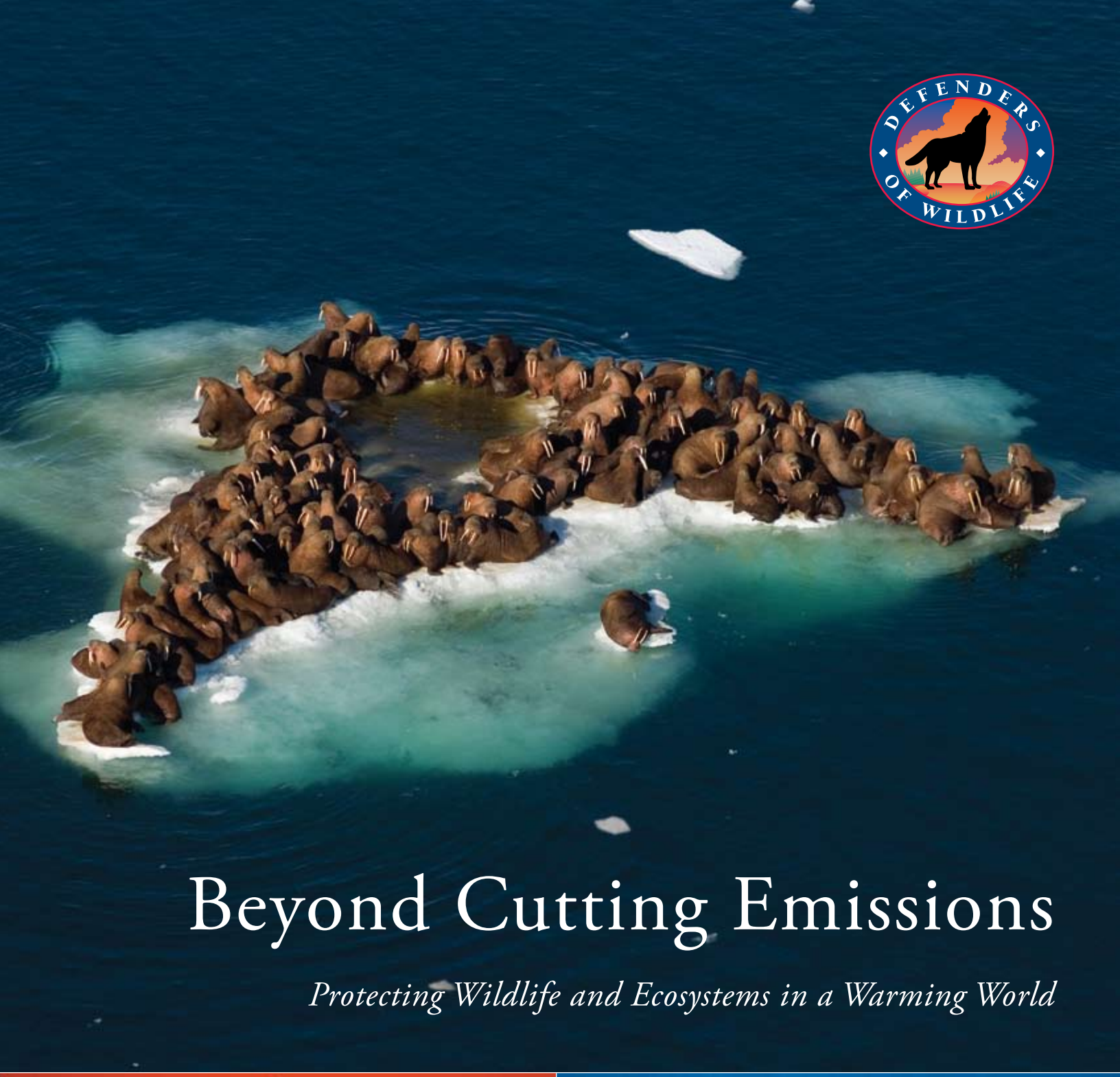

Beyond Cutting Emissions

Protecting Wildlife and Ecosystems in a Warming World

DEFENDERS OF WILDLIFE

Defenders of Wildlife is a national, nonprofit membership organization dedicated to the protection of all native wild animals and plants in their natural communities.

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Beyond Cutting Emissions

Protecting Wildlife and Ecosystems in a Warming World

Executive Summary

GLOBAL WARMING IS UPON US, and it is already having significant impacts on wildlife and the natural ecosystems that sustain civilization. Earlier snowmelt and longer summer drought have increased the number and size of forest fires. Rising sea level and stronger storm surges are eroding coastal marshes that protect coastal communities, support billion-dollar fisheries and provide vital habitat to a host of species. Insect pests are pushing into areas that once were too cold, destroying millions of acres of forests from Colorado to Alaska. Drought threatens to dry up the prairie potholes, birthplaces of most U.S. waterfowl, which could shrink duck populations in that region by up to 70 percent. Ocean acidification caused by excess carbon dioxide in the atmosphere is bleaching and killing corals worldwide.

Unless we act now to cut the emissions of heat-trapping greenhouse gases—the primary cause of global warming—the consequences will be enormous. Scientists warn that up to 37 percent of the Earth's plants and animals could go extinct by 2050. Human communities and industries will lose the healthy ecosystems that enhance our quality of life, produce valuable natural resources, help purify our air and water, and perform other life-sustaining services. But cutting greenhouse gas emissions alone is not enough. The delayed impact of the gases already in the atmosphere guarantees warming and its consequences for decades to come. The United States must act swiftly to reduce the impacts of the global warming already set in motion, and make addressing these impacts on ecosystems and wildlife a top national priority.

Unfortunately, most federal, state and tribal resource-management agencies have not yet made addressing global warming a central part of their missions. Efforts that do exist are not well-coordinated, and resource managers lack the scientific information and predictive models they need to determine the best way to help species and ecosystems adapt. To complicate matters, the past eight years of inadequate budgets and destructive policies have left our federal resource-management agencies unable to meet current demands, let alone the additional challenges posed by global warming.

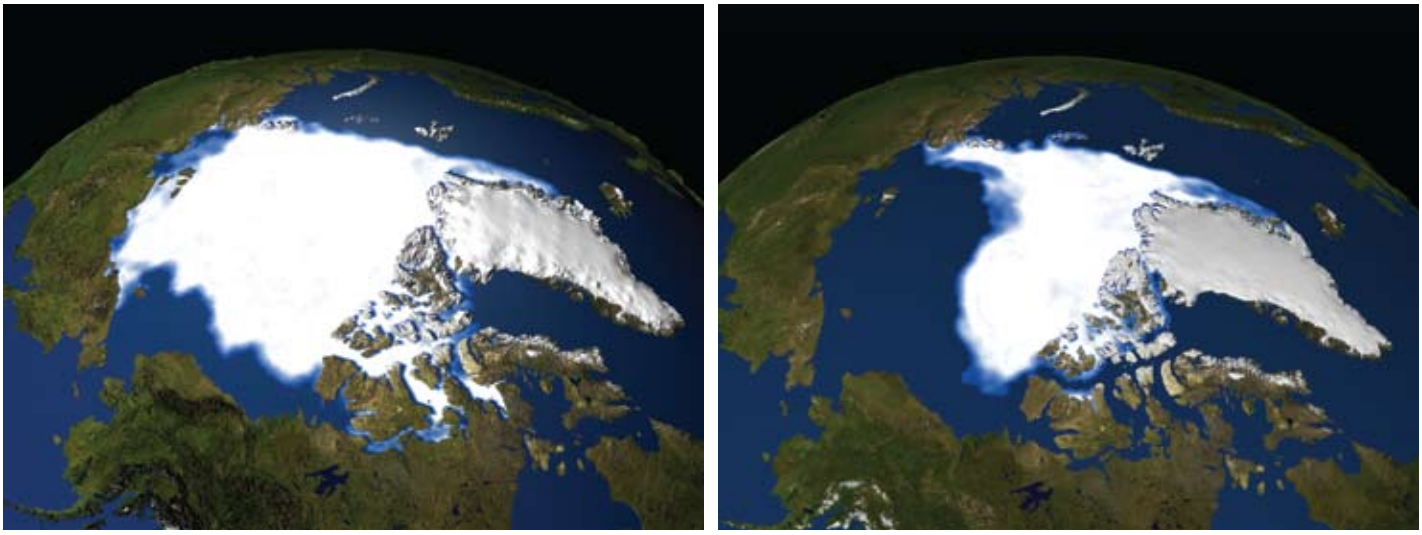
Meanwhile, global warming is shuffling plants and animals in new and unpredictable ways, and resource managers can no longer rely on conservation techniques designed to recreate past conditions. Our warming world requires a new conservation paradigm, a science-based approach based on anticipating changing conditions and managing for ecosystem resilience—the capacity to cope with disturbances.

