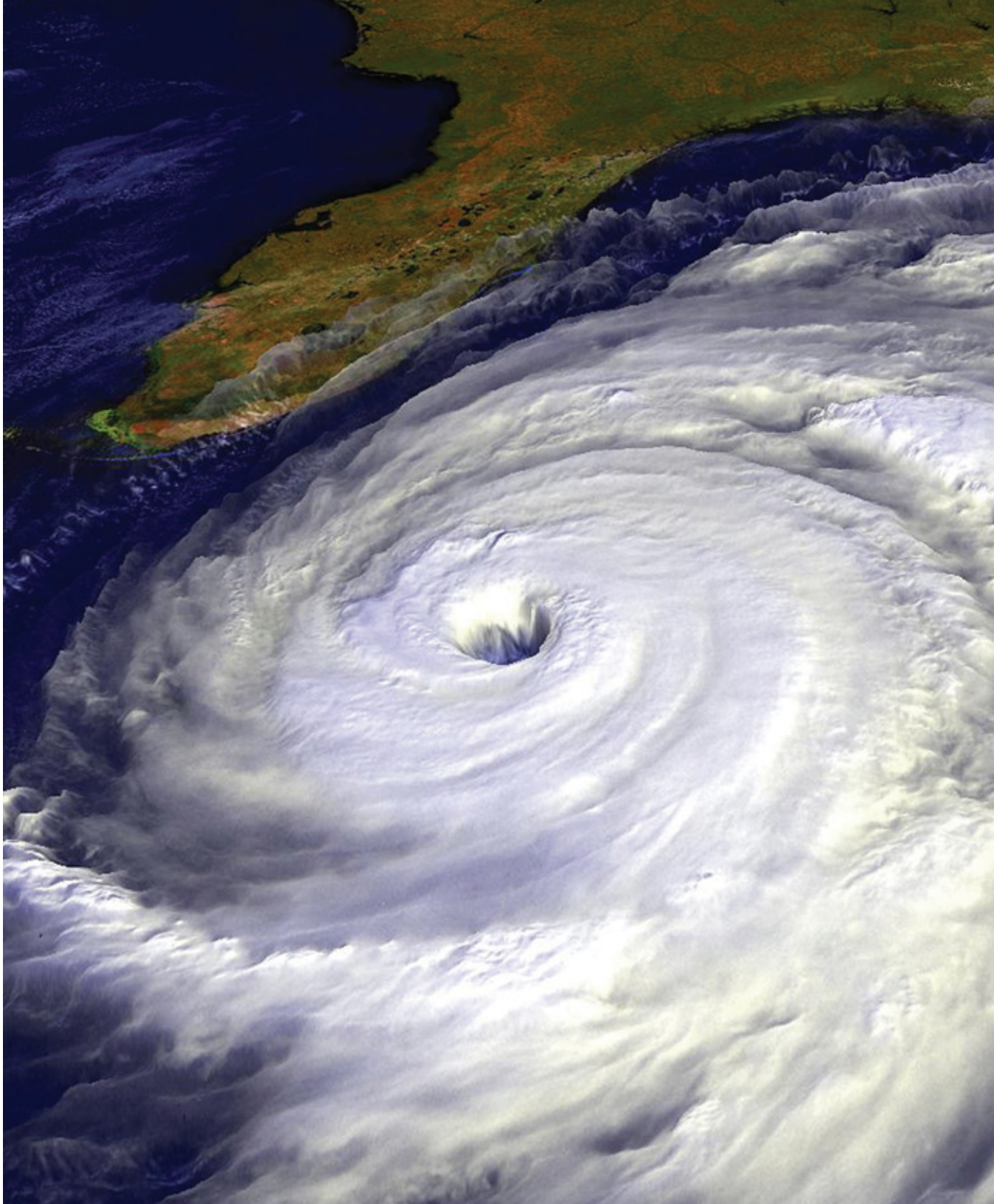

National Parks Conservation Association®
Protecting Our National Parks for Future Generations®
Unnatural Disaster:
Global Warming and Our National Parks

"If global emissions of carbon dioxide continue to rise at the rate of the past decade… there will be disastrous effects, including increasingly rapid sea level rise, increased frequency of droughts and floods, and increased stress on wildlife and plants due to rapidly shifting climate zones."

"'Business-as-usual' would be a guarantee of global and regional disasters."

— **James Hansen**, NASA Goddard Institute for Space Studies, citing 2007 research by NASA and the Columbia University Earth Institute.



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ICON KEY

= Hotter air and water temperatures


= More wildfires


= More destructive coastal storms


= Damage to historic sites


= Increasing air pollution


= Degraded habitat for plants and animals


= Rising sea levels


= Bigger downpours and flooding

Unnatural Disaster:

Global Warming and Our National Parks

GATES OF THE ARCTIC (AK)
YUKON-CHARLEY (AK)
GLACIER BAY (AK)
Caribou ranges and population size may become less predictable, affecting the diet and culture of native Alaskans who rely on them.

KATMAI (AK)
Ocean warming may affect salmon fisheries and scientists are exploring possible links between warmer river temperatures and increased parasites in salmon.

WRANGELL-ST. ELIAS (AK)
Thawing permafrost will damage infrastructure and reduce the size and location of ponds on which waterfowl depend.

NORTH CASCADES (WA)
Seventy to 90 percent of the snow pack could disappear by the end of this century, threatening winter sports and water supplies.

OLYMPIC (WA)
Warmer winters and more extreme precipitation events could increase winter flood risk.

LEWIS AND CLARK (OR)
Earlier snowmelts and spring flooding can decimate already-stressed salmon populations.

YOSEMITE (CA)
Warming and drought have made wildfire season longer and more damaging, and increased insect damage.

SEQUOIA and KINGS CANYON (CA)
Warmer temperatures will worsen ground-level ozone problems. Increasing wildfires will contribute more smoke and airborne particulates.

It's not too late to save our national parks from the worst effects of climate change. See the Action Center on page 45 for things we can do now to protect our national parks for future generations.

APPALACHIAN NATIONAL SCENIC TRAIL (ME-NH-VT-MA-CT-NY-NJ-PA-MD-VA-WV-NC-TN-GA)
More floods can lead to higher landslide risk, threatening portions of the high elevation trail, and communities that lie below.

CHESAPEAKE BAY (DC-MD-DE-NY-PA-VA-WV)
Warmer water is likely to increase outbreaks of two dangerous oyster diseases.

HISTORIC JAMESTOWNE (VA)
Jamestown celebrated its 400th anniversary in 2007, but much of the park could be under water before its 500th anniversary.

SHENANDOAH (VA)
More droughts, floods, and warmer streams can diminish native trout populations.

BLUE RIDGE PARKWAY (VA-NC-TN)
Warmer summers can produce more ozone pollution and more "code red" air quality days, increasing health risks for visitors.

GREAT SMOKY MOUNTAINS (TN-NC)
Rare and ancient forests may be threatened by increasing ground-level ozone and insect pests unleashed by warming.

FORT RALEIGH (NC)
CAPE HATTERAS (NC)
WRIGHT BROTHERS NATIONAL MONUMENT (NC)
FORT SUMTER (SC)
DRY TORTUGAS (FL)
FORT PULASKI (GA)
GULF ISLANDS NATIONAL SEASHORE (MS-FL)
Sea level rise, increasing storm strength, and flooding threaten low-lying historic areas and historical structures that tell the story of our nation from its earliest days.

EVERGLADES (FL)
More powerful hurricanes combined with sea level rise could destroy park buildings and roads, increasingly cutting-off visitor access.

BISCAYNE (FL)
DRY TORTUGAS (FL)
Rising, warming, and acidifying seas threaten coral reefs and sport fishing. Toxic or unusual algal blooms may threaten wildlife and tourism.

Introduction

- GLOBAL WARMING — THE BIG PICTURE
- NATIONAL PARKS: A KEY TO THE FUTURE

INTRODUCTION

Flying over Wrangell-St. Elias National Park and Preserve last summer revealed hundreds of acres of spruce trees that appeared to have been charred by fire. On closer inspection, the grayish brown skeletons that blanketed the hillsides were what remained from an invasion by spruce bark beetles. Spruce bark beetles have killed trees in Alaska in the past, but what makes this die-off unusual is the vastness of the acreage.

The evidence suggests, as scientists and others have pointed out, that the climate in Alaska is changing. In many parts of Alaska, including Wrangell-St. Elias, the climate has become warm enough and dry enough to favor the spruce bark beetle rather than the trees.

Alaska and its national parks are feeling dramatic effects from climate change. Permafrost — ground that stays frozen for a minimum of two years — is now melting because the temperatures do not stay cold enough to keep the ground permanently frozen; polar bears that rely on ice floes to hunt and feed are drowning because the polar ice cap is retreating; and migratory birds and fish that feed off Alaska's bounty are returning earlier at times that may not coincide with the availability of their food sources.

While Alaska provides some dramatic examples, the effects of global warming are being felt throughout America and the rest of the world. Our country has experienced flooding, droughts, heat waves, hurricanes, and tornadoes at levels and intensities far greater than they have in the recorded past. One of the most dramatic effects of global warming is the impact on extreme weather events. The earth's warming is drowning some areas with rain while denying others any moisture at all.

In November 2006, more than 18 inches of rain fell in 36 hours, overwhelming streams and creeks running through Mount Rainier National Park. The Park Service estimates that the damage from flooding exceeds $36 million. Hurricanes Katrina and Wilma caused widespread destruction throughout the Gulf states, including damage at Everglades National Park and Gulf Islands National Seashore that two years later has yet to be repaired.

If we do not take action to slow or halt climate change now the future of our national parks will include the accelerated loss of glaciers at Mount Rainier National Park; the loss of Joshua trees at Joshua Tree National Park; and the submersion from sea level rise of Everglades National Park, as well as portions of historic sites such as Colonial National Historical Park, site of the first permanent English settlement at Jamestown.

LEFT: POWER PLANT © BIGSTOCKPHOTO.
RIGHT: TOM KIERNAN, LAKE CLARK NATIONAL PARK, ALASKA © JAMES NATIONS/NPCA.

Although the situation seems dire, we can still halt the most severe effects of global warming if we take action now.

Although the situation seems dire, we can still halt the most severe effects of global warming if we take action now. The Centennial anniversary of the National Park System in 2016 provides sufficient time and a symbolically important deadline in which to act. Federal, state, and local governments, along with individuals, can take actions within that timeframe that will slow and in some cases halt the damage. Over the next nine years, the national parks offer a unique opportunity to draw attention to America's priceless resources at risk, and to showcase opportunities to act to protect them.

As chronicled in this report, national parks already are helping us to understand how global warming affects our natural world. Within them, we see the warning signs of major changes ahead. We must learn how to manage parks to maintain healthy ecosystems in the face of climate change, and we must build public support for doing so.

