National Parks in Peril
The Threats of Climate Disruption

YOSEMITE NATIONAL PARK

At stake are the resources and values that make our national parks the special places that Americans love.

the Rocky Mountain Climate Organization

NRDC
The Earth's Best Defense

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A Report by

The Rocky Mountain Climate Organization

and

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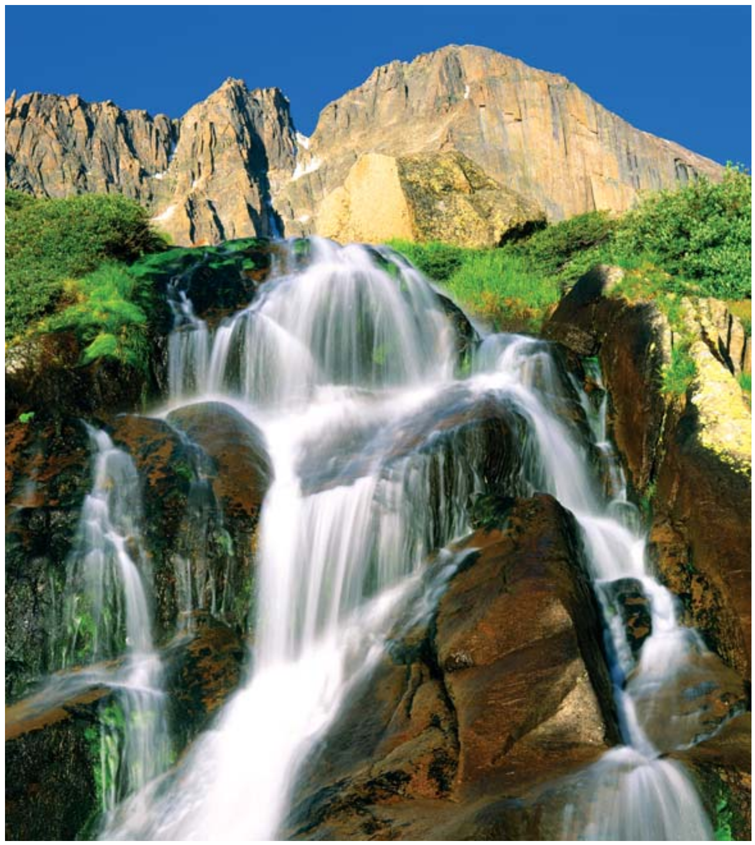

ROCKY MOUNTAIN NATIONAL PARK / PHOTO: JOHN FIELDER

the ROCKY MOUNTAIN CLIMATE Organization

NRDC

THE EARTH'S BEST DEFENSE

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

NRDC (Natural Resources Defense Council) is a national nonprofit organization with more than 1.2 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, D.C., Los Angeles, San Francisco, Chicago and Beijing. Visit us at www.nrdc.org.

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THE GREATEST THREAT TO NATIONAL PARKS

Human disruption of the climate is the greatest threat ever to our national parks.

This report focuses primarily on 25 national parks that we identify as having the greatest vulnerabilities to human-caused climate change. They face 11 different types of risks.

A **loss of ice and snow** is one of the most obvious impacts of a changing climate. Glaciers are melting in our national parks, a handful of which contain the vast majority of the nation's glaciers. In many national parks, snow-covered mountains contribute to some of the most spectacular scenery in the nation. But higher temperatures, less snowfall, and earlier snowmelt are already leading to declines in mountain snowpack across the West. With less snow, fewer visitors will be able to see snow-capped mountains in parks. Opportunities for cross-country skiing, snowshoeing, and other winter activities in parks also will be reduced. (See pages 7-10.)

For a summary of how losses of ice and snow, and other impacts, are already underway in national parks, see the next page.

Parks in the West and along the Great Lakes face a **loss of water**. In the West, a changed climate will reduce water availability, especially in the summer. The Colorado Plateau, home to our largest concentration of national parks, is expected to get particularly hotter and drier. In Zion National Park, reductions in river flows could change how the Virgin River is continuing to shape Zion Canyon. Water levels of the Great Lakes are likely to fall, affecting ecosystems and recreation in Great Lakes parks. (See pages 11-14.)

The 74 national parks on our coasts face **higher seas and stronger coastal storms**. Depending on future emissions of heat-trapping gases, seas are expected to rise from about 2.3 feet to 3 or 4 feet by century's end. Nearly all of Everglades, Biscayne, and Dry Tortugas national parks and Ellis Island National Monument are less than that above the current sea level. All four parks could be lost to rising seas, representing the first-ever losses of entire national parks. (See pages 15-18.)

How National Parks Are Already Changing

Glaciers are already melting in all national parks that have them, including Denali, Mount Rainier, and Yosemite national parks. All glaciers in Glacier National Park could be gone in 12 or 13 years. (See pages 7-9.)

Mountain parks are already losing late-summer streamflows as smaller glaciers produce less meltwater. In one glacier-fed watershed in North Cascades National Park, summer flows already are down 31 percent. (See page 9.)

In the West, more winter precipitation is already falling as rain rather than snow, and snow is melting earlier. Western parks already have less mountaintop snow in spring and summer. (See pages 9-10.)

In Yellowstone National Park, the winter season for snowcoaches and snowmobiles already is starting in December or even January rather than November. (See page 10.)

The Colorado Plateau already has both drier conditions and the greatest temperature increase in the 48 contiguous states. In Bandelier National Monument and Mesa Verde National Park, as many as 90 percent of piñon pines have died. (See page 12.)

The coastal barrier island of Assateague Island National Seashore, already hammered by a rising sea level and coastal storms, is not far from being broken apart by the sea. (See page 16.)

The National Park Service has already had to move Cape Hatteras Lighthouse inland to keep it above the rising sea. (See page 34.)

Across the country, more heavy storms already are producing bigger downpours. A heavy downpour in 2006 flooded Mount Rainier National Park so much that it was closed for six months. (See page 18.)

Western mountains already are hot enough that tree-killing bark beetles are spreading to higher elevations than before and reproducing faster, in some places with one generation each year instead of one every three years. In Rocky Mountain National Park, nearly all mature lodgepole pine trees are being killed by beetles. (See pages 19-21.)

In Yosemite and Sequoia/Kings Canyon national parks and other spots across the West, trees of all types and ages are dying at faster rates than before. (See page 21.)

In Yosemite, winters have already warmed up so much that the lower-elevation edges of conifer forests are dying out and being replaced by oak and chaparral. (See pages 21-22.)

In Saguaro National Park, hotter temperatures already are promoting the spread of buffelgrass, an invasive species that brings wildfire into the desert ecosystem for the first time, threatening saguaros and other native desert species. (See page 22.)

In Yellowstone National Park, mountain pine beetles already are infesting higher elevations than before and threatening to wipe out whitebark pines, a mountaintop species. Their nuts are such an important pre-hibernation food for the region's grizzly bears that reduced whitebark pine nuts lower grizzly birth rates. (See page 28.)

Pikas, mountaintop mammals especially sensitive to warm temperatures, already have been eliminated in several of the lower-elevation mountains they used to inhabit. (See page 26.)

In Yosemite National Park, mammals already are changing where they live by moving to higher elevations. (See page 26.)

In Rocky Mountain National Park, mountaintop tundra areas already are warming up earlier in the spring, which is linked to a 50 percent decline in white-tailed ptarmigan, which live on the tundra year-round. (See page 27.)

In Yosemite and Sequoia/Kings Canyon national parks, conditions already are hotter and drier, apparently driving a 10 percent per year decline in mountain yellow-legged frogs. (See page 29.)

In Yellowstone National Park's Firehole River in 2007, temperatures already were hot enough for several days to kill as many as a thousand trout in the largest documented fish kill in the park's 135-year history. (See page 30.)

In Virgin Islands National Park, 50 percent of the corals in the park's coral reefs have died since 2006 from causes related to excessive water temperatures. (See page 31.)

In Yellowstone National Park, summer heat has already become excessive enough to stress trout, which are coldwater fish, prompting the National Park Service to close 232 miles of rivers to fishing. (See page 37.)

More downpours and flooding are occurring everywhere, as a changing climate already is leading to more precipitation coming in heavy storms. The forecast is for the heaviest precipitation events to continue getting stronger, causing erosion and flooding that threatens resources in virtually all parks. (See page 18.)

An altered climate is leading to a **loss of plant communities** of parks, including a disruption of mountain forests, tundra, meadows, and wildflowers; of desert ecosystems; and of coastal plant communities. In Saguaro National Park, saguaros could be eliminated, and in Joshua Tree National Park, Joshua trees could be eliminated. (See pages 19-24.)

A **loss of wildlife** in parks is projected to result from a changed climate, as some species may go completely extinct and some local wildlife populations in particular parks may be eliminated or decline sharply. Among the populations that are vulnerable are grizzly bears in Yellowstone and Grand Teton national parks, lynx, Florida panthers, pikas, mountain and desert bighorn sheep, white-tailed ptarmigan, sooty terns, sea turtles, amphibians, trout, salmon, corals, and butterflies. (See pages 25-32.)

Higher seas, stronger coastal storms, and increased downpours and flooding threaten a **loss of historical and cultural resources** in national parks. At particular risk are Ellis Island National Monument in Upper New York Bay, less than three feet above the current high tide level, through which passed the arriving ancestors of 40 percent of all living Americans; the Statue of Liberty National Monument, also in Upper New York Bay; and the Jamestown National Historic Site, part of Colonial National Historical Park in Virginia, where the first European ancestors of today's Americans arrived in 1607. (See pages 33-34.)

National parks in the hottest parts of the country could suffer **intolerable heat**, simply becoming too hot for long stretches of the year for many people. Under a higher-emissions future, Big Bend, Death Valley, Joshua Tree, and Saguaro national parks, Mojave National Preserve, and Lake Mead National Recreation Area are projected to average more than 100 days a year over 100°F. Those parks, Biscayne and Everglades national parks, and Big Cypress National Preserve are projected to average 90°F or hotter for half or more of the entire year. (See page 35-36.)

As temperatures soar with a changed climate, cooler northern and mountain parks and national seashores could experience overcrowding as people flock to them to escape oppressive heat. (See pages 36-37.)

Hotter temperatures could sharply reduce populations of trout and salmon, which are coldwater fish species, and lead to a **loss of fishing** in national parks. Damage to coral reefs and other marine resources also could reduce sportfishing in coastal parks. (See pages 37-38.)

A hotter climate is also projected to lead to **more air pollution** in parks by worsening concentrations of ground-level ozone, the key component of smog. Many national parks already violate the health-based air quality standard for ozone, and that air pollution problem could get worse with a changed climate. (See page 38.)

RECOMMENDATIONS

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. Needed are both actions specific to parks to preserve their resources and actions to curtail emissions of climate-changing pollutants enough to reduce the impacts in parks and elsewhere.

This report recommends 32 actions specific to national parks, including:

- The Congress, the Administration, and the NPS should set aside new national parks and expand existing parks as necessary to preserve for future generations representative and sufficient examples of America's best natural and cultural resources.
- The NPS should promote, assist, and cooperate in preservation efforts beyond park boundaries to preserve large enough ecosystems, crucial habitat, and migration corridors so that plants and animals have opportunities to move and continue to survive in transformed landscapes.
- The Congress, the Executive Branch, and the NPS should consider the combined effects of climate change and of other stresses on park resources and values, and work to reduce all the stresses that pose critical risks to parks.
- The NPS should develop park-specific and resource-specific plans to protect the particular resources most at risk in individual parks.
- The NPS should use all its authorities to protect parks from a changing climate, including its "affirmative responsibility" under the Clean Air Act to protect the air-quality related values of national parks.
- The NPS should adopt a nationwide goal of becoming climate-neutral in its own operations within parks, as has been adopted by its Pacific West Region. The Service should give an even greater priority to reducing the greater levels of emissions coming from visitor activities.
- NPS officials should speak out publicly about how climate change and its impacts threaten national parks and the broader ecosystems on which they depend.
- The NPS should use its environmental education programs to inform park visitors about a changed climate and its impacts in parks and about what is being done in parks to address climate change and its impacts. The NPS should require concessionaires to do so, too.
- The Congress and the Administration should adequately fund NPS actions to address a changing climate, through the energy and climate legislation now in Congress, through new NPS authority to use entrance fees to reduce emissions of heat-trapping gases and address impacts in parks, and through funding of the Land and Water Conservation Fund.
- The Congress and the Administration should reestablish within the NPS the scientific and research capacity it had prior to 1993, by returning to NPS the programs and staff transferred that year to the U.S. Geological Survey.

Ultimately, to protect our national parks for the enjoyment of this and future generations, federal action to reduce heat-trapping gases is needed so that a changed climate and its impacts do not overwhelm the parks. The federal government must take three essential steps:

- Enact 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 multi-million and multi-billion dollar capital investments.
- Overcome barriers to investment in energy efficiency to lower emission reduction costs, starting now.
- Accelerate the development and deployment of emerging clean energy technologies to lower long-term emission reduction costs.

ROCKY MOUNTAIN NATIONAL PARK
PHOTO: JOHN FIELDER

INTRODUCTION

EVERGLADES NATIONAL PARK

THE GREATEST THREAT TO NATIONAL PARKS

Human disruption of the climate is the greatest threat ever to our national parks.

This is not just a concern for the future. The national parks that we Americans so cherish are already being harmed by a changing climate. In Yosemite National Park, trees of all types and ages are dying more often, and both forests and mammals are moving upslope to stay ahead of higher temperatures. Yellowstone National Park is losing its whitebark pines and their nuts, so important as a food for grizzly bears that fewer whitebark nuts before hibernation mean lower grizzly birth rates the following year. Summers in Yellowstone now are sometimes hot enough to kill trout, which are cold-water fish that cannot tolerate hot waters. Rocky Mountain National Park is losing its mature lodgepole pines. Bandelier National Monument and Mesa Verde National Park have lost most of their piñon pines. Mount Rainier National Park was recently shut down for six full months because of extreme flooding, an example of the extreme weather now occurring more often.

If we continue heedlessly adding heat-trapping pollution to the atmosphere, we could lose whole national parks for the first time. Nearly all of Everglades, Biscayne, and Dry Tortugas national parks, as well as Ellis Island National Monument, are barely above the current sea level, lower than the projected rise in the sea. All four parks could be lost to rising seas. Glacier National Park could lose all its glaciers. Virgin Islands Coral Reef National Monument could lose all its coral reefs. Joshua Tree National Park could lose all its Joshua trees. Saguaro National Park could lose all its saguaros.

Of course, climate change is a global phenomenon, with global causes and effects. Why focus on national parks? Because the parks have been set aside to preserve, unimpaired, the very best of our natural and cultural heritages, and to provide for their continued enjoyment by future generations. To ignore the enormous threats a changed climate poses to national parks because other places are also threatened would be to give up on our parks. Instead, we can identify and address the threats to parks, through actions both to reduce the effects of climate change in parks and to reduce the causes of climate change. And in dealing with human-caused climate change in the national parks, we can learn and demonstrate how to deal with it elsewhere. That is in the best traditions and interests of the national parks and of America.

"National parks that have special places in the American psyche will remain parks, but their look and feel may change dramatically."

U.S. Climate Change Science Program (2008)[1]

What Happens Is Up to Us

The climate is already changing. The world's scientists, through the Intergovernmental Panel on Climate Change (IPCC), have declared that it is "unequivocal" that the climate is now hotter than it used to be, with more than a 90 percent likelihood that most of the temperature increase over the past 50 years is a result of human emissions of heat-trapping pollution, mostly from the burning of fossil fuels.[2] The planet as a whole so far this century averages about 1°F hotter than during the 20th century, with particularly sharp increases in the most recent years.[3] Without the effects of human activities, global temperatures likely would have cooled since 1950.[4]

How much more the climate changes will be determined by how much more heat-trapping pollution we produce. A recent, comprehensive climate-change report from the U.S. government's Global Change Research Program estimated that, compared to the 1960s and 1970s, our nation is projected to get 7 to 11°F hotter by the end of the century under a higher-emissions scenario and by approximately 4 to 6.5°F under a lower-emissions scenario.[5] These two scenarios differ because of different assumptions about future populations, technologies, economic activity, and the like. Neither scenario assumes new policies to reduce emissions, and so it is certainly possible to bring down both the projected emissions and changes in the climate. But the same government report also points out that a variety of studies suggests that even 2°F of additional warming "would lead to severe, widespread, and irreversible impacts."[6] To have a good chance—but still no guarantee—of no more warming than 2°F over the long term, the report says that atmospheric levels of heat-trapping gases would have to be stabilized at about today's level, with no more new emissions than can be removed from the atmosphere by natural processes.[7]

Which future we choose will determine what our national parks, along with the rest of the planet, will be like. Many of the threats to our national parks described in this report are from scientific projections for a high-emissions future and can be reduced with a lower-emissions future and reduced even further with a stable-climate future. Sadly, though, even the most unsettling projections of a higher-emissions future could turn out to be understatements if we do not change our current ways. In recent years, worldwide emissions of heat-trapping pollutants have gone up faster than the scientists' high-emissions scenarios.[8]

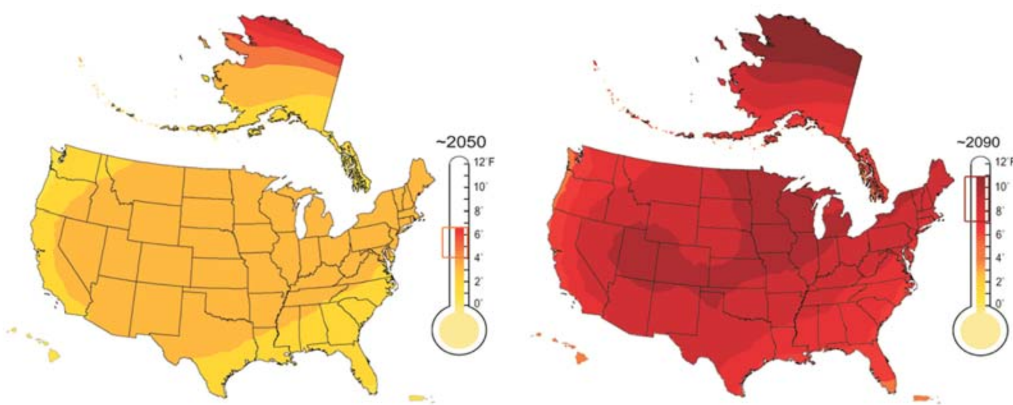
Time is running short, but it is still possible to bring down emissions sharply enough to ward off the worst possible effects of climate disruption. The last chapter of this report contains recommendations on how we can begin doing that, while also strengthening our economy.

Higher Emissions Scenario Projected Temperature Change

Degrees F Compared To 1961-1979 Baseline

Mid-Century (2040-2059 average)

End-of-Century (2080-2099 average)

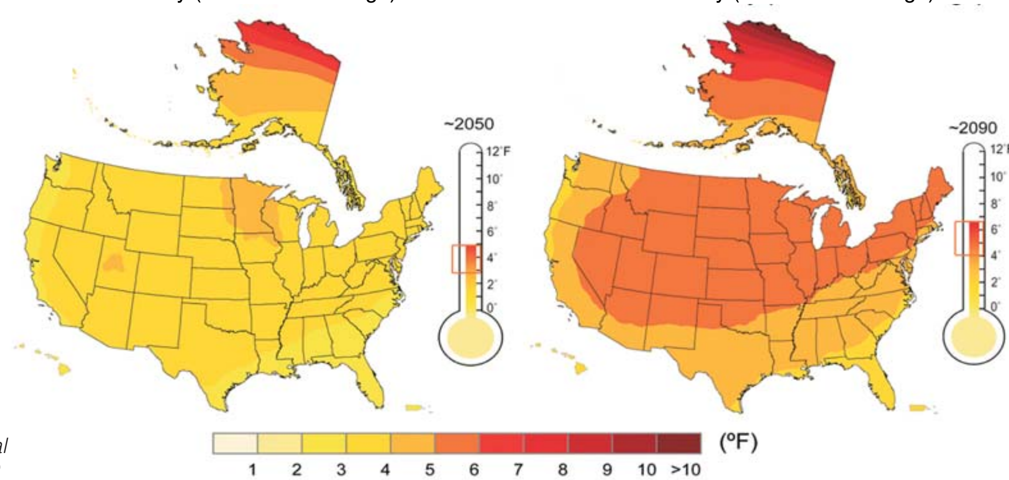


Lower Emissions Scenario Projected Temperature Change

Degrees F Compared To 1961-1979 Baseline

Mid-Century (2040-2059 average)

End-of-Century (2080-2099 average)



Average results from 16 climate models.

Graphics source: U.S. Global Change Research Program.[9]

1

National Parks Most at Risk

Human-caused climate change puts at risk nearly every resource and value that makes our national parks so special. The scenery of parks is being affected as glaciers melt, mountains lose snow-covered peaks, and forests die back. Wildlife is being affected by climate-driven changes in habitat and disruptions of food sources. Cultural resources are being affected as rising seas, stronger storms, and bigger floods erode historic and prehistoric structures and wash away artifacts. Visitor enjoyment is being affected as fishing is prohibited, boating is curtailed, and opportunities for cross-country skiing diminish.

These impacts are imperiling most, if not all, of the 391 parks* in the national park system. This report focuses primarily on 25 national parks that we identify as having the greatest vulnerabilities to human-caused climate change. They were chosen, first, based on how much an altered climate may affect the overall integrity of a particular park's resources and values. Parks at risk of being entirely submerged by a rising sea obviously are in greater overall peril than most parks. Second, the parks on the list reflect both the diversity of the national park system and the variety of threats an altered climate poses to parks. Third, the list was necessarily influenced by the information available about the particular risks individual parks face.

Unfortunately, there usually is very little information about how a disrupted climate may affect an individual park. As the National Park Service (or NPS) and others further assess the impacts of climate change on parks, it may become clear that some parks not on the list actually have greater vulnerabilities than ones on it. This could especially be true for the 17 national parks in Alaska, which so far has gotten hotter at twice the rate of the rest of the country and which is expected to continue getting hotter than elsewhere. But how parks in Alaska will be affected is not yet well documented. For now, Denali National Park and Preserve, the one Alaskan park on our list, should be considered as broadly representative of the threats to all parks in Alaska.

> *"We identified the lack of any climatic data within Glacier Bay as a significant gap in knowledge about a very important and basic driver of the physical and biological systems within the Park, a sentiment echoed by many Park staff and researchers alike. Although specific funding for climate monitoring could not be secured, it was an obvious data gap that we have tried to fill by establishing the current network of climate sites."*
>
> — Daniel E. Lawson and David C. Finnegan, Dartmouth College (2008) [1]

The 25 national parks in greatest peril are identified in the chart on the following pages, which also indicates the particular risks faced by each park. There are 11 categories of such risks: a loss of ice and snow, addressed in chapter 2; a loss of water, in chapter 3; higher seas and stronger coastal storms, in chapter 4; more downpours and flooding, also in chapter 4; a loss of plant communities, in chapter 5; a loss of wildlife, in chapter 6; a loss of historical and cultural resources, in chapter 7; and intolerable heat, overcrowding, a loss of fishing, and more air pollution, all in chapter 8.

