many options exist to lower emissions. According to the federal government's national assessment, to have "a good chance (but not a guarantee)" of avoiding a further global temperature increase above 2°F, it has been estimated that atmospheric concentrations of heat-trapping gases would need to stabilize in the long term at around today's levels.[19] The report also points out that because heat-trapping pollutants have a long-lasting effect, emission reductions made as soon as possible will do more to ward off climate change than reductions made later would.[20]

LESS WATER

The effects of heat-trapping pollution on the climate are also expected to include changes in precipitation and water availability in California.

A 2009 report from the California Climate Change Center includes projections of possible changes in the water cycle in the state, including:

> Continuation of the state's pattern of wet winters and dry summers, with an increase in its already-high variability of precipitation levels.
> An overall decline in total precipitation by the middle and end of the century for southern and central California, but with no clear, consistent projections for changes in future precipitation levels in the northern part of the state.
> An earlier depletion in spring of the mountain snowpacks that feed the state's major rivers, leading to increased summer dryness, with less soil moisture in summer.[21]

These projected changes in the climate – both the increases in temperature and changes in the water cycle – are likely to significantly affect national parks in California.

> *"National parks that have special places in the American psyche will remain national parks, but their look and feel may change dramatically."*
>
> U.S. Climate Change Science Program[22]

SCENARIOS AND MODELS

The new climate projections for ten national parks summarized in Table 2 are based on two emissions scenarios and six climate models. These are the same scenarios, the same terminology to describe them, and the same climate models used by the California Climate Change Center in assessing statewide climate-change impacts.[23]

Most recent projections of future climate conditions use one or more scenarios of future emissions developed through the IPCC for its 2007 reports on climate change and its effects. None of the IPCC scenarios has been

IPCC Emissions Scenarios

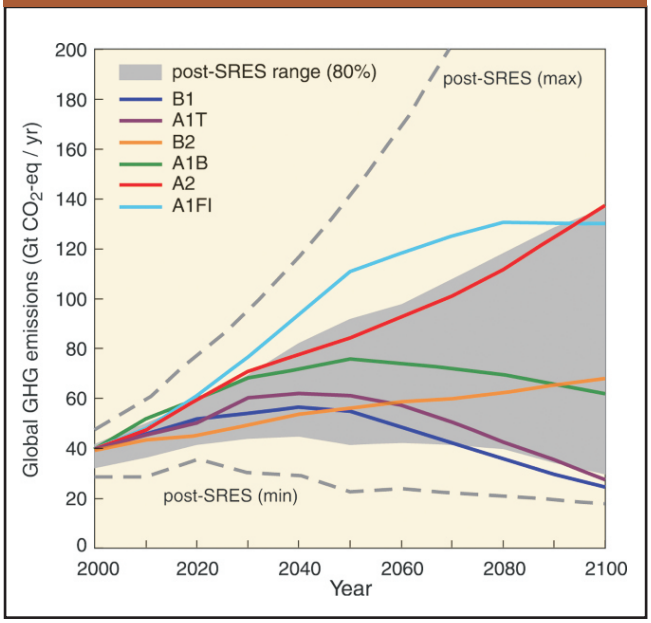

Figure 1. Selected IPCC emissions scenarios used in its 2007 reports. A2 and B1 are used for the projections in this report. Dashes indicate the range of newer ["post-SRES"] scenarios; the shaded area, the middle 80th percentile of that range. Figure from IPCC.[24]

determined to be more likely than others. Differences among the scenarios are due to different assumptions about changes in population, rate of adoption of new technologies, economic growth, and other factors.[25]

The two scenarios used for the RMCO projections are scenario B1, referred to as a lower-emissions scenario, and scenario A2, referred to as a medium-high one. Some reports refer to the A2 scenario as assuming "higher" emissions. But as stated above, actual emissions in recent years have been going up faster than assumed in any of the current IPCC scenarios, even those projecting higher emissions than the A2 scenario. In the next IPCC reports, scenarios like A2 will be considered intermediate ones and new higher-emissions scenarios will be developed, in part to reflect the high level of recent actual emissions.[26]

The future extent of climate change will depend not just on the actual levels of future emissions but also on the sensitivity of the climate to heat-trapping gases, which is approximated differently by different climate models. While climate projections from these models yield precise-appearing numbers, they should be taken as suggestions of possible futures, not as actual predictions. Attention should be paid to the range of individual projections and the degree of agreement or disagreement among them, as well as to the averages of individual projections. For the full range of the model results in the RMCO projections, see tables 3, 4, and 5, on pages 9, 14, and 18.

"U.S. average temperature has risen more than 2°F over the past 50 years and is projected to rise more in the future; how much more depends primarily on the amount of heat-trapping gases emitted globally and how sensitive the climate is to those emissions."

U.S. Global Change Research Program[27]

NPS

Mojave National Preserve

4 Yosemite, Sequoia, and Kings Canyon

Mountain parks face effects on temperature, snow and ice, forests and other ecosystems, wildfire, wildlife, and air quality.

National parks in California's Sierra Nevada Mountains protect some of the nation's best-loved natural wonders. Yosemite, a crown jewel of America's national parks, is 1,200 square miles of majestic mountains, deep valleys, crashing waterfalls, grand meadows, giant sequoias, vast wilderness, and much more – a place beloved by Californians and people from all around the world.