To adopt this new approach, we need much more information about how wild plants and animals will respond to climate change and new climate models capable of predicting temperature or rainfall down to the local level—the scale managers need to make sound, science-based decisions. We also need vastly improved coordination and collaboration among scientific disciplines, government agencies and private landowners to ensure the habitat connectivity that allows species to move to suitable habitat as conditions change.

Fortunately, Congress, the states and the federal scientific agencies are beginning to recognize the importance of helping wildlife and ecosystems adapt to and survive global warming's unavoidable impacts. Over the past year, they have held hearings, advanced legislation, issued reports and established the National Global Warming and Wildlife Science Center under the U.S. Geological Survey. But much more action is needed. The magnitude and complexity of the threat demands a coordinated, national response that offers clear federal policy direction, creates an organizational framework for cooperation, details steps that each participating agency must take and sets an implementation timeline.

Federal, state and tribal agencies will require a high and sustained level of funding to effectively address global warming's unavoidable impacts. Addressing global warming pollution through a proposed cap-and-trade system provides an historic opportunity and an appropriate avenue to meet this funding imperative. Dedicating a portion of the revenues from the auction of pollution permits under this system would provide a significant and certain funding stream to ensure that agencies have the resources necessary to meet the challenge posed by global warming—the greatest conservation challenge of our time.

NASA



Images created from satellite data collected in 1979 (left) and 2007 (right) offer graphic evidence of shrinking Arctic sea ice.

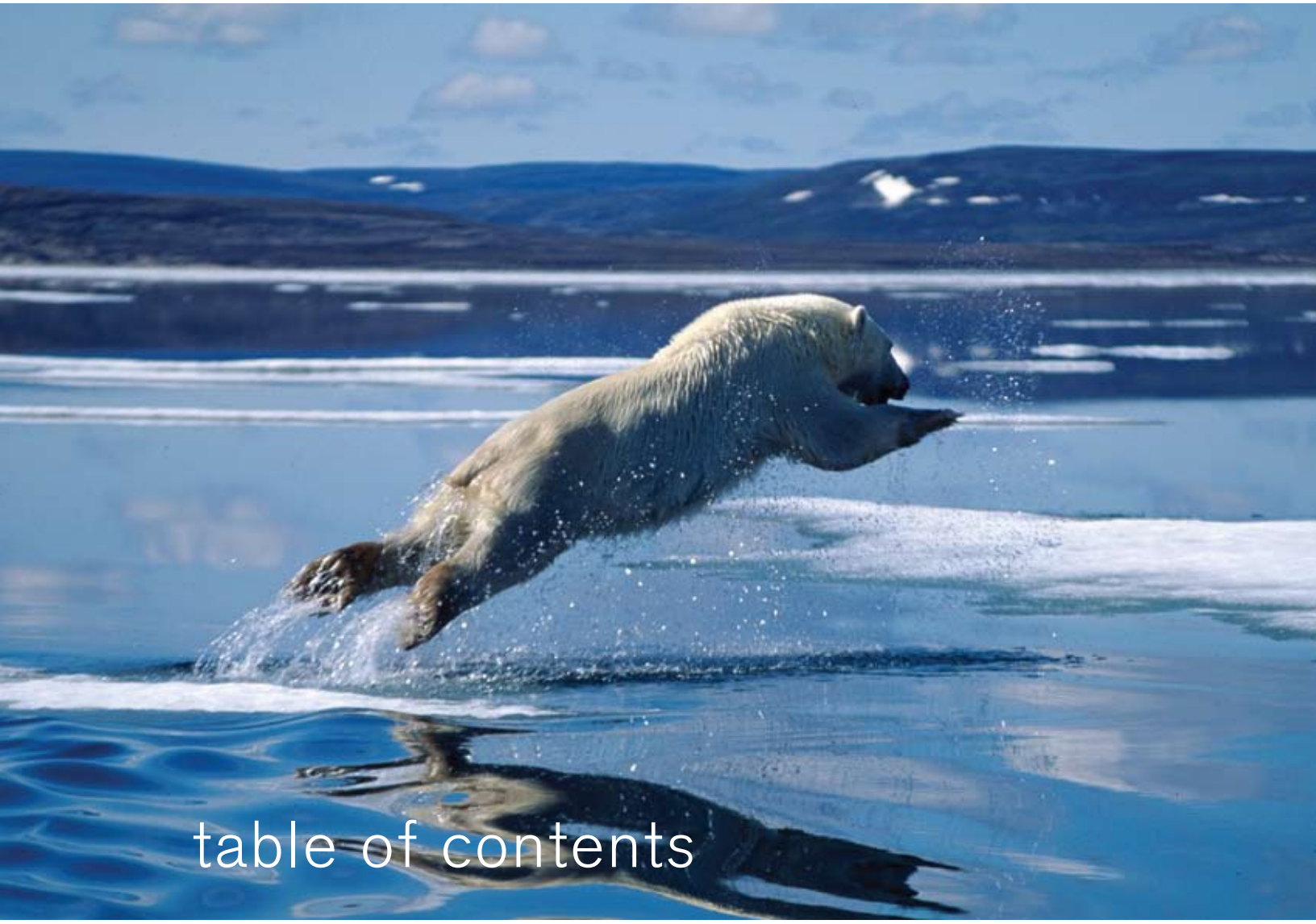


table of contents

POLAR BEAR NEAR CHURCHILL, MANITOBA © THOMAS D. MANGELSEN

Foreword

GLOBAL WARMING CONFRONTS policymakers with two significant and serious challenges to wildlife and ecosystem conservation and the web of life on which we all depend. The first, reducing levels of heat-trapping greenhouse gas emissions, has at last begun to receive significant and much-needed attention from the public and in the halls of Congress. The important work of former Vice President Al Gore and the release of major scientific studies, particularly the landmark 2007 Intergovernmental Panel on Climate Change reports, have contributed greatly to this visibility. The second, helping species and ecosystems survive and adapt to a warming world, has received far less attention. The plain truth is that, regardless of how quickly and significantly we reduce greenhouse gas emissions levels, global warming will have major and unavoidable impacts on wildlife and the ecosystems that sustain us.

Beyond Cutting Emissions focuses on the second of these two challenges. It details the enormous magnitude of anticipated impacts and the extent to which they will affect the natural ecosystems that provide essential life-support services, drive local economies, yield discoveries that lead to medical innovations, and enhance our quality of life. It highlights how, with clear policy direction and adequate, new dedicated federal funding, we can successfully address the threat that unavoidable warming poses to the basic fabric of life.

The challenge is immense, but time and again our nation has met other seemingly insurmountable challenges. Indeed, the history of American conservation is replete with major accomplishments achieved in the face of crisis. In the 1930s, we responded to the threat of the Dust Bowl head-on by creating effective new agricultural conservation programs. And through the years we have protected countless species by preserving millions of acres of land as national wildlife refuges, national parks and preserves.

This report explains how addressing the threat global warming poses to wildlife and ecosystem health requires an unprecedented "all hands on deck" response by the federal government and state and tribal conservation agencies. It emphasizes the need for governments to tackle this challenge with a clear focus, solid coordination, expanded scientific capability and, very importantly, an unprecedented commitment of assured federal funding. Despite the huge scale of the challenge and the inadequate action taken to date, these agencies are well-suited to the task. Relying on the depth of their organizational expertise, they can implement the necessary research, planning and on-the-ground management responses.

Conservation agencies cannot do it alone, however. They will need direction and support from policymakers, many of whom recognize the urgency and are willing to respond, but have yet to take final action to implement the new approaches and large-scale financial commitment that will be necessary. *Beyond Cutting Emissions* makes a compelling case for taking immediate action and describes what it should entail. Since our planet faces no greater conservation imperatives than to rapidly reduce carbon emissions and successfully transition our life-support systems to a warmer climate, we all must demand that our policymakers act as soon as possible. We simply cannot afford to wait.

Rodger Schlickeisen
President, Defenders of Wildlife

Introduction

Global warming, once the province of computer modelers and futurists, is upon us. Each year since 1993 has been among the top 20 warmest years on record, with 1998 and 2006 the hottest years ever for the United States.[1] A recent report by the Department of Agriculture concluded that global warming is already here and will continue to affect U.S. water resources, agriculture, land resources and biodiversity.[2] The Intergovernmental Panel on Climate Change (IPCC)—an organization that represents the international scientific consensus on climate change—predicts that by the end of the 21st century there will be global warming between 3 and 10 degrees Fahrenheit (F), possibly warmer than anytime in the past 450,000 years.[3]

Scientists warn that mid-range climate warming could cause 15 percent to 37 percent of the Earth's plants and animals to go extinct between now and 2050.[4] The composition and functioning of our natural ecosystems—and the vital life-supporting services they provide to people and wildlife alike—are changing and deteriorating with increasing speed.