* This report refers to all units of the national park system as national parks or parks, even if they are designated as national monuments, national seashores, or something else. All are managed under the same general laws and policies.

25 National Parks Most at Peril from

	Loss of Ice & Snow	Loss of Water	Higher Seas & Stronger Storms	More Downpours & Floods	Loss of Plant Communities
Acadia NP, ME	✹		✹	✹	✹
Assateague Island NS, MD/VA			✹	✹	✹
Bandelier NM, NM	✹	✹		✹	✹
Biscayne NP, FL			✹	✹	✹
Cape Hatteras NS, NC			✹	✹	✹
Colonial NHP, VA			✹	✹	
Denali NP&P, AK	✹	✹		✹	✹
Dry Tortugas NP, FL			✹	✹	✹
Ellis Island NM, NY/NJ			✹	✹	
Everglades NP, FL			✹	✹	✹
Glacier NP, MT	✹	✹		✹	✹
Great Smoky Mts NP, TN/NC	✹			✹	✹
Indiana Dunes NL, IN	✹	✹		✹	✹
Joshua Tree NP, CA				✹	✹
Lake Mead NRA, NV/AZ		✹		✹	✹
Mesa Verde NP, CO	✹	✹		✹	✹
Mount Rainier NP, WA	✹	✹		✹	✹
Padre Island NS, TX			✹	✹	✹
Rocky Mountain NP, CO	✹	✹		✹	✹
Saguaro NP, AZ		✹		✹	✹
Theodore Roosevelt NP, ND				✹	✹
Virgin Islands NP/Virgin Islands Coral Reef NM, VI			✹	✹	
Yellowstone NP, WY/MT/ID	✹	✹		✹	✹
Yosemite NP, CA	✹	✹		✹	✹
Zion NP, UT	✹	✹		✹	✹

Legend:
NP = National Park
NM = National Monument
NS = National Seashore
NHP = National Historical Park
NP&P = National Park and Preserve
NL = National Lakeshore

Climate Disruption and the Risks They Face

Loss of Wildlife	Loss of Cultural Resources	Intolerable Heat	More Overcrowding	Loss of Fishing	More Air Pollution
☀	☀		☀	☀	☀
☀			☀	☀	☀
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NRA = National Recreation Area

Locations of National Parks Most at Peril

Legend:
NP = National Park
NM = National Monument
NS = National Seashore
NHP = National Historical Park
NP&P = National Park and Preserve
NL = National Lakeshore
NRA = National Recreation Area

2

Loss of Ice and Snow


DENALI NATIONAL PARK

Of the 25 national parks most in peril, these face loss of ice and snow:

- Acadia National Park
- Bandelier National Monument
- Denali National Park and Preserve
- Glacier National Park
- Great Smoky Mountains National Park
- Indiana Dunes National Lakeshore
- Mesa Verde National Park
- Mount Rainier National Park
- Rocky Mountain National Park
- Yellowstone National Park
- Yosemite National Park
- Zion National Park

As the climate gets hotter, national parks in the North and in mountain ranges are losing snow and ice—one of the most obvious effects of a changed climate on our national parks.

LOSS OF GLACIERS

The Intergovernmental Panel on Climate Change reported in 2007 that glaciers are melting worldwide and expressed "confidence that the glacier wastage in the late 20th century is essentially a response to post-1970 global warming."[1] In the United States, glacial melting is concentrated in our national parks, a handful of which contain the vast majority of the nation's glaciers.

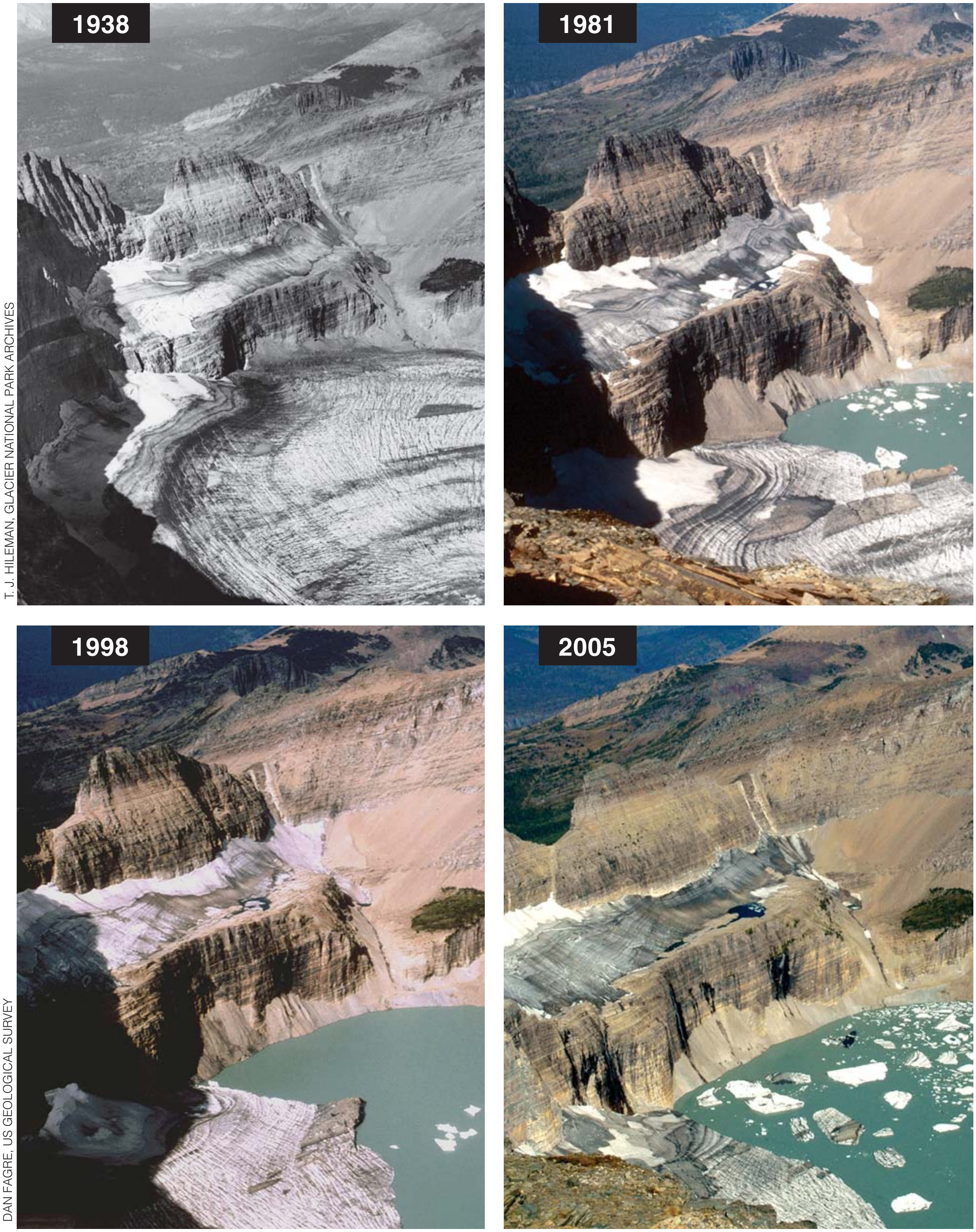
Glacier National Park in Montana was designated a national park in large part to preserve the glaciers after which it was named. Scientists have documented rapid melting of the park's glaciers and linked the melting to higher temperatures. The acreage of Grinnell Glacier, for example, shrank by a quarter between 1993 and 2004.[2] Observing this kind of melting, researchers in 2003 projected that by 2030 all glaciers in the park would be gone if current emission trends continue.[3] But since then the glaciers actually have melted much faster than expected. Between 2005 and 2007, for example, Grinnell Glacier lost an additional nine percent of its acreage. In October 2007, the U.S. Geological Survey's Dan Fagre said, "[W]e're about eight and a half years ahead of schedule… Our initial projection has proved too conservative. They're going faster than we thought."[4]

Glaciers are also disappearing elsewhere around the West.

North Cascades National Park in Washington has 312 glaciers, about half of all glaciers in the contiguous United States. All of the park's glaciers are in retreat.[5] Forty-seven glaciers monitored since 1984 have lost an average of 20 to 40 percent of their mass, with five having melted entirely away.[6] Because of the extra summer melting resulting from today's hotter climate, a National Park Service scientist estimates that a winter's snowfall now has to be about 25 percent above average to keep the park's glaciers from having a net loss of ice that year.[7] At the same time, winter snowfalls in the region are already in decline, and are projected to decline much more; see below.

In Mount Rainier National Park in Washington, 25 major glaciers comprise the largest collection of permanent ice on a single U.S. peak south of Alaska. Those glaciers lost 21 percent of their area between 1913 and 1994.[8] The NPS began in 2003 tracking two glaciers' estimated total mass of ice, a more precise measurement of a glacier than its surface area; both glaciers have lost mass every year since the monitoring began. The net loss of water from these two glaciers in only six years is estimated at 18 billion gallons, or enough water to cover about 55,000 acres to a depth of one foot.[9]

Glacial Melting in Glacier National Park



T. J. HILEMAN, GLACIER NATIONAL PARK ARCHIVES

CARL KEY, US GEOLOGICAL SURVEY

DAN FAGRE, US GEOLOGICAL SURVEY

BLASE REARDON, US GEOLOGICAL SURVEY

Photographs of Grinnell Glacier in Glacier National Park taken from the same point over seven decades demonstrate the retreat of the glacier.

In Yosemite and Sequoia/Kings Canyon national parks in California, six glaciers (along with a seventh just outside Yosemite) lost an average of 55 percent of their area since 1900. After about a quarter century of relative stability, since 1985 the glaciers have been in a period of retreat, which accelerated after the turn of the century. The glaciers' retreat appears to be driven by higher spring and summer temperatures, much more than by reductions in snowfall levels.[10]

Not surprisingly, glaciers are also melting in Alaska, which has heated up more than any other state. Alaska's glaciers are melting so rapidly that they are responsible for about half of the worldwide loss of ice from glaciers, and are responsible for the world's largest documented glacial contribution to sea-level rise. Most of the state's glaciers are in national parks. Wrangell-St. Elias National Park and Preserve, our largest national park, by itself has 60 percent of all glaciers in Alaska. The park's glaciers have not yet been well studied, but the scanty evidence that exists verifies their decline. In Denali National Park and Preserve, where glaciers cover one-sixth of the park, twice-yearly measurements for a decade have documented the shrinkage of Kahiltna Glacier, one of the park's great glaciers, which begins on Mount McKinley and flows for 36 miles.[11] In Kenai Fjords National Park, the Harding Icefield crowns the park and is the source of 38 glaciers that have sculpted the park's landscape. University of Alaska Fairbanks's researchers have documented that nearly all the park's glaciers are thinning and in retreat.

As glaciers in national parks melt, scenery is affected, and so is visitor enjoyment; eventually, tourism could be, too. The ecosystem effects can be significant, as well. When glaciers disappear and produce no more meltwater, rivers and streams lose reliable late-season flows that are not dependent on the vagaries of the previous winter's snowpack or that summer's rainfall. The National Park Service estimates that as much as 50 percent of late-summer natural stream flows in North Cascades National Park come from glacial meltwater. In one watershed, shrinking glaciers have already reduced summer flows by 31 percent.[12] In Glacier National Park, a reduction in glacial runoff has dried up streams and scenic waterfalls and jeopardized the park's aquatic and riparian life. At particular risk are Glacier's native bull trout, a threatened species, which spawn in the fall and need strong late-season stream flows to get to their spawning grounds.[14]

"Glaciers are excellent barometers of climate change, because they respond directly to trends in temperature, precipitation, and cloud cover (which mediates solar radiation). These same climatic factors also drive ecosystem change. Unlike plants and animals, however, glaciers do not adapt behaviorally or physiologically in ways that mitigate the impacts of climatic change."

Myrna H. P. Hall, State University of New York, and Daniel B. Fagre, U.S. Geological Survey (2003)[13]

In Glacier Bay National Park in Alaska, melting glaciers have geologic effects. There, the rapid loss of glacial ice mass has eased an enormous weight on the underlying land, leading it to rise dramatically. The changes are so profound that they actually could set off earthquakes because the Earth's tectonic plates are more prone to shift without the extreme weight of the ice holding them in place.[15]

Other parks that could experience a loss of glaciers include Gates of the Arctic (in Alaska) and Grand Teton (in Wyoming) national parks and Lake Clark National Park and Preserve in Alaska.

LOSS OF SNOW-COVERED MOUNTAINS

Glaciers are in relatively few national parks, but snow-covered mountains are in many—especially in the West, where they contribute to some of the most spectacular scenery in the nation. But higher temperatures, less snowfall, and earlier snowmelt are already leading to less snow coverage of western mountains. An analysis by University of Washington researchers of 824 government snowpack measurement sites across the West showed that snowpack levels declined at most of those sites between 1950 and 1997. The greatest decreases occurred where winters are mild and warming of a few degrees more often pushes temperatures above freezing. After considering possible contributing factors, the researchers concluded that the pattern of the declines points to the warming already underway in the West as the cause.[16] A more recent study has specifically attributed about half of the observed reduction in snowpack to the effects of human emissions of heat-trapping gases.[17] The reduction in snowpack has been cited by the IPCC as one of seven indicators that climate change is underway in North America.[18]

The trend is expected to accelerate sharply. Scientific forecasts for future springtime peak snowpack levels across the West are shocking, with projected declines of 29 to 89 percent in California, nearly 50 percent in the Columbia River basin, and 30 percent in the higher and colder mountains of the Colorado River basin.[19] These projections typically are for snowpacks as of April 1, around the time of peak snow levels. In some parks, such as Zion National Park in Utah, snow does not linger that long, but with less snow in winter fewer visitors would get to see the parks at their scenic best. In other parks, snow cover typically has lasted into the summer, when most people go to national parks. In the future, sadly, visitors to Glacier, Grand Teton, Great Smoky Mountains (in Tennessee and North Carolina), Mesa Verde (in Colorado), Mount Rainier, Rocky Mountain (in Colorado), and Yellowstone (in Wyoming, Montana, and Idaho) national parks will be less likely to see snowcapped mountains.

> *"Over the last 50 years, there have been widespread temperature related reductions in snowpack in the West, with the largest reductions occurring in lower elevation mountains in the Northwest and California where snowfall occurs at temperatures close to the freezing point."*
>
> — U.S. Global Change Research Program (2009)[20]

LOSS OF WINTER RECREATION

Global warming very likely will decrease opportunities for snow-dependent outdoor winter recreation in national parks.

Yellowstone National Park is the most popular national park for snow-dependent recreation. It is the only park in the lower 48 states whose interior roads are mostly closed in winter to con-ventional motor vehicles and instead groomed for travel by over-snow vehicles—snowcoaches and snowmobiles. There has been pitched controversy for more than a decade over whether and to what extent snowmobiles should be allowed in the park, or whether motorized access to the park's interior should be only by snowcoach. Continued, extensive public access to the park in winter can be provided through an expanded fleet of cleaner, quieter, and modern snowcoaches, which disturb wildlife less and so afford visitors more opportunities for viewing wildlife. The park also is open, and will remain so, to cross-country skiers, many of whom ski into the park's interior from the end of plowed roads, with others entering on snowcoaches before beginning to ski. What is not controversial, in any event, is that Yellowstone in winter is a special wonderland that offers unique enjoyment to all park visitors. That special experience, however, depends on the presence of adequate snow. Already, the National Park Service has sometimes had to delay the opening of the winter over-snow season, traditionally in mid-November, until the middle of December or even January. In the Yellowstone area so far, as across North America, winter temperatures have gone up more than in other seasons and the largest increases in winter have been in nighttime low temperatures, which are important for building and maintaining snow cover.[21]

Opportunities for cross-country skiing, snowshoeing, and other winter activities are also likely to be reduced in other parks, including Acadia (in Maine), Crater Lake (Oregon), Glacier, Grand Teton, Mount Rainier, North Cascades, Olympic (in Washington), Rocky Mountain, Sequoia/Kings Canyon, Voyaguers (in Minnesota), and Yosemite national parks; Bandelier National Monument (in New Mexico); and Apostle Islands (in Wisconsin), Indiana Dunes (in Indiana), Pictured Rocks (in Michigan), and Sleeping Bear Dunes (in Michigan) national lakeshores.

YELLOWSTONE NATIONAL PARK

3

Loss of Water


ZION NATIONAL PARK

Of the 25 national parks most in peril, these face loss of water:

- Bandelier National Monument
- Denali National Park and Preserve
- Glacier National Park
- Indiana Dunes National Seashore
- Lake Mead National Recreation Area
- Mesa Verde National Park
- Mount Rainier National Park
- Rocky Mountain National Park
- Saguaro National Park
- Yellowstone National Park
- Yosemite National Park
- Zion National Park

In the West, a changed climate will reduce water availability, especially in the summer, when it is most needed by wildlife, plants, and entire ecosystems. In the upper Midwest, the water level of the Great Lakes is likely to fall. In both regions, the loss of water will substantially affect national parks.

A DRIER WEST

Human-caused climate change has already altered, and will continue to alter, natural water cycles. For much of the world, hotter temperatures have increased the water-holding capacity of the atmosphere and precipitation has increased. The increases, though, have been concentrated in heavier storms, mostly in coastal and other already-wet areas. In the interior American West and other dry inland regions of the world, the opposite is happening and they are getting drier. Droughts, a natural occurrence in these regions, are likely to become more frequent, longer-lasting, and, especially when coupled with hotter temperatures, more destructive. Winters in western mountains are no longer as cold as before, so now winter precipitation is falling more often as rain instead of snow. Mountain snowpacks are not as large and are melting earlier, with peak spring flows from snowmelt coming as much as three weeks earlier. As summers continue getting longer and hotter, evaporation from soils and bodies of water likely will increase. The U.S. Global Change Research program reports that many of these changes are already underway, caused by human emissions of heat-trapping gases.[1]

> *"Climate models consistently project that the East will experience increased runoff, while there will be substantial declines in the interior West, especially the Southwest. Projections for runoff in California and other parts of the West also show reductions, although less than in the interior West. In short, wet areas are projected to get wetter and dry areas drier."*
>
> — U.S. Global Change Research Program (2009)[2]

The Colorado Plateau: A Special Region, Particular Vulnerability

A changed climate is expected to make the Colorado Plateau especially hotter and drier. This region of uplifted land, named after the Colorado River that cuts through it, spans much of Utah, Colorado, New Mexico, and Arizona, and is home to many of the country's greatest natural and cultural wonders. It also contains our greatest concentration of national parks—about two dozen, with the exact number depending on the particular boundary used for the Colorado Plateau. For the millions of people who travel to the region each year to visit Arizona's **Grand Canyon** National Park, Utah's **Arches, Capitol Reef, Canyonlands,** and **Zion** national parks, Colorado's **Mesa Verde** National Park, and New Mexico's **Chaco**

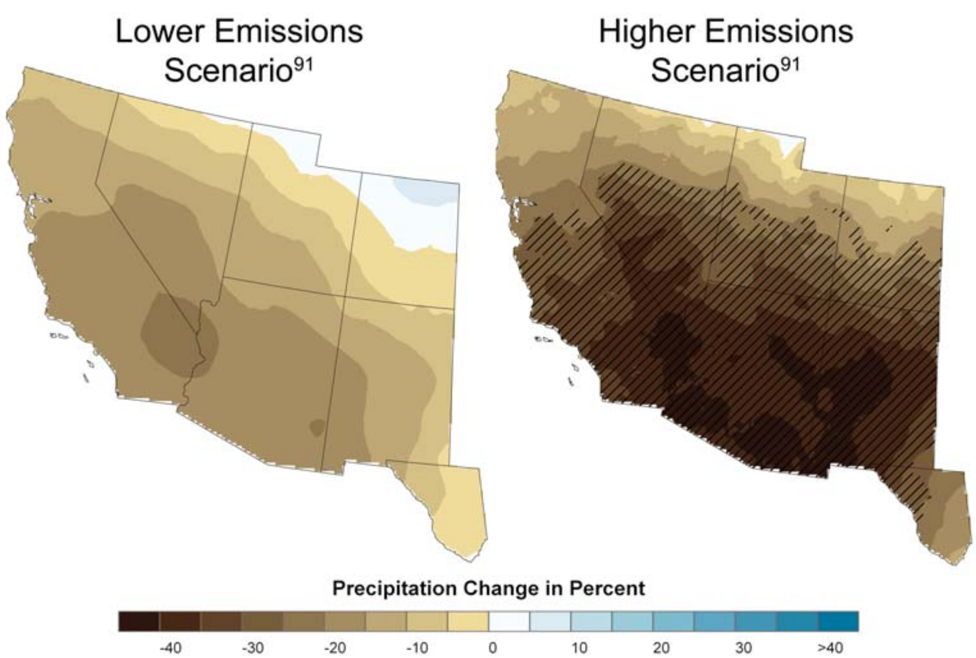
Culture National Historical Park, this is a special, even magical, place.

But dramatic changes are underway in these and other treasured places on the plateau as temperatures rise and water supplies shrink. The Colorado River basin, which includes the Colorado Plateau, has experienced more warming since the 1970s than any other part of the United States outside of Alaska.[3] According to an analysis done by the Rocky Mountain Climate Organization and published in a joint report with Natural Resources Defense Council, the average temperature in 2003-2007 across the Colorado basin was 2.2°F hotter than the basin's 20th-century average. In comparison, the entire 11-state American West averaged 1.7°F hotter, and the planet as whole 1°F hotter.[4] The Colorado River, the major water source of not just this region but also the entire Southwest, is in its most severe drought in more than a century of record-keeping—consistent with scientific projections that human-caused climate change will dry out this region more than any other in the country. As atmospheric circulation patterns change and storm tracks move northward, naturally low precipitation levels in the arid Southwest may drop by 40 percent or more under a high-emissions future. Scientists have estimated that flows in the Colorado River could be diminished by 4 percent to 18 percent by 2050—enough, in this arid, fast-growing region, to have enormous consequences on national parks, ecosystems, and people.[5]

Zion National Park illustrates the vulnerability of the Colorado Plateau parks to a loss of water. Spectacular Zion Canyon in the heart of the park was formed through the erosive power of a rapidly flowing North Fork of the Virgin River, which is still cutting into rock layers and continuing to shape the canyon. At the upper end of the canyon, in the Narrows of the Virgin River, the river cuts through a high layer of firm sandstone, where it has created the most accessible large slot canyon in the national park system. Below the Narrows, the river is eroding a softer, lower formation, undermining the overlaying sandstone and causing it to collapse, widening the main body of the canyon. Unlike most western rivers, including those flowing through most national parks, the North Fork of the Virgin River is undammed, so its flows are not determined by reservoir releases. If the river's natural flows are diminished, they will no longer continue shaping the canyon's geology as they have.

Other parks on the Colorado Plateau that could be affected by water losses are Canyonlands, Capitol

Projected Change in Spring Precipitation, 2080-2099



Percentage change in March-April-May precipitation for 2080-2099 compared to 1961-1979 for a lower emissions scenario (left) and a higher emissions scenario (right). Confidence in the projected changes is highest in the hatched areas.

—Source of graphic: U.S. Global Change Research Program.[6]

Reef, Grand Canyon, and Mesa Verde national parks. South of the Colorado Plateau but probably similarly vulnerable is Saguaro National Park in Arizona.