Adjacent to each other in the southern Sierra Nevada, Sequoia and Kings Canyon national parks testify to nature's breadth, beauty, and diversity. The parks span two and a half vertical miles, from an elevation of 1,500 feet in the foothills to Mount Whitney, at 14,494 feet the tallest mountain in the contiguous United States. The namesake giant sequoia trees of Sequoia National Park, also found in Kings Canyon, include the largest individual trees on the planet. These are only a few of the highlights of the geological as well as biological diversity that await visitors to these two special places – which are managed as one, jointly referred to as Sequoia/Kings Canyon national parks.

MORE HEAT

The climate projections produced by the Rocky Mountain Climate Organization (see pages 5-7) project how much hotter Yosemite and Sequoia/Kings Canyon could get in two different possible futures – one with lower future levels of emissions of heat-trapping gases, and one with medium-high emissions. For each scenario, six climate models were used to produce downscaled projections focused on the national parks. (See pages 7-8 and note 15 for details.) Table 3 presents for each park not just the average projection of the six models for each scenario (as was shown in Table 2) but also the range of the six individual projections in each case. As nobody knows which model may turn out to be most accurate, the full range of projections presents a fuller picture of the possible outcomes as humans continue to change the climate.

How Hot These Parks Could Get by 2070-2099

	With Lower Emissions	With Medium-High Emissions
Yosemite NP		
Average of 6 climate models	+ 4.5ºF	+ 7.5ºF
Range of model projections	+ 2.9 to + 6.4ºF	+ 4.7 to + 9.4ºF
Sequoia/Kings Canyons NPs		
Average of 6 climate models	+ 4.6°F	+ 7.7°F
Range of model projections	+ 2.9 to 6.5°F	+ 4.8 to 9.5°F

Table 3. Temperature comparisons to 1961-1990 levels. Data from World Climate Research Program; analysis by the Rocky Mountain Climate Organization.[28]

The easiest way to grasp the consequences of these possible temperature changes is to equate the future climate that could occur in these parks with the average temperatures of places that people know. As shown in Table 2 on page 6, if we were to pollute the atmosphere so much that we make Yosemite 7.5º hotter by the last three decades of this century, it would be on average as hot as Sacramento was in the 1961-1990 period. Sequoia/Kings Canyon, if 7.6º hotter, would be as

7.6º hotter, would be as hot as the Sonoma County coast has historically been.

But even these drastic changes could be understatements, as we now are on a path for higher emissions. (See pages 7-8.)

LOSS OF SNOW AND ICE

A hotter future may have more of an effect on water cycles in Yosemite and Sequoia/Kings Canyon than in most national parks, because the former get nearly all of their precipitation in winter.[29] Winter precipitation falling as rain rather than snow, smaller snowpacks being built up during winters, and snowpacks melting earlier would combine to result in more water flowing into rivers in winter, when it can be a hazard, and less in summer, when ecosystems and wildlife need it most.[30]

Sequoia/Kings Canyon national parks contain some 3,200 lakes and ponds and approximately 2,600 miles of rivers and streams, principally fed by melting snowpacks. In years of low snowpack accumulation, there is less water available for plant growth; trees and other plants grow less; and reduced plant growth and fruit and seed production result in altered food production for wildlife.[31]

With smaller snowpacks and earlier snowmelt in a hotter future, drier conditions are likely to appear more often, and earlier in the year, affecting the ecosystems and wildlife in these parks.[32]

Among the natural resources that are vulnerable is Yosemite Falls, the spectacular waterfalls dropping into Yosemite Valley. They are largely fed by snowmelt and typically goes dry by the end of summer. But smaller snowpacks and earlier snowmelt likely would dry out Yosemite Falls earlier in the summer, depriving more summer park visitors of one of the park's most famous sights.[33]

Effects on snow and ice of warmer winters already are showing up in the parks. Seven glaciers in and near Yosemite and Sequoia/Kings Canyon national parks have shrunk by 55 percent since 1900. Rapid retreat of the glaciers since 1985 appears to have been driven by higher temperatures, according to the scientists who study them.[34]

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Yosemite National Park

INCREASED TREE MORTALITY

In Yosemite and Sequoia/Kings Canyon, scientists have documented that small pine and fir trees are dying more quickly as the park gets hotter and drier. In 21 old-growth areas in the parks where individual trees have been inventoried since 1983, the rate at which trees have died nearly doubled over the course of just two decades. The increase is a change in “background” mortality in trees, not in deaths caused by insect outbreaks, fires, or other clear causes. The increase in tree death rates was widespread, across both different elevations and different species of trees, but concentrated in smaller trees. The researchers concluded that the most plausible explanation is that increasingly hot temperatures since 1984 have created a water deficit, stressing the trees in the plots enough to lead to an increase in mortality rates.[35]

BREAKUP OF ECOSYSTEMS

Changes in temperature, water availability, and soil moisture may cause broad-scale ecosystem changes in California. The range of suitable living conditions for many species may shift, typically to the north or to higher elevations. Also, the timing of seasons, such as earlier arrival of springs and delayed falls, can alter life cycles of and competitive advantages among species. Entire communities of species that make up an ecosystem, however, are not expected to respond together to these and other changes. Instead, each species likely will respond in its own ways and at different times. The end result is likely to be the break-up of existing ecosystems and formation of new, altered assemblages of places, plants, and animals.[36]

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Sequoia National Park

In Yosemite and Sequoia/Kings Canyon, substantial changes in forests could occur. Statewide, subalpine forests – the kind mostly found in these parks – could be reduced statewide by 50 percent to more than 80 percent by 2070-2099, according to models used in one study. The results suggest that subalpine forests would persist more in these national parks than in most of the state's mountain areas. But given the uncertainty of this type of modeling, the parks certainly could experience significant changes. Where subalpine forests are lost, their place is projected to be taken mostly by the different types of forests now found at lower elevations.[37]