As we look to sustaining and restoring healthy parks for the system's next century, the fiscal challenges, ecological challenges, and threats to the integrity of cultural resources also must be addressed. If parks are to thrive in the future, we must act now to reduce greenhouse gas emissions, both within the national parks and nationally. We have less than a decade remaining before the National Park System's Centennial. To make progress in protecting parks from global warming, we must now put into action a plan to protect national parks. That is our centennial challenge.

GLOBAL WARMING — THE BIG PICTURE

Evidence is mounting that our planet is undergoing rapid and troubling change. In short, this is what is happening:

1) Average global temperature is rising. In the past 100 years the average temperature on Earth's surface has increased 0.74° C (1.3° F); 11 of the last 12 years rank among the hottest on record since 1850 (IPCC, 2007). The current rate of warming is faster than anything detected for thousands of years.

2) Billions of tons of greenhouse gases blanket the globe. Emissions of carbon dioxide, methane, and nitrous oxide — so-called greenhouse gases that trap heat in the atmosphere — have been rising since the start of the Industrial Revolution, and their concentration in the atmosphere is now more than 70 percent higher than pre-industrial levels. Combustion of fossil fuels such as coal account for most emissions in the United States (U.S. EPA, 2006).

3) Ecosystems are changing. Blossoms and leaves are appearing earlier in the spring, birds are migrating and reproducing earlier, and winters are no longer cold enough to control insect and other pests. High alpine species have nowhere higher to go, and polar species are running out of ice. Invasive species are more prevalent. (Parmesan, 2006).

4) Weather is less predictable and more extreme. Droughts, heat waves, floods, and intense hurricanes have all increased in many locations (IPCC, 2007).

5) Glaciers and snow packs are disappearing. The famed snows of Kilimanjaro will be gone by 2020 (Thompson et al., 2002), ski resorts in the Alps are canceling competitions due to lack of snow (Burke, 2006), and Glacier National Park will be largely glacier-free by 2030 (Hall and Fagre, 2003).

6) Arctic sea ice is thinning and retreating. Satellite images document a rapid decrease in the extent of sea ice across the Arctic (IPCC, 2007). Native people say it's no longer safe to hunt on the unstable ice, and there's not enough sea ice along the coasts to protect communities from fall and spring storms.

7) Sea level is rising. Since 1900, sea level has been rising ten times faster than over the past two millennia (IPCC 2007, IPCC 2001a).

8) The ocean is becoming more acidic. As carbon dioxide reacts with seawater, acidity increases, making it more difficult for marine animals like corals and clams to create and maintain calcium carbonate shells and skeletons. Acidification is so rapid in the southern ocean that within the next 100 years shell-building animals may be unable to survive (Raven et al. 2005).

What happens to Earth's climate in the next few centuries depends to a large extent on decisions that we as individuals, organizations, and governments make in the next decade.

There is a growing scientific consensus that by stabilizing atmospheric carbon dioxide at 450 parts per million by 2100 we can avert severe damage to some coral reef systems and probably prevent catastrophic jumps in sea level that would result from disintegration of large land ice sheets (O'Neill and Oppenheimer, 2002).

If we start now, achieving this goal is possible without draconian measures, scientists say. Options ranging from capping industrial emissions to broad use of more fuel-efficient vehicles to increased reliance on alternative energy sources could, if applied together, keep emissions in check for the next 50 years (Pacala and Socolow, 2004), buying us time to develop safe, feasible technologies for even greater reductions.

See our *Action Center* on page 45 for what we can all do now to help keep greenhouse gas levels from reaching dangerously high levels.

CHANGING TIMES

Global warming is changing the rhythm of the seasons. Lilacs bloom earlier in the spring; the first frost arrives later in the fall. The study of the timing of these events is called phenology, and getting good phenological data takes the active involvement of thousands of volunteers. Anyone old enough to observe nature can help. Wisconsin's Department of Natural Resources, for instance, has a phenology program targeting children in grades 4 — 8. The National Park Service has recently joined with other organizations to form the USA National Phenology Network (NPN) whose mission is "to facilitate systematic collection and free dissemination of phenological data from across the United States." The NPN helps professionals, citizen scientists, teachers, and anyone else who's interested choose species in their area to monitor for change and provides a central website where people can record their data and look at information collected by others around the country. To find out more, check **http://www.uwm.edu/Dept/Geography/npn/**

NATIONAL PARKS: A KEY TO THE FUTURE

From melting glaciers at Glacier National Park to disappearing Joshua trees at Joshua Tree National Park, climate change threatens to radically alter our national parks. But our parks also can help us understand the extent of climate change, how to minimize its effects, and how to protect natural treasures for the enjoyment of generations to come.

PARKS CAN HELP NATURE RESPOND AND ADJUST TO CLIMATE CHANGE

National parks are valuable for many reasons: They protect our natural and historic heritage, provide opportunities for recreation, and serve as an escape from the pressures of modern life. In a time of unsettling change, parks play another vital role — helping America's plants, animals, and ecosystems adjust to new climatic conditions. Large remote parks like **Gates of the Arctic National Park and Preserve** in Alaska, which encompasses more than 7.5 million acres and helps support three herds of caribou, may protect sufficiently large, intact, and diverse ecosystems to allow some degree of adaptation to occur within the park. Other parks, like the **Appalachian National Scenic Trail**, may provide a corridor to enable populations of plants and animals to shift their range northward as the climate warms. To the extent they provide refuge from other environmental stresses, such as habitat fragmentation and pollution, parks are places where natural communities have a better chance of coping with changing climate.

PARKS CAN HELP BUILD UNDERSTANDING

National parks encompass an array of ecosystems — from reef to tundra, desert to rainforest — and a wide geographic range. Some, like Rhode Island's **Roger Williams National Memorial** are in the middle of a city, while others, like **Katmai National Park and Preserve** in southwest Alaska, are so remote they are accessible only by air. The national parks are valuable laboratories for learning how organisms and ecosystems in diverse locales respond to climate change. Which species are likely to fare better, and which worse? How do factors like changes in the timing and frequency of fires affect forest and grassland ecosystems? How might population growth rates of culturally and commercially important species change? How will elevated levels of atmospheric carbon dioxide affect plants and soil microbes? Such information can help natural resource managers make the best decisions in a changing world.

PARKS CAN DEMONSTRATE CLIMATE-FRIENDLY SOLUTIONS

National parks provide numerous examples of how to slow climate change through practices such as energy efficiency and use of renewable energy. Through a partnership between Sandia National Laboratory and the National Park Service in the 1990s, diesel generators were replaced with hybrid photovoltaic systems in a number of national parks. At **Joshua Tree National Park** in California, an old diesel-fueled system produced 120 tons of carbon dioxide annually and cost $49,770 to operate. The new photovoltaic-hybrid system emits less than eight tons of carbon dioxide annually and costs around $4,000 a year to operate, paying for itself in just six years.

A number of parks have increased the fuel efficiency of their vehicles. **Cabrillo National Monument** in Southern California uses electric vehicles for all travel within the park, and **Yosemite National Park's** shuttle fleet now includes 18 electric-diesel hybrid buses.

In 2002, the Park Service began a ***Climate-Friendly Parks*** Program to help parks measure and reduce their greenhouse gas emissions, evaluate their vulnerability to climate change, monitor for climate change effects, and educate visitors. Learn more at www.nps.gov/climatefriendlyparks.

YOSEMITE FALLS © DAN HORNER/NPS.

Global Warming & National Parks

CASE STUDIES:

- **THE APPALACHIAN REGION**
- **SOUTH FLORIDA**
- **ALASKA**
- **PACIFIC COAST MOUNTAINS**
- **HISTORIC COASTAL REGIONS**

Impacts of global warming already are being documented in our national parks, and the challenges grow daily. This is a crisis of our own creation that will not go away on its own. It will require decisive action to reduce greenhouse gas emissions through conservation and development of carbon-free power sources. There is growing scientific consensus that greenhouse gas emissions will need to fall by at least 80 percent below 1990 levels by 2050 to avoid some of the most catastrophic effects of climate change (IPCC 2006b).

While climate change is a global phenomenon, it manifests itself differently in different places. Some areas may get drier, while others may get more frequent and destructive downpours. While most regions will get warmer, others may get cooler. Nor are the stakes the same everywhere. In this section we highlight several regions and parks to illustrate how climate change might play out in very different parts of the county.

The good news is that significant reductions in greenhouse gas emissions are possible with today's technology and can go a long way towards limiting environmental damage. Effective responses to climate change also differ by region. While stabilizing atmospheric greenhouse gas concentrations will require reducing emissions around the globe, each region should take action to limit effects of climate change based on local resources and realities. Therefore, we end each case history with a few solutions that may be particularly relevant or achievable for each region.

The Appalachian Region

1. More droughts, floods, and warmer streams could hurt native trout populations. More floods can lead to higher landslide risk.

2. Warmer summers can produce more ozone pollution and more "code red" air quality days, increasing health risks for visitors.

3. Rare and ancient forests may be threatened by increasing ground-level ozone and insect pests unleashed by warming.

GREAT SMOKY MOUNTAINS NATIONAL PARK, NORTH CAROLINA AND TENNESSEE © JAY DICKMAN/CORBIS

THE APPALACHIAN REGION

The Appalachian Mountains are an ancient range stretching between Georgia and Canada. The **Appalachian National Scenic Trail** travels through 14 states, passing through such jewels as **Great Smoky Mountains** and **Shenandoah** National Parks, **Delaware Water Gap National Recreation Area,** and **Harpers Ferry National Historical Park**. The mountains reach their greatest heights in the Black and Great Smoky Mountains of North Carolina and Tennessee, where eight peaks top 6,000 feet.

This complex topography creates a mosaic of microhabitats, home to the rich diversity of species and ecosystems that won **Great Smoky Mountains National Park** designation as a World Heritage Site and International Biosphere Reserve. The park contains the southernmost remnant of the great boreal forests that stretched across the region during the last ice age, as well as the largest block of virgin red spruce on Earth (Peine and Berish, 1999). Archaeological sites representing 10,000 years of human occupation dot the area.

Appalachian parks, such as **Great Smoky Mountains** and **Shenandoah,** provide islands of wildness in the most populated part of country. People head for the mountains to get away from it all, to bird watch, to fish, and to ski in the northern reaches of the Appalachians. But the mountains that generations have treasured and relied upon may be fundamentally diminished as a result of climate change.

Temperatures in the Appalachian region have been on the rise since the 1970s (Allard and Keim, 2007; Burkett et al, 2001), and already warming has begun to take its toll. The ski season is getting shorter and less predictable. Iconic species, like the Fraser fir trees so typical of high elevations here, could eventually disappear. (U.S. EPA 1997b, 1999). One study predicts that if carbon dioxide levels double from average 1961 — 1990 levels, which could occur between the middle and end of this century, conditions in **Great Smoky Mountains National Park** would become unsuitable for red squirrels, southern red-back voles, and northern flying squirrels (Burns et al., 2003; IPCC 2007). And climate change may make it even harder for trees to deal with such stresses as acid rain and invasive pests, which are already decimating regional forests. (NPS 2007, NPCA 2006, Webster et al. 2004, Peine and Berish 1999, Malcome and Markham 1997).

