Investing in America's Natural Resources

The Urgent Need for Climate Change Legislation

NATIONAL WILDLIFE FEDERATION

National Wildlife Federation
11100 Wildlife Center Drive
Reston, VA 20190
703-438-6000
www.nwf.org

Investing in America's Natural Resources
The Urgent Need for Climate Change Legislation

May 2008

Prepared by:
Douglas B. Inkley, Ph.D., Senior Scientist

Larry J. Schweiger
President and Chief Executive Officer
National Wildlife Federation

Acknowledgments
On the National Wildlife Federation staff, I especially thank Jim Adams, Barbara Bramble, Juanita Constible, Ben Deeble, Sarah Gannon-Nagle, Patty Glick, Laura Hartt, Pat Lavin, Steve Malloch, David McArthur, Michael Murray, Amanda Staudt and Garrit Voggesser for contributing their expertise and research on various ecosystems. The guidance and special skills of Laura Hickey, Jennifer Jones, John Kostyack, Aislinn Maestas and Karla Raettig were essential to successful completion of this report.

Thank you to Joe Barbato of Barbato Associates for early drafts from which this report was developed and to Julie Young of Young Design for her design work.

Thank you to all the professionals in resources conservation who are working so hard to conserve and protect the nation's natural resources.

FRONT COVER PHOTOGRAPHS: iStock

Investing in America's Natural Resources

The Urgent Need for Climate Change Legislation

AMERICA is blessed with an abundance of natural resources: from the fertile Great Plains to the stunning coasts teeming with fish, from the vast forests that span much of our country to the unparalleled freshwater reservoir of the Great Lakes. These natural resources are essential for our food, shelter and economic vitality, provide for our physical and spiritual well-being, and are integral to what it means to be American.

Since the conservation leadership of President Theodore Roosevelt, millions of Americans have devoted their talents and energies to protecting, restoring and enhancing our country's natural resources. We have all benefited in countless ways.

Now, because of global warming, a century of conservation achievements is in jeopardy.

It used to be that direct habitat destruction was the most prominent cause of decline and extinction of our nation's wildlife. Soon this will no longer be the case.

Today, global warming has become the single greatest threat to wildlife, and to the natural resources on which we all depend.

The Southeast has experienced water shortages. Western forests have become more susceptible to wildfires, with unprecedented loss of habitat in recent years. Native trout are finding requisite cold water streams too warm for survival. Coastal habitats are being destroyed by rising ocean levels. Moose of northwestern Minnesota have virtually disappeared due to rising temperatures. Florida's coral reefs are experiencing more frequent bleaching events.

> "The nation behaves well if it treats the natural resources as assets which it must turn over to the next generation increased, and not impaired, in value." [1]
>
> – President Theodore Roosevelt, 1907

continued

W. Steve Sherman

Investing in America's Natural Resources

The Urgent Need for Climate Change Legislation

continued

In the lifetime of a child born today, 20-30 percent of wild plants and animals worldwide are expected to face an increasingly high risk of extinction due to global warming.[2]

With the loss of wildlife will come an unfortunate undermining of America's connection to the land. Our storied hunting and fishing traditions, and the economic stimulus that they provide to our rural communities, could be compromised beyond repair.

Now, we must chart a new course for natural resources conservation, working against the clock to find answers to a problem we have never confronted before – global warming.

The escalating impacts of global warming call for restoring viable habitats and carrying out rigorous scientific research and monitoring to discover new strategies for conserving natural resources. We must be willing to invest the necessary funds now to avoid potentially much higher costs later to restore or replace the natural resources that we all depend upon.

Now, Congress has an historic opportunity to help sustain America's unsurpassed natural legacy for our children and grandchildren.

Scientists tell us that cutting global warming pollution by 80 percent by 2050 is the only way we can avoid catastrophic global warming. Congress should implement a "cap-and-trade" system that reduces global warming pollution by 2 percent annually to achieve this goal. Two percent annual global warming pollution reductions are doable. By doing its part in cutting global warming pollution, the U.S. can generate clean technology jobs at home and market new clean energy technologies world-wide.

But, more than reducing global warming pollution is required. **We must also invest in protecting natural resources from the global warming that is inevitable due to pollution already emitted and the new pollution that will be emitted.**

Under a cap-and-trade program, the auctioning of permits to polluters can generate funding to invest in protecting natural resources from global warming impacts. These investments include developing alternative energy technologies, assisting low income households to make the transition to a new energy future, supporting nations facing the worst threats of rising sea levels, and helping secure the many benefits America's natural resources provide for our economy and our daily well-being.

Congress must take action now to ensure that we will not fail future generations by leaving them a world diminished from the one we know today.

Congress should pass legislation which:

1) Reduces global warming pollution by 2 percent annually through 2050 with a cap-and-trade program; and

2) Invests dedicated financial resources in restoring and protecting natural resources threatened by global warming.

Now is the time to pass global warming legislation.

USFS

Natural Resources at Risk from Climate Change

AMERICA'S natural resources are essential to our robust economy and a high quality of life. From the boreal forests of Alaska to the prairie potholes of the Midwest to magnificent coral reefs of Florida, we depend greatly on healthy ecosystems – for safe drinking water, flood protection, food, healthy fisheries, forest products, clean air, pollination of crops, and so many other benefits. America's bountiful natural resources enrich our lives and provide a strong basis for a healthy economy. These precious natural resources and the benefits they provide to all Americans are threatened by global warming.

Global warming is here. The 10 warmest years on record have all occurred since 1990. Thousands of scientific studies and the broad consensus of scientists around the world make it clear that our planet is undergoing rapid global warming as a result of human-kind's greenhouse gas emissions. The consequences of global warming include rising temperatures, changing precipitation patterns, intensified storms and hurricanes, more severe droughts and floods, melting ice caps and rising sea levels.

> "The warming of the earth could potentially have more far-reaching impacts on wildlife and wildlife habitat than any challenge that has come before us." [3]
>
> – Dale Hall, Director, U.S. Fish & Wildlife Service, 2007

The negative impacts to our natural resources of global warming are already apparent:

- Coastal habitats are disappearing as sea levels rise due to the melting of ice caps and the thermal expansion of ocean waters.
- Arctic summer sea ice is rapidly disappearing – it now covers less than half the area covered in the late 20th century and is melting even faster than scientists predicted.
- Extreme droughts in the southeastern United States have led to bone dry reservoirs and water wars among states.
- Western droughts and increasing temperatures have led to a four-fold increase in major forest fires and six-fold increase in area burned, in just two decades.
- Declining and earlier melting snow pack in western mountains has reduced water for cities, summer irrigation and native salmon and trout streams.
- Drought has weakened the piñon pines of the Southwest, leading to bark beetle infestations that have killed millions of trees.
- Warmer temperatures are providing opportunities for many cold-intolerant invasive species, such as fire ants and kudzu, to expand northward.

Global Warming and the Risk to America's Wildlife

It used to be that loss of habitat was the leading factor responsible for the decline and extinction of our nation's wildlife. Not any more. Now global warming has become the greatest threat to wildlife in the U.S. and around the world.

Scientists warn that many plant and animal species – 20 to 30 percent worldwide – could face an increasingly high risk of extinction if temperatures increase by about 3 to 4 degrees Fahrenheit.[2] This is not a far-off prediction – it is expected to happen within the lifetime of some children born today, unless significant and meaningful action is taken now. If we ignore global warming altogether and continue "business as usual," the impact to wildlife will be even greater. The challenge is immediate because global warming pollution remains in the atmosphere for decades, all the while doing harm. Acting now will help to ensure that our children's future includes the rich wildlife heritage we have the privilege of enjoying today.

> ". . . active outdoor recreation contributes a total of $730 billion annually, supporting 6.5 million jobs (1 in 20 U.S. jobs), generating $88 billion in federal and state tax revenue and stimulating 8 percent of all consumer spending." [15]
>
> – The Outdoor Industry Foundation, 2006

The Economic Benefits of Acting Now

Investment now of just 1 percent of global gross domestic product (GDP) in addressing global warming, could avoid global warming causing up to a 20 percent reduction in global GDP.[4] Furthermore, action now would avoid impacts that will "be difficult or impossible to reverse."[4]

The potential economic costs of climate-related disasters brought on or exacerbated by global warming are enormous. Insurance companies have reported a rapid rise in weather-related disasters and attribute this in part to global warming.[5] During the 1980s, there were just three weather-related natural disasters with losses of $1 billion or more. The number rapidly increased to 26 during the 1990s, and another 26 between 2000 and 2006.[6]

Increases in weather-related disasters associated with global warming carry more than an economic cost. The perils of weather-related disasters are exemplified by Hurricane Katrina, which caused one million evacuees to flee and more than 1,800 deaths.[7] A two-foot rise in sea level is likely this century and projected to subject nearly 2,200 miles of major roads and 900 miles of railroads to regular inundation in Maryland, Virginia, North Carolina and the District of Columbia.[8]

The natural resources at risk from global warming have high economic value. For example, using a very conservative estimate of $1,000 in value of benefits per acre,[9] the remaining 100 million acres of wetlands in the lower-48 states are worth an incredible $100 billion. Global warming is projected to dry up many wetlands, especially in the prairie pothole region where up to 90 percent of the wetlands could be lost.[10] Many other wetlands will be significantly altered in their structure and function. Although the extent of potential damage is unknown, the value of wetlands for flood control, water purification, ground and surface water supply, and wildlife habitat will be compromised due to global warming.

The U.S.'s 520 million acres of forests[11] are valued at more than $60 billion for the annual benefits they provide, such as water, timber production and recreational opportunities.[12] As the climate has warmed, the area burned by fires in the Western U.S. has increased six-fold and firefighting costs have sky-rocketed, costing the federal government $1.5 billion in 2006.[13] The major increase in fires accelerates erosion, lowers water and air quality, and decreases timber yields, among other impacts.