Already, some forests and other plant communities are moving upslope to higher and cooler areas of the Sierra Nevada. These changes have been documented in Yosemite and to its north; Sequoia/Kings Canyon was not included in the study. In the areas that have been studied, low-elevation edges of mixed conifer forests have changed. Ponderosa pines are disappearing and giving way to oak and shrubs of the chaparral plant community. The changes have occurred in areas where winters no longer get below freezing. As winters get even warmer, forests are expected to continue their general upslope march.[38]

POTENTIAL EFFECTS ON SEQUOIAS

The giant sequoias after which Sequoia National Park is named could be vulnerable to human alteration of the climate. Both the chief of resources management and science at Sequoia/Kings Canyon and a U.S. Geological Survey research ecologist stationed there have expressed concern to the authors of this report that giant sequoias may not be resilient to the effects of rapid climate change, including water stress and increased wildfire.[39] Another NPS scientist at the parks has written that of all challenges facing the sequoias, "perhaps the most uncertain of the future stresses is that associated with predictions of human-induced climatic change."[40]

Obviously, any adverse effects on the parks' sequoias would have significant effects on the character of the parks and on the experience of visitors to them.

MORE WILDFIRE

Two recent reports from the California Climate Change Center project that climate change will lead to increased wildfire in many parts of the state, including in and near Yosemite and Sequoia/Kings Canyon.[41]

Wildfires have many effects, from the positive (such as opening up forests to natural

regeneration) to the negative (obviously including risks to lives and property). In national parks, fires also can lead to closures of park areas, which can interfere with vacations of park visitors.

LOSS OF WILDFLOWERS

Mountain wildflowers, too, seem to be at risk across the West. Research done in the Rocky Mountains suggests what could be in store for western mountains. In the Rockies, scientists have used heaters for more than a decade to raise summer temperatures of test plots. In the heated areas, fewer wildflowers grow, having been replaced by sagebrush, normally is found in lower-elevation, drier areas.[42] In another study, earlier snowmelt – a result of warmer winters – has been found to cause more wildflowers to be lost to frost. Earlier snowmelt starts the growing season earlier and flower buds open sooner, but then are more exposed to mid-spring frosts. From 1999 through 2006, the percentage of wildflower buds lost to frost doubled, compared to the previous seven years.[43]

DISRUPTION OF WILDLIFE

A changed climate could mean disruptions in the wildlife species now found in these three parks, as elsewhere. Some species may go extinct. The Intergovernmental Panel on Climate Change warns that just 4° to 5°F of higher temperatures could leave 20 to 30 percent of plant and animal species in climatic conditions far outside those of their current ranges, making them "likely to be at increasingly high risk of extinction."[44] One reason this percentage is so high is that stresses resulting from climate change would come atop others such as habitat loss.[45] Human alteration of the climate already is affecting wildlife species by leading to changes in the ranges species occupy and the timing of such activities as migration and breeding. These adaptations may promote species survival or create new risks – for example, if one species changes its timing in a way that creates mismatches with food sources or habitat requirements.[46] New species moving into an area also may increase competitive pressures on current species for food, habitat, or other necessities.[47]

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Pika

A study of bird populations in these parks identifies possible climate-change impacts that may already be underway. In recent years, bird populations in Sequoia/Kings Canyon have been both lower than expected and lower than in Yosemite. Importantly, breeding adults have increased in Sequoia/Kings Canyon while young birds have declined, indicating less successful reproduction. Scientists have offered as a possible explanation that climate change may have made Sequoia/Kings Canyon enough hotter and drier to lower the birds' breeding success. Yosemite, by contrast, being higher and cooler, may not have been affected enough to alter breeding success rates there.[48]

In Yosemite, mammals are moving upslope to stay ahead of a higher temperatures. In the early 20th century, biologist Joseph Grinnell surveyed the distributions of small mammals in the park. A recent re-survey showed about half the species in the park have shifted to different elevations than before. Most have moved higher, by an average of about 500 yards. High-elevation specialists, such as pikas and alpine chipmunks, have lost the lower ends of their ranges and are left in smaller areas. These shifts are consistent with how scientists expect wildlife to respond to higher temperatures.[49]

Researchers a few years ago projected how climate change may affect the mammals present in Yosemite and seven other national parks. They used computer models to project how a doubled atmospheric concentration of heat-trapping gases would lead to shifts in plant communities, then assumed that mammals would move to stay with their habitats. For Yosemite, they projected that one current species would be eliminated, as the park would no longer have its habitat. (The species was not identified in their article.) They also projected that 25 new mammal species (also unidentified) would move into the park as new

habitats appear there.[50]

A few caveats, however, are in order. First, the projections rest on a model of how an altered climate can drive changes in the distribution of plants. Those changes are difficult to model, and those projections cannot be taken as definitive. Second, as the researchers acknowledged, they did not consider whether geographic or other barriers would keep new mammals from moving into the parks. Third, the fact that the study's authors did not identify in their publication the particular mammal species that might move makes it more difficult to assess the likelihood of these changes occurring. Still, this study suggests that Yosemite, and by extension Sequoia/Kings Canyon, could see different mammals present there as a result of climate change.