A FAREWELL TO TROUT

Cold, quick-flowing streams found in abundance in **Shenandoah** and **Great Smoky Mountains** national parks support a thriving recreational fishing economy. Because these parks are at the southern edge of where trout can live, a little warming has a huge effect. An increase of just 2° C (3.6° F) could eliminate 37 percent of trout habitat in the region; with a 4° C (7.2° F) increase, predicted to occur by the end of this century, 80 to 90 percent of trout habitat in Virginia and North Carolina could disappear (Flebbe et al., 2006; IPCC 2007).

Global warming also will alter the flow of Appalachian streams. Models predict lower base flow and bigger floods (e.g. Mulholland et al., 1997), both of which can be disastrous for native brook trout. A major drought in 1988 led to high trout mortality and such low reproductive rates that an entire year-class was lost (Peine and Berish, 1999). Floods can flush adult brook trout downstream where other fish species have a competitive advantage, and depending on time of year, can scour trout eggs and larvae out of gravel nests too soon, leading to large die-offs.

Streams surrounded by healthy, intact forest may stay cooler, dry out more slowly, and experience less severe flooding than those without such cover. High-elevation streams and surrounding forests protected within the boundaries of **Shenandoah** and **Great Smoky Mountains** national parks may provide the last best hope for trout to survive at the southern end of their range. However, as discussed below, climate change is contributing to the decline of Shenandoah's Eastern hemlocks, which provide shade along the park's trout streams.

A REFUGE LOST

As summers get hotter along the Eastern seaboard — scientists predict that July will feel 8 to 15 degrees Fahrenheit warmer within the next century (Burkett et al, 2001) — more people likely will flock to nearby mountain refuges like **Great Smoky Mountains** and **Shenandoah** National Parks. **Great Smoky Mountains** is already the most visited national park in the country, receiving more than 9 million visitors a year. More than 20 million people annually drive along the **Blue Ridge Parkway**, which connects **Great Smoky Mountains** and **Shenandoah** parks.

Larger crowds will detract from the park experience and make a visit to the mountains less and less an escape from hot, congested cities. Increased traffic and smog fostered by warmer temperatures will add to air quality woes, already a significant problem for these parks. If drought becomes more common, as some models predict, increasing numbers of forest fires also will contribute to a decline in air quality, as happened during

Streams surrounded by healthy, intact forest may stay cooler, dry out more slowly, and experience less severe flooding than those without such cover.

LEFT: RED SPRUCE FOLIAGE © CONNIE TOOPS.
RIGHT: FAMILY CAMPING © INMAGINE.COM.

the 1988 drought when a record 41 forest fires swept through the Great Smokies (Peine and Berish, 1999).

Even getting to the parks could be difficult. Some climate models predict more floods for the region, which could cause trouble for the many gateway communities that sit at the bottom of steep slopes. Gatlinburg, Tennessee, for instance, is in a gorge near the bottom of one of the steepest watersheds in **Great Smoky Mountains National Park**. Interstate 40, one of the main access roads to the park, already is prone to landslides; stronger floods and more intense storms will only intensify the risk. Besides inconveniencing visitors, such events wreak economic havoc on communities that depend heavily on park traffic.

LOSING RARE AND ANCIENT FORESTS

Part of what makes Appalachian parks special are, in the words of one park enthusiast, the "primeval, dark, mysterious forests." **Great Smoky Mountains National Park** is home to one of the biggest — and one of the few — remaining tracts of eastern old-growth deciduous forest, as well as to majestic stands of Fraser fir and hemlock. There are more tree species in this one park than in all of Europe.

However, forests in the southern Appalachians have been struggling for decades with the stress of acid rain, and there is evidence that the combination of climate change and pollution can be worse than either alone. In the 1980s, for example, the combined effects of drought and acid rain may have led to a 15 percent decline in healthy crowns on red spruce (Peine and Berish, 1999).

A warmer climate will increase ground-level ozone concentrations and favor the spread of insect pests that already are taking their toll. Native pine-bark beetle populations are increasing so fast that many lumber companies are abandoning pine plantations altogether (J. Peine, pers. comm. 2007).

Throughout the region, highly-invasive non-native insects called adelgids have laid waste to Eastern hemlock and Fraser fir to the point that the future of the Fraser fir is in doubt. Trees weakened by climate change may be even more vulnerable to the pest (Malcolm and Markham, 1997). At the same, time, available habitat is disappearing and becoming fragmented due to development. As a result, tree species that live along the high crests and ridges of the Appalachians may have a difficult time migrating to cooler regions as their current home heats up.

SOLUTIONS FOR THE APPALACHIAN REGION

INVEST IN RENEWABLE CLEAN ENERGY

Solar power is feasible for homes and small businesses, and there is potential to develop wind energy, though siting of wind installations must protect the ecological and historical values of the region. Other options include geothermal systems, which are increasingly being used for schools, government buildings, and homes.

Both Tennessee and North Carolina encourage the use of alternative energy sources by allowing customers to sell excess energy back to the power company through the Tennessee Valley Authority's Green Switch Power Program, a step in the right direction (Kent and Risch, 2006). Finally, there is great potential to reduce demand for electricity through greater efficiency and conservation. In the absence of federal and state leadership, localities like Arlington and Fairfax, Virginia, are moving forward with initiatives to enable county residents and businesses to take relatively easy, affordable steps to reduce greenhouse gases.

RETIRE EXISTING COAL-FIRED POWER PLANTS

Coal currently generates 50 percent of the electricity in the United States. The oldest and most polluting coal plants should be retired systematically and replaced with renewable energy and energy efficiency programs. Coal plants that continue to operate should be required to significantly reduce their carbon dioxide emissions with low and no-carbon technologies.

RECRUIT CITIZENS TO MONITOR THE EFFECTS OF CLIMATE CHANGE

Public involvement serves two purposes: It generates valuable data to help scientists and land managers understand and address the effects of climate change. It also motivates volunteers to take action and to encourage their friends to do so as well. Through a new collaborative project, the Appalachian Trail Mega-transect, the National Park Service and many partner organizations and individuals are developing data collection guidelines so that volunteers can effectively monitor the status of natural resources along the 2,175 miles of the **Appalachian National Scenic Trail**. Volunteers will then be able "to better tell the story of the status of the health of the Appalachian Trail's lands to visitors, trail neighbors in 14 heavily populated eastern states, and the general public," according to the Appalachian Trail Conservancy (ATC, 2006).

TROUT FISHING

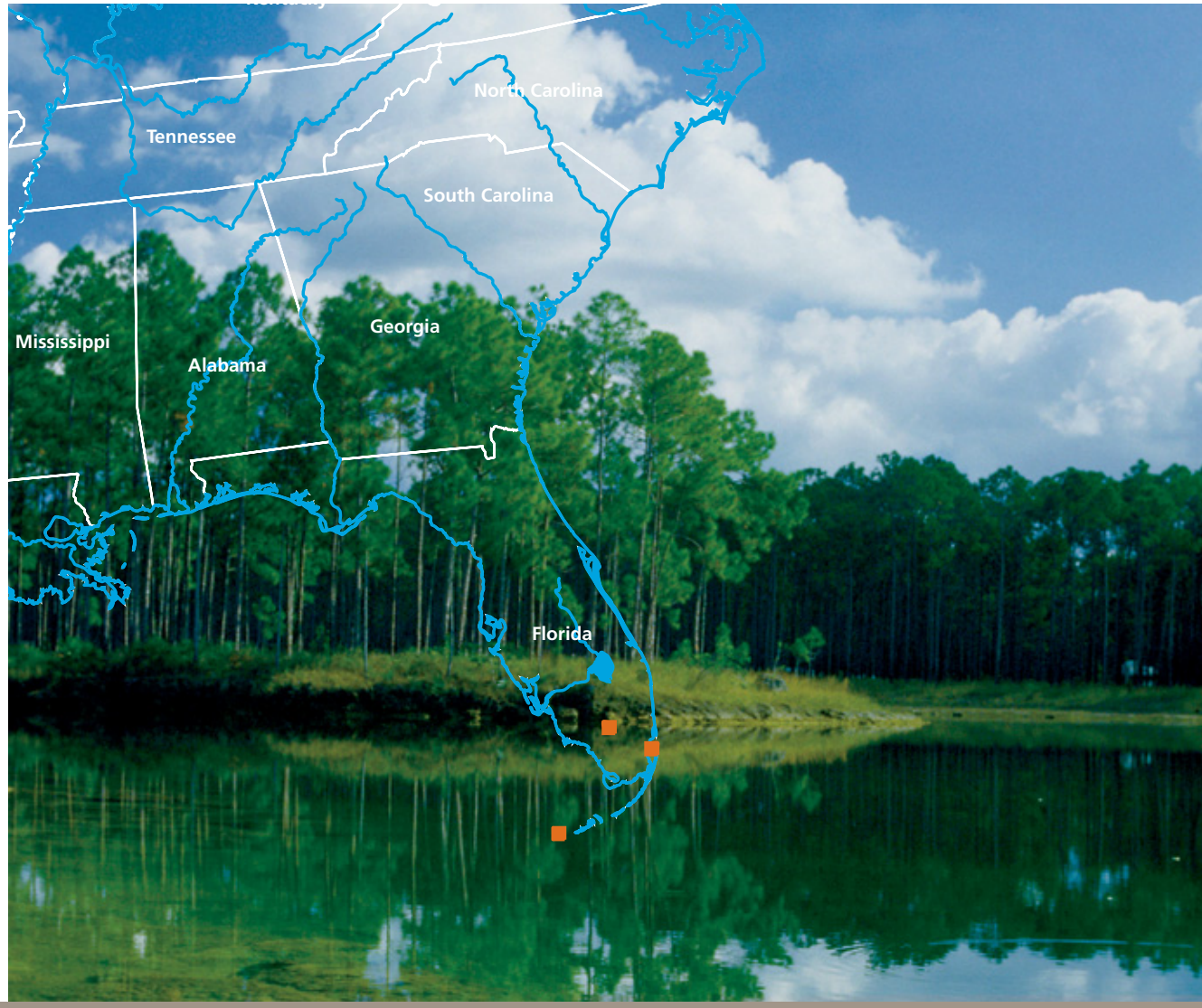
Don Ayer, who has been trout fishing in the Appalachians for more than 20 years, wonders what climate change might mean for his favorite fishing areas. "Brook trout have clung to life for so long, and their survival is so tenuous in a lot of these little streams," says Don. "We must do everything we can not to lose them." High in **Shenandoah National Park**, brook trout thrive in small, aquifer-fed streams that stay cold year-round. The big, wide rivers west of the Appalachians are more vulnerable to hot summers. One summer when the temperature was too high and water and oxygen levels were too low, Don could smell dead and dying fish before he actually reached the stream. Luckily, rivers and streams can recover. A 1995 flood and its debris scoured more than a mile (1.9 km) of the Staunton River in **Shenandoah National Park**, eliminating fish and riverside vegetation in that area, but three years later, native brook trout populations had bounced back (Roghair et al, 2002). National parks are vital to a river's resilience. They protect its watershed and nearby fish stocks that can re-populate damaged areas.