The nation's natural environment makes possible camping, fishing, hunting, paddling, hiking, wildlife viewing, and other forms of outdoor recreation. These activities contribute $730 billion annually to the U.S. economy, support 6.5 million jobs, generate $88 billion in federal and state tax revenues, and stimulate 8 percent of all consumer spending.[14]

Clearly, we must act now to safeguard our natural resources for their aesthetic values, essential benefits that support our way of life, huge economic values and to avoid their permanent impairment or loss. What we do today will determine the well-being of our children and grandchildren, and the economic security of our country.

The Critical Importance of the Global Warming Legislation

To effectively protect and restore essential natural resources threatened by global warming, Congress will need to enact legislation that **reduces global**

continued

NOAA

A flooded New Orleans after Hurricane Katrina

continued

warming pollution by 80 percent by 2050. Scientists tell us that if we do this we will avoid the worst case impacts of global warming. Reducing emissions by 2 percent annually gets us to that 80 percent goal. Two percent is doable.

To achieve a 2 percent annual reduction of global warming pollution emissions, a carbon cap-and-trade system is urgently needed. It would enable companies to buy and sell annual permits or allowances to release global warming pollution, thus creating financial value in pollution-cutting endeavors. The annual auction of the allowances would generate revenues than could be dedicated to various public purposes, including the conservation of wildlife and other natural resources damaged or threatened by global warming.

Why Investment in Natural Resources Is Essential

Conservation of wildlife and other natural resources in the face of global warming presents at least three new challenges we have never encountered before. First, professional managers have never needed to account for long-term shifts in climate; they could assume that climate would remain essentially unchanged during their planning time scales. This is no longer feasible. Rapid global warming is underway and already impacting natural resources in ways we have never experienced before.

Second, instead of relatively minor and predictable impacts of nearby human activity, managers are now being faced with continent-wide impacts of a type never experienced before. With global warming, every acre on earth is being affected. No longer can we rely on untouched areas remaining pristine, and we must anticipate changes everywhere.

Third, greenhouse gas pollution emitted today remains in the atmosphere for decades. It is essential that we plan ahead and take action now to protect natural resources from impacts that are already inevitable. Even as global warming emissions are scaled back, global warming pollution will continue to be emitted and impact natural resources.

To conserve our natural resources and the many essential benefits they provide us, we must be willing to invest the necessary funds now to protect and restore ecosystems impacted by global warming, and to avoid potentially much higher costs later to restore or replace them.

Natural resource agencies are best suited to handle the challenges of preventing the worst damage from global warming. They are trained to learn as they go and to recalibrate management strategies based on new information. Carrying out this "adaptive management" approach will require considerable investment in monitoring and research. Data collected from monitoring will provide managers with necessary information on the status and trends of natural resources. With this information in hand, they can then implement appropriate management strategies to conserve the impacted resources. Furthermore, by monitoring the outcomes of management strategies, managers can assess their effectiveness and make needed modifications.

There is much to be learned about how we can keep our forests, rivers, lakes, wetlands, coasts, and other habitats healthy in the face of inevitable global warming. Some of the key research problems that must be investigated include:

- Identifying which species, ecosystems, and conservation areas are most vulnerable to global warming and in greatest need of intervention.

- Understanding how different ecosystems and natural systems are interconnected so that managers can make well-informed conservation decisions.
- Modifying existing tools and developing new tools to help resource managers take global warming fully into account in their management strategies.
- Developing computer models to project climate-induced shifts in vegetation, habitats, and species ranges.
- Understanding how global warming will alter migration routes and the implications this has for conservation strategies and establishing migration corridors.

State wildlife agencies have already developed state wildlife action plans (SWAPs) to conserve wildlife. They can integrate the new research findings and management strategies into these plans to help protect wildlife and other natural resources from the impacts of global warming. Because these plans are at large geographical scales and can easily be updated to take into account new information and changed circumstances, they are well-suited to serve as conservation planning frameworks in a warming world.

> "The climate change crisis that we believe is occurring is not something we can wait ten years, five years, even a year, to address." [16]
>
> – Reverend Richard Cizik,
> Vice President for Government Affairs,
> National Association of Evangelicals

Targeting Conservation Strategies for Specific Ecosystems

Resource managers around the country are seeing the impacts of global warming and beginning to understand that actions need to be taken to safeguard wildlife and other natural resources. Depending on the ecosystem, methods of protection vary from reducing the risk of major wildfires through prescribed burns, to accommodating sea level rise in conservation plans, to preventing the spread of non-indigenous species that harm ecosystems, to restoring habitats and thereby making them more resilient to the effects of global warming.

Following this overview we present just a few examples of the impact of global warming on major ecosystems, and some of the conservation actions that are needed to minimize these impacts. Although they are only a small representation of the many ways in which resource managers will need to act to protect natural resources threatened by global warming, they demonstrate the enormity of the challenges that lie ahead and the need to take action now.

Congress Must Invest Now in America's Future

In December 2007, the Climate Security Act (S.2191) was approved by the Senate Environment and Public Works Committee to provide an average of roughly $7.2 billion annually during the first 19 years of the law – an amount commensurate with the gravity of the threat and the huge ecological and human costs of not taking timely and effective action. In fact, this amounts to a new annual investment of less than 1 percent of the annual forestry, wetland and recreational benefits alone of natural lands in the U.S., and does not even account for the billions saved by minimizing climate-related disasters.

Unless we cut global warming pollution and make the necessary investments in protecting our natural resources, global warming could overwhelm generations of conservation accomplishments.

Congress has an historic opportunity to help the challenge of global warming and protect our nation's wildlife and other natural resources for generations to come. It should pass legislation which:

1) **Reduces global warming pollution by 2 percent annually through 2050 with a cap-and-trade program; and**
2) **Invests dedicated financial resources in restoring and protecting natural resources threatened by global warming.**

We must not fail future generations by passing to them a world which is diminished from the world we know today.

The need for action is urgent.

For further information:

John Kostyack
Executive Director, Wildlife Conservation and Global Warming
National Wildlife Federation
1400 Sixteenth Street, N.W., Suite 501
Washington D.C. 20036-2266
kostyack@nwf.org
202-797-6879

Karla Raettig
Legislative Representative, Conservation Programs
Office of Congressional and Federal Affairs
1400 Sixteenth Street, N.W., Suite 501
Washington D.C. 20036-2266
raettigk@nwf.org
202-797-6869

Doug Inkley, Ph.D.
Senior Scientist, Conservation Programs
National Wildlife Federation
11100 Wildlife Center Drive
Reston VA 20190-5362
inkley@nwf.org
703-438-6460

Coral Reefs

The Habitat

The spectacular and delicate coral reefs of Florida, Hawaii and Puerto Rico are ecological gems and important economic resources. Often called "rainforests of the sea" for their rich biodiversity, the coral on which these diverse ecosystems are based are actually living organisms themselves.[17] They form when polyps – the living portion of stony corals – extract calcium from seawater and combine it with carbon dioxide to construct the elaborate limestone skeletons that form the reef.

Between just Key Biscayne and Dry Tortugas, the Florida Keys contain about 6,000 coral reefs.[18] This reef system – third largest in the world – contains more than 100 species of soft and stony corals and hundreds of fish species, from tiny sergeant majors to giant barracudas.

Benefits for Humans and Wildlife

In coral reefs around the world thousands of marine species find food and shelter, which in turn support economically valuable recreational and commercial fishing. Coral reefs also form a breakwater for adjacent coasts, providing natural protection from storm surges.

Coral reefs are hotspots for the tourism industry, which thrive on providing visitors with unforgettable scuba diving and snorkeling experiences. The coral reefs off the Florida Keys help generate more than $1.6 billion in revenues annually.[19]

Threats from Global Warming

Higher sea temperatures from global warming have already caused major coral bleaching events. Bleaching occurs when corals respond to the stress of warmer temperatures by expelling the colorful algae that live within them.[20] Some coral are able to recover, but too often the coral dies, and the entire ecosystem for which it forms the base, virtually disappears.

Longer-lasting and more extensive bleaching events are already on the rise, with further increases expected in the decades ahead as ocean temperatures continue to rise.[21] Warmer waters are also expected to increase the incidence of other coral diseases such as black band disease, white band disease, white plague, and white pox, all of which can lead to mass mortality of coral, and subsequently the entire ecosystem it supports.[22]

Ocean acidification – which occurs when oceans

Brain coral bleached by warm ocean waters

Craig Quirolo, *Reef Relief*, Marine Photobank

"Sportsmen know climate change threatens the fish we love and the habitats they live in." [26]

– Captain Dan Kipnis, Florida

absorb carbon dioxide from the atmosphere – is also a threat to coral.[23] As the oceans become more acidic, the corals' ability to form skeletons through calcification is inhibited, causing their growth to slow. A doubling of atmospheric carbon dioxide will reduce calcification in some corals by as much as 50 percent.[24]

Loss and degradation of coral reefs from global warming puts at risk the tourism, commercial fishing and recreational fishing industries these important ecosystems support.

Conservation Investments to Minimize Global Warming Impacts

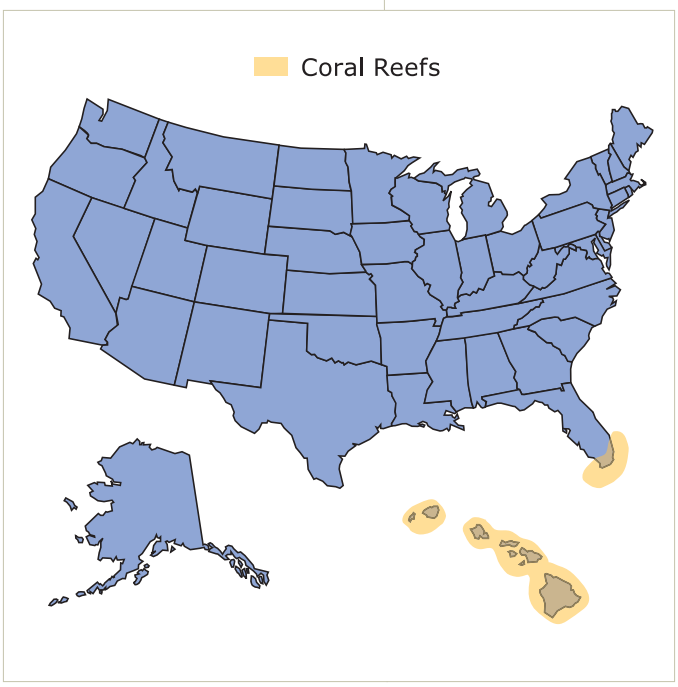
Reducing overall global warming pollution is essential to minimize ocean temperature increases causing coral bleaching. However, minimizing other impacts not directly related to global warming can improve the ability of these sensitive ecosystems to withstand the duress of global warming.[25]

Managers will need to improve water quality by reducing water pollution from ocean sources (e.g. ocean dumping) and improving watershed management of nearby lands. Other management options could include local restrictions on ocean dredging and large boat traffic, as well as appropriate modifications of regulations relating to tourism, and commercial and recreational fisheries.

Coral monitoring must be expanded to include ocean acidification, calcification rates, water temperatures, and coral bleaching rates if managers expect to be able to effectively conserve these reefs as the climate warms. Research is needed to develop and implement new methods of restoring damaged or destroyed coral reefs.

NOAA

Healthy coral reef



Eastern Hemlock Forests

The Habitat

Eastern hemlocks grow on 19 million acres throughout the eastern U.S. and are the dominate tree species on 2.3 million acres, ranging from the Southern Appalachians of Georgia and Alabama north to Maine and the Canadian Maritimes as well as west to Minnesota.[27]

The hemlock's shallow root system excels along riparian corridors, where the soil remains moist throughout the year.[28] These shade-tolerant trees form dense canopies that provide cool refuge for fish and wildlife.[29] Rich in biodiversity, eastern hemlock forests are habitat for more than 120 different vertebrate species, including black bear, marten, fisher, bobcat, white-tailed deer, snowshoe hare, red squirrel, porcupine, ruffed grouse, pileated wood pecker, yellow-bellied sapsucker, goldfinches, crossbills, and grosbeaks. They provide essential foraging and nesting habitat for the Blackburnian warbler, Arcadian flycatcher, and blue-headed vireo.[27] Fish, salamanders, and freshwater invertebrates intolerant of seasonal drying are also found in and along hemlock-shaded streams.[30]

Benefits for Humans and Wildlife

The eastern hemlock is used commercially for pulp, paper, lumber, and mulch.[31]

As an evergreen that loses water to the atmosphere year-round, hemlocks profoundly affect water dynamics across eastern mountain ecosystems,[31] regulating streamflow and moderating water temperature.[32] They also minimize nitrate and other nutrient runoff, thereby improving downstream water quality for human consumption and wildlife.[33]

Hemlocks shelter white-tailed deer and other wildlife during New England's harsh winter storms.[34] Cool and densely shaded in the summer, hemlock stands provide important wildlife habitat, as well as hunting, camping, and other recreational opportunities. Streams sheltered by hemlocks are more likely to contain brook trout[28] and are therefore popular areas for trout fishing.

Threats from Global Warming

Global warming poses a threat not only by reducing suitable habitat for hemlocks[35] but, perhaps more importantly, by facilitating the expansion of the hemlock woolly adelgid (HWA).[33,36] The HWA is a sap-sucking insect accidentally introduced from Japan into the southeast in the early 1950s[37] and has infested more than half of the eastern portion of the hemlock's range. Lacking natural enemies, the HWA can kill a hemlock tree in as few as four years.[38] Cold hard winters lower the survival rate of

Hemlock forests provide habitat for more than 120 vertebrate species, including the bobcat.

USFWS

"Caroline hemlocks are being attacked by the woolly adelgid, abetted by warmer winters." [42]

– Steve Moore, Director of Climate and Energy, South Carolina Wildlife Federation, 2008

HWAs, but, rising temperatures due to global warming will likely allow the HWA to expand northward throughout the hemlock's range.[39,40]

The loss of the hemlocks from global warming's combined effects on habitat availability and HWA infestation threatens to destroy the entire ecosystem, leading to an irreversible loss of North American biodiversity.[34,39] Forest canopies will become more open as hemlocks are lost, and cold water streams will become warmer and thus less suitable for brook trout and other aquatic and semi-aquatic species.

In the northeast alone, with nearly 23 percent of the total volume of softwood available for commercial use at risk,[41] economic losses may be significant.

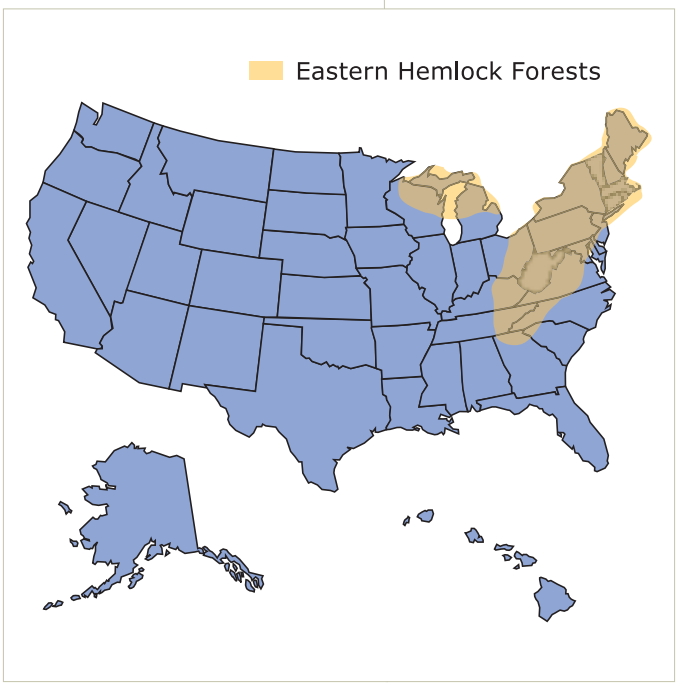
Connecticut Agricultural Experiment Station Archive

Egg sacks of the Woolly Adelgid, an invasive non-native species, on Eastern hemlock

Conservation Investments to Minimize Global Warming Impacts

Forest managers are seeking methods to control the populations, spread and impacts of woolly adelgids. This is of greater importance now as global warming hastens the northward spread of this deadly pest. Scientists must research and implement integrated pest management to facilitate prevention and treatment of infestations.[28] Efforts may include using chemical agents to protect healthy trees (until natural enemies of the pest can be identified) and setting standards for salvage logging that reflect best management practices.[28]

Where hemlocks have died out and when woolly adelgid infestations are better managed, widespread efforts will be needed to restore hemlocks in their historic range so that they may once again provide their many unique ecological and economic benefits.



Estuaries and Coastal Wetlands

The Habitat

The nation has more than 88,000 miles of tidal shoreline[43] harboring vast areas of coastal wetlands and more than 100 estuaries where major rivers enter the sea. These habitats are transition zones between fresh water and salt water, and among the most productive habitats on Earth.

The nation's largest estuary – Chesapeake Bay – exemplifies the economic and aesthetic values of estuaries, even though significantly degraded from its historic productivity. This estuary alone supports more than 3,600 species of plants, fish, and animals.

Louisiana is home to about 40 percent of the nation's coastal wetlands,[44] sheltering more than 120 plant species.[45] Estuaries and coastal wetlands contain important nursery areas for many marine species and harbor large populations of wintering waterfowl, ospreys, bald eagles and a diversity of other wildlife.

Benefits for Humans and Wildlife

Fishing, tourism, and recreational boating associated with estuaries supports more than 28 million jobs in the U.S. In 2006, an estimated $491 million in fish and wildlife was extracted from Louisiana,[46] with much of that dependent upon or from coastal wetlands. Chesapeake Bay waters alone produce some 500 million pounds of seafood for human consumption each year. Some 75 percent of commercial fisheries rely upon estuaries and coastal wetlands for habitat.

These areas improve water quality, provide flood control benefits, and dissipate storm surges, thereby helping to protect coastal areas. Important in rural economies, estuaries and coastal wetlands support both local subsistence needs and a strong recreational fishing industry.[47]

Threats from Global Warming

Global warming has the potential to completely alter the structure and function of the nation's estuaries and coastal wetlands. Sea level rise threatens to inundate many coastal wetlands, with little room to move inland because of coastal development. Already sharply reduced in acreage, coastal freshwater wetlands are especially vulnerable to rising sea levels. In the next 100 years, taking into account the ongoing sinking of land in some coastal areas, net sea-level rise could exceed six feet.[48]

Warmer water from global warming will alter the species composition and contribute to worsening dead zones and harmful algal blooms, increased

Blackwater National Wildlife Refuge

USFWS

"We must invest in conserving our estuaries and coastal wetlands, because they are on the front line of major global warming impacts." [51]

– Doug Inkley, Senior Scientist,
Conservation Programs,
National Wildlife Federation, 2008

incidence of marine diseases, and expansion of harmful invasive species.[49]

Floods, droughts and other extreme weather events will alter water flows, leading to more polluted runoff and lower water quality. Stronger hurricanes and storms threaten to damage coastal wetlands, as demonstrated by Hurricanes Katrina and Rita which destroyed more than 100 square miles of Louisiana's coastal wetlands.