There is other evidence, too, of wildlife changes in and around these parks. Populations of Sierra Nevada yellow-legged frog populations are in sharp decline in the parks and elsewhere in the region. Scientists have identified as one cause that smaller snowpacks have lowered pond water levels to the point that fewer tadpoles now survive.[51]

MORE AIR POLLUTION

Despite their distance from large cities, Yosemite and Sequoia/Kings Canyon have very significant air-pollution problems, one of which – ozone levels – is likely to worsen with a hotter climate. Ground-level ozone has been firmly established to harm people's health, and the U.S. Environmental Protection Agency (EPA) has set air quality standards at the levels necessary to protect public health. EPA in 2008 strengthened the ozone standard based on new health information, and in 2010 proposed to further strengthen it.

Yosemite and Sequoia/Kings Canyon consistently exceeded the old, pre-2008 federal standard, the latter with among the highest levels in the national park system. In 2007, for example, Sequoia/Kings Canyon had 44 days more polluted than the standard then in effect. That was the highest such total of any of the nearly 50 park units with air quality monitors in or next to them.[52] More ozone forms when temperatures are higher, so a hotter climate would lead to higher ozone levels. More pollution control measures will be required to get the parks' air clean enough to protect people's health.[53]

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Kings Canyon National Park

5 Points Reyes, Golden Gate, Redwood, and Muir Woods

Northern coastal parks face effects on temperature, sea level, forests and other ecosystems, wildfire, wildlife, and air quality.

In northern California, 2.2 million visitors a year are drawn to the spectacular scenery of Point Reyes National Seashore's beaches, cliffs, and upland wilderness, home to some of the greatest biological diversity in the country.

Golden Gate National Recreation Area is the "backyard" national park to those who live and work in the San Francisco Bay Area – hence its astonishing 15 million visitors each year. It has something for almost anyone – a place to walk on a beach, tour any of five National Historic Landmarks, or enjoy wetlands and other coastal habitats and the wildlife they support.

Redwood National Park and Muir Woods National Monument protect many resources and offer many attractions. But none rival their amazing, majestic coast redwoods – up to 35 stories high, as old as 2,200 years, and found only along California's North Coast.

These special places and their nationally important resources, though, face several major threats from human-caused climate change.

MORE HEAT

Table 4 presents the climate projections produced by the Rocky Mountain Climate Organization of how much hotter these parks could get with lower future levels of heat-trapping gases or with medium-high levels. As is the case with Table 3, the lowest and highest individual projections are shown here, giving a full picture of the range of changes suggested by the different climate models.

With medium-high future emissions, the average of the six climate models is that toward the end of the century Point Reyes would be as hot as Santa Barbara historically has been. Golden Gate would

How Hot These Parks Could Get by 2070-2099

	With Lower Emissions	With Medium-High Emissions
Point Reyes NS		
Average of 6 climate models	+ 3.6ºF	+ 6.0ºF
Range of model projections	+ 2.7 to + 5.2ºF	+ 4.2 to + 7.5ºF
Golden Gate NRA		
Average of 6 climate models	+ 3.7°F	+ 6.0°F
Range of model projections	+ 2.7 to 5.3°F	+ 4.2 to 7.6°F
Redwood NP		
Average of 6 climate models	+ 3.5ºF	+ 5.7ºF
Range of model projections	+ 2.6 to + 5.0ºF	+ 4.3 to + 6.7ºF
Muir Woods NM		
Average of 6 climate models	+ 2.9°F	+ 5.9°F
Range of model projections	+ 2.0 to 4.6°F	+ 4.2 to 7.5°F

Table 4. Temperature comparisons to 1961-1990 levels. Data from World Climate Research Program; analysis by the Rocky Mountain Climate Organization.[54]

become as hot as Santa Monica Beach; Redwood, 0.5°F hotter than Santa Barbara; and Muir Woods, as hot as San Diego. (See page 6.)

SEA LEVEL RISE

A rising sea is one of the greatest threats of an altered climate. A 2009 report from the California Climate Change Center projects that lower to medium-high levels of future emissions of heat-trapping gases would lead to the sea level along the California coast rising by 2.0 to 4.7 feet by the end of the century.[55] The higher sea would result from expansion of the volume of ocean water (since water expands when it is warmer) and melting land-based ice (which adds water to the oceans).

Both Point Reyes and Golden Gate are among the areas highly vulnerable to this sea-level rise. The threats include both inundation of low-lying areas and, as storm surges from coastal storms operate atop a higher sea, increased flooding and erosion from those storms.

At Point Reyes, the National Park Service says that a higher sea level "will transform the Point Reyes visitors have come to treasure, both for its wildlife and for its powers to rejuvenate."[56]

Although all coastal areas of the seashore stand to be affected, the U.S. Geological Survey (USGS) has identified the entire western coast of the seashore as having a very high vulnerability to a rising sea, based on such factors as wave heights, the range of local tides, and coastal slopes.[57] Most of this particularly vulnerable side of the seashore is comprised of Point Reyes Beach, a very popular 10-mile-long natural, undeveloped beach.

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Point Reyes National Seashore

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Point Reyes National Seashore

Other areas vulnerable to a higher sea include the seashore's other beaches, including Drakes Beach, which features a wide stretch of beach, a backdrop of dramatic white sandstone cliffs, and drive-up access, all of which combine to make it a very popular place.

Wetlands, too, are at risk, including the wildlife-rich estuaries of Abbotts Lagoon and Drakes Estero, one of the most ecologically pristine estuaries in California and the only coastal waters in California that are in the National Wilderness Preservation System.