The hotter and drier conditions of the Colorado Plateau are already having dramatic effects on the piñon-juniper forests that are the region's dominant wooded ecosystem. Sustained heat and drought in the early years of this century weakened piñon pines so much that an infestation by a piñon bark beetle has caused widespread regional forest die-back. In 2002 and 2003 alone, heat, drought, and beetles combined to kill 90 percent of the piñon pines in studied portions of Bandelier National Monument and Mesa Verde National Park. This region has known drought before and trees have died before, but more trees died in the recent drought than during an even drier period in the 1950s. The difference, researchers say, is that this century's higher temperatures increased the forest die-off. "This recent drought episode in southwestern North America," they write, "may be a harbinger of future global-change type drought throughout much of North America and elsewhere, in which increased temperature in concert with multidecadenal drought patterns... can drive extensive and rapid changes in vegetation."[7] Other parks on the Colorado Plateau that have experienced or are at risk of losing piñon forests include Lake Mead National Recreation Area in Nevada and Arizona and Zion National Park.

Other Western Parks

Rocky Mountain National Park is not on the Colorado Plateau, but the portion of the park on the western side of the Continental Divide contains the highest headwaters of the main stem of the Colorado River. Consistent with general scientific projections for the interior West, the park's staff and other experts expect that an altered climate there will mean reduced snowpack, earlier snowmelt, and greater dryness, with consequences for all park ecosystems.[8] The western side of the park, for example, is naturally much wetter than the eastern side, as the prevailing western winds wring water out of air as it is forced up and over the Divide and gets too high to continue holding all its moisture. The resulting lush forests and meadows on the park's west side support the park's largest populations of moose, pine martens, and other animals, as well as different plant species. Reductions in the amount of water and changes in the timing of streamflows could make this side of the park much drier, significantly changing its ecological character. Other interior western parks that could be similarly vulnerable include Dinosaur National Monument in Colorado and Utah and Grand Teton, Great Basin (in Nevada), and Yellowstone national parks.

Loss of Glacial Water

National parks losing glaciers will also lose meltwater from the glaciers, which normally is a reliable source of water in late summer and often is important to ecosystems. (See page 9). Among parks suffering a loss of water as glaciers shrink could be Gates of the Arctic, Glacier, Glacier Bay, Grand Teton, Kenai Fjords, Mount Rainier, North Cascades, Rocky Mountain, Sequoia/Kings Canyon, Yosemite, Yellowstone, and Wrangell-St. Elias national parks and Denali and Lake Clark national parks and preserves.

> *"Warmer temperatures will subject park water supplies to less reliable late summer streamflow. Not only will snow melt earlier, but glacial meltwater will soon disappear in many western national parks. 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."*
>
> — J. Lundquist, University of Washington, and J. Roche, Yosemite National Park (2009)[9]

LOSS OF BOATING AND RAFTING

With less water in western rivers, there will be fewer opportunities for boating, rafting, and kayaking. Nearly 300,000 visitors each year go whitewater rafting and kayaking through some of the West's most dramatic landscapes in Black Canyon of the Gunnison (in Colorado), Canyonlands, Grand Canyon, and Grand Teton national parks and Dinosaur National Monument. Almost 10 million visitors a year go to Lake Mead and Glen Canyon (in Arizona and Utah) national recreation areas, most to enjoy boating on the reservoirs.

In 2005, after five straight years of severe drought in the Colorado River basin, Lake Powell had fallen to its lowest level of storage since 1969 (when it was still being filled for the first time) and Lake Mead had fallen to its lowest level since 1967. The number of people visiting Lake Mead National Recreation Area fell by 1.2 million, or 13 percent. The National Park Service spent $20 million to extend boat ramps to the new, lower edge of the reservoir; a concessionaire spent $2 million to move a marina 12 miles; and at Boulder Beach people had to walk a half mile to reach restrooms left behind by the receding waterline.

LOWER WATER LEVELS IN GREAT LAKES

While water levels are rising in the world's oceans, the opposite is happening in the Great Lakes. With higher temperatures, lake levels have dropped and are expected to drop farther, because of less winter ice and more summer evaporation. In 2007, visitors to Apostle Islands National Lakeshore, Indiana Dunes, Pictured Rocks, and Sleeping Bear Dunes national lakeshores and Isle Royale National Park (in Michigan) got a glimpse of this future. That year, high temperatures and below-average precipitation dropped Lake Superior 21 inches below its 1918-2006 average (a record low) and Lake Michigan 23 inches below its average.[11] Scientists project that Great Lake levels could fall by as much as several feet by 2090.[12] In the Great Lakes parks, fixed docks and boat ramps could be too high, deeper-draft boats could lose access to docks and anchorages, and drying wetlands on lake edges could affect habitat and food for fish and birds. The lakes also are projected to be ice-free for more of the year. At the rate it currently has been losing ice, Lake Superior could be ice-free all winter in another 30 years.[12]

U.S. GLOBAL CHANGE RESEARCH PROGRAM

Photographs taken 18 months apart—on June 29, 2002, on top and December 23, 2003, on the bottom—show the effects on the water level of Lake Powell, in Glen Canyon National Recreation Area, of the recent drought.

4

Higher Seas & More Extreme Weather

NATIONAL OCEANIC AND ATOMSPHERIC ADMINISTRATION

The National Park System includes 74 coastal national parks, national seashores, and other units along more than 7,000 miles of coastline, virtually all of which are vulnerable to the related risks of rising sea levels and stronger coastal storms. The casualties could include the first losses of entire national parks, as some could be submerged by rising seas. For both coastal and inland parks, more extreme weather—a corollary of a changed climate—also creates new risks to park resources from more downpours and flooding.

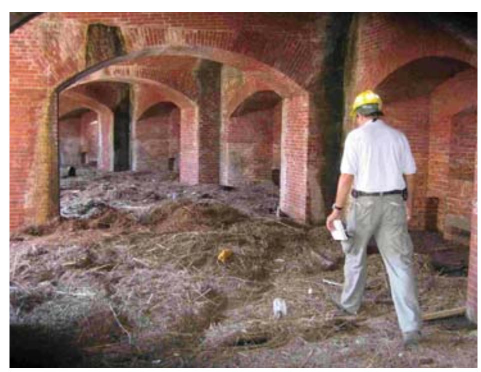
HIGHER SEAS AND STRONGER COASTAL STORMS

Of the 25 national parks most in peril, these face higher seas and stronger coastal storms:

- Acadia National Park
- Assateague Island National Seashore
- Biscayne National Park
- Cape Hatteras National Seashore
- Colonial National Historical Park
- Dry Tortugas National Park
- Ellis Island National Monument
- Everglades National Park
- Padre Island National Seashore
- Virgin Islands National Park/Virgin Islands Coral Reef National Monument

A hotter climate raises sea levels by melting land-based ice, which adds more water to the oceans. Also, water increases in volume when it is warmer, so thermal expansion also pushes sea levels higher. Sea levels already have risen along most of the coast of the United States over the past 50 years, and scientists say future increases will be greater. According to a recent U.S. government report, current estimates are that with a high-emissions future sea level will rise three to four more feet by the end of the century. Under a lower-emissions future, seas could rise about 2.3 feet—still enough to eliminate most of the nation's remaining coastal wetlands, affect coral reefs and other ecosystems, fragment barrier islands, and inundate parts of major cities such as New York City.[1] A separate U.S. government report also says that "thoughtful precaution" suggests that we should plan for a three-foot rise.[2]

Dry Tortugas National Park is in danger of being our first national park to be completely lost. A remote national park 70 miles west of Key West and reachable only by boat or seaplane, it is made up of seven islands—all of which are mostly less than three feet above the current sea level, and so at risk of being submerged in this century. Every terrestrial park resource is vulnerable to being lost—from Fort Jefferson (see page 34), boat anchorages, and a beach with easy access to a spectacular coral reef, to important nesting grounds for endangered sea turtles and for seabirds breeding nowhere else in the United States (see pages 27 and 29).



NPS

Debris from Hurricane Katrina in Fort Massachusetts, Gulf Islands National Seashore.

"Sea-level rise and the likely increase in hurricane intensity and associated storm surge will be among the most serious consequences of climate change."

U.S. Global Change Research Program (2009)[3]


DRY TORTUGAS NATIONAL PARK / PHOTO: NPS

In a recent report, the U.S. government says that a substantial portion of Assateague Island National Seashore, having been breached and segmented by recent sea-level rise and storms, may already be at a threshold of permanent geological change. Much of Cape Hatteras National Seashore may also be at a similar threshold. For both seashores, with any increase in the current rate of sea-level rise, it is "virtually certain" that they will experience large changes and degradation. With even a modest increase of an additional inch of sea-level rise every dozen years, it is "very likely"—at least a two-thirds chance—that the seashores will be broken into separate segments.[8]

Assateague Island National Seashore is in the area experiencing the fastest rate of sea-level rise along the Atlantic coast, and one of the fastest in the nation. At Ocean City, Maryland, just across a narrow inlet from the northern end of the seashore, the sea-level rise has been the second fastest measured so far along the Atlantic, at a rate of 1.80 feet per century. The only spot with a faster measured rate (1.98 feet per century) is the next station to the south, at the Chesapeake Bay Bridge-Tunnel, about 60 miles south of the seashore's southern end.[9]


ASSATEAGUE ISLAND NATIONAL SEASHORE / PHOTO: JANE THOMAS

Padre Island National Seashore has the world's longest stretch of undeveloped barrier island, much of it less than three feet above current sea level.[10] The park is a Globally Important Bird Area because of its role in migration and the most important U.S. nesting site for the world's most endangered sea turtle, the Kemp's ridley. (See page 20.)

Another park also at risk of being submerged in this century is Ellis Island National Monument in New York and New Jersey. (See page 33. For more

Everglades National Park has the largest expanse of land vulnerable to sea-level rise in the national park system. The highest spot in the park is only 11 feet above mean sea level.[4] Most of the park would be inundated by a rise of only 23 inches in sea level.[5] Virtually all of it would be submerged if the sea were to rise six feet.[6] What is at stake is a unique resource of great national and international significance. It is the first national park to be established as a biologic marvel, not a scenic showplace, with the largest freshwater sawgrass prairie in North America, the largest protected mangrove ecosystem in the Western Hemisphere, the most significant breeding and feeding grounds for tropical wading birds in the country, and habitat for a wide variety of endangered species. Its worldwide value has been recognized with designations as a World Heritage Site, an International Biosphere Reserve, and a Wetland of International Importance.

"Sea level rise would likely push salt water into the Everglades and threaten the viability of South Florida's drinking water supply."

Dan Kimball, Superintendent, Everglades National Park (2007)[7]

Neighboring Biscayne National Park is similarly at risk of being submerged. The average elevation of its land is about two feet above the sea, and 90 percent of the park's land is less than five feet high.

Well before portions of Everglades, Biscayne, and nearby Big Cypress National Preserve, also in Florida, might be inundated by the sea, their fresh-water ecosystems could be irrevocably changed by recurring intrusions of salt water. (See page 23.)

information on sea-level rise at Cape Hatteras National Seashore and Colonial Historical National Park, see pages 33 and 34.)

A second major risk to coasts and coastal parks comes from stronger coastal storms, including hurricanes. Where hurricanes develop in the North Atlantic, sea surface temperatures have increased about 2°F in the last 30 years, corresponding with an increase in the intensity of hurricanes, especially the most powerful ones, those rated as Category 4 and 5. According to a recent U.S. government report, climate models project that further warming of ocean waters will lead to stronger tropical storms.[11] The combination of higher seas and stronger storms also would produce storm surges of water pushed farther inland than now, increasing flooding and erosion.[12]

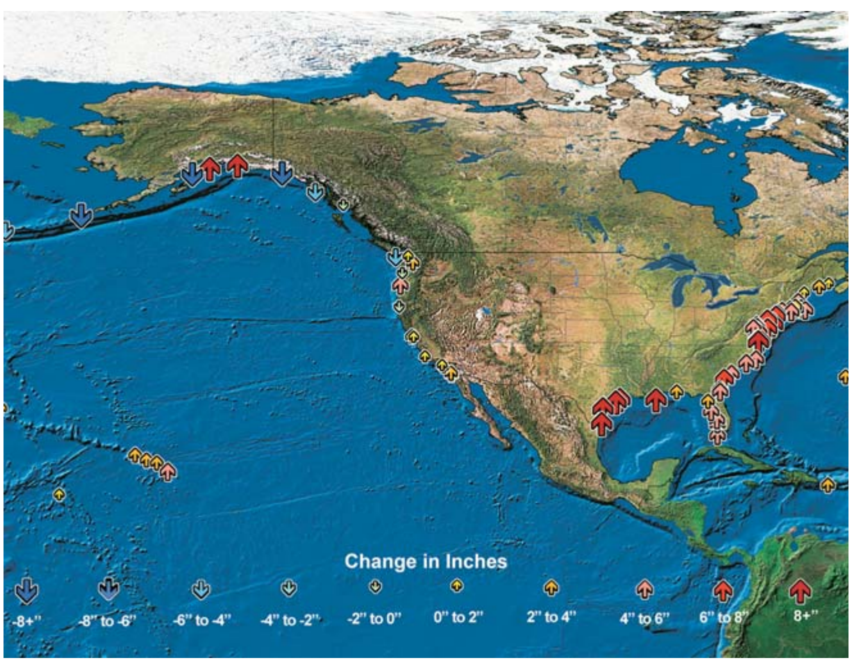
Stronger coastal storms also put these parks at risk. In Everglades, back-to-back hurricanes Wilma and Katrina in 2005 damaged or destroyed the structures in the one developed area inside the park, the Flamingo area, including the only lodging inside the park. Not surprisingly, the number of visitors to the park has since declined; in the three full years since Wilma and Katrina, visitation has averaged 23 percent below the 2005 level. The NPS has approved a long-term vision for an environmentally sensitive redevelopment of the area, including new lodging, but it could cost $50 million, and it is not clear how it will be funded.

An even more powerful example of how hurricanes can affect national parks is what happened when Biscayne National Park took a direct hit in 1992 from Hurricane Andrew, when it became only the third Category 5 (most powerful) storm to make landfall in the United States since the beginning of the 20th century. The park was essentially put out of business for two years. The number of visitors to the park, averaging over half a million a year before Andrew, plummeted to about 20,000 the year after the storm and about 25,000 the next year.

Padre Island National Seashore is also vulnerable not just to coastal storms hitting it directly but also to others in the Gulf of Mexico, because prevailing currents bring debris ashore from storms elsewhere. Following Hurricane Ike in 2008, the NPS had to remove 580 tons of trash washed up on park beaches by the hurricane.

Gulf Islands National Seashore in Florida and Mississippi was hit hard in a little more than a year by four hurricanes and two other tropical storms. In 2004, Hurricane Ivan caused $30 million in damage to the Florida units. Several miles of roads were washed out; the road to the Fort Pickens unit, near Pensacola, was not reopened until May 2009. The following year, Katrina produced a storm surge 35 feet high over the Mississippi units, slicing one

Recent Changes in Sea Level



Observed changes in sea level from 1958 to 2008 along the coasts of the United States. Assateague Island, Cape Hatteras, and Padre Island national seashores and Ellis Island National Monument are in areas experiencing greater than average increases.

— *Source: U.S. Global Change Research Program.*[13]

barrier island in half and eroding others. A lighthouse was destroyed, and a visitor center still has not reopened.

Similar risks are faced by many other coastal parks, including Canaveral National Seashore in Florida, Cape Lookout National Seashore in North Carolina, Cumberland Island National Seashore in Georgia, Virgin Islands National Park/Virgin Islands Coral Reef National Monument in the U.S. Virgin Islands, and Wright Brothers National Memorial in North Carolina.

MORE DOWNPOURS AND FLOODING

Of the 25 national parks most in peril, all face more downpours and flooding.

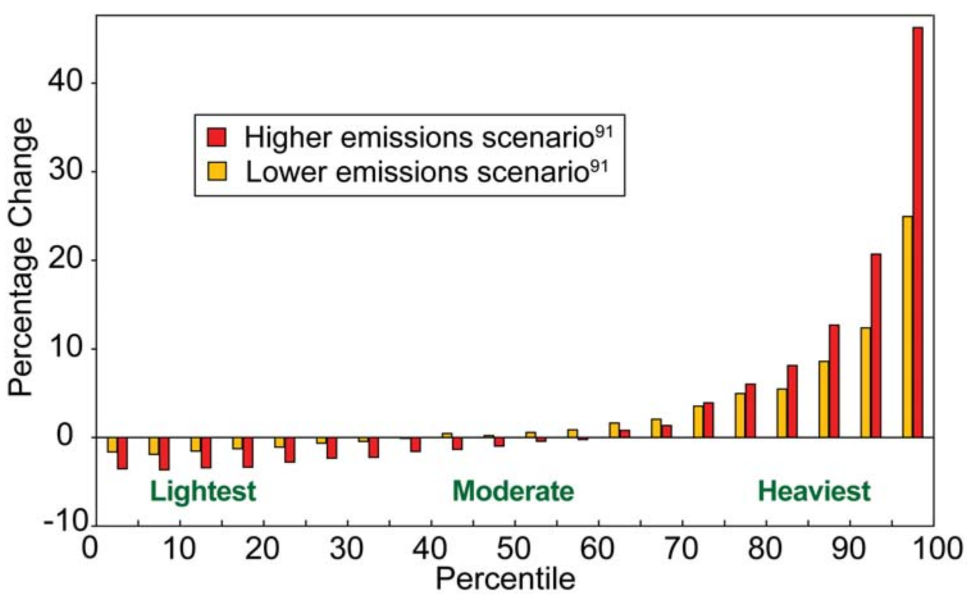
With a changed climate, more precipitation now comes in downpours. The amount of rain falling in heavy storms increased by 20 percent over the past century, while there has been little change in the amount from light and moderate storms. The changes are evident across the country, with the greatest increase in downpours in the Northeast and the Midwest. In its recent report, the U.S. Global Change Research Program says there is at least a 90 percent likelihood that heavy downpours will become even more frequent and intense.[14] With an increase in downpours, flooding also is likely to increase.[15]

Virtually all national parks are at risk, as the forecast is for more downpours everywhere. A recent downpour and flooding at Mount Rainier National Park illustrates the kinds of risks that it and other parks now face. In November 2006, 18 inches of rain fell in the park in 36 hours, washing out roads, destroying trails, severing power, telephone and sewer systems, damaging campgrounds, and, in the Park Service's words, "changing the landscape of the park forever."[16] The entire park was closed for six months, a period of time when about 170,000 people normally would have visited it.

North Cascades National Park was affected by this same storm. Similar "pineapple express" storms caused floods that closed Yosemite Valley in Yosemite National Park in January 1997 and May 2005.[17]

(For information on the effects of more downpours and flooding on historical and cultural resources, see pages 33-34.)

Projected Changes in Light, Moderate, and Heavy Precipitation
Projected Levels in 2090s Compared to Actual Levels in 1990s



Projected changes in precipitation from light storms (on the left) to heavy (on the right), presented for each five percent of storms based on the precipitation from them. Projections represent percentage changes in precipitation between levels in the 1990s and the 2090s. Light storms are projected to produce less precipitation and heavy storms more, with greater changes in a higher-emissions future.

—Source: U.S. Global Change Research Program[18]

5

Loss of Plant Communities

ROCKY MOUNTAIN NATIONAL PARK
PHOTO: JOHN FIELDER

Of the 25 national parks most in peril, these face loss of plant communities:

- Acadia National Park
- Assateague Island National Seashore
- Bandelier National Monument
- Biscayne National Park
- Cape Hatteras National Seashore
- Denali National Park and Preserve
- Dry Tortugas National Park
- Everglades National Park
- Glacier National Park
- Great Smoky Mountains National Park
- Indiana Dunes National Seashore
- Joshua Tree National Park
- Lake Mead National Recreation Area
- Mesa Verde National Park
- Mount Rainier National Park
- Padre Island National Seashore
- Rocky Mountain National Park
- Saguaro National Park
- Theodore Roosevelt National Park
- Yellowstone National Park
- Yosemite National Park
- Zion National Park

An altered climate can lead to fundamental changes in the natural plant communities of parks, including a disruption of mountain forests, tundra, meadows, and wildflowers; a disruption of desert ecosystems, including the possible elimination of saguaros from Saguaro National Park and Joshua trees from Joshua Tree National Park; and a loss of coastal plant communities.

Mountain pine beetle

U.S. CLIMATE CHANGE SCIENCE PROGRAM

DISRUPTED MOUNTAIN ECOSYSTEMS

Mountain Pine Beetles and Changed Mountain Forests

There is growing evidence that a changed climate is disrupting forests. For example, both a recent U.S. government report and the Intergovernmental Panel on Climate Change point out that rising temperatures increase outbreaks of insects in forests.[1] One such large outbreak, by mountain pine beetles, is killing most large lodgepole pines in Rocky Mountain National Park, as it is across Colorado.

Mountain pine beetles are unusual parasites in that they kill their hosts—in this outbreak, primarily mature lodgepole pines. When conditions are right, large outbreaks can occur, killing most large trees in a forest. Much of today's western lodgepole is vulnerable to such outbreaks, in part because widespread fires and logging in the 19th century and human fire suppression since then have increased the proportion of mature trees that beetles favor. The changing climate is also making it possible for bark beetles to spread faster and higher. Hotter and drier conditions have stressed trees, making them more vulnerable to beetle attacks. Longer, hotter summers have extended reproductive and growth periods, while fewer cold snaps and higher winter temperatures have permitted increased bark beetle survival in winter, spring, and fall, and infestation of higher eleva-

"Mountain pine beetles in Colorado have crossed an elevational threshold that has not been seen before. Until the recent warmer weather, mountain pine beetles have not been able to withstand the cold temperatures above 9,500 feet."

Colorado State Forest Service (2008)[2]

tions.[3] As the report from a recent scientific symposium put it, "Mature forests are the loaded gun for severe bark beetle infestations, and weather is the trigger."[4]

One key way in which the current bark-beetle epidemic in Rocky Mountain National Park and elsewhere differs from previous ones is that the beetles now are able to proliferate in high-elevation forests that used to be too cold to sustain epidemic-level populations.[5] In national forests near Yellowstone National Park in the 1970s, most bark beetles at 8,000 to 9,000 feet in elevation apparently took three years to complete a generation. With warmer temperatures, though, by 2006, most apparently were doing so in a single year.[6]

The resulting mountain pine beetle epidemic is especially widespread in Colorado. In 2008, officials of the U.S. Forest Service and the Colorado State Forest Service declared, "At current rates of spread and intensification of tree mortality, the MPB [mountain pine beetle] will likely kill the majority of Colorado's large diameter lodgepole pine forests within the next 3 to 5 years."[7] A more accurate statement would be that the majority of large lodgepole pine *trees* will be killed; the forests are being changed, but not eliminated. (See below.) Aerial surveys later in 2008 showed that areas infested since 1996 had reached 1.9 million acres—an area half again as large as Delaware—with 400,000 acres newly infested that year.[8]

The infestation has spread across Rocky Mountain National Park. The NPS is now spraying thousands of trees a year with an insecticide in high-value areas such as around visitor centers. A campground was closed for over a year to let the NPS remove standing dead trees that could have fallen on campers. Visitors are shocked by the expanses of dead and dying trees. And the park is on its way to losing most of its large lodgepole pines, substantially changing the park's current mixed-conifer forest ecosystem.