South Florida

1. Rising, warming, and acidifying seas can threaten coral reefs and sport fishing.

2. Toxic or unusual algal blooms may threaten wildlife and tourism.

3. More powerful hurricanes combined with sea level rise could destroy park buildings and roads, increasingly cutting-off visitor access.



SOUTH FLORIDA

Southern Florida hosts the only barrier reef system in the United States and one of the largest in the world. Extending between **Biscayne National Park** in the north and **Dry Tortugas National Park** in the south, the reef is stunningly beautiful and diverse. The coral reef ecosystem is intertwined with extensive seagrass, marsh, and mangrove habitats, which serve as nurseries for numerous reef animals and help filter harmful pollutants and nutrients from the water. This vibrant underwater life makes Florida the most popular snorkeling and scuba diving destination in the country and supports a recreational fishing industry that generates more than $3 billion for the state's economy. And of course there are the beautiful expanses of sandy beach that attract thousands of other sun lovers to south Florida's coasts.

These very features, which make south Florida so special to locals and visitors alike, are in serious jeopardy. Rising seas and more intense hurricanes are eating away at the coastline. Warmer sea temperatures are destroying corals in **Biscayne** and **Dry Tortugas** National Parks and elsewhere. The endangered Cape Sable seaside sparrow no longer lives on **Everglades National Park's** Cape Sable; it has been forced north in part by rising seas (U.S. Fish and Wildlife Service, 1999). Also at risk are sea turtles, crocodiles, and other animals for which warmer temperatures can cause all the young to develop as the same sex. (Janzen 1994).

BISCAYNE NATIONAL PARK: REEFS AT RISK

A haven for snorkelers and divers, **Biscayne National Park** alone generates close to $24 million a year for local economies (Hardner and McKenney, 2006). Unfortunately, the south Florida reef that attracts those visitors is a fading beauty. The brilliant colors of the reef come from tiny algae that live inside the cells of healthy coral, but when corals are stressed, they lose these algae and turn white — a process known as bleaching. Often fatal for the coral, bleaching also can cause long-term changes in the community of fish that live on the reef (Bellwood et al., 2006). Significant coral bleaching occurred in Florida in 1997 and 1998, and the threat of bleaching is now an annual summer concern (Kelly 2004). Coral diseases, which thrive in warmer water, also have increased four-fold since 1994 (Lynch et al., 2002). Destruction of Florida's reefs would mean losing a rich and diverse ecosystem as well as one of the country's greatest marine vacation destinations. It also would make the coastline more vulnerable to storm-generated waves.

Damage is not limited to coral reefs, however. Biscayne Bay could lose 79 percent of its tidal flats habitat and

LEFT: EVERGLADES, FLORIDA © ROLF W. HAPKE/ZEFA/CORBIS.
RIGHT: CORAL REEF © JIM LIPSCHUTZ/ISTOCKPHOTO.

54 percent of its salt marsh within a century if no action is taken to limit the rate of sea level rise; other south Florida areas may lose even more. (NWF 2006). These losses threaten such popular fish species as bonefish, yellowtail snapper, and tarpon (NWF 2006). While Florida's anglers have been instrumental in passing key legislation to protect fish, these measures may be insufficient without additional actions to limit global warming and help ecosystems adapt to changes already under way.

Ecosystems along south Florida shores also are increasingly plagued by algal blooms fueled in part by warmer temperatures and by strong hurricanes that pump excess nutrients and freshwater into Biscayne and Florida Bays. Toxins released by the so-called "red tide" algae can be dangerous to humans who inhale them and to marine animals that consume them.

EVERGLADES NATIONAL PARK: HURRICANE DAMAGE AND THE COST OF REBUILDING

Climate change may be ushering in a new era of more powerful hurricanes in the North Atlantic. Hurricanes get their energy from the ocean, and warmer oceans mean stronger storms. As sea surface temperature has risen steadily over the past century, hurricanes have become more intense (Trenberth and Shea, 2006; Emanuel 2005), and experts expect the trend to continue (IPCC 2007). Future storms also are likely to cause greater devastation. Much of a hurricane's damage comes from its storm surge — huge waves generated by the storm's strong winds and low atmospheric pressure. As sea level rises, these surges will reach farther and farther inland.

As hurricanes become more frequent and more powerful, insurance companies are increasingly refusing to offer coverage because the risk is too great. The issue affects parks as well as businesses and homeowners and has delayed repair of park infrastructure pounded by recent storms. One notable casualty is the area known as Flamingo, an important gateway to **Everglades National Park**, which was hit by hurricanes Katrina and Wilma in 2005. All existing structures, including a visitor center, lodge, restaurant, and cabins were severely damaged or destroyed by wind and storm surge, though Park Service personnel managed to evacuate many artifacts from the Flamingo Museum before the storm struck. Flamingo provided the only overnight accommodations in the park and was a popular destination for anglers, boaters, birders, campers, and paddlers, but rebuilding and reopening depend in part on finding an insurer and a concessionaire willing to take the risk.

SOLUTIONS FOR SOUTH FLORIDA

While many projections present a depressing future for south Florida — much of it may be under water within a century — the region has an opportunity to demonstrate to the world how smart planning can limit the extent of climate change and help both natural and human communities survive inevitable changes.

RESTORE ECOSYSTEMS WITH AN EYE TO THE FUTURE

In the face of dire predictions for the southern tip of Florida, restoration might seem pointless. In fact, restoration can help populations and ecosystems adapt or migrate in response to climatic shifts, buying them critical time while we work to limit climate change (Hansen et al., 2003). Managers can replant damaged areas with species or varieties of native plants better adapted to changing conditions. For example, scientists are identifying salt-tolerant varieties of coastal bald cypress to help restore cypress forests now dying as a result of saltwater intrusion in estuaries along the Gulf and southern Atlantic coasts of the U.S. (Conner and Inabinette, 2005).

ACQUIRE PROPERTY INLAND FROM EXISTING PARKS

Because some sea level rise is inevitable, the National Park Service and other managers of coastal protected areas should work to acquire new land or links to public lands inshore from existing parks, where possible, and plan infrastructure to connect the parks to these lands. This potentially would allow park ecosystems, such as critical sea turtle nesting beaches, to migrate landward as sea level rises. Similarly, a network of marine protected areas could provide a corridor from southern Florida north along the East and Gulf Coasts to allow marine species to slowly move to cooler water.

DEVELOP CLEAN ENERGY RESOURCES

Florida could reduce the need for new power plants by taking advantage of one of the state's biggest assets: sunshine. Subsidizing the installation of solar panels on homes and businesses would go a long way toward reducing Florida's greenhouse gas emissions. Just as Floridians stopped offshore drilling because of the potential negative effects on their valuable and beloved coastline, they need to aggressively demand energy sources that will help counter global warming. In particular, Florida should reject the spate of new coal-fired power plants proposed for the state — even right next to the Everglades. Besides producing more greenhouse gas emissions than any other energy source, coal-fired plants emit mercury and other dangerous toxins that can poison wildlife such as the Florida panther and manatee, which Floridians have been struggling to protect. Clearly, Florida has much to gain by becoming a clean energy leader.

While many projections present a depressing future for south Florida — much of it may be under water within a century — the region has an opportunity to demonstrate to the world how smart planning can limit the extent of climate change and help both natural and human communities survive inevitable changes.

Alaska

1. Caribou ranges and population size may become less predictable.

2. Ocean warming may affect salmon fisheries and scientists are exploring possible links between warmer river temperatures and increased parasites in salmon.

3. Thawing permafrost will damage infrastructure and reduce the size and location of ponds on which waterfowl depend.

ALASKA

Alaska is "ground zero" for global warming in the United States. Temperatures there are rising almost twice as fast as elsewhere (IPCC 2007), probably because of such factors as its naturally variable climate and increasing heat absorption as reflective ice melts. (Kerr 2006; Kattenberg et al. 1996). Sea ice and glaciers are rapidly retreating, insect outbreaks and fires are destroying huge swaths of forest, coastal communities are threatened by encroaching ocean waters, and whole villages may have to relocate.

Alaska is home to more national park land than any other state. Its biggest park, **Wrangell-St. Elias National Park and Preserve**, is bigger than the four smallest U.S. states combined. **Denali National Park and Preserve** is home to North America's tallest mountain. Like much of Alaska, these parks are wilder than those in the Lower 48 and are intimately tied to the lives of rural Alaskans, who rely on hunting and fishing as vital sources of food.

GATES OF THE ARCTIC NATIONAL PARK AND PRESERVE: CHALLENGES FOR CARIBOU

National parks provide valuable habitat for caribou, the most hunted large mammal in Alaska. Hunted as food for at least 10,000 years, caribou is still central to the diet and culture of many Native Alaskans, such as the Nunamiut people who live within the northern boundaries of **Gates of the Arctic National Park and Preserve**. (National Park Service, 2004). During past ice ages, caribou lived as far south as northern Mississippi (Grayson and Delpech, 2004), but warming has pushed them about as far north as they can go.

Climate change affects caribou in many ways. While warmer summers generally produce more forage for nursing mothers and young, they also bring more parasites and harassment by insects, which can decrease survival. In parts of Alaska, warmer winters increase the frequency of freeze-thaw cycles, creating thick layers of ice that caribou must break through to get to winter forage. In other areas, climate change means deeper winter snows, also making it harder for caribou to find food. The tundra ecosystem on which caribou depend is being pushed steadily north, and up to 90 percent of Alaska's tundra may disappear by 2100 (Bachelet et al., 2005). More frequent wildfires in a warmer Alaska destroy the older, lichen-rich spruce forest that caribou prefer as winter habitat and create numerous burned-

LEFT: DAWES GLACIER AT THE END OF ENDICOTT ARM, SOUTHEAST ALASKA © CARL & ANN PURCELL/CORBIS.
RIGHT: FISHING IN ALASKA © SETH KANTNER.

CARRYING THE EFFECTS SOUTH

Bird lovers who eagerly await the seasonal arrival of species like green-winged teal, sandhill cranes, or common goldeneye have good reason to care deeply about the implications of climate change for Alaska. Hundreds of bird species migrate annually between summer breeding grounds in Alaska and wintering grounds in the Lower 48. By affecting the success of migratory birds on their summer feeding and nesting grounds, changes in Alaska's ecosystems will impact bird populations across North, Central, and even South America. National parks can protect birds from some threats, but protecting them from climate change will take help from all of us.

over areas that caribou tend to avoid for as long as 50 to 60 years after a fire. Fires are blamed in part for the recent decline in the Nelchina caribou herd often found around **Denali National Park and Preserve** (Rupp et al., 2006). For some herds the costs of climate change seem to be outweighing the benefits. (Jenkins and Barten, 2005).