The National Park Service says that seashore roads at risk of increased flooding include many of the park's most important roads, including sections of Sir Francis Drake Boulevard and Highway 1 along Tomales Bay, Sir Francis Drake Boulevard at the head of Schooner Bay, and Highway 1 and the Olema-Bolinas Road along Bolinas Lagoon. Many of these roads already flood during winter storms, and governments may have to expend extra millions of dollars to either protect or relocate these roads as sea levels rise even higher.[58]

Cultural resources are at risk of flooding and erosion, also, including some of the 120 known sites at Point Reyes that are evidence of the Coast Miwok Indians settlements going back 5,000 years.[59]

At Golden Gate National Recreation Area, USGS has rated half of the 59 miles of the national recreation area's shorelines as very high or high in vulnerability to sea-level rise.[60] Among the areas identified as at risk in this study or by NPS are heavily visited Ocean

Beach, China Beach, and Baker Beach, all near San Francisco; Muir Beach and Stinson Beach; broad coastal areas, such as Crissy Field; lower portions of freshwater streams; historic Fort Point and its access road; Fort Mason; and portions of the Presidio of San Francisco, the oldest continuously used military post in the nation.[61] These areas account for many of the park's 15 million visitors a year, one of the highest totals in the national park system.

NPS at Golden Gate has been a pioneer in undertaking forthright public education about the reality of climate change and its threats to the park. At one public display – "Sea level is rising now!" – NPS informs visitors that the impacts of the higher seas will be especially felt during winter storms, when storm surge, large waves, and high tides will flood coastal lowlands, wash away beaches, and undermine coastal bluffs. The display also states that what today represents a 100-year coastal flood would likely occur every year.[62]

> *"If global warming progresses at predicted rates, sea level could rise three feet or more by the end of this century. The park could lose its beaches and suffer severe coastal erosion. Historic buildings, archaeological sites, and roads will be threatened."*
>
> National Park Service[63]

At Redwood, shoreline resources endangered by sea-level rise include 15 miles of sandy beaches, estuaries, lagoons, stretches of Highway 101, a visitor center, campgrounds, and picnic areas.[64]

DISRUPTION OF WILDLIFE

Among the many effects of higher seas and of storm surges reaching further inland because they start atop higher seas is likely to be a loss of important areas of wildlife habitat. At Point Reyes, harbor seals could lose haul-out sites where the seals pup, molt, and rest. These are crucial areas for sustaining the local year-round population of about 7,000 harbor seals at the seashore, which make up 20 percent of the mainland population of the species in the state. For this and other reasons, NPS states that future climate change could dramatically alter the number of seals and the location of their colonies at the seashore.[65]

An example of a wildlife area important to many species that could be disrupted by flooding and erosion from higher seas and storm surges is Drakes Estero at Point Reyes. It harbors many of the seashore's harbor seals and shorebirds, plus endangered species from peregrine falcons and marbled murrelets to several fish and plant species.[66]

At Redwood, harbor seal and Steller's sea lion breeding and haul-out areas could be lost to higher seas, as could important shorebird areas.[67]

Point Reyes is particularly famous for its diversity of bird life. With nearly 490 species recorded – fully 45 percent of all bird species in North America – the seashore easily claims the prize for the most bird species identified in any U.S. national park. The seashore's species total is larger than the bird lists of 40 entire states.

Widespread changes have already begun occurring, in California and across America, in where bird species live and the timing of their migration.[68] For the future, significant changes have been projected in where bird species will live.[69] One projection for California is that by 2070 over half of the state could be populated by novel assemblages of bird species, as birds both expand and contract their ranges in response to the effects of a disrupted climate.[70] Widespread changes affecting America's birdlife can be expected to be manifested at Point Reyes, and changes in the bird species present at the seashore must be considered likely. As anywhere, the effects are most likely to first appear among species that already are at risk, especially those with specialized needs for habitats that are vulnerable. An example is the western snowy plover, a threatened species that nests on the seashore's beaches and so is at risk of losing habitat to sea-level rise.

Gene Nieminen
U.S. Fish & Wildlife Service

Piping plover

NPS

Redwood National Park

percent of their annual water supply. Their adaptations to get moisture from fog include branches covered with fine needles that are very efficient at catching the fog, which then condenses and falls to the forest floor below, where their roots can absorb the water.[71]

But a recent study indicates that significantly less fog is drifting in from the Pacific Ocean, stressing the trees and this unique coastal ecosystem. Scientists have found that during the last century the amount of fog has dropped by about one-third. At the same time, records show that the temperature difference between the coast and interior California has also declined substantially, in step with the decreasing fog. The scientists who did this study expect that a long-term continuation of the decline in summer fog would affect future growth of the area's coast redwoods.[72] These trees, the tallest in the world, may have future trouble growing so high.

For northern California, models do not show clear or consistent projections of changes in total precipitation. In Muir Woods, to the south, less precipitation is expected in the future. (See page 7.) If both precipitation and fog levels go down there, that could be even more problematic for that park's coast redwoods.[73]

RISKS TO COAST REDWOODS

Coast redwoods are limited to a few hundred coastal miles in northern California, where a favorable confluence of location, climate, and elevation provides the only place where they can be found. Redwood National Park and Muir Woods National Monument are among the favored spots.

Crucially, the cool, moist air created by the Pacific Ocean keeps the trees there continually damp, even during summer droughts. The summertime fog, in fact, provides about 40

"Decreases in summer fog could devastate the majestic, centuries-old redwood trees at Muir Woods."

National Park Service[74]

6 JOSHUA TREE, DEATH VALLEY, AND MOJAVE

Southern California parks face effects on temperature, plants and ecosystems, wildfire, wildlife, and air quality.

These three natural treasures in southern California encompass an incredible diversity of landscapes and ecosystems.