Ultimately, though, the forests themselves are not being lost. Post-outbreak forests will recover much as Yellowstone National Park's forests are recovering after large fires in 1988. In Rocky Mountain National Park, researchers from Colorado State University have confirmed that even in areas of heavy beetle infestation, all lodgepole pines under four inches in diameter and some mature ones have survived. The smaller, younger trees now are likely to grow more rapidly without competition from mature trees.[9] Other tree species may move into areas now dominated by lodgepole pines, creating different types of mixed forests. Still, to the extent that this bark-beetle epidemic has spread higher, and perhaps faster and wider than previous outbreaks, it illustrates how ecosystems can be changed, on a landscape-wide scale, when one natural force (the beetle) is no longer held in natural check by another (cold weather).

The current mountain pine beetle outbreak is not confined to Colorado, although that is where it is

PHOTO: NPS

The pine trees with red needles in Rocky Mountain National Park have been killed by mountain pine beetles.

most widespread in the United States. Across the West, it has grown to affect nearly 6.5 million acres in 2008, an increase in just one year of about 50 percent.[10] In the Yellowstone region, the unprecedented spread of mountain pine beetles to high elevations is disrupting the ecosystem in a unique way—ultimately threatening the park's grizzly bears. (See page 28.) Other bark beetles are affecting piñon pines in Colorado Plateau parks. (See page 12.)

Sudden Aspen Decline

Another development in western forests recently linked to a changed climate is a rapid dieback of aspen trees that scientists have labeled "sudden aspen decline," which could put at risk the scenic aspen groves of Rocky Mountain, Grand Teton, Yellowstone, and Glacier national parks. Beginning in 2004, people noticed that aspen trees in Colorado were dying in large numbers and that the dead trees were not regenerating as usual through new trees growing from the roots of the old. This aspen dieback has increased rapidly, with the affected acreage in Colorado having increased four-fold between 2006 and 2008. Aspen die-off has also been observed in northern Arizona, southern Utah, and Montana.[11] Research by the U.S. Forest Service has identified the hotter and drier conditions that represent an altered climate in the interior West as likely causes of the sudden aspen decline in Colorado.[12]

Increased Tree Death

A particularly ominous finding is from a team of scientists who recently found in undisturbed western forests that trees of all types and ages are dying faster than they used to. The increase in "background" tree mortality—not caused by fires, insects, wind, or any other obvious agent of forest change—was documented through examinations of census records of all individual trees in 76 undisturbed forest stands with counts of all living trees as far back as 1955. The studied forests were in Yosemite and Sequoia/Kings Canyon national parks; in forests like those of Rocky Mountain, Glacier, Yellowstone, and Grand Teton national parks in the interior West; and in the Northwest, including near Olympic (in Washington), Mount Rainier, and North Cascades national parks. Eighty-seven percent of the plots had experienced an increase in the rate of tree deaths, with the greatest change in the Northwest (where the average mortality rate had doubled in 17 years) and the lowest in the interior West (with doubling in 29 years.) The researchers suggested that higher temperatures and drier conditions—manifestations of a changed climate—may be the reasons for the accelerated tree deaths.[13]

Loss of Alpine Tundra

Alpine tundra—a mountain ecosystem that is treeless because conditions are too harsh for tree growth—may be especially vulnerable to a warming climate. Temperature increases have been greater atop mountains than at lower elevations.[14] As mountaintop temperatures warm, plants adapted for survival there may not be able to tolerate the changed conditions and may have no nearby higher, cooler environments in which to disperse. At the same time, forests may move upslope and overtake the tundra as mountaintop conditions become less harsh and trees have a chance to survive there.

In Rocky Mountain National Park, millions of Americans have driven up Trail Ridge Road, the highest paved through road in the United States, to experience the largest easily accessible expanse of alpine tundra in the United States outside of Alaska. Scientists have projected that a temperature increase of 5.6°F (consistent with a lower-emissions future by the end of the century) could cut the park's area of tundra in half. They also projected that a temperature increase of 9 to 11°F (possible with a higher-emissions future) could virtually eliminate it.[15]

Observations in Glacier National Park have detected what could be the first signs of changing plant communities above and at mountain treelines. In one study, scientists recorded 31 percent to 65 percent declines in abundance of seven tundra plants from 1989 through 2002.[16] In a second, repeat photography has documented that trees just below timberline have begun to grow more upright and have filled in gaps in forest edges at timberline.[17]

Forests Moving Upslope

In California, scientists have documented that the lower edge of the mixed conifer forests in the Sierra Nevada has moved upslope in the last 60 years, with ponderosa pines—the dominant lower-elevation tree of the forests—giving way to oak and chaparral. The change in forest types has coincided with a change in temperature; areas that formerly but no longer

> *"The upslope retreat of conifers is a clear biological signal that conditions are changing."*
>
> California Environmental Protection Agency (2009)[18]

have sub-freezing temperatures are where the conifers have given way to other plants. These changes have already reached the lowest elevations of Yosemite National Park.[19]

Loss of Mountain Meadows

Mountain meadows exist where the combination of heavy snow cover in the winter and a short growing season in the summer makes it impossible for tree seedlings to survive. Global warming is likely to reduce snow cover and extend the growing season, shrinking alpine meadows. Scientists have already detected that a loss of mountain meadows is underway in Glacier, Olympic, Sequoia/Kings Canyon, and Yosemite national parks.[20]

Loss of Wildflowers

In work that suggests what could happen in national parks in mountains across the West, researchers at the Rocky Mountain Biological Laboratory near Crested Butte, Colorado—the official wildflower capital of the state—have documented how higher temperatures suppress the growth of mountain wildflowers. Using electric heaters to raise summer temperatures of test plots by 4ºF for more than a decade, they have observed a reduction in wildflowers and their replacement by sagebrush, normally found in lower-elevation, dryer areas.[21] Another study shows that, paradoxically, earlier snowmelt—a result of warmer winters—actually leads to more wildflowers being lost to frost. With earlier snowmelt, the growing season starts earlier and flower buds open sooner, leaving them exposed to mid-spring frosts. From 1999 through 2006, the percentage of wildflower buds lost to frost doubled, compared to the previous seven years.[22]

DISRUPTION OF DESERT ECOSYSTEMS

Loss of Saguaros

Another type of threat comes from invasive plants, which may adapt to changed conditions better than native species, reproduce quickly, and crowd out native plants. In Saguaro National Park, buffelgrass, an introduced African species, is the invader, and the native saguaros could be the victim. Buffelgrass thrives in heat, is spreading prolifically and crowding out native plants, and has created conditions ripe for wildfire in an ecosystem that naturally is fire-free. When ignited, buffelgrass burns at very high temperatures and promotes rapidly spreading fires; it also re-grows quickly after fires. The hotter and drier conditions of a changed climate also may contribute to the likelihood of wildfires in the desert. (See page 12 for projections of extreme precipitation decline in southern Arizona.) Saguaros, like some other species native to the Upper Sonoran Desert, have not evolved with fire and are particularly vulnerable to it.[23] Other native species, including desert tortoises, are also at risk from the disruption of the ecosystem.[24] In Saguaro National Park, despite aggressive attempts by the NPS and volunteers to control buffelgrass, infested areas are doubling in size every two years. If this were to continue, most of the park would be infested within a decade.[25] The result could be the transformation of the park's desert ecosystem into savannas of grass and mesquite—and the elimination from the park of the saguaros for which it is named.[26] As a U.S. Geological Survey scientist

SAGUARO NATIONAL PARK

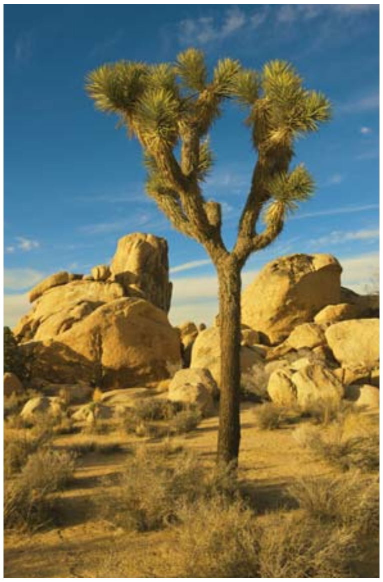
> *"Deserts and drylands are likely to become hotter and drier, feeding a self-reinforcing cycle of invasive plants, fire, and erosion."*
>
> — U.S. Global Change Research Program (2009)[27]

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.”[28]

Loss of Joshua Trees

Joshua trees need winter freezes to flower and set seeds. In a hotter future, they may not be able to survive in much of their current range, including all or major parts of Joshua Tree National Park in California.[29]

(For information on a widespread loss of piñon pines on the Colorado Plateau, see page 12.)



JOSHUA TREE NATIONAL PARK

> *“One day we may not only face a Glacier National Park without glaciers, but also a Joshua Tree National Park without Joshua trees and a Saguaro National Park without its iconic saguaro.”*
>
> — Thomas Swetnam, University of Arizona (2009)[30]

LOSS OF COASTAL PLANT COMMUNITIES

In coastal parks, the plant communities of wetlands, intertidal areas, and near-shore ecosystems could be lost to the effects of sea-level rise, stronger coastal storms, storm surges, and saltwater intrusion, all of which are projected to result from a human-changed climate.

“It has been estimated that 3 feet of sea-level rise (within the range of projections for this century) would inundate about 65 percent of the coastal marshlands and swamps in the contiguous United States.”

U.S. Global Change Research Program (2009)[31]

South Florida Parks

The current plant communities of Biscayne, Dry Tortugas, and Everglades national parks are particularly threatened. (See page 16.) In Biscayne and Everglades, coastal mangrove forests protect inland areas from storm surges and flooding, and prevent saltwater incursion into the freshwater marshes behind them. If the sea level were to rise very slowly—perhaps no more than one additional foot in this century—the mangroves may be able to maintain themselves by regenerating farther inland. But if the sea level rises even at the rate predicted for a low-emissions future, scientists warn that the mangroves may not be able to disperse inland rapidly enough to stay ahead of the rising sea. Then they would no longer serve as a dam holding out salt water, and the freshwater resources behind them would be quickly lost. The current ecosystem and 27 rare plant species could disappear.[32] In Everglades, if the sea level were to rise even as little as two feet, the park’s pinelands, one of the rarest ecosystems in South Florida, would be submerged, and half of the park’s signature freshwater marsh would be transformed by salt water pushed landward.[33]

EVERGLADES NATIONAL PARK

“At the fastest estimates of sea-level rise, predictions point to catastrophic inundation of South Florida and loss of freshwater resources.”

South Florida Natural Resources Center, National Park Service (2009)[34]

OTHER PLANT-COMMUNITY VULNERABILITIES

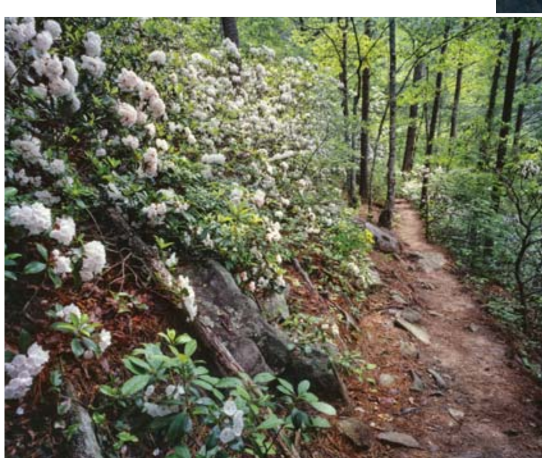
The particular local vulnerabilities of other parks are often not yet documented in detail, but general information about the impacts of a disrupted climate on plant communities suggests that many other parks are vulnerable. Great Smoky Mountains National Park in Tennessee and North Carolina has a greater diversity of native plants than any other national park, including more than 1,660 kinds of flowering plants. "Vegetation is to Great Smoky Mountains National Park what granite domes and waterfalls are to Yosemite and geysers are to Yellowstone," says the National Park Service.[35] Indiana Dunes National Lakeshore, too, has an astonishing diversity of plants, with more than 1,100 flowering plants. Theodore Roosevelt National Park in North Dakota preserves one of the few expanses of prairie in the national park system. All three parks are already struggling with invasive plant species that threaten the local ecosystems, a problem which could be worsened by an altered climate.

The coastal dune ecosystems and marshes of Assateague Island, Cape Hatteras, and Padre Island national seashores could be overtaken by rising seas. (See page 16.) So could biologically rich intertidal zones in Acadia, Olympic, and Glacier Bay national parks. Also in Acadia, as across the Northeast, there could be large changes in the distributions and numbers of tree species.[36]

(For an illustration of how changes in plant cover in Denali National Park and Preserve could affect caribou, see page 27.)

ACADIA NATIONAL PARK

THEODORE ROOSEVELT NATIONAL PARK



GREAT SMOKY MOUNTAINS NATIONAL PARK

6

Loss of Wildlife

Of the 25 national parks most in peril, these face loss of wildlife:

- Acadia National Park
- Assateague Island National Seashore
- Bandelier National Monument
- Biscayne National Park
- Cape Hatteras National Seashore
- Denali National Park and Preserve
- Dry Tortugas National Park
- Everglades National Park
- Glacier National Park
- Great Smoky Mountains National Park
- Indiana Dunes National Lakeshore
- Joshua Tree National Park
- Mesa Verde National Park
- Mount Rainier National Park
- Padre Island National Seashore
- Rocky Mountain National Park
- Saguaro National Park
- Theodore Roosevelt National Park
- Virgin Islands National Park/Virgin Islands Coral Reef National Monument
- Yellowstone National Park
- Yosemite National Park
- Zion National Park

For many Americans, the highlight of a trip to a national park is the wildlife they see. But a changed climate could mean less of the wildlife now in a particular park. Some species may go completely extinct. The Intergovernmental Panel on Climate Change warns that just 4° to 5°F of higher temperatures would leave 20 to 30 percent of plant and animal species that have been studied in climatic conditions far outside those of their current ranges, making them "likely to be at increasingly high risk of extinction."[1] One reason this percentage is so high is that stresses resulting from climate change would come atop others such as habitat loss.[2] Even if species do not become extinct, local populations in particular parks may be eliminated.

Very few studies so far have focused on the vulnerability of wildlife in particular national parks. As with other impacts of a changed climate, though, the available evidence suggest the impacts could be major.

LOSS OF MAMMALS

Grizzly Bears

In the Yellowstone ecosystem, including Yellowstone and Grand Teton national parks, the fate of grizzly bear populations could depend on that of a much smaller creature—mountain pine beetles—which are infesting and threatening to eliminate high-altitude whitebark pines and their nuts, the most important food source for grizzly bears in this region. (For background on the mountain pine beetles, see pages 19-21; for the effects on grizzly bears, see page 28.)

Lynx

Glacier National Park and several parks in Alaska are home to the Canada lynx, a threatened species in the contiguous United States under the Endangered Species Act. One team of researchers has documented that most areas where lynx now occur have

"Boreal forest, snow, and snowshoe hare–the primary food source for the lynx–may not shift synchronously. So climate change could produce habitat fragmentation and, at the least, disruption of the conditions that the Canada Lynx require for survival."

Patrick Gonzalez, University of California, Berkeley[3] four months of snow cover and average January temperatures under 17°F. Just a 4° to 7°F increase in average annual temperatures could reduce the overlap of those two climatic conditions and the types of forests where the cats live to eliminate about half of the suitable habitat in the contiguous United States. Across all of North America, about 10 percent of lynx habitat could be eliminated.[4]

Florida Panthers

The Florida panther, found in Everglades National Park and Big Cypress National Preserve, is one of the most critically endangered mammals in the world, with only about 100 individuals. Like other south Florida species, it could be affected because of the likely disruption of the region's ecosystems. (See page 28.) An even larger risk for the Florida panther could be its lack of a key advantage for any species—enough genetic variation in its population to give some individual animals different traits that would help them survive in profoundly different conditions. With a tiny population and a history of inbreeding, the Florida panther could fall short.[5]


NPS

Pikas

Pikas, which look like hamsters but are more closely related to rabbits, are mountaintop residents unusually sensitive to high temperatures, making them candidates as "early sentinels" to a changed climate.[6] Researchers recently surveying 25 sites in the Great Basin (between the Rocky Mountains and the Sierra Nevada) known to have previously had pika populations failed to find any pikas in nine sites—primarily those at lower, hotter elevations.[7] This raises concerns for the future of the species as the climate continues getting hotter. The risks to pikas could be greater in the lower-elevation areas where they occur, such as Bandelier and Lava Beds (in California) national monuments, Craters of the Moon National Monument and Preserve (in Idaho), and Zion National Park. The U.S. Fish and Wildlife Service is considering whether pikas should be protected under the Endangered Species Act because of the threats of climate change.

Mountain Sheep

At Rocky Mountain National Park, the National Park Service has expressed concern that the park's bighorn sheep population could decline over time due to loss of open alpine habitat as forests move upslope.[8] Other parks where forests could encroach on bighorn sheep habitat include Yellowstone, Grand Teton, Glacier, Yosemite, and Sequoia/Kings Canyon national parks.

Desert Bighorn Sheep

Of 80 separate populations of desert bighorn sheep in California about 65 years ago, 30 no longer exist. Scientists have determined that the local extinctions occurred most often in the hottest, driest areas.[9] Other research in Canyonlands National Park and a national wildlife refuge in New Mexico shows that birth and survival rates of desert bighorn lambs go up in wet years and down in dry years.[10] With projections that a changed climate will make the interior West even dryer, this raises concerns about the desert bighorn's future across its range, including in Joshua Tree and Zion national parks.

Range Shifts in Yosemite

In Yosemite National Park, a pioneering biologist's inventory of mammals early in the 20th century established a rare baseline for assessing changes in which species live where in the park. A recent resurvey shows that about half of the mammal species are now at different elevations. Most have moved to higher elevations—on average, about 500 yards higher—as would be expected in response to the park getting hotter.[11] The Yosemite movements are consistent with changes in wildlife ranges around the world; an analysis of 143 separate studies shows that many species are changing where they live, and more than 80 percent of those changes are consistent with adaptation to a changed climate, such as moving north or up in elevation to stay ahead of higher temperatures.[12]

Projected Habitat Losses and Species Changes

Researchers from Yale University studied the possible effects of climate change on mammals in eight national parks. They projected that the doubled atmospheric levels of heat-trapping gases could change habitat in the parks enough to eliminate some species. The greatest losses were projected for the southernmost parks in their study, Big Bend and Great Smoky Mountains national parks. They also projected that many new species might move into parks as habitats change. A major caveat, though, is that the researchers did not consider whether there would be geographic or other barriers to species moving into parks. Should as many new species move into parks as the researchers projected, there would be substantial new competition for habitat and food, creating another stress on the native local wildlife.[14]

> *"In Alaska, vegetation changes are already underway due to warming. Tree line is shifting northward into tundra, encroaching on the habitat for many migratory birds and land animals such as caribou that depend on the open tundra landscape.;"*
>
> — U.S. Global Change Research Program (2009)[13]

There is some evidence in particular parks of how habitat changes could affect park mammals. In Denali National Park and Preserve and Wrangell-St. Elias National Park, frequent winter thaws could lead to ice-crusted snow that is harder for foraging caribou to penetrate to get sufficient food in winter. The caribou also could suffer from changes in park plant communities that diminish their food sources.[16] Moose populations have declined significantly in Isle Royale National Park since the 1980s, and the effects of higher temperatures could be to blame.[17] In Theodore Roosevelt National Park, bison and other native prairie animals may lose habitat and food sources because of invasive plant species that thrive in a hotter climate. (See page 24.)

Projected Changes in Mammals

National Park	Current Number of Species	Projected Species Lost	Projected Species Gained
Acadia	43	3	8
Big Bend	48	10	22
Glacier	52	2	45
Great Smoky Mountains	48	8	29
Shenandoah	33	3	11
Yellowstone	53	0	19
Yosemite	64	6	25
Zion	53	1	41

Data source: Burns, Johnson, and Schmitz (2003)[15]

LOSS OF BIRDS

To American bird-watchers, one of the most accessible and famous population of white-tailed ptarmigan is on the tundra of Rocky Mountain National Park along Trail Ridge Road. Between 1975 and 1999, though, their numbers have been cut in half in response to increases in April and May temperatures and corresponding earlier hatching of ptarmigan chicks. If the same relationship between ptarmigan numbers and increasing temperatures persists, researchers have suggested that the birds could become locally extinct in the park in another 10 to 20 years as temperatures continue rising—although the researchers did not identify a particular temperature-related cause for the birds' decline.[18]

Sea-level rise could pose problems for some bird populations. With a three-foot sea-level rise, Dry Tortugas National Park could be completely submerged (see page 15), eliminating a key mid-Gulf resting stop for migrating birds and the only significant breeding colony in the United States of sooty terns. With the same sea-level rise, much of Padre Island National Seashore and an adjacent estuary would be inundated, eliminating habitat for migrating and

Yellowstone Case Study of Wildlife Effects

Global Warming, Bark Beetles, Whitebark Pine, and Grizzly Bears in Yellowstone

— *Contributed by* Dr. Jesse A. Logan

I consider the large-scale bark beetle mortality occurring in lodgepole pine forests across the West (see pages 19-21) interesting and unusual— but I have no doubt that lodgepole forests will remain on the landscape for generations. The current mortality in whitebark pines, though, breaks my heart. We are witnessing the catastrophic collapse of high mountain ecosystems as a result of human-caused climate change, and grizzly bears could pay the price.

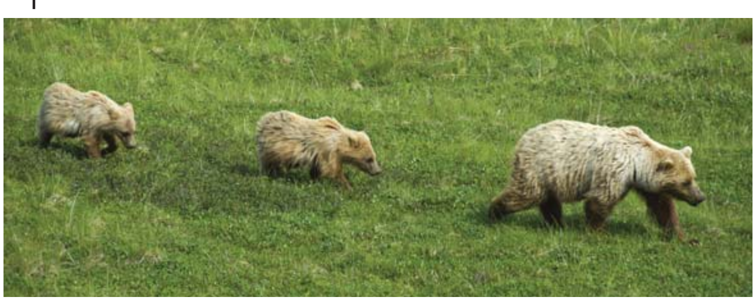
The grizzly bear is the most emblematic symbol of America's remaining wildlands. Unfortunately, in one of its last strongholds, the Greater Yellowstone Ecosystem, its very existence is in peril. The most challenging of its many threats there is a loss of critical food resources. Most important in the grizzly diet are the large and nutrient-rich seeds of whitebark pine, as the bears depend on them in the fall to prepare for hibernation. Nutritionally stressed bears in years with poor whitebark nut supplies have a lowered over-winter survival rate, and, more importantly, lower cub birth rates as embryos will be reabsorbed if pregnant females lack sufficient fat entering hibernation. Without enough whitebark pine nuts, grizzly bears are also more likely to get into human conflicts as they search for other foods.

In recent years, a new threat has erupted to this critical element in the grizzly diet: the expansion into high-elevation forests of a small, native bark beetle in response to a warming climate.

