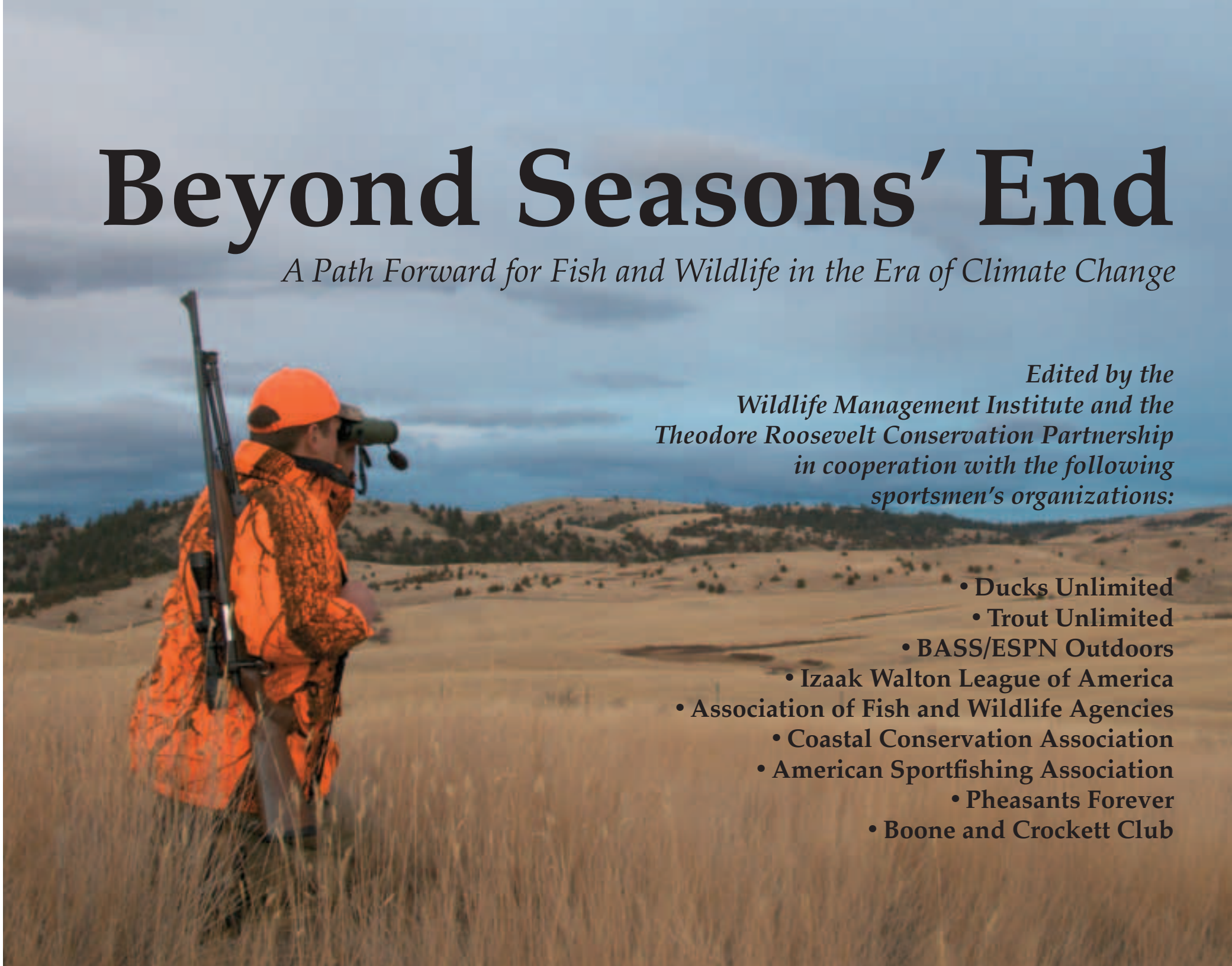

Beyond Seasons' End
A Path Forward for Fish and Wildlife in the Era of Climate Change
Ducks Unlimited | Trout Unlimited | BASS/ESPN Outdoors | Izaak Walton League of America
Association of Fish and Wildlife Agencies | Coastal Conservation Association | American Sportfishing Association
Pheasants Forever | Boone and Crockett Club



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Edited by the Wildlife Management Institute and the Theodore Roosevelt Conservation Partnership in cooperation with the following sportsmen's organizations:

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Bipartisan Policy Center

Concept development, editing and design by Koupal Communications, Pierre, South Dakota

Additional information related to fish and wildlife confronting the threats of climate change, including unabridged chapters of this book and a download of the companion book, Seasons' End, can be found at

www.seasonsend.org

Dusan Smetana's Photography Featured in *Beyond Seasons' End*

All the photographs in *Beyond Seasons' End* are the work of outdoor photographer Dusan Smetana. Raised in a small village in the Czech Republic's Carpathian Mountains, Dusan spent his boyhood following in the footsteps of his father in quest of trout, red deer and wild boar. He studied forestry and photography in Czechoslovakia, became mesmerized by stories of cowboys and Indians in the American West and eventually escaped the communist regime of his homeland.

His work is widely used by editorial and corporate clients.

Today he makes his home in Montana with his wife, two children and a loft full of homing pigeons. To see more of his images, please visit www.dusansmetana.com.

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Ducks Unlimited Inc.
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"Each generation has its own rendezvous with the land … By choice, or by default, we will carve out a land legacy for our heirs." — Stewart Lee Udall

Foreword

by Steve Williams, President, Wildlife Management Institute, and George Cooper, President and Chief Executive Officer, Theodore Roosevelt Conservation Partnership

Since publishing *Seasons' End: Global Warming's Threat to Hunting and Fishing*, the urgency to address the effects of climate change on fish and wildlife has become increasingly evident. Already waterfowl exhibit changes in seasonal distribution. Higher water temperatures and diminished stream habitat are threatening coldwater fish such as trout and salmon. Big game are shifting to more northerly latitudes and to higher elevations to escape summer heat and find suitable forage. With each passing season, the need to develop strategies and invest in management practices to assist fish and wildlife adapting to a warmer world becomes more imperative.

The economic, ecological and recreational values of fish, wildlife and their habitats make a persuasive case for conservation, but the legal, moral and ethical responsibilities that humans have to the environment compel the American sporting community to take up this conservation challenge in the 21st century.

Historically, our nation has made numerous commitments to the conservation of fish and wildlife and their habitats in the form of legal protections, financial investments and formal recognition of the public benefits, including recreational opportunities, that

they provide. To secure these benefits for the American people, Congress has invested in more than 683 million acres of public lands. The return on this national investment will be realized only if those lands and their wild inhabitants are protected and appropriately managed in perpetuity.

Beyond our legal and financial obligations, we have a moral and ethical responsibility to conserve fish, wildlife and their habitats. How we respond to the repercussions of climate change will determine the condition of the environment that we pass on to our children; it is our duty to our country and our descendants to protect and preserve the wildlife and wild places that prior generations have bequeathed to us.

The spiritual values that we associate with our natural inheritance oblige us to stewardship.

A Crucial Role for Sportsmen

The consequences of climate change will resonate across this country in an unprecedented fashion. As a result, sportsmen will need to encourage and support state and federal agencies as they respond to this threat with major expansions in projects that attack the problem at the landscape level. They must insist that these agencies use adaptive management techniques and established best practices.

Funding will need to go beyond conventional sources and include those without a history of supporting fish and wildlife. Private philanthropic, foundation and corporate investment must be combined with federal, state, and local government dollars. Programs conducted through these efforts will likely be directed toward

- reducing present threats to wildlife populations to increase their ability to withstand the immediate consequences of climate change
- restoring and managing habitat to address the effects of changes in temperature, weather and precipitation patterns on species' ranges
- establishing and conserving fish and wildlife movement corridors
- allocating sufficient water for fish and aquatic habitats
- adjusting harvest management and population restoration policies
- preparing regional and national fish and wildlife management plans

Models for Success

Fortunately there are models of corporate and private partnerships as well as of cross-jurisdictional programs that can point the way to success.

Freedom to Roam

If wildlife is to adapt to the combination of habitat fragmentation and climate-caused habitat shifts, corridors maintaining habitat connectivity will be essential. They facilitate wildlife's regular travel to find food or mates, seasonal migrations and population dispersal. Corridors can vary in size to accommodate transcontinental migrations such as of shorebirds, marine mammals and songbirds; the wide-ranging journeys of large predators; or the seasonal movements of amphibians from wetland to wetland. Regardless of its length and breadth, each pathway is critical to some species of North American wildlife and allows animals to adapt as their habitats are affected by a warming climate. If wildlife lose the capability to move in a climate that is ever changing, we risk losing much of the natural heritage of our country forever.

Emblematic of the innovation necessary to confront the effects of climate change on wildlife, Freedom to Roam is a nonprofit coalition bringing together businesses, government agencies and conservation organizations to address the challenges of wildlife adaptation. By working with the private sector, Freedom to Roam is engaging a powerful new constituency to help save wildlife. But whether for-profit or nonprofit, liberal or conservative, hunter, angler or simple wildlife observer, the diverse stakeholders comprising the coalition have set aside their self-interests in favor of implementing wildlife corridor-friendly practices and securing the habitat connectivity essential for wildlife's survival in a warmer, more crowded world.

Indicative of the unique composition of the coalition, members of Freedom to Roam steering committee include such corporate, government, and nonprofit entities as Southern California Edison, Wal-Mart, Patagonia Clothing Company, BP America, Microsoft, National Wildlife Federation, National Geographic Society, Defenders of Wildlife, Yellowstone to Yukon, National Fish and Wildlife Foundation, Theodore Roosevelt Conservation Partnership, Wildlife Conservation Society, World Wildlife Fund, Association of Fish and Wildlife Agencies and Western Governor's Association.

North American Waterfowl Management Plan

Modeling another approach that will be crucial to successful conservation is the North American Waterfowl Management Plan. Conserving migratory waterfowl in Mexico, the United States and Canada, the plan sets a precedent for working across geographic and jurisdictional boundaries. Developing a similar national climate change plan for federal and state agencies, tribal governments and

conservation organizations could help to prioritize and coordinate adaptation projects regionally and country-wide.

The national plan will need to address all habitats and species of fish and wildlife affected by climate change, including well established species such as elk and mule deer, bear, brook trout and bass, waterfowl, grouse and pheasant. Success will depend on fish and wildlife managers learning which methods work and which do not, then adjusting management practices based on this information. With appropriate monitoring, adaptive management will ensure responsible, effective and efficient expenditure of funds.

History Clarifies the Task Ahead

Beginning in the late 1800s and continuing throughout the early 20th century, the sportsmen of America recognized how dire the threat of unrestricted commercial hunting and fishing was to the country's natural resources. They took steps to regulate those activities, creating the North American model of professional fish and wildlife management, establishing the public lands estate and encouraging investing in conservation.

Today, fundamental alterations to the Earth's climate pose another profound threat to the country's fish and wildlife. Again sportsmen are called upon to act to ensure that fish, wildlife and their habitats endure in the decades to come. This is the challenge of our generation.

There is an ongoing debate over the appropriate way to fund responses to the effects of climate change on energy production, agriculture, infrastructure, health, the environment and our economy. One such way is a cap-and-trade system that establishes a cap — an allowance, or credit — for annual carbon emissions and provides a market in which industry could trade — buy and sell — those credits. This incentive-based system provides certainty about approaches and regulations and allows flexibility to develop innovative ways to reduce carbon emissions. The auction of carbon credits throughout the lifetime of the cap-and-trade market could generate funding for fish and wildlife conservation projects.

However, designating expenditures from a cap-and-trade system for fish and wildlife management will continually compete with advocates for programs such as job creation, new energy source development, even taxpayer rebates. To secure the funding essential for effective conservation— billions of dollars a year — the sporting community must join with fish and wildlife professionals to explain

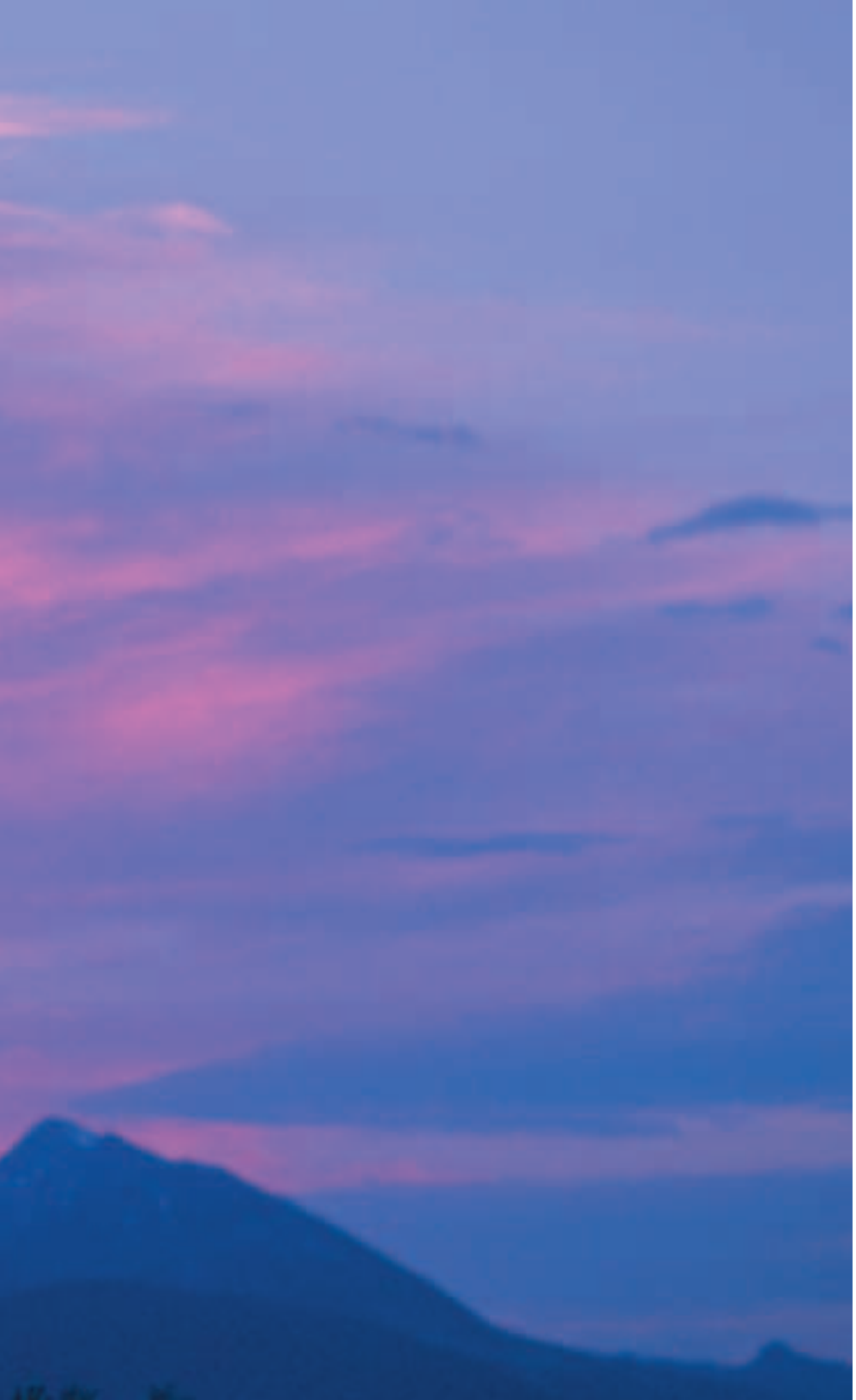
- why maintaining ecosystems capable of supporting fish and wildlife populations is critically important to the nation's health, economy and psyche

- how America's quality of life and the survival of its fish and wildlife are connected
- why the annual expenditure of billions of dollars on fish and wildlife projects will be a cost-effective investment
- why existing effective conservation practices must continue while projects more specifically addressing the consequences of global warming on fish and wildlife are developed and implemented

Congress has the opportunity and the obligation to assist our fish and wildlife by establishing a national program to reduce emissions of greenhouse gases, sequester carbon from the atmosphere, and commit the financial resources necessary to develop and implement conservation strategies responding to a rapidly changing climate.

The time to take action is at hand. Investments that we elect to make today will prove less costly than those we would be forced to make in the future. Should we fail to undertake adequate measures, the landscape of our nation and its current suite of fish, wildlife and habitats will be inextricably altered and degraded.

Beyond Seasons' End presents ideas of fish and wildlife professionals about actions that the human community can take to assist the wild community adapting to climate change. The question is not so much can we do something, but will we, as a nation, commit the resources to honor our obligation to sustain wildlife and wild places.



"… in the present phase of our civilization we have a profound, a fundamental need for areas of wilderness — a need that is not only recreational and spiritual but also educational and scientific." — Howard Zahniser

The Human Connection

by Nancy Lange, Izaak Walton League of America, and Arpita Choudhury, Association of Fish and Wildlife Agencies
The complete text of this chapter is posted at www.seasonsend.org.

America's Legacy of Wildlife and Wild Places

Our country is blessed with an abundance of lands of unsurpassed beauty and inestimable value. From mountains and forests to prairies and wetlands, these treasures enrich us as a nation and inspire us as a people. They are the foundation of our economic well-being, an essential component of our quality of life and a legacy we hold in trust for future generations.

Today, climate change poses an unparalleled threat to these lands and the people, fish and wildlife they support. If we are to pass America's rich natural heritage on to our children, we must be good stewards of our wildlife and wild places in this time of great challenge.

Overheating the Planet

Concentrations of heat-trapping gases in the atmosphere are at their highest levels in at least 800,000 years. During the 20th century, average global temperatures rose by more than one degree Fahrenheit (F), and scientists project that without explicit climate protection policies to reduce greenhouse gas emissions, temperatures will rise another two to 11 degrees F by 2100. Even if greenhouse gas emissions were stabilized immediately, the long lifetime of carbon dioxide in the atmosphere and the vast heat storage capacity of the oceans would fuel climate change beyond 2100. Earth cannot escape experiencing the consequences of climate change, some of which are already alarmingly evident.

Climate change is displacing ecosystems

Northern and arctic regions are warming at an accelerated rate, and ecosystems are on the move. Boreal forests are retreating to more northerly latitudes and may be replaced by grasslands or deciduous temperate forests. Alpine systems are moving upslope. Across the globe, ranges of wildlife and plant species are shifting northward and to higher elevations.

Climate change is melting Earth's ice

Winter ice cover on lakes is declining in duration and thickness, and summertime sea ice in the Arctic is shrinking much faster than previously projected. The Arctic Ocean is expected to have its first ice-free summer within the next 30 years, not at the end of the 21st century as previously predicted.

Climate change is raising sea levels

As ocean temperatures warmed over the past century, sea levels rose about eight inches. Now the accelerated melting of glaciers, ice caps and polar ice sheets also contributes to rising seas. Scientists predict that sea levels could rise an additional three to four feet within this century, with devastating consequences for low-lying, flood-prone areas.

Climate change is altering the world's oceans

As levels of greenhouse gases increase, the oceans are absorbing greater amounts of carbon from the atmosphere. Not only does this reduce the oceans' capacity to absorb yet more carbon, it causes

sea water to become more acidic. This increased acidity is causing widespread damage to the world's coral reefs, threatening the many marine species that rely on reef ecosystems.

Climate change is causing weather events to intensify

While some of Earth's regions are drought-stricken, others are receiving too much water. With increasing frequency, extreme rain events are exacerbating floods. Warmer ocean surface waters are fueling hurricanes of greater intensity and duration that will devastate coastal communities around the world.

Climate change is posing threats to human health and safety

Disease outbreaks and mass disruptions in food production and water distribution are predicted if man-made greenhouse gas emissions continue unchecked.

Fish and Wildlife at Risk on an Overheated Planet

Although in the past plants and animals have demonstrated remarkable resiliency, today's rate of change could outpace many species' ability to adapt.