Death Valley National Park is famous for its extremes – having the hottest place in North America, with summer highs routinely topping 120ºF; the driest; and the lowest, 282 feet below sea level. It also is the largest national park in the contiguous United States.

Joshua Tree National Park spans three California ecosystems: the Colorado Desert (an extension of the Sonoran Desert); the Little San Bernardino Mountains; and the Mojave Desert. The park's namesake Joshua tree, a testament to the resilience and vulnerability of life in the desert, is part of a rich breadth of plant life in the park.

In Mojave National Preserve, the third largest national park in the contiguous United States, the Great Basin, Sonoran, and Mojave deserts converge. It is a land of mountain ranges, sand dunes, great mesas, and extinct volcanoes, with a wide variety of desert plant life in combinations that exist nowhere else in the country.

MORE HEAT

The RMCO climate projections for these parks are presented in Table 5, again with the range of all six projections for each emissions scenario as well as the average of the six.

How Hot These Parks Could Get by 2070-2099

	With Lower Emissions	With Medium-High Emissions
Joshua Tree NP		
Average of 6 climate models	+ 4.4ºF	+ 7.4ºF
Range of model projections	+ 2.9 to + 6.0ºF	+ 4.7 to + 9.0ºF
Death Valley NP		
Average of 6 climate models	+ 4.9°F	+ 8.1°F
Range of model projections	+ 3.0 to 6.9°F	+ 5.0 to 10.2°F
Mojave NPRES		
Average of 6 climate models	+ 4.7ºF	+ 8.0ºF
Range of model projections	+ 3.0 to + 6.5ºF	+ 5.0 to + 9.8ºF

Table 5. Temperature comparisons to 1961-1990 levels. Data from World Climate Research Program; analysis by the Rocky Mountain Climate Organization.[75]

The average projection with medium-high emissions would make Death Valley much hotter than any place in North America, as the park already is the hottest on this continent. Joshua Tree would be 5.1ºF hotter than Death Valley historically has been, and Mojave 7.3ºF hotter. (See page 6.)

INTOLERABLE HEAT

Already among the hottest places in the country, these parks could become intolerably hot for many people for longer stretches of the year. In the Death Valley of today, most summer days exceed 100ºF. In 2001 there were 154 such days. Days even get much hotter than that. The summer of 1996 had 40 days over 120ºF, and

105 days over 110ºF. Joshua Tree and Mojave, too, have many extremely hot days. If their average temperatures approach or exceed Death Valley's historical averages, their hottest days would get even hotter.

Visitors to these desert parks face real exposure to this heat, since they typically are outdoors, not in air-conditioned buildings. Already, Joshua Tree's lowest monthly visitation levels are in June through September, and Death Valley's July visitation is lower than all other non-winter months.[76] By contrast, most national parks see much higher visitation in summer than in other seasons. With even more extremely hot days, summer visitation to the desert parks in the future may be much less than it otherwise would be.

> *"Some recreation areas that are already hot during the summer recreation season will see decreases in use."*
>
> U.S. Climate Change Science Program[77]

LOSS OF JOSHUA TREES

The namesake plant species of Joshua Tree National Park is, as one would expect, found there. Death Valley and Mojave also have the trees, with the latter park home to the largest Joshua tree forest anywhere.

But scientists believe that the hotter temperatures in all three parks in the future likely will eliminate them from much of their current range, including throughout the park named for them. In a study, scientists identified the climate conditions in which Joshua trees can survive and compared them to seven climate projections – six from individual models and another from an ensemble of 22 models. Each projection shows that suitable climate conditions for Joshua trees will be eliminated across most of its current range, leaving perhaps only 10 percent suitable for the tree's continued survival. Most of the Joshua tree's range in California, including all of Joshua Tree National Park, would no longer be able to sustain the species. Stands would be greatly reduced in the other desert parks. Conditions are projected to remain sustainable for some existing populations – in California, only in the northernmost Mojave Desert, and also in parts of Nevada, Arizona, and Utah. The Joshua tree's ability to expand into new suitable areas will be constrained by limits on seed dispersal.[78]