The mountain pine beetle is a native insect that has co-evolved with some pine forests. Trees killed by the beetles (and fire) open up the forests to new growth; otherwise, some types of trees, especially lodgepole pine, would be replaced by shade-tolerant spruce and fir. But whitebark pines are different from lodgepoles. Whitebarks live for centuries, not decades, and are restricted to high elevations (with one of their adaptations being their large, highly nutritious seeds). Whitebark pines do not depend on catastrophic forest disturbances to survive; instead, they are threatened by them. One hypothesized reason for the restriction of whitebark pines to high elevations is that they are poorly defended against the insect pests and pathogens of lower elevations. Mountain pine beetles have not before been a major threat to white-bark pine survival; their defense has been the high-elevation climate, historically too cold for long-term survival of large beetle populations.

Unfortunately, things have dramatically changed in response to climate warming since the mid 1970s. Computer simulations had predicted mountain pine beetle outbreaks into high-elevation systems, but even the modelers were surprised by how quickly and how far beetles have now spread into whitebark pines. Significant mortality is occurring across the entire American distribution of whitebark pine, with no sign of it diminishing. When added to another stress—from a pathogen, white pine blister rust—the spread of bark beetles into higher elevations puts in question the continued existence of these ecosystems and of Yellowstone's grizzly bears.

Given the likelihood of continued warming, what, if anything can be done to protect whitebark pines and the grizzlies that depend on them? First, we need to better understand mountain pine beetle infestations of whitebark pine, which differ from the host/insect interactions of other pine species. Understanding the unique aspects of mountain pine beetle in whitebark pines may let us tip the scale to favor the host. Second, we need better tools to evaluate the extent of mortality. Whitebark pine habitats are in the most remote and wild places (often designated wilderness areas) in the Rocky Mountains, where mortality goes almost undetected. Advanced technology, such as satellite imagery combined with traditional aerial photography and ground surveying, is needed. Third, management tools (e.g., pheromone strategies) need to be fine-tuned for high-elevation environments. All of these approaches need to be integrated across large, remote, and inhospitable landscapes.



— Dr. Logan, an entomologist, retired in 2006 from the U.S. Forest Service.

overwintering shorebirds and waterfowl.[19] In Everglades National Park, rising seas and stronger coastal storms could destroy habitat for the endangered Cape Sable Seaside Sparrow, roseate spoonbills, wood storks, snail kites, and other species not found in many other places in the country.[20]

In Mesa Verde National Park, Mexican spotted owls apparently no longer can be found in the park, which the park staff attributes to the drier conditions and altered habitat that represent a changed climate in this region.[21]

Reductions in the number of saguaros in Saguaro National Park—let alone their possible elimination (see page 22)—would remove nesting sites for elf owls and gilded flickers and food sources for white-winged doves—all species found in this country only in the extreme Southwest.

LOSS OF REPTILES

In Dry Tortugas National Park, a study of nesting endangered loggerhead and green sea turtles from 1995 through 2006 showed that in years of strong coastal storms the hatching success of both species declines, as high, storm-driven waves flood or expose turtle nests in beaches. These turtle species doubtless have always lost nests to coastal storms. Previously, larger populations and more widely spread nesting areas helped sustain them. Now, nesting sites have been lost to human developments and population levels have dropped to 10 percent or less of those before European settlement. As a result, they now have little remaining margin of safety in the face of any further stresses, such as the projected increase in coastal storm strength.[22]

Other parks are at similar risk of losing sea turtles. The beaches of Padre Island National Seashore provide key nesting habitat for the Kemp's ridley sea turtle, the most endangered of all sea turtles in the Gulf of Mexico. After successful reintroduction of Kemp's ridley turtles from Mexico to Padre Island, the seashore now hosts most Texas nests of these turtles. But the seashore is vulnerable to sea-level rise and stronger storms (see page 16), and as a result so are the sea turtles. Also at risk are Assateague Island and Cape Hatteras national seashores, where sea turtles occasionally nest.

In Everglades National Park, alligators, crocodiles, sea turtles, and mangrove terrapins have an unusual vulnerability to hotter temperatures: The gender of offspring is determined by temperatures during embryo incubation, so unnaturally high temperatures could disrupt the gender balance of new generations.[23]

LOSS OF AMPHIBIANS

Worldwide, amphibians appear to be the first large-scale wildlife victims of a hotter climate, in part because higher temperatures promote the spread of a fungus that kills amphibians.[24] In Yosemite and Sequoia/Kings Canyon national parks, researchers have discovered a recent 10 percent decline per year in the population of mountain yellow-legged frogs in park lakes and streams. Most remaining frogs are infected with the same fungal disease becoming more widespread elsewhere. Researchers also link the decline to shrinking snowpacks that dry up ponds and make the frogs more vulnerable to the trout that prey on them.[26] The vulnerability of these frogs to hotter, drier conditions illustrates how a changed climate is causing amphibian declines in ways other than promoting the spread of the same

"The potential prospects of earlier, more numerous, and more powerful storms pose an additional and significant threat to loggerhead and green sea turtles nesting in southwest Florida, and perhaps beyond. This may be especially true for turtle rookeries like those at Dry Tortugas National Park where nesting beaches are exposed to high surf and storm surges that accompany strong storms."

K. S. Van Houtan and O. L. Bass[25]


NPS

A ranger at Padre Island National Seashore shows off a hatchling Kemp's ridley sea turtle.

fungus.[27] As another example, at Bandelier National Monument a decline in Jemez Mountains salamanders is thought to be the result of hotter, drier conditions.[28]

LOSS OF FISH

An altered climate is likely to reduce inland populations of coldwater fish species, including trout and salmon. For trout in the interior West, a hotter climate is the single greatest threat to their survival; when water temperatures reach the mid-70°s, trout can die.

In Yellowstone National Park's Firehole River in 2007, temperatures topped 80°F for several days and as many as a thousand trout died in the largest documented fish kill in the park's 135-year history.[29] Under a high-emissions future, Rocky Mountain streams could warm up enough to reduce trout habitat by 50 percent or more by the end of the century.[30] Affected parks could include Glacier, Grand Teton, Mount Rainier, North Cascades, Rocky Mountain, Yellowstone, and Yosemite national parks. About 90 percent of bull trout, which live in western rivers in some of the country's wildest places, are projected to be lost due to warming. In the southern Appalachian Mountains, which includes Great Smoky Mountains National Park, over half of wild trout populations could disappear because of hotter streams.[31] Trout populations in Acadia and Shenandoah (in Virginia) national parks also could be affected.

Salmon, too, are vulnerable to higher water temperatures, as well as to changes in streamflows and heat-driven increases in diseases and parasites. Studies suggest that perhaps 40 percent of Northwest salmon populations could be lost by 2050.[33] By 2040 in Olympic National Park, water in streams with Chinook and coho salmon could reach about 68°F in summer, high enough to be stressful for fish. On the Skagit River, which flows through North Cascades National Park, by 2080 temperatures could reach 72°F.[34]

Marine fish populations may also suffer from an altered climate, in part because of the destructive impacts on coral reefs, as explained below.

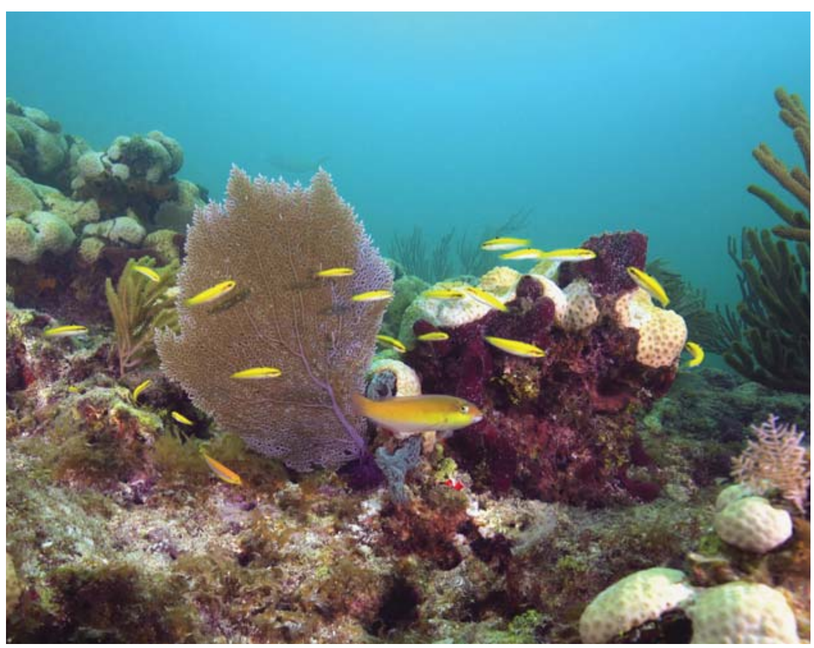
(For the effects of these losses on fishing in inland, coastal, and marine parks, see pages 37-38.)

LOSS OF CORAL REEFS

Corals, which are marine animals, and the astonishingly rich ecosystems of the reefs they build are

"Intensities and frequencies of bleaching events, clearly driven by warming in surface water, have increased substantially over the past 30 years, leading to the death or severe damage of about one third of the world's corals... [T]he corals that form the reefs in the Florida Keys, Puerto Rico, Hawaii, and the Pacific Islands are projected to be lost if carbon dioxide concentrations continue to rise at their current rate."

— U.S. Global Change Research Program (2009)[32]



"In 2005, the Caribbean basin saw unprecedented water temperatures and some dramatic bleaching, followed by coral disease and mortality. The most dramatic monitored bleaching took place in the U.S. Virgin Islands, where National Park monitoring showed that at some sites 90 percent of the coral bleached... To date there is an estimated 50 percent combined mortality from bleaching and disease in the Virgin Island National Park surveys. As of yet, there are no reports of recovery as amounts of mortality continue to increase."

U.S. Climate Change Science Program (2008)[35]

represented in our national parks more than many people realize. Parks containing coral reefs are American Samoa, Biscayne, Dry Tortugas, Haleakala (in Hawaii), and Hawaii Volcanoes national parks; Buck Island Reef National Monument (in the U.S. Virgin Islands); Kalaupapa (in Hawaii), Kaloko-Honokohau (in Hawaii), Pu'uhonua o Honaunau (in Hawaii), Salt River Bay (in the U.S. Virgin Islands), and War in the Pacific (in Guam) national historical parks; and Virgin Islands National Park/Virgin Islands Coral Reef National Monument.

Coral reefs are among the ecosystems most affected by human emissions of heat-trapping gases. The primary reef-building corals in Atlantic waters, elkhorn and staghorn corals, have already declined by more than 97 percent since the 1970s along the Florida Keys, in Dry Tortugas National Park, and in the U.S. Virgin Islands; disease, heat-driven bleaching, and damage from hurricanes are the principal culprits.[36] As a result, they were given federal protection under the Endangered Species Act in 2006.

Coral bleaching is a particular threat clearly linked to hotter temperatures. The often brilliant colors of corals actually come from algae that the corals host; when stressed enough, though, corals eject the algae and lose their color. Since the 1980s, this coral bleaching has greatly increased. On a small scale, bleaching can be caused by a variety of factors, but large-scale, mass bleaching has been conclusively linked to a single cause—unusually high water temperatures. The most extensive episodes of coral bleaching have been in 1998-99 and 2005, the world's hottest years on record.[37] A well-studied example was in the waters of Virgin Islands National Park in 2005, where researchers documented the loss of half of the park's corals from high water temperatures.[38] Other parks have experienced losses of coral reefs, too; during the late 1990's, Biscayne National Park, like much of the Florida Keys, lost approximately 40 percent of its corals.[39]

When corals die, not just the coral reef ecosystem but also the larger marine environment are affected. As one example, reefs are important feeding grounds for wide-ranging marine fish species. In the Caribbean, the loss of coral reefs has been associated with an overall decline in fish populations since the mid-1990s.[40]

LOSS OF BUTTERFLIES

Butterflies are particularly sensitive to temperature and so are vulnerable to a changed climate. Monarch butterflies illustrate the risks. They make one of the most amazing migrations of all wildlife, taking several generations to complete a round trip thousands of miles long to return to particular wintering grounds. Scientists do not even know how the great-great-great grandchildren find the winter roosting

sites. But scientists project that an altered climate will make the wintering grounds wetter, causing problems for the monarchs, which cannot survive the area's occasional freezing temperatures if they are wet.[41]

Monarchs migrate through and to all 48 contiguous states. If their populations drop, though, that would be felt particularly at Assateague Island National Seashore. Many monarchs migrate along the coast in the fall; Assateague Island is adjacent to a national wildlife refuge where a monitoring project has recorded as many as 243 monarchs per hour in a peak migration year.

For other butterflies, climate change is already tolling. Local populations of the Edith's checkerspot butterfly, which inhabits Yosemite and Sequoia/Kings Canyon national parks and other locations in California, have gone extinct in certain areas during extreme drought and low-snowpack years.[42] At Indiana Dunes National Lakeshore, numbers of Karner blue butterflies, an endangered species, have declined in years of low snow cover, thought to be from a loss of the protection that snow provides for over-wintering eggs.[43] Research at North Cascades National Park indicates that much of the habitat of Anicia checkerspot butterflies in the park could be lost if snowmelt occurs earlier and soils dry out faster, as climate scientists project.[44]

DISRUPTION OF TIMINGS

Another type of risk facing nearly all kinds of wildlife is a disruption of their ecosystems from changed timing of seasons. In the United States, spring now arrives ten days to two weeks earlier than two decades ago, along the lines of what is also happening around the world. About 60 percent of all species worldwide appear to already be responding by changing where they live or the timing of their life cycles, for example by ending hibernation, migrating, or breeding earlier. A risk is that one species may change in one way and other species on which they depend may respond in different ways and with different timing, disrupting habitats, food supplies, or other needs of the first species.[45]

> *"Large-scale shifts have occurred in the ranges of species and the timing of the seasons and animal migration, and are very likely to continue."*
>
> — U.S. Global Change Research Program (2009)[46]

7

Loss of Historical & Cultural Resources

MESA VERDE NATIONAL PARK
PHOTO: NPS

Of the 25 national parks most in peril, these face a loss of historical and cultural resources:

- Acadia National Park
- Bandelier National Monument
- Biscayne National Park
- Cape Hatteras National Seashore
- Colonial National Historical Park
- Dry Tortugas National Park
- Ellis Island National Monument
- Joshua Tree National Park
- Mesa Verde National Park
- Zion National Park

By preserving some of the best of our historical and cultural resources—buildings, landscapes, archaeological sites, and artifacts—America's national parks provide information about the past and provide important links to the present. Many of these resources are at risk from a changing climate.

CULTURAL RESOURCES LOST TO SEAS AND STORMS

Rising seas and stronger coastal storms (see pages 15-18) threaten cultural resources in coastal parks.

The entirety of Ellis Island National Monument in Upper New York Bay is less than three feet above the current high tide level.[1] The whole national monument, through which passed the arriving ancestors of 40 percent of all living Americans, is in substantial danger of being completely lost to higher seas. Even before being permanently inundated, the historic immigration center could be damaged or destroyed by storm surges. One analysis based just on projected local changes in sea levels (without considering an increase in storm severity) suggests that a 100-year coastal flood in the New York City metropolitan area—the highest coastal flooding now expected to occur once every 100 years—could happen by century's end every 11 years in a higher emissions future or every 22 years in a lower emissions future.[2] Another study says what currently is a 100-year coastal flood in the metro area could occur every 15 to 35 years in the future.[3]

Similarly at risk is the Statue of Liberty National Monument, on Liberty Island, like Ellis Island in Upper New York Bay.

Also vulnerable is where the first European ancestors of today's Americans arrived in 1607— the Jamestown National Historic Site, part of Colonial National Historical Park in Virginia. The original Jamestown fort was thought for over two centuries to have been lost to erosion of the James River's bank. The buried fort, however, was recently rediscovered and is being excavated—except for one part now definitely known to have been washed away. In this tidal stretch of the James River, the remainder of the first settlers' fort is at risk to rising seas (which in the Chesapeake Bay area are rising at twice the global average rate), storms, and storm surges.[4] Already, in

Ellis Island National Monument in Upper New York Bay is less than three feet above the current high tide level.

2003, Hurricane Isabel flooded 90 percent of the park's one million artifacts, forcing the NPS to relocate the entire collection to another facility for restoration.

As explained on page 15, Dry Tortugas National Park also could be entirely lost to higher seas. The park's major cultural resource—Fort Jefferson, the Western Hemisphere's largest brick fort—is at risk.

Cape Hatteras National Seashore's barrier islands erode under natural conditions from tides, currents and waves. With an altered climate, the U.S. Global Change Research Program reports that it is virtually certain that barrier islands in the mid-Atlantic region, including those at Cape Hatteras, will erode more quickly.[5] Already, the seashore's Cape Hatteras Lighthouse, the tallest brick lighthouse in the United States, has been moved once because of sea-level rise. When built in 1870 it was 1,500 feet from the shoreline; by 1998, only 120 feet separated it from the Atlantic Ocean. After the National Academy of Sciences confirmed that the lighthouse was in danger of being lost to the continued rise of the Atlantic, the lighthouse was moved 2,900 feet inland. That took two years and cost taxpayers $4.6 million. Knowing that this relocation may prove inadequate in the face of rising seas and stronger storms, the National Park Service left steel beams under the lighthouse to make the next move easier.

Other coastal parks and their cultural resources at risk from higher seas and stronger storms include:

- Acadia National Park—historic structures and cultural landscapes along the shoreline;
- Biscayne National Park—a lighthouse and other historic structures on Boca Chita Key;
- Channel Islands National Park in California—archaeological treasures dating back 11,000 years;
- Olympic National Park—petroglyphs carved into shoreline rocks;
- Point Reyes National Seashore in California—sites of Coast Miwok Indian settlements going back 5,000 years;
- Golden Gate National Recreation Area in California—historic Fort Mason and portions of the grounds of the Presidio of San Francisco, the oldest continuously used military post in the nation;
- Kaloko-Honokohau National Historical Park—outstanding examples of native Hawaiian culture, including religious sites, currently protected by a seawall that will be inadequate if the sea level rises even 1½ feet.[6]

CULTURAL RESOURCES LOST TO FLOODING AND EROSION

Increased downpours, flooding, and erosion (see page 18) likely will increase damage to ancient structures and cause a loss of artifacts. This is particularly true in arid areas, where the land is dry and hard enough that downpours are not absorbed into the soil but instead produce floods and erosion. The results can include a loss of historic and prehistoric structures and, particularly, undiscovered artifacts. In Bandelier National Monument, for example, 80 percent of the park's archeological sites have been affected by erosion. The National Park Service identified in a "Vanishing Treasures" program irreplaceable pueblos, cliff dwellings, churches, and forts that are "rapidly disappearing from the arid West," often because they are "in immediate, imminent danger from natural erosive factors." Parks containing the vanishing treasures include Bandelier National Monument and Joshua Tree, Mesa Verde, and Zion national parks.[7] Not all sites that could be affected are even known to the Service; in Big Bend National Park, for example, the NPS has estimated that there could be 26,000 archaeological sites, of which only three percent have even been identified.

The Cape Hatteras lighthouse being prepared to be moved to keep it above the rising sea.

8

Less Visitor Enjoyment

GRAND CANYON NATIONAL PARK

In addition to impacts already described in this report, there are four other particular ways in which a changed climate could diminish the enjoyment that people get from visiting national parks. First, some parks may become so hot that they will be intolerable for long stretches of time. Second, enough people may be drawn to relatively cooler parks to escape the increased heat of the summertime to make those parks overcrowded. Third, fishing may be reduced in some parks. Finally, a hotter climate may lead to increased air pollution in some parks—affecting not only the enjoyment of visitors but also their health.

INTOLERABLE HEAT

Of the 25 national parks most in peril, these face intolerable heat:

- Biscayne National Park
- Everglades National Park
- Joshua Tree National Park
- Lake Mead National Recreation Area
- Saguaro National Park
- Zion National Park

As the world continues to heat up, heat itself will become a real problem in areas that are already hot to begin with and then get much hotter. People visiting national parks in these areas will particularly feel the heat, since they typically are outdoors, not in air-conditioned buildings. These parks may simply become intolerably hot for long stretches of the year for many people. These parks include:

- Death Valley National Park, the hottest place in North America. Average high temperatures already are 99°F in May, 109°F in June, 115°F in July, 113°F in August, and 106°F in September. The park's record high temperature is 134°F.
- Nearby Joshua Tree National Park, nearly as hot, with average high temperatures of 100°F or more in June, July and August.
- Lake Mead National Recreation Area, which averages 98°F in June, 105°F in July, 103°F in August, and 97°F in September.
- Arches and Zion national parks, both with an average high temperature of 100°F for July. In Arches, the average high is 97°F in August. In Zion temperatures average over 90°F in June, August, and September.
- Saguaro National Park, where the average highs in both June and July are 98°F and are over 90°F in August and September.
- Grand Canyon National Park, where summer temperatures at Phantom Ranch—the most popular hiking destination at the bottom of the canyon—typically exceed 100°F.

These parks already are too hot for many people during the summer, when the number of people visiting the parks declines while it is going up in most parks. If these hot parks get even hotter because of human-caused changes to the climate, they would be intolerably hot for many people for longer stretches.

Some other parks, while not quite as hot as those above, are still hot enough that it would not take much more heat to make them intolerably hot for significant stretches. Examples are:

- The desert floors of Big Bend National Park average over 90°F for highs in June, July and August.
- In Biscayne and Everglades national parks, high temperatures average nearly 90°F from June through September.