Conservation Investments to Minimize Global Warming Impacts

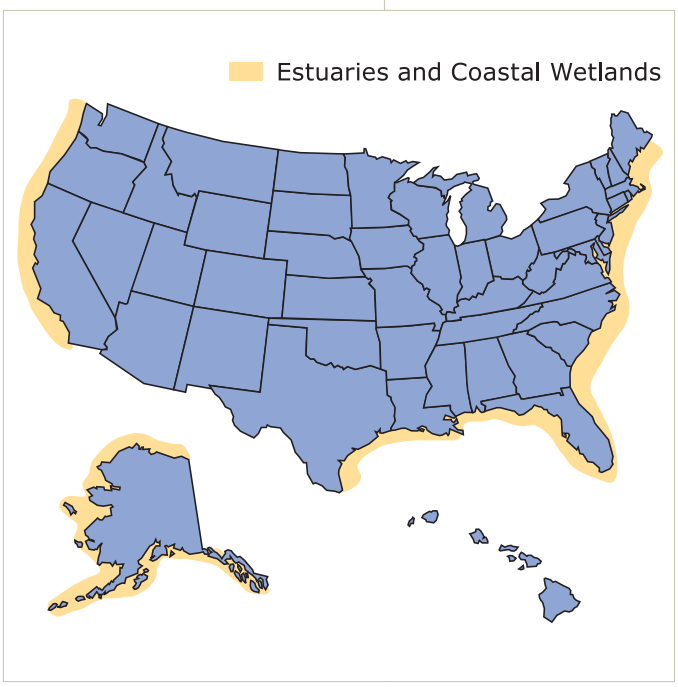
Extensive restoration of coastal wetlands has great potential to minimize the impacts on coastal communities of stronger hurricanes associated with global warming. This is because storm surges and hurricane strength are dissipated by coastal wetlands – a lesson learned too late in Louisiana. Needed actions for restoration include diverting freshwater and sediment from the Mississippi and its distributaries, replanting marsh vegetation and closing channels that allow saltwater to flow into freshwater marshes.[50]

Wherever coastal wetlands exist it will be necessary to account for sea level rise if commercial and recreational fisheries are to be retained at even near current values. This will require protection of current upland areas where coastal wetlands can develop as the sea level rises. It will also be necessary to improve storm water management to minimize exacerbated storm flows and keep stream temperatures down.

Increased monitoring of fish populations will be necessary so that commercial and recreational fishing regulations can be adjusted as populations are affected by changing water temperatures and quality.

NOAA

Blue crab



The Great Lakes

The Habitat

The Great Lakes are a crown jewel of North America, holding nearly one-fifth of the planet's surface freshwater. They have nearly 11,000 miles of shoreline and harbor more than 530,000 acres of coastal wetlands and the world's largest freshwater delta (in Lake St. Clair).[52,53] They range from the cold and deep waters of Lake Superior to the relatively warm and shallow waters of Lake Erie.

The watershed drains more than 200,000 square miles ranging from heavily forested areas to mixed urban and agricultural development, and supports approximately 6,000 species. The lakes are home to numerous fish, including species undergoing restoration efforts such as lake trout and lake sturgeon, and species that are popular in commercial or recreational fisheries, including lake whitefish, walleye, muskellunge and several introduced salmon species.

Benefits for Humans and Wildlife

The Great Lakes are important sources of drinking water, economic livelihood and recreation opportunities for millions of Americans and Canadians.[54]

Recreational boating in the eight Great Lakes states produces more than $35 billion in economic activity annually, and fishing, hunting and wildlife watching amount to more than $18 billion in annual economic activity in these states.[55]

Threats from Global Warming

Global warming adds yet another stress to a Great Lakes system already struggling with aquatic invasive species, deleterious land use changes, nonpoint source pollution, toxic chemical contamination, and coastal habitat degradation/wetlands loss.[56] Potential global warming impacts include reduced water levels (due in particular to decreased winter ice cover allowing more evaporation), increased frequency of intense storm events (altering the timing of inflows), and warmer water temperatures.[57] Already, Lake Superior has increased water temperatures and an earlier onset of summer stratification by about two weeks in just the past 30 years. Within another 30 years Lake Superior may be mostly ice-free in a typical winter.[58] Lake Erie water levels, already below average, could drop 4-5 feet by the end of this century, significantly altering shoreline habitat.[59]

Global warming could change internal water cycling in the Great Lakes with longer summer stratification potentially leading to larger dead

Lake Michigan and the other Great Lakes provide important natural resources.

iStock

"Climate change is already making an impact on the environment of the Great Lakes region. Waiting to begin reducing emissions or to plan for managing the effects of climate change only increases the eventual expense and the potential for irreversible losses." [63]

– George W. Kling (and coauthors),
Professor, Department of Ecology & Evolutionary Biology,
University of Michigan, 2003

zones (lacking in oxygen).[60] Other potential consequences include less habitat for cold water fish, more suitable temperatures for aquatic invasive species and hazardous algal blooms, and more mobilization of contaminated sediments as well as nutrients and toxic chemicals from urban and agricultural runoff.[61]

Conservation Investments to Minimize Global Warming Impacts

Global warming-induced water level declines increase the need to adopt the Great Lakes-St. Lawrence River Basin Water Resources Compact to protect against large-scale out-of-basin diversions, and implement programs to reduce agricultural and urban water use through conservation. As lake levels decline and shoreline wetlands are lost, efforts will be needed to enhance protection, restoration, and development of wetlands at lower water levels to retain their many functions including wildlife habitat and water purification.

The potential for new exotic species to take hold as the water warms could exacerbate an already serious aquatic invasive species problem. Adequate programs to prevent the introduction of new species (e.g., through adequate screening, early detection and rapid response, and treatment protocols) and restrict movement for those invasive species already in the region are essential.

Global warming has the potential to profoundly influence water supply and its quality for the Great Lakes from the surrounding watershed. To maintain healthy lakes it will be important to monitor and manage impacts in the watershed, such as storm surge inputs and erosion. The altering of hydrological cycles by global warming may even require that stormwater and wastewater treatment infrastructures are redesigned or upgraded.

The Great Lakes Regional Collaboration process recommended major restoration of the Great Lakes at a cost of about $20 billion over five years.[56] If implemented, this could result in $80 - $100 billion in short and long-term economic benefits to the regional and national economies and is a worthy cause.[62] However, to be effective, these assessments and the restoration efforts must take into account global warming.

Mangroves

The Habitat

Mangrove forests live in two worlds at once – at the interface between land and sea – anchoring their stilt-like roots in brackish waters where other plants cannot grow. In the United States, they are found along the coasts of Florida, covering some 469,000 acres from St. Augustine south on the Atlantic, and from Cedar Key south on the Gulf Coast. Four species of mangrove trees – red, black, and white mangroves, and buttonwoods – grow on Florida's offshore islands and tidal estuaries. They also are important in Puerto Rico and the Virgin Islands. In many tropical countries, mangroves are the prevalent ecosystem along low-lying estuaries and coasts.

Mangroves host a variety of fish and wildlife, including wading and sea birds, such as the great white heron and brown pelican, which roost and nest in the mangroves.

Benefits for Humans and Wildlife

Mangroves play a critical role in protecting lives and property in low-lying coastal areas from storm surges, which are expected to increase with global warming. They also stabilize shorelines and improve water quality.

Mangrove ecosystems serve as breeding, feeding, and nursery grounds for many shellfish, fish, and other wildlife. An estimated 75 percent of game fish, and 90 percent of commercial species in South Florida depend on mangrove ecosystems.[64] Endangered species such as the Key deer live here.

The annual economic value of mangrove habitats is estimated at $80,000 - $360,000 per acre.[65]

Threats from Global Warming

Rising sea levels and changing salinity pose the most serious threats to these ecosystems. Where mangroves are sheltered by coral reefs killed by global warming, damage to mangroves from increased wave action is expected to rise.

Loss of mangroves will have a serious economic impact on both fisheries and coastal communities. In developing countries, mangroves have proven critical for saving human lives by their dampening of the wave heights and wind speeds during coastal storms.

Conservation Investments to Minimize Global Warming Impacts

With so little known, it will be important to

Mangroves buffer coasts from the impacts of coastal storms.

James Denny Ward, US Forest Service

"What we learn about how global warming affects mangroves will be important for their conservation around the world." [51]

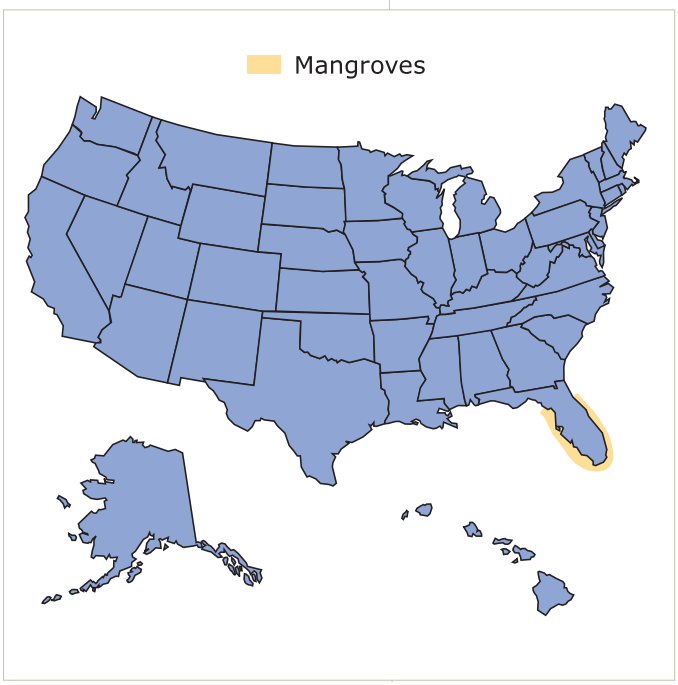
– Barbara Bramble, Senior Program Advisor, International Affairs, National Wildlife Federation, 2008

monitor the responses of mangroves to global warming, and from this learn methods of minimizing these impacts and reestablishing mangroves. This will be especially important for assisting developing countries that depend on the health of these ecosystems for sustenance. Restoring mangrove vegetative cover and ecological functions can cost up to $87,000 per acre.[66]

Unable to directly control sea level, managers will need to ensure that other human stresses on mangroves are minimized to give mangroves the best opportunity to withstand the duress of global warming impacts. This may require, for example, improving land-use management and stream water quality on nearby lands. Other possible actions may include implementation or adjustment of recreational and commercial fishing regulations.

Wendy Lefkowich, Flickr

Tri-colored heron



Prairie Potholes

The Habitat

Sweeping across five Midwestern states (North Dakota, South Dakota, Iowa, Minnesota, and Montana) and four Canadian provinces, America's prairie potholes occupy 64 million acres of what was once the heart of the Great Plains of North America. Millions of shallow depressions were left as the ancient glaciers retreated. These round (like a 'pot') depressions are often filled with water, especially in wetter years, creating valuable wetlands. While some of these potholes never dry up, during times of drought the number of potholes with water declines dramatically.

Waterfowl breeding here include pintail, gadwall, blue-winged teal, green-winged teal, shovelers, canvasbacks and redheads and wigeon. Many other birds also depend on the potholes, such as the marbled godwit, bobolink, short-eared owls, Wilson's phalarope, Baird's sparrow, Sprague's pipit, and the increasingly rare grasshopper sparrow.

Benefits for Humans and Wildlife

The prairie potholes are extremely important to the nation's waterfowl populations. Some 50 to 80 percent of North America's annual duck production comes from the prairie potholes.[67] During migration ducks from this region disperse throughout the lower-48 states and Alaska, where they are highly sought after by waterfowl hunters and bird-watchers, serving as an important economic resource for local cities and towns.

Prairie potholes also serve as natural sponges that hold excess water, and recharge groundwater systems that supply water to farmlands and wells in the region. In addition, the potholes provide water and forage for livestock.

Threats from Global Warming

Left unaddressed, global warming may dramatically reduce the suitability of prairie potholes for waterfowl. As open water and soil moisture decrease with rising temperatures and more severe droughts, many prairie potholes are expected to dry up more frequently or sooner in the spring, thereby eliminating or reducing their suitability for breeding waterfowl. Drought conditions brought on by global warming could dry up as much as 90 percent of the region's remaining wetlands, leading to nearly a 60% decline in breeding waterfowl in the region, and declines in other wetlands species as well.[68]

Compounding the impact of global warming is the fact that the prairie pothole region has already

The prairie potholes of the upper Midwest provide breeding habitat for 50-80 percent of the continent's waterfowl, which migrate throughout North America.

USFWS

"The current difficulties of protecting prairie pothole wetlands will be exacerbated by climate change, and addressing them will require significant new investments." [51]

– Scott Yaich, Director of Conservation Operations, Ducks Unlimited, Inc., 2008

lost up to 70 percent of its original wetlands, mostly to agriculture, and the losses continue. Thus, conserving the remaining prairie potholes is all the more important to maintain waterfowl populations, but also to maintain both surface and ground water availability for agricultural purposes, including grazing and crop irrigation.

Conservation Investments to Minimize Global Warming Impacts

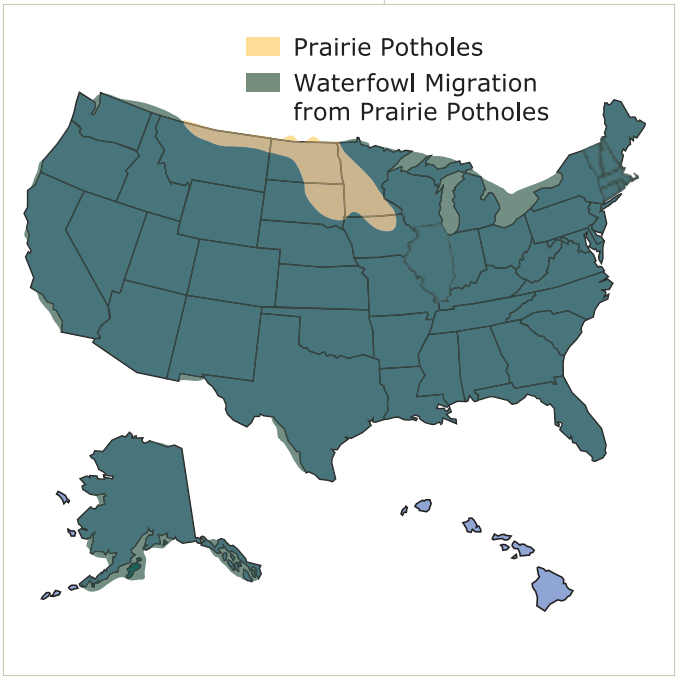
Minimizing impacts of global warming will require programs to secure conservation easements and discourage further draining or plowing of the remaining pothole wetlands. This is important to ensure that during times of severe droughts from global warming, a sufficient number of potholes with water are left to sustain minimal waterfowl populations.

Further protection from global warming can be achieved by undertaking efforts to restore degraded, drained and destroyed prairie potholes across a broad expanse of this historic region. Studies have shown that the most suitable areas for waterfowl production vary from year to year within the prairie pothole region due to local climatic conditions. Thus, conserving and restoring wetlands across a broad range is necessary so that as the region becomes dryer overall due to global warming, there will still always be some areas for waterfowl to breed.

The Prairie Pothole Joint Venture (PPJV), established in 1987 under the North American Waterfowl Management Plan, has called for the protection of 1.4 million acres of wetlands and 10.4 million acres of surrounding grasslands (for nesting and cover) to help conserve waterfowl and wildlife populations. The PPJV estimates it will cost $2.7 billion to conserve the 11.8 million acres.[69]

USFWS

Canvasbacks breed primarily in the Prairie Potholes.



Sagebrush Steppe

The Habitat

Sagebrush steppe habitats cover 165 million acres in eleven western states (and one Canadian province). This widespread yet fragile ecosystem is characterized by abundant sagebrush, but also contains a diversity of other native shrubs, grasses, and flowering plants. Sagebrush steppe terrain is typically flat or gently rolling, with water running intermittently through shallow creeks and occasionally deeper canyons. With low rainfall, vegetation is low and sometimes sparse, with the few trees largely confined to stream channels where water is more abundant.

Benefits for Humans and Wildlife

The headwaters of several great river systems – the Columbia, Colorado, and Missouri – originate in sagebrush steppe and provide important ecological services such as retaining nutrients and sediments, and capturing scarce snow and rainfall which flow downstream to provide critical water needs for agriculture and cities.

Sagebrush steppe is important to the ranching industry, as nearly all sagebrush habitats are grazed by livestock, whether on private or public lands.

Sagebrush steppe habitats are essential for survival of sage-grouse and pronghorn, both uniquely adapted to consume sagebrush, and important for mule deer and elk, all of which are much sought after by sportsmen. More than 170 other species of birds and mammals utilize these semi-arid and cold habitats, including black-tailed jackrabbits, prairie falcons and golden eagles.[70]

Threats from Global Warming

Nearly 60 percent of all sagebrush habitats could be lost if global warming pollution continues on a path of "business as usual," with carbon dioxide concentrations reaching double historic levels.[71]

The combination of global warming with other human-associated impacts, such as overgrazing, make these areas especially vulnerable. More severe droughts, together with high levels of livestock grazing would cause significant loss of soil as well as significant declines of perennial grasses and forbs important to many wildlife species and livestock.

The increase of severe droughts associated with global warming will exacerbate cheatgrass growth and the spread of other harmful invasive species, thereby converting sagebrush steppe into exotic annual grassland with less forage value. Furthermore, cheatgrass and other invasive plants increase the frequency and intensity of wildfires, thereby leaving sagebrush habitat with little chance of recovering, increasing the costs of fire suppression and control, and increasing risks to human lives and facilities.

Conservation Investments to Minimize Global Warming Impacts

Maintenance of grazing land productivity for both wildlife and livestock as the climate warms will necessitate range-wide programs to limit the spread of cheatgrass and other harmful invasive species, and to restore already degraded areas so that they have greater resilience to global warming. Erosion control measures will likely become necessary to reduce stream erosion and sedimentation to protect downstream water quality for ranchers, farmers and cities. As soil moisture declines and even mild droughts exacerbate water loss, efforts may be needed to supply surface water where natural sources have dried up.

Sagebrush steppe habitat

RickC – Flickr

"Global warming can disrupt the balance of the entire sagebrush steppe ecosystem. It's much less costly to conserve what we have now than to try to restore these habitats after they are damaged." [51]

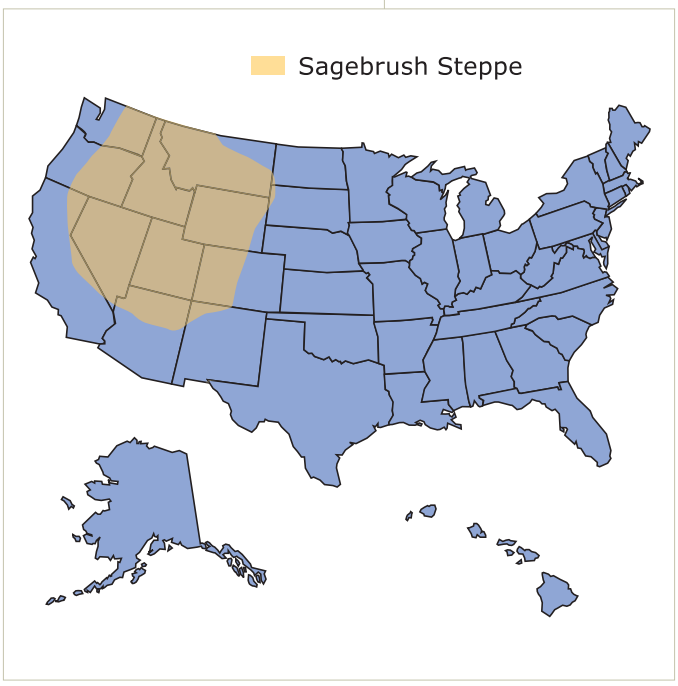
– San Stiver, Wildlife Biologist,
Western Association of Fish and Wildlife Agencies, 2008

The Western Association of Fish and Wildlife Agencies has called for new conservation measures to increase the resiliency of the sagebrush steppe habitats and sage-grouse populations they support.[72] Protecting just sage-grouse habitats and populations, which now must endure the additional stresses of global warming, will require an estimated $431 million in spending by 2014. Management activities include wildfire suppression, regeneration of sagebrush habitats and control of exotic invasive plants species.

Managers will also need to monitor sagebrush steppe habitats for unexpected impacts of global warming and develop and implement programs to minimize these impacts as the needs arise.

Donald M. Jones / www.donaldmjones.com

Sagebrush steppe habitat is critically important to pronghorn.



Southwestern Streams

The Habitat

Southwestern streams originating in high mountains are fed by snow pack and often flow throughout the year because of this summertime water source. There are also an abundance of intermittent or ephemeral southwestern streams that flow only in spring or during heavy rains. At lower altitudes these streams flow through desert and steppe habitats with very low rainfall, and are often the only water source across large landscapes. The stream corridors harbor plants, such as native cottonwood and willows that are unable to survive in the dryer surrounding uplands.

Benefits for Humans and Wildlife

The value of western streams is so great that it is essentially incalculable. Just their importance for supplying drinking water to major cities, such as Phoenix, Las Vegas and Los Angeles, is huge. They also supply essential irrigation water for large-scale farming, especially during the summer growing period when temperatures are high and snow pack melt becomes the primary source of water.

Western streams provide critical instream flows that nurture diverse ecosystems and wildlife, without which the ecology of the Southwest would be radically different. The diversity and productivity of western streams are important for many Native American tribes. For example, the Lower Colorado is vital to the Cocopah Tribe for subsistence, cultural, economic, and recreational activities.

Whether permanent or intermittent, western streams are important recreational areas throughout the southwest, with both the permanent and higher altitude streams supporting recreational fishing. The stream habitats are used extensively by migratory birds during nesting and migration, as well as a variety of other wildlife including beaver and deer.

Threats from Global Warming

The threat to western streams from global warming is extensive. As a result of rising winter temperatures reducing the winter accumulation of snow pack in western mountains, the amount of available spring and summer melt water is declining. An equally significant threat is that spring temperatures are arriving as much as 3-4 weeks earlier than in the past, also reducing the amount of water available in the summer and fall. With only a 1.5 degree F increase in average global temperature, the Colorado River may shrink to its lowest level in at least 500 years.[73] This is expected to occur within the lifetime of children born now, even with immediate reductions in greenhouse gas emissions. Lake Mead, a major reservoir on the Colorado River, is less than half full and could run dry by 2020.[74] Increased severity of droughts and flood events from global warming will also affect water supply, and water quality.

The decline of water availability caused by global warming will exacerbate an already severe shortage of water in many areas of the Southwest. Water prices will likely sky-rocket as growing water demand conflicts with declining water availability. Mandatory water restrictions will likely affect people's daily lives and the economic survival of irrigated croplands. These water wars may leave fish and wildlife last in line.

The white "bathtub ring" marks the level of high-standing water in Lake Mead. Lake Mead could run dry by 2020 due primarily to global warming.

"The Cocopah are the River People. Climate change threatens the survival of the Colorado River. If you take the river, the trees and animals away, I will have no identity. If the river stops flowing, we will no longer exist." [51]

– Colin Soto, Cocopah Tribal Elder, 2008

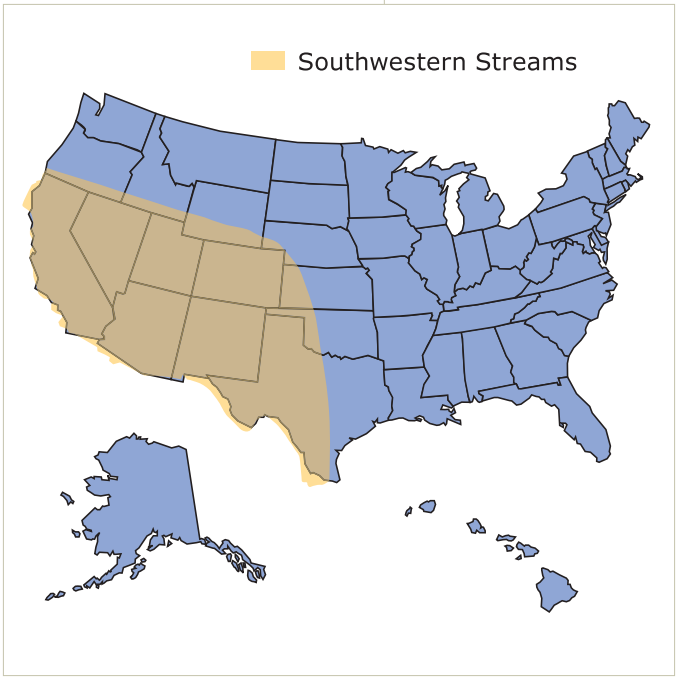
Conservation Investments to Minimize Global Warming Impacts

Addressing exacerbated water shortages brought on by global warming will require a diversity of approaches. Considerable investment will be needed to reduce water demand by assisting homes, businesses and agriculture in developing new water conservation strategies and low water use technologies.

Stream corridors should be restored to natural conditions wherever possible to maintain optimal water flows and habitat for fish and wildlife. Restoration of native plant species along southwestern streams is vital for wildlife survival and diversity. Ensuring base flows and restoring natural flood flows is also critical to preserving natural stream habitat processes. On the Lower Colorado River alone, riparian and river flow restoration has a price tag of more than $250 million.

USFWS

Western rivers provide diverse productive habitats, like this wetland on the lower Colorado River, in relatively dry landscapes.



Western Forests

The Habitat

Western forests (including Alaska) cover more than 360 million acres across vast and often rugged terrain.[75] Ranging from large fast-growing trees along the Pacific coast to high-altitude tree lines where tree size is smaller and growth much slower, most western forests are coniferous, although there are also significant hardwood forests.

The interspersion of western forests with shrub steppe habitats, mountain meadows and streams provide important habitat for a rich diversity of wildlife species ranging from songbirds to large ungulates such as elk, moose and deer.

Benefits for Humans and Wildlife

Western forests are extensively managed and harvested to supply wood for home construction and other purposes. In many areas of the West lumbering is the major economic driver. Forests and their interspersed grasslands provide grazing lands used extensively for ranching. These habitats also contribute greatly to water supply and quality, as well as air quality.

Western forests are very important for hunting, fishing and many other popular outdoor recreational activities, such as hiking.

Threats from Global Warming

Global warming will have a huge impact on western forests, and in fact already is. Warmer winter temperatures are contributing to unnaturally large, frequent and deadly outbreaks of bark beetles. As a result, nearly half of Colorado's 660,000 acres of lodgepole pine forests were infested by mountain pine beetles in 2006.[76] Eastern Washington State lost 4 million ponderosa and lodgepole pine trees in 2004 alone.[77] Outbreaks have also occurred in Alaska, Arizona, California, Idaho, Montana, New Mexico, Oregon and Wyoming.

These tree-killing insect epidemics set the stage for catastrophic wildfires, especially in combination with the higher temperatures caused by global warming, leading to lower soil moisture. Moderate fire is natural and helpful in many ecosystems, but catastrophic, drought-fueled fire with abundant fuel from large acreages of dead trees can destroy vast expanses of wildlife habitat, put human lives at risk and cause extensive property damage. In the Western United States scientists have documented a six-fold increase in the area burned over the past two decades, which they attribute to global warming.[78] These forest fires exacerbate the global warming problem because the burning forest

Western forests experience larger and more frequent deadly spruce beetle outbreaks due to global warming.

Andris Eglitis, USDA Forest Service

> "The western U.S. in particular is in for longer, hotter summers and I can conclude nothing else but that's going to increase wildfire dynamics." [80]
>
> – Steven Running, Professor of Ecology, University of Montana

releases more carbon dioxide into the atmosphere.

The economic costs of tree die-offs and catastrophic fires associated with global warming are almost beyond reckoning. Damage to homes and property from wildfires totaled $3.2 billion during the 1990s. In 2006 alone, the Federal government spent $1.5 billion to fight forest fires (throughout the U.S.).[79] While loggers have in some places turned to harvested trees killed by insect epidemics, large forest fires lead to the loss of income and jobs in the logging industry. Continued warming and more severe droughts associated with global warming will only further increase the risks and costs of catastrophic wildfires.

Catastrophic fires are especially damaging when they destroy the fertile detritus layer of soils, leaving only highly erodible mineral soils. Reduced vegetative cover, increased erosion and higher stream temperatures are harmful to cold-water species such as trout.

Conservation Investments to Minimize Global Warming Impacts

Minimizing the impact of global warming on western forests will require extensive financial investment in a variety of management actions. The beetle outbreaks aided by global warming have created challenges for forest managers who must now incorporate new ecological, economic and social issues into forest management plans.

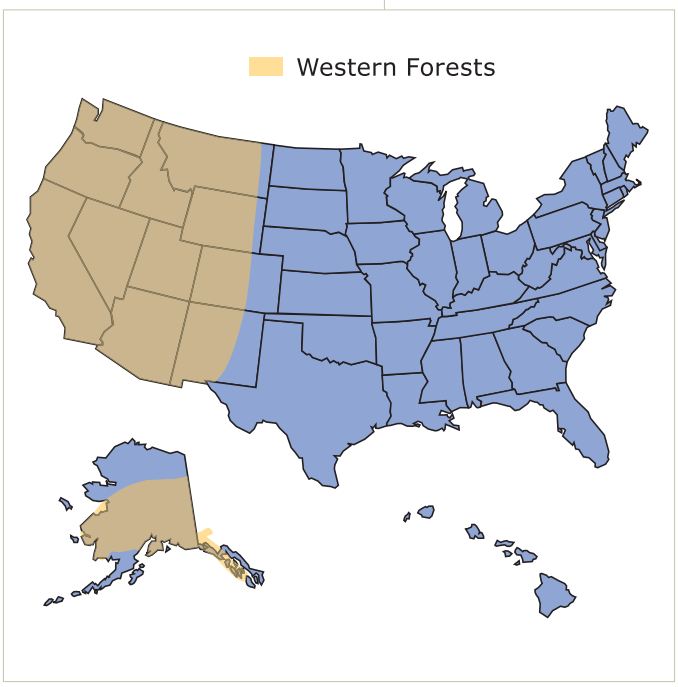
Forest managers need to research and implement new methods of suppressing large beetle outbreaks to avoid extensive loss of mature trees. They will also need to study methods of reducing fuel loads and fire risks without detriment to natural ecological cycles. This may require extensive increases in prescribed (controlled) burning, selective logging, and other techniques to reduce fire risk.

The cost of additional firefighting alone will be enormous. Already costing $1.5 billion annually, investing in additional fire management and control will be essential for minimizing an increase in fire risk associated with a hotter and dryer climate.

The increase in area burned requires extensive restoration efforts to minimize impacts. These efforts will need to include, among other things, reforestation and erosion control. Reforestation reduces water problems caused by loss of snowpack. It also will improve air quality, and enable sequestration of atmospheric carbon dioxide through growth.

Ducks Unlimited Canada (D. Faucher)

Western forests provide habitat for many species, including this evening grosbeak.



References

[1] www.amnh.org /common/faq/quotes.html

[2] Intergovernmental Panel on Climate Change (IPCC). 2007.

[3] www.fws.gov/home/climatechange/

[4] Stern Review: The economics of Climate Change. 2006.
www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm

[5] www.munichre.com/en/press/press_releases/2007/2007_12_27_press_release.aspx

[6] Brown, L. 2008. Plan B 3.0 Mobilizing to Save Civilization. Earth Policy Institute. W.W. Norton and Company.

[7] *transcripts.cnn.com/TRANSCRIPTS/0508/29/asb.01.html* and Peter Grier, "The Great Katrina Migration", Christian Science Monitor, 12 September 2005.

[8] CCSP. 2008. Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, DC, USA, 445 pp. www.climatescience.gov/Library/sap/sap4-7/final-report/

[9] Costanza, R. et al. 1997. "The Value of the World's Ecosystem Services and Natural Capital." Nature 387:253-260 and Wetland Values and Functions. Also: The Ramsar Bureau. www.ramsar.org/info/values_intro_e.htm

[10] M.G. Anderson and L.G. Sorenson. 2001. "Global Climate Change and Waterfowl: Adaptation in the Face of Uncertainty." Transaction of the 66th North American Wildlife and Natural Resources Conference (Washington, DC: Wildlife Management Institute, 300-319.

[11] Pimentel, D. Wilson, C. McCullum, C. Huang, R. Dwen, P., Flack, J. Tran, O., Saltman, T. And B. Cliff. 1997. Economic and Environmental Benefits of Biodiversity. BioScience 47(II)747-757.

[12] Krieger, D.J. 2001. The Economic Value of Forest Ecosystem Services: A Review. The Wilderness Society.

[13] www.infoplease.com/spot/forestfire1.html

[14] Outdoor Industry Foundation. 2006. Active Outdoor Recreation Economy.
www.outdoorfoundation.org/pdg/ResearchRecreationEconomy.pdf

[15] www.outdoorfoundation.org/news.oif.php?news_id=1522&sort_year=2007

[16] www.thegreatwarming.com/revrichardcizik.html

[17] E. Roberts. 2003. "Scientists Warn of Coral Reef Damage from Climate Change," Marine Scientist 2: 21-23.

[18] Florida Keys National Marine Sanctuary. floridakeys.noaa.gov/sanctuary_resources/welcome.html

[19] C. Birkeland, ed., 1997. Life and Death of Coral Reefs (New York, NY: Chapman and Hall).

[20] P.L. Jokiel. 2004. "Temperature Stress and Coral Bleaching," pp. 401-428 in E. Rosenberg and Y. Lola, eds., Coral Health and Diseases (Berlin, Germany: Springer).

[21] C. Wilkinson, ed. 2004. Status of Coral Reefs of the World: 2004 (Townsville, Queensland, AU: Global Coral Reef Monitoring Network and Australian Institute of Marine Science).

[22] C.D. Harvell, et al. 2007. "Coral Disease, Environmental Drivers, and the Balance Between Coral and Microbial Associates," Oceanography 20: 172-195.

[23] I Kruffner and A. Tihansky. 2008. Coral Reef Builders Vulnerable to Ocean Acidification (Reston, VA: U.S. Geological Survey).

[24] J.A. Kleypas, et al. 2006. Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research, report of a workshop held 18-20 April 2005, St. Petersburg, FL., sponsored by NSF, NOAA & USGS.

[25] G.D. Grimsditch and R.V. Salm. 2005. Coral Reef Resilience and Resistance to Bleaching (Gland, Switzerland: The World Conservation Union).

[26] www.fieldandstreamextras.com/heroes/blog/labels/Discussion%20Topics.php

[27] J.S. Ward, M.E. Montgomery, C.A.S.J. Cheah, B.P. Onken, and R.S. Cowles. 2004. Eastern Hemlock Forests: Guidelines to Minimize the Impacts of Hemlock Woolly Adelgid. U.S.D.A. Forest Service, Northeastern Area State and Private Forestry. Report NA-TP-03-04.

[28] B.P. Onken. 1996. Long-term impact assessment of eastern hemlock forests. Pp. 58-63 in S.M. Salom, T.C. Tigner, and R.C. Reardon (eds.). Proceedings: First Hemlock Woolly Adelgid Review, Oct. 12, 1995. Charlottesville, VA. U.S.D.A. Forest Service.

References

[29] M. Yamasaki, R.M. DeGraaf, and J.W. Lanier. 2000. Habitat associations in Eastern hemlock birds, smaller mammals, and forest carnivores. Pp. 135-141 in K.A. McManus, K.S. Shields, and D.R. Souto (eds). Proceedings: Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America, June 22-24, 1999. Durham, NH: U.S.D.A. Forest Service.

[30] C.D. Snyder, J.A. Young, and D. Smith, et al. 2002. Influence of eastern hemlock (Tsuga Canadensis) forests on aquatic invertebrate assemblages in headwater streams. Canadian Journal of Fisheries and Aquatic Sciences 59: 262-75.

[31] C.R. Ford and J.M. Vose. 2007. Tsuga Canadensis (L.) Carr. Mortality will impact hydrologic processes in southern Appalachian forest ecosystems. Ecological Applications 17(4): 1156-67.

[32] R.A. Evans. 2002. An ecosystem unraveling? Pp. 23-33 in B. Onken, R. Reardon, L. Lashomb (eds). Proceedings: Hemlock Woolly Adelgid in the Eastern United States Symposium, Feb. 5-7, 2002. East Brunswick, NJ: Rutgers University.

[33] P.C. Frumhoff, J.J. McCarthy, J.M. Melillo, S.C. Moser, and D.J. Wuebbles. 2007. Confronting Climate Change in the U.S. Northeast: Science, Impacts, and Solutions. Synthesis report of the Northeast Climate Impacts Assessment. Cambridge, MA: Union of Concerned Scientists

[34] A.M. Ellison, M.S. Bank, B.D. Clinton, E.A. Colburn, K. Elliott, C.R. Ford, D.R. Foster, B.D. Kloeppel, J.D. Knoepp, G.M. Lovett, J. Mohan, D.A. Orwig, N.L. Rodenhouse, W.V. Sobczak, K.A. Stinson, J.K. Stone, C.M. Swan, J. Thompson, B.Von Holle, and J.R. Webster. 2005. Loss of foundation species: consequences for the structure and dynamics of forested ecosystems. Frontiers in Ecology and the Environment 3(9): 479-486; R.S. Reay. 2000. Management of eastern hemlock for deer wintering areas. Pp. 144-47 in K.A. McManus, K.S. Shields, and D.R. Souto (eds). Proceedings: Symposium on Sustainable Management of Hemlock Ecosystems in Eastern North America, June 22-24, 1999. Durham, NH: U.S.D.A. Forest Service.

[35] L. Iverson, A. Prasad, and S. Matthews. 2007. Modeling potential climate change impacts on the trees of the northeastern United States. Published online Oct. 31, 2007. www.springerlink.com/content/1381-2386

[36] Paradis, A., J. Elkinton, K. Hayhoe, and J. Buonaccorsi. 2007. Role of winter temperature and climate change on the survival and future range expansion of the hemlock woolly adelgid (Adelges tsugae) in eastern North America. Mitigation and Adaptation Strategies for Global Change. Published online Oct. 11, 2007. www.springerlink.com/content/1381-2386.

[37] N.P. Havill, M.E. Montgomery, G.Y. Yu, S. Shiyake, and A. Caccone. 2006. Mitochondrial DNA from hemlock woolly adelgid (Hempiptera: Adelgidae) suggests cryptic speciation and pinpoints the sources of the introduction to eastern North America. Annals of the Entomological Society of America 99: 195-303.

[38] McClure. 1991. Density dependant feedback and population cycles in Adelges tsugae (Homoptera: Adelgidae) on Tsuga Canadensis. Environmental Entomology 20: 258-64.

[39] Paradis, A., Elkinton, J., Hayhoe, K., and J. Buonaccorsi. 2007. Role of winter temperature and climate change on the survival and future range expansion of the hemlock woolly adelgid (Adelges tsugae) in eastern North America. Mitigation and Adaptation Strategies for Global Change (In Press).

[40] K. Knauer, J. Linnane, K. Shields, and R. Bridges. 2002. An initiative for management of hemlock woolly adelgid. Pp. 9-11 in B. Onken, R. Reardon, L. Lashomb (eds). Proceedings: Hemlock Woolly Adelgid in the Eastern United States Symposium, Feb. 5-7, 2002. East Brunswick, NJ: Rutgers University.

[41] W.B. Smith, P.D. Miles, J.S. Vissage, and S.A. Pugh. 2002. Forest Resources of the United States, 2002. General Technical Report NC-241. U.S.D.A. Forest Service. North Central Research Station, St. Paul, MN.

[42] www.charleston.net/news/2008/mar/11/s_c_s_climate_heritage_threatened_by_glo33426/

[43] www.infoplease.com/ipa/A0001801.html

[44] www.gao.gov/new.items/d08130.pdf

[45] Lester, G.D., S.G. Sorensen, P.L. Faulkner, C.S. Reid, and I.E. Maxit. 2005. Chapter 4: Conservation Habitats & Species Assessments. Louisiana Comprehensive Wildlife Conservation Strategy. Louisiana Department of Wildlife & Fisheries. Baton Rouge, LA. www.wlf.state.la.us/experience/wildlifeactionplan/wildlifeplandetails/

[46] LSU AG Center. 2006. Fish and wildlife enterprises, state totals. www2.lsuagcenter.com/agsummary/

[47] Gramling, R. and Hagelman, R. 2005. A Working Coast: People in the Louisiana Wetlands. Journal of Coastal Research. SI(44): 112-133.

[48] Twilley, R.R. 2007. Coastal wetlands and global climate change: Gulf Coast wetland sustainability in a changing climate. Pew Center on Global Climate Change. www.pewclimate.org/docUploads/Regional-Impacts-Gulf.pdf

[49] Roessig, J. M., C. M. Woodley, J. J. Cech, Jr., and L. J. Hansen. 2004. Effects of global climate change on marine and estuarine fishes and fisheries. Reviews in Fish Biology and Fisheries 14: 251–275

References

[50] Day, J. W., D. F. Boesch, E. J. Clairain, G. P. Kemp, S. B. Laska, W. J. Mitsch, K. Orth, H. Mashriqui, D. J. Reed, L. Shabman, C. A. Simenstad, B. J. Streever, R. R. Twilley, C. C. Watson, J. T. Wells, D. F. Whigham. 2007. Restoration of the Mississippi Delta: Lessons from Hurricanes Katrina and Rita. SCIENCE 315: 1679-1684

[51] Personal communication to National Wildlife Federation, 2008.

[52] Government of Canada and U.S. Environmental Protection Agency. 1995. The Great Lakes: An Environmental Atlas and Resource Book, Fuller, K., Shear, H., and Wittig J., Eds.; Michigan Sea Grant, The Great Lakes fact sheet. www.miseagrant.umich.edu/education/greatlakes/images/pdf/06-701-fs-great-lakes.pdf ; Great Lakes Regional Collaboration Strategy to Restore and Protect the Great Lakes, December 2005. www.glrc.us/strategy.html

[53] Pimentel, D., 2005, Aquatic Nuisance Species in the New York State Canal and Hudson River Systems and the Great Lakes Basin: An Economic and Environmental Assessment, Environmental Management, 35(5):692-701.

[504] Government of Canada and U.S. Environmental Protection Agency, 1995, The Great Lakes: An Environmental Atlas and Resource Book, Fuller, K., Shear, H., and Wittig J., Eds.

[55] Great Lakes Regional Collaboration Strategy to Restore and Protect the Great Lakes, December 2005. www.glrc.us/strategy.html.

[56] Bails, J., Beeton, A., Bulkley, J., DePhilip, M., Gannon, J., Murray, M., Regier, H., and Scavia, D. 2005. Prescription for Great Lakes Ecosystem Protection and Restoration. www.healthylakes.org/site_upload/upload/prescriptionforgreatlakes.pdf.

[50] Sousounis, P.J., and Bisanz, J.M., Eds., Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, A Summary by the Great Lakes Regional Assessment Group For the U.S. Global Change Research Program. 2000. www.geo.msu.edu/glra/PDF_files/GLRA_report.pdf.

[58] Austin, J.A., Colman, S.M. 2007. Lake Superior Summer Water Temperatures Are Increasing More Rapidly Than Regional Air Temperatures: A Positive Ice-Albedo Feedback, Geophysical Research Letters, L06604, pp. 1-5.

[59] Lofgren, B.M., Quinn, F.H., Clites, A.H., Assel, R.A., Eberhardt, A.J., Luukkonen, C.L. 2002. Evaluation of Potential Impacts on Great Lakes Water Resources Based on Climate Scenarios of Two GCMs, Journal of Great Lakes Research, 28(4):537–554.

[60] Sousounis, P.J., and Bisanz, J.M., Eds., Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change, A Summary by the Great Lakes Regional Assessment Group For the U.S. Global ChangeResearch Program, October 2000. www.geo.msu.edu/glra/PDF_files/GLRA_report.pdf.

[61] Mortsch, L., Alden, M., Scheraga, J. 2003. Climate Change and Water Quality in the Great Lakes Region: Risks, Opportunities, and Responses, A Report prepared for the Great Lakes Water Quality Board of the International Joint Commission, August, 2003. www.ijc.org/rel/pdf/climate_change_2003_part3.pdf

[62] Austin J.C., Anderson, S., Courant, P.N., Litan, R.E., America's North Coast: A Benefit-Cost Analysis of a Program to Protect and Restore the Great Lakes, September 2007. www.healthylakes.org/site_upload/upload/America_s_North_Coast_Report_07.pdf

[5063] Kling, G.W., K. Hayhoe, L.B. Johnson, J.J. Magnuson, S. Polasky, S.K. Robinson, B.J. Shuter, M.M. Wander, D.J. Wuebbles, D.R. Zak, R.L. Lindroth, S.C. Moser, and M.L. Wilson. 2003. Confronting Climate Change in the Great Lakes Region: Impacts on our Communities and Ecosystems. Union of Concerned Scientists, Cambridge, Massachusetts, and Ecological Society of America, Washington, D.C.

[64] "Mangroves – Florida's Coastal Trees" FOR 43 University of Florida, Cooperation Extension Service, Institute of Food and Agricultural Sciences www.sfrc.ufl.edu/Extension/pubtxt/for43.htm

[65] Wells ,S., C. Ravilous, E. Corcoran. 2006. In the front line: Shoreline protection and other ecosystem services from mangroves and coral reefs. United Nations Environment Programme World Conservation Monitoring Centre, Cambridge, UK, 33 pp.

[66] Lewis, R.R. 2003. Mangrove restoration – Costs and benefits of successful ecological restoration. Proceedings of the Mangrove Valuation Workshop. Stockholm, Sweden, Beijer International Institute of Ecological Economics.

[67] United States Environmental Protection Agency. 1999. "Climate Change and Birds, Change on the Wing." Report Number EPA-236-F-99-0003. yosemite.epa.gov/oar/globalwarming.nsf/UniqueKeyLookup/SHSU5BNNUT/$File/ccandbirds.pdf

[68] M.G. Anderson and L.G. Sorenson. 2001. "Global Climate Change and Waterfowl: Adaptation in the Face of Uncertainty." Transaction of the 66th North American Wildlife and Natural Resources Conference (Washington, DC: Wildlife Management Institute, 2001, 300-319.

[69] Ringelman, J. Conservation Needs in the U.S. Prairie Pothole Region www.ppjv.org/PPJV_presntations/NAWCA_NAWMP_wrapup.pdf

[70] Paige, Christine and Sharon A. Ritter. 1999. Birds in a sagebrush sea: managing sagebrush habitats for bird communities. Partners in Flight, Western Working Group. Boise, ID. 47 pp.

[71] USGS

References

[72] Western Association of Fish and Wildlife Agencies. 2006. Greater sage-grouse comprehensive conservation strategy. National sage-grouse conservation planning framework team, Western Association of Fish and Wildlife Agencies, August 2006.

[73] Saunders,, S., C. Montgomery, and T. Easley. 2008. "Hotter and Drier: The West's Changed Climate" (Rocky Mountain Climate Organization, March 2008).

[74] Barnett, T. and D. Pierce. 2008. "When Will Lake Mead Go Dry?" Water Resources Research 44 (2008).

[75] Derived from America's Private Forests: Status and Stewardship. Constance Best and Laurie A. Wayburn. Island Press, Washington D.C. Pacific Forest Trust Publications. Summer 2001. 224 pp.

[76] today.colostate.edu/index.asp?url=display_story&story_id=1002318

[77] www.nwenvironmentalforum.org/documents/DNRthirdprogressreportOct202006.pdf

[78] Westerling, A. L., H. G. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increases Western U.S. forest wildfire activity. Science 313: 940-43..

[79] www.infoplease.com/spot/forestfire1.html

[80] www.helenair.com/articles/2007/11/02/montana/a011102_05.txt

National Wildlife Federation
11100 Wildlife Center Drive
Reston, VA 20190
703-438-6000
www.nwf.org

Printed on 100% post-consumer chlorine-free paper that is Forest Stewardship Council certified. Printed with soy-based inks.