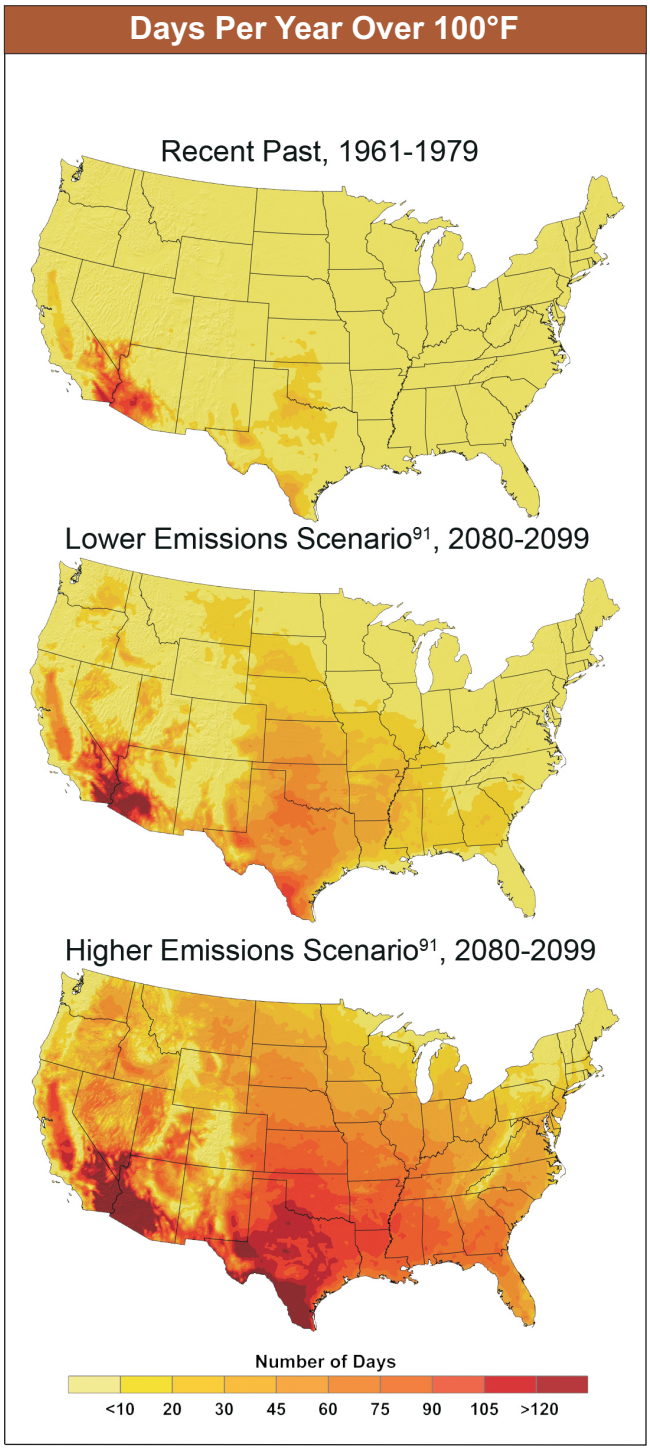

Figure 2. Figure source: U.S. Global Change Research Program.[79]

These projections are consistent with the long-standing scientific understanding that Joshua trees need crisp winter freezes to flower and set seeds. Apparently the freezing temperatures damage the growing end of a branch and stimulate flowering, which is necessary for seed production.[80]

A study done in Joshua Tree National Park also documents that Joshua trees have low rates of survival when damaged by wildfires and even lower rates when wildfire is followed by drought conditions.[81] As wildfires have become more common in the desert because of the spread of non-native grasses (see below) and drought conditions are expected to become more common in a disrupted future climate, this study, too, suggests that persistence of Joshua trees is imperiled there.

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Joshua Tree National Park

BREAKUP OF ECOSYSTEMS

Changes in temperature and precipitation can drive the breakup of existing assemblages of places, plants, and animals. Deserts across the arid Southwest are projected to get even hotter and drier in this century, feeding a self-reinforcing cycle of invasive plants, fire, and erosion. Invasive plants can be major threats because some are highly adaptable to hotter or otherwise changed conditions, reproduce quickly, and crowd out native plants.[82]

Perhaps the greatest such threat now present in a desert park is not in California but in Saguaro National Park in Arizona. There, the invader is buffelgrass, an introduced African species, which is disrupting the park and nearby areas, primarily by promoting the spread of wildfire.[83] As a U.S. Geological Survey scientist says, “Buffelgrass is the worst environmental problem we face in the Sonoran Desert. We're getting ready to see the unhinging of a unique American ecosystem.”[84]

California desert parks do not now face anything as severe as the buffelgrass problem in Arizona. But the National Park Service staff in Joshua Tree has already documented the extensive spread into the park of non-native grasses of the type that can be promoted by an altered climate, such as red brome and cheatgrass. Among the effects are changes in the desert's natural fire regime. Historically, wildland fires in desert systems such as these were rare and covered limited areas. Native plant communities evolved without a tolerance for fires. Over the past 40 years, however, wildfires have been occurring more frequently and burning larger areas because of the spread of non-native grasses.[85]

LOSS OF WILDLIFE

The desert tortoise, a threatened species, could be further stressed by a hotter and drier climate at Death Valley, Joshua Tree, and Mojave. Desert tortoise populations have been in a state of decline in the Mojave and Sonoran deserts of southern California since the 1950s, with average populations dropping from 200 to only 5 to 60 per square mile.

Like all reptiles, tortoises have minimal ability to self-regulate their internal temperature, and when the air temperature exceeds 91°F or so they must find shade or retreat to burrows to survive. Droughts also force the tortoises to spend more time in their underground burrows to minimize water loss. The tortoises normally spend about 95 percent of their time in burrows, so more time there would further limit their ability to search for food, which itself could be reduced by droughts.

Reproduction also could be affected by hotter and drier conditions. Females lay fewer eggs during drought years, and elevated soil temperatures could threaten eggs that are laid. The gender of tortoises is determined by soil temperature during incubation, with only females being born when temperatures are above about 89°F, so a hotter climate could change gender ratios. And soil temperatures above 95°F are lethal to developing young tortoises.[86]

Desert bighorn sheep in California are also vulnerable to climate disruption. Of 80 separate populations that roamed southern California about 65 years ago, 30 no longer exist. Scientists

have determined that the local extinctions occurred most often in the hottest, driest areas.[87] Other research in Utah and New Mexico shows that birth and survival rates of desert bighorn lambs there go up in wet years and down in dry years.[88] So projections for a hotter, drier climate raises concerns about the desert bighorn's future across its range, including in California's desert parks.

MORE AIR POLLUTION

Death Valley, Joshua Tree, and Mojave already have excessive levels of ozone, having consistently exceeded the old federal health-based air quality standard, with readings among the worst anywhere in the national park system. In 2007, for example, of nearly 50 park units with monitoring stations in or near the park, Joshua Tree had the highest measured ozone levels and the second highest number of days (40) exceeding the maximum 8-hour average concentration of the old standard.[89] In a hotter climate, achieving and maintaining air quality that protects people's health will be even harder, requiring additional emission control measures.[90] (See page 13.)