YUKON-CHARLEY RIVERS NATIONAL PRESERVE: CHALLENGES FOR SALMON

Chinook salmon in the Yukon River and its tributaries, including those in the **Yukon-Charley Rivers National Preserve,** are experiencing the effects of a single-celled parasite previously unknown in Alaskan salmon. Scientists are exploring links between rising water temperature and the prevalence of this parasite (Kocan et al., 2004). Called Ichthyophonus, the parasite can kills fish it infects and reduces the ability to reproduce in those that survive. Infected fish can have an unpleasant taste and texture, and rural Alaskans have developed alternative uses, such as fertilizer and dog food, for the portion of the harvest now unfit for human consumption.

The outlook is grim for salmon in Alaska's southern parks as well. By the middle of this century, the ocean around southern Alaska may be too warm to support healthy, wild salmon (Welch et al., 1998). The traditional subsistence lifestyle of rural Alaskans, a thriving commercial fishing industry, and the delicately balanced natural food chain would be devastated by crashing salmon numbers. This would be a particular concern for **Wrangell-St. Elias National Park and Preserve**, home to the famed Copper River salmon, as well as the salmon rich rivers of other national parks, such as **Glacier Bay** and **Katmai** National Parks.

WRANGELL-ST. ELIAS NATIONAL PARK AND PRESERVE: NOT SO PERMA-FROST

The Copper River Basin in **Wrangell-St. Elias National Park and Preserve** has lost more than half of its shallow, closed-basin ponds since the 1950s (Riordan et al., 2006), likely due to a combination of thawing permafrost and changes in the regional water balance.

Some 85 percent of Alaska is underlain by permafrost, a layer of permanently frozen soil anywhere from ten to 2,200 feet thick (NAST, 2001). Seasonal thawing on top of permafrost is a normal process which creates ponds and wet conditions that favor tundra ecosystems, but the rate and depth of thawing have increased dramatically over the past century. (Camill 2003; Lawrence and Slater 2005). Besides creating more sinkholes, landslides, and erosion and damaging build-

MUIR GLACIER, GLACIER BAY NATIONAL PARK IN 1941

MUIR GLACIER, GLACIER BAY NATIONAL PARK IN 2000

ings and roads, thawing permafrost is also reshaping Alaska's aquatic landscape.

While shallow thawing creates and expands lakes and ponds, adding favorable habitat for aquatic wildlife (Hinzman et al., 2005), extensive thawing can actually cause lakes and ponds to shrink or disappear completely. Many shallow bodies of water are essentially permafrost "bathtubs" sitting on top of underground aquifers. If the permafrost thaws enough to connect surface water to these aquifers, it's like pulling the

If the permafrost thaws enough to connect surface water to these aquifers, it's like pulling the bathtub plug.

bathtub plug. The ponds drain, and surface soils dry out (Yoshikawa and Hinzman, 2003). Such changes in freshwater habitat alter the location and availability of breeding territories for birds and the predictability of food sources for local people. Subsistence hunters in Alaska have noted that lakes and rivers are already too low for many birds (Deborah Williams, pers. comm., January 20, 2007)

SOLUTIONS FOR ALASKA

INCLUDE CLIMATE CHANGE IN RESOURCE MANAGEMENT PLANS

Alaska's resource management agencies have generally done a good job of maintaining healthy and strong populations of fish and game that now stand a much better chance of adapting to variable conditions. However, climate change is making it harder to predict fluctuations in populations or predict where important game animals will be found at any given time, increasing the risk of inadvertent overharvesting. In the fall of 2006, for example, the protected Nelchina caribou herd migrated into part of the traditional area for hunting the Fortymile herd, a region where the Nelchina caribou were rarely seen prior to 20 years or so ago (Mowry, 2006), resulting in an unintentional harvest of the Nelchina herd. Such increasing uncertainty makes it essential for resource managers and local people to work together to monitor, evaluate, and manage resources.

GET TOUGH ON STATE EMISSIONS

A recent study found that on a per capita basis, Alaskans generate almost four times as much carbon dioxide as other Americans (Bryson, 2007). The high cost of climate change in Alaska is already apparent; stringent controls on emissions are critical to keeping the costs, both financial and cultural, from becoming catastrophic.

HELP RURAL VILLAGES BECOME MORE ENERGY EFFICIENT

Because of the large number of remote communities dependent on diesel generators for power, reducing greenhouse gas emissions in Alaska requires a local approach. One village decided to pay for power ahead of time and metered its use in homes. When residents saw how quickly their investment was spent by actions such as leaving lights on or radios playing, many voluntarily adjusted their behavior and reduced energy consumption (Townsend 2006).

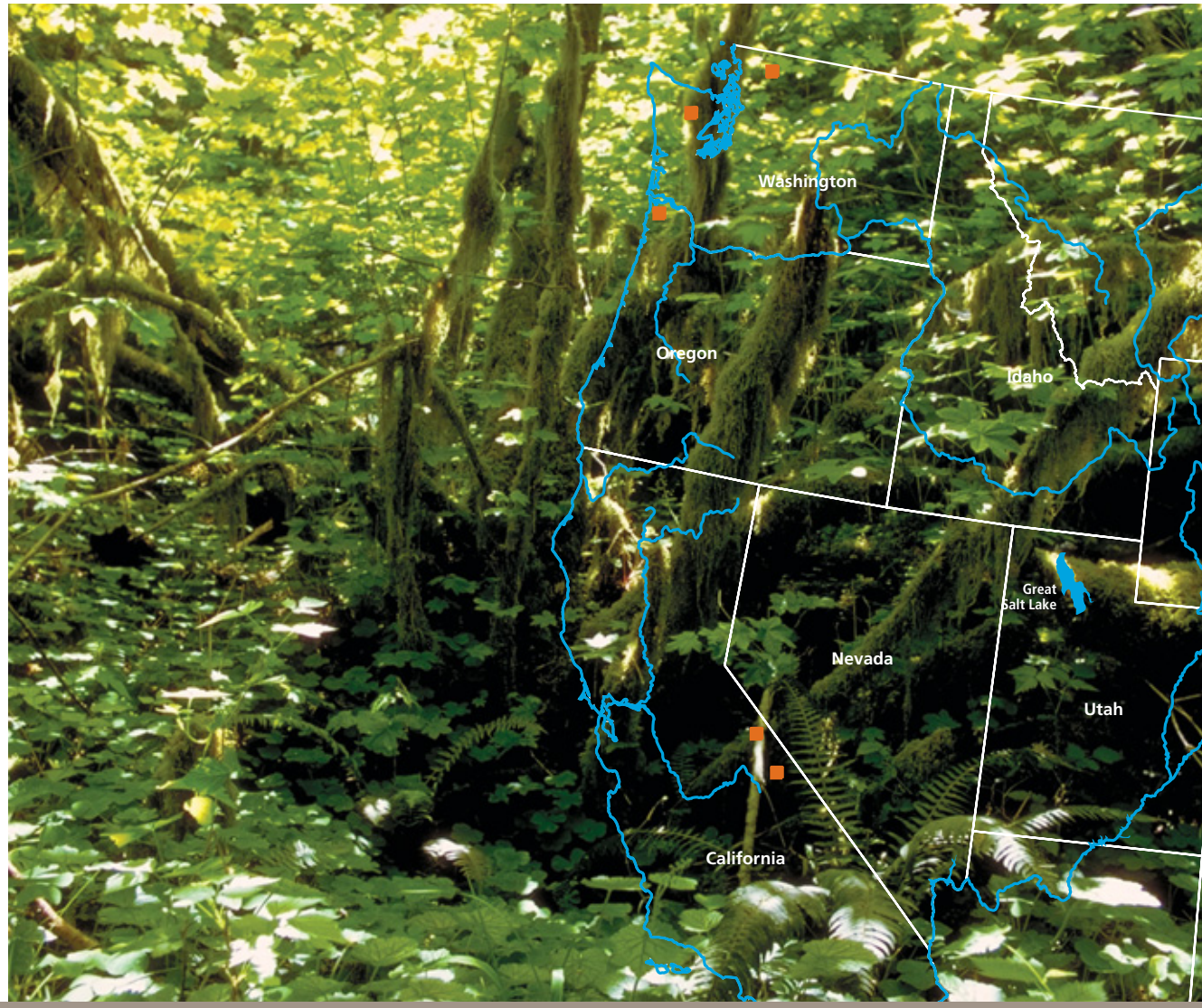
Wind energy is successfully providing power for some rural Alaskan communities, and entrepreneurs are start-

Pacific Coast Mountains

1. Warming and drought have made wildfire season longer and more damaging, and increased insect damage.

2. Seventy to 90 percent of the snow pack in the Sierra and Cascade Mountains could disappear by the end of this century, threatening winter sports and water supplies. Warmer winters and more extreme precipitation events could increase winter flood risk.

3. Warmer temperatures will worsen ground-level ozone problems. Increasing wildfires will contribute more smoke and airborne particulates.



OLYMPIC NATIONAL PARK, WASHINGTON © NPS.

PACIFIC COAST MOUNTAINS

The high, jagged peaks of America's coastal Pacific mountains are a defining feature of the West Coast and represent some of America's most spectacular and beloved scenery. The Sierra Nevada were the spiritual home of John Muir, who was instrumental in the creation of **Yosemite** and **Sequoia** National Parks in 1890. The dramatic landscapes of **Yosemite** were further immortalized in the stunning black-and-white photographs of Ansel Adams. In Washington, the **North Cascades National Park** complex encompasses the largest, most rugged alpine wilderness in the Lower 48 and is home to grizzly bears, wolves, and virgin Douglas fir and Western red cedar forests. Its 300 glaciers cover more area than glaciers in any other U.S. national park south of Alaska (Post, 1971).

These majestic mountain ecosystems are already feeling the effects of climate change. Glaciers and alpine meadows are disappearing (Millar et al, 2004; Fagre and Peterson, 2000), along with the oak woodlands so typical of the Sierra Nevada (Kueppers et al., 2005). As the climate warms, high-mountain species like the pika are retreating uphill (Jim Patton, pers. com., 2007), but eventually there will be nowhere higher to go. Warmer streams and lower flows threaten cold-water fish, including endangered salmon and trout. Non-native species may gain an advantage, while increased droughts and floods may disrupt ecosystems. Indeed, changes in the most basic elements of the physical environment — fire, water, and air — could radically reshape the landscape of the coastal mountain ranges.

FIRES AND PESTS

Hot, dry conditions generated by climate change can give rise to highly destructive wildfires. Since 1987, western wildfires have become four times more frequent than during the period 1970 to 1986. The average wildfire season is 78 days longer, and overall fires are taking five times longer to control (Westerling et al., 2006). Some models suggest that without limits on greenhouse gas emissions, the number of large wildfires in California alone will increase by more than 50 percent by the end of the century (Westerling and Bryant, 2006). The high cost of fighting fires in national parks will continue to strain the budget of the already severely under-funded National Park Service.

Besides sparking fires, a hot, dry climate weakens many trees, making them more vulnerable to insect pests that thrive as temperatures rise. Drought and insect infestations exact an even greater toll in areas where many years of fire suppression have created unusually dense forests. Indeed, high density contributed to widespread

mortality in mixed-conifer forests in **Yosemite National Park** during an extended drought between 1987 and 1992 (Guarin and Taylor, 2005). In the long term, such die-offs thin forests and may make them more drought-resistant (Millar et al., in press), but large wildfires fueled by warm, dry conditions and large numbers of dead trees could drastically alter forests in the parks. In a changing climate, trees are increasingly expanding into meadows and former snowfields across the Sierra Nevada (Millar et al., 2004), further adding fuel for the fires.

DROUGHT AND FLOODING

Generous snowfall makes national parks in the Sierra Nevada and Cascade Mountains, such as **North Cascades, Yosemite**, and **Sequoia and Kings Canyon** meccas for skiing, snowshoeing, and winter mountaineering enthusiasts. But snow pack in these parks also serves as a vital reservoir, slowly releasing winter precipitation in the form of meltwater throughout the dry summer months. People depend on this natural reservoir for drinking water, irrigation, and hydropower; and salmon and other fish depend on it for habitat.

Yet, this valuable resource is disappearing before our eyes. Snow is melting sooner in the spring with runoff from the Sierra Nevada and North Cascade Mountains occurring ten to 30 days earlier than half a century ago (Stewart et al., 2005). More and more winter precipitation is falling as rain instead of snow, especially in January, traditionally the top snow-producing month (Knowles et al., 2006). Analyses suggest that these changes reflect a long-term warming trend that is expected to get worse. If greenhouse gas emissions are not reduced, as much as 70-90 percent of the snowpack in the Sierra Nevada and Cascade Mountains could disappear by the end of the century (Cayan et al., 2006; Leung et al., 2004). Snow sport opportunities along the West Coast will shrink, and the already fierce battles over water supply will surely intensify.

Ironically, the same forces that worsen summer droughts also increase the risk of floods in other seasons (Parson et al., 2001; Mote et al., 2003). Because winter temperatures in coastal Pacific mountains hover close to freezing, the few degrees rise predicted for this region will cause more and more precipitation to fall as rain rather than snow (Leung et al., 2004). Predicted increases in extreme winter precipitation with expected shifts toward rain rather than snow could greatly increase the likelihood of flooding. (Leung et al., 2004). In **North Cascades National Park**, the three worst floods in park history have occurred in the fall when rain fell on snow that already had accumulated in the mountains. The fact that all three of these once-in-100-years floods happened in the past 12 years suggests that climate change is the culprit, according to park officials.

Other Pacific Coast parks have experienced similar disastrous flooding. A heavy rainstorm hit high in **Yosemite National Park** in May 2005, a time of year when snow rather than rain would normally have fallen at high elevations. Trails, campgrounds, and roads were so flooded that Yosemite Valley was shut down for a day. In November 2006, **Mount Rainier National Park** suffered the most damaging flood in its 108-year history when nearly 18 inches of rain fell in just 36 hours. The flooding broke the main utility lines, destroyed large sections of roads, trails, and campgrounds, and filled reservoirs with mud and debris. The major year-round road through the park was closed for six months, and a major north-south road will be closed for at least a year. Rebuilding will likely cost between $36 million and $100 million (Blumenthal, 2007).

Ironically, the same forces that worsen summer droughts also increase the risk of floods in other seasons…

LEFT: BRIDGE DAMAGE ALONG THE NISQUALLY RIVER, MOUNT RAINIER NATIONAL PARK, WASHINGTON © NPS.

DOCUMENTING CHANGES OVER TIME

In the early 1900s, ecologist Joseph Grinnell and colleagues surveyed plants and animals across California, a project known as the Grinnell Transect. Since then, the Sierras have seen fire suppression, dramatic shrinking of glaciers, and a steep increase in temperature. To document the effects of these changes, scientists from the University of California-Berkeley are retracing Grinnell's footprints through **Yosemite National Park**. (Museum of Vertebrate Zoology, 2007, and Jim Patton, pers. comm. February 13, 2007). This is some of what they've found:

Moving In

Yosemite now hosts four small mammal species that were absent in Grinnell's time. One of these, the piñon mouse, has extended its range up-slope by more than 2,000 feet.

Moving Up

Ranges of several high-elevation mammal species have retreated upward. American pikas and alpine chipmunks used to be common at altitudes as low as 7,800 feet but in the Yosemite area are now found only above 9,500 feet.

Moving Out

Shadow chipmunks and bushy-tailed woodrats, plentiful in Yosemite in Grinnell's time, are now uncommon, and their ranges have shrunk significantly.

UNHEALTHY AIR

More than 90 percent of Californians live in areas that violate state air quality standards (Cayan et al., 2006), and, unfortunately, some of their parks are just as polluted. **Sequoia and Kings Canyon, Joshua Tree,** and **Yosemite** National Parks all have ozone levels higher than allowed by EPA's health standards (NPS, 2006). Global warming will make it significantly harder to restore air quality to healthful levels, because warmer temperatures boost formation of ground-level ozone. A 4° C (7.2° F) rise in temperature in California's Central Valley would translate to 20 percent higher ozone concentrations (U.S. EPA, 1997a). Ozone also chemically burns leaves, harming plants and detracting from the beauty of the forests.

As the climate warms, stagnant conditions will become more frequent in summertime, trapping particulates and ozone closer to the ground. (Kleeman and Cayan 2006 as cited in Cayan et al. 2006). If forest fires increase as predicted, smoke and dust particles will compound poor air quality. The number of days when people with asthma or respiratory problems can safely hike in the parks will continue to dwindle, and visitors in general will find the national parks much less attractive places to visit.

SOLUTIONS FOR PACIFIC MOUNTAIN PARKS

USE CLIMATE CHANGE DATA TO MANAGE FORESTS AND FIRES

California, Oregon, and Washington are fortunate to have a wealth of regional climate models, scientific information on the possible effects of a warmer, dryer climate, and coordinated ongoing research efforts. Natural resource managers should draw on such data and partnerships to make informed and proactive decisions that may help limit the negative effects of fire on forests and surrounding communities and increase the resistance of forest ecosystems to climate change.

TOUGHEN CONTROLS ON AIR POLLUTION

California's existing air quality problems will only get worse with climate change. To prevent increasingly severe effects on parks, natural resources, and human health, the state must take even more comprehensive steps to improve air quality, such as the major new effort recently launched to clean up pollution in the Central Valley. The "Government Regional Partnership for San Joaquin Valley-air quality group" is working to achieve attainment of federal healthy air standards by 2020. If successful, these efforts would ensure support by way of federal funding and incentives to address the valley's massive ozone and particulate pollution problems. In addition, California's efforts to reduce vehicle emissions would have the double benefit of fighting both local pollution and global warming.

PREPARE FOR FLUCTUATING WATER RESOURCES

The challenge facing water managers in California and the Pacific Northwest is how to deal with the opposing threats of too little and too much water. They will need to store enough water in reservoirs to prepare for summer shortages caused by disappearing glaciers, shrinking snow pack, and earlier melting but leave enough capacity to capture floodwaters before they wreak havoc downstream. Protecting healthy ecosystems high in the mountains of **Yosemite** and **Sequoia and Kings Canyon** National Parks **in California** and **Olympic** and **North Cascades** parks in the Pacific Northwest may help reduce flooding to some extent.

LEFT: STRIPED MICE © NICO SMIT/ISTOCKPHOTO.
RIGHT: OLYMPIC NATIONAL PARK, WASHINGTON © JAMES NATIONS/NPCA.

Historic Coastal Regions

1. Sea level rise, increasing storm strength, and flooding threaten low-lying historic areas such as 400-year-old Jamestown and other historical structures.

2. Warmer water is likely to increase outbreaks of two dangerous oyster diseases.

3. Earlier snowmelts and spring flooding can decimate already-stressed salmon populations.

HISTORIC COASTAL REGIONS

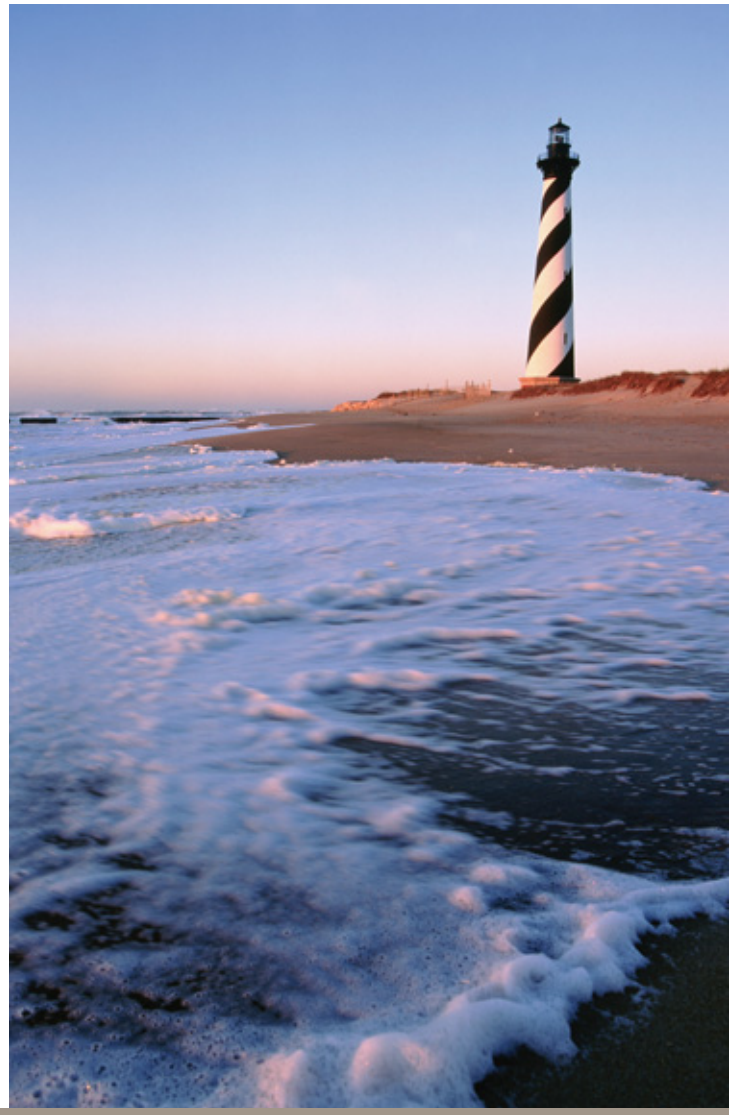
Cultural and historical treasures safeguarded by our national parks also are threatened by climate change. Warmer, moister conditions foster explosions in insect populations and speed the decay of structures and artifacts. Rising sea levels, stronger storms, larger, more frequent floods, and greater fluctuations between wet and dry conditions all take a toll. Not surprisingly, historic and archaeologically important sites in coastal regions are most at risk.

The East and Gulf Coasts are rich with sites that tell the story of the birth of our country and of the Civil War that nearly destroyed it. Even in well-established parks like **Colonial National Historical Park** in Virginia**,** new archaeological discoveries are continually being made. Many of these coastal sites are especially vulnerable to the increasingly intense hurricanes expected to accompany global warming. A look at damage wrought by recent storms gives an idea of what's at stake.

In 1989, Hurricane Hugo filled South Carolina's **Fort Sumter**, where the Civil War began, with 7 to 8 feet of water. In 2004, Park Service employees rescued 300,000 artifacts by boat from Fort Pickens museum in **Gulf Islands National Seashore** after Hurricane Ivan struck (Dvorak, 2005). The collections are still recovering (Allen Bohnert, pers. comm. February 22, 2007), and the heavily-damaged road to the fort is still closed. The following year, Hurricane Katrina filled Gulf Islands' Fort Massachusetts with several inches of mud and debris; wrecked the reconstructed Ship Island lighthouse, site of the first white settlement in the Mississippi Valley; and destroyed historic ruins, sand-blasted cannons, and damaged brickwork in **Dry Tortugas National Park** (Heritage Emergency National Task Force, 2005).

JAMESTOWN: A LOST COLONY?

Formed by retreating glaciers and rising seas around the end of the last ice age, Jamestown Island, Virginia, has been slowly shrinking ever since. The site of the first permanent English colony in the New World, established in 1607, is preserved as **Historic Jamestowne National Historic Site** within **Colonial National Historical Park**. As Americans celebrate the 400th anniversary of Jamestown's founding, the island faces accelerated erosion from strong hurricanes and rapidly rising sea levels induced by global warming. Archaeological sites that were originally inland are now on the shore, and the site of a Confederate Civil War fort is slipping into the James River. (Thornberry-Ehrlich 2005). A marker placed on the shoreline just a decade or two ago is now more than 10 feet out in the water.



LEFT: FORT JEFFERSON/DRY TORTUGAS NATIONAL PARK, FLORIDA © AMOS NACHOUM/CORBIS.
RIGHT: CAPE HATTERAS LIGHTHOUSE, NORTH CAROLINA © OWAKI - KULLA /CORBIS.

Most of Jamestown Island is below the 100-year floodplain, and the entire island is below the 500-year floodplain. In 2003, the island was completely flooded when Hurricane Isabel, a category 1 storm, hit at high tide. Some archaeological sites were washed away, and the visitor center and museum were so badly damaged that they were condemned (Thornberry-Ehrlich, 2005). Following the storm, NPS personnel dried and blotted one million artifacts to prevent their loss to mildew and rot (Dvorak, 2005).

The island is especially vulnerable to storms because its loosely consolidated soil is easily eroded. The National Park Service has attempted to protect important sites by installing a variety of breakwaters, riprap, walls, and other structures over the years. Some structures have been compromised during major storms; one has been bypassed by the creek it was intended to contain (Thornberry-Ehrlich, 2005).

To safeguard artifacts while keeping them on site, a new curatorial facility was built to withstand a category 2 hurricane. While Virginia hasn't experienced anything stronger in recent history, a category 3 or even a category 4 is not out of the question (Virginia Department of Emergency Management, 2007), particularly in light of the predicted increase in hurricane strength. We must act now to limit climate change if Jamestown Island is to be around for the 500th anniversary of the historic settlement.

The entire mid-Atlantic coast from Maryland to North Carolina is also at risk. Because of the region's gentle coastal slope, soft sandy shores, and slowly sinking land, the sea level is rising at a relative rate well above the global average (Thieler and Hammar-Klose, 1999). Most vulnerable of all are barrier islands like North Carolina's Outer Banks, home to **Fort Raleigh National Historic Site** where the first English settlement in North America was attempted, **Cape Hatteras National Seashore**, and **Wright Brothers National Memorial**.

CHESAPEAKE BAY: A DISAPPEARING WAY OF LIFE

Chesapeake Bay gets its name from an Algonquian word meaning "Great Shellfish Bay," and indeed crabbing and oystering traditionally have been central to the region's culture and economy. The riches of seafood in these waters led writer H.L. Mencken to describe the Bay as a "great protein factory." Overharvesting and declining water quality have caused shellfish populations in the Bay to plummet, however, and climate change will make efforts to restore the Bay and its living riches all the more difficult. In particular, warmer

water and periodic spikes in salinity predicted by some climate models (Barron, 2000) are likely to increase outbreaks of two dangerous oyster diseases (Cook et al., 1998; Ewart and Ford, 1993). Overall, more than 50 national parks lie within the Bay's watershed, with a number having shorelines along the Bay or its tributaries. **C&O Canal National Historical Park**, **Fort McHenry National Monument and Historic Shrine**, **Piscataway** and **Anacostia** parks, and several others participate in the **Chesapeake Bay Gateways Network**, managed by the National Park Service to promote and link Bay-area historical sites and natural areas. Recently, the president signed legislation establishing **Captain John Smith Chesapeake National Historic Trail**, the nation's first water trail. It was designated to complement the gateway's network.

LEWIS AND CLARK NATIONAL HISTORICAL PARK: SALMON SWIM NO MORE

Historically, life and culture in the Pacific Northwest centered around its seemingly endless supply of salmon. When Lewis and Clark's Corps of Discovery arrived there in 1805, up to 16 million salmon a year returned to the Snake and Columbia Rivers to spawn. (Lichatowich, 1999). When the explorers arrived in a Nez Perce village tired and starving, the Native Americans fed them a welcome meal of salmon. Canoeing seaward on the Columbia, they saw salmon drying on scaffolds all along the route. Trapped for six days by fierce weather in Dismal Nitch (now part of **Lewis and Clark National Historical Park**), they survived by purchasing salmon from visiting Cathlahma Indians and catching 15 of their own salmon in Megler Creek.

Today, Lewis and Clark would likely go hungry. Salmon populations have plummeted so sharply that some are now extinct or endangered. While overfishing, hydropower dams, and habitat modification are largely to blame, climate change will make it harder to bring salmon back. Earlier snowmelts predicted for this region will bring earlier spring floods, which can kill salmon eggs and fry that would normally have grown large enough to survive by the time floods arrive. Warmer water can stress or kill salmon of all ages. Increasingly hot, dry summers could intensify the existing pressure to use water for farms and hydropower rather than leaving enough in the river for salmon.

Historically, life and culture in the Pacific Northwest centered around its seemingly endless supply of salmon.

LEFT: BLACKWATER NATIONAL WILDLIFE REFUGE, MARYLAND © DAVID HARP.
RIGHT: LEWIS AND CLARK NATIONAL HISTORIC TRAIL © NPS.

THE VIEW FROM THE WATER

Joe Weems has worked on the Chesapeake Bay all his life. His forbearers farmed the fertile fields of Talbot County, Maryland on the Bay's Eastern Shore before starting a marine construction business in the 1960s. Founded by Joe's father Edmund ("Woody") and uncle Robert, Weems Brothers specializes in building boat piers, "riprap" stone shorelines, and timber bulkheads to protect land and buildings from the effects of tide and weather.

For decades the family built structures that stood up to the predictable rhythms of the Bay. But about ten years ago they began seeing dramatic changes. Water levels in the Bay were gradually rising, and warmer winters allowed termite-like marine "bores" to survive year round, increasing damage to wooden piers throughout the Eastern Shore. At a family meeting they decided it was time to warn property owners that bulkheads would have to be built higher and stronger to withstand the rising water and stronger storms they were starting to see, and that piers would need to be replaced more frequently. All of this, of course, meant more business for Weems Brothers. But Joe's concern is first and foremost the changes he is seeing in the Bay. "This is not the Bay I remember as a child. We used to crab around the shores, but now the crabs are gone because the grasses they rely on are gone. Bigger and more frequent rainstorms are causing more algae blooms and red tides. Hurricane Isabel in 2003 brought the biggest storm surge we've ever seen — almost nine feet — causing a huge amount of property damage."

To help clients deal with the changes, Weems Brothers is now building more "living shorelines" that rely on natural grasses to absorb the tides and storm water. But Joe thinks that if we don't get climate change under control, the Bay will suffer ever greater decline. "We can do our part to make property owners aware of the changes and to suggest the best options to deal with them," says Joe, "but global warming is beyond our control. Everyone who cares about a healthy Chesapeake Bay should be doing everything possible to moderate the environmental changes we're experiencing."

SOLUTIONS FOR COASTAL HISTORY SITES

PLAN FOR CLIMATE CHANGE, BE PREPARED TO MAKE TOUGH DECISIONS

The National Park Service needs to work closely with archaeological, curatorial, and preservationist groups to develop a coordinated plan to protect priceless artifacts from storms, floods, droughts, and temperature and humidity extremes. Because climate change could increase the frequency and severity of storms, park managers should revisit their emergency plans in light of predictions for their area. In addition, the Park Service must face difficult decisions about what can and can't be saved and when to move artifacts permanently to safer locations rather than leave them at their home historic sites.

KEEP ON TOP OF BASIC MAINTENANCE

As cultural heritage specialist May Cassar put it, "climate change often highlights long-standing preservation issues, rather than discovering new problems" (Cassar, 2005). While ecosystems may adapt if left alone, the same is not true of historic buildings, artifacts, and archaeological sites. Every unrepaired leak and every poor drainage system makes it that much more likely that parts of our heritage will be swept away by future storms or floods. The problem is that national parks usually receive just two-thirds of what they need to cover annual operating expenses, leading to more than an $800 million a year shortfall (NPCA, 2006). Combine this deficit with the added expenses of coping with unexpected disasters such as the 2005 hurricane season and the situation becomes truly challenging.

LEFT: TOP, JOE WEEMS © JAMES GIBBONS. BOTTOM, CHESAPEAKE BAY BLUE CRAB © SANDY FRANZ/ISTOCKPHOTO.
RIGHT: PHOTO. FORT JEFFERSON/DRY TORTUGAS NATIONAL PARK, FLORIDA © AMOS NACHOUM/CORBIS.

SAVING A BELOVED LANDMARK

North Carolina's Cape Hatteras lighthouse was erected in 1803 to mark a set of shallows so treacherous that the area around them was known as the "graveyard of the Atlantic." The lighthouse survived countless hurricanes, nor'easters, and even a powerful earthquake, but erosion along this section of coast was so rapid that in 1936 the U.S. Coast Guard abandoned the lighthouse believing it would eventually fall into the sea. In 1950 the beacon was returned to the lighthouse, but by 1989 it was clear that the only way to save the distinctively striped landmark was to move it inland. It took the Park Service ten years to plan the move, secure funding from Congress, and settle lawsuits by people worried that the move might harm the structure. In 2000, at a cost of approximately $12 million, the lighthouse was finally installed safe and sound 2,870 feet from its original location. As erosion continues, the Park Service is planning to move two more historic structures off the beaches of North Carolina's Outer Banks (Mark Hardgrove, pers. comm., February 20, 2007).

Climate Friendly Parks

More than 250 million people visit national parks every year. Park visitors are generally inclined to care about the environment, and parks provide a superb natural setting for motivating people to do more. If each visitor took away a key message about climate change and how he or she can reduce greenhouse gas emissions, the impact would be significant.

Recognizing the value of the parks to educate visitors and catalyze change, the National Park Service has established a partnership with the U.S. Environmental Protection Agency to make the national parks models of climate stewardship and education.

Through its Climate Friendly Parks program the National Park Service seeks to:

- Educate every park employee about climate change and air pollution and the role each person can take in addressing the problem;
- Identify a strategy for each Climate Friendly Park to reduce its emissions of greenhouse gases and air pollutants in order to help mitigate the effects of climate change and air pollution; and
- Communicate to the public how climate change and air pollution affect their park's natural resources, how the park is dealing with these effects, and how individuals can be stewards of our climate and other natural resources.

Climate change is perhaps the most far-reaching and irreversible threat the National Park System has ever faced. Recognizing Americans' strong desire to preserve and protect our national parks for present and future generations, National Parks Conservation Association is partnering with NPS to help implement and expand its Climate Friendly Parks program. NPCA believes this program can play a critical role in helping park visitors understand the causes and consequences of climate change. Even more important, Climate Friendly Parks can inspire park visitors and supporters to reduce the climate change threats by making changes in their personal lives, and by demanding stronger leadership from their local, state, and federal policymakers.

CLIMATE FRIENDLY PARKS MAKING A DIFFERENCE

To date ten national parks participating in the Climate Friendly Parks program have completed climate action plans. Here are just a few examples of what some of these parks are doing to make a difference.

Everglades National Park performed an inventory of its greenhouse gas emissions in 2004 and discovered that almost one-third of the park's emissions come from transportation, primarily visitor vehicles. Park staff have since committed to a range of actions, including operating visitor shuttles, encouraging the use of bicycles and non-motorized boats, increasing the fuel efficiency of park marine and automotive fleets, rewarding contractors who run more than half of their vehicles on alternative fuels, and educating employees on climate-friendly actions they can take in their area of control (CFP 2005).

Delaware Water Gap National Recreation Area in Pennsylvania and New Jersey has committed to reducing its fuel consumption by 15 percent over three years, and will perform energy audits with the goal of decreasing energy demand by 25 percent.

Gateway National Recreation Area in New York and New Jersey is adopting new grounds management practices to reduce emissions, including identifying areas where wildlife could benefit from limited mowing, planting trees in unused lots, and designing parking lots to enhance vegetation.

Glacier Bay National Park in Alaska found that marine vessels account for 97 percent of its greenhouse gas emissions, and more than half comes from cruise ships. The park is now changing criteria for awarding cruise ship contracts to favor those committed to reducing emissions.

Zion National Park in Utah has undertaken numerous projects to reduce its "environmental footprint," from buying environmentally preferable materials and recycling to obtaining alternative transportation means for park employees and using renewable fuels in its vehicles. According to park superintendent Jock Whitworth, however, "most important are the education and outreach efforts that reflect the passion of both the park and a model gateway community committed to stewardship."

LEFT: KOTZEBUE ELECTRIC'S WIND FARM, ALASKA © SETH KANTNER.
RIGHT: ZION NATIONAL PARK © ISTOCKPHOTO.

INDIVIDUALS MAKING A DIFFERENCE

Hon. Laurence William "Bill" Lane, Jr., has had a long and distinguished career — Navy Lieutenant during World War II, advisor to several California governors and U.S. presidents, U.S. Ambassador to Australia, and Ambassador-at-Large in Japan are just a few highlights. But while he has worn many hats over the years, Bill's love for our national parks and other wild lands is the common thread that ties together many of his diverse pursuits. He was Chairman of the Presidential Commission for the Centennial of the National Parks and is an honorary NPS ranger. As the publisher of *Sunset* Magazine, Bill shared his enthusiasm for the parks with millions of Americans, many of whom made their first visit to a national park because of one of many articles they read in *Sunset* Magazine and Books.

In recent years, Bill has grown increasingly concerned about the effects of global warming on our national parks. He knows the parks intimately from his days as a mountain guide in Sequoia and Yosemite National Parks, and he sees how climate change is diminishing these treasured places. Through his work as an advisor to many conservation, civic, and business organizations, Bill has helped others understand global warming and its consequences for our environment.

As a former publisher, Bill also understands the power of the parks to educate and inspire individuals. Helping people understand what is at stake and what they can do about it are critical first steps in preventing global warming from inflicting irreversible damage on the parks Bill has fought to protect. That is why Bill and his wife Jean have made a substantial financial commitment to help NPCA educate park visitors and supporters — especially young people — about climate change, how it affects the western national parks, and what we can all do to protect them. Solving an issue as big and complex as global warming may well take a generation's worth of effort. The gift from Bill and Jean will help ensure that the next generation of park supporters will be equipped for the task and motivated to act.

COMPANIES MAKING A DIFFERENCE

Xanterra Parks & Resorts, which operates lodges, restaurants, and other concessions in 11 national parks, has committed to reducing its greenhouse gas emissions to 10 percent below 2000 levels by 2015. At six national parks, half of Xanterra's electricity now comes from wind power. Two employee houses at **Yellowstone National Park** get up to 40 percent of their power from solar panels. The company has increased vehicle fuel efficiency, begun using more biodiesel, reduced fuel oil usage, upgraded the efficiency of appliances, and installed countless energy-saving control systems. As a result of such initiatives, Xanterra is almost halfway to its emissions reduction goal without compromising the quality of service it provides. Says Chris Lane, vice president of environmental affairs, "As a company working in some of the most beautiful places on Earth…Xanterra knows it has a primary responsibility to help protect these natural treasures from global warming."

LEFT: HON. LAURENCE WILLIAM LANE JR. AND HIS WIFE JEAN, YOSEMITE NATIONAL PARK. COURTESY OF MR. LANE.
RIGHT: SOME OF THE WAYS XANTERRA IS REDUCING ITS FOOTPRINT AT THE NATIONAL PARKS IT SERVES: SOLAR PANELS AND FUEL EFFICIENT CAR. COURTESY OF XANTERRA

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Unnatural Disaster:

Global Warming and Our National Parks

ACTION CENTER: What we need to do now to protect our national parks for future generations

It is not too late to change course. Significant reductions in greenhouse gas emissions are possible with today's technology and will go a long way toward limiting dangerous climate change. With the centennial of the National Park System less than ten years away, we need to act now to ensure that we have healthy parks for the next century.

TEN STEPS TOWARDS HEALTHY NATIONAL PARKS

1. CAP AND REDUCE POWER PLANT EMISSIONS.

Coal-fired power plants are the largest industrial emitters of carbon dioxide and many other air pollutants that harm the national parks. Their emissions must be capped and significantly reduced in order to protect the parks from global warming, acid rain, unsightly haze, and unhealthy air.

2. INCREASE VEHICLE FUEL EFFICIENCY.

Motor vehicles are among the largest emitters of greenhouse gases. Technologies available today can reduce their emissions, increase their fuel economy, and save consumers money at the gas pumps.

3. PROMOTE CLEAN SOURCES OF ENERGY.

America can meet much of its growing energy needs by simply using more of the energy saving appliances and building practices that have been around for years. We can also deploy more clean renewable energy generating facilities, such as those powered by solar, wind, geothermal technologies.

4. INCREASE FUNDING FOR THE NATIONAL PARK SERVICE.

Parks have a tough time responding to the disasters that may become more frequent with climate change — like the 2007 flooding in Mount Rainier National Park that caused an estimated $36 million in damage and closed the entire park. Congress must ensure NPS has funding to keep up with basic maintenance, be at the forefront of research on the effects of climate change, protect the parks' scenery, ecosystems, history, and recreational values, and educate the public about climate change.

5. EXPAND THE CLIMATE FRIENDLY PARKS PROGRAM.

This innovative NPS program is helping national parks reduce their greenhouse gas emissions, educate visitors about climate change and clean energy solutions, and develop ways to protect natural and cultural resources from the detrimental effects of climate change. Learn more at www.nps.gov/climatefriendlyparks.

6. INNOVATE AT THE STATE AND LOCAL LEVELS.

Effective solutions to global warming are being put in place by cities and states across the country. California developed a program to reduce greenhouse gases from motor vehicles, and a dozen states are following its lead. Mid-Atlantic and New England states are capping carbon dioxide emissions from power plants. The Cities for Climate Protection Campaign is helping local governments reduce their greenhouse gas emissions. The federal government should not stand in the way of these innovative programs, but should instead work to emulate them.

7. HELP NATIONAL PARKS ADAPT TO CLIMATE CHANGE.

Climate change is already altering vital ecosystems protected by our parks. Federal, state, and local authorities must work together to ensure parks stand the greatest chance of surviving these changes with their natural treasures intact. Examples include creating buffers around parks and wildlife corridors between protected lands to give plants and animals room to migrate as their preferred temperature and other environmental conditions shift. Parks can also start to determine whether different varieties of indigenous plants might have a better chance of surviving the changing conditions.

8. ENGAGE WITH THE INTERNATIONAL COMMUNITY.

Global warming is, of course, a global problem, and significant emissions reductions from every nation will be necessary to avoid the worst impacts. The president must engage with our international partners to put in place meaningful and enforceable agreements for reducing greenhouse gases to a safe level.

9. INVEST IN NEW CLIMATE-FRIENDLY TECHNOLOGIES.

Climate change has been described as the biggest challenge facing our nation and our world in a generation. The resources we invest in stopping catastrophic warming should be commensurate with the threat. There are many innovative technologies — such as hydrogen-powered motor vehicles and zero emission power plants — that could play an enormous role in keeping our planet safe. Our elected leaders must ensure that these technologies get off the drawing board into widespread use as quickly as possible.

10. INDIVIDUAL AMERICANS CAN MAKE A DIFFERENCE!

Not every solution to climate change takes an act of Congress or a scientific breakthrough. All of us can do things in our everyday lives to reduce pollution and help save our national parks. Buying a new car? Why not consider a hybrid or other high-mileage model. Buying a new appliance? "Energy Star" models will use less energy and save on your electric bills. But you don't have to buy anything to make a difference. Simply driving less, turning off the lights when you don't need them, and recycling can make an enormous difference, especially when we all pitch in. **Find out more about what you can do to help stop global warming and protect our national parks at ww.npca.org/globalwarming**

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