BACKGROUNDER

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# Climate Change and Outdoor Recreation Resources

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RESOURCES FOR THE FUTURE

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## I. Introduction

It is now widely recognized that climate change is taking place, and in the absence of serious policy to reduce greenhouse gas emissions—and in fact, even with it—the planet will continue to grow warmer over the next century. In North America, mean temperatures are expected to increase between 1°C and 3°C by 2039, according to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007). Beyond 2039, 2 to 3°C of warming will likely occur on the continental edges, with more than 5°C of warming possible in higher latitudes. Precipitation is predicted to increase across the continent with the exception of the southwestern United States, which will experience decreased mean annual rainfall.

In this backgrounder, we look at the impacts these changes are likely to have on recreation resources in the United States. We focus our attention on freshwater resources, coastal areas, and public lands. Specifically, we assess the likely changes in snowmelt and the resulting impact on winter recreation activities; the impacts on streams and reservoirs and how they may affect recreational fishing and boating; and the impacts on noncoastal wetlands, which may impact hunting and wildlife viewing opportunities. Rising sea levels will accompany climate change, and we assess how this change will impact coastal recreation in various areas of the United States. Finally, we look at impacts on forests, large wildlife, national parks, and national wildlife refuges, and assess their likely influence on recreation opportunities and outcomes. Wherever possible, the discussion highlights policies that can help recreation adapt to new climate realities.

Many studies have been published, and many more are underway, of the impacts of climate change on a variety of ecosystems and species. We are not comprehensive in covering that literature in this backgrounder. Instead, we provide a selective overview of the most significant findings for resources that are important for outdoor recreation. The penultimate section of the paper includes a review of the limited number of economics studies on the

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recreational benefits and costs of climate change. In the conclusion, we discuss the role played by adaptation.

## II. Freshwater Resources and Recreation

Because water often dictates the functionality of natural systems, it is one of the key considerations in assessing the impacts of climate change and is pervasive in discussions about the role played by adaptation. Water is critical for many recreation activities, from boating and fishing to mountain biking and backpacking. Impacts on water resources from climate change will vary by region of the country and by season. In this paper, we limit our discussion to impacts on winter recreation from reduced snowpacks, impacts on fishing and boating from lower streamflows and reservoir levels, and changes in hunting and wildlife viewing opportunities from alterations in noncoastal wetlands.