7 Tackling Climate Disruption

To keep California's national parks such special places, new efforts will be needed to protect their resources. Even more important will be reducing heat-trapping gases enough to avoid dangerous climate disruption.

As the risks of a changed climate dwarf all previous threats to our national parks, new actions to face these new risks must also be on an unprecedented scale. Parks should be managed to preserve their resources at risk, to adapt as best as possible to unavoidable changes, and to provide visible leadership in addressing climate change. Ultimately, of course, we need to curtail emissions of climate-changing pollutants enough to reduce their impacts, in parks and everywhere else.

A full suite of actions by the National Park Service and others will be needed to protect national parks and their imperiled resources. Recommended actions were outlined in section 9 of *National Parks in Peril: The Threats of Climate Disruption*, an October 2009 report by the Rocky Mountain Climate Organization and the Natural Resources Defense Council.[91] In September 2010, NPS adopted its first-ever *Climate Change Response Strategy*.[92] It provides an excellent roadmap, with many of the steps that are needed and within the Service's control. Now NPS actions are needed to implement that strategy. Also, Congress and others need to take additional actions that are within their areas of responsibility. Examples include:

- The NPS should consider the combined effects of climate change and of other stresses on the resources and values of areas they manage, and work to reduce all the stresses that pose critical risks.
- NPS should develop area-specific and resource-specific plans to protect the particular resources and values most at risk from climate change and other stresses.
- National Park Service officials and managers should speak out publicly about how climate change and its impacts threaten the areas for which they are responsible and the broader ecosystems on which they depend.
- NPS managers should use environmental education programs to inform visitors about a changed climate and its impacts in managed areas and about what is being done to address climate change and those impacts. The NPS should require concessionaires in parks to do so, too.
- The Congress and the Administration should adequately fund NPS actions to address a changing climate.
- The NPS should reduce emissions in its own operations, and provide information to visitors on those actions to inspire them to undertake their own emission reduction actions.
- The Congress and the Administration should rebuild and enhance the scientific and research capacity the NPS had prior to 1993.

"The focus of the climate change discussion has largely shifted from the evidence that climate change is occurring to what we can do about it. As stewards of our nation's natural and cultural heritage, we have an obligation to act now."

Jon Jarvis, Director
National Park Service[93]

PREVENTING DANGEROUS CLIMATE DISRUPTION

This section contributed by Theo Spencer, Natural Resources Defense Council

Ultimately, to protect California's national parks for the enjoyment of this and future generations, it will take actions by all of us to reduce emissions of heat-trapping pollutants enough so that climate disruption does not overwhelm these special places.

California must continue strong implementation of AB 32, the California Global Warming Solutions Act of 2006. The cornerstones of this effort are a firm cap that declines over time, cost-effective energy efficiency, and pursuit of clean energy resources. Strategies to cut global warming pollution will protect California's environment, improve public health, and grow the economy by stimulating development of new technologies and processes for reducing pollution.

The federal government also must lead the way, with broad, aggressive actions on four essential fronts:

> Enacting comprehensive mandatory limits on global warming pollution to reduce emissions by at least 20 percent below current levels by 2020 and 80 percent by 2050. This will deliver the reductions that scientists currently believe are the minimum necessary, and provide businesses the economic certainty needed to make capital investments to achieve those reductions.
>
> Protecting the current Clean Air Act authority of the U.S. Environmental Protection Agency (EPA). This includes current authority under the Clean Air Act to set standards to curb global warming pollution from vehicles, power plants, and large industrial sources. The Supreme Court held in its landmark 2007 decision that EPA must act if it finds, based on the science, that carbon dioxide and other global warming pollutants endanger public health and the environment.

Accordingly, EPA issued consensus national standards on April 1 to cut global warming pollution from new vehicles. And on May 13, EPA issued a rule requiring that the biggest new and expanded pollution sources start applying available and affordable pollution control measures starting in 2011.

EPA authority must also be maintained to institute the tightest pollution controls necessary to protect public health and the environment. That includes standards for the pollution that causes smog and other dangerous and fatal respiratory ailments, pollution of hazardous materials like mercury and dioxin, and dangerous waste from power plants and other industrial facilities.

Overcoming barriers to investment in energy efficiency to lower emission-reduction costs, starting now. To fully harness energy efficiency potential, many opportunities require additional federal, state, or local policies to unleash investments that are already cost-effective even without a price on greenhouse gas emissions. Policies include building, industry, and appliance efficiency (standard) upgrades, as well as incentives for "smart" transportation and growth and for advanced vehicles.

Accelerating the development and deployment of emerging clean-energy technologies to lower long-term emission reduction costs. That means incentives and investments in renewable electricity, low-carbon fuels, and carbon capture and storage; a federal renewable-energy standard; and infrastructure upgrades to support transmission capacity for these renewable assets. Finally, regulations are needed to require any new coal-fired power plant to capture and permanently geologically sequester at least 85 percent of its carbon dioxide emissions, along with state and federal regulatory frameworks for site selection, operation, and monitoring for carbon capture and geologic storage systems.

Notes

For general information on climate change and its overall impacts, readers are referred to a report by the U.S. government's Global Change Research Program, *Global Climate Impacts in the United States*, released in 2009, which is cited in many of the following notes. It is perhaps the single clearest statement of the current overall state of scientific knowledge. For any reader interested in digging deeper, it also lists several hundred sources on particular points. The California Climate Change Center also has many excellent reports on climate change and its impacts in California.

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