Some species will respond to climate change by attempting to migrate to a more hospitable habitat. For example, some waterfowl could shift their ranges as global warming reconfigures vegetation and precipitation patterns. Coastal organisms could attempt to move inland as rising seas inundate shoreline habitats. Unfortunately, access to more hospitable environments could be restricted by predators; by natural barriers such as mountains, rivers and deserts; or by man-made barriers such as sea walls and roads. Development that blocks wildlife corridors or fragments wildlife habitats will reduce migratory success and could lead to the extinction of many vulnerable species.

Highly mobile species such as birds and big game might move to habitats where their presence disturbs the existing ecological community. Expanded ranges of pests and diseases could introduce new risks to migratory populations, while environmental factors such as declining water quality and availability, altered vegetative nutrition and increasingly frequent wildfires diminish a habitat's capacity to support wildlife.

Species that cannot migrate or are at the boundaries of their habitat could face extinction or extirpation. Particularly threatened are the many arctic species dependent on a world of ice. Current habitat changes imperil their very survival.

Climate change is also causing disruptions in the timing of critical life-cycle events. Plants are blooming and leafing out sooner in the year. Birds, insects and other wildlife are breeding, migrating or emerging from hibernation earlier. Shifts in the advent and length of growing seasons could alter critical pairings of predators and prey, of insects and their host plants. Foods may no longer be available when fish and wildlife need them.

The United Nations' Intergovernmental Panel on Climate Change (IPCC) has concluded that unless meaningful steps are taken to halt future warming, 20 to 30 percent of the world's plants and animals — perhaps a million species — could be pushed to the brink of extinction within the lifespan of a child born today.

Planetary Systems Vulnerable to Climate Change

As well as threatening fish, wildlife and their natural habitats, climate change is damaging the planet's systems that provide clean air, clean water, food and places of shelter. The natural environment delivers fundamental life-support services such as water purification, soil production, nutrient, cycling and drought and flood mitigation. As natural ecosystems are destroyed or diminished by climate

change, humanity is forced to search for expensive but often inferior substitutes. However, in many instances there are no substitutes that people can create.

In 1997, the entire non-market value of Earth's ecosystems was estimated to be $33 trillion, exceeding the world's gross domestic product. Humanity could not exist without these systems, yet often their value is acknowledged only when they are damaged or disrupted.

An examination of two ecosystems exemplifies the value of natural environments and their vulnerability to climate change.

Wetlands

Wetlands — marshes, estuaries, swamps, deltas and floodplains — are among nature's most productive ecosystems and perform multiple services.

- Wetlands provide primary habitat for an enormous variety of fish, shellfish, amphibians, reptiles and birds.
- Wetland aquatic nurseries are critical to sustaining sport and commercial fisheries.
- Nearly 45 percent of the nation's threatened and endangered species and 85 percent of the country's waterfowl and other migratory birds rely on wetlands to rest, feed or breed.

- Wetlands across the country buffer intense rain events, purify water, provide sources of ground water, and filter and store surface water.
- Wetlands produce soil and store carbon. Globally, wetlands may presently sequester as much as 700 billion tons of carbon.
- Coastal marshes and swamps control floods, buffer the force of hurricanes and diminish storm surges, thus delivering protective services valued at $23 billion annually.

Already subject to degradation from urban and rural development, America's low-lying coastal wetlands face threats from increasingly violent storms, sea-level rise and saltwater intrusion — results of a warmer climate. Restoring the nation's wetlands, floodplain habitats and other natural buffer zones conserves critical ecosystems and protects human health and property.

Conservatively estimating the value of their ecosystem services at $10,000 per acre, the 100 million acres of wetlands remaining in the lower 48 states deliver benefits worth approximately $1 trillion.

Forests

As well as providing habitat for myriad species of fish and wildlife, forests deliver goods and benefits essential to the nation's health, commerce and well-being. Covering 520 million acres, the forests of the United States

- stabilize soils and reduce erosion and flooding by slowing storm runoff and maintaining the integrity of riparian habitats
- purify air and store carbon by taking carbon dioxide out of the atmosphere
- purify water by absorbing rainfall, filtering water and refilling underground aquifers. Forestlands supply about 80 percent of the clean water needed for human consumption, agriculture and recreation. Watersheds located in national forests supply drinking water to 60 million Americans.
- yield timber for fuel and shelter and present a potential source of energy that could replace fossil fuels
- provide recreational opportunities

In the western United States, where minimum winter temperatures have risen by as much as 10 degrees in 50 years, a warming climate threatens forestlands by fostering extensive droughts, catastrophic wildfires, invasive species and insect outbreaks.

- Without killing cold to limit larval survival, insects spread rapidly. For example, explosive pine beetle infestations increased by 50 percent between 2007 and 2008, affecting nearly 6.5 million forested acres in the U.S. by preying on drought-stressed trees.

- Warmer conditions have led to regional die-offs of vast swaths of forests, creating ideal circumstances for catastrophic wildfires.
    - Since the mid-1980s, major forest fires in the West have increased four-fold, and the area of acreage burned has increased six-fold. The wildfire season is now 78 days longer than in previous decades. Annual federal appropriations for fighting wildfires have risen to about $3 billion.
    - Fires release carbon stored in forests, raising greenhouse gas levels.
    - Fires' extreme heat can damage the soils in forest watersheds, causing erosion and runoff that pollute water supplies. In the Southwest, water resources for millions of people are exposed to this risk.

Altogether, the country derives more than $60 billion in benefits from its forests each year.

The Economic Engine of Outdoor Recreation

Throughout the nation, rural communities rely on healthy ecosystems to support agriculture and logging, the traditional backbone of their economies. But often an outdoor recreation economy is also evident and responsible for job growth, rising income levels and improved social conditions like health and education. Outdoor recreation resists the trend of sluggish economic growth in rural America even in economic downturns, as tough times encourage Americans to rediscover simple pleasures such as fishing, camping and observing wildlife.

With more than three out of every four Americans engaging in some type of outdoor recreation, annual retail sales of outdoor equipment and expenditures on excursions approach $300 billion. When the full economic effect is tallied, outdoor recreation

- contributes $730 billion to the U.S. economy
- stimulates 8 percent of all consumer spending
- provides 6.5 million jobs nationwide — one job out of every 20
- contributes to all major sectors of the U.S. economy

Wildlife and Wilderness, Essential American Values

Beyond sustaining physical and economic health, nature nourishes the human mind and spirit. To experience the natural world fulfills a deeply seated human need. Even though 80 percent of Americans

today live in metropolitan areas and may never encounter a grizzly bear or wolf, Americans deeply value the existence of wildlife and appreciate that wildness thrives.

Cultivated over generations, American traditions are steeped in the country's wild places. The American people cherish the recreational opportunities found in nature. Each year

- 40 million Americans go fishing
- 13 million Americans hunt
- guests visit national parks 270 million times
- countless numbers hike and camp and view wildlife

Sporting experiences in fields and streams confirm that change is underway. Hunters, anglers and other outdoor enthusiasts are keenly aware that the country's treasured fish and wildlife are under pressure and that climate change threatens American traditions rooted in wild places and wildlife.

Funding Conservation to Respond to Climate Change

Unlike any previous conservation crisis, global climate change affects all ecosystems everywhere. To properly conserve wildlife and their habitats, particularly those that are most vulnerable or those providing the greatest environmental or economic value, requires on-the-ground actions the scale and cost of which challenge natural resource management worldwide. In the United States, federal and state fish and wildlife agencies are responsible for protecting and conserving the nation's wild places. Reducing the loss of wildlife and wildlife habitat resulting from climate change will require these agencies to adopt new strategies that

- assist wildlife through actions such as acquiring land for migratory corridors, restoring habitats and assessing the vulnerability and monitoring the condition of wildlife populations
- develop landscape-level conservation approaches, particularly those that are habitat-based
- partner with parties across jurisdictional boundaries to encourage consistent management practices and achieve landscape-level conservation objectives
- engage in efforts such as biological carbon sequestration projects and carbon emission reduction programs to mitigate the consequences of climate change

Costs for projects will vary depending on their time scales, geographic ranges and the degree of management required for implementation. The price tag for all federal and state natural resource initiatives confronting climate change will reach billions of dollars annually, but without this funding the environmental and economic losses could be catastrophic for the nation.

A New Era for Conservation

Taking swift action can significantly limit future damage and loss from a changing climate. Doing so will preserve a legacy of wildlife and wilderness to pass along to our children and grandchildren.

Some think that global climate change is too big and too intractable an issue to address and see no option but walking away from the problem, turning their backs on conservation. It is true that, even if funds and labor were unlimited, some species will be lost and unimagined new habitats will present new conservation issues. But whether considering the spiritual and psychological benefits of nature, the value of outdoor recreation or the importance of ecosystem services, failure to assist fish and wildlife adapting to climate change is not an option.

We owe it to our forefathers who protected wild places before us, to our grandchildren who will cherish the wild places we preserve, and to ourselves to face the challenges that lie ahead in a new era of conservation. While taking account of the enormous value of the natural environment to human health and prosperity, there is no dollar amount that can be assigned to the ethical duty to act and uphold our responsibility to pass a healthy planet on to the world's future generations.

"When we see land as a community to which we belong, we may begin to use it with love and respect."
— Aldo Leopold

Waterfowl

by Dawn Browne and Dale Humburg, Ducks Unlimited, Inc.
The complete text of this chapter is posted at www.seasonsend.org.

Greenhouse gases, which trap heat in the atmosphere, are causing the planet to warm. The climatic changes resulting from even a few degrees' rise in average global temperatures will result in environmental responses with far-reaching effects on waterfowl and waterfowl habitat.

Climate change will raise temperatures

Warmer average temperatures will cause

- shorter winters: Shifts in seasonal temperatures will almost certainly alter the timing of vegetation growth patterns, affecting the availability of food and cover at critical points in duck and

goose life cycles. Earlier springtimes would trigger earlier runoffs and alter seasonal flooding and wetland drawdown cycles. Reduced freshwater stream flows could alter salinity levels in coastal estuaries from the mid-Atlantic region to the Pacific Northwest.

- longer ice-free seasons: Waterfowl would not need to fly as far south to find ice-free water and suitable food, possibly causing changes in migratory timing and routes and in wintering locations.

- altered hydrology: In the western Boreal Forest, the melting of permafrost will disrupt the historic hydrology and alter the ecosystem, which in springtime supports up to 15 million ducks.

- sea-level rise: Oceans expand as they warm, and their volumes will further increase as land-based glaciers melt. Sea-level rise will inundate critical, low-lying waterfowl habitat such as that found along the coastline of the Gulf of Mexico. Where urban and agricultural development limits coastal wetlands' inland migration, waterfowl will be squeezed into narrowing bands of habitat.

Climate change will alter precipitation patterns

Changing precipitation patterns will result in

- more — or less — precipitation: Although some regions may get wetter, precipitation levels are expected to decline in important waterfowl habitats, including the "duck factory" Prairie Pothole Region. Even without reduced precipitation, greater drying of wetlands will occur due to increased evaporation rates under extended warmer, ice-free conditions. Diminished water supplies will increase competition among urban, agricultural, industrial and ecological uses.

- more rain and less snow: Less snowfall results in smaller snow packs, reducing a primary source of water for summertime stream flows from northern or mountainous regions. Rain falling on snow speeds snow melt, further reducing stored water reserves. Lower seasonal flows of water into coastal marshes in the Pacific Northwest, for example, will change water and soil salinity and affect the suitable mix of plant species and food for waterfowl.

- more intense storms: Patterns of rainfall affect waterfowl habitat as much as does the amount of rainfall. Fierce storms cause erosion and diminish water quality by increasing sediment and nutrient loads in waterways.

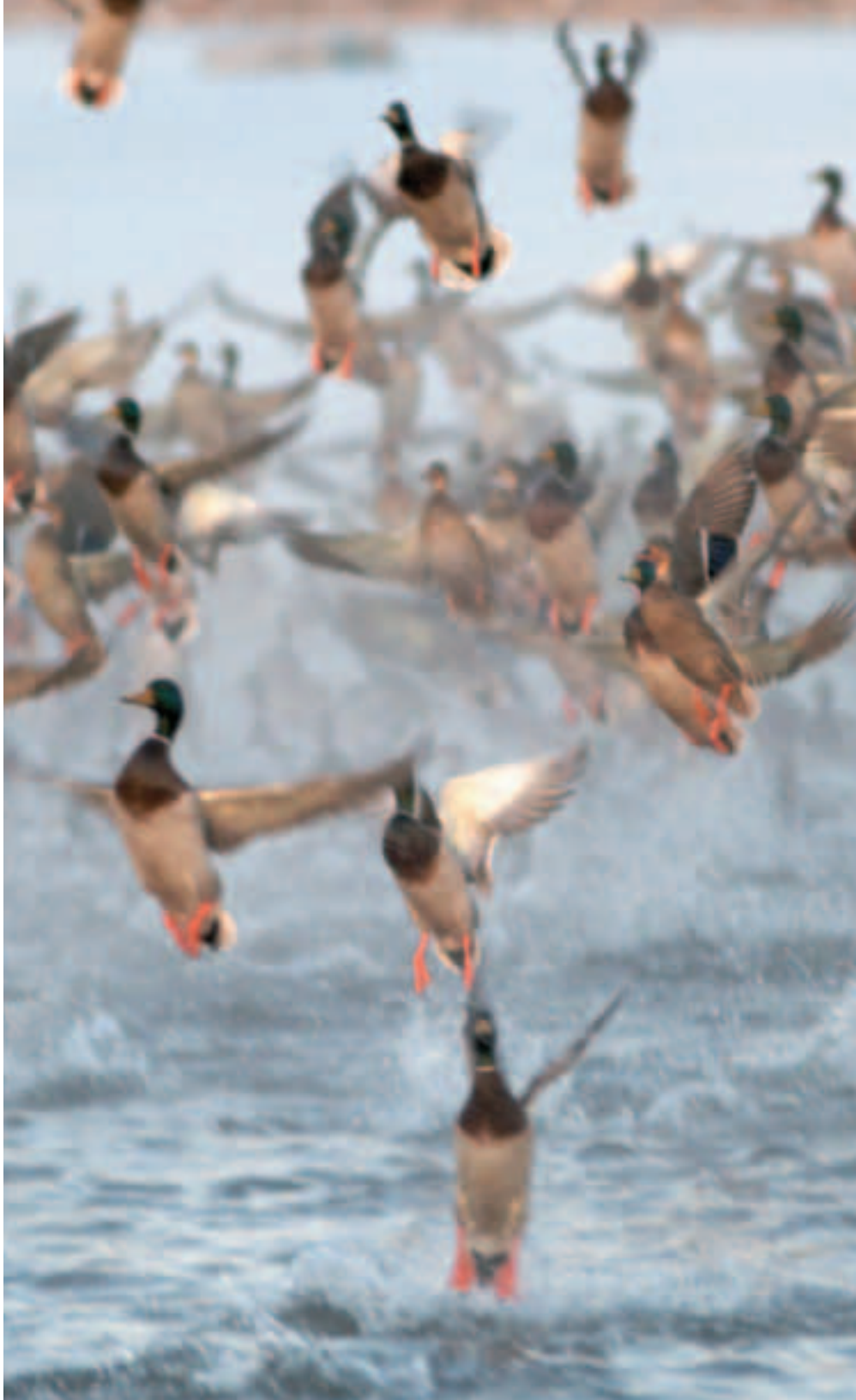
- floods and droughts: Intense or repeated flooding can ruin waterfowl habitat or render it temporarily useless, with long-term consequences for waterfowl abundance and distribution. Untimely flooding during the growing season can affect a year's worth of foods derived from annual plants or agricultural crops. Extended summer flooding can cause the loss of a bottomland hardwood forest in a single year, though the effects are felt for decades. Longer and more severe drought conditions will further shrink wetlands, dry up small streams and diminish or completely destroy waterfowl habitat.

Resilient, thriving ecosystems have the best chance of withstanding or adapting to these consequences of climate change. North American waterfowl habitats, however, already face grave threats that climate change will only magnify.

Climate change will exacerbate current threats to waterfowl habitat

Ongoing threats to waterfowl habitat include

- land-use practices: Converting land to agricultural and urban use has reduced waterfowl habitat throughout the country. In the Prairie Pothole Region, converting wetlands and grassland to agriculture has reduced this landscape's capacity to support



traditional numbers of breeding waterfowl. Greater climatic variability is particularly detrimental to livestock producers who sustain grasslands and associated wetlands important to breeding ducks.

- water-use practices: The fragile balance between water needed for sustaining wetland ecosystems and for agricultural, industrial and domestic uses is becoming increasingly precarious, as seen in the California Central Valley, where 96 percent of the wetlands have already vanished, and in the Mississippi Alluvial Valley, where irrigation and fish farming put additional pressures on water supplies. Altering local hydrology through drainage or water diversions risks degrading the quality of both water and waterfowl habitat.
- demands of a growing human population: Throughout the country, waterfowl habitat dwindles when urban areas expand and shorelines are developed. For example,
    - wetlands in portions of the Great Lakes region have declined from their historic levels by 60 percent. Capacity for breeding and migrating ducks will continue to decline in wetlands that remain unprotected from development.
    - in the Great Basin, an expanding populace sharpens competition with waterfowl for scarce water resources.
    - the mid-Atlantic and Pacific Northwest regions illustrate the negative effects of a densely populated coast on shallow-water estuarine habitats. Decreased wetland acreage, degraded water quality and reduced aquatic vegetation are among the causes of the declining use of some wintering grounds, for some species by as much as 80 percent.
- limited budgets for resource management: Even as needs grow, funding to protect and conserve waterfowl and waterfowl habitat remains inadequate.

How Waterfowl Will Respond to Climate Change

In some regions, warmer and drier conditions will change where, when and how successfully waterfowl breed, migrate and winter. Model simulations indicate that the heart of today's most productive breeding habitat would shift east, away from the center of the Prairie Pothole Region in the Dakotas and southeast Saskatchewan. Although the region is wetter toward its eastern fringes, wetland systems there have been highly altered or drained for agriculture, and waterfowl production would be severely reduced.

Even though restoring wetlands remaining in the agricultural Midwest is essential, waterfowl adaptation to and survival under changing climatic conditions will require conservation strategies across much broader landscapes.

Warmer fall and winter conditions are widely expected to cause a redistribution of waterfowl populations. Climate change could affect the timing of migrations as well as the distance traveled. Warming winters in northern regions could extend open water and food availability, limiting southern movements. Changes in temperature and precipitation would further reduce breeding habitat and cause breeders to relocate to marginal landscapes.

Yesterday's Programs Can't Solve Today's Problems

Current conservation efforts are not sufficient to ensure sustaining waterfowl populations or hunting traditions even today. Consider that

- in the United States, the wetlands most important to waterfowl are lost at the rate of 80,000 acres per year
- seventy percent of the historical expanse of grasslands across the Great Plains has been lost
- loss of native grasslands in the Missouri Coteau alone is projected to reach at least 150,000 acres every 10 years

Without a comprehensive, national climate policy and adequate funding, state and regional efforts can only provide fragmented solutions insufficient to address climate change at effective scales.

Even as waterfowl confront new threats from climate change, programs to encourage habitat conservation are in decline. However, the following three proven conservation strategies must be strengthened and expanded to the scale needed to affect the consequences of climate change.

Grassland conservation

The U. S. Department of Agriculture's Conservation Reserve Program (CRP) is one of the nation's largest and most effective means of converting lands from crop agriculture to grasslands. However, Congressional changes in existing programs and creation of new, powerful incentives to destroy prairie, put marginal land into crop production, and convert CRP back into cropland stress conservation investments. Higher commodity prices, increased land rents and the production of energy crops raise concerns that, as CRP contracts expire, landowners will convert millions of acres of grasslands to agricultural production.