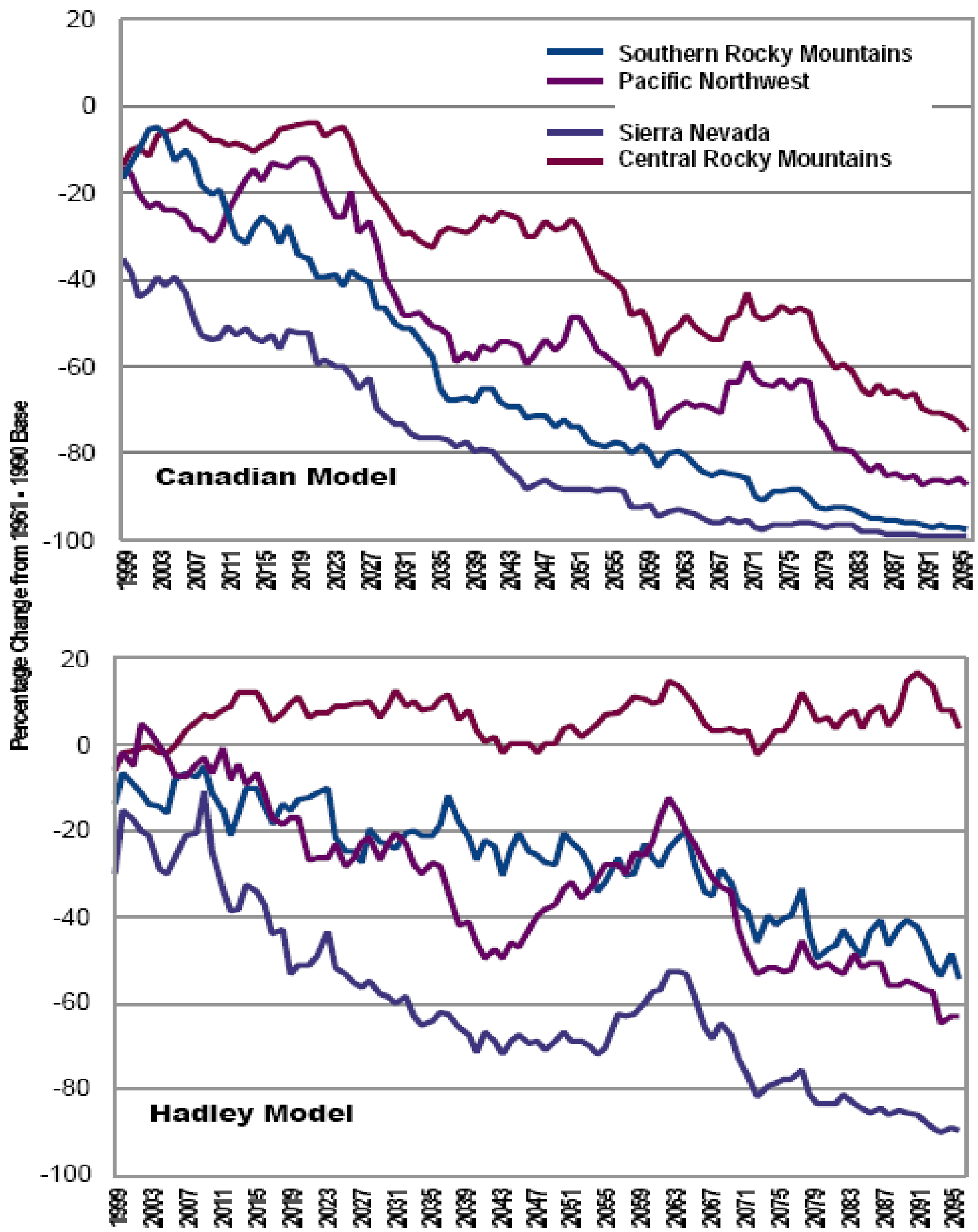
### *Impacts on Snowpack*

Climate models overwhelmingly predict that snowpack levels will decrease in the future as a result of climate change. The snowpack in most locations is expected to accumulate later in the winter months and melt away much more quickly in the spring. Increased precipitation is expected in many regions under climate change, but will present few benefits to snowpacks because higher temperatures during the events will cause much of it to fall as rain (Knowles et al. 2006). As a result, the number of areas where snow reliably falls is expected to shrink as the climate warms. The Sierra Nevada Range in California may experience a 99 percent loss of its April 1 baseline snowpack, and other western mountain ranges will suffer reduced late-season snowpacks by the end of the century (USGCRP 2000). Ski areas with comparatively warmer mean microclimates, such as those found in New Mexico, Arizona, Nevada, and California, will experience more snowpack loss than areas that remain colder, such as those found in Colorado, Montana, Utah, and Wyoming. A study of the impact on Washington state ski resorts found that 12.5 percent of the areas in the Cascade Mountains and 61 percent of the areas in the Olympics are “at risk” from future climate change (Nolin and Daly 2006). The authors defined areas as “at risk” if their snow currently accumulates at temperatures at or near freezing. Figure 1 shows a graph of estimated snowpack declines in the western United States under a likely future climate change scenario.[1]

Skiers and snowboarders tend to favor lower temperatures and more snow, and low-quality snow can affect the demand for ski days (Englin and Moeltner 2004). Once again, warmer ski areas in the Southwest are more at risk for significant reductions in snow quality than colder areas in the central Rocky Mountains and are thus more likely to see reduced demand (Butsic et al. 2008). Estimates for ski season day losses range from 7 percent with major adaptation efforts to 100 percent with no adaptation efforts (Scott et al. 2003). The adaptation options that are currently available are limited in scope and often constrained by financial resources. The most obvious option is snowmaking, which many ski areas already use to some degree. With warmer temperatures, advanced snow-making technology will be needed. A study that simulated ski season operations under shifting climatic conditions in southern Ontario found that the season will be reduced by 11 percent to 50 percent by 2080 with current snowmaking capacity, but improved snowmaking technology leads to a reduction of the season by 4 percent to 39 percent (Scott et al. 2003). Other adaptation options include landscaping slopes to reduce the need for deep snowpacks and moving ski operations to higher, more north-facing peaks to maximize snowpack accumulation (OECD 2007). The extent to which such changes are feasible or financially viable will vary by region.

[1] In Europe, only 30 percent of ski resorts that currently receive reliable to marginal snow will continue to receive snow with 4°C of warming (OECD 2007).

**Figure 1. Estimated Percentage Changes in Snowpack in the Western United States: Results from Two General Circulation Models**




Source: United States Global Change Research Program. 2000. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. Overview: Water.

### *Impacts on Streams and Reservoirs*

Seasonal changes in precipitation will not only affect winter recreation, but could have a major influence on the quality and availability of activities that depend on reservoirs and streams. More rain during the winter months is expected to combine with smaller snowpacks that melt sooner to generate peak streamflows earlier in the spring and reduced summer streamflows (USGCRP 2000). Moreover, reduced snowpack contributions to streams combined with warmer air temperatures will likely result in warmer water temperatures. Both sportfishing and boating will be affected by these changes, but in different ways. Sportfishing is dependent on water quality, including water temperature, streamflow levels, and ecological conditions, whereas recreational boating is more sensitive to lake, reservoir, and stream levels.

Water quality and temperature are major influences on the distribution of aquatic species, and warmer streams are expected to reduce the current habitat of rainbow trout and other coldwater fisheries that are valued by anglers. Pendleton and Mendelsohn (1998) combine general circulation models, ecological models, and economic models to estimate the effects of a doubling of atmospheric $CO_2$ on sportfishing in the northeastern United States. Their model estimates that, on net, the annual economic benefits from climate change range from –$4.6 million to $20.4 million, depending on negative trends in rainbow trout populations and positive trends in brook trout populations. In other words, there could be an economic cost related to recreational fishing due to rainbow trout population declines resulting from increased water temperatures. Conversely, rising water temperatures could make North Carolina streams more hospitable for other trout species, like brook trout, leading to population increases and potential benefits of up to $20 million per year. Other studies show brook trout have variable reactions to global warming. Some scenarios predict that a 3.8°C overall increase in mean annual temperatures could result in an 89 percent loss of brook trout from streams in Virginia and an 82 percent loss in North Carolina, whereas others project that the maximum loss of brook trout habitat does not top 30 percent (Ahn et al. 2000). Drier, warmer summers are resulting in warmer water and lower streamflow throughout the eastern and western United States (Covich 2009), which could stress many trout and salmon species.

Fluctuating reservoir and stream levels will influence the quality and availability of recreational boating in a changing climate, but these effects are likely to vary widely by region of the country. The West will be hardest hit as mountain snowpacks feed streams throughout the spring and into the summer, and snowpack levels will be lower. The Colorado River, for example, gets 70 percent of its water from snowmelt (Christensen et al. 2004). Vanishing snowpacks and higher summertime temperatures will decrease streamflows and lower reservoir levels, which can impede recreational boating and reduce waterfront property values (Covich 2009). Climate model runs with a 2.4°C warming show a 17 percent reduction in runoff in the Colorado River Basin, which leads to a 40 percent reduction in basin storage (Christensen et al. 2004). Reservoirs in the basin include such popular recreation areas as Lake Powell, Lake Mead, and Lake Havasu. Reductions in runoff may lead to more demand for water storage as an adaptation measure, but large dams have major environmental costs and are very expensive.

In addition to impacts on boating and fishing, reductions in stream flows—particularly in the hot and dry Southwest—could also have negative impacts on hiking, mountain biking, and backpacking opportunities. Not only is water essential for engaging in these activities in the outdoors, but it also enhances the appeal of the environment. Water is a draw for outdoor recreation of all types.

### *Impacts on Noncoastal Wetlands*

Wetlands in the northern plains states and the Canadian provinces of Alberta, Saskatchewan, Manitoba, and northern British Columbia form the basis of what is known as the Prairie Pothole Region. This system of wetlands, which covers over 216 million acres of land, has been called the "duck factory" for its importance in providing breeding areas for a variety of birds such as pintails, mallards, and blue-winged teal, and critical migratory habitat for lesser scaup, Canada geese, and snow geese, among others. In most climate change scenarios, many of the wetlands in the Prairie Pothole region are expected to dry up, and the portion of the region that has optimum conditions for breeding is predicted to shift south and east (Johnson et al. 2005). Figure 2 shows a map of the region as it now exists, along with three alternatives for the location of these key wetlands in a world of climate change. In some scenarios, 90 percent of the region's wetlands are predicted to disappear, which could lead to a 69 percent reduction in the area's breeding duck populations.

The Prairie Pothole Region is not the only waterfowl habitat under threat; lowering water levels in the Upper Great Lakes area could lead to a 39 percent loss in regional duck populations (Yaich and Wentz 2007). In addition to habitat loss, migrating game birds will face shifting seasonal pressures that will alter migration patterns, including departure times and winter locations. As the country warms, migrating flocks will not have to travel as far south to find open water and suitable food sources, meaning once-productive hunting areas in the southern United States could become bereft of game fowl. Moreover, warmer fall and winter temperatures will muddle seasonal signals that initiate flock migration, leading to more erratic behavior among migrating species. Hunters and birdwatchers who plan their activities around the migration of birds at certain times of the year will potentially have fewer and less reliable recreation opportunities.

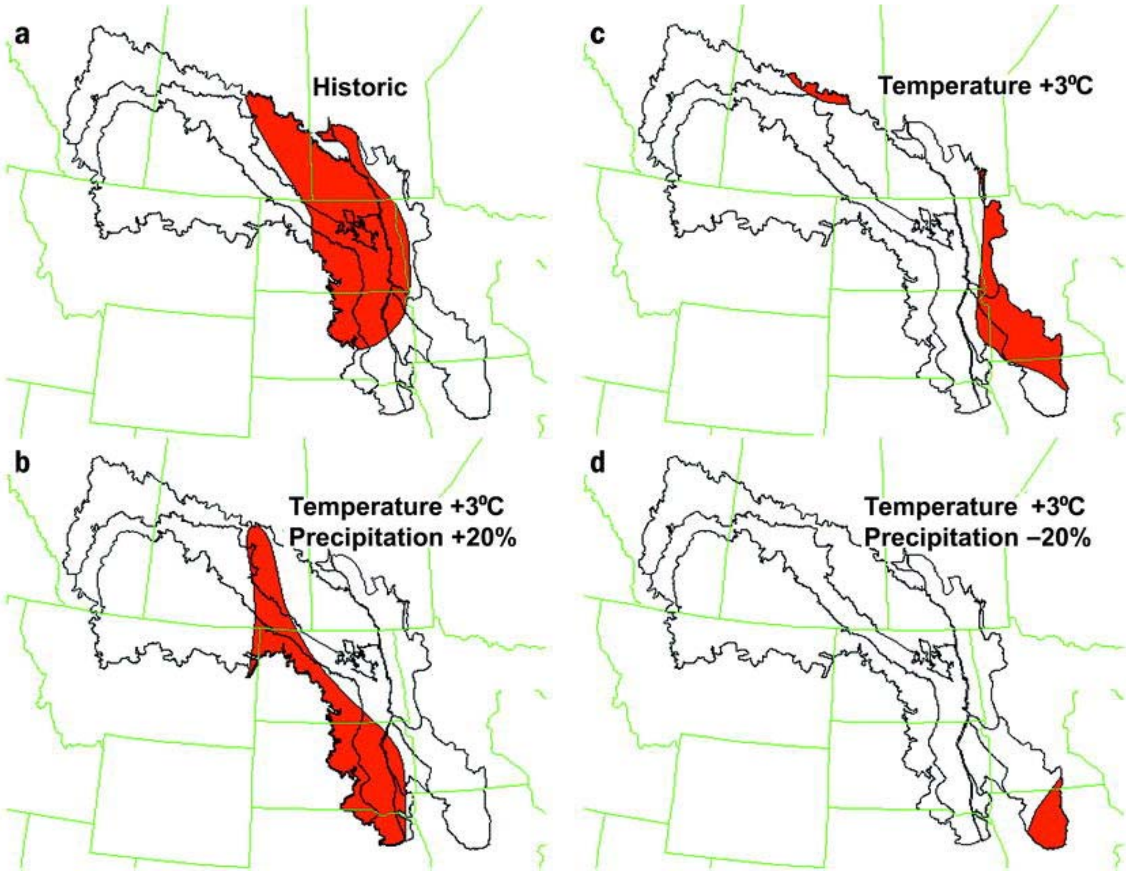
While climate change may have negative effects on water supplies, ranging from reduced streamflows, warmer water temperatures, lower reservoir levels, and shifting patterns of noncoastal wetlands, the demand for recreational boating, fishing, and swimming is expected to soar in a warmer climate. A longer summer season and higher temperatures during the season will increase demand for water-based outdoor activities. In addition, warmer temperatures affect the demand for other recreational activities such as hunting and wildlife viewing. We discuss this issue and the related calculations of recreational values in Section V below.

## III. Coastal Areas and Recreation

Sea level rise is one of the most serious outcomes expected from climate change. The IPCC estimates that for global temperature increases between 1.1°C and 6.4°C, which is the range predicted by climate models under various conditions, global average sea levels should rise between 0.18 and 0.59 meters over the next century. This forecast excludes any impact from disintegration of the Greenland and Antarctica ice sheets, which could exacerbate the problem.

In the United States, sea levels could rise anywhere between 0.13 and 0.95 meters, though 0.48 meters appears to be the best estimate for the average rise across all areas (USGCRP 2000). Impacts vary widely across the United States, however. Coastal areas with shallow slopes, high tidal ranges, and high wave height are more vulnerable to widespread inundation (U.S. Geological Survey 2002). In some regions—Louisiana, the Midatlantic, and the South Atlantic, for example—land subsidence contributes to the net rise; in these areas, fairly significant increases have already occurred. Current sea level rise in the midatlantic region is estimated to be 3mm to 4 mm per year, which is nearly two times the global average, and many scenarios see this rate as increasing (U.S. CCSP 2009). Figure 3 shows the estimated land area in different regions of the country that would be under water with a sea level rise of 20 inches (0.51 meters).

**Figure 2. Prairie Pothole Region and Coverage of Optimum Wetland Conditions under Alternative Climate Scenarios**

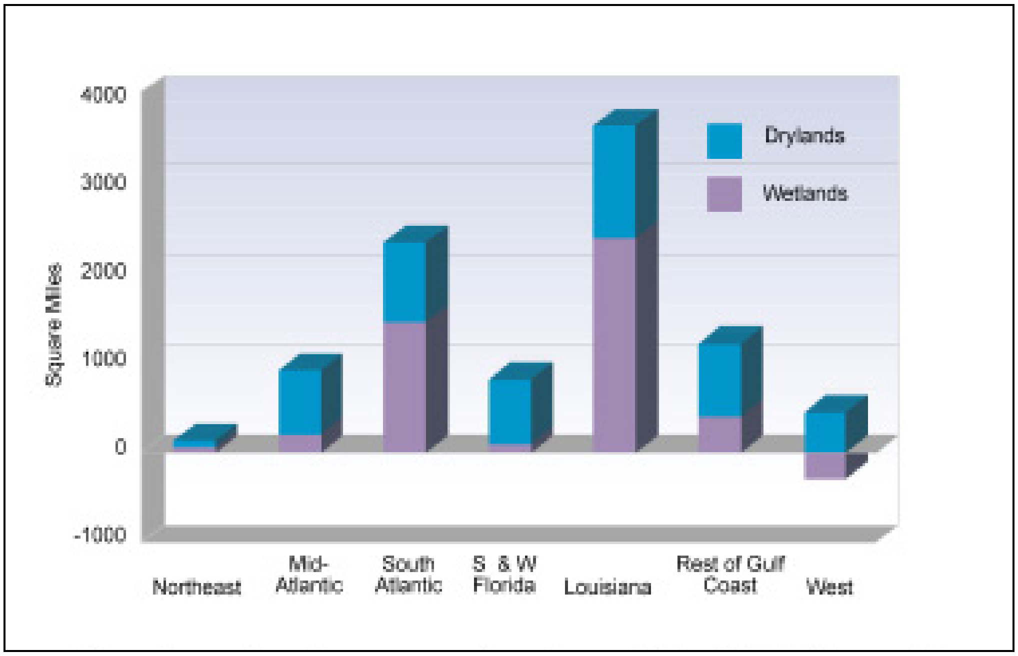



Source: Johnson et al. 2005.
Note: The figure shows historic conditions (a) and modeled future conditions (b, c, and d). The outlined area in each map is the Prairie Pothole Region; the red area is the area with optimum wetland conditions for waterfowl breeding.

Several concerns arise in the south and midatlantic regions because of sea level increases. Serious impacts on tidal wetlands, for example, are virtually certain. Moreover, many of these wetlands have nowhere to migrate or reform because of extensive land development and inadequate areas of dry land (U.S. CCSP 2009). Because much of the land is close to sea level, in some scenarios spring high tides are expected to lead to large areas of land under water. Most of the mid and south Atlantic states are bordered by barrier islands, which are expected to be seriously impacted from climate change. There is a great deal of uncertainty in the predictions, but in some scenarios, these islands are predicted to completely disappear. Studies of impacts along the Pacific coast also suggest some areas of serious concern. In the Puget Sound region of

Washington state, which includes the cities of Seattle and Tacoma, an area of about 56 square miles could be under water within 50 years as a result of a 2-inch sea level rise, which is the upper bound of projections (Bauman et al. 2006); this area would affect over 44,000 people.

**Figure 3. Coastal Lands of the United States at Risk from a 20-Inch Sea Level Rise**




Source: United States Global Change Research Program. 2000. Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change. Overview: Coastal Areas and Marine Resources.
Note: Graph shows square miles of both dry lands and wetlands expected to be under water in a 20-inch sea level–rise scenario.

It is well-established that coastal recreation and tourism are immensely valuable. Studies have shown that beaches are the leading tourist destination in the United States, followed by national parks and historic sites (Houston 1996). A full 85 percent of tourism-related revenues in the United States are generated by coastal states. And within those states, tourism and recreation contribute significantly to the economy. Dwight et al. (2007) estimate that tourism and recreation generate 59 percent of California's ocean-related economy, which is the largest in the nation. In addition, many of these states have coastal areas with unique ecological resources. There are ten national seashores: seven along the Atlantic coast, from Cape Cod National Seashore in Massachusetts south to Cape Canaveral in Florida; two in the Gulf of Mexico; and one in California. In 2008, these sites had nearly 16 million visitors, accounting for 6 percent of visitors to all National Park System sites while making up only 2 percent of the 391 units in the system

(National Park Service 2009; National Park Conservation Association 2009). Gulf Islands National Seashore in Mississippi and Florida has large areas of land that are extremely vulnerable to climate change because the park is almost entirely a low-lying barrier island (U.S. Geological Survey 2002).

In addition to the national seashores, there are several national wildlife refuges in coastal areas that have high recreational values. Chincoteague National Wildlife Refuge in Virginia is one of the most popular units with more than 1.5 million visitors per year. The refuge lies entirely on Assateague Island, a 37-mile barrier island that runs along the coasts of Maryland and Virginia. Scientists expect the island to migrate landward over time. Although many species of birds and other animals that live in the refuge may continue to have habitat, albeit in a new location, popular recreational sites such as the Wildlife Loop Road that circles Snow Goose Pond, a major feeding and nesting spot for snow geese, will likely disappear (U.S. EPA 2009). In a recreation demand model by Loomis and Crespi (1999) that we describe more fully in Section V below, the authors estimate a net welfare loss from more limited bird viewing and waterfowl hunting nationally as a result of a loss in coastal wetland acreage.

Given the popularity of coastal beaches, the importance of beach recreation and tourism to local economies, and the highly developed nature of many coastal communities, it is likely that inundation of some beaches will be replaced by comparable beaches in a slightly altered location. Many beaches will simply move inland (Yohe et al. 1999). Moreover, the coastline can be reinforced by beach nourishment, which consists of depositing sediment on beaches to replace what is naturally eroded. Beach nourishment can protect shores from erosion and inundation as well as maintain important recreation value (Hamilton 2007). This kind of adaptation activity is likely to occur in many locations. And even though nourishment cannot protect all beaches, people will not lose their desire to visit the coast. Loomis and Crespi (1999) found that, even with a 15 percent net loss of beaches, user days will increase by 29.71 million by 2060 with climate change, resulting in an additional $370 million in economic gains.

Unfortunately, although there are numerous studies of the impacts of sea level rise on coastal lands, there have been few systematic attempts such as the Loomis and Crespi (1999) study to link these changes to impacts on coastal recreation and recreational benefits. Wall (1998) suggested that sea level rise could become a major cause for marine wetland loss, especially if human structures like levees and seawalls impede the intrusion of sea water inland. Hunting and fishing activities rely on the diversity that thrives within marine wetlands, and those activities could be severely impacted if wetlands are converted into open water by rising seas. Migrating waterfowl that rely on coastal wetlands and the hunters who pursue them on both sides of the country will suffer as well. The rising Atlantic may destroy up to 45 percent of coastal wetland habitat for important game birds like canvasbacks, pintails, and redheads; the encroaching Pacific will swallow habitat for migrating ducks and geese along the length of the Pacific flyway that stretches from Alaska to California. Some estimates predict Louisiana's Chenier Plain marshes, which currently support over 1.3 million waterfowl, will be so inundated that they will eventually only support 1 percent of current populations (Yaich and Wentz 2007).

The loss of beaches in some locations can be serious. Whitehead et al. (2008) investigate the economic effects of sea level rise on recreational coastal fishing in North Carolina. Barrier islands lie along the entire North Carolina coast. These authors find that narrower beaches are less attractive to anglers because they are more difficult to access and make transporting equipment more difficult. The study combines projected beach widths resulting from anticipated erosion in 2030 and 2080 with revealed willingness-to-pay preferences based on spatial differences observed on popular angling beaches. The study projects substantial aggregate welfare losses from 2006 to 2080 due to reduced fishing access and quality, possibly as high as $1.29 billion in net present value terms. In a related study, Bin et al. (2007) estimate that 34 percent of the recreational value of trips to North Carolina beaches will be lost by 2080 as a result of reduced beach width and complete loss of some beaches. Moreover, the authors emphasize that this is likely to be an underestimate because it fails to account for increased congestion on remaining beach acreage.

## IV. Public Lands

### *Impacts on National Forests*

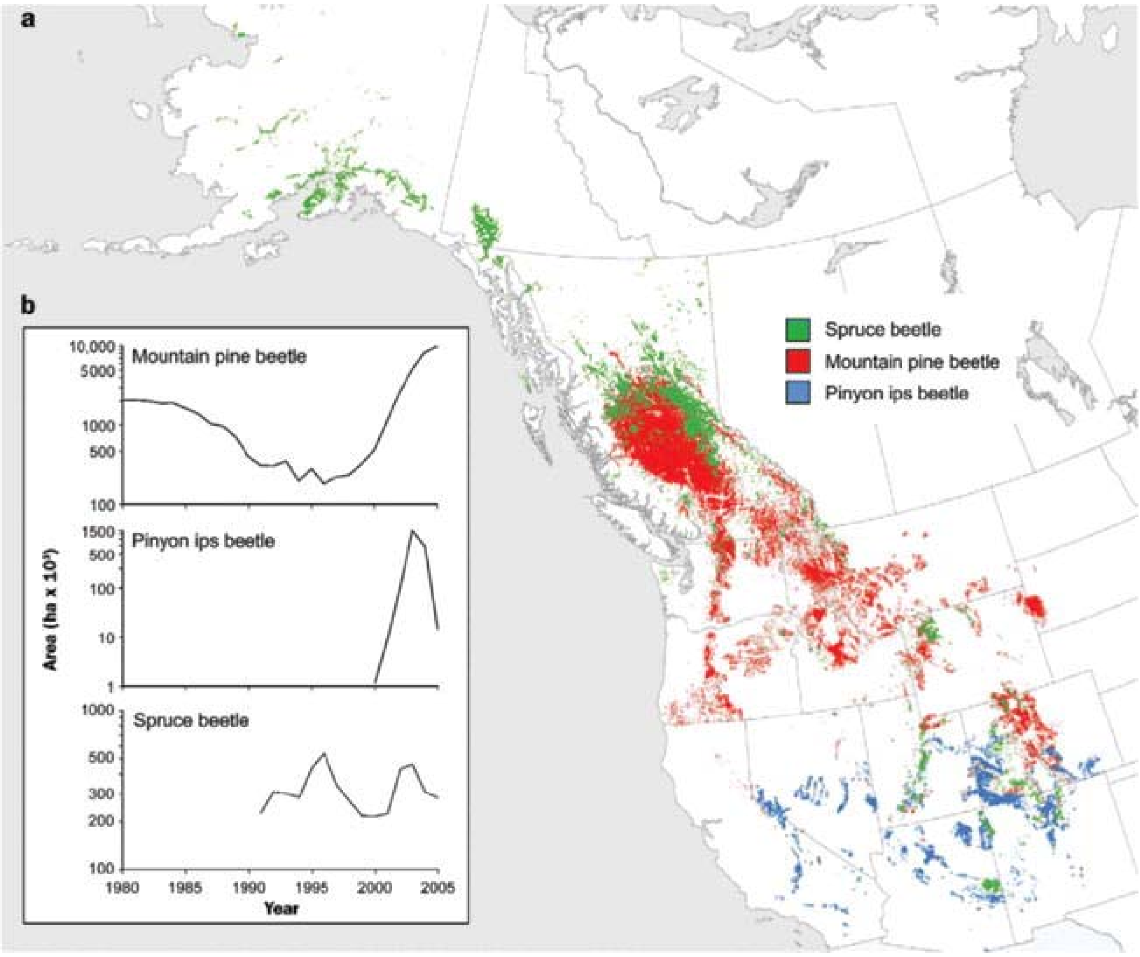
The national forests cover 188 million acres of land in the United States and provide the settings for much of the nature-based recreation that takes place in the country. Several types of damage are expected to be inflicted on forests as a result of climate change and in some cases, some of that damage may already be manifesting. These damages are not the result of new disturbance regimes in forest ecosystems but rather an exacerbation of current disturbances (Dale et al. 2001). Drought, wildfire, insect infestation, and extreme weather are all significant impacts that will grow more intense in a changing climate.

Drought is not as visually obvious as other disturbances, but it is perhaps the most devastating because it can significantly weaken a forest's defenses against fire and insect invasion. Almost all forest ecosystems evolved with drought as a regular stressor; forests throughout the intermountain West and Southwest experience seasonal summer droughts along with droughts that can sometimes last for years, while more humid forests in the northwestern and eastern United States experience infrequent droughts (Dale et al. 2001). Climate models suggest that the combination of higher overall temperatures and less frequent, more intense rainstorms over long time periods will not only aggravate droughts in the forests of the interior West, but is also likely to generate more frequent droughts in the forests of the Northwest and East. Warmer summers will reduce both the amount of water available in soil and aquifers and affect overall net primary productivity. Additionally, intensifying rainstorms that occur more often in winter may impede ecosystems from storing water reserves that are critical to get through hot summers. This will lead to higher mortality rates in young trees, which in turn leads to more fuel generation for wildfires. In addition, all trees are likely to be weakened against insect invasion and disease infection.

Similar to drought, insects are a natural and integral part of forest ecosystems. Bark beetles are one of the most important mortality agents in western and southern forests (Dale et al. 2001; Fettig et al. 2007). The populations of the beetles, which are no bigger than a grain of rice, are heavily affected by seasonal temperatures. Cold, harsh winters can knock back beetle populations considerably, whereas warmer winter temperatures ensure that more beetle larvae survive to become full-grown. Winter temperatures tempered by climate change can potentially enhance bark beetle larvae's chances of surviving and generate huge populations that can overwhelm a forest. Concurrently, climate change–induced drought can deprive individual trees of the ability to effectively defend themselves against the beetles, possibly leading to massive infestation and tree mortality.

Some of these problems are already manifesting throughout the country, as states all over the West, South, and as far north as Alaska have seen unprecedented levels of tree mortality (Fettig et al. 2007). The telltale sign of infestation, forests smeared with wide strokes of red-needled evergreens, can be seen throughout the country. Beetles killed 2.5 million acres of trees in Colorado and Wyoming in 2006 and 2007, and they were expected to finish off another 2 million acres by the end of 2008 (Robbins 2008). Figure 4a shows a map of the extent of infestations by three beetle species across western North America. Figure 4b shows the change in the size of the area affected between 1980 and 2005.

**Figure 4. Area of Forests Damaged by Bark Beetle Infestations**




Source: Raffa et al. 2008. Data are from the Canadian Forest Service, the British Columbia Ministry of Forests and Range, and the U.S. Forest Service.

Deceased trees can pose a serious threat to the safety of recreationists. As a result of massive tree dieoffs, officials in Colorado and Wyoming closed 38 campgrounds in the summer of 2008 (Robbins 2008). The threat of falling trees is not limited to campgrounds; roads, trails, picnic and other areas are all locations where forest users are vulnerable to deadfall. Most dead trees will not injure people directly, but both standing and fallen trees present a different threat because they are large fuel stocks for forest fires.

As drought and bark beetles work in concert to weaken forests and kill trees, they set the stage for wildfire to scour the landscape. Although fire is an integral part of many forest ecosystems, especially in the western United States, where it is too dry to encourage decomposition of deadfall, government policies during the twentieth century to suppress all fires have led to a dangerous overload of fuel. Combined with dry conditions brought on by climate change, this creates a volatile situation that has major implications for forest recreation. In 2007, 9.9 million acres of forest burned across the country, and the federal government is anticipating having to deal with similarly destructive fire seasons over the next five years. Recognizing this threat, the Obama Administration allotted $1.1 billion to the U.S. Forest Service to combat fires in 2010, with an additional $282 million available in safety valve funds (Leber 2009).

Recreation is vulnerable to disruption from wildfire because people often recreate in environments and seasons with high fire risks, although there is no clear link between recreational user mortality and wildfire (Morehouse 2001). The effects of fires on recreation can vary; prescribed fires that are closely monitored may not impede recreation activities, whereas catastrophic stand-altering fires can close off popular areas for months or even years. Additionally, even if burned areas are not closed to recreation, fire can degrade them to a point where they are less attractive for users. A survey of outdoor recreationists found that 75 percent said scenery quality was very or extremely important and between 73 and 85 percent of users value safety while recreating (Morehouse 2001). The combination of inaccessibility due to forest closures and the degradation of viewsheds and resources may drive visitors away. Fewer visitors can, in turn, have a negative impact on local economies for which recreation is a valuable input. Starbuck et al. (2006) use a combined travel cost/contingent valuation model to estimate the consequences of catastrophic fires on recreation days and the concomitant economic effects. Extrapolating from data gathered by mail surveys and on-site surveys in five national forests throughout New Mexico, the model suggests a massive destructive fire would reduce forest visits the following year in New Mexico by 7 percent, resulting in an $81 million loss in economic output and more than 1,900 lost jobs. Along with these easily identifiable disturbances, climate change may manifest in more subtle and significant ways. A recent study by Van Mantgem et al. (2009) finds that background (i.e., not attributable to a distinct disturbance) tree mortality rates in old-growth forests across the western United States have doubled over the past few decades, and recruitment of new saplings is not correspondingly increasing. After eliminating factors such as insect invasion, diseases, and endogenous changes in forest structure as reasons for mortality increase, the study suggests that regional warming is the culprit, as it is occurring consistently through different forest types from Washington to Colorado to Arizona. While these mortality rate increases will not directly result in large swaths of dead trees, the study points out that increasing mortality rates may be indicative of vulnerability to significant dieback events and can presage major alterations in forest function, structure, and composition. These systematic stresses may eventually collude with some of the large disturbances we described above to push forest ecosystems past their tipping point, creating a scenario from which they cannot recover.

As these multiple disturbances manifest throughout public lands over time, animal species that depend on the ecosystems found on those lands, especially big game animals like deer, elk, and moose, will have to adjust to or migrate away from harsher conditions. Otherwise, their populations will suffer significantly. Drought and wildfires represent obvious threats to big game species' habitats, and extreme events will force populations to migrate to more suitable areas. More subtle effects of climate change will contribute to the movement of large animals as well. For instance, milder winter temperatures may reduce moose populations, which are keenly adapted to harsh, cold conditions, but could boost populations of animals that struggle in such conditions, such as white-tailed deer and elk. Moose may be so stressed by milder winters that they disappear completely from the upper Midwest (Wildlife Management Institute 2008). Similarly, as alpine ecosystems retreat further up mountainsides in reaction to warmer temperatures, they will continue to isolate populations of bighorn sheep and mountain goats. In contrast, as increasing temperatures increase the survival odds of deer and elk, they will also likely assist the survival of parasites and pests, which in turn may negatively affect herd populations. As populations begin to expand, they will need more food sources, yet climate change will present them with another challenge. Plants will absorb increasing amounts of $CO_2$, which will decrease the nutritional value of the leaves mule deer are particularly dependent on, possibly leading to malnutrition. Elk are better evolved to survive on marginally nutritious plants (Wildlife Management Institute 2008). Overall, hunters and wildlife watchers could have a more difficult time finding healthy big game animals, especially in areas with marginal habitat conditions. In a climate-altered world, areas with more robust ecosystems, such as those protected by national parks, will become critical support areas for charismatic megafauna.

### *Impacts on National Parks*

Some of the forest problems that we describe may occur in national parks, which could have a serious impact on recreation given the high recreational value of these distinctive areas. In addition, other problems have been identified that are unique to some individual parks. To illustrate these impacts, it is useful to look at two very different parks: Glacier National Park, situated next to the Canadian border in the Rocky Mountains of Montana, and Joshua Tree National Park in the rugged Mojave Desert of southeastern California. These two parks could not have more different climates or ecosystems, but both may see their namesake resources disappear from within their borders by the end of the century.

In a study now over 25 years old, Carrara and McGimsey (1981) found that more than two-thirds of the 150 glaciers that had existed in the Glacier National Park area in 1857 had already disappeared completely by 1980, and the remaining glaciers had shrunk in size. Hall and Fagre (2003) estimate that under likely future climate scenarios, the glaciers remaining in the park will all vanish by 2030. Such a dramatic change has many repercussions for the park's ecosystems. As the glaciers melt, streams will initially have greater summer flows but are likely to transport more sediment, which has implications for aquatic life; eventually, as the glaciers disappear, stream flow will decline. The distribution of plants and trees will change, as some species will grow on land formerly covered by ice. From a recreation perspective, the glaciers are, not surprisingly, a strong draw for visitation to the park—the park drew over 2 million visitors in 2007. How that will change as the glaciers disappear is unclear.

Like Glacier, Joshua Tree National Park also faces threats from increasing temperatures. The trees that are the park's namesake covered a wide range of land during the last Ice Age, when seeds were transported long distances by a now extinct animal, the Shasta ground sloth. The extent of land covered by the tree is now much more limited, and without the sloth to carry its seeds, the tree is expected to be unable to migrate in response to rising temperatures. Studies have posited that the southern half of the tree's range, which includes the national park, will grow too warm to sustain them and that Joshua trees will vanish from Joshua Tree National Park within the next 100 years (Shogren 2008). The tree, which has been described as the "canteen of the desert" provides sustenance to many animal species, including the antelope ground squirrel and the blacktail jack rabbit. It is unclear whether these species can migrate and survive without the trees. How recreational values will be affected by loss of the trees is unclear, but is likely to be negative. With warmer temperatures in a desert environment and with loss of the unique asset of the park, some park rangers have speculated that there will be nothing there to attract visitors (Shogren 2008).[2]

### *Impacts on National Wildlife Refuges*

There are 550 refuges in the National Wildlife Refuge System covering 97 million acres of land. Scott et al. (2008) cite research findings in a recent doctoral dissertation showing 309 of

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[2] The ranger's comment may be overly pessimistic. The park attracts visitors for horseback riding, mountain biking, off-road vehicles, and viewing other natural attractions besides the trees. Moreover, it is one of the most popular rock climbing areas in the United States.

these refuges will lose waterfowl species as a result of range contraction due to climate change. Concerns over an inadequate land base and worries about development and other activities on contiguous properties have always been a concern of the National Wildlife Refuge System. With climate change altering the land in many refuges or leading to the disappearance of land in others, there is added concern about these issues. Scott et al. (2008) conclude that the most vulnerable refuges are the 162 coastal refuges, along with those refuges in Alaska. We discussed some of the impacts on key coastal areas above—Chincoteague National Wildlife Refuge, for example, is expected to shift and move westward over time. Blackwater National Wildlife Refuge, on the Chesapeake Bay in Maryland, is expected to be one of the most severely affected refuges. The wetlands there, which are home to the largest concentration of nesting bald eagles on the east coast north of Florida, are expected to completely disappear within 30 years (U.S. EPA 2009). The J.N. Ding Darling National Wildlife Refuge on Sanibel Island near Ft. Myers, Florida, is also expected to face serious impacts, losing 67 percent of its dry land, 99 percent of its tidal flats, and 58 percent of its hardwood swamp (U.S. CCSP 2008). The refuge is a highly popular tourist and recreation destination, with over 850,000 visitors per year (Wyman and Stein 2007).

Although the primary mission of the National Wildlife Refuge System is protection and management of native fish and wildlife and their habitats, many of the refuges, such as the Ding Darling Refuge in Florida, are highly desirable recreation destinations. In 2006, 35 million people visited the refuges, generating an estimated $1.7 billion in total economic activity (Carver and Caudill 2007). Fully 82 percent of expenditures related to these visits were for “nonconsumptive” uses, such as hiking, biking, and mostly, wildlife viewing; fishing accounted for 12 percent and hunting, 8 percent. Wildlife viewing is one of the key recreational activities that takes place on national wildlife refuge lands, and this activity has grown in popularity in recent years (Cordell et al. 2008). How these values would be affected by climate change is uncertain. Much is likely to depend on the adaptation measures taken by refuge managers and policymakers.

## V. Estimates of Recreational Benefits and Costs from Climate Change

The studies we cite above present a sampling of the many research efforts that are underway to model and predict the impact that climate change will have on natural resources and ecosystems across the United States. We have tried to draw out the particular influence these changes are likely to have on recreational resources. In this section, we discuss some of the economics studies that take the next step and estimate the full social benefits and costs from changing recreation as a result of climate change. We discussed a few of these studies above—Pendleton and Mendelsohn (1998), Whitehead et al. (2008), Bin et al. (2007), and Loomis and Crespi (1999)—which we describe more fully below.

Using statewide aggregate demand models, Mendelsohn and Markowski (1999) extend previous studies (Cline 1992) that focused solely on skiing to predict climate effects on economic benefits from seven recreation activities: boating, camping, fishing, golfing, hunting, skiing, and wildlife viewing. They use cross-sectional data for the lower 48 states (from 1991) and estimate the aggregate number of days spent in these various activities as a function of population, income, prices, and various temperature and precipitation variables. The authors use their results to calculate welfare effects in 2060 from changes in temperature ranging from 1.5°C to 5°C and increases in precipitation of 7 and 15 percent; they also look at welfare effects by using region-specific changes in temperature and precipitation. They look only at the direct effects on demand and do not incorporate any indirect effects due to changes in resource availability or site characteristics.

The authors find that these climate change scenarios will result in major losses for snow skiing, camping, and wildlife viewing, but that those losses will be swamped by substantial gains for fishing and boating. Overall, there are welfare gains in the recreation sector from climate change; for the central case of a 2.5°C temperature rise and 7 percent increase in precipitation, the benefit ranges from $2.8 to $4 billion (in 2060) depending on the model used.

Loomis and Crespi (1999) use a similar approach. They estimate recreation demand models by using aggregate visitation and other data, but they also, for some categories of activities, use demand elasticities estimated from other studies. They include a wider set of activities, 17 in all, and unlike Mendelsohn and Markowski (1999), Loomis and Crespi do incorporate some changes in site characteristics due to climate change when predicting changes in recreation in the future. For example, in their model of reservoir recreation, they include both the direct positive effect of higher temperatures on the number of recreation visits and the indirect negative effect on surface area of the reservoir (as higher temperatures reduce water levels). They incorporate similar effects in their snow skiing model, including the reduced length of the ski season as a result of climate change, and in their model of waterfowl hunting, with reduced wetlands acreage. Even with these differences from the Mendelsohn and Markowski approach, Loomis and Crespi find positive net recreational benefits overall from climate change, and they are on the same order of magnitude as the Mendelsohn and Markowski results.

Richardson and Loomis (2004) conduct a contingent valuation survey to estimate how changes in climate factors will affect visitation in Rocky Mountain National Park in Colorado. Using models to construct different scenarios of climate change effects on the park, the study surveyed park visitors to gauge how they think changes in the park would affect their recreational behavior. The results of the surveys indicate that climate change could positively affect visitation rates and that temperature is a significant factor in determining visitation behavior, implying that warmer temperatures could encourage more people to visit Rocky Mountain National Park. The authors of the study suggest these findings may be applicable to other high-altitude alpine parks. These results, though based on a different methodology, support the findings in Loomis and Crespi (1999) and Mendelsohn and Markowski (1999).

All three of these studies highlight the importance of weather and climate in determining the demand for outdoor recreation, and all forecast that demand will increase in a world with climate change. Although the incorporation of changes in resource supply and recreation site characteristics is rudimentary in the Loomis and Crespi (1999) study and nonexistent in the Mendelsohn and Markowski (1999) and Richardson and Loomis (2004) studies, these findings about the effect that a warmer climate might have on recreation demand are instructive. Warmer temperatures, earlier springs, and longer-lasting summers are expected to increase the demand for many kinds of outdoor recreation activities, making it all the more important for policymakers to develop adequate adaptation policies directed at recreational resources.

In addition to these studies that predict overall increases in demand, other studies have emphasized the effect on recreation in colder areas. Assuming recreation will increase with economic growth, simulation models of international tourism demand show that climate change is likely to shift tourism patterns toward higher latitudes and altitudes (Hamilton et al. 2005). Domestic tourism will also move toward cold regions, resulting in a doubling of tourism for colder countries and a 20 percent reduction of tourism in warmer countries (Bigano et al. 2005). As tourism and recreation are closely related, these findings are presumably representative of recreation patterns, meaning that more recreation is likely to shift to higher latitudes and altitudes.

## VI. Conclusion

Over the next century, climate change will be one of the most important and pervasive influences on natural systems. Even if all emissions of $CO_2$ ended today, the atmosphere is still guaranteed another 30 to 40 years of warming. Recent studies have also found global warming is essentially irreversible over 1,000 years even after a complete halt to emissions (Solomon et al.

2009). Regardless of mitigation efforts, the planet's environment and inhabitants will have to adapt to a new climate reality. Some plants and animals will naturally adjust to warmer temperatures or less water availability, through processes known as autonomous or reactive adaptation, but their natural adaptability will only go so far. In the best cases, plants and animals will continue to survive under more adverse conditions. Many species will struggle more than others and may have to migrate (or be transported) to new habitats as ecosystems shift and natural cycles adjust to new climate realities. In the worst cases, some species will go extinct and some of the country's most treasured places will be altered for generations.

Anticipatory or planned adaptation, unlike autonomous adaptation, does not wait for conditions to shift. Instead, natural resource managers can look ahead, anticipate some of the negative consequences of climate change, and adjust management schemes in a way that gives resources a better opportunity to weather those consequences. In one sense, climate change does not present many new problems, just stronger versions of familiar problems. People and ecosystems have always had to deal with droughts, wildfires, floods, and insect invasions. Unfortunately, however, that does not mean people know how to deal well with those problems. Fire suppression policies over the past 100 years led to the accumulation of huge fuel stockpiles that have increased the ferocity of wildfires throughout the nation's forests. Water policies, especially in the western United States, have reduced once-mighty rivers to trickles and driven a number of species to the brink of extinction. Levees that snake along the banks of powerful rivers to protect against seasonal floods may not be able to withstand the onslaught of increasingly stronger spring floods. If climate change is the ultimate challenge of the twenty-first century, adapting to it will require serious overhauls of twentieth century policy.

Congress has not entirely ignored the issue of adaptation. In the 110th Congress, there were 75 different bills that tried to address climate change adaption in some way. The Lieberman–Warner Climate Security Act of 2008 (S. 3036) required the government to develop a national adaptation strategy and contained a provision that could have funneled up to $5 billion a year in the next decade toward adaptation projects. Similarly, the Climate Change Adaptation Act (S. 2355), sponsored by Senator Maria Cantwell, would require the government to develop a five-year strategic adaptation plan that would be updated continuously every five years. While these bills show that there is some recognition by policymakers that adaptation must be addressed, the nation is still far away from a comprehensive and effective policy to adapting to climate change.

A national adaptation policy is only a part of the adaptation puzzle. The federal government must supply needed resources to maintain adaptation programs, whether that be more money to fight wildfires or to build and maintain sea walls, but it alone cannot sculpt a policy that is both comprehensive and flexible enough to address the myriad effects of climate change. As we have highlighted, climate change impacts are heterogeneous across geography and resource area. States and municipalities may require more autonomy to effectively and responsibly adapt to different problems, and they will have to develop their own specific adaptation plans. Adaptation policy that reforms existing institutions while allowing them to prepare to manage extremes will be our best chance to properly adjust to the changing climate.

Climate impacts on natural resources are pervasive. In this Backgrounder, we have highlighted the particular impacts on recreation resources. We have also shown that some economics literature indicates that the value of these resources for recreation purposes may be higher than ever. Recreation demand is highly dependent on climate, and several studies show that longer and warmer summers are expected to increase the demand for outdoor recreation, from hiking, fishing, and camping to simple beach visits. This makes it all the more important that government policy at all levels—federal, state, and local—develop climate adaptation programs and funding.

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