Climate models project that the parks named above are likely to get substantially hotter, especially in a higher-emissions future. Stretches of the country that include Big Bend, Death Valley, Joshua Tree, and Saguaro national parks, Mojave National Preserve in California and Lake Mead National Recreation Area are projected to average more than 100 days a year over 100°F.[1] Those parks, Biscayne and Everglades national parks, and Big Cypress National Preserve are projected to average 90°F or hotter for half or more of the entire year.[2]

Number of Days a Year Over 100°F

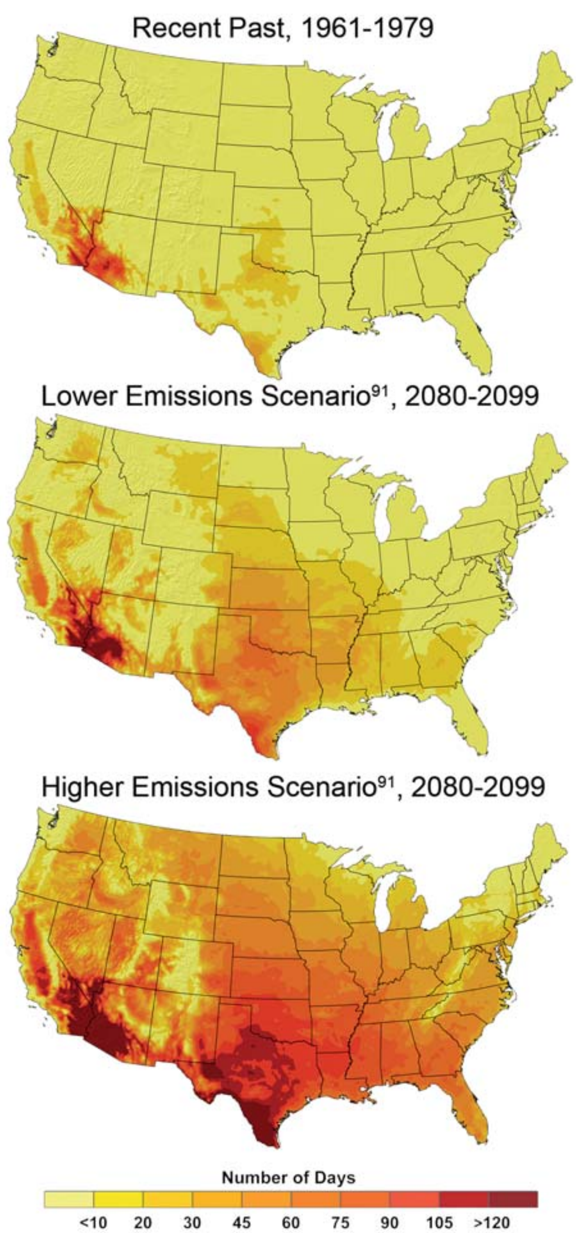


Figure source: U.S. Global Change Research Program.[3]

OVERCROWDING IN COOLER PARKS

Of the 25 national parks most in peril, these face overcrowding:

- Acadia National Park
- Assateague Island National Seashore
- Biscayne National Park
- Cape Hatteras National Park
- Great Smoky Mountains National Park
- Indiana Dunes National Lakeshore
- Mount Rainier National Park
- Padre Island National Seashores
- Rocky Mountain National Park
- Yellowstone National Park
- Yosemite National Park

As temperatures soar with a changed climate, to escape oppressive heat enough people may flock to cooler northern and mountain parks and to national seashores to overcrowd them. In Rocky Mountain National Park, a survey of park visitors suggests that under the climate conditions projected by as soon as 2020 enough people could come more often and stay longer to increase the number of visitor days by more than one million a year—nearly a one-third increase.[4] Researchers in a comprehensive study of Canadian national parks found similar results there, and noted:

> The implications for tourism and park management are substantive. Revenues for Parks Canada could increase substantially and communities with park-based tourism economies could benefit extensively if the opportunities to increase visitation can be accomplished in a sustainable manner. Conversely, parks that already report visitor-related ecological stress would require more intensive visitor management, perhaps including strategies such as de-marketing, visitor quotas, and variable pricing for peak periods.[5]

So far, there has been surprisingly little research done, by the National Park Service or others, on how higher temperatures may increase visitation to cooler parks, national seashores, and national lakeshores—or on how that increased visitation can be accommodated. Based on the two studies cited above, though, overcrowding could be a significant problem particularly for those parks that offer a break from heat and are close to major population centers, including:

- Golden Gate National Recreation Area, with several beaches in the San Francisco Bay area and 14.5 million visits in 2008;
- Gateway National Recreation Area in New York and New Jersey, with beaches in the New York City metropolitan area and 9.4 million visitors in 2008;
- Cape Cod National Seashore in Massachusetts, with beaches near Boston and other New England cities and 4.6 million visitors;
- Indiana Dunes National Lakeshore, with beaches just a few miles from Gary and about 2 million visits;
- Great Smoky Mountains National Park, with the highest mountains in the Southeast and more than 9 million visits; and
- Yosemite National Park, the most visited mountain park in the West, with 3.4 million visits.

Other parks that could be vulnerable to overcrowding as people escape heat include Acadia, Biscayne, Mount Rainier, and Yellowstone national parks; Assateague Island, Cape Hatteras, Fire Island (in New York), and Padre Island national seashores; and Sleeping Bear Dunes National Lakeshore.

YELLOWSTONE NATIONAL PARK / PHOTO: NPS

LOSS OF FISHING

Of the 25 national parks most in peril, these face loss of fishing:

- Acadia National Park
- Assateague Island National Seashore
- Biscayne National Park
- Cape Hatteras National Seashore
- Dry Tortugas National Park
- Everglades National Park
- Glacier National Park
- Great Smoky Mountains National Park
- Indiana Dunes National Seashore
- Mount Rainier National Park
- Padre Island National Seashore
- Rocky Mountain National Park
- Virgin Islands National Park/Virgin Islands Coral Reef National Monument
- Yellowstone National Park
- Yosemite National Park
- Zion National Park

Anglers have long enjoyed fishing amid the natural settings of our national parks. But now a changed climate threatens to reduce fish populations (see page 29-30) and recreational fishing opportunities in the parks.

Populations of trout, a cold-water fish, are threatened with widespread declines because of hotter water temperatures. Already, bull trout fishing is banned in Glacier and Olympic national parks and restricted in North Cascades National Park. At Yellowstone National Park, the extreme heat of July 2007 led the National Park Service to close 232 miles of rivers to mid-day fishing.[6] In the future, if populations of other trout species decline as precipitously as scientists project, anglers might face more restrictions on trout fishing in these parks and others in the West, including Black Canyon of the Gunnison (in Colorado), Glacier, Crater Lake, Grand Teton, Mount Rainier, North Cascades, Olympic, Rocky Mountain, Sequoia/Kings Canyon, Yosemite, and Zion national parks and Bighorn Canyon National Recreation Area in Montana and Wyoming. In the East, trout fishing could be affected in Acadia, Great Smoky Mountains, and Shenandoah national parks.

Salmon, another type of cold-water fish, are threatened by a hotter climate, too, which could affect fishing for salmon in parks including North Cascades and Olympic national parks.

In Great Lakes parks—Isle Royale National Park and Apostle Islands, Indiana Dunes, Pictured Rocks, and Sleeping Bear Dunes national lakeshores—fishing for Chinook and coho salmon and trout could be affected if, as projected, warmer temperatures lead to the creation of deep, oxygen-depleted layers of water in the lakes, reducing salmon and trout populations.[7]

In the nation's coastal parks, fishing for marine species could be affected, too. In the bays of Everglades and Biscayne national parks, sea-level rise could disrupt or eliminate most of the tidal flats, saltmarshes, and estuarine beaches that support local fisheries.[8] Climate change impacts on coral reefs and other marine ecosystems (see page 31) could affect fishing in Biscayne and Dry Tortugas national parks and Virgin Islands National Park/Virgin Islands Coral Reef National Monument. In Assateague Island, Cape Hatteras, and Padre Island national seashores, surf fishing is popular, but the beaches where people fish—or access to them—could be lost if those islands are fragmented or inundated by sea-level rise. (See page 16.)

MORE AIR POLLUTION

Of the 25 national parks most in peril, these face more air pollution:

- Acadia National Park
- Assateague National Seashore
- Ellis Island National Monument
- Great Smoky Mountains National Park
- Indiana Dunes National Lakeshore
- Joshua Tree National Park
- Lake Mead National Recreation Area
- Padre Island National Seashore
- Rocky Mountain National Park
- Saguaro National Park
- Yosemite National Park
- Zion National Park

A hotter climate is projected to worsen concentrations of ground-level ozone, a component of smog created when pollutants mix in sunlight.[9] (Naturally occurring ozone higher in the atmosphere, which filters the sun's ultraviolet rays, is a different thing.) Ground-level ozone has been firmly established to harm people's health, and the U.S. Environmental Protection Agency has set air quality standards at the levels necessary to prevent adverse health effects.

Many people think of ozone as a big-city air pollution issue, but it is a problem in many national parks, affecting both the enjoyment and the health of visitors. In 2005-2007, 11 national parks with permanent air-quality monitoring stations, including Acadia, Great Smoky Mountains, Joshua Tree, Saguaro, Yosemite, and Zion national parks, had levels of ozone violating the national health-based air quality standards for ozone, as recently strengthened by EPA.[10] In addition, Rocky Mountain National Park had ozone levels right at (but not violating) the new standard. Most parks, however, do not have fixed monitors for ozone and other air pollutants, and so their exact status is not known. Based on monitoring with portable equipment, monitoring sites near parks, and other methods, the NPS thinks that many more parks in 2005-2007 violated the ozone standard. Of the 25 parks listed in this report as having the greatest overall vulnerability to a changed climate, five others may be in violation: Assateague Island National Seashore, Ellis Island National Monument, Indiana Dunes National Lakeshore, Lake Mead National Recreation Area, and Padre Island National Seashore.[11] Because future climate-change-driven increases in ozone levels are expected to be greatest where ozone levels already are high, all of these parks are at risk of continued, perhaps worsened, levels of unhealthful air.[12]

In particular, Great Smoky Mountains National Park could have a worse ozone problem.[13] The park exceeded an older, less stringent health-based standard for ozone more than 300 times since 1990.[14] Ozone levels there are chronically so high that they affect visitors and plants in the park.[15] Ozone-caused damage to vegetation has also been documented in other national parks, including Sequoia/Kings Canyon and Shenandoah national parks.[16]

9

RECOMMENDATIONS


YOSEMITE NATIONAL PARK

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.

To protect our parks for the enjoyment of this and future generations, we need to act now to reduce emissions of climate-changing pollutants, which come mostly from the burning of fossil fuels like coal and gasoline. If we continue with a business-as-usual approach into a higher-emission future, our country could heat up another 7° to 11°F, which would have extraordinarily severe effects on national parks. The most important step we can take to protect parks is to reduce those impacts by beginning to cut heat-trapping emissions to a level that would stabilize further warming at about an additional 2°F. That would minimize impacts on national parks, other ecosystems, and other resources. (See pages 1-2.)

But even an additional 2°F of warming would increase the harm that is already being done to parks by the climate changes that are already underway. So we also need bold, visionary actions to protect our national parks in the face of whatever climate changes we end up causing.

Both these types of actions—cutting emissions and ensuring our parks are prepared for the impacts of a changing climate—need to be driven by the federal government, primarily the Congress and the National Park Service.

ACTIONS SPECIFIC TO NATIONAL PARKS

The mission of the National Park Service, defined by the 1916 Organic Act for the NPS, is "to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." This strong mandate of preservation, sustainability, and non-degradation is embodied in the NPS's policies and its long, proud tradition of environmental stewardship. "The Service will use all available authorities to protect park resources and values from potentially harmful activities," the NPS *Management Policies* boldly declares. Sadly, the NPS has not yet followed its creed and exercised its authorities to address human disruption of the climate and its effects. The U.S. Government Accountability Office concluded in 2007 that the Park Service and other federal natural resource management agencies:

> have not made climate change a priority, and the agencies' strategic plans do not specifically address climate change. Resource managers focus first on near-term, required activities, leaving less time for addressing longer-term issues such as climate change. In addition, resource managers have limited guidance about whether or how to address climate change and, therefore, are uncertain about what actions, if any, they should take. In general, resource managers lack specific guidance for incorporating climate change into their management actions and planning efforts. Without such guidance, their ability to address climate change and effectively manage resources is constrained.[1]

Too often, the NPS has so far just looked the other way when it comes to climate-change impacts. Typical is this statement from the latest management plan (in 2000) for Dry Tortugas National Park, at risk of being totally submerged by rising seas, about harm to its resources from climate changes: "These external forces are beyond the scope of this plan."[2]

Fortunately, change is underway at the Park Service. President Obama's choice as NPS Director, Jon Jarvis, built the strongest record of leadership on climate change of any top NPS manager when he served as regional director of the Service's Pacific West Region. In particular, he established a vision for NPS operations in all parks in that region to become carbon-neutral—to avoid any net emissions of heat-trapping gases from the Service's own operations. We hope and expect that as NPS Director, Jarvis will demonstrate similar leadership on a national, Service-wide scale. We also are confident that if he does, he will be met by enthusiastic support from other NPS managers and employees—many, perhaps most, of whom have long been frustrated by the Service's inaction on this front. A fully mobilized NPS, however, still will need strong support and additional resources, from elsewhere in the Executive Branch, from Congress, and from the American people.

Addressing a changing climate and its effects on national parks will require a full suite of actions by the National Park Service and others.

New and Expanded Parks

For several reasons, the current boundaries of many national parks are not adequate to allow for the preservation of the resources and values that are the purposes of the parks. One key reason is that most park boundaries were established in the 19th and 20th centuries, long before any consideration was given to how human-caused climate change could affect park resources and values. Also, the 391 parks now in the national park system do not adequately include a fully representative sample of America's best natural and cultural resources. This is, again, especially so in the face of the myriad threats that a changing climate poses to existing parks and their resources and values. Accordingly:

1. The Congress, the Administration, and the National Park Service should comprehensively assess the need for new national parks, and designate new parks as necessary to ensure the preservation for future generations of representative and sufficient examples of America's best natural and cultural resources.

2. Similar assessments should be undertaken of the adequacy of existing park boundaries to determine where a changed climate may so alter local conditions and ecosystems that current park boundaries will no longer be adequate to ensure the preservation of park resources. Parks should be expanded as necessary to ensure the preservation of the resources and values whose preservation was the purpose of the parks' designations or whose preservation is provided for in the management of the parks.

3. In these assessments and designations, priority attention should be given to the impacts and challenges of human-caused climate change. The new and expanded parks should include enough examples of America's most important natural and cultural resources to ensure the preservation of an adequate representation of those resources. The new and expanded parks should be of sufficient size to allow for the preservation of the integrity of the park's resources and values over time, as ecosystems and species are affected by and respond to a changing climate. In particular, the new and expanded parks should be of sufficient size to allow for adaptation and migration by species and their continued survival. The new and expanded parks also should sufficiently include and represent those resources and values that are not now appropriately represented in the national park system, such as prairies and marine resources.

Ecosystem Protection and Migration Corridors

Areas within park borders often will not be sufficient to provide the room and flexibility for wildlife and plants to adapt to changes in park ecosystems and habitat caused by a disrupted climate. Actions on a broad geographic scale will be needed to provide that room and flexibility.

4. Where new, expanded, or existing parks will not be adequate to ensure the preservation of park resources, the NPS should promote, assist, and cooperate in bringing about preservation efforts that reach beyond current boundaries. These efforts should include cooperative management with other land management agencies and landowners to preserve large enough ecosystems, crucial habitat, and migration corridors among them so that plants and animals have opportunities to move and continue to survive in transformed landscapes.

5. The Congress and Administration should give the NPS the resources and tools to enable it to provide assistance to other landowners so they can contribute to the preservation of ecosystems of the scale necessary to preserve park resources and values. Examples of that assistance could be payments for the costs of actions by other landown-

ers that benefit park resources, sharing of information, or the provision of technical assistance; all such assistance should be fully consistent with the rights of other landowners.

Non-Climate Threats

Often, park resources and values face compound threats, from both an altered climate and other sources. Removing or reducing the other threats often can ease the overall risks to park resources and values while the effects of a changing climate are also being addressed.

6. The Congress, the Executive Branch, and the NPS should consider the combined effects of climate change and of other stresses on park resources and values, and work to reduce all the stresses that pose critical risks to parks. Addressing activities outside of parks that can disrupt parks, reducing conventional air pollutants that harm parks, restoring degraded habitat, and removing invasive species, for example, can make parks and their resources more resilient.

Other Resource Preservation Efforts

According to the service's *Management Policies*, "NPS managers must always seek ways to avoid, or minimize to the greatest degree possible, adverse impacts on park resources and values." To preserve park resources from the threats of an altered climate will require NPS actions on an unprecedented scale. In addition to other actions called for in these recommendations:

7. The NPS should develop park-specific and resource-specific plans for protection of the resources most at risk in individual parks.

8. The NPS, consistent with applicable laws and policies, should plan for a changed future that may be markedly different from the past, including in unexpected ways. One tool is to consider different possible future scenarios—plausible conditions that could occur but may not—instead of relying on a single set of future conditions. To await certainty in what the future will bring may take away the ability to address it in a sufficient and timely manner.

9. The National Park Service should use all its authorities to protect parks from the adverse impacts of a changing climate. In particular, under the Clean Air Act the Service has "an affirmative responsibility to protect the air-quality related values" of national parks. Park resources and values that are adversely affected by human-caused climate change fall within this mandate, and the NPS should fulfill its affirmative responsibility under the Clean Air Act to protect them.

> *"Current general management plan (GMP) guidance does not explicitly require paying attention to the effect that changing climate will have on future park natural and cultural resources, infrastructure, and visitors."*
>
> — Coalition of National Park Service Retirees (2008)[3]

Emission Reductions

National parks are among the most important places to concentrate efforts to reduce emissions of heat-trapping gases, because successful actions there can inspire the millions of Americans visiting the parks to make and support similar efforts elsewhere. Parks can demonstrate model management programs and provide a laboratory to teach technicians and educate the general public.

10. The NPS should adopt for all parks nationwide a goal of becoming climate-neutral in the Service's own operations within parks, as was adopted by the Pacific West Region by its Climate Change Leadership Initiative. The NPS should consider whether to adopt a schedule, either nationwide or park-by-park, for fulfilling this vision.

11. The NPS should give an even greater priority to reducing emissions from visitor activities than from its own operations, as emissions from visitor activities dwarf those from NPS operations. In Glacier Bay National Park and Preserve, for example, 97 percent of all emissions of heat-trapping gases come from marine vessels, essentially all of which are vessels other than the Service's. In the case of all actions to bring about reductions in emissions from visitor activities, the NPS (or concessionaires, as appropriate) should explain the actions taken and the reasons for them, as part of NPS's public education efforts.

Communication

With 275 million visits to national parks in 2008, the NPS has an enormous, unique opportunity to communicate what climate change may do to us and what we can do about it.

12. NPS officials, beginning with the Director, should speak out publicly about the threats that climate change and its impacts pose to national parks and the broader ecosystems on which they depend. The

NPS *Management Policies* state that when park resources and values are at risk from external threats, "It is appropriate for superintendents to engage constructively with the broader community in the same way that any good neighbor would... When engaged in these activities, superintendents should promote better understanding and communication by documenting the park's concerns and by sharing them with all who are interested." This guidance especially makes sense with respect to climate change impacts—and makes sense for other NPS officials, too, not just park superintendents.

13. The NPS should require concessionaires in a position to provide environmental education to park visitors (and many are required to do so) to provide information on climate change and its effects in national parks and what the NPS and the concessionaires are doing to address them. For example, visitor lodging within parks can have unobtrusive displays pointing out how energy and water are being conserved and why that is important.

Climate Change as a NPS Priority

The Service should accord a changing climate the attention it deserves given the threats it poses to parks. In particular:

14. The NPS Director should issue a Director's Order making it clear that addressing climate change and its impacts is among the highest priorities throughout the Service, consistent with applicable laws and policies. The order should launch action on particular recommendations outlined below.

15. The NPS should amend its management policies to incorporate specific references to management responsibilities with respect to climate change and its impacts in parks, consistent with applicable laws and policies, including the Wilderness Act.

16. The NPS should hold its managers accountable, through personnel evaluations, for their actions in complying with Service policies and requirements for addressing climate change and its impacts.

> *"[P]erhaps most importantly, the onset and continuance of climate change over the next century requires NPS managers to think differently about park ecosystems than they have in the past. Preparing for and adapting to climate change is as much a cultural and intellectual challenge as it is an ecological one."*
>
> — U.S. Climate Change Science Program (2008)[4]

17. The Service should continue to seek, and Congress should support, the creation of a separate NPS climate change office within the Service's natural resources stewardship and science program, to ensure cross-cutting support for Service actions to address climate change and its impacts in parks. Addressing climate change should be identified as a core mission of the natural resources and science program.

Funding

The National Park Service will need new funds to be able to address the new threats of climate change, and the Congress and the Administration should provide that funding.

18. Pending congressional climate bills would provide a portion of the revenue raised from the sale of emission permits under a national cap-and-trade emission-reduction program to the National Park Service and other federal land management agencies for natural resources adaptation activities. Those proposals would provide an important source of funds to the NPS and others to enable them to address climate change impacts.

19. As another source of funding, the Administration and NPS should seek, and the Congress should approve, an amendment to the Federal Lands Recreation Enhancement Act to be able to use funds from national park entrance and recreation fees to address climate change and its impacts in national parks, including actions to reduce emissions from NPS operations or visitor activities and actions to adapt to climate change threats and impacts, so long as information on those expenditures and their accomplishments is communicated to park visitors. The authorization for the NPS to use entrance and recreation fees within the parks, without awaiting separate congressional appropriation actions, was an important breakthrough in 1997 to enable the Service to address what was then widely regarded as a primary need of the national parks—reducing the backlog of unmet maintenance and construction needs. With climate change now looming as a greater threat to national parks, the use of these funds should be broadened to include addressing climate-change needs as well as maintenance and construction needs. This amendment to the law would provide funding for emission-reduction measures and visitor-education measures as well as adaptation measures, and so it would be a broader

and more flexible source of funds than the natural resources adaptation fund described above.

20. The Administration should request and the Congress should approve adequate funding of the Land and Water Conservation Fund to enable the acquisition of important lands within or near existing parks for addition to those parks, and of lands for the creation of new parks.

NPS Science and Research

Identifying and monitoring climate change effects on key resources of national parks are not only essential for protection of those resources, but also important for a broader understanding of climate change effects in the world at large. National parks are areas with spectacular resources, usually much less affected by human activities and other stresses than other lands; the parks provide some of our very best opportunities to learn how climate change is affecting and will affect natural and cultural resources. The abilities of the National Park Service to acquire scientific knowledge about park resources, however, was set back when much of its scientific research capacity was transferred to the U.S. Geological Survey in 1993.

21. The Congress, the Administration, and the NPS should reestablish within the Service the full range of scientific and research capacity, and the authority to direct that science and research, that it had prior to 1993, by returning to the NPS the research programs and staff that were transferred that year to the U.S. Geological Survey.

22. The NPS scientific capacity should not just be restored to earlier levels, but strengthened to enable the Service to assess (and then address) the full range of climate-change-related threats to parks, now and in the future. This will require expanded NPS scientific and research capacity at national, regional, and park levels.

23. The NPS should identify in every unit of the national park system the resources and processes at risk from climate change. This need not await full park management planning efforts; it can be accomplished through summaries of the literature, guided research, gatherings of experts, and simple brainstorming. Climate Friendly Parks workshops (see below) are a beginning.

24. The NPS should review its Inventory and Monitoring Program, in which every national park has established a number of vital signs for monitoring change over time; these should be reviewed to ensure they adequately include the impacts of climate change. If not, the vital signs and the monitoring plans should be updated.

> *"There is no comprehensive coordinated research on climate change ongoing in parks."*
>
> — Coalition for National Park Service Retirees (2008)[5]

Partnerships

The NPS does not have, and never will have, the resources or the ability to address climate change by itself. Given the scope of the challenges that it now faces, it is more important than ever that the Service strengthen existing partnerships with others and create new partnerships to deal with climate change. This includes:

25. The NPS will need to cooperate more with federal, state, and local natural-resource agencies and land managers to achieve coordinated management responses in national parks and on surrounding lands to climate-change impacts, which obviously transcend political and land borders.