Wetland conservation

The U.S. Supreme Court ruled that, after more than three decades of guiding resource management, the Clean Water Act (CWA) offers no protection to certain wetlands and other geographically isolated waters based solely on migratory bird use, regardless of other water quality and supply considerations. Further, in 2006 the court ruled that wetlands without a "significant nexus" to navigable waters were not subject to jurisdiction under the CWA. Following those decisions, regulatory guidelines issued by the U.S. Army Corps of Engineers and the Environmental Protection Agency severely reduced protection of wetlands important to waterfowl.

Waterfowl management

Adopted in 1986, the North American Waterfowl Management Plan has provided a framework for collaborating on waterfowl conservation at a continental level. Funded largely through the North American Wetlands Conservation Act with matching grants to partners, the program appears to have enhanced habitat for waterfowl and other wetland-dependant species and has offset some habitat loss. However, it is inadequate to ensure habitat gains, especially under a changing climate. Without expanded funding and incentives for private landowners to engage in landscape-scale solutions, waterfowl-focused programs alone are not sufficient today — and certainly will not be sufficient as climate changes — to make certain a positive future for ducks and geese.

What Can Be Done: Project Types

Surprisingly few on-the-ground projects have been implemented that specifically focus on helping waterfowl and other wildlife adapting to climate change. The following project types provide an overview of several approaches to facilitating adaptation, promoting resilience or resistance to climate change and providing a means of funding conservation programs.

Coastal buffer projects

Sea-level rise will adversely affect coastal wintering and migratory stopover sites for many waterfowl species. For example, half of all tidal flats and brackish marshes along the Oregon and Washington coasts may be lost to rising seas within the next 90 years. Coastal marshes can be conserved if the sea is allowed to migrate inland, as has happened in the geological past. Unfortunately, hard sea walls and earthen levees along much of the coast prevent such movement. Farmland easements in regions like the Pacific Coast can help restrain urban development and preserve corridors for the inland migration of coastal wetlands critical to waterfowl.

Sediment diversion projects

In some important waterfowl regions, disruptions in natural drainage patterns and land formation processes have caused drastic wetland losses. For example, dams and levees throughout the Mississippi

River basin have prevented seasonal floodwaters from delivering land-building sediment to Louisiana's deltaic marshes. As a result, during the past 80 years more than 750,000 acres of Louisiana's coastal wetlands have converted to open water. Restoring historic hydrological processes by diverting sediment-laden water from the Mississippi may be the only means of combating the consequences of sea-level rise in these wetlands.

Pothole protection projects

Acquiring and securing perpetual conservation easements on the remaining prairie pothole wetlands and the surrounding native prairie grasslands can protect this unique and irreplaceable breeding habitat. Additionally, restoring pothole wetlands that have been drained for agriculture and grasslands can decrease habitat fragmentation, a major cause of declines in nesting success. Protecting and restoring grasslands reduces the transport of sediment into pothole wetlands and provides critical waterfowl nesting cover. Additionally, grasslands perform an essential biological service by sequestering carbon, offsetting the effects of climate change and benefiting wildlife habitat.

Environmental market projects

Ecosystem markets provide a method of buying and selling ecosystem services that have been converted into units of trade such as credits. For example, markets currently exist under the Clean Water Act and the Endangered Species Act that allow banking wetland mitigation and habitat credits. In the United States, the regulatory frameworks that drive and sustain these markets and the protocols for various credit transactions continue to evolve. Additional incentives could encourage opportunities for ecosystem markets to supplement public and private conservation-program funding, thereby expanding the number of acres conserved or protected and benefiting both waterfowl and people.

Carbon projects

Conversion of habitats such as native grasslands to agricultural use not only has negative consequences for waterfowl but also releases considerable quantities of carbon dioxide into the atmosphere — up to 25 percent of global greenhouse gas emissions is attributed to land-use changes.

Without adequate financial incentives to leave grasslands intact, carbon storage in these landscapes will continue to decline. A national carbon-offset program creating incentives for increasing carbon storage could reduce emissions from terrestrial sources while protecting or restoring habitat for waterfowl and other wildlife.

Solutions for Waterfowl: A Case Study

Editor's note: Fish and wildlife professionals contending with the effects of climate change need a framework to consider the essential factors of a successful field project. The following case study demonstrates the approach of Ducks Unlimited to common project components such as goal identification, implementation barriers and costs.

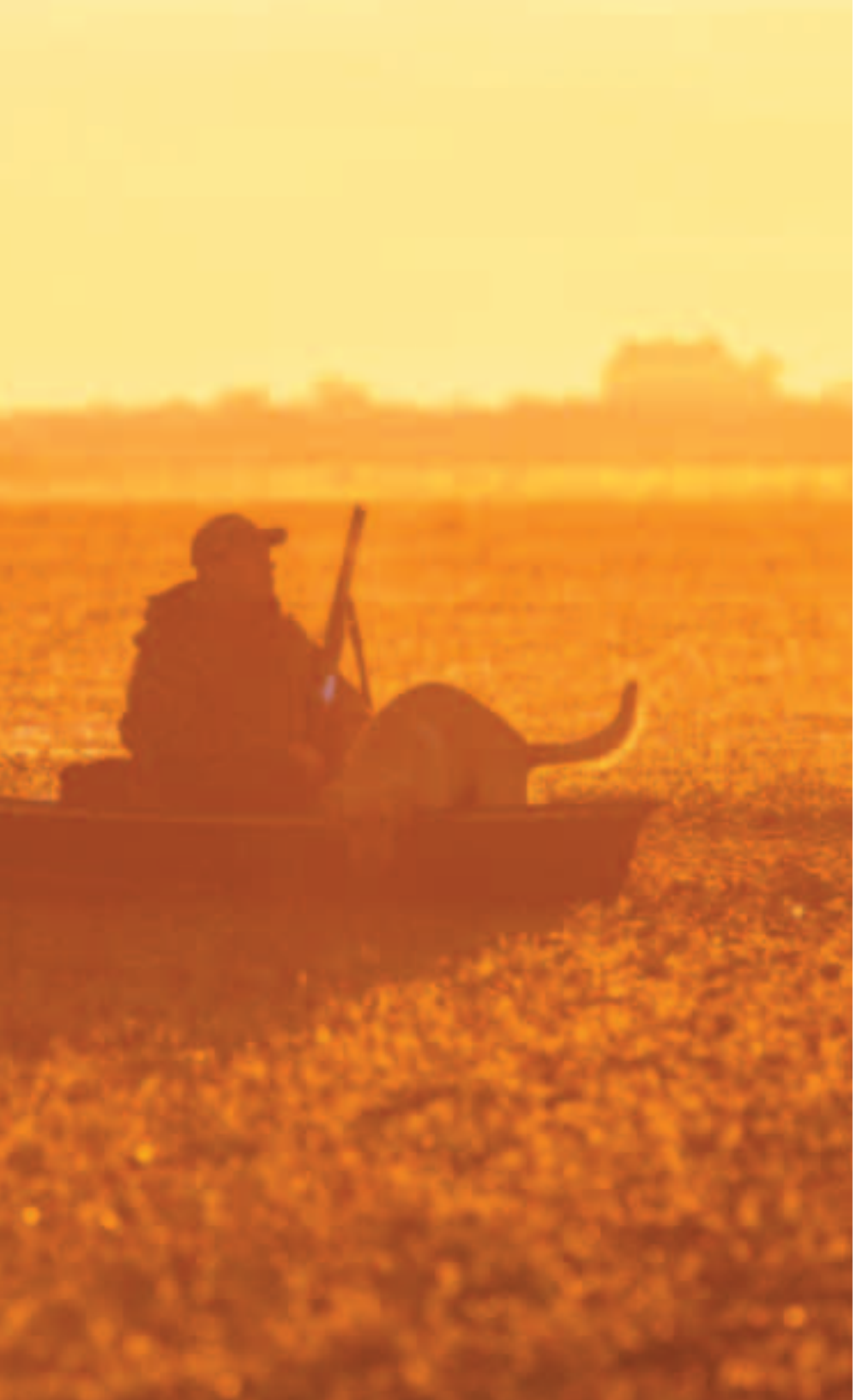
Project location

The initial project encompasses 5,000 acres of North Dakota grasslands, with the potential for considerable expansion. The site is within the Missouri Coteau, a large plateau covering approximately 17 million acres in Canada and the United States in the Prairie Pothole Region (PPR). This region is known as North America's "duck factory" because of its critical importance to waterfowl production.

Background

During the past century, conditions for waterfowl in this area have deteriorated as wetlands have been drained and filled and two-thirds of its grasslands have been plowed and planted in crops. Compared to other land use options, programs and economic activities that historically supported grassland conservation have become uncompetitive and underfunded.

Pressure is increasing to convert remaining prairie acreage to agricultural use. New technologies permit farming on lands that previously were untillable. New varieties enable cultivation of plants



that historically were unsuitable to the region. It is ironic that concern about climate change has promoted growing crops for biofuels, inasmuch as plowing the prairie releases vast amounts of stored organic carbon. The freed carbon converts to carbon dioxide (CO_2) and adds significant quantities of greenhouse gas to the atmosphere, exacerbating global warming and climate change.

Project goals

This project demonstrates that combining a traditional practice — conservation easements — with a contemporary funding approach — carbon markets — can create powerful and cost-effective results. The project will achieve three critical goals: conserving habitat to help waterfowl adapting to climate change, reducing releases of greenhouse gases and providing a new funding source for the conservation effort.

Waterfowl habitat conservation

Landscape-scale conservation of waterfowl habitat can be achieved through a combination of avoiding the loss of native prairie and restoring grass on prairies that have been converted into cropland. This case study implements traditional conservation easements to protect and preserve approximately 5,000 acres of critical waterfowl breeding habitat on existing native prairie grasslands in the Missouri Coteau region of North Dakota.

If the goal is achieved, the project will help protect the region's biodiversity and its critical waterfowl breeding habitat, currently under significant threat.

Greenhouse gas reductions

Implementing perpetual conservation easements on the project properties will prohibit conversion of native grasslands to crop-based agriculture. Prohibiting conversion reduces greenhouse gases by preserving organic carbon sequestered in soil, thus preventing its oxidation and consequent release. Over a 99-year period, 5,000 acres of protected lands will prevent approximately 151,000 metric tons of CO_2 from entering the atmosphere.

Carbon-market funding

The project proposes to fund traditional conservation easements with private carbon-offset financing. Current voluntary and regulatory carbon markets already recognize terrestrial carbon sequestration as a method of reducing greenhouse gas emissions. Future legislation must also recognize that protection of current grasslands from conversion into croplands and the return of existing croplands to grasslands are valid carbon sequestration strategies. This approach would encourage landowner participation and facilitate private investment in these conservation practices.

Implementation barriers

Easement purchases, a practice popular with landowners and effective in sustaining grasslands, requires significant upfront capital investment. Currently, the rate of securing easements is limited by inadequate sources of traditional funding and by the financial challenges of a front-loaded investment for carbon credits that are realized annually over a long term (99 years).

If a carbon market is to be used to finance conservation easements, a standardized method for calculating the carbon sequestration and storage benefits of terrestrial carbon projects must be developed. Within a national carbon offset program, grassland preservation and restoration must be recognized as providing environmental benefits equally important as re-forestation, improved forest management and avoided deforestation. Cooperation among policy makers, scientists and the financial sector is needed to ensure proper development of the carbon market and the accounting rules for terrestrial carbon offsets.

Project tasks, timeline and costs

The following table outlines the tasks, timeline and estimated costs for the PPR. Actual easement costs may vary from estimates. Estimated revenue relies on legislation resulting in a regulated carbon market.

Tasks	Narrative	Cost
	Year One	
Develop a carbon project design document (PDD) for validation by an approved third-party verifier	Assess project's methods. Prepare documentation used to evaluate its qualifications as an emissions reduction activity within a particular greenhouse gas reduction program or standard. The PDD addresses project components including • technology used • carbon measurement methods • project participants • explanation of co-benefits • monitoring plan	$30,000-$50,000
Enroll landowners	Pay staff and administrative costs for aggregating suitable native prairie grassland tracts averaging 300 acres and enrolling landowners at a cost of $10 to $15 per acre X 5,000 acres	$50,000-$75,000
	Year Two	
Pay landowners for easements	$100-$250 per acre X 5,000 acres	$500,000-$1,250,000
Purchase greenhouse gas rights	Difficult to determine due to limited availability of market price signals; estimated purchase price of greenhouse gas rights based on the Chicago Climate Exchange and other competing land use practices: $20-$30 per acre X 5,000 acres	$100,000-$150,000
	Year Three	
Monitor easements for compliance	Initiate annual monitoring of perpetual conservation easements to ensure compliance with stipulated land management practices. Cost is assumed by the agency holding the easement (US Fish and Wildlife Service).	Not applicable
Verify carbon credits	Measure and verify carbon credits. Because the carbon value of grasslands is stored underground, monitoring might be achieved in aerial surveys, satellite or other forms of remote sensing. Frequency and cost of third-party credit verification vary by program. Credit buyer assumes verification costs for this project.	Not applicable
	Year Four	
Sell carbon credits	Potential annual revenue based on the aggregated properties producing approximately 1,513 metric tons of CO2 credits per year at $6 per metric ton. Policy and accounting rules could develop that increase incentives or facilitate the sale of forward streams of credits for terrestrial carbon projects using perpetual conservation easements. Upfront revenue potential could then approach $900,000 for all carbon offsets produced over the 99-year project.	Annual revenue: $9,078
	Totals	
	Total project implementation costs	$650,000-$1,475,000
	Potential revenue from carbon credit sales: $ 9,000 annually X 99 years	$891,000
	Depending on actual expenses and credit sales, net cost or earnings of conserving and protecting 5,000 acres of Prairie Pothole Region waterfowl grassland habitat for 99 years	Costs up to $1,475,000 or earnings up to $250,000

Conclusion

Because traditional conservation strategies are part of the solution assisting waterfowl adapting to climate change, protecting existing investments in landscapes important to waterfowl should be a policy priority. Other national policies currently being considered will help reduce carbon dioxide levels and other atmospheric emissions. Conservation partners and policy makers must continue to discover ways in which landowners can receive financial incentives for protecting waterfowl habitat and for preserving carbon stores on their property. Since prairie wetlands and grasslands provide both benefits, future government policies could supply significant new support for conserving these vital waterfowl breeding habitats.

The mutual benefits of conserving habitat for waterfowl and reducing carbon dioxide levels in the atmosphere are not limited to the prairies. Conservation of boreal forest landscapes, bottomland hardwood forests and coastal wetlands could also help reduce carbon dioxide levels while providing vital habitat for waterfowl and other wildlife. This could lead to even greater support for waterfowl habitat conservation — a critical key to sustaining duck populations and to the very future of waterfowling.

"In the end, our society will be defined not only by what we create but by what we refuse to destroy."
— John C. Sawhill

Coldwater Fish

by Jack E. Williams, Amy L. Haak, and Nathaniel G. Gillespie, Trout Unlimited
The complete text of this chapter is posted at www.seasonsend.org.

The rapid pace of climate change is causing unprecedented environmental changes that significantly affect freshwater ecosystems. Coldwater fishes, dependent on an abundant supply of cold, clear water throughout all stages of their complex life histories, are particularly vulnerable to the following consequences of a changing climate.

Climate change raises water temperature

Coldwater fish rely on sources of cold, clean water, such as groundwater, springs, spring-fed creeks, coldwater seeps, and streams flowing from heavily forested, north-facing slopes. For coldwater fish, warming water temperatures will affect

- habitat availability: As water temperatures rise, trout and salmon habitat will shrink and become confined to high-elevation headwaters. Warmwater species will likely expand their ranges into regions historically dominated by coldwater fish. The number of coldwater refuges from drought, high summer temperatures and winter extremes will decline.
- migration and spawning: Trout and salmon respond to temperature cues to initiate these life-history events. Many trout species have evolved so that their spawning coincides with the melting of snow packs, a time of abundant cold water; the high concentrations of dissolved oxygen found in cold water create ideal conditions for spawning and the rearing of juveniles. Fall spawners such as bull trout are particularly susceptible to detriments of warmer water temperatures and low late-season stream flows.
- the availability of food: Warmer water triggering the early emergence of mayflies and other aquatic insects puts the food supply of trout and salmon at risk.
- the spread of pests, parasites and diseases previously limited by cold water: For example, with temperatures warming in high-altitude lakes, nuisance algae are proliferating and reducing dissolved oxygen to levels which could be lethal to fish.

Climate change alters stream flows

Storing water for seasonal release, snow packs melt gradually and soak into the ground throughout the spring and summer. Warming temperatures diminish this source of seasonal stream flow by

- increasing the occurrence of precipitation falling as rain rather than as snow
- reducing snow accumulation
- causing snow to melt sooner and stream flows swollen with runoff to peak earlier

For adult fish returning from the ocean and moving upstream to spawn, reduced summer and fall flows increase the difficulty of negotiating waterfalls and other barriers.

Changes in the timing of peak flows could result in smaller and fewer insects, decreasing the amount of available food.

Climate change exacerbates natural disturbances

As climate change escalates the frequency and magnitude of disturbances such as wildfire, flood and drought, they pose ever-growing dangers to aquatic systems.

- Warmer temperatures dry forests and promote conditions conducive to fire; snow accumulating later in the fall and melting earlier in the spring increases the length of the fire season. Fire can destroy riparian habitat immediately and cause acute and possibly lethal spikes in water temperature. Erosion and sedimentation are long-term consequences of rapid rainfall runoff in a burned watershed.

- Particularly in mid elevations where warmer winter temperatures cause more rain to fall and melt snow banks, occurrences of winter flooding could increase. As storms intensify, rivers erode their banks more readily and transport greater loads of sediment downstream. Severe winter flooding and erosion can scour incubating eggs from spawning beds.

- In some regions, especially the Southwest, heat-related moisture loss could give rise to extreme and prolonged summertime droughts, with deleterious consequences on the hydrology.

Climate change promotes non-native and invasive species

Because many exotic or invasive species thrive in disturbed or degraded habitats, the increased disturbances that climate change causes will compound problems associated with degraded environments.

Non-native organisms will continue to use the altered habitats of impoundments and compromised river systems as a base from which to spread and modify native ecosystems.

How Coldwater Fish Will Respond to Climate Change

Coldwater fish will react physiologically

Water temperature that is within the preferred range of coldwater fish, generally 50° F to 65° F, may be the most critical characteristic of high-quality habitat. Physiological effects of warm water on trout and salmon include

- increased metabolic demands
- increased stress due to reduced levels of dissolved oxygen
- greater susceptibility to toxins, parasites and disease

Ultimately, prolonged exposure to unsuitable water temperatures results in death.

Coldwater fish will congregate in constricted habitats

In general, complex and diverse habitats favor the long-term sustainability of native fish communities. Characteristics of high-quality habitat include connectivity among various habitat types, including silt-free gravel areas for successful spawning and riverine habitats with deep pools and woody debris that provide cover from predators and refuge from floods, droughts and extreme temperature conditions.

As climate change reduces the availability of quality habitat, coldwater fish will concentrate in small, fragmented headwater streams. Native trout and salmon populations will increasingly retreat to shrinking coldwater refuges to avoid warming conditions.

Coldwater fish will compete with invasive species

Numerous predatory species stocked in reservoirs could imperil native coldwater fish by dispersing into riverine areas both upstream and downstream.

As water temperatures rise, coldwater fish will likely compete for habitat with warmwater species expanding their ranges. Introduced coldwater species will also threaten native trout and salmon populations. In the intermountain West, for example, non-native trout will continue to compete with native cutthroat trout. As suitable habitat shrinks and waters warm, introduced rainbows and hybrid trout will expand into headwaters that currently support genetically pure cutthroat.

Yesterday's Programs Can't Solve Today's Problems

"You can't divorce a stream from its valley," said British ecologist H.B.N. Hynes. Indeed, to consider the broad watershed context in which stream restoration takes place makes more ecological sense than to focus on the stream itself.