If we do not take action now to address both the causes and effects of global warming from a social, ecological and economic point of view, the consequences will be enormous. Human communities and industries will lose the healthy ecosystems and the plants and animals that enhance our quality of life, produce valuable natural resources, help purify our air and water and perform other life-sustaining services.

Reducing emissions of the heat-trapping greenhouse gases—the primary cause of global warming—is not enough to protect our vulnerable natural systems. Because of the delayed climatic impact of greenhouse gas emissions, gases already in the atmosphere guarantee warming for many decades to come.[5] The United States also must act rapidly to lessen the impact of the global warming we have already set underway and make addressing the effects of global warming on ecosystems and wildlife a top national priority.

This report underscores the urgency of the situation by identifying specific threats global warming poses to our wildlife and ecosytems and the failures and weaknesses in the response of our government agencies so far. It also lays out a specific course of action that calls for a new conservation paradigm to guide resource managers in our warming world and a well-funded, coordinated, national response involving state, tribal and federal agencies.

A forest fire rages north of Fairbanks, Alaska. Warmer temperatures linked to global warming mean longer, drier fire seasons and ideal conditions for big blazes.

Understanding the Threats to Wildlife and Ecosystems

ANALYSES OF HUNDREDS OF STUDIES REVEAL a disturbing truth: Global warming is already affecting a majority of U.S. species. One review found that more than 80 percent of plants and animals studied are shifting their ranges because of warming.[6] These species are responding to a global temperature rise of less than 1 degree F over the past 100 years and are likely to be put at risk by at least another 3 to 10 degrees of warming by 2100, if we do not take immediate and decisive action to reduce greenhouse gas emissions.[7]

Our clearest warning of the future lies in the Arctic, where warming has been more rapid than in the rest of the United States. Many areas of Alaska have already experienced rises of more than 5 degrees F and melting permafrost. Spruce and other trees are dying over many millions of acres, killed by spruce budworm and other pests previously controlled by colder temperatures. Even tundra is warming and drying to the point of burning: the largest-ever tundra fire on Alaska's North Slope—220,000 acres—was reported in 2007.[8]

The IPCC predicts global mean temperatures could rise well above 5 degrees F within this century.[9] If this happens, one-quarter of known species could become extinct and over one-fifth of the world's ecosystems could disappear.[10]

Global warming is already having an impact on the natural ecosystems that provide fundamental life-sustaining services without which human civilizations would cease to thrive. These "ecosystem services" include purifying air and water, forming fertile soils, pollinating crops, controlling insects, protecting coastal communities from storm surges and regulating the climate. Plants and animals also provide many direct goods to society, ranging from timber to food to new medicines. Nature and wildlife also offer significant recreational, aesthetic and emotional benefits.

The effects of global warming on the physical and biological elements of nature pose numerous threats to wildlife and the ecosystems that sustain and fulfill human life.

MELTING ICE AND SNOW

Researchers predict a 30-percent loss of Arctic sea ice by 2040,[11] possibly resulting in the disappearance of all polar bears from Alaska due to drowning, starvation, reproductive declines, dispersal and related effects.[12] Other species threatened by loss of Arctic sea ice include spectacled eider ducks, Ross and ivory gulls, ice-breeding seals, walruses and gray whales. The latter have been washing up emaciated since 2001, apparently because melting ice is decreasing their crustacean food supply.[13] The world-renowned Porcupine caribou herd, which calves in the Arctic National Wildlife Refuge, has declined more than 3 percent every year since 1989. Some scientists believe an important factor in the decline is the freezing rain—a result of climate change—that now ices over the caribou's winter food.[14]

DROUGHTS AND FOREST FIRES

In some areas, climate change will decrease rainfall, but even in areas where rainfall remains constant or increases, warming will increase evaporation rates, which can dry soils and make droughts more frequent. With rising temperature, the snow pack melts quickly so less water is available in late spring and early summer when wildlife, farmers and communities need it most. As forests die from rising temperatures and drought, their ability to store and gradually release water is impaired.

Water loss is expected to decrease freshwater fish habitat by 28 percent in the Rocky Mountains and reduce salmon habitat 18 percent nationwide.[15] One study projected that drought in the 64-million-acre prairie pothole region could reduce North America's annual duck production by up to 70 percent,[16] dealing a significant economic blow to the nation's hunting industry. In the Arctic, waterfowl breeding areas are projected to decrease by up to 50 percent within this century.[17]

Drought stress makes trees vulnerable to insect attack, and the combination of insect-killed trees, low moisture and high temperatures

More than 80 percent of plants and animals studied are shifting their ranges because of warming.

THE ECONOMIC BENEFITS OF PROTECTING WILDLIFE AND ECOSYSTEMS

Natural ecosystems provide goods, such as food and medicine, and life-support services essential to a civilization's ability to thrive. Society often greatly undervalues the services flowing from natural systems because many of them are performed "for free." These "ecosystem services" include purifying air and water, generating fertile soils, controlling pests that destroy crops, providing essential habitat for wildlife, sequestering carbon and controlling floods. As the examples below illustrate, protecting natural ecosystems and the wildlife that inhabit them from global warming and other threats is essential to sustaining human life and a vibrant economy with measurable benefits for individuals, businesses and communities.

Drinking Water: A conservative estimate for the value of water flowing from our national forests, where the headwaters of many rivers lie, is more than $4.3 billion annually.[18] The Catskill watershed provides New York City with much of its clean drinking water. Replacing the water filtration services provided by this watershed with a water treatment plant would cost $6 billion to $8 billion plus annual operating costs of $300 million.[19]

Medicine: Thirty percent of all pharmaceuticals on the market today were developed from natural compounds found in the wild.[20] Examples range from the commonplace (aspirin) to potent anticancer agents.[21]

Recreation: Fishing, hunting, wildlife watching, hiking and other outdoor pursuits that rely heavily on healthy wildlife populations, forests, rivers and ecosystems contribute $730 billion annually to the U.S. economy, support nearly 6.5 million jobs and generate $88 billion in state and national tax revenue.[22] One study of campsites in eastern Texas showed that recreation income is dropping dramatically as the southern pine beetle—a pest that has flourished with warmer winters and springs—kills increasing numbers of pine trees.[23]

U.S. coral reefs, significantly threatened by warming ocean temperatures and ocean acidification, are worth an estimated $30 billion per year in tourism, fish breeding habitat, shoreline protection and other services.[24] The Florida Keys National Marine Sanctuary alone supports almost 10,000 jobs in Monroe County, Florida.[25]

A fly fisher works Maroon Lake in Colorado's White River National Forest. Healthy wildlife populations and ecosystems are essential to the outdoor recreation industry, which pumps an estimated $730 billion a year into the U.S. economy.

Storm Surge Protection: Coastal marshes and mangroves are essential barriers for protecting coastal and inland communities from storm surges. A recent study estimates that these storm-protection services are worth more than $23 billion annually to U.S. cities and regions most vulnerable to hurricane and tropical storm surges.[26]

Agriculture and Forestry: More than 30 percent of our food crops rely on the services of pollinators,[27] and the value of the free pollination services provided by native insects is an estimated $3.1 billion per year. The estimated value of the pest control provided by insects and other wildlife is $4.5 billion per year.[28] The U.S. timber industry, already suffering from widespread insect attacks associated with warming, generates more than $125 billion annually, while supporting more than 500,000 jobs.[29]

resulted in a seven-fold increase in the amount of forested federal land that burned from 1987 to 2003 as compared to 1970 to 1987.[30] The largest number of acres ever burned to date was 8.6 million in 2005.[31] In the West, most climate models foresee significantly wetter winters with more fuel growth, leading to drier summers—the precise conditions conducive to massive wildfires that cause billions of dollars in property damage and destroy millions of acres of habitat.[32]

INCREASED RAINFALL AND FLOODING

Increased annual or seasonal precipitation expected in some areas will severely stress ecosystems currently adapted to drier conditions. For example, some researchers predict that increased precipitation and temperatures in the interior West may allow oak and other woody species to invade sagebrush lands, reducing them from millions of acres to isolated remnants.[33] Larger peaks in spring runoff due to faster snowmelt could cause floods that destroy streamside vegetation and fish spawning areas. More runoff can also be expected in areas where global warming impairs the ability of forests to store and gradually release water.

SEA-LEVEL RISE

Rising seas threaten coastal ecosystems and the communities and businesses that depend upon them. Storm surges from the larger and more frequent storms caused by global warming could inundate or wash over coastal wetlands that support critical seafood and recreation industries. One study of four coastal wetlands projected a mean loss of 44 percent of coastal bird habitat resulting from a 4.5-degree F global temperature rise.[34]

HABITAT AND RANGE SHIFTS

Some species will lose habitat altogether as their ranges shift or disappear due to climate change. Global warming is already resulting in significant range shifts among a wide variety of species. Ranges of reef fish in southern California have been shifting to the north since the 1970s.[35] Edith's checkerspot butterfly has shifted its range north by roughly 65 miles and upward 312 feet since the 1930s.[36] Many common birds such as the northern mockingbird and the common ground dove have also shifted their ranges north over the past 26 years.[37] The pika, a small, mountain-dwelling mammal, is moving farther upslope in search of a cooler environment, often to no avail.

DIRECT TEMPERATURE EFFECTS

Many studies have demonstrated that global warming is causing plants to flower earlier, insects to mature more quickly, and birds to migrate sooner.[38] For alligators, sea turtles and some other reptiles for which the number of male and female hatchlings is determined by egg incubation temperatures, some researchers fear global warming could skew sex ratios enough to prevent successful mating and lower reproductive success.[39] Corals are extremely susceptible to temperature increases—warming of even 2 degrees F above 1990 levels will bleach all coral reefs and warming of 3.6 degrees F would result in mass mortality of corals throughout the world.[40] Eastern brook trout, an iconic species that supports an important recreational fishing industry, dies when exposed for only a few hours to stream

temperatures of 76 degrees F or higher.[41] One study predicted that with an increase of 5.4 degrees F, up to 92 percent of the streams suitable for brook trout in North Carolina and Virginia would be lost.[42]

EXCESS CARBON DIOXIDE

High carbon dioxide levels—one of the major causes of warming—are changing the oceans' acidity. This is because the ocean absorbs much of the carbon dioxide in the atmosphere. The resulting increase in acidity reduces concentrations of calcium carbonate that coral animals need to build their limestone reefs. Some scientists believe that within the current century many corals will be unable to build reefs.[43]

INVASIVE SPECIES

Invasive species have played a role in the decline of 35 percent to 46 percent of the plants and animals on the U.S. endangered species list.[44] Unfortunately, most harmful invasive species in the United States are native to tropical and subtropical areas. These species will benefit from global warming at the expense of native plants and animals that prefer cooler temperatures.

According to a recent study, 48 percent of harmful invasive species

A herd of caribou stampedes through the Arctic National Wildlife Refuge. The Porcupine caribou herd has declined more than 3 percent every year since 1989, possibly due to climate-change-related freezing rain icing over lichens and other vital winter foods.

surveyed are likely to expand their ranges with rising temperature and only 4 percent are likely to contract their ranges.[45] Species likely to spread include the aggressive water-depleting shrub tamarisk,[46] the freeze-intolerant Chinese tallow tree and the disease-carrying Asian tiger mosquito.[47] The balsam wooly adelgid, a sap-sucking insect from Europe that reproduces more quickly under warmer conditions, has already destroyed 95 percent of Fraser firs in Great Smoky Mountains National Park.[48]

The cost of controlling fire ants, an invasive species that kills off native ants and preys on young bobwhite quail, least terns, gopher tortoises and other vertebrates, tops $1.2 billion per year in Texas alone.[49] After an explosive colonization in the southern United States, cold temperatures slowed the northward expansion of these ants,[50] but experts warn that global warming is likely to restart this harmful ant's march north.[51]

CHANGES IN ECOSYSTEM COMPOSITION

As the Earth warms, species will shift their geographic ranges. Birds might shift rapidly to the north, colonizing new areas, while slow movers like land snails and salamanders will seriously lag behind, possibly surviving only as remnant populations at higher elevations where temperatures remain cool. Such range shifts will shuffle species, creating new communities of plants and animals as most areas lose species and others gain new ones. Plants and animals will find themselves coping with new predators, diminished or different prey, and new competitors.[52] Many species—up to 25 percent, according to the IPCC—will be unable to survive these new conditions.

Migratory birds and other species that depend on different habitats at different times will face multiple threats if multiple habitats change. The red knot is an endangered sandpiper that flies more than 9,000 miles every spring from South America to the United States.[53] This migratory shorebird could lose up to 37 percent of its tundra breeding habitat to climate change by 2100—about the same time rising sea levels are expected to claim vital stopover habitat for knots and other migratory shorebirds in Delaware Bay.[54] The red knot's situation is not unique. One study projects that parts of the United States will lose 30 to 57 percent of their migratory bird species if temperatures rise 6.5 degrees F.[55]

Entire ecosystems may be lost when trees, corals or other foundation species that determine ecosystem structure dwindle or disappear. Eastern hemlock forests provide 2.3 million acres of dense forest habitat for species like deer and shade-loving brook trout.[56] The hemlock, the most long-lived tree in eastern North America, is under attack throughout the southern portion of its range from the hemlock wooly adelgid insect, a pest particularly lethal to drought-stressed trees.[57] Scientists fear that global warming will increase the range and severity of this insect, killing entire forests and affecting the species dependent on them.

IMPACTS TO ALREADY STRESSED SPECIES

Climate change will increasingly threaten the more than 1,300 species listed as threatened and endangered in the United States that are already vulnerable to human-caused stresses, such as habitat loss, fire suppression, pollutants and invasive species. Entire ecosystem types are in serious trouble even without climate change. Filling, dredging, dams and flood control have claimed 50 percent of wetlands in the continental United States and another 60,000 acres of wetlands vanish every year.[58] Midwest tallgrass prairies have vanished under the plow.[59] Suburban development in California has left only 15 percent of the coastal sage scrub ecosystem intact.[60] In the Southeast, habitat fragmentation, logging and fire suppression have reduced 90 million acres of longleaf pine ecosystem to scattered remnants and put its gopher tortoise, Eastern indigo snake and red-cockaded woodpecker on the endangered species list.[61]

Migratory birds and other species that depend on different habitats at different times will face multiple threats.

Because of habitat loss, many ecosystems and the plants and animals that inhabit them are isolated in tiny islands of habitat surrounded by cultivated land, highways and cities. When temperatures rise, species will try to follow their preferred climates north or upslope, but human development will completely block such movements and cause further risk of extinctions.[62]

Despite these many daunting threats, our federal, state and tribal agencies have yet to respond effectively to global warming. Before we can rise to the challenge of helping fish, wildlife and ecosystems reduce their vulnerability to climate change, we must recognize and overcome the weaknesses and failures of our response so far.

A western grebe nest floats from its tether of submerged vegetation in a South Dakota prairie pothole. Global warming could dry up the heartland marshes where 80 percent of America's waterfowl are born.

Assessing Government Actions to Date

ONLY RECENTLY have federal land-management agencies started seriously considering helping species and ecosystems adapt to global warming. In 2007, the U.S. Geological Survey established the National Global Warming and Wildlife Science Center. This year, the U.S. Climate Change Science Program released a review of adaptation options for climate-sensitive ecosystems and resources. Agencies are only now forming climate change working groups such as the internal task force within the Department of the Interior.

Some states are also beginning to take action. In 2008, the Western Governors' Association adopted the recommendations of the Climate Change Working Group of its Wildlife Corridors Initiative for actions the governors can take to conserve crucial habitat and wildlife corridors to protect wildlife resources in the face of climate change.[63]

It is similarly encouraging that through the State Wildlife Grants Program, established by the Department of the Interior and Related Agencies Appropriations Act of 2001, all 50 states and six territories have developed for the first time comprehensive conservation plans, known as state wildlife action plans. These plans are designed to manage biodiversity within each state to protect species of concern before they become endangered. At this point, however, few of these plans explicitly address climate change. Several state wildlife agencies, including those in California, Virginia and Washington, are currently revising their plans to address climate change's impacts on wildlife and other natural resources. Ideally, these reworked plans will serve as examples for other states. Under legislation passed in the U.S. House of Representatives in 2007 and considered in the U.S. Senate in 2008, all states would have to revise their plans to qualify for assistance from a new national program to promote adaptation to global warming.

These efforts are a start, but to proactively and effectively deal with global warming, our government agencies must recognize and address the failures and weaknesses in their responses to date.

FAILURE TO PRIORITIZE

Most federal, state and tribal agencies have not yet made addressing global warming a central part of their mission. The Government Accountability Office (GAO) completed a study in 2007 that found federal agencies under the Bush administration are not coping with climate change's effects on natural resources, and reports by both the GAO and the National Research Council warn that little has been done to translate scientific principles into effective on-the-ground management.[64] Today, if the manager of a wildlife refuge wanted to address global warming, he or she most likely would not know what to do. The 2007 GAO study concluded that the major federal agencies have not made climate change a priority and that their strategic plans do not specifically address climate change.[65] Crucial pieces of information needed to formulate a national response are still weak or missing, but that is no excuse. Immediate action and more decisive policy direction are urgently needed.

LACK OF COORDINATION

Given that federal, state and tribal efforts are just beginning, it is not surprising that they are not well-coordinated. A recent report by the National Research Council concluded that the U.S. Climate Change Science Program must do a better job working with state and local officials, nongovernmental organizations and the climate-change technology community. The report also identified the need for better coordination among programs that study marine and terrestrial ecosystems.[66] One barrier to coordination is that the federal and state agencies with lead responsibility for managing the land within their jurisdictions often have conflicting missions, policies and programs, and are used to having sole responsibility for their lands.

INCOMPLETE SCIENTIFIC INFORMATION

The recent National Research Council study also concluded that climate-change predictions are still poor at the regional and local scales most relevant for managers.[67] There is even less ability to link

Crucial pieces of information needed to formulate a national response are still weak or missing.

A National Park Service biologist studies Hawksbill turtle hatchlings on a nesting beach in the Virgin Islands. Warmer sands favor the development of females, a bias that could accelerate the decline of this already imperiled species.

climate predictions to ecological responses, and agencies have little understanding of what on-the-ground management techniques would best help species and ecosystems adapt. The GAO report concurred with this finding, concluding that federal resource managers do not yet have the site-specific information needed for effective management decisions.[68] On the state level, the Western Governors' Association acknowledged this need by calling for a federal-state multidisciplinary task force to work with each state to determine specific impacts of global warming on individual fish and wildlife species, habitats, ecosystem services and ecological processes.[69]

We need better ways to predict likely climate-change scenarios at the level of management units.

Basic biological inventory information and monitoring programs to identify how species and ecosystems are responding to climate change are weak and poorly coordinated. The National Park Service has completed inventories on individual units, but the National Wildlife Refuge System and other federal land systems do not have comprehensive biological inventories.

We need better ways to predict likely climate-change scenarios at the level of management units. We need to inventory the ranges and abundances of at-risk species to identify species declines or changes in ecosystem structure or function. We need nationally coordinated monitoring efforts so scientists have a baseline against which to measure changes and to evaluate the effects of management actions. We need practical ways to translate the phrases "adaptive management" and "managing for uncertainty" into effective prescriptions for action.

INADEQUATE FUNDING

Lack of funding for efforts to meet the immense threat to wildlife and ecosystems is the single greatest obstacle for natural resource agencies. Federal and state agencies with responsibility for fish and wildlife and natural ecosystems have been underfunded for years. Consequently these agencies have serious backlogs in land acquisition, maintenance and resource management programs needed to satisfy their missions even under pre-global-warming conditions. Congressional Research Service experts recently estimated the maintenance backlog is $14 billion to $21 billion.[70] The North American Wetlands Conservation Act and other partnership programs also have demands that greatly exceed current funding. In 2000, the most recent year for which estimates are available, the reported cost to acquire needed inholdings in national parks, wildlife refuges and other public lands was $10 billion. Since then, national real estate values have climbed 72 percent.

Operations needs are equally daunting. The U.S. Fish and Wildlife Service alone lost 800 employees from 2004 to 2007, an 8 percent cut. Without funding increases, the agency will be forced to eliminate staff from entire wildlife refuges and cut wildlife and habitat restoration programs. An analysis of agency needs found that it will take $160 million just to complete listing of all the plant and animal species that currently qualify under the Endangered Species Act. The national forest system has lost 35 percent of its staff, including a 44 percent reduction in inventory and monitoring staff and a 39 percent reduction in biologists and biological technicians.[71] Wildfire-related costs consume almost half of the U.S. Forest Service's budget.[72] The Bureau of Land Management lost 9 percent of its staff from 2003 to 2007. From 2001 to 2008, administration budget requests included severe cuts for key agencies with responsibility for stewardship of the environment and natural resources—in 2008 dollars, cumulative cuts of 17.7 percent for the Department of the Interior, 27.2 percent for the Environmental Protection Agency, and 35.4 percent for the U.S. Forest Service. These federal agencies do not have the capacity to address global warming without additional and substantial dedicated funding.

The fact that agencies do not have the authorization to spend scarce resources on global warming is another difficulty. The U.S. Climate Change Science Program lacks authority to allocate or prioritize funding in the agencies it works with, and the members of the interagency working group often have little budgetary authority to implement the research directions that they define.[73]

Federal, state and tribal conservation agencies face a formidable and unprecedented challenge in addressing the damage caused by global warming. However, America has a rich history of rising to meet great conservation challenges, ranging from the great Dust Bowl to DDT contamination to the loss of wetlands, and can effectively respond to global warming.

Acknowledging the reality and severity of global warming and the failures and weaknesses in addressing it to date is a start, but we must also rethink traditional conservation management techniques.

Lake Powell in Utah shows the ravages of a four-year drought. Global warming has heightened concerns about the sustainability of the water level in the lake, a major source of power and electricity in the West.

Adopting a New Conservation Paradigm

CONSERVATION IN A WARMING WORLD REQUIRES a whole new approach. Traditional conservation management techniques are based on the implicit assumption that the climate will not change significantly and habitats will remain basically intact. Global warming is altering this tenet of conservation by shuffling plants and animals in new and unpredictable ways. Land, water and wildlife managers can no longer simply try to recreate past conditions. The ever-changing conditions of our rapidly warming world demand a new conservation paradigm, one that incorporates resiliency and other key management concepts outlined below.

ECOSYSTEM RESILIENCE

Ecosystems are said to be resilient to the degree that they can absorb damage and still return to their normal state.[74] By managing for resiliency, we can help ecosystems and the plants and animals they support cope with many of global warming's impacts. A recent review of hundreds of scientific papers concluded that marine ecosystems are more likely to avoid collapse and to recover from disturbance if they retain most of their original plant and animal species.[75] This dynamic of resiliency also holds true for other ecosystems.

Many species and ecological systems have the ability to tolerate and adapt to some degree of ecological and climate change. If global warming was the only stressor, more species and ecosystems might be able to weather some of its impacts. Unfortunately, most ecosystems throughout the globe have been affected in some measure by human-caused stressors, inhibiting the ability of species and ecosystems to adapt to global warming. Global warming heightens all of the threats to natural systems that have been the center of attention for decades, including habitat loss, pollution, invasive species and overexploitation.

Just as a sick person is more likely to recover if he or she is not exposed to additional diseases, ecosystems and their species will respond better to global warming if we decrease or eliminate human-caused stressors. By actions such as reducing water withdrawals that disturb natural hydrologic regimes, allowing natural fires to decrease fuel loads in forests, and removing bulkheads along coastlines so that marshes can migrate upslope as sea level rises, we can help build ecosystem resiliency.

SCIENCE-BASED MANAGEMENT

Effective management must be based on the best possible science. Although scientists have been working for decades to understand how wild plants and animals will respond to climate change, many knowledge gaps remain. Climate models are broad in scale and cannot yet predict local temperatures or rainfall down to the level of even the largest national forests—the scale needed to make sound management decisions.

One particularly pressing need is the development of simulation maps of expected vegetation changes in response to global warming. These maps will have to be refined as our understanding grows of how habitats are responding to changing climatic conditions, but they are extremely important for helping managers plan land and conservation programs.

Building more robust inventory and monitoring programs is essential to managing wildlife and federal lands in a world changed by global warming. Monitoring provides consistent measurement and analysis to evaluate trends in ecosystem health and to gauge success of management and determine whether a change is required.

Even when accurate climate projections are available, ecosystems may be too complex for scientists to predict exactly how they will respond. Ecosystems contain thousands of interacting species, each responding to temperature, precipitation and evaporation, carbon dioxide levels and other environmental stressors such as invasive species. Predicting ecological responses is particularly difficult when ecosystems have been extensively disturbed by humans.[76]

This uncertainty should not be an excuse to do nothing or to take only incremental action. The agencies charged with protecting our nation's living natural resources can use adaptive management techniques that allow for immediate action even as science evolves.

INTERAGENCY COORDINATION

New governmental processes and structures need to be explored that will themselves be resilient and adaptive to the threats of

global warming. While it is important for each federal agency to develop measures for protecting wildlife from the effects of global warming, it is insufficient for individual agencies or land units to contemplate and plan strategies purely on their own. The problems presented by global warming are simply too complex and far-reaching. Effective conservation will require unprecedented coordination and collaboration across federal, state, tribal and local agencies, as well as across scientific disciplines.

LANDSCAPE CONNECTIVITY

Natural lands should be protected to connect wildlife habitats and allow species to move to suitable habitat when local climate changes. Ensuring habitat connectivity across management unit borders will require federal, state, tribal, local and private land managers to cooperate. Many more species will survive global warming if management agencies can ensure there are large areas of protected habitat to serve as climate "refugia" in a warming world. Measures to minimize roads, urban sprawl, agricultural development and other human activities that reduce and fragment habitat are essential.

These basic management tenets should guide the actions we take to help wildlife and ecosystems survive the impacts of global warming. Wildlife managers must also explore and test new approaches and innovative strategies to build ecosystem resiliency. This is essential to ensure that wildlife and the ecosystems that sustain us all have the ability to adapt to the unavoidable impacts of global warming. With this new conservation paradigm and the necessary policy direction and investment starting at the national level, the nation's conservation agencies can rise to the formidable challenge of helping fish, wildlife and ecosystems reduce their vulnerability to climate change.

A resident of West Des Moines, Iowa, carries his cat down a flooded street. In the central states, warmer, moister air is causing heavier precipitation and bigger and more frequent floods.

Formulating a Comprehensive National Response

GLOBAL WARMING IS ALREADY HARMING living natural resources worth billions of dollars to the U.S. economy and directly contributing to species extinctions and ecosystem degradation. Properly supported by policymakers, federal, state and tribal governments have the potential to respond effectively with clearly focused and, most important, adequately funded efforts. With more decisive national policy direction, greatly enhanced scientific capacity and record-level increases in federal conservation funding, we can help wildlife and ecosystems adapt and survive.

CLEAR FEDERAL POLICY DIRECTION

Given the magnitude and complexity of global warming's impacts on fish, wildlife and ecosystems, the need to develop a national strategy for ecosystem and wildlife survival in the face of climate change is urgent. Within the administration, the Council on Environmental Quality could be the lead organization coordinating development of such a strategy.

The strategy should prioritize national conservation goals, create an organizational framework for cooperation, detail steps that each participating agency must take, outline an implementation timeline, and collectively do the following:

1. Monitor plants, animals, habitat and associated ecological processes likely to be harmed by climate change and ocean acidification and identify those in greatest need of conservation, protection and restoration.
2. Improve our ability to predict future changes in local climates and how species and ecosystems will respond.
3. Develop coordinated, regional and/or nationwide protection plans for plant and animal species and ecosystems vulnerable to climate change and ocean acidification.
4. Create effective management tools to help species and ecosystems survive, including techniques for restoration and reintroduction.
5. Protect, acquire, maintain and restore habitat to build resilience to climate change and ocean acidification.
6. Provide habitat linkages and corridors to facilitate fish, wildlife and plant movement in response to climate change and associated sea-level rise.
7. Ensure that federal, state and tribal agencies that receive federal funding incorporate adaptation strategies and activities into their planning efforts and management decisions.

The federal, state, territorial and tribal agencies responsible for managing lands, waters and wildlife should develop our national strategy for addressing global warming in consultation with conservation organizations, research centers, universities and other stakeholders. A science advisory board composed of members recommended by the president of the National Academy of Sciences should provide scientific oversight.

All states should develop wildlife and climate change strategies, consistent with the goals of the national strategy. These state climate change adaptation plans should ultimately be incorporated into the state wildlife action plans, the primarily federally funded comprehensive plans completed by all states and territories in 2005. Several states have already begun to do this.

A major goal of the national strategy must be to develop effective management tools for frontline managers to help species and ecosystems adapt to the unavoidable impacts of global warming. The national strategy should ensure that these management tools are disseminated widely, that site-specific plans guide their application, and that adequate training and technical assistance is available for managers. Regional workshops where state and tribal practitioners can learn about management tools, share their experiences in applying such tools and stimulate further improvements would be helpful.[77]

The national strategy must direct a high level of coordination among agencies to ensure that management activities complement each other and that research is focused on filling the most critical knowledge gaps. Adaptive management will require experiments at multiple sites, with sharing of results so that scientists and managers across the country can learn from one another. Recent reports stress a call for such coordination, acknowledging that it does not yet exist. For example, the Western Governors' Association recommends immediate creation of a regional partnership among state and federal agencies, academics and science-based nongovernmental organizations.[78] The U.S. Climate Change Science Program recently concluded that the United States might need

Spruce trees decimated by the spruce bark beetle near Homer, Alaska. Populations of this forest pest are increasing with the record-high temperatures and dry summers caused by global warming.

new organizational structures to foster collaboration and transcend traditional "agency-by-agency" responses.[79]

The national strategy should facilitate federal, state and tribal agencies working together to develop strategic plans and internal guidance, conduct and share biological research, and develop and adopt effective management tools.

The four major federal land-management agencies—the National Park Service, U.S. Fish and Wildlife Service, U.S. Forest Service and Bureau of Land Management—will be key players. These agencies are stewards of more than 600 million acres—over a quarter of all U.S. land, with large areas of relatively undisturbed, contiguous wildlife habitat. Many species and ecosystems will require expanses of protected land to survive the effects of global warming and these federal lands will be crucial. Other important federal land-management, marine resource and conservation agencies include the U.S. Army Corps of Engineers, Bureau of Reclamation, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Department of Defense, Environmental Protection Agency and the Natural Resources Conservation Service. State and tribal fish and wildlife agencies must also be involved.

Because roughly 70 percent of lands in the contiguous United States are in private ownership and many ecosystems and species of concern occur on these private lands,[80] ranchers, farmers and private foresters must be part of any effective response. Federal, state and tribal agencies should work with landowners to develop conservation easements to protect key habitat and provide incentives to improve management practices.

Existing wildlife partnership programs that provide federal resources to states, tribes and private partners will be essential and should be revised to include climate change in their missions. These programs include the North American Wetlands Conservation Act, the State Wildlife Grants program, the Farm Bill conservation programs and the Cooperative Endangered Species Fund, which provides grants to states for wildlife and habitat conservation activities on nonfederal lands.

ENHANCED SCIENTIFIC CAPACITY

Helping ecosystems and wildlife survive in a changing climate requires adequate data on species and habitats and a solid understanding of ecosystem processes. As noted in this report, federal agency scientific research programs currently are woefully inadequate to address the unparalleled challenges presented by climate change and the full magnitude of wildlife adaptation needs. Agencies will have to expand these programs to build improved predictive models and associated monitoring networks, develop new decision-support tools, design experimental approaches to management and foster the innovative analytical capacity needed to formulate appropriate and adaptive responses to global warming.

The National Global Warming and Wildlife Science Center that Congress established under the U.S. Geological Survey in 2007 should be a central planner and coordinator of national efforts to develop tools that resource managers need to assist wildlife in becoming resilient and adapting to the impacts of global warming. The center should provide needed scientific support to the group developing the national strategy.

Using an intergovernmental steering committee, workshops and other mechanisms, the National Global Warming and Wildlife Science Center will coordinate with, and solicit information from, federal and state agencies, nongovernmental organizations and scientists. The center should also coordinate with the other climate-change research programs that are broader in scope but complementary such as the U.S. Climate Change Science Program and the IPCC.

UNPRECEDENTED FEDERAL CONSERVATION FUNDING

Federal, state and tribal agencies will require a significant federal investment to help wildlife and ecosystems survive and adapt to an altered climate. Funding is sorely needed to carry out key adaptation activities that focus on building ecosystem resiliency by protecting important habitat and species migration corridors and reducing stressors not related to climate. Funding should also support programs that partner with landowners to restore and protect species on privately owned lands.

Efforts to estimate the investment it will take to help wildlife and ecosystems vulnerable to climate change's impacts are too preliminary to precisely quantify. Like the mitigation of greenhouse gas emissions, the size and seriousness of the threat requires an urgent and paradigm-changing response whatever it costs.

Making a substantial new commitment to conservation funding is a significant challenge. Given both the magnitude of the funding necessary and the need for a reliable funding stream, this challenge cannot be met through the annual congressional appropriations process. This process, already short of resources to fund existing needs, is not designed to deliver the high level of funding that will need to be sustained over multiple decades.

Fortunately, legislation to address global warming provides

an historic opportunity and an appropriate avenue to meet this funding imperative. Virtually all of the legislative proposals advanced in the 110th Congress to reduce global warming emissions appropriately recognized the need to address the unavoidable and severe harm that warming will have on wildlife and the ecosystems that sustain us all.[81] These proposals did so by dedicating a portion of the revenues from the auction of pollution permits under a federal cap-and-trade system. The Senate's Climate Security Act, for example, designates roughly 7 percent of federal revenues from the sale of allowances, or roughly $9 billion per year to addressing the impacts of global warming on wildlife. This funding would be made available automatically and not be subject to the uncertainties of the annual federal appropriations process. Such funding would be but a small fraction of the value of the life-supporting services provided annually by our nation's forests, wetlands and other natural lands and is commensurate with the challenge before us.

Given the direct and severe impact of global warming on wildlife and natural systems, it is appropriate that at least a small percentage of the significant federal revenue from the sale of pollution permits, which estimates place as high as hundreds of billions of dollars, be used to address the damage and protect life-supporting ecological services. Funding wildlife and natural resource programs from pollution permits is also consistent with, and a logical extension of, the "polluter pays" principle. Only the significant and certain funding stream provided in a cap-and-trade bill can provide the effective mechanism to ensure that the nation's federal, state and tribal natural-resource agencies will have the financial resources necessary to effectively address global warming's unavoidable impacts.

The Key deer, an endangered species found only in the Florida Keys, is literally losing ground as more intense storms and rising sea levels erode its island habitat.

Conclusion

Action on the policy recommendations presented in this report cannot happen soon enough. Ecosystems across the nation are showing the effects of warming, and numerous species and types of habitat could disappear from the United States altogether during the lifetime of many Americans.

Federal, state and tribal wildlife and natural resource agencies are way behind in addressing global warming, but they have great expertise and a long history of addressing difficult ecological challenges. To be successful in tackling this exceptional challenge, decision makers will need to be forthcoming in providing clear policy direction, increased scientific capacity and, especially important, significant levels of dedicated funding.

Provided with these basic needs, we are confident that the agencies charged with protecting our natural resources can respond effectively and help wildlife and ecological systems meet the greatest threat to their survival in our nation's history.

"Global warming is the conservation challenge of our time. The success of our efforts to conserve and recover fish, wildlife and other natural resources for future generations of American citizens will depend on how well we respond to this challenge."

—Jamie Rappaport Clark

Executive Vice President, Defenders of Wildlife

Testimony before the U. S. House of Representatives Committee on Natural Resources, June 24, 2008

Lemon damselfish swim amid bleached coral on Australia's Great Barrier Reef. Bleaching occurs when rising temperatures increase ocean acidity, driving out the bright-hued algae that sustain and color coral reefs.

Endnotes

1. National Oceanic and Atmospheric Administration, *2006 Annual Climate Review: U.S. Summary,* accessed 23 July 2008; available from http://www.ncdc.noaa.gov/oa/climate/research/2006/ann/us-summary.html.

Union of Concerned Scientists, *2006 Warmest Year on Record in U.S.*; accessed July 23, 2008; available from http://www.ucsusa.org/news/press_release/2006-warmest-year-on-record.html.

2. U.S. Climate Change Science Program, *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States, A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research,* P. Backlund, A. Janetos,D. Schimel, J. Hatfield, K. Boote, P. Fay, L. Hahn, C. Izaurralde, B.A. Kimball, T. Mader, J. Morgan, D. Ort, W. Polley, A. Thomson, D. Wolfe, M.G. Ryan, S.R. Archer, R. Birdsey, C. Dahm, L. Heath, J. Hicke, D. Hollinger, T. Huxman,G. Okin, R. Oren, J. Randerson, W. Schlesinger, D. Lettenmaier, D. Major, L. Poff, S. Running, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson, R. Shaw. (Washington, DC: U.S. Department of Agriculture: 2008), 362.

3. Jonathan Overpeck, Julia Cole and Patrick Bartlein, "A 'Paleoperspective' on Climate Variability and Change,"in *Climate Change and Biodiversity*, ed. Thomas E. Lovejoy and Lee Hannah (New Haven: Yale University Press, 2005), 97-98.

4. C. D. Thomas et al., "Extinction risk from climate change," *Nature*, 427 (2004): 145-148.

5. Wigley, T. M. L., "The Climate Change Commitment," *Science*, 307, no. 5716 (2005):1766-1769.

6. Raphael Sagarin, "Historical Studies of Species' Responses to Climate Change," in *Wildlife Responses to Climate Change: North American Case Studies*, ed. Terry L. Root and Stephen H. Schneider (Washington, DC: Island Press, 2002), 31.

7. Terry L. Root and Stephen H. Schneider, "Overview and Implications for Wildlife" in *Wildlife Responses to Climate Change: North American Case Studies*, ed. Terry L. Root and Stephen H. Schneider (Washington, DC: Island Press, 2002), 39.

8. "Largest Recorded Tundra Fire Burning on Slope," *Anchorage Daily News*, 28 September 2007, accessed 23 July 2008; available from http://dwb.adn.com/news/alaska/rural/story/9337371p-9252045c.html.

9. Intergovernmental Panel on Climate Change, "Summary for Policymakers," in *Climate Change 2007: Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Cambridge: Cambridge University Press, 2007), 23.

10. Ibid., 792.

11. Ibid., 662.

12. Charles Peterson, untitled presentation transcript, *Symposium 2007: Innovations in Wildlife Conservation, Panel 1*; accessed 23 July 2008; available from http://www.defenders.org/programs_and_policy/global_warming/symposium2007/pdfs/04_Charles_Pete_Peterson.pdf, 2.

13. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report,* 668.

14. Deborah Williams, "Global Warming in Alaska," *Symposium 2007: Innovations in Wildlife Conservation, Panel 3*; available from http://www.defenders.org/programs_and_policy/global_warming/symposium2007/pdfs/12_Deborah_Williams.pdf; 4.

Anne Gunn, "Impacts of Climate Change on Caribou," presentation, *Climate Change Impacts and Adaptation Strategies for Canada's Northern Territories: Final Workshop Report,* February, 2000, accessed 23 July 2008; available from http://adaptation.nrcan.gc.ca/projdb/pdf/70_e.pdf, 13.

15. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report,* 242.

16. The Wildlife Society, *Global Climate Change and Wildlife in North America: Technical Review 04-2-2004*, ed. Krista E. M. Galley (Bethesda, MD: The Wildlife Society, 2004), 12.

17. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report,* 239.

18. U.S. Forest Service, *Water and the Forest Service,* James Sedell, Maitland Sharpe, Daina Dravnieks Apple, Max Copenhagen and Mike Furniss (Washington, DC: U.S. Department of Agriculture, 2000), 26.

19. A. Alonso, F. Dallmeier, E. Granek and P. Raven, *Biodiversity: Connecting with the Tapestry of Life,* 2nd ed. (Washington, DC: Smithsonian Institution Monitoring and Assessment of Biodiversity Program, 2007), 13.

20. Ibid., 8.

21. Eric Chivian and Aaron Bernstein, eds., *Sustaining Life*, (New York: Oxford University Press, 2008), 145.

22. Outdoor Industry Association, *The Active Outdoor Recreation Economy*. (Boulder, Colorado: Outdoor Industry Foundation, 2006), 3.

23. William A. Leuschner, *Bark and Wood Boring Beetles of the World. Chapter 7: Impacts of the Southern Pine Beetle* (University of Georgia Bugwood Network, accessed 20 August 2008); available from http://www.barkbeetles.org/spb/spbbook/Chapt7.html.

24. A.L. Janetos, L. Hansen, D. Inouye, B.P. Kelly, L. Meyerson, B. Peterson and R. Shaw, "Biodiversity" in *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States*. (Washington, DC: U.S. Climate Change Science Program and the Subcommittee on Global Change Research, 2008), 159.

25. Vernon Leeworthy and P.C. Wiley. 2001. "Current Participation Patterns in Marine Recreation" in *National Survey on Recreation and the Environment 2000*. (Silver Spring, MD: National Oceanic and Atmospheric Administration, National Ocean Service, Special Projects, 2000).

26. Robert Costanza, Octavio Pérez-Maqueo, M. Luisa Martinez, Paul Sutton, Sharolyn J. Anderson and Kenneth Mulder, "The Value of Coastal Wetlands for Hurricane Protection," *Ambio* 37, no. 4 (June 2008): 241.

27. Alonso et al., *Biodiversity: Connecting with the Tapestry of Life,* 10.

28. John E. Losey and Mace Vaughan, "The economic value of ecological services provided by insects," *BioScience* 56, no. 4 (2006): 311-323.

29. Rachel Hodgetts and Roseanne Freese. *An Economic Overview of the United States Solid Wood Industry.* (Washington, DC: Foreign Agricultural Service, U.S. Department of Agriculture, 2000, accessed 23 July 2008.); available from http://www.fas.usda.gov/ffpd/Economic-Overview/overview.html.

30. "More Large Forest Fires Linked to Climate Change," *ScienceDaily*, 10 July 2006, accessed July 23, 2008; available from http://www.sciencedaily.com/releases/2006/07/060710084004.htm.

31. Dennis O'Brien, "Climate Change Link Seen in Surge of Western Blazes," *San Francisco Chronicle*, 7 July 2006; accessed 23 July 2008; available from http://www.sfgate.com/cgi-bin/article.cgi?f=/c/a/2006/07/07/MNG7JJR8521.DTL&feed=rss.news.

32. Pacific Northwest Research Station, "Western Forests, Fire Risk, and Climate Change," *Pacific Northwest Research Station Science Update*, issue 6 (January 2004): 1.

33. Ibid., 10.

34. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report*, 243.

35. Root and Schneider, *Wildlife Responses to Climate Change: North American Case Studies*, 130.

36. Lisa Crozier, "Case Study of the Sachem Skipper Butterfly" in *Wildlife Responses to Climate Change: North American Case Studies*, eds. Terry L. Root and Stephen H. Schneider (Washington, DC: Island Press, 2002), 63.

37. TerraDaily, "North American Birds Moving North As a Result of Climate Change," *TerraDaily*, January 17, 2008; accessed 23 July 2008; available from http://www.terradaily.com/reports/North_American_Birds_Moving_North_As_A_Result_Of_Climate_Change_999.html.

Root and Schneider, *Wildlife Responses to Climate Change: North American Case Studies*, 20, 30-39.

38. Root and Schneider, *Wildlife Responses to Climate Change: North American Case Studies*, 19-39.

Terry L. Root and Lesley Hughes, "Present and Future Phenological Changes in Wild Plants and Animals" in *Climate Change and Biodiversity*, eds. Thomas E. Lovejoy and Lee Hannah (New Haven: Yale University Press, 2005), 61-69.

39. Charles W. Caillouet and Marcel J. Duronslet, "Sea Turtle Sex Ratios and Incubation Temperature: Are We on the Right Track?," *Marine Turtle Newsletter*, vol. 35., (1985):14-16.

Lovich, Jeffrey E., *Turtles and Global Climate Change*. Presentation at U.S. Geological Survey Global Change Research Program workshop, Impact of Climate Change and Land Use in the Southwestern United States, July 1997, accessed 23 July 2008; available at http://geochange.er.usgs.gov/sw/impacts/biology/turtles/.

40. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report*, 792.

41. Eastern Brook Trout Joint Venture, *Conserving the Eastern Brook Trout: An Overview of Status, Threats, and Trends* (Conservation Strategy Work Group, Eastern Brook Trout Joint Venture: 2005), 6.

42. Ibid., 5.

43. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report,* 235

44. Jewell, Susan, "A United Defense Against Invasive Species." *Endangered Species Bulletin* 25, no. 5 (September/October 2000): 9.

45. Erika Zavaleta and Jennifer Royval, "Climate Change and the Susceptibility of U.S. Ecosystems to Biological Invasions: Two Cases of Expected Range Expansion. In *Wildlife Responses to Climate Change: North American Case Studies*, eds. Terry L. Root and Stephen H. Schneider (Washington, DC: Island Press, 2002), 278.

46. Ibid., 305.

47. Vicki Brower, "Vector-borne Diseases and Global Warming: Are Both on an Upward Swing?" *European Molecular Biology Oreganization Reports* 2, no. 9 (15 September 2001):755-757, accessed 23 July 2008; available from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1084047.

48. National Park Service, *Summary of Forest Insect and Disease Impacts* (Great Smoky Mountains National Park, National Park Service, 2007), 2; accessed 23 July 2008, available from http://www.nps.gov/grsm/parkmgmt/upload/Brief-Forest%20Insect-Disease.pdf.

49. Curtis F. Lard. et al. *The Statewide Economic Impact of Red Imported Fire Ants in Texas: A Part of the Texas Fire Ant Initiative 1999-2001* (College Station, Texas: Department of Agricultural Economics, Texas A & M University, 2001); accessed 23 July 2008, abstract, available from http://fireantecon.tamu.edu/Publications/Statewide_RIFA_TX.pdf.

50. Zavaleta and Royval, *Wildlife Responses to Climate Change: North American Case Studies*, 296.

51. Ibid., 305.

52. Eric Sanford, "Community Responses to Climate Change," in *Wildlife Responses to Climate Change: North American Case Studies*, eds. Terry L. Root and Stephen H. Schneider (Washington, DC: Island Press, 2002) 165-200.

53. U.S. Fish and Wildlife Service, *Status of the Red Knot (Calidris canutus rufa)*, bulletin, accessed 23 July 2008; available from http://www.fws.gov/northeast/redknot.

54. Intergovernmental Panel on Climate Change, *Climate Change 2007: Impacts, Adaptation and Vulnerability. Working Group II Contribution to the Fourth Assessment Report*, 239.

55. Ibid., 244.

56. U.S. Forest Service, *Eastern Hemlock Forests: Guidelines to Minimize the Impacts of Hemlock Woolly Adelgid* (Morgantown,WV: U.S. Forest Service, 2004, accessed 23 July 2008; available from http://www.uky.edu/Ag/CritterFiles/casefile/bugconnection/teaching/weebeasties/win06/guidelines_to_minimize_hwa_impacts_pub.pdf.

57. Ibid., 12.

58. The Wildlife Society, *Global Climate Change and Wildlife in North America: Technical Review 04-2-2004*, 11.

59. U.S. Fish and Wildlife Service, *Tallgrass Prairie Ecosystems,* accessed 23 July 2008; available from http://www.fws.gov/midwest/EcoSystemConservation/tallgrass_prairie.html.

60. World Wildlife Fund, *California Coastal Sage and Chaparral*; accessed 23 July 2008; available from http://www.worldwildlife.org/wildworld/profiles/terrestrial/na/na1201_full.html.

61. Cecil C. Frost. "Four Centuries of Changing Landscape Patterns in the Longleaf Pine Ecosystem," in *Proceedings of the Tall Timbers Fire Ecology Conference*, ed. Sharon Hermann (Tallahassee, FL: Tall Timbers, 1993), 17-44.

62. Robert Peters and J.D.S. Darling. "The Greenhouse Effect and Nature Reserves," *BioScience* 38 (1987): 707-717.

63. Western Governors' Association, *Wildlife Corridors Initiative* (Jackson, WY: Western Governors' Association, 2008).

64. U.S. Government Accountability Office, *Report to Congressional Requesters: Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources* (Washington, DC: Government Accountability Office, August, 2007), 8. Available from www.gao.gov/cgi-bin/getrpt?GAO-07-863.

65. Ibid., 7-8.

66. National Research Council, *Evaluating Progress of the U.S. Climate Change Science Program: Methods and Preliminary Results,* prepublication copy, (Washington, DC: National Academies Press, 2008), 34.

67. Ibid., 34.

68. U.S. Government Accountability Office, *Report to Congressional Requesters: Climate Change,* 9.

69. Western Governors' Association, *Wildlife Corridors Initiative,* 96.

70. Congressional Research Service, *CRS Report for Congress: National Park Management* (Washington, DC: 25 September 2006), accessed 23 July 2008; available from http://www.ncseonline.org/NLE/CRSreports/06Oct/RL33484.pdf.

71. R. Max Peterson, F. Dale Robertson, Jack Ward Thomas, Michael Dombeck and Dale Bosworth (former U.S. Forest Service chiefs), 24 March 2008, letter to Rep. Nick J. Rahall, Chairman, U.S. House of Representatives Committee on Natural Resources.

72. Ibid.

73. National Research Council, 3.

74. U.S. Climate Change Science Program, *Adaptation Options for Climate-Sensitive Ecosystems and Resources, Third Review Draft,* 9-16.

75. Ibid., 9-17.

76. Ibid., 9-14.

77. Western Governors' Association, *Wildlife Corridors Initiative,* 97.

78. Ibid., 69.

79. U.S. Climate Change Science Program, *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States,* 9-36.

80. C.R. Groves, L.S. Kutner, D.M. Stoms, M.P. Murray, J. M. Scott, M.Schafale, A.S. Weakley, R.L. Pressey, "Owning up to our responsibilities. Who owns lands important for biodiversity?" in *Precious Heritage: The Status of Biodiversity Conservation in the United States,* eds. B.A. Stein, L.S. Kutner and J.S. Adams (New York: Oxford University Press, 2000), 275-300.

81. As of publication, this list includes the Lieberman-Warner Climate Security Act (S. 3036), the Global Warming Pollution Reduction Act (S. 309), the Climate Stewardship and Innovation Act of 2007 (S. 280), the Low Carbon Economy Act (S. 1766), the Safe Climate Act of 2007 (H.R. 1590), the Climate Stewardship Act of 2007 (H.R. 620), the iCAP Act (H.R. 6186) and the Climate MATTERS Act (H.R. 6316).

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