26. The NPS also should actively engage others outside the Service, including scientists, non-governmental organizations, and members of the general public, to develop a shared understanding of the problems posed by climate change, identify ways to preserve park resources and to pursue effective efforts in response. For example, in 2007, the managers of Saguaro National Park, recognizing that the threats to the park from an invasive grass—buffelgrass (see page 22)—could not be dealt with just by actions within park boundaries, joined with 14 other public and non-profit entities in a Buffelgrass Working Group. In short order, that collaborative effort has led to a public summit, the development of an area-wide strategic plan for addressing the threat, and the creation of a new nonprofit organization, the Southern Arizona Buffelgrass Coordination Center, to lead regional action.[6] If the park's resources, including its namesake saguaros, are to be saved, these kind of creative institutional arrangements and partnerships will be essential.

27. On scientific research, much of the best work done in national parks to acquire information about climate change and its effects is done by others besides the NPS, including the U.S. Geological Survey, universities, and others. (Much important research work would remain within USGS even if the National Park Service's scientific research capacity is restored according to the pre-1993 organizational structure within the Department of the Interior, as recommended above.) The NPS should expand its arrangements with others to encourage and allow additional research on climate change in the parks.

Climate Friendly Parks

Over 80 national parks (out of 391) have participated in some way in the Climate Friendly Parks program, NPS's most visible climate-change initiative to date. That program is a partnership between NPS and the U.S. Environmental Protection Agency to help those parks protect their natural and cultural resources from climate change. Twenty-three have conducted an inventory of their emissions of heat-trapping gases, and 19 have action plans to reduce their emissions. So far, decisions about participation in the programs are up to the discretion of individual park superintendents.

28. The NPS should make a national commitment and develop a schedule to expand the Climate Friendly Parks program to all parks (with exceptions only for those few parks with small enough operations and visitation where doing so would not make sense.)

29. The NPS should post online summaries of all Climate Friendly Parks workshops in particular parks. (Not all now are posted.)

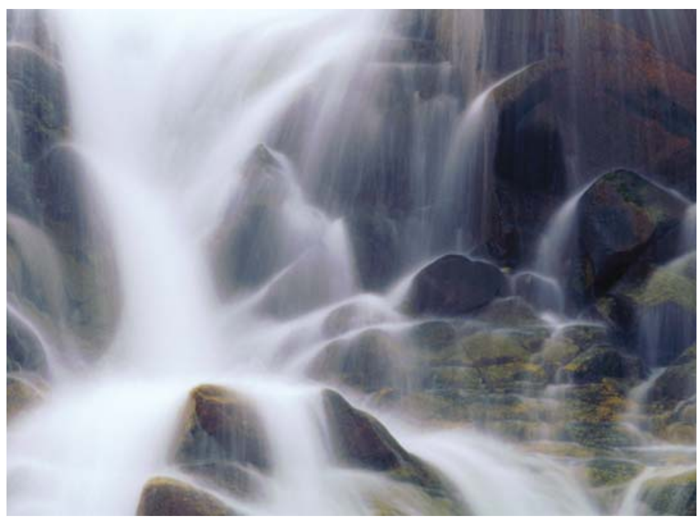
30. The NPS should post online all emission inventories and climate action plans for all parks for which they are completed. (Not all now are posted.)

31. The NPS should make Climate Friendly Parks program activities a priority for interpretation efforts for environmental education of park visitors.

International Leadership

The National Park Service is the best known and most respected natural resource management agency in the world, and has a worldwide role to play in addressing human-caused climate change.

32. The NPS should exercise leadership among natural resources management agencies around the world in exploring and promoting new institutional arrangements and creative approaches needed to address the broad-scale problems precipitated by climate change.



ROCKY MOUNTAIN NATIONAL PARK / PHOTO: JOHN FIELDER

FEDERAL ACTION TO REDUCE HEAT-TRAPPING GASES

— *Contributed by* Theo Spencer, NRDC

Global warming is one of the most serious threats not only to our national parks, but to our environment, our health, and our economy. The most recent scientific studies prove that global warming is here now and is already causing environmental changes that will have significant economic and social impacts. In fact, scientists say that carbon dioxide levels in our atmosphere are the highest they have been in the past 650,000 years.

The good news is that we can stop the worst effects of global warming by making factories more efficient, cutting energy waste in homes and offices, making cars go farther on a gallon of gasoline, and shifting to cleaner technologies. But we need to act now, and act decisively, to prevent dangerous impacts from becoming inevitable. Each year that passes without tackling global warming head-on makes the problem more difficult and expensive to solve.

Unfortunately, a host of market barriers and irrational incentives currently block investment in cost-effective global warming solutions. To unlock the potential that these technologies offer, we need a comprehensive package of policies to transform the capital-intensive and slow-moving energy sectors. Well-designed policies can promote investment in global warming solutions while improving the competitiveness of U.S. businesses and minimizing costs for residential, commercial, and industrial energy consumers.*

To help solve this problem, the federal government must take three essential steps:

- Enact 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 multi-million and multi-billion dollar capital investments.
- Overcome barriers to investment in energy efficiency to lower emissions reduction costs, starting now.
- Accelerate the development and deployment of emerging clean energy technologies to lower long-term emissions reduction costs.

Enact Mandatory Limits on Global Warming Pollution

A mandatory cap will guarantee that we meet emissions targets in covered sectors of the economy and will drive investment toward the least costly reduction strategies. If properly designed to support efficiency and innovation, such a program can actually reduce energy bills for many consumers and businesses. The following design elements are essential to achieving these results:

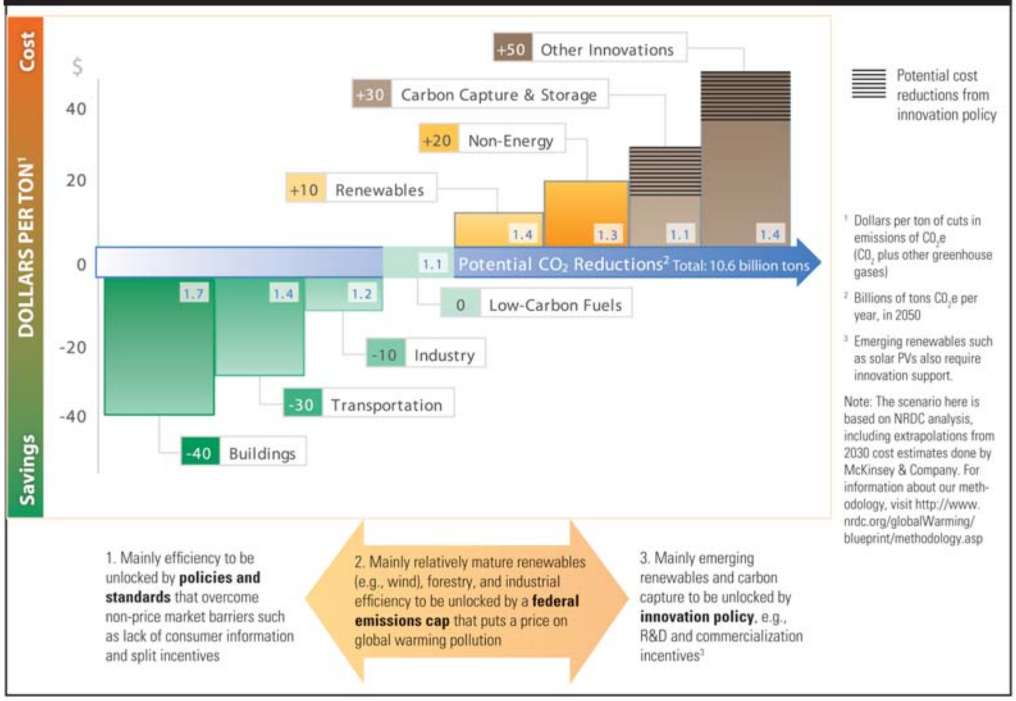
Comprehensive Coverage. At a minimum, a federal emissions cap should cover heat-trapping pollutants from all large stationary sources (power plants, factories, etc.) and the carbon content of transportation and heating fuels at the point of wholesale distribution (oil refineries and natural gas distribution companies).

Use Allowance Value in the Public Interest. As with other public goods such as the broadcast spectrum, the value of pollution allowances should be used for public purposes, such as achieving additional emission reductions from uncapped sources as well as to reduce costs for residential and non-residential energy users through energy efficiency and investments in low-carbon technologies. A portion of the allowances' value can also be used to help adversely affected workers and low-income families, as well as to adapt to the impacts of global warming that can no longer be avoided.

Limited Use of Offsets. Offsets are credits generated by specific projects outside the capped portion of the economy. Any offsets provision must include standards to ensure that reductions are real, surplus, verifiable, and permanent, as well as have a firm numerical limit.

* Although in the United States the vast majority of global warming emissions are from fossil fuel combustion, in many developing countries the largest source of emissions is deforestation, which leads to a loss of CO_2 stored in both trees and soils. Thus, in those countries, a somewhat different suite of abatement approaches will be required. However, as these countries develop, they will be in the market for energy systems, and the United States, if it effectively develops and deploys clean energy and energy efficiency technologies domestically, could find major export opportunities in this area.

Cutting U.S. Global Warming Pollution 80% by 2050: Cost and Payoff by Sector



Overcome Barriers to Energy Efficiency

Today there are few incentives for investment in cost-effective energy efficiency and emerging low-carbon technologies. While a mandatory cap on emissions is essential and can help fund efficiency investments, many opportunities require additional federal, state, or local policies to overcome barriers to investments that are already cost effective even without a price on greenhouse gas emissions.

Building, Industry, and Appliance Efficiency. Policies should include:

- Codes, standards, and incentives—Minimum efficiency codes and standards for commercial and residential buildings, appliances, and equipment are essential for driving the market to more efficient products that can also save consumers money.* Refrigerators today are bigger and less expensive but still use less than one-third the energy of those 35 years ago—because appliance standards have changed the market.

* As an example of the effectiveness of this strategy, in the 1990s, NRDC joined with the public and private sector to implement long-term market incentives that were given to the first refrigerators that both met ambitious energy efficiency standards and phased out ozone-depleting chemicals. As a direct result of this "golden carrot" design competition, energy use in refrigerators today has been cut by 75 percent and the real price of refrigerators has declined as well.

- Federal and state-level regulatory reform—A federal cap-and-trade system for global warming emissions could distribute allowance value to states based on demonstrated improvements in the energy intensity of buildings to help put efficiency on a level playing field with new energy supply. We also need to reform utility regulation with measures like "decoupling" profits from sales, plus incentives for delivering efficiency so that helping customers save energy becomes the most profitable thing utilities can do.

Smart Transportation: Advanced Vehicles and Smart Growth. Policies should include:

- Performance standards—The federal government should further increase automobile fuel economy standards or set global warming pollution standards to promote the production of efficient vehicles that reduce consumers' fuel costs.
- Transportation, smart growth, and support for local governments—To minimize vehicle miles traveled, federal, state, and local government must establish policies that encourage investment in transportation, housing, and neighborhood design to reduce sprawl and improve convenience.

Promote Emerging Low-Carbon Solutions

To accelerate the "learning by doing" needed to develop an affordable low-carbon energy supply, we must support rapid development and deployment of renewable electricity, low-carbon fuels, and carbon capture and storage, including channeling a substantial share of CO_2 allowance value from a federal emissions cap towards innovation.

Renewable Electricity. Policies should include:

- Renewable electricity standards and incentives—The federal government should establish a national standard to ensure steady expansion of the renewable electricity market, as 25 states already do. Following the states' lead, the federal government should also provide long-term, performance-based incentives to support the continued growth of promising technologies, such as solar photovoltaics.

- Infrastructure upgrades—Energy regulators must support transmission capacity upgrades to enable increased use of renewables, subject to careful environmental review.

Carbon Capture and Storage. Policies should include:

- No new dirty coal plants—Federal regulations should require any new coal-fired power plant to capture and permanently geologically sequester at least 85 percent of its carbon dioxide emissions.

State and federal governments must also develop an effective regulatory framework for site selection, operation, and monitoring for carbon capture and geologic storage systems (CCS). Additionally, state and federal incentives are needed to overcome the current cost barrier to CCS.

The United States is finally starting to move toward addressing the threat of global warming. We have the solutions at hand to solve the problem while creating jobs and enhancing our national security by reducing our dependence on imported oil. Starting now will build the momentum the market needs to generate even more technological advances. And acting now means we stop wasting money on old polluting infrastructure and start leading the global economy to a clean energy future. Failure to act will result in unacceptable economic and environmental risks from climate disruption —not just to our national parks, but to our health, our security, and our children's future. The time is now for political leadership both at home and abroad.

EVERGLADES NATIONAL PARK

NOTES

For general matters of science with respect to climate change and its overall impacts, readers are referred principally to an excellent 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 a summary of the science of climate change and the impacts of climate change on the United States, now and in the future, in eminently readable form. For any reader interested in more detailed information on climate change and its effects across the United States, that report lists several hundred sources on particular points.

For matters of specific relevance to climate change and its impacts in national parks, this report relies on 52 government reports and other sources and 63 scientific sources.

Introduction

1. J. S. Baron and others, "National Parks," in U.S. Climate Change Science Program ["USCCSP"], *Preliminary review of adaptation options for climate-sensitive ecosystems and resources*, S. H. Julius and J. M. West, eds., report by USCCSP and the Subcommittee on Global Change Research, U.S. Environmental Protection Agency, Washington, DC, 2008, p. 4-4, http://downloads.climatescience.gov/sap/sap4-4/sap4-4-final-report-all.pdf.
2. Intergovernmental Panel on Climate Change ["IPCC"], "Summary for Policymakers," prepared by R. Alley and others, in IPCC, *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change,* S. Solomon and others, eds., Cambridge University Press, Cambridge, U.K., 2007, pp. 5, 10, http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-spm.pdf.
3. U.S. Global Change Research Program ["USGCRP"], T. R. Karl, J. M. Melillo, and T. C. Peterson, eds., *Global Climate Change Impacts in the United States*, Cambridge University Press, New York, NY, 2009, p. 17, http:/www.globalchange. gov/publications/reports/scientific-assessments/us-impacts.
4. IPCC, "Technical Summary," prepared by S. Solomon and others, in IPCC, *The Physical Science Basis* (see note 2), p. 60, http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-ts.pdf. USGCRP, *Climate Change Impacts* (see note 3), p. 16.
5. USGCRP, *Climate Change Impacts* (see note 3), p. 29.
6. USGCRP, *Climate Change Impacts* (see note 3), p. 23.
7. USGCRP, *Climate Change Impacts* (see note 3), pp. 23-24.
8. USGCRP, *Climate Change Impacts* (see note 3), p. 23.
9. USGCRP, *Climate Change Impacts* (see note 3), p. 29.

Chapter 1 – National Parks Most at Risk

1. D. E. Lawson and D. C. Finnegan, "Climate monitoring in Glacier Bay National Park and Preserve: Capturing climate change indicators: 2008 annual report," p. 6, http://www.nps.gov/glba/naturescience/upload Lawson_Finnegan_2008_AnnualClimateMonitoringReport.pdf.

Chapter 2 – Loss of Ice and Snow

1. IPCC, "Observations: Changes in snow, ice, and frozen ground," prepared by P. Lemke and others, in IPCC, *The Physical Science Basis* (see note 2, Introduction), p. 357.
2. D. B. Fagre, "Adapting to the reality of climate change at Glacier National Park, Montana, USA," in *Proceedings of the Conferencia Cambio Climatico, Bogota, Colombia, 2005*, in press, http://www.nrmsc.usgs.gov/files/norock/products/GCC/Fagre_Bogota_Conference_paper_FINAL.pdf.

PHOTO: JOHN FIELDER

3. M. H. P. Hall and D. B. Fagre, "Modeled climate-induced glacier change in Glacier National Park, 1850-2100," *Bioscience* 53, 2 (2003): 131-140.

4. M. Jamison, "Melting into history," *Missoulian*, Oct. 2, 2007; reprinted in *USA Today*, Oct. 14, 2007, http://www.usatoday.com/weather/climate/globalwarming/2007-10-11-glacier-park_N.htm.

5. North Cascades National Park, National Park Service ["NPS"], "North Cascades National Park Service Complex: Glacier Monitoring Program," http://www.nps.gov/noca/naturescience/glacial-mass-balance1.htm.

6. M. Pelto, "North Cascade glacier retreat 1984-2007," Nichols College North Cascades Glacier Climate Project, http://www.nichols.edu/departments/ Glacier/globalwarming.html. M. Pelto, "The disequilibrium of North Cascade, Washington glaciers," presentation at MTNCLIM 2006 conference, Sept. 2006, slide 38, http://www.fs.fed.us/psw/cirmount/meetings/mtnclim/2006/talks/pdf/pelto_talk_mtnclim2006.pdf.

7. J. Riedel, North Cascades National Park, NPS, personal communication (email to T. Easley), Aug. 21, 2009.

8. T. H. Nylen, "Spatial and temporal variations of glaciers (1913-1994) on Mt. Rainier and the relation with climate," M.S. thesis, Portland State University, 2004, http://www.glaciers.pdx.edu/Thesis/Nylen/Nylen_2004.pdf.

9. Riedel, personal communication (see note 7, this chapter).

10. H. Basagic, "Quantifying twentieth century glacier change in the Sierra Nevada, California," M. S. thesis, Portland State University, 2008, http://www.glaciers.pdx.edu/Thesis/Basagic/basagic_thesis_2008.pdf.

11. Denali National Park and Preserve, NPS, "Denali National Park & Preserve: Kahiltna Glacier," http://www.nps.gov/dena/naturescience/kahiltna.htm.

12. J. Riedel, North Cascades National Park, NPS, personal communication (telephone conversation with T. Easley), May 19, 2006.

13. Hall and Fagre, "Modeled glacier change" (see note 3, this chapter), pp. 131-132.

14. University of Montana and others, "The case for restoring bull trout in Glacier National Park…and a framework to do it," p. 4, http://www.montana.edu/mtcfru/GNP%20Bull%20Trout%20Brochure.pdf. U.S. Fish and Wildlife Service, "Bull Trout facts," 1998, http://library.fws.gov/Pubs1/bulltrout.pdf.

15. Environmental Leadership Program, NPS, "Glacier Bay National Park & Preserve action plan," pp. 1-2, http://www.nps.gov/climatefriendlyparks/downloads/Action%20Plans%20and%20Inventories/Glacier%20Bay%20Action%20Plan.pdf.

16. P. Mote and others, "Declining mountain snowpack in western North America," *Bulletin of the American Meteorological Society* 86 (2005): 39-49.

17. D. W. Pierce and others, "Attribution of declining western U.S. snowpack to human effects," *Journal of Climate* 21 (2008): 6425- 6444.

18. IPCC, "North America," prepared by C. B. Field and others, in IPCC, *Climate Change 2007: Impacts, Adaptation and Vulnerability: Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M. L. Parry and others, eds., Cambridge University Press, Cambridge, UK, 2007, p. 621.

19. K. Hayhoe and others, "Emissions pathways, climate change, and impacts on California," *Proceedings of the National Academy of Sciences*, 101 (2004): 12422–12427. J. T. Payne and others, "Mitigating the effects of climate change on the water resources of the Columbia River, *Climatic Change* 62 (2004): 233–256. N. S. Christensen and others, "The effects of climate change on the hydrology and water resources of the Colorado River Basin," *Climatic Change* 62 (2004): 337–363.

20. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 45.

21. S. Saunders and T. Easley, *Losing Ground: Western National Parks Endangered by Climate Disruption*, report of the Rocky Mountain Climate Organization and Natural Resources Defense Council, NRDC, New York, 2006, p. 21, http://rockymountainclimate.org/website%20pictures/Losing%20Ground.pdf. IPCC, "Observations: Surface and atmospheric climate change," prepared by K. Trenberth and others, in IPCC, *The Physical Science Basis* (see note 2, Introduction), p. 251.

Chapter 3 – Loss of Water

1. USGCRP, *Climate Change Impacts* (see note 3, Introduction), pp. 41-46.

2. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 45.

3. National Research Council of the National Academies, *Colorado River Basin Water Management: Evaluating and Adjusting to Hydroclimatic Variability*, National Academies Press, Washington, DC, 2007, p. 83.

4. S. Saunders, C. Montgomery, and T. Easley, *Hotter and Drier: The West's Changed Climate*, report of the Rocky Mountain Climate Organization and Natural Resources Defense Council, NRDC, New York, 2008, p. 15, http://rockymountainclimate.org/website%20pictures/Hotter%20and%20Drier.pdf.

5. M. Hoerling and others, "Reconciling projections of Colorado River streamflow," *Southwest Hydrology* 8,

3 (2009): 20-21, 31, http:/www.swhydro.arizona.edu/archive/V8_N3/feature2.pdf.

6. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 130.
7. D. D. Breshears and others, “Regional vegetation die-off in response to global-change-type drought,” *Proceedings of the National Academy of Sciences* 102, 42 (2005): 15144-15148.
8. Continental Divide Research Learning Center, NPS, “Climate change in Rocky Mountain National Park: Preservation in the face of uncertainty,” summary of workshop on Nov. 13-14, 2007, http://www.nps.gov/romo/parkmgmt/upload/climate_change_rocky_mountain2.pdf.
9. J. Lundquist and J. Roche, “Climate change and water supply in western national parks,” *Park Science* 26, 1 (2009), http://www.nature.nps.gov/ParkScience/print.cfm?PrintFormat=pdf.
10. Environment Canada, “Below-average conditions throughout the system,” *Level News* 15, 10 (Oct. 5, 2007), http://www.on.ec.gc.ca/water/level-news/ln200710_e.html.
11. Great Lakes Area, NPS, “Impacts of Midwest Warming,” 2007, http://www.nps.gov/apis/naturescience/upload/2007%20MWR%20Climate%20Change%20Site%20Bulletin%20-%20Great%20Lakes%20FINAL.pdf. B.M. Lofgren and others, “Evaluation of potential impacts on Great Lakes water resources based on climate scenarios of two GCMs,” *Journal of Great Lakes Resources* 28, 4 (2002): 537–554, http://www.glerl.noaa.gov/pubs/fulltext/2002/20020020.pdf.
12. Natural Resources Stewardship and Sciences Directorate, NPS, “Climate Change and Impacts to Resources around the Great Lakes,” U.S. Department of the Interior, 2007, http:/www.nps.gov/apis/naturescience/upload Climate%20Change%20Talking%20Points%20Great%20Lakes-August2007.pdf.

Chapter 4 – Higher Seas & More Extreme Weather

1. USGCRP, *Climate Change Impacts* (see note 3, Introduction), pp. 25, 150.
2. S. J. Williams and others, “Sea-level rise and its effects on the coast,” in U.S. Climate Change Science Program, Coastal Sensitivity to Sea-Level Rise: A Focus on the Mid-Atlantic Region, J. G. Titus (coordinating lead author) and others, U.S. Environmental Protection Agency, Washington DC, 2009, p. 20.
3. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 114.
4. D. Kimball, Everglades National Park, NPS, testimony to the Subcommittee on Interior, Environment, and Related Agencies, Committee on Appropriations, U.S. House of Representatives, Apr. 26, 2007.
5. C. Mitchell, Everglades and Dry Tortugas National Parks, NPS, “Climate change and Everglades National Park: A park manager’s perspective,” presentation at Florida Bay and Adjacent Marine Systems Conference, Naples, Florida, Dec. 8, 2008, slide 6, http://conference.ifas.ufl.edu/FloridaBay2008/presentations/Tuesday/am/0910%20Mitchell.pdf.
6. L.G. Pearlstine and others, South Florida Natural Resources Center, NPS, *Potential ecological consequences of climate change in South Florida and the Everglades: 2008 Literature Synthesis*, SFNRC Technical Series 2009:1, Everglades National Park, Homestead, Florida, 2009, p. 9, http://www.nps.gov/ever/naturescience/featuredpublication.htm.
7. Kimball, testimony (see note 51).
8. B. T. Gutierrez, S.J. Williams, and E.R. Thieler, “Ocean coasts,” in USCCS, *Coastal Sensitivity* (see note 2, this chapter), pp. 43-56, 55-56.
9. National Oceanic and Atmospheric Administration, “Linear mean sea level (MSL) trends and 95% confidence intervals in feet/century,” http://co-ops.nos.noaa.gov/sltrends/msltrendstablefc.htm.
10. R. Alvarez and others, “Fair warning: Global warming and the Lone Star State,” Environmental Defense, 2006, p.11, http://www.edf.org/article.cfm?contentID=5239.
11. USGCRP, *Climate Change Impacts* (see note 3, Introduction), pp. 34-36.
12. IPCC, “North America,” (see note 18, Chapter 2), p. 630.
13. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 37.
14. U.S. Climate Change Science Program [“USCCSP”], T.R. Karl and others, eds., *Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands*, National Oceanic and Atmospheric Administration, Washington, DC, 2008, pp. 4-5. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 32.
15. USCCSP, *Weather and Climate Extremes* (see previous note), p. 104.
16. Mount Rainier National Park, NPS, “Mount Rainier National Park: A year after the flood” (news release), Nov. 2, 2008, http://www.nps.gov/mora/parknews/upload/Flood%20Anniversary%20Release%20Nov%2007.pdf.
17. J. Lundquist and J. Roche, “Climate change and water supply in western national parks,” *Park Science* vol. 26, no. 1 (2009), http://

www.nature.nps.gov/ParkScience/print.cfm?PrintFormat=pdf.

18. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 32.

Chapter 5 – Loss of Plant Communities

1. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 82. IPCC, "North America" (see note 18, Chapter 2), pp. 624, 631.
2. Colorado State Forest Service, Colorado Department of Natural Resources, *2006 Report on the Health of Colorado's Forests*, p. 15, http://csfs.colostate.edu/pdfs/06fhr.pdf.
3. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 82. "Bark beetle outbreaks in western North America: Causes and consequences," B. Bentz, ed., report of Bark Beetle Symposium, Snowbird, Utah, Nov. 15-18, 2005, University of Utah Press, p. 24.
4. Benz, "Bark beetle outbreaks" (see previous note), p. 24.
5. W. Romme and others, "Recent forest insect outbreaks and fire risk in Colorado forests: a brief synthesis of relevant research," Colorado State University Fort Collins, 2006, http://www.colorado.edu/geography/class_homepages/geog_5161_ttv_s09/RommeEtAl_Insects&FireRisk_CFRI_06.pdf. Colorado State Forest Service, *2006 Report* (see note 2, this chapter), p. 15.
6. B. J. Bentz and G. Schen-Langenheim, "The mountain pine beetle and whitebark pine waltz: Has the music changed?," proceedings of conference "Whitebark pine: A Pacific Coast perspective," U.S. Forest Service, Logan, UT, 2007, http://www.fs.fed.us/r6/nr/fid/wbpine/papers/2007-wbp-impacts-bentz.pdf. See also Benz, "Bark beetle outbreaks" (see note XXX, this chapter), p. 24.
7. Region 2, U.S. Forest Service and Colorado State Forest Service, "Forest health aerial survey highlights*"* (news conference handout), Jan. 14, 2008, http://www.fs.fed.us/r2/news/2008/01/press-kit/survey_higlights.pdf.
8. Colorado State Forest Service, Colorado Department of Natural Resources, *2008 Report: The Health of Colorado's Forests*, p. 17, http://csfs.colostate.edu/pages/documents/894651_08FrstHlth_www.pdf.
9. M. E. Rocca and W. H. Romme, "Forest not "destroyed": survivors of bark beetle outbreaks will become the future forest," unpublished paper, Colorado State University, Fort Collins, 2008. Colorado State Forest Service, *2008 Report* (see note 8, this chapter), p. 17.
10. R. Cables, Rocky Mountain Region, U.S. Forest Service, testimony, Subcommittee on National Parks, Forests and Public Lands and Subcommittee on Water and Power, Committee on Natural Resources, U.S. House of Representatives, June 16, 2009, http://resourcescommittee.house.gov/images/Documents/20090616/joint/testimony_cables_bentz.pdf.
11. Colorado State Forest Service, *2008 Report* (see note 8, this chapter), p. 4.
12. J. J. Worrall and others, "Rapid mortality of Populus tremuloides in southwestern Colorado, USA," Forest Ecology and Management 255 (2008): 686–696, http://www.fs.fed.us/r2/fhm/reports/sad_2008.pdf.
13. P. van Mantgem and others, "Widespread increase of tree mortality rates in the Western United States," *Science* 323 (2009): 521- 523.
14. H. Diaz and J. Eischeid, "Disappearing 'alpine tundra,' Köppen climatic type in the western United States," *Geophysical Research Letters* 34 (2007): L18707, doi:10.1029/2007GL031253. K. Redmond and J. Abatzoglou, "Recent accelerated warming in western United States mountains," presentation to American Geophysical Union, San Francisco, Dec. 12, 2007, slides 18-30, http://www.fs.fed.us/psw/cirmount/meetings/agu/pdf2007/redmond_talk_agu2007.pdf.
15. N. Hobbs and others, *Future Impacts of Global Climate on Rocky Mountain National Park: Its Ecosystems, Visitors, and the Economy of Its Gateway Community – Estes Park*, 2003, pp. 16-17, http://www.nrel.colostate.edu/projects/star/papers/2003_final_report.pdf.
16. P. Lesica and B. McCune, "Decline of arctic-alpine plants at the southern edge of their range following a decade of climatic change," *Journal of Vegetation Science* 15, no. 5 (2004): 679-690.
17. D. B. Fagre, "Spatial changes in alpine treeline patterns, Glacier National Park, Montana," http://www.nrmsc.usgs.gov/research/treeline_rsrch.htm.
18. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, L. Mazur and C. Milanes, eds., *Indicators of Climate Change in California*, California Environmental Protection Agency, Sacramento, CA, 2009, p. 137, http://oehha.ca.gov/multimedia/epic/pdf/ClimateChangeIndicators April2009.pdf.
19. California Environmental Protection Agency, *Indicators of Climate Change*(see previous note), pp. 137-142.
20. D. B. Fagre and D. L. Peterson, "Ecosystem dynamics and disturbance in mountain wildernesses: Assessing vulnerability of natural resources to change," *Climatic Change* 59, nos. 1-2 (2003): 74-81. C. Millar and others, "Response of subalpine conifers in the Sierra Nevada, California, U.S.A., to 20th-century warming and decadal climate variability," *Arctic, Antarctic and Alpine*

Research 36 (2004):181-200. Yosemite National Park, NPS, "Tuolumne Meadows Lodgepole Pine Removal," 2006, http://www.nps.gov/archive/yose/planning/projects/tmtrees.pdf.

21. T. J. Perfors, J. Harte, and S. Alter. "Enhanced growth of sagebrush (Artemisia tridentate) in response to manipulated ecosystem warming," *Global Change Biology* 9, 5 (2003): 736-742. See also F. Saavedra, and others, "Changes in flowering and abundance of Delphinium nuttalianum (Ranunculaceae) in response to a subalpine climate warming experiment," *Global Change Biology* 9, 6 (2003): 885-894.
22. D. W. Inouye, "Effects of climate change on phenology, frost damage, and floral abundance of montane wildflowers," *Ecology* 89, 2 (2008): 353-362.
23. T. C. Esque and others, "Buffelgrass fuel loads in Saguaro National Park, Arizona, increase fire danger and threaten native species," Park Science 24, 2 (2007), http://www.nature.nps.gov/ParkScience/print.cfm?PrintFormat=pdf.
24. Esque, "Buffelgrass" (see previous note).
25. Saguaro National Park, NPS, "The fight to save saguaros," 2008, http://www.nps.gov/sagu/naturescience/upload/FightSaveSaguaros2.25.pdf.
26. Esque, "Buffelgrass" (see note 24, this chapter).
27. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 83.
28. M. Murphy, "Freeze-free desert," Southwest Climate Change Network, 2008, http://www.southwestclimatechange.org/feature-articles/freeze-free-desert.
29. K.L. Cole and others, "Transient dynamic of vegetation response to past and future climatic changes in the southwestern United States," poster, http://www.climatescience.gov/workshop2005/posters/P-EC4.2_Cole.pdf; K. P. Dole and others, "The relative importance of climate change and the physiological effects CO2 on freezing tolerance for the future distribution of *Yucca brevifolia," Global and Planetary Change,* vol. 36, nos. 1-2 (2003), pp. 137-146.
30. T. Swetnam, University of Arizona, testimony, Subcommittee on National Parks, Forests and Public Lands, Committee on Natural Resources, U.S. House of Representatives, Apr. 4, 2009, http://resourcescommittee.house.gov/images/Documents/20090407/testimony_swetnam.pdf.
31. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 84.
32. South Florida Resource Center, *Potential Ecological Consequences* (see note 6, Chapter 4), pp. 12-15.
33. Kimball, testimony (see note XX).
34. South Florida Natural Resources Center, *Potential Ecological Consequences* (see note 6, Chapter 4), p. iv.
35. Great Smoky Mountains National Park, NPS, "Plants," http://www.nps.gov/grsm/naturescience/plants.htm.
36. USGCRP, *Climate Change Impacts* (see note 3, Introduction), pp. 81, 108.

Chapter 6 – Loss of Wildlife

1. IPCC, "Ecosystems, their properties, goods, and services," A. Fischlin and others, authors, in IPCC, *Impacts, Adaptation and Vulnerability* (see note18, Chapter 2), p. 213.
2. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 82.
3. Nature Conservancy, "Climate change: Alaska sees shifting lands and species on the move," http://www.nature.org/initiatives/climatechange/features/art24460.html.
4. P. Gonzalez and others, "Potential impacts of climate change on habitat and conservation priority areas for Lynx canadensis (Canada Lynx)," report to the U.S. Forest Service, Nature Conservancy, Arlington, VA, 2007, http://conserveonline.org/workspaces/climate.change/climate.change.vegetation.shifts/climate_change_Lynx.pdf.
5. South Florida Natural Resources Center, *Potential Ecological Consequences* (see note 6, Chapter 4), p. 11.
6. E. A. Beever, "Persistence of pikas in two low-elevation national monuments in the western United States," *Park Science* 21, 2 (2002), pp. 23-29, p. 23.
7. E. A. Beever, P .F. Brussard, and J. Berger, "Patterns of apparent extirpation among isolated populations of pikas *(Ochotona princeps)* in the Great Basin," *Journal of Mammology* 84, 1 (2003), 37-54. K. Krajick, "All Downhill from Here?" *Science* 303 (2004): 1600-1602.
8. "Climate Change in Rocky Mountain National Park" (see note 8, Chapter 3), p. 7.
9. C.W. Epps and others, "Effects of climate change on population persistence of desert-dwelling mountain sheep in California," *Conservation Biology* 18, 1 (2004): 102-113.
10. C. L. Douglas, "Weather, disease, and bighorn lamb survival during 32 years in Canyonlands National Park," *Wildlife Society Bulletin* 29, 1 (2001): 297-305. L. C. Bender and M. E. Weisenberger, "Precipitation, density, and population dynamics of desert bighorn sheep on San Andres National Wildlife Refuge, New Mexico," *Wildlife Society Bulletin* 33, 3 (2005): 956-962.

11. California Environmental Protection Agency, *Indicators of Climate Change in California* (see note 18, Chapter 5), pp. 155-160.

12. T. L. Root and others, "Fingerprints of global warming on wild animals and plants," *Nature* 421 (2003): 57–60.

13. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 81.

14. C. E. Burns, K. M. Johnson, and O. J. Schmitz, "Global change and mammalian species diversity in U.S. national parks," *Proceedings of the National Academy of Sciences* 100, 20 (2003): 11474-11477.

15. Burns, "Species diversity" (see previous note).

16. Committee on Ecological Impacts of Climate Change, National Research Council, *Ecological Impacts of Climate Change*, National Academies Press, Washington, DC, 2008, p. 33, http://www.nap.edu/catalog/12491.html. See also L. S. Vors and M. S. Boyce, "Global declines of caribou and reindeer," *Global Change Biology* (2009, in press), early edition online at http://www3.interscience.wiley.com/search/allsearch?mode=viewselected&product=journal&ID=122380516&view_selected.x=97&view_selected.y=8.

17. Great Lakes Area, NPS, "Impacts of Midwest Warming," (see note 11, Chapter 3).

18. Hobbs, *Future Impacts* (see note 15, Chapter 5), p. 19.

19. Alvarez, "Fair Warning" (see note 10, Chapter 4), p.11.

20. South Florida Natural Resources Center, *Potential Ecological Consequences* (see note 6, Chapter 4), pp. 18-21.

21. G. San Miguel, Mesa Verde National Park, NPS, personal communication (email to S. Saunders), Aug. 10, 2009.

22. K. S. Van Houtan and O. L. Bass, "Stormy oceans are associated with declines in sea turtle hatching" *Current Biology* 17, 15 (2007): R590-R591, https://webdrive.service.emory.edu/users/kvanhou/public_html/articles/VanHoutan_Bass_2007.pdf.

23. South Florida Resource Center, *Potential Ecological Consequences* (see note 6, Chapter 4), pp. 17-18.

24. IUCN-The World Conservation Union, "Climate change - impacts," http://www.iucn.org/themes/climate/impacts.htm. J.A. Pounds and others, "Widespread amphibian extinctions from epidemic disease driven by global warming," *Nature* 439 (2006): 161-167.

25. Van Houtan, "Stormy oceans" (see note 22, this chapter), p. R591.

26. I. Lacan and K.R. Matthews, Sierra Nevada Research Center, U.S. Forest Service, "Loss of breeding habitat for imperiled mountain yellow-legged frog," Slide 7, http://www.fs.fed.us/psw/programs/snrc/bio_diversity.

27. A. Janetos and others, "Biodiversity," in USCCSP and the Subcommittee on Global Change Research, *The Effects of Climate Change on Agriculture, Land Resources, Water Resources, and Biodiversity in the United States*, Washington, DC., 2008, p. 158, http://www.globalchange.gov/publications/reports/scientific-assessments/saps/304.

28. C.A.F. Enquist, E.H. Girvetz, and D.F. Gori, "Climate change vulnerability assessment for biodiversity in New Mexico, part II: Conservation implications of emerging moisture stress due to recent climate changes in New Mexico," Nature Conservancy in New Mexico, Santa Fe, NM, 2008, http://nmconservation.org/dl/CC_report2_final.pdf.

29. R. Tosches, "Warm waters deadly to Yellowstone trout," *Denver Post*, July 29, 2007, http://www.denverpost.com/ci_6489924?source=rss. S. Kinsella, "Trout in trouble: The impacts of global warming on trout in the interior West," report of Natural Resources Defense Council and Montana Trout Unlimited, 2008, p. 7, http://www.nrdc.org/globalWarming/trout/contents.asp.

30. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 87.

31. USGCRP, *Climate Change Impacts* (see note 3, Introduction), pp. 84, 152.

32. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 84.

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33. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 87.

34. N. Mantua, I. Tohver, and A. Hamlet, "Chapter 6: Salmon: Impacts of climate change on key aspects of freshwater salmon habitat in Washington state," in J.S. Littell and others, eds., *Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*, University of Washington, Seattle, WA, 2009, p. 228, http://cses.washington.edu/db/pdf/wacciach6salmon649.pdf.

35. Janetos, "Biodiversity," (see note 27, this chapter), p. 160.

36. *Acropora* Biological Review Team, "Atlantic *Acropora* status review document," report to National Marine Fisheries Service, 2005, http://sero.nmfs.noaa.gov/pr/pdf/050303%20status%20review.pdf.

37. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 84. South Florida Natural Resources Center, *Potential Ecological Consequences* (see note 14, Chapter 4), p. 16. USCCSP, *Weather and Climate Extremes* (see note Chaper), p. 38.

38. USCCSP, "Biodiversity" (see note 27, this chapter), p. 160.

39. M. Lewis, Biscayne National Park, NPS, personal communication (email to S. Saunders), Aug. 21, 2009.

40. M. J. Paddack and others, "Recent region-wide declines in Caribbean reef fish abundance," *Current Biology* 19, 7 (2009): 590-595.

41. K. Oberhauser and A. T. Peterson, "Modeling current and future potential wintering distributions of eastern North American monarch butterflies," *Proceedings of National Academy of Sciences* 100, 24 (2003): 14063-14068.

42. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 80-81.

43. J. Marburger, Great Lakes Research and Education Center, NPS, personal communication (email to S. Saunders), Sept. 11, 2009.

44. S.M. Imholt, "Effects of forecasted climate change on a butterfly-plant interaction in the North Cascades National Park," M.S. thesis, Western Washington University, 2006, http://www.nps.gov/noca/naturescience/upload/Butterfly%20Climate%20Change.pdf.

45. USCCSP, "Biodiversity" (see note 27), pp. 151-181.

46. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 82.

Chapter 7 – Loss of Historical and Cultural Resources

1. J. G. Titus and J. Wang, "Maps of lands close to sea level along the Middle Atlantic coast of the United States: An elevation data set to use while waiting for LIDAR," Section 1.1, in *Background Documents Supporting Climate Change Science Program Synthesis and Assessment Product 4.1*, J.G. Titus and E.M. Strange, eds., U.S. Environmental Protection Agency, Washington, DC, 2008, http://www.epa.gov/climatechange/effects/coastal/section1_1_may2008.pdf; http://maps.risingsea.net/Regional_Jue/NYC_Area_1m_ntidal_600dpi.jpg.

2. P. C. Frumhoff and others, *Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions,* synthesis report of the Northeast Climate Impacts Assessment, Union of Concerned Scientists, Cambridge, MA, 2007, p. 19, http://www.northeastclimateimpacts.org/pdf/confronting-climate-change-in-the-u-s-northeast.pdf.

3. New York City Panel on Climate Change, *Climate Risk Information,* 2009, p. 20, http://www.nyc.gov/html/om/pdf/2009/NPCC_CRI.pdf.

4. U. S. Geological Survey, "A plan for a comprehensive national coastal program," 2006, p. 6, http://marine.usgs.gov/coastal-plan/index.html.

5. S. J. Williams and others, "Sea-level rise and its effects on the coast," in USCCSP, *Coastal Sensitivity* (see note 2, Chapter 4), pp. 11-24, 17-18.

6. *Pu'ukohol-Heiau and Kaloko-Honok-hau national historical parks,* NPS, "Coastal hazard report, coastal inundation, overtopping of swells and sea-level rise, *http://www.soest.hawaii.edu/coasts/nps/coastalInundation.php.*

7. Intermountain Region, NPS, "Vanishing treasures: A legacy in ruins: Ruins preservation in the American Southwest," 1998, http://www.cr.nps.gov/archeology/vt/longRangePlan.pdf.

Chapter 8 – Less Visitor Enjoyment

1. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 90.

2. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 34.

3. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 90.

4. R.B. Richardson and J.B. Loomis, "The effects of global warming on mountain tourism: A contingent behavior methodology," prepared for Hobbs, *Future Impacts* (see note 15, Chapter 5), p. 9.

5. B. Jones and D. Scott, "Climate change, seasonality and visitation to Canada's national parks," Department of Geography, University of Waterloo, Waterloo, Ontario, 2005, p. 2, http://lin.ca/Uploads/cclr11/CCLR11-132.pdf.

6. Yellowstone National Park, NPS, “Yellowstone to implement mandatory fishing restrictions,” news release, July 20, 2007, http://www.nps.gov/yell/parknews/0739.htm.
7. Natural Resources Stewardship and Sciences Directorate, “Great Lakes” (see note 12, Chapter 3), pp. 8, 10.
8. P. Glick and J. Clough, *An Unfavorable Tide: Global Warming, Coastal Habitats and Sportfishing in Florida*, report of National Wildlife Federation and Florida Wildlife Federation, NWF, Reston, VA, 2006, p. 33, http://www.targetglobalwarming.org/files/AnUnfavorableTideReport.pdf.
9. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 92.
10. J. D. Ray, “Annual data summary 2007,” NPS, Denver, CO, 2008, p. 21, http://www.nature.nps.gov/air/Pubs/pdf/ads/2007/GPMP-XX.pdf.
11. Ray, “Annual data” (see previous note), pp. 21-24.
12. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 92.
13. USGCRP, *Climate Change Impacts* (see note 3, Introduction), p. 92.
14. T. Baxter and others, “Dark horizons: 10 national parks most threatened by new coal-fired power plants,” National Parks Conservation Association, Washington, DC, 2008, pp. 15-16.
15. Great Smoky Mountains National Park, NPS, “Air quality,” http://www.nps.gov/grsm/naturescience/air-quality.htm.
16. Air Resources Division, NPS, “2006 annual performance & progress report: Air quality in national parks,” 2007, p. 5, http://www.nature.nps.gov/air/Pubs/pdf/gpra GPRA_AQ_ConditionsTrendReport2006.pdf.

Chapter 9 – Recommendations

1. U.S. Government Accountability Office, “Climate change: Agencies should develop guidance for addressing the effects on Federal land and water resources,” report no. GAO-07-863, Aug. 7, 2007, http://www.gao.gov/products/GAO-07-863.
2. Dry Tortugas National Park, NPS, “Final general management plan amendment environmental impact statement,” 2000, p. 13, http://www.nps.gov/drto/parkmgmt/upload/drtofgmpeis.pdf.
3. Coalition of National Park Service Retirees, “Global climate change creates new environments and organizational challenges for national parks,” professional report series no. 11, p. 5, http://www.npsretirees.org/files/press_attach/PRS%2011%20Climate%20Change.pdf.
4. Baron, “National Parks” (see note 1, Introduction), p. 4-6.
5. Coalition of National Park Service Retirees, “New Environments and Organizational Challenges” (see note 3, this chapter), p. 4.
6. See http://www.buffelgrass.org.

End Page

1. M. Finley, personal communication (email to S. Saunders), Sept. 28, 2009.

ROCKY MOUNTAIN NATIONAL PARK / PHOTO: JOHN FIELDER

ROCKY MOUNTAIN NATIONAL PARK / PHOTO: JOHN FIELDER

"The establishment and protection of the National Park System is one of the best ideas America has institutionalized. Our parks provide inspiration, education, and enjoyment. Moreover, they represent some of our greatest resources of genetic and biological diversity and intact ecosystems. They are our seed banks for restoring the nation's land and waters already ravaged by our careless development and the early impacts of climate change. In one sense, they represent a life boat for our biological future. We need to take immediate action to reduce our use of fossil fuels and the resulting climate disruption before we sink our life boat and destroy the values and purposes of our national parks for future generations."

Mike Finley, former superintendent of Everglades, Yosemite, and Yellowstone national parks[1]

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ACADIA NATIONAL PARK

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the ROCKY MOUNTAIN CLIMATE Organization

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