Because of the long, linear nature of streams and rivers, they tend to cross numerous boundaries of agency jurisdictions and land ownerships. Headwater and mid-elevation areas are more common on public lands, such as national forests, parks and Bureau of Land Management (BLM) lands, than on private lands, which often dominate downstream rivers and valley bottoms. Public programs frequently focus on narrow jurisdictions, tending to fragment and disrupt natural connections among streams, tributaries and rivers.

As climate change magnifies existing stresses on coldwater fish habitat, a watershed-scale approach to restoration programs will become increasingly important. For conservation to be successful, it must expand beyond the traditional stewardship of public lands and develop productive and cooperative relationships with private landowners.

What Can Be Done: Project Types

Fish and wildlife professionals recognize that they can't rely on yesterday's programs to address the consequences of global climate change. The first step toward innovation is to see clearly the broad categories within which new ideas can take shape. The following survey of project types offers that perspective.

Headwater projects

For many native fishes, headwater tributaries contain the last remaining strongholds of genetically pure populations. These cold, clear waters are extremely important as spawning grounds and as reliable sources of cold water for downstream habitats. Despite the generally high quality of these small mountain stream habitats, resident coldwater fish populations are vulnerable to catastrophes such as drought, floods and wildfires. Therefore, safeguarding genetically pure populations may require protecting strongholds, increasing available habitat and re-establishing stream connectivity to allow fish to disperse if their habitat is threatened and to repopulate it when conditions improve.

Valley bottom projects

Reconnection can reach its full potential only if the habitats being reconnected are of a quality that will support wild populations of trout and salmon. Although valley bottoms have sustained the most damage from human development, they also offer the greatest opportunity to restore channel diversity and deep pools.

A comprehensive restoration plan would include projects that address not only instream habitat conditions but also the contiguous landscape. Many of the nation's large rivers have been disconnected from their floodplain and riparian zones. Re-establishing riparian corridors that stabilize banks and provide shade helps natural systems build resistance to climate change.

Similarly, reconnecting rivers and their floodplains restores natural processes that benefit water quality, instream conditions, insects and fish. It also moderates cycles of wet and drought and the effects of floods. In valley bottom restoration, it is important to understand what is happening in the watershed upstream, to identify sources

of sediment, rapid runoff or diversions that deliver consequences downstream. Local stresses such as eroding stream banks, elevated water temperatures or the loss of deep pools must be addressed at the site, be it the valley bottom or a distant, upstream landscape.

Riparian zone projects

Dynamic and biologically rich, riparian habitats link aquatic and terrestrial systems. Often environmental restoration projects seek to maintain the critical functions that riparian zones provide to stream systems by

- establishing riparian zones of adequate width and length to buffer stream banks from upslope activities
- restoring native plants and fostering vegetation that shades and thereby cools water flows
- curtailing activities that contribute pollutants and increase erosion and sedimentation

Whenever possible, transportation and energy corridors should not run in close proximity nor parallel to streams. Fencing is frequently used to define riparian zone boundaries and to exclude undesirable practices such as livestock grazing or unregulated off-trail vehicle use.

Floodplain projects

Channelization and the construction of levees and dikes have disconnected many rivers from their floodplains. With no place to spread out and disperse, swift floodwaters can cause high rates of erosion.

Floodplains and adjacent wetlands are also integral to recharging groundwater, which reduces flooding and supports higher base stream flows. Removing levees or increasing their setbacks and dismantling armoring and other structural flood restraints allow rivers to reconnect to their floodplains. Adequately sized floodplains facilitate the lateral movement of rivers and the formation, over time, of sand and gravel bars important to many native fish and plant communities.

Fish passage projects

During extreme flow events or other disturbances, coldwater fish may find refuge by moving freely among headwater streams and between headwaters and larger rivers. Unfortunately, common management projects, including road crossings, small dam constructions, diversions and other flow reduction measures, have disconnected many streams from one another. Often improperly

designed culverts do not permit fish passage throughout the range of likely flow conditions. Most watersheds contain so many barriers to fish movement that restoration planning requires prioritizing the importance of their removal by evaluating at least four factors:

- how complete the blockage is in different seasons or under various flow conditions
- where the barrier is located within the watershed
- how much habitat becomes accessible with the barrier's removal
- cost of addressing each barrier

Properly designed culverts, bottomless archway culverts and bridges can replace restrictive culverts. Installing baffles in existing culverts may slow water and allow fish to pass, but often a significant drop in elevation downstream makes more extensive alterations necessary. Restoring flows in dry stream segments or downstream of diversion structures may involve a combination of securing alternative sources of water; restoring stream flows through land purchases, water rights acquisitions or other agreements; and sustaining greater stream volume by increasing efficiency when using water. Tradeoffs between removing barriers to facilitate movement and keeping barriers to separate desirable from undesirable species require case-by-case evaluation.

Stream channel improvement projects

Restoring or modifying stream channels can create coldwater refuges, including areas near downed logs, root wads or large boulders; deep pools; undercut banks; side channel or alcove habitats; and spring inflow areas. Placing large wood, whole trees with root wads and boulders in streams or in adjacent riparian areas encourages complex channels and deep pools to develop. Allowing rivers to meander cultivates the kind of in-channel refuges that trout and salmon need. Mainstem rivers and river segments that currently contain complex channel conditions with coldwater refuges should be protected.

Invasive species control projects

Climate change may alter long-term habitat conditions to favor more invasive, "weedy" species. Some species or small populations of non-native fish may be compatible with management goals, but other species may need to be eliminated altogether. Managing fisheries on the scale of large watersheds requires adequate monitoring and control of non-native species.

Solutions for Coldwater Fish: Two Case Studies

Editor's note: Fish and wildlife professionals contending with the effects of climate change need a framework to consider the essential factors of a successful field project. The following case studies demonstrate the approach of Trout Unlimited to common project components such as goal identification, implementation barriers and costs.

A case study: Eastern trout streams

Project location

Thorn Creek and its primary tributaries, Blackthorn and Whitethorn creeks, comprise a mountainous subwatershed dominated by private lands in rural Pendleton County, West Virginia. Thorn Creek is a tributary to the headwaters of the South Branch of the Potomac River, which flows into the Chesapeake Bay. Seventy-five percent of the 32,808-acre Thorn Creek subwatershed is forested and 25 percent is in some form of agricultural or livestock production. Forested ridge tops and steep slopes are actively managed for timber and wildlife habitat, and valleys are primarily used as pasture for beef cattle, for industrial-scale chicken production, or cropped for hay, corn and other vegetables. The geology is underlain with karst limestone and many tributaries are spring-fed. Sixteen springs with a minimum base flow of 100 gallons per minute have been identified in the subwatershed.

Background

Native brook trout currently occupy less than 50 percent of their historical habitat in the eastern United States. Primary detriments to brook trout populations and aquatic habitat are warm water temperatures, livestock grazing, poor agricultural practices and degraded riparian and floodplain conditions, particularly in valley bottoms where much of the native forest vegetation has been removed for agricultural development. The habitat in Thorn Creek is typical of current conditions for brook trout throughout much of the East.

With most of the historical, migratory populations that occupied the larger mainstem habitats lost, brook trout populations in the Thorn Creek subwatershed are small and isolated in the upper tributaries. Native brook trout survive where forested hillsides and mountainous terrain limit agricultural development.

Small dams and road culverts as well as the legacy of past clear-cut timber harvests fragment and reduce available habitat in the subwatershed. Limited protection has left the land vulnerable to continued agricultural production, livestock grazing and unsustainable timber harvest. Along many valley-bottom streams the entire riparian plant community has been cleared, and many stream sections have been channelized or disconnected from the floodplain by berms constructed for agricultural development or flood management. In the valley bottoms, degraded conditions no longer support trout, although introduced smallmouth bass and other freshwater species with a tolerance for high water temperatures are present.

Despite these conditions, the Thorn Creek subwatershed provides many restoration opportunities. Abundant cold, clear spring water on forested hillsides offers potential coldwater refuges that could be critical for the remaining brook trout.

Project goals

The project will create a coldwater refuge and promote increased brook trout numbers within the larger headwaters of the South Branch Potomac River by restoring the subwatershed of Thorn Creek. The project proposes to restore degraded springs, stream channels and riparian habitats along the entire stream network and to remove existing stream passage and water temperature barriers so that brook trout can occupy the full extent of their historic habitat in the Thorn Creek system.

Restoration work will increase brook trout habitat in the Thorn Creek watershed by 15 stream miles, recover more than 45 miles of connected, spring-fed stream habitat and vastly improve the quality of water flowing into the South Fork of the Potomac River — and

ultimately into the Chesapeake Bay. Restored riparian communities and reconnected hydrology will reduce stream temperatures and increase habitat resilience to consequences of climate change such as floods and drought.

Implementation barriers

The most significant challenge to restoring the Thorn Creek subwatershed is developing and maintaining trust with private landowners. Historically, landowners in this region have resisted engaging in cost-share programs with state or federal agencies. However, the cause of restoring brook trout has succeeded in rallying a multitude of private landowners and enlisting their participation in a watershed-scale effort. Restoration success will continue to depend on enrolling landowners in state and federal programs to improve water quality, reconnect fragmented aquatic habitat and protect and restore riparian and instream habitat.

Funding to install the best management practices on farmland and to maintain essential project leadership and personnel may pose another barrier to successful project implementation over the next decade.

Project tasks, timeline and costs

The following table outlines the tasks, timeline and estimated costs for the Thorn Creek project.

Tasks	Narrative	Cost
	Year One	
Complete fish and habitat inventory	Inventory fish and habitat in the subwatershed to precisely define opportunities and limiting factors and to establish baseline conditions	$30,000
	Years Two-Four	
Initiate staffing	Hire a dedicated watershed coordinator to develop project planning, landowner relationships, interagency coordination and permitting. $70,000/year X 9 years:	$630,000
Complete agreements and grant applications	Develop conservation agreements and grant applications for private land restoration	$100,000
	Years Three-Seven	
Conduct on-the-ground restoration work	Erect livestock exclusion fencing	$200,000
	Develop off-stream watering facilities	$200,000
	Restore riparian plant communities	$200,000
	Prioritize removal of culverts and other barriers to fish movement	$350,000
	Perform maintenance	$50,000

Tasks	Narrative	Cost
	Continuous, Years One-10	
Conduct monitoring and evaluation	Monitor and evaluate the project to determine effectiveness and need for maintenance or changes in restoration approaches Monitor fish populations to determine effectiveness of habitat restoration and the presence of invasive fish species. $25,000/year x 10 years:	$250,000
	Totals	
	Total project implementation costs over 10 years	$2,010,000

Project update

Because of the large amount of private land in the subwatershed, developing good working relationships with landowners is integral to project success. Bringing a watershed-scale approach to Thorn Creek, Trout Unlimited (TU) staff have persuaded 14 landowners to enter into conservation agreements funded through the Natural Resources Conservation Service (NRCS) and the Farm Services Agency (FSA) incentive-based programs. Techniques to achieve riparian reforestation and water source protection include fencing to exclude livestock, developing springs and wells, constructing water trough facilities with solar charges and solar pumps, and installing instream channel structures.

Since 2007, landowners and partner agencies together have installed over 25,000 linear feet of fence and replanted 32 acres of riparian forest. Projects to protect eight additional miles of stream via livestock exclusion and riparian reforestation are under contract and await federal funding. Grant applications have been submitted to upgrade or replace nine stream crossings that partially or totally block fish passage to 25 stream miles of historic habitat. Committed to this watershed approach that focuses on brook trout restoration, resource agencies have agreed to spend $400,000 on work in Thorn Creek over the next three years.

A case study: Rocky Mountain trout streams

Project location

This project is located in a small watershed on the east slope of the Wyoming Range in the Upper Green River drainage of Wyoming. Most of the larger stream system is located on private lands, with BLM and state-owned lands scattered among cattle ranches. The entire Cottonwood Creek watershed was historic habitat for Colorado River cutthroat trout, which are now restricted to three small headwater streams on national forest lands. Numerous instream barriers divide habitats and isolate trout populations in creeks

that may support only a few hundred or, at most, a few thousand fish. Downstream from the cutthroat trout, the fish assemblage is a combination of other sensitive native species such as flannelmouth and mountain suckers and non-native species such as rainbow trout and white suckers.

Background

Compared to its historic distribution, native trout habitat is reduced and fragmented in much of the Rocky Mountain West. Remaining native trout populations characteristically occupy small headwater streams found often on public lands and are absent from the larger stream systems now mostly inhabited by non-native fishes.

Throughout the West, problems with non-native fishes and habitat degradation are common. Non-natives include introduced trout species that would hybridize with natives if given access to headwaters. While a number of small irrigation diversion dams and poorly designed culverts fragment remaining native trout habitat and prohibit upstream fish movement, they may also prevent undesired species from mixing with native populations.

As headwater streams coalesce into larger streams, they typically flow onto public lands managed by the BLM or onto private ranch land. Historically the larger stream systems often provided the best trout habitat, but now they are routinely degraded by agricultural practices, livestock grazing and diminished riparian vegetation. The results of energy development, including disturbed land surfaces and sullied waterways, are a growing threat to coldwater fish habitat. Stream channels on private lands are degraded and simplified. Deep pools, undercut banks and shaded stream sides that would provide cooler water and help ameliorate the impacts of climate change are mostly absent. Existing stressors will combine with climate change and substantially intensify their effects on watersheds and native fish populations.

Although each watershed is unique, the project represents a typical setting for native trout habitats, including those of Bonneville cutthroat trout, Colorado River cutthroat trout, greenback cutthroat trout, Rio Grande cutthroat trout, Gila trout and Montana Arctic grayling; and for some habitats of redband trout, Yellowstone cutthroat trout, westslope cutthroat trout and bull trout.

Project goals

The project will restore and protect a watershed-scale area where native fish conservation is emphasized. This will be accomplished by

- protecting remaining high-quality habitats
- removing instream barriers to fish passage
- reconnecting stream habitats

- improving stream conditions
- controlling non-native fish species

In the Cottonwood Creek watershed, there are approximately 200 stream miles of historic habitat for Colorado River cutthroat trout. Three small, isolated populations currently exist in approximately 35 miles of stream. Increasing streamside shading and developing deep pools and undercut banks should allow native trout to occupy the entire watershed, at least on a seasonal basis. Expanded habitat would bolster a cutthroat trout population capable of supporting migratory as well as resident fish. Removing barriers such as small irrigation diversions and impassable culverts and reconnecting stream segments will allow fish to find suitable habitats and avoid areas temporarily degraded by wildfire, drought or other climate change-driven disturbances.

Stream and riparian zone restoration would also provide substantial benefits to other native fishes, amphibians and riparian-dependent wildlife. Management actions would have to accommodate other rare native fishes — in this case, the flannelmouth sucker. Managing non-native species may require eliminating them or separating them from native species by installing an instream barrier at the base of the watershed.

Activities on privately owned lands would focus on restoring riparian areas and improving livestock management. This might require erecting fences, changing the timing of livestock use and developing off-stream watering devices.

Implementation barriers

Any multiple-year project tests the stamina of partners, funding sources and community support. Implementing restoration and best-management practices relies on sustaining partnerships with private landowners within the watershed. Projects may require funding or other incentives to attract landowners into good working relationships.

Controlling multiple non-native species in a large number of streams could present significant obstacles. Use of fish toxicants and the potential of fish kills may raise concerns among landowners and recreational visitors. Promoting the expansion of native species could require removing non-native game fish such as rainbow trout, resulting in temporarily diminished fishing opportunities.

Project tasks, timeline and costs

The following table outlines the tasks, timeline and estimated costs for the Rocky Mountains trout stream project.

Tasks	Narrative	Cost
	Year One	
Complete inventory of fish and habitat	Define opportunities and limiting factors; establish baseline conditions by taking an inventory of fish and habitat	$30,000
	Year Two	
Project planning	Implement project planning, coordination and permitting	$30,000
	Years Three-10	
Control non-native fish	40 miles at $6,000 per mile	$240,000
Remove instream barriers	6 small barriers per watershed at $25,000 per barrier	$150,000
Increase fish habitat	Separate native from non-native species as needed. 3 non-native fish control barriers at $75,000 per barrier; costs increase substantially for large barriers and stream systems	$225,000
Improve riparian habitat	Plant native vegetation; control livestock; erect fencing 30 miles at $10,000 per mile	$300,000
Restore stream channels	Place large wood, root wads, or large boulders as required; 30 miles at $10,000 per mile	$300,000
Monitor and evaluate	Determine effectiveness of management actions and future needs; $20,000 per year X 8 years (years 3-10)	$160,000

continued

Tasks	Narrative	Cost
	Years Four-Eight	
Procure easements	Procure easements and acquisitions for improved land and water management; costs could vary greatly.	$350,000
Complete reconstruction	Close or reconstruct roads; replace culverts; costs increase substantially if roads are hard surface and culverts are greater than 36" diameter.	$160,000
	Totals	
	Total estimated project implementation costs over 10 years for a 153,000-acre watershed. Costs could vary substantially depending on factors such as current habitat condition, land ownership patterns, non-native species concerns and size of the watershed	$1,945,000

Conclusion

A warmer future characterized by frequent and intense disturbances such as flooding, wildfire and prolonged drought are consequences of climate change predicted to affect coldwater fish. Strategies to assist fish adapting to climate change are more likely to be successful if they target large, watershed-scale processes and stressors rather than specific streams or stream segments.

Obtaining funding adequate to mitigate the effects of climate change, especially at the scale of an entire watershed or river basin, will be a daunting challenge. However, many actions — particularly those that secure stream flows, provide water during drought and help to protect downstream locales from floods or wildfire — deliver benefits to both aquatic resources and human communities. This should increase the potential for finding revenue sources.

Protecting the best remaining strongholds and reconnecting fragmented habitats continue to be sound conservation principles during rapid climate change. The best approaches to assisting fish are those designed to conserve the remaining genetic, life-history and ecological diversity of native trout and salmon within protected, reconnected and restored watersheds.

Fortunately, trout and salmon have an evolutionary history of exposure to wide-ranging conditions and an inherent resilience to change. Change is coming faster than ever, but if trout and salmon can access high-quality, interconnected habitats, they will continue to provide extensive cultural, recreational, economic and ecological value well into the future.

"On some summer vacation or some country weekend we realize … that we have joined the greatest of all communities, which is not that of men alone but of everything that shares with us the great adventure of being alive." — Joseph Wood Krutch

Warmwater Fish

by Mike S. Allen, Mark W. Rogers and Christopher M. Horton, BASS/ESPN Outdoors

The complete text of this chapter is posted at www.seasonsend.org.

Although one might expect a warming climate to benefit warmwater fish, some effects of climate change will likely be counterintuitive, influencing warmwater fish populations in many negative ways. This chapter provides an overview of the problems that climate change poses to warmwater fish and possible solutions.

Warmwater fish may be particularly susceptible to the following consequences of climate change:

Climate change will shift precipitation patterns

Shifts in rain and snowfall that intensify the severity and duration of both droughts and floods will be the most profound effect of climate change on warmwater fish in freshwater aquatic systems.

Several key studies predict that long and severe summer droughts will be followed by pulses of extreme high-water events. A strong sport fish year-class (individuals spawned in the same season) often follows a year of high water levels. However, extended periods of low water diminish habitat quality and reduce juvenile fish survival, with low numbers of young fish entering the population.

Climate change will alter aquatic plant growth

The effects of global climate change on aquatic plants could be contradictory: Longer growing seasons and improved growth rates would bolster the abundance of aquatic plants in freshwater systems, but variable water levels could impede growth. High water levels could shade out plants but droughts will expose them to drying. Additionally, threats from exotic plants, most of which are tropical in origin, would increase as the thermal environment becomes more favorable to their establishment and range expansion.

Climate change will accelerate sea-level rise

By forcing salt water into freshwater portions of rivers, rising sea levels will cause a contraction of suitable habitat for freshwater species. Habitats most susceptible to sea-level rise would be in coastal areas of low elevations, wetlands and dammed rivers where fish have no escape from saline conditions. The counter to saltwater intrusion into estuarine fisheries is inflows of fresh water. If, during years of drought, freshwater flows are not available, the effects of rising seas could be exacerbated.

Climate change will aggravate existing stresses

Humans have altered watersheds with dams, water control structures and development in flood plains and riparian zones. Increasingly frequent droughts and severe floods could magnify the effects of these alterations on aquatic systems and the warmwater fish that they support.

How Warmwater Fish Will Respond to Climate Change

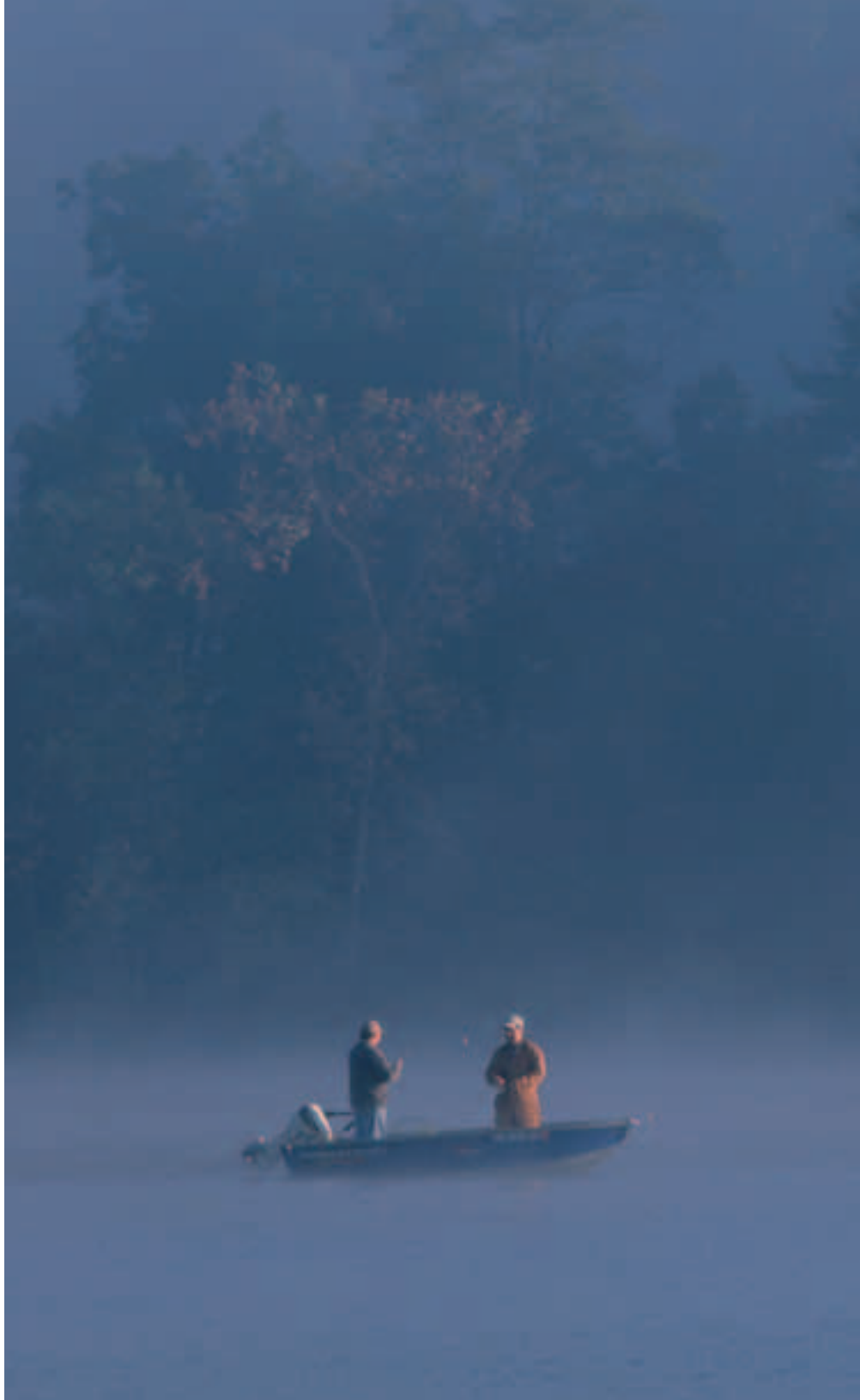
As water temperatures rise and rainfall patterns change, increased floods and droughts will compromise fish habitat and reduce its complexity in lakes, reservoirs and rivers. Changes in habitat quality will influence the abundance of warmwater sport fish and ultimately threaten the quality and sustainability of the fisheries. In response to sea-level rise increasing salinity levels in rivers and estuaries, warmwater fish could shift to upstream habitats. Warming temperatures in the southern reach of their range could force warmwater fish to withdraw and move northward. In regions such

as the Great Lakes and the Rocky Mountain states, warmwater fish could replace coldwater fish as dominant species.

Yesterday's Programs Can't Solve Today's Problems

Presently the federal dollars spent to improve warmwater fisheries come from the Dingell-Johnson Sport Fish Restoration Funds. Taxes on fishing tackle, supplies and fuel furnish the funds, from which money is allocated to states based, in part, on fishing license sales. The Dingell-Johnson Funds, however, are inadequate to finance effective responses to climate change. Maintaining warmwater fisheries under conditions of climate change will require new, broad-scale renovation and restoration programs.

States, particularly if helped by local government and private partners, can conduct projects on smaller lakes and rivers, but cannot undertake new issues such as aquatic plant management or fish habitat loss in large reservoir and lake systems. Furthermore, large rivers and impounded systems often cross state boundaries and have regional water-use implications that are currently beyond the scope of states to address. As a consequence, large, system-wide projects to assist warmwater fish adapting to climate change would require substantial new funding.



What Can Be Done: Project Types

Fish and wildlife professionals recognize that they can't rely on yesterday's programs to address the consequences of global climate change. The first step toward innovation is to see clearly the broad categories within which new ideas can take shape. The following survey of project types offers that perspective.

Nutrient reduction projects

Excess nutrients in a water body stimulate inordinate plant growth and algal blooms and cause poor oxygen conditions. In response, fish assemblages shift away from sport fish species toward rough fish (carps). Occurrences of this phenomenon could multiply as a longer growing season — a consequence of global warming — combines with increased nutrient loads produced by an expanding human population.

Water-level management projects

Restoring water volumes and depths to healthy levels in rivers and reservoirs shows the greatest potential for improving warmwater fisheries on a large, watershed scale. This type of project can be accomplished by renegotiating water use permits and allocations, but requires fisheries managers to work as teams, across jurisdictions, and with competitors using water for other purposes, such as hydropower generation and agriculture.

Riparian management projects

Improved management of soil and vegetation along the banks of waterways — the riparian zones — bolsters fish populations in lakes and reservoirs. Projects that reduce sediment and nutrient loads from agricultural and urban areas can increase water clarity, foster beneficial aquatic plant growth and improve fish habitat throughout lakes and watersheds. Examples in Iowa provide excellent case studies of the costs of watershed-scale riparian improvements and their benefits to lake water chemistry and fisheries.

Projects mitigating effects of human development

Urban encroachment and development along shorelines can reduce fish habitat in lakes and throughout watersheds. Extensively developed lake shorelines support less sport fish biomass and slower fish growth rates than do natural shorelines. Due to concerns about flooding, urban development constrains management of water levels in reservoirs and rivers. Droughts and floods that alter water flows will only exacerbate pressures of an expanding human presence on water resources. To mitigate the negative consequences of hydrological manipulations, projects involving homeowners and land planners can restore habitat, reduce further habitat loss and benefit warmwater fisheries.

Aquatic plant control projects

High vegetative coverage — greater than 80 percent of surface area — reduces angler access and fish growth rates. Control of native and exotic plants will be important as growing seasons lengthen and increase the number of locations requiring aquatic plant management.

Aquatic plant establishment projects

Establishing aquatic plants could mitigate fish habitat losses that result from increased droughts and floods. Establishing aquatic plants has succeeded in improving fish habitat in reservoirs and lakes such as Lake Conroe, Texas, and Lake Monroe, Florida.

Artificial habitat projects

Inserting woody debris and brush piles, adding rock and stone, and dredging to improve the substrate are common methods of restoring lake and stream habitat. Typically these projects focus on developing fish attractors for anglers and are conducted on a relatively small scale, but such projects may be viable for improving fish abundance on the large scale of entire lakes or rivers.

Angler access projects

Low water levels, whether caused by severe droughts or resource management actions, can have disastrous effects on local economies reliant on warmwater fisheries. An example comes from Cumberland

Lake, Kentucky: The U.S. Army Corps of Engineers estimated that lowering the lake level by 40 feet to repair the Wolf Creek Dam would cause local economic losses of up to $75 million, with the fishing and boating industries bearing the brunt of the losses.

Such extreme water-level fluctuations will become more common under global climate change. Existing boat ramp construction and maintenance are not suited for such drastic fluctuations in water levels, and sustaining fisheries-based economies will require new lake and river access projects. Large investments in infrastructure — boat ramps, lake and river access and parks — will be needed.

Solutions for Warmwater Fish: Three Case Studies

Editor's note: Fish and wildlife professionals contending with the effects of climate change need a framework to consider the essential factors of a successful field project. The following case studies demonstrate the approach of BASS/ESPN Outdoors to common project components such as goal identification, implementation barriers and costs.

Warmwater fish management agencies should consider three types of projects for countering the effects of climate change. Presumably some states would implement all three types, others only one or two, but all states except Alaska would need at least one type to address the effects of climate change on warmwater fisheries.

A case study: Small water bodies

Project location

Water bodies and riparian areas ranging from 50 to 10,000 acres across nearly all of the United States

Background

This project would improve fish populations in a small reservoir system within a single watershed that is affected by the combination of land-use practices and climate change. The project is typical of those undertaken on smaller lakes (100-3,000 acres) and streams throughout the United States. These waterways are characterized by

- high sedimentation, a result of riparian habitat loss
- increased levels of nutrients, caused by agricultural runoff
- undesirable fish communities, including high biomass of invasive species like gizzard shad and non-native species like common carp

These problems would be exacerbated by further urban development along shorelines and by the effects of climate change. For example, erosion will wash more sediment into streams and rivers as buildings and roads replace trees and shrubs, droughts expose shorelines and then floods scour the exposed shorelines. Increased nutrient loads

and longer growing seasons will intensify algal blooms and multiply fish deaths caused by a lack of oxygen.

Project goals

This project seeks to restore lake habitat by addressing watershed issues such as land-use practices and runoff and in-lake issues such as shoreline degradation and the presence of exotic fish species. The project's goals include

- improving fish habitat in lakes and streams
- improving warmwater fish spawning habitat
- boosting sport fish abundance
- reducing interactions between sport fish and invasive or exotic species
- reducing algal blooms that can result in fish kills and consequent dominance of undesirable fish species

Implementation barriers

Implementing these programs takes a strong commitment from public and private stakeholders. State agencies cannot accomplish these projects alone; doing the work and garnering state and federal aid require effort and support from local communities.

Project tasks, timeline and costs

Based on existing programs in Iowa, the tasks, timeline and estimated costs for renovating a 500-acre water body within a 5,000-acre watershed comprising both agricultural and urban components are outlined below. An effective state program would initiate two or three renovation projects of this type every year, with each project taking two to three years and costing close to $8 million.

Tasks	Narrative	Cost
	Years One-Three	
Dredge lakes and streams, construct fish barriers, stabilize shorelines, construct settling ponds	$11,00 per lake-acre X 500 acres	$5,500,000
Acquire land or easements	$4,500 per land-acre X 5,000 acres	$2,250,000
	Totals	
	Total project implementation costs over three years	$7,750,000

A case study: Large water bodies and river systems

Project location

Watersheds ranging from 3,000 to 150,000 acres with multiple impoundments, including reservoirs operated for hydroelectric, flood control or navigation purposes, occurring in most states

Background

Systems of large, impounded lakes (e.g., Kissimmee Chain of Lakes in Florida) and rivers (e.g., Missouri River in the Midwest) include many of the most valuable warmwater fisheries in the U.S. As global climate change causes droughts and consequent low water levels, large-scale losses in warmwater fish habitat throughout the lower 48 states could occur. Recent, persistent droughts in the West, upper Midwest and Southeast demonstrate the threat of uncontrolled lower and more variable water levels in large, impounded river systems.

Nearly all large reservoirs were built for purposes such as navigation, flood control, power generation and water supply. Recreational fisheries are usually a secondary objective of dam operations in large river basins. Although a decade of managing varied water levels in Missouri River reservoirs has demonstrated the advantages this approach could deliver to fish, designing flow and stage regimes solely to benefit warmwater fisheries is unlikely.

Project goals

This project would improve fish habitat and promote fish abundance while maintaining other community benefits of reservoirs such as flood control, hydropower and navigation. The project goals include

- establishing native aquatic vegetation: Pilot projects will plant small founder colonies of native aquatic plants within protected enclosures. This approach promises to improve habitat at the whole-lake scale.

- maintaining adequate oxygen levels for open water fish such as striped bass: Rising water temperatures can limit suitable zones of both oxygen and temperature within the water column for sport fish and particularly for striped bass. Oxygen diffuser systems can alleviate this "thermal squeeze," which is expected to become more common as temperatures rise under climate change.

- improving fish habitat by managing water levels in a chain of reservoirs: In staggered years, water levels in designated reservoirs would be kept elevated during spring fish-spawning season to produce strong year-classes among their fisheries. Managing for fish would alternate among reservoirs, with each reservoir prioritizing fisheries at three- to six-year intervals while other reservoirs in the chain are managed for hydropower generation or other basin objectives. This schedule would allow strong year-classes to occur with sufficient frequency to preserve fishing quality in the basin even under long-term drought conditions. Potentially improving fisheries across large areas while ensuring that human use of water resources is sustainable, this concept would be developed by multidisciplinary teams that include engineers, economists, civic planners and natural resource managers.

Implementation barriers

Installing and operating diffuser systems to maintain adequate oxygen levels for striped bass is expensive. Policy makers would have to weigh the cost against the value, which exceeds $25 million annually for some striped bass fisheries.

Managing water levels in a chain of impoundments would require fisheries agencies to work with power companies and federal agencies to be certain that other basin objectives such as hydropower generation or flood control would not be compromised. This goal would be the most difficult to accomplish, as it would encounter barriers involving

- power generation
- multi-state jurisdictions
- conflicting stakeholder interests
- political commitment to reallocate water within basins to maximize benefits to all user groups
- a significant financial investment to identify viable schedules

Project tasks, timeline and costs

Three project tasks, used singly or in combination, could sustain and improve warmwater fisheries where decades of extended droughts or low levels of spring runoff are expected to cause harm. All tasks are important in reaching the desired outcome, but regulating water levels on an alternating schedule shows the most promise for improving fisheries on a basin-wide scale.

Tasks	Narrative	Cost
	Single-year projects	
Establish native aquatic vegetation	Pilot projects to evaluate founder colonies' potential to spread and improve fish habitat. Cost per pilot project:	$50,000-$100,000
Install oxygen diffusers in lakes and impoundments	Although costly, diffuser systems could maintain popular striped bass fisheries.	Installation: $300,000-$2,000,000 Annual operation: $75,000-$800,000
Develop alternate water flow plan	Alternates spring high-water levels for a chain of reservoirs.	Not available

A case study: Managing aquatic plants

Project location

Most states will need to manage increased aquatic plant growth in warmwater fisheries. Presently many states are not prepared to meet this challenge.

Background

Because climate change will raise water temperatures and extend growing seasons, aquatic plants are expected to expand into regions that have not previously conducted intensive plant management.

Goals and objectives

The project will provide moderate levels of aquatic plants for fish habitat while maintaining lake access for homeowners, boaters and anglers.

Implementation barriers

Barriers to implementing aquatic plant control in a lake usually involve conflicts among different user groups. State agencies will need to educate the public about today's safe aquatic herbicides and stress the negative result of using grass carp (i.e., elimination of aquatic plants).

Project tasks, timeline and costs

Outlined below are the tasks, timeline and estimated costs for managing *hydrilla* colonization in a 500-acre lake. Each management option results in a slightly different outcome.

Tasks	Narrative	Cost
	Single-year projects	
Introduce grass carp	Grass carp could eliminate hydrilla from the system, thereby reducing the quality of recreational fishing but satisfying the boaters and homeowners who object to plants.	$10,000
Use herbicides	Herbicides require expensive, regular treatments but could retain some aquatic plant presence and maintain quality fisheries while opening areas for boating, swimming and skiing. Depending on herbicide used, annual costs for treating 250 acres of a lake:	$75,000-$250,000
Use mechanical control measures	Use of mechanical controls such as plant harvesters, feasible around boat ramps and some docks, is not economically viable for areas larger than 50 acres. Annual costs for clearing a 50-acre area around boat ramps and docks:	$25,000

Conclusion

These projects address the stresses on warmwater fish that are most likely to demand management action, but there will be other costly consequences of global climate change that are difficult to forecast. For example, protecting warmwater fish populations could require eradicating or controlling the spread of exotic fish and invertebrates.

Mitigating the effects of global climate change on warmwater fisheries will require fish and wildlife agencies to use a multifaceted approach. Almost all states would engage in two or more project types at multiple locations. Thus, annual costs per state to sustain and improve warmwater fisheries could easily add $10-20 million to current resource management expenditures.

But project funding even at this level will be insufficient to eliminate all climate-change-induced threats to warmwater fish. Unfortunately, it will not be cost-effective to preserve or restore all fisheries. Agencies will have to make tough choices and prioritize systems based on the probability of success and the popularity of the water body among the angling public.

Many of the challenges that warmwater fish already face will intensify under the looming threat of global climate change. Management agencies must begin addressing those challenges now through monitoring and project planning to be able to counter their increasing severity under future conditions.

"For in the end the human community will flourish or decline as the earth and the community of living species flourishes or declines." — Thomas Berry

Big Game

by Kaush Arha, Boone and Crockett Club, with research assistance from Jeffrey Wright and thoughtful reviews by Jack Ward Thomas, Paul Krausman, Hal Salwasser, Val Geist, Steve Mealey and Robert Model
The complete text of this chapter is posted at www.seasonsend.org.

The rebuilding of the country's big game population is the great American conservation success of the 20th century. Today's challenge is sustaining this legacy in the face of climate change. The fundamental question big game face is whether they will have the freedom to move and adapt to altered conditions, given the constraints that humans place on the landscape. Populations that are isolated, unable to adapt or barred from moving to suitable habitats will certainly decline and may face extinction.

Climate change will affect big game food resources, life-history events and habitat range.

Climate change will alter plant phenology

The timing of plant life-cycles (phenology) is critical to big game: The most nutritious plant growth must be available when demands on the animals' energy are greatest. For example, in order to recover from winter weight loss and have sufficient energy to nurse their young, most ungulates (e.g., deer, elk and moose) have evolved to give birth when forage greens in the spring. Disruptions in the coincidence of food availability and life-history events such as migration and birthing can be damaging to a large mammal's balance of energy.

Over the past decade, drivers of plant life-cycles — the onset and length of warm seasons — have changed markedly in the temperate latitudes of North America. Of nearly 1,600 plant and animal species studied, 60 percent exhibited shifts in distribution, phenology or both over a time horizon that varied from 20 to 140 years. If big game are not able to keep pace with changes in plant phenology, the costs — while not precisely predictable — will be high.

Climate change will cause shifts in plant ranges

Projected changes in precipitation and temperature could cause dramatic shifts in the composition, distribution and functions of terrestrial ecosystems, thus altering availability of big game food and cover. As warm-weather species invade or as sub-dominant species displace dominant species, plant communities will change. Boreal forests may invade present tundra, while temperate forests and grasslands may move toward the north. Deserts are expected to expand northward. Across large portions of western mountain ranges, alpine habitats are likely to diminish. Some scientists contend that the rate of climate change will outstrip the migration rates of most plants, leaving slowly migrating species to go extinct in their present environment.

Climate change will cause changes in temperature and precipitation

Rising temperatures will increase energy demands on most cold-adapted large mammals. Unlike bovids such as goats and sheep, cervids (e.g., deer, elk, caribou and moose) evolved in cooler climates. Rising air and water temperatures will stress these species' thermo-regulatory systems and cause them to expend more energy in moderating their body temperatures.

Arctic sea ice is now melting faster than most models had projected, drastically altering the behavior, condition and composition of sea-ice-dependent, large-mammal communities, including those of polar bears, walruses and seals.

Climate change will increase pests and pathogens

Warming temperatures will cause the range and virulence of pests and pathogens infesting big game populations and habitats to expand. Warm summers abet growth rates. Mild winters enhance larvae survival. While other plants and animals adapt to changing climatic conditions more slowly, pests and pathogens could lead a rapid and alarming migration toward the pole.

Under a warming climate, American forests have become more vulnerable to infestations of insects such as pine and spruce bark beetles. In 2006 pine beetle outbreaks killed about five million lodgepole pines in Colorado — a four-fold increase from 2005. Forest die-offs following insect infestations set conditions for catastrophic fires with severe repercussions on big game populations.

Climate change will promote forest fires

Frequent, low-intensity fires improve forage quality for most big game. However, hot fires that burn large stands of timber may directly harm large mammals and render portions of their habitat unusable. As climate has warmed in recent years, forest fires in the United States, especially in the northern Rockies and the Sierra Nevada, have dramatically increased in number and intensity. In 2008, approximately 800,000 wildfires burned 68.6 million acres in

the United States; over the previous four decades, annual fires were more numerous — about 1.15 million per year — but burned less area — an average of 34.5 million acres. Hot and frequent fires will combine with the spread of invasive species (e.g., cheat grass) in the Big Basin and of temperate grasses in the Arctic tundra to change those ecosystems' dominant plant species and consequently affect big game food supplies.

Climate change will compound the effects of the human presence

Relocating cropland, developing alternative energy sources and migrating to more comfortable northerly climes are likely ways the nation's citizens will respond to global warming. Supported by new roads and infrastructure, these responses would fragment and damage connectivity among big game habitats and create additional barriers hindering wildlife movement.

How Big Game Will Respond to Climate Change

Big game are expected to adapt to global climate change as flatland-dwelling mammals have done during warming periods for eons: by moving northward or to higher elevations. Availability of suitable habitat and barriers to animals' movement could limit the success of these migrations.

The present warming trend is markedly different from others occurring since the last ice age in two important ways: The current rate of warming is much faster, which increases pressure on big game populations to adapt quickly; and the pervasive human presence riddles the landscape with development that not only displaces animal habitats but also bars animal movement.

Big game species are likely to respond to climate change in the following ways:

Mountain goats and sheep, bears, musk ox and caribou

Species relatively less mobile and with highly specialized habitat needs are most vulnerable to the effects of climate change. Mountain goats are among the most threatened species because of their fidelity to alpine habitat and their limited capacity to disperse to other environments. The fast disappearance of their favored climes could force goat populations to compete for increasingly isolated, fragmented and diminished habitat areas. Consequently, goats would suffer declining birth rates, increased predation, enhanced vulnerability to disease and intensified competition from wild and domestic sheep.

Many populations of mountain sheep are similar to goats in their restrictive habitat requirements and their limited ability to disperse.

Though their habitat zone is larger than that of mountain goats, mountain sheep will face similar pressures, including heightened susceptibility to diseases transmitted by domestic sheep.

Human development already limits mountain goats and mountain sheep to "islands" of suitable high-elevation habitats. Without continual management efforts, it is probable that isolated mountain goat and mountain sheep populations will vanish as climate change alters habitat conditions.

As warmer oceans reduce their hunting and foraging opportunities, wildlife habituated to Arctic sea ice could weaken and starve. Although polar bears have high dispersal abilities, when confronted with the steady shrinking of their specialized sea-ice habitat, they are highly vulnerable to climate change.

Under climate change, interactions and competition between polar bears and brown bears will become more frequent. Black bears and brown bears are opportunistic feeders and wide-ranging generalists, but for eons they have closely tied their denning and reproduction to seasonal changes in the length of daylight hours. It is not known if these animals will modify timing of their breeding, inactivity and reproduction in response to changes in weather and consequent alterations in plant phenology. For grizzly bears, a warming climate could diminish important food sources, including whitebark pine and cutworm moths.

Although highly mobile, caribou and musk ox populations face inexorably shrinking habitats as tundra vegetation gives way to more temperate plant types. Alterations in the composition of plant communities and increases in fire-prone conditions could reduce winter habitat and forage. Severe winter storms and weather extremes causing variable snow depth and snow crusting could deprive animals of access to forage, resulting in high over-winter mortality among caribou herds. In springtime, warmer temperatures and variable precipitation might affect caribou migration and reproduction. Expanded numbers of harassing insects could drive caribou to reduce the time they spend in feeding and lead to declining health and vigor.

The experience of musk ox under global warming will be similar to that of caribou, although their digestive tolerance for shrubs provides them a larger forage base.

Moose

Evolved to withstand severe cold and snow, moose are intolerant of warm temperatures. Studies correlate an increase in mean summer

temperatures with the prevalence of disease and declines in moose populations. Warmer temperatures force moose to expend more energy on thermal regulation, depress fecundity and lower survival rates. Additionally, rising temperatures would shrink the riparian and wetland vegetative habitats that moose prefer and reduce the availability of foods comprising the highly specialized moose diet.

Moose populations are expected to shift northward, with populations in the Rocky Mountains, Great Lakes and the Northeast predicted to decline. Extirpation of moose in some of their current habitats is likely.

Elk, mule deer, white-tailed deer and pronghorn

Highly mobile and able to use diverse habitats, elk and white-tailed deer are among the big game species least vulnerable to climate change.

Rather than directly affected by its consequences, the health and adaptive success of individual elk, deer and pronghorn populations will be influenced by

- pressures from human development
- barriers to movement
- presence and density of predators

- susceptibility to pathogens
- nutritional quality of newly evolving plant communities

In the short term, wetter summers may lead to increased forage production. Warmer winters may enhance access to forage and improve survival rates among elk, deer and pronghorn. But where warm winters and wet summers converge, in the absence of ecologically effective populations of predators these species' numbers could exceed the long-term carrying capacity of local conditions.

Elk are well suited to exploit habitats altered by changing weather patterns. However, predators and barriers to movement could substantially affect an elk population's survival. Changing conditions will cause elk, deer and antelope to shift their ranges northward and to develop new migratory corridors. White-tailed deer are expected to continue their westward march along riparian zones, leading to increased competition with mule deer.

Yesterday's Programs Can't Solve Today's Problems

Traditionally, efforts undertaken by state and federal agencies and private organizations to conserve big game have focused on improving productivity of seasonal habitat and enforcing hunting regulations. There is little detailed information on how climate change will affect individual wildlife populations, and wildlife management agencies have no strategies in place to assist big game facing climate change. Existing funds are inadequate to gather needed data and to facilitate wildlife adaptations to altered conditions. New funding for wildlife conservation in a changing climate is urgently needed.

What Can Be Done: Project Types

Fish and wildlife professionals recognize that they can't rely on yesterday's programs to address the consequences of global climate change. The first step toward innovation is to see clearly the broad categories within which new ideas can take shape. The following survey of project types offers that perspective.

Assessment projects

To aid big game conservation in a changing climate, each state must undertake a comprehensive assessment of its big game populations to

- identify both climatic and non-climatic factors limiting big game health and survival
- collect and analyze all existing information on big game movements and potential corridors

- determine the current status and probable future trends of productivity, diversity and connectivity in big game habitat

Computer modeling of all habitat limitations will assist in developing conservation strategies to facilitate big game adaptation to climate change.

Habitat productivity, diversity and redundancy projects

Projects enhancing habitat diversity and redundancy across landscapes will bolster big game resiliency and resistance to climate change. Robust buffer zones contribute to habitat redundancy, as do hydrological improvements, seeding and prescribed fire. Historically, western mountain states have focused on improving winter range productivity for wild ungulates; climate change may cause management agencies to shift their focus to improving spring and summer ranges.

Methods to improve big game habitat include

- reseeding native grasses, forbs and shrubs to improve forage for wild ungulates
- conducting prescribed burns to improve nutrient cycling and forage quality
- thinning overstocked forests to
    - reduce vulnerability to drought, insects and fire
    - open the forest floor to more sunlight
    - induce growth of more productive and diverse big game foods
- planting vegetation, installing fences to exclude domestic livestock and implementing other restoration measures to improve riparian habitat for cover and forage
- using mechanical means to
    - improve stream drainage and habitat cover
    - contain, reduce or remove exotic species
    - accomplish other habitat enhancements

Corridor and connectivity projects

Most big game conservation efforts have focused on identifying and improving habitat on seasonal ranges. Less attention has been devoted to identifying migratory corridors among seasonal ranges for individual populations or wildlife pathways between two or more populations.

Specific projects to improve corridors and connectivity among big game populations include

- redesigning fences: Use smooth instead of barbed wire for the bottom strand and increase fence height to 18 inches to allow pronghorn to crawl under the fence.
- seeding and planting trees: Improve both forage and cover for wild ungulates along critical stretches of corridors. Improving habitats particularly along riparian corridors benefits other classes of wildlife as well as big game.
- constructing overpass and underpass crossings: Build passageways allowing wildlife to avoid roads, often the most significant barrier to big game movement.
- securing conservation easements: Develop agreements between state or private parties and willing landowners to allow wildlife movement across private property.
- mitigating development: Identify and execute proper mitigation measures, either on- or off-site, for energy, residential and other development projects that affect wildlife movement.

Habitat monitoring projects

Data derived from monitoring big game habitat productivity, diversity, redundancy and disturbance are integral to formulating management decisions. Standard monitoring protocols should be developed and monitoring schemes coordinated among all agencies and conservation groups. Widespread use of remote sensing technologies can improve accuracy and greatly reduce habitat monitoring costs.

Solutions for Big Game: A Case Study

Editor's note: Fish and wildlife professionals contending with the effects of global warming need a framework to consider the factors of a successful field project. The following case study demonstrates an approach to common project components such as goal identification, impementation barriers and costs.

Project location

Big game populations range within and across state boundaries. The Wildlife Corridors Initiative (WCI) is conducted among the 19 states that are members of the Western Governors' Association (WGA).

Background

Big game species will adapt to a changing climate principally in two ways: by moving to suitable habitats and by adjusting the physical

and biochemical characteristics of offspring through the process of natural selection.

Assisting big game in adapting to climate change requires anticipating habitat shifts and identifying present and probable future wildlife corridors and barriers to big game movement. Such information does not currently exist at state or regional levels in a format that management agencies can use.

Project goals

The goal of the WCI is to increase the success of big game species adapting to a changing climate by identifying, enhancing and protecting wildlife corridors in 19 western states. Through collaboration among state and federal resource management agencies, the initial project will

- develop current, comprehensive and compatible maps
- identify present and probable future wildlife corridors
- identify present and probable future barriers to wildlife movement
- develop integrated policies and programs that permit economic development while preserving wildlife corridors

Implementation barriers

Designing and executing a wildlife corridor initiative face financial, institutional, programmatic and developmental barriers, of which financing is by far the most challenging. The WCI requires substantial effort to map and gather information in the field and to organize and coordinate numerous state and federal agencies responsible for implementing appropriate policies. Funds for this work are limited and dependent on federal financial support.

Lack of information about wildlife habitat and movement is a major barrier to protecting and enhancing wildlife corridors. Other barriers include difficulties in developing and executing coordinated policies among various state and federal agencies and problems stemming from incompatible information databases. Updated information accessible to all involved parties will facilitate establishing regional wildlife corridors spanning multiple states.

Project tasks, timeline and costs

The following table outlines the tasks, timeline and estimated costs for a wildlife corridor initiative spanning 19 states.

Tasks	Narrative	Cost
	Years One-Three	
Develop decision support system (DSS)	Enhances mapping of corridors and crucial habitat areas across western states to inform decisions on energy and transportation infrastructure and residential development $1 million/year/state X 19 states X 3 years	$57,000,000
Establish a wildlife adaptation advisory council	Consists of state and federal agencies, academic institutions and science-based non-governmental organizations to assess climate-change effects on wildlife and wildlife habitat $100,000/year/state X 19 states X 3 years	$5,700,000
Establish a regional information clearinghouse	Communicates information on wildlife corridors and crucial habitat $100,000/year X 3 years	$ 300,000
Address habitat fragmentation	Uses incentives to encourage landowners to appropriately manage habitats and wildlife corridors on private lands $1 million/year/state X 19 states X 3 years	$57,000,000
Encourage collaboration among working groups	Includes groups conducting hydrologic strategic planning, hydrologic climate modeling, water storage development and state invasive species strategies $100,000/year X 3 years	$300,000
	Totals	
	Total project implementation costs	$ 120,300,000

Conclusion

The future of big game in the United States rests on species' ability to adapt to climate-induced alterations in habitats and to stresses resulting from human manipulation of the landscape.

State and federal agencies are rich in experience and have a record of success in undertaking landscape-level resource planning and management. With federal funding assistance, states have recently completed wildlife action plans to conserve sensitive species, and a similar effort is needed to develop climate action plans to conserve big game.

The administration and Congress must again exercise historic leadership on wildlife conservation issues and develop a funding structure enabling state and federal resource agencies to manage and preserve big game in the face of global warming.

"To waste, to destroy, our natural resources, to skin and exhaust the land … will result in undermining in the days of our children the very property which we ought by right to hand down to them amplified and developed."
— Theodore Roosevelt

Upland Birds

by David E. Nomsen and Robert A. St.Pierre, Pheasants Forever, Inc. and Quail Forever
The complete text of this chapter is posted at www.seasonsend.org.

Extremes in climate and weather affect ground-nesting game birds at every stage of their life cycle, from initiating breeding behavior to selecting nesting sites to finding available food. The extremes also create conditions that foster the spread of invasive plants, animals and insects, potentially disrupting the food web and upsetting the ecological community's delicate balance. The consequences of climate change, some of which are already affecting game birds, will intensify in the coming decades.

Climate change will cause extremes in weather

The incidence of major weather events, exemplified by historic floods in the Midwest in 2008 and 2009, will increase. Exceptionally wet springs not only wash away nests and drown chicks, they also influence where hens nest after the waters begin to recede. Once the land dries, nesting sites selected during high water may prove to be extremely vulnerable to predation.

By contrast, anticipated increases in drought would limit the development of large, sustainable, upland bird populations. More arid springs and summers in Texas, Oklahoma, Kansas, Nebraska and Missouri would accelerate bird losses in these top five quail states.

Nesting quail are particularly susceptible to disruptions caused by severe storm seasons. Increasingly intense hurricanes and tropical storms could reduce the Southeast's bobwhite quail population toward the point of no return.

Climate change will change the form of precipitation

During cold winters, precipitation falls as soft snow. In severely cold weather, ruffed grouse burrow into that soft snow to create a kind of igloo and conserve heat. Without snow, exposure to severe cold or freezing rain leads to significant mortality among grouse.

Climate change predictions suggest snowfall will decrease across the primary range of grouse habitation. Relying on snow depth for roosting as well as for thermal cover, grouse populations decline following winters of low snowfall. Further, freezing rains during a warm winter can coat snow with a shell of ice, effectively entombing roosting grouse or preventing them from roosting at all.

Climate change will disrupt life cycles

As spring weather arrives earlier each year, phases of an upland bird's life cycle, including reproduction, also accelerate. Whether temporal changes in the emergence of insects and plants will correspond to birds' altered schedules is unknown. If food sources adapt to climate change at a rate different from that of birds, a warm-season grass or insect particularly important in a developing chick's diet could be absent.

Climate change will redistribute habitats

Warming temperatures will shift the boundaries of suitable habitat. For instance, global climate change could create more quail habitat in northern states like Wisconsin, Minnesota, and the Dakotas but decimate populations remaining in the Southeast.

As well as facing habitat loss, upland birds will confront threats from new predators within their habitat. Opossums, for example, have expanded their range northward to join raccoons and skunks in a powerful triumvirate of nest predators. As habitat suitable for upland birds becomes increasingly fragmented, predators become more effective at finding nests.

How Upland Birds Will Respond to Climate Change

Pheasants

Pheasants are a highly adaptable species, able to rebound from periodic bouts of deadly weather. But regular and frequent wet springs, arid summers or severe winters could devastate pheasant populations long-term.

Quail

More moderate winters may result in northern bobwhite quail re-establishing populations in historic, northerly habitat. But shifts in forest composition and the increasing frequency of catastrophic wildfires, hurricanes and other extreme weather events increase the likelihood of quail numbers continuing their already precipitous decline.

Ruffed Grouse

Dependent on snow cover for roosting and thermal protection, ruffed grouse are vulnerable to even minor changes in winter temperature and snowfall. Of even greater concern is the changing complexion of North America's forests under climate change. The continued loss of early successional forests, which make up the habitat necessary for every stage of a grouse's life cycle, would be catastrophic. These phenomena are predicted consequences of global climate change and could lead to dramatic ruffed grouse losses across their core Northwoods range.

Yesterday's Programs Can't Solve Today's Problems

In the past, federal, state and private conservation organizations have offered a suite of voluntary, incentive-based programs to protect and restore wildlife habitats. Although inadequate funding limits their reach, overall the programs have worked well in supporting upland game birds. However, these conservation efforts are buffeted by the prevailing agricultural economy; when land or commodity prices rise, participation in the programs declines.

Clearly, the present system is unable to implement the vigorous conservation programs that responding to climate change requires. If comprehensive and necessary programs are not adequately funded, upland bird populations as a whole will decline drastically.

What Can Be Done: Project Types

Fish and wildlife professionals recognize that they can't rely on yesterday's programs to address the consequences of global climate change. The first step toward innovation is to see clearly the broad categories within which new ideas can take shape. The following survey of project types offers that perspective.

Public and private partnership projects

Climate change accelerates the need to conserve upland birds and their habitats. Even as demands on management agencies grow, citizen participation in their conservation programs becomes more crucial. Non-governmental organizations can provide assistance to educate farmers, ranchers and landowners about the consequences of climate change and to enroll them in conservation programs that will help upland birds confronting a changing climate.

Exotic and invasive species control projects

During the past century monocultures of exotic species such as fescue, Bahia and brome spread over large swaths of land open to

wildlife and hunters. Effectively choking out native plants, these thick, sod-forming grasses offer wildlife little value in nutrition nor in cover. Many climate change models predict that higher levels of atmospheric carbon dioxide will favor the growth of such invasive plants and lead to their dominance in critical upland bird habitats.

Converting land from invasive, exotic species to native grasses, forbs and legumes could improve upland bird habitat on millions of acres. This could be accomplished by encouraging managed disturbances on land enrolled in the U.S. Department of Agriculture's Conservation Reserve Program (CRP).

Buffer and corridor projects

As upland bird ranges shrink and become more fragmented under the assault of climate change, strips of land along the edges of fields and waterways could provide vital habitat and become crucial corridors connecting larger habitat tracts. Likewise, roadsides could develop into an extensive network of grassy paths for wildlife traversing the agricultural landscape.

Minor adjustments in management practices could maximize the habitat potential of these small but critical areas. Introducing native plants in swales and filter strips could enhance the environment for birds without jeopardizing the water-cleansing function of these

drainages. Delaying summer mowing of roadsides until broods are capable of escape would markedly reduce bird mortality.

Prescribed burning projects

As climate change threatens the health and productivity of upland birds throughout their ranges, prescribed burns could encourage the habitat conditions most supportive of bird populations.

Controlled burning accomplishes two main objectives of upland bird habitat management: First, burning limits the growth of woody plant material and other unwanted vegetation, thereby maintaining prairie land as a distinct ecosystem, maintaining open space in pine forest understories for bobwhite quail, or creating early successional forests for ruffed grouse.

Second, prescribed burning consumes duff — partially decayed vegetative material on the forest floor — and releases nutrients bound in the plant litter, stimulating vigorous new growth of grasses, forbs, trees and legumes. This new growth promotes the proliferation of insects, a critical food source for young birds.

Water-management habitat projects

Moist soils nourish the kinds of vegetation that attract insects, so increased frequency of drought conditions in late spring and early summer greatly reduces insect populations. Various moist-soil management techniques and wetland preservation and restoration can bolster the number of insects available for young chicks' consumption. In arid regions, guzzlers installed by landowners could reduce the stresses that limited water supplies place on wildlife.

Solutions for Upland Birds: A Case Study

Editor's note: Fish and wildlife professionals contending with the effects of climate change need a framework to consider the essential factors of a successful field project. The following case study demonstrates the approach of Pheasants Forever to common project components such as goal identification, implementation barriers and costs typical of a Midwestern pheasant state.

Project location

A Midwestern state with historic pheasant habitat

Background

Pheasant populations are highly sensitive to changes in habitat availability, food resources and weather conditions. Global climate change is expected to deteriorate habitat and produce weather conditions that jeopardize pheasants' survival throughout their range.

Fortunately, agricultural policies and practices are responding to the demands of climate change and realizing opportunities that will assist upland birds in their adaptation. As demonstrated in this

project, the habitat requirements of pheasants can be incorporated into the design of easily harvested, highly cellulosic biofuel crops and land management policies that promote carbon sequestration. Thus, this project would provide habitat essential for upland birds adjusting to changing weather patterns while diminishing greenhouse gas accumulations and reducing the nation's dependence on fossil fuels.

Project goals

To secure pheasant habitat and assist birds adapting to climate change, the project will

- enroll 1.5 million acres over 10 years in programs to grow biofuels or to sequester carbon and simultaneously increase pheasant habitat
- maintain a minimum enrollment of 1.5 million acres in conventional conservation programs that provide pheasant and other upland wildlife habitat
- identify and test suitable biofuel plant species that also provide quality pheasant habitat
- develop and implement practices for carbon sequestration that preserve and develop wildlife habitat
- establish upland bird habitat enhancement as an objective of federal biofuel cultivation programs
- encourage including perennial grasses and forbs that support bird populations in biofuel crops
- develop standards to ensure winter habitat and nesting cover for pheasants while allowing efficient harvesting of biofuel crops

Implementation barriers

The project will require plant-specific research, experimentation, monitoring and evaluation to maximize the results of all its components. Educating farmers and landowners about new land management practices that integrate upland bird habitat with biofuel production and carbon sequestration will be challenging. In particular, the project must demonstrate that the approach increases producers' incomes.

Project tasks, timeline and costs

The following table outlines the tasks, timeline and estimated costs for this project.

Tasks	Narrative	Cost
	Year One	
Establish baseline	Define opportunities, limiting factors and habitat inventory	$40,000
Develop, research and evaluate plant mixes	Develop, research and evaluate test sites to identify biofuel plant mixes that provide quality pheasant habitat	$1,200,000
Develop, research and evaluate carbon sequestration practices	Develop, research and evaluate wildlife-friendly carbon sequestration practices, including species mix, management and harvest tactics and measurement of carbon storage	$5,000,000
	Years One-10	
Employ personnel	Hire project coordinator, 10 field biologists at $525,000/year X 10 years = $5,250,000 15 additional biologists at $675,000/year X 9 years = $6,075,000	$11,325,000
	Years Two-Six	
Conduct advocacy program	Promote establishing upland bird habitat enhancement and including perennial grasses and forbs that support bird populations as objectives of federal biofuel cultivation programs	$50,000
	Years Two-10	
Maintain enrollment in conventional conservation programs	Enroll 100,000 acres/year in CRP, CCRP, CREP to maintain an annual minimum of 1.5 million acres $115/acre/year X 100,000 acres X 9 years	$103,500,000

Tasks	Narrative	Cost
	Years Four-10	
Enroll acreage in biofuel program	Enroll 100,000 acres/year in new biofuel program $120/acre for land preparation, seed, mowing, chemicals, etc., X 100,000 acres X 6 years	$72,000,000
Enroll acreage in carbon sequestration program	Enroll 50,000 acres/year to sequester carbon $100/acres/year for land preparation, seed, etc., X 50,000 acres X 6 years	$30,000,000
	Years Five, Seven & Nine	
Monitor, evaluate, adapt	Determine programs' effectiveness, adapt management as needed. $75,000/year X 3 years	$225,000
	Totals	
	Total implementation costs over 10-year project life	$223,540,000

The costs of this 10-year project would be offset by the value of the following associated benefits:

- addition of renewable fuels
- carbon sequestration
- water quality protection
- soil erosion prevention
- rural economic stimulation
- additional wildlife and recreational benefits
- flood damage mitigation
- crop insurance cost reduction

Conclusion

While the goal of maximizing upland bird habitat through current conservation programs and new strategies is applicable across the continent, approaches to developing and preserving habitat will differ from state to state. Variables include the upland bird species of focus, the composition of major crops, forest cover, topography, state agency priorities and the prevailing conservation culture. Both federal and state natural resource agencies, along with non-governmental organizations, will need independence and flexibility to be able to accomplish habitat goals to assist upland birds adapting to a changing climate.

"A true conservationist is a man who knows that the world is not given by his fathers, but borrowed from his children." — John James Audubon

Saltwater Fish

by Mike Leonard, American Sportfishing Association
The complete text of this chapter is posted at www.seasonsend.org.

Humankind has been able to survive in almost all the regions of Earth — from dry deserts to frigid tundra to sultry rainforests to snowcapped mountains. For saltwater fish, however, it's another matter. Without the adaptive capability of humans, saltwater species have evolved over millennia to dwell in relatively small bands of ocean environments — environments that are at least as extreme and as varied as those on land. A slight alteration in environmental characteristics such as water temperature or salinity levels can be fatal to fish accustomed to occupying habitats with very specific conditions.

Moreover, how humans are now living makes survival more difficult for saltwater fish. As nature's capacity to recycle carbon is overwhelmed by the combination of burning fossil fuels and cutting down forests, the planet's seas and their inhabitants are profoundly affected. The precise consequences of climate change are difficult to predict, but they are certain to affect saltwater fish.

Climate change will cause oceans to warm

Although forecasts differ as to the extent, all scientific models indicate that rising atmospheric temperatures will warm the oceans. Scientists predict that if carbon emissions are not curtailed, ocean temperatures will increase 6-8° Fahrenheit (F) by the end of the century. Even if emissions are reduced, the oceans may still warm 4-5° F. While these increases may seem insignificant to adaptable humans, these few degrees can mean the difference between survival and extinction for marine fishes.

Climate change will cause sea levels to rise

During the past century, the average sea level across the globe rose an estimated four to eight inches. As the air and oceans warm, water expands and glaciers melt, increasing the volume of oceans and raising the surface of the seas. The degree of rise varies among regions, but sea levels in the mid-Atlantic region are rising at almost twice the global average, with a rise of more than two feet expected by the end of the century.

As seas rise, extensive coastal development may block the natural inland migration of mangrove and marsh habitats. Even where coastal borders have room to expand landward, the speed of sea-level rise may exceed the rate that marshes and mangroves can move inshore, leaving them vulnerable to inundation.

Climate change will increase precipitation and intensify storms

The increases in average precipitation experienced over the past hundred years are expected to continue. Increased precipitation is possible because a warmer atmosphere is capable of holding more moisture. Additionally, under global warming, storm events such as hurricanes will become more frequent and severe. The amount of fresh water that these combined phenomena will dump into the oceans could alter currents, estuary dynamics and regional salinity gradients.

Climate change will alter sea-water chemistry

By absorbing atmospheric carbon dioxide (CO_2), oceans play a vital role in combating climate change — but it is not without a price: As a result of dissolving CO_2 at an accelerated rate since the beginning of

the industrial revolution — roughly two hundred years ago — oceans have become more acidic. Greater sea-water acidity disrupts vital chemical processes such as shell formation in calcifying organisms including bivalves and coral reefs. Losing shellfish and coral reefs would be catastrophic for the saltwater fish that rely on them for food and habitat.

How Saltwater Fish Will Respond to Climate Change

Not all saltwater fish will react to the profound effects of climate change in the same way.

- Some saltwater fish may be able to tolerate elevated temperatures in their home range. Sedentary species sensitive to unfavorably warm water but incapable of migrating would suffer reduced growth, poorer reproductive success and greater mortality.
- Other saltwater fish will respond to warming temperatures by moving to new areas. Such shifts will alter community assemblages, bringing together species that were previously separated and creating new patterns of competition for food and habitat resources.
- As invasive species become more prevalent, native fishes might disappear from their customary habitats.

- With the loss of coral, mangroves and submersed aquatic vegetation, species like grouper, snook and spotted sea trout could suffer local extinctions.

Many saltwater fish life-history events rely on cues from temperature, currents and precipitation. Slight changes in any of these can destroy the correspondence between key events and the environmental conditions necessary for their success. For example, the spawning runs of salmon, striped bass and shad are stimulated by water temperature and are precisely timed to provide the best chance for their offspring's survival. An increase in temperature might prompt some fish species to migrate earlier, which could void correspondence between juvenile development and food sources or could displace adults or young of other species. Stronger stream flows resulting from increased precipitation could compromise reproductive success.

Yesterday's Programs Can't Solve Today's Problems

Programs conducted by state and federal agencies in cooperation with private organizations such as the FishAmerica Foundation have achieved laudable accomplishments in restoring and enhancing coastal fish habitats at local and regional levels. However, these programs are not sufficiently funded to address all the problems

anticipated to face the nation's saltwater fish and their habitats. State natural resource agencies that conduct fisheries conservation projects are funded primarily through license sales and the Sport Fish Restoration and Boating Trust Fund. Both state license sales and trust fund receipts have remained relatively static over the past decade.

Despite ongoing restoration efforts, researchers estimate that 40 percent of the saltwater fish populations in the United States are in decline and half of the country's waters are impaired. Given the reach and the extent of climate change, funding levels are clearly insufficient to address the threats posed to saltwater fish. Investment in projects to help saltwater fish adapting to a changing climate must increase significantly.

What Can Be Done: Project Types

Even if no additional greenhouse gases were released into the atmosphere, saltwater fish and their habitats would still suffer effects of climate change. However, investing in habitat improvement projects can increase saltwater fish's resiliency and resistance to the consequences of climate change, ameliorate conditions for vulnerable populations and promote their survival.

Coastal wetlands projects

Over half of the U.S. population lives within 50 miles of a coast. Dense development in these highly populated areas strains coastal ecosystems and reduces the amount of quality habitat available to saltwater fish.

Many species of recreationally important fish rely on coastal wetlands for vital spawning, rearing and feeding grounds. In addition to providing critical habitat, wetlands can absorb floodwaters and act as a barrier to storm surges; restoring native wetlands can therefore protect both aquatic and terrestrial organisms from some climate-change effects. Methods of slowing wetland degradation and protecting essential saltwater fish habitat include removing invasive plants, replanting native vegetation and installing protective barriers like breakwaters to prevent shoreline erosion.

Oyster reef projects

Oysters contribute beneficially to marine ecosystems by filtering excess nutrients from the water and forming vital, offshore reef habitat for saltwater fish. A plethora of prey thronging around oyster reefs attracts species such as striped bass, sea trout and croaker.

In many areas, overharvesting and pollution have significantly reduced oyster populations. In the Chesapeake Bay, for example, oysters currently stand at less than 2 percent of their historic numbers.

Oyster reef restoration projects obtain oyster shells by either dredging them from the ocean floor or acquiring them from the oyster shucking and packing industry. The shells, transported and built into reefs, are then colonized by naturally occurring oyster larvae or by larvae transplanted from hatcheries.

Federal and state agencies, non-governmental organizations and community groups have all carried out successful oyster reef restoration projects. Nonetheless, there is still great need to increase the abundance of this economic and environmental resource.

Fish passage projects

Several of the most valuable recreational saltwater fishes, such as salmon and striped bass, migrate into fresh water to spawn. However, man-made barriers block many of these fish in their arduous journey.

Dams provide benefits such as water retention, flood control and hydroelectric power generation, but they can also pose nearly insurmountable obstacles to anadromous fish (fish living in oceans but spawning in fresh water). To assist fish migrating to their spawning grounds, some dams have been fitted with structures that enable fish to swim and leap up a series of low steps until reaching waters above the dam. Other old and unused dams throughout the country have been removed to restore spawning habitat essential to migrating fish.

Proponents of conserving anadromous fish populations urge that dams serving important public purposes facilitate fish migrations around them, and that dams no longer of critical use be removed.

Riparian buffer zone projects

Because inland water quality inevitably affects ocean water quality, controlling stream pollution and erosion improves conditions for saltwater fish. Riparian buffer zones, vegetated areas adjacent to streams and rivers, reduce the amount of runoff entering waterways and help to control erosion and the influx of excessive nutrients. These vegetated zones also provide shade that cools stream waters, a vital service to those migratory fish that rely on suitable water temperatures for reproductive success.

Across the country, construction and agricultural practices have destroyed riparian buffers, with consequences evident downstream. Excessive nutrients in fertilizer runoff lead to harmful algal blooms that deplete dissolved oxygen in a water body. Ocean dead zones occur

when there is not enough oxygen to support aquatic life; organisms that are unable to move away quickly suffocate and die.

Restoring riparian zones may require returning a stream bed to a meandering configuration; placing rock or other protection along banks to reduce erosion; and replanting buffers to stabilize soils, slow runoff and provide the filtering capacity of vegetation. Actions not proximate to waterways may be equally essential to riparian zone restoration: Regulations that control floodplain development, protect stream set-backs, require agricultural drainage systems to settle out contaminants and encourage farming practices that exclude livestock from creek banks are critical to conserving riparian buffers.

Coral reef restoration

The effects of ocean warming and acidification will endanger valuable, vulnerable coral reef resources. Factors already contributing to the decline of coral reefs include hurricanes, disease, nutrient loading, sedimentation, various forms of pollution, coral mining, trampling by tourists and divers, and damage caused by ship anchors and groundings. Additionally, overfishing certain species has thrown off the balance in food webs, resulting in accelerated bio-erosion of corals or leading to overgrowth of algae. Coral reef restoration projects may involve re-establishing assemblages of coral reef species to prior natural states, mitigating physical damage caused by

human activity and transplanting cultured corals from nurseries to degraded sites. Finding approaches to help corals cope with warmer temperatures and more acidic waters will challenge managers, but current restoration strategies can help repair and rebuild coral reefs and the fish populations that depend on them, thereby increasing their resiliency to future threats.

Solutions for Saltwater Fish: A Case Study

Editor's note: Fish and wildlife professionals contending with the effects of climate change need a framework to consider the essential factors of a successful field project. The following case study demonstrates the approach of the American Sportfishing Association to common project components such as goal identification, implementation barriers and costs.

Project location

White's Gulch, a tributary of the North Fork Salmon River, is located in Siskiyou County, California, near the Oregon border and within the 1.7 million-acre Klamath National Forest. The White's Gulch watershed is rural, mountainous terrain, forested primarily in pine, fir and cedar. Seasonal flows in White's Gulch are highly variable; flow is greatest in February, attaining approximately 30 cubic feet per second, but falls to nearly dry in summer.

With dense riparian habitat, numerous pools and a low percentage of fine sediments, White's Gulch once offered approximately a mile and a half of prime spawning grounds. Historic accounts of chinook and coho salmon and steelhead trout spawning runs on the Salmon River describe "walking across the river on the backs of fish." In the past, canneries operated on the river banks and recreational fishing was extremely popular, but multiple pressures on salmon populations have reduced their abundance to the point where fishing for salmon in the river is no longer allowed.

Two dams located on White's Gulch are considered the primary factors driving the decline of salmon in the watershed. The upper dam, located approximately a mile from the confluence of White's Gulch and the North Fork Salmon River, dates back to the late 1800s. The dam blew out in 1984 but was rebuilt in 1986, at which time another dam was constructed about half a mile downstream to supply water for a privately owned pond.

Background

Human activities have significantly harmed salmon populations on the United States' Pacific coast. The combination of overfishing, pollution and water diversions has reduced Pacific salmon numbers to the point where, in 2008 and 2009, a moratorium was imposed on the fishery in California and southern Oregon. As climate change alters the environmental conditions that migratory fish depend on for reproductive success, the situation for salmon will only worsen.

Manmade barriers such as dams pose major threats to migratory fish on their spawning runs. Dams are estimated to account for as much as 92 percent of the deaths of salmon moving out to sea and up to 25 percent of the salmon dying on their return upstream. Clearly, removing these dams will contribute to rebuilding salmon stocks and promote greater resiliency as the fish confront the effects of a changing climate.

Project goals

The overall goal of the White's Gulch dam removal project is to restore access to spawning grounds for Chinook salmon, coho salmon and steelhead trout.

Accomplishing this goal requires

- removing two concrete dams in White's Gulch
- relocating a water inlet for a power station from adjacent to the upper dam to a site upstream of a natural barrier
- constructing a headstock and fish screen to prevent mortality of larval fish passing through the water inlet

The removal of the two dams as well as a culvert located downstream of the lower dam opens one and a half miles of spawning and rearing habitat for spring chinook salmon, threatened coho salmon and steelhead trout.

Implementation barriers

Dam removal projects often face community opposition as people object to losing the historic, recreational or aesthetic values that may be associated with the dam.

Lengthy and tedious permitting processes can slow or even halt a project. Assessments to determine if a dam's removal poses significant environmental or public health risks must comply with state and federal laws. Sediment collected behind a dam must be tested for heavy metals before it is released downstream.

Natural disturbances can interrupt and delay work.

Project tasks, timeline and cost

The following table outlines the tasks, timeline and estimated costs for the White's Gulch project.

Tasks	Narrative	Cost
	Year One	
Complete planning	Coordinate partners and volunteers, develop landowner relationships, determine project design	$15,000
	Year Two	
Complete testing	Apply for permits, perform pre-project monitoring including testing sediment for heavy metals	$20,000
	Year Three	
Complete construction	Conduct in-stream construction; install water supply pipe, fish screen and headstock; rent excavator and blasting equipment for dam removal, pay transportation costs	$75,000
	Continuous, Years Three-10	
Complete monitoring and testing	Conduct post-project monitoring and evaluation, retest sediment for heavy metals, monitor stream conditions (flow, temperature, quality), conduct annual fish surveys in winter and spring to evaluate dam removal success: $5,000/ year X 8 years	$40,000
	Totals	
	Total project implementation costs over 10-year period	$223,540,000

Project update

In early 2006, the Salmon River Restoration Council (SRRC), in partnership with the U.S. Forest Service (USFS), California Department of Fish and Game (CDFG), and local, private landowners, began the process of removing two dams blocking fish passage on White's Gulch. The coalition prepared the project design and initiated the permitting.

Environmental assessments were completed and permits approved in 2007. Through its partnership with the National Oceanic and Atmospheric Administration's Restoration Center, the FishAmerica

Foundation granted additional funding, which was matched by CDFG, the USFS and a private landowner.

Although large wildfires forced work to stop for several weeks during the summer, both dams were removed in 2008. All instream construction took place over the course of two months in the fall.

Monitoring following the dams' removal has checked water temperature and flow, tested for heavy metals near the upper dam site and conducted fish surveys.

Conclusion

Clearly, given the magnitude and extent of potential effects on saltwater fish, merely continuing current resource management practices will be inadequate for addressing the threats that climate change poses.

Large-scale, regional plans that incorporate a suite of projects and tools to help saltwater fish adapting to climate change could have a long-term price tag of several billion dollars. Despite the costs, such an investment is not only prudent because of the high economic value of these resources, it is also responsible. As anyone who has stalked tarpon in crystal clear tropical waters, witnessed marlin majestically soaring through the air at the end of the line, or simply enjoyed watching the sun set after a peaceful day on the water can attest, saltwater fish are valuable for reasons less tangible than economics. As stewards of the environment, it is our duty to ensure that these treasured resources are available for future generations to enjoy, even if the conditions they are found in are not the same as today's.

"Only in a viable natural world can there be a viable human world." — Thomas Berry

A Path Forward

by Eric Washburn and John Cooper, Bipartisan Policy Center

Rapid, profound and global in scope, climate change is bringing about a new era in the natural world — an era that isn't different simply in degree, but different in kind. Assisting fish and wildlife adapting to this unprecedented challenge requires a comparably unprecedented shift in the way wildlife professionals perceive, plan and implement their projects. Fortunately, many state and federal agencies, sportsmen's organizations and concerned private corporations recognize the magnitude of the threat and are responding with bold steps. Here are a few examples.

The Natural Resources Climate Change Adaptation Panel's adaptation strategy

Under the leadership of the chair of the White House Council on Environmental Quality and consisting of federal department or agency heads, the panel is developing the Natural Resources Climate Change Adaptation Strategy to enable natural resources to become more resilient, adapt to and withstand the impacts of climate change and ocean acidification.

The U.S. Department of Interior climate change initiative

The department has created

- a national Climate Change Response Council and eight regional centers to synthesize new climate change research and management strategies, intra-bureau communications and public education
- a network of Landscape Conservation Cooperatives crafting practical, landscape-level strategies focused on wildlife migration patterns, wildfire risk, drought and invasive species

The U.S. Geological Survey's National Climate Change and Wildlife Science Center

The center acts as a conduit between science and management by linking physical climate change models with ecological and biological responses in the landscape. It also funds integrated climate change research for a wide range of projects.

The Fish and Wildlife Service's Strategic Plan for Climate Change

The service's climate change plan provides direction to the agency's refuge managers and other wildlife professionals as they respond to new scientific, technological and implementation challenges associated with assisting fish and wildlife adapting to climate change and with educating the public about this phenomenon. By 2020 the service intends to be a carbon-neutral agency.

The U.S. Department of Agriculture's strategic plans

Responding to the dramatic effects of climate change on national forests, including a four-fold increase in major forest fires and a six-fold increase in burned areas in just two decades, the U.S. Forest Service is implementing strategic plans aimed at enhancing the adaptive capacity of natural resources. Goals include managing for ecosystem function, protecting biological diversity, establishing

habitat buffer zones, increasing monitoring and implementing science-based management projects that improve the resilience of natural systems.

Western Governors' Association Wildlife Corridors Initiative

Recognizing that climate change threatens key wildlife corridors, the initiative will coordinate and manage all Western Governors' Association corridor programs, projects and advocacy positions. By acting aggressively now, this initiative will assist wildlife as it responds to climate changes, land use changes, expanding roads and railway systems, renewable energy projects, power grids and oil and gas development.

Freedom to Roam, a private sector migration corridor project

Initiated by the Patagonia Clothing Company, Freedom to Roam is tapping expertise in some of the country's most successful companies, including Microsoft, British Petroleum, Wal-Mart, Southern California Edison and National Geographic, to partner with many of the nation's top conservation groups. The project serves as a catalyst for large-scale migratory corridor initiatives, creates broad national awareness of wildlife corridors and expands funding for projects that enhance habitat connectivity.

Boone and Crockett Club's principles of action

The Boone and Crockett Club's principles of action on climate change include funding habitat damage mitigation and wildlife population adaptation, accelerating conservation and restoration of forests and rangelands to sequester carbon and prevent uncharacteristic wildfires and investing in energy conservation and technologies that reduce emissions of greenhouse gases into the atmosphere.

Ducks Unlimited's climate change programs

Realizing that climate change has the potential to dramatically and adversely affect North America's wetlands and waterfowl populations, Ducks Unlimited has been at the forefront in educating its membership and Congress. The organization has encouraged public and private investment in the protection, restoration and enhancement of wetlands in locations predicted to be productive even as the effects of climate change become increasingly severe.

Theodore Roosevelt Conservation Partnership's Climate Change Working Group

The Theodore Roosevelt Conservation Partnership (TRCP), a coalition of numerous hunting and fishing organizations as well as labor unions, established the Climate Change Working Group to develop and promote policies to ensure the future of hunting and fishing in the face of a changing climate. Toward that end, the partnership has

developed its *Principles for Including a Natural Resources Adaptation Fund within Cap-and-Trade Climate Legislation to Help America's Fish, Wildlife, and Ecosystems Survive Global Warming.*

Sportsmen's coalitions

A broad coalition of national sportsmen's organizations supports establishing a dedicated stream of new funding for state and federal conservation programs to address climate change. Appendix A contains copies of the most recent sportsmen's letters to members of the U.S. House of Representatives and the U.S. Senate. These efforts have already been productive, as many of the bills introduced into Congress to reduce greenhouse gas emissions, including the Waxman-Markey bill that passed the full House of Representatives in June, 2009, have included billions of dollars in funding for fish and wildlife conservation.

International conservation programs

The long-term survival of fish and wildlife that migrate across national boundaries depends on the protection of habitat throughout their migration corridors. International conservation initiatives like the North American Wetland Conservation Act (NAWCA), which is based on international cooperation, will become increasing critical to the protection of these species.

The High Cost of "Doing Nothing"

Climate change threatens every aspect of our environment, including water, air, oceans, wetlands, rivers and streams. Too often, however, and to our great peril, the natural environment and the critical services it delivers to the world's economies are ignored. The loss of any portion of these services or of related outdoor activities would be stunning to human economies. For example, in letters to Congress dated April 9, 2009, a consortium of sportsmen's organizations noted that

- wetlands and coastal marshes provide inland communities with flood control and storm surge protection valued at $23 billion annually
- the national forest system generates nearly 20 percent of the nation's water supply, an annual value of $7.2 billion
- outdoor activities such as fishing, hunting, hiking and camping, if combined into a single business, would rank in the top 10 Fortune 500 companies
- one out of twenty jobs in America is related to fishing, hunting or wildlife-related goods and services
- a survey conducted in 2006 showed that 87 million Americans were involved in outdoor recreation, spending $120 billion

Benefits that ecosystems provide have an estimated annual value of $300 billion in the United States alone and between $3 trillion and $26 trillion across all of the world's economies.

There are no substitutes for these ecosystems and the services they offer, no other suppliers of fresh water nor distributors of wetlands. To do nothing to protect these irreplaceable resources from the consequences of climate change will put them on track for destruction and human societies in queue for chaos.

A New National Conservation Commitment

Over the past 100 years, generations of Americans have devoted themselves to restoring and conserving our country's natural resources. Presidents as well as the U.S. Congress have played significant roles in conserving the resources that are essential to our nation's food, shelter, economic viability and spiritual well-being. Congress now has a new and ominous conservation challenge to address: passing legislation that

- achieves significant near-term reductions in carbon pollution of the earth's atmosphere
- provides incentives to sequester carbon in soils and plants
- creates a dedicated funding mechanism to safeguard wildlife and natural resources threatened by climate change

Substantial funding will be essential if ecosystems are to continue to provide the goods and services that humans depend on for their survival and quality of life. Although studies have not determined the full cost of conserving species and ecosystems in the face of climate change, federal, state and non-governmental conservation organizations estimate that it will be between $5 billion and $7 billion annually. This tally combines what is currently known and what is forecast regarding the consequences of climate change and the cost of a "reasonable response" by the professional conservation community. The following are some of the high priority projects that will be required:

- Developing comprehensive, multi-year strategies for conserving at-risk natural resources affected by climate change
- Delivering adaptation solutions through existing conservation programs, pursuant to science-based strategies and plans
- Integrating climate change adaptation projects into State Wildlife Action Plans (SWAP) to attain consistency within each state's comprehensive wildlife strategy

- Creating a national scientific advisory board to ensure the scientific integrity of federal adaptation planning, research and implementation
- Addressing the needs of Native American tribes dealing with the consequences of climate change on their land and water resources
- Reducing other, non-climate stressors such as habitat destruction, fragmentation, pollution and invasive species to improve the ability of our natural systems to withstand or adapt to climate change
- Managing for ecological function and protection of biological diversity to increase resilience to climate change
- Establishing habitat buffer zones and wildlife corridors to improve connectivity so that species can migrate and shift ranges as needed
- Implementing proactive management and restoration strategies as necessary to protect highly valued species or ecosystems when other options are insufficient or unavailable
- Promoting and facilitating project implementation even under the uncertainty associated with climate change. Careful monitoring coupled with management approaches that acknowledge these uncertainties will be required.

The $5 billion to $7 billion annual price tag necessary to respond to climate change's effect on natural ecosystems is substantial, but the expenditure is highly cost-effective. The value of those resources easily reaches the hundreds of billions of dollars annually, making those resources as fundamental to a healthy economy as roads, utilities and energy. Congress' commitment to the protection of these irreplaceable assets is the essential first step on the nation's path forward in the era of climate change.

Cutting Greenhouse Gases, Saving Fish and Wildlife

Most debate related to greenhouse gases in Congress has focused on an approach called cap-and-trade. This approach has the following components:

- The federal government would establish caps, or annual limits, on emissions of greenhouse gases for regulated industries such as oil companies or fossil-fuel-burning electric utilities.
- Companies within these sectors would purchase annual permits from the federal government that would allow emissions up to the capped levels.
- Carbon credits would be generated by sources that reduce greenhouse gases, such as farmers who sequester carbon in the soil, conserve plants in wetlands or plant perennial grass or shrubs on their farmlands.
- Regulated companies could buy, sell or trade these credits among themselves or could purchase additional credits to offset any carbon emission above their cap.
- The marketplace would establish the price or value of the credits (e.g., $15 per ton of emitted carbon dioxide).

All of the major greenhouse gas control programs in place today are based on the cap-and-trade concept. The international Kyoto Protocol is a cap-and-trade system, as is the European Union (EU) emissions trading scheme (ETS). In the United States, the Regional Greenhouse Gas Initiative (RGGI) was developed by several New England and mid-Atlantic states to cap and trade CO_2 emissions from power plants. RGGI now involves 10 states. California also is developing a cap-and-trade system to limit emissions of greenhouse gases. Nevertheless, it is unclear when or if Congress will adopt such an approach for the entire country.

Funding for Fish and Wildlife

Many of the cap-and-trade bills that have been introduced into Congress in the last few years are very promising for sportsmen because they allocate billions of dollars annually for conservation

programs. While differing on the merits of competing national climate change bills, the nation's leading hunting and fishing organizations broadly support taking some action to reduce emissions of greenhouse gases and providing billions of dollars in new funding for critical conservation work annually.

On June 26, 2009, the House of Representatives passed the American Clean Energy and Security Act (ACES), which established a cap-and-trade system to reduce greenhouse gases and authorizes and funds natural resources adaptation programs. That legislation requires state and federal conservation agencies to develop detailed plans to help species adapt to climate change and would fund those plans annually with billions of dollars through a range of existing conservation programs including

- state game and fish agency programs
- the North American Wetlands Conservation Act
- the National Fish Habitat Action Plan
- the Land and Water Conservation Fund
- national forests and grasslands
- Bureau of Land Management lands
- national wildlife refuges
- national parks
- Fish and Wildlife Service easements
- federal and state freshwater, coastal and estuarine conservation programs

To fund these programs, the bill creates the Natural Resources Climate Change Adaptation Fund, which would assist federal and state agencies to implement natural resources adaptation strategies and measures. Funding for these programs would come from the annual auctioning of carbon allowances (permits), with the adaptation programs receiving 1 percent from 2012 to 2021, 2 percent from 2022 to 2026 and 4 percent from 2027 to 2050. This is expected to produce annual funding beginning at roughly $600 million per year and ramping up to nearly $5 billion per year. Annual conservation funding would average $1.7 billion between 2012 and 2030. As of December, 2009, the U.S. Senate had yet to act on climate change legislation.

Appendix

Sportsmen's Letters to the U.S. Senate on Climate Change Legislation

American Fisheries Society * American Fly Fishing Trade Association * American Sportfishing Association * Association of Fish and Wildlife Agencies * B.A.S.S. * Berkley Conservation Institute * Campfire Club of America * Ducks Unlimited * International Hunter Education Association * Izaak Walton League * Mule Deer Foundation * National Wildlife Federation * National Wild Turkey Federation * Northwest Sportfishing Industry Association * Pheasants Forever * Quail Forever * Quail Unlimited * Quality Deer Management Association * Sand County Foundation * The Nature Conservancy The Wildlife Society * Theodore Roosevelt Conservation Partnership * Trout UnlimitedWildlife Forever * Wildlife Management Institute *

April 20, 2009

Dear U.S. Representative,

Our organizations represent millions of hunter and angler conservationists, scientists, and outdoor enthusiasts, and we write you today regarding the urgent need to address the effects of climate change on the natural resources of this Nation and quality of life of our citizens. Scientists now generally agree that the concentration of heat-trapping gases already in the atmosphere is causing and will cause significant adverse impacts to the environment. Thus, a comprehensive government-wide program must address not only the cause of climate change, but also the effects of the climate change we already are facing and which will accelerate in coming years.

This challenge should be met through a comprehensive effort to 1) reduce emissions of greenhouse gases, 2) enhance sequestration of carbon, and 3) assist fish and wildlife and the ecosystems on which we all depend to adapt to climate change. There appears to be a strong and growing national commitment to reducing greenhouse gas emissions and establishing programs to encourage carbon sequestration. We are writing to encourage you to help ensure that sufficient revenues are dedicated to the task of making the conservation investments necessary to protect America's natural ecosystems and the services and products that these ecosystems provide the nation, including the fish and wildlife that inhabit them.

As you consider the climate change legislation that is moving through the several House Committees, we hope that you will support provisions dedicating a portion of climate-derived revenues to federal and state natural resource adaptation programs to remediate the effects of climate change on fish, wildlife and their habitats.

Functioning ecosystems are critical to the future of life on this planet. They provide a wide range of life-sustaining services in the form of clean water, clear air, and other benefits that determine the quality of human life. Ecosystems can significantly capture carbon thorough sequestration, thus being part of the climate change solution by reducing carbon levels. In addition, functioning ecosystems provide quality habitat that sustains fish and wildlife, provides other vital natural products, and thus provides billions of dollars in direct economic benefits.

For example, wetland systems such as coastal marshes and mangrove forests attenuate floods and buffer coastal and inland communities from storm surges. A recent study estimates that wetlands provide $23 billion annually in services. Further, one of the primary reasons for the creation of the National Forests was to "secure favorable conditions of water flow". The U.S. Forest Service estimates that the total value of high quality fresh water flowing from National Forest System lands in terms of instream and offstream uses exceeds $7.2 billion annually. These lands contribute nearly 20% of the Nation's water supply, and in the western U.S. more than 50% of the region's water supplies. Approximately 60 million citizens rely on water flowing from NFS lands for their drinking water.

Additionally, natural resources and their use make enormous contributions to our national, state and local economies. The combined economic contribution of outdoor activities such as fishing, hunting,

hiking, camping and other forms of wildlife-dependent recreation, if combined into one business, would rank in the top 10 Fortune 500 companies. One out of every 20 jobs in this country is related to fishing, hunting and wildlife-related activities, goods and services, and these activities stimulate 8% of all consumer spending. The 2006 National Survey of Fishing, Hunting and Wildlife-Associated Recreation reported that over 87 million Americans pursued outdoor recreation in 2006 and spent $120 billion that year on those activities. Without adequate resources to adapt to climate change impacts, these changes are likely to significantly undermine this economic engine.

State fish and wildlife agencies, federal natural resources agencies, and non-governmental conservation organizations will be instrumental in implementing conservation strategies to mitigate the impacts of climate change on fish and wildlife resources and their habitats. Hunters and anglers strongly support the legislative approach to natural resources adaptation that is currently reflected in Chairman Waxman's Discussion Draft Title IV, Subtitle E, Part 1, Subpart C – Natural Resource Adaptation. This approach, which parallels the approach by Congressmen Dingell and Boucher in 2008, is broadly and strongly supported in the conservation and environmental communities and represents language which matured over the last 2 years in the 110th Congress. We urge your strong support for this provision, which dedicates revenues to state and federal natural resource agencies to implement on-the-ground conservation responses.

In conclusion, we respectfully urge that you support the dedication of a portion of climate-derived funding to state and federal natural resource adaptation programs to remediate the effects of climate change on fish, wildlife and their habitats. A modest investment of climate-derived revenue is small compared to the long-term dividends it will pay for the quality of life for our citizens, the delivery of ecosystem services, our fish and wildlife, and the security of our Nation.

Thank you.

* American Fisheries Society * American Fly Fishing Trade Association *
American Sportfishing Association * Association of Fish and Wildlife Agencies
* Berkley Conservation Institute * Campfire Club * Dallas Safari Club *
Ducks Unlimited * Houston Safari Club * Izaak Walton League of America *
Mule Deer Foundation * National Trappers Association * National Wildlife
Federation * Pheasants Forever * QualityDeer Management Association *
The Wildlife Society * Theodore Roosevelt Conservation Partnership
* Trout Unlimited * Wildlife Forever
* Wildlife Management Institute *

September 21, 2009

Dear Senator,

On behalf of the millions of organized sportsmen and women and conservation professionals from across the country, we urge you to work with your colleagues to ensure that the Senate passes comprehensive climate and energy legislation this year. In order to safeguard fish, wildlife, and their habitats which also provide for ecosystems services and quality of life for our citizens, we urge that legislation must include both reductions of greenhouse gas emissions and dedication of an adequate and appropriate amount of the total carbon allowance value for natural resources adaptation programs at the federal and state levels.

Hunting, fishing, and wildlife related recreation generate more than $172 billion annually in economic activity at the state and local level, which equates to 1% of the gross domestic product. Climate change poses an immediate and profound threat to fish and wildlife, and the healthy natural systems that provide us with clean drinking water, flood protection, food, medicine, timber, biomass, recreational opportunities, scenic beauty, jobs, and numerous other services. Given these threats, climate legislation must both reduce greenhouse gas emissions and invest in our natural resources so that they will continue to provide substantial social and economic benefits for generations. State, federal, and tribal fish, wildlife and land managers are critically short of funding needed to effectively respond to the combination of these challenges to help safeguard our natural resources in a changing climate. The adaptation effort will be substantial, and adequate resources are necessary in order to be successful.

Our federal public lands are more important than ever in maintaining sustainable ecosystems that deliver services to our citizens, reduce carbon in the atmosphere through sequestration, and maintain viable populations of fish and wildlife with associated quality hunting and fishing opportunities. Public lands also provide crucial habitat linkages and connective migration corridors for fish and wildlife and their management should be directed towards climate change adaptation by the federal land management agencies.

The state fish and wildlife management agencies and the federal land management, natural resources management, and agriculture agencies will be critical components in a viable national climate change strategy and should receive dedicated funding to implement natural resource adaptation measures and strategies to remediate the effects of climate change on fish, wildlife and their habitats. It is equally important that these agencies engage the private farm, ranch, and forest landowners with technical assistance and financial incentives to reduce emissions and sequester carbon on their lands. In fact, it will be critical to ensure that management of state, federal, tribal, and private forests is conducted in a manner that maximizes their resiliency to climate change and reduces the future likelihood of intense fires that can put enormous quantities of carbon dioxide into the atmosphere when released from trees and soils.

We need not create new state or federal bureaucracies to receive and administer funds for natural resources adaptation to be implemented consistent with national and state adaptation strategies to be developed under the provisions of a comprehensive climate and energy bill. Existing programs such as the Wildlife Restoration Act, Sportfish Restoration Act, Coastal Management Act of 1972, and Land and Water Conservation Fund of 1965 already have established procedures, rules, and accounts capable of getting money to the agencies efficiently. Further, a USDA administered offset program would encourage farmers and landowners to implement carbon sequestration activities through land management and conservation programs. For example, the restoration of grasslands and protection of native prairie will sequester tons of carbon on private lands while greatly enhancing nesting habitat for waterfowl and other grassland nesting birds. This approach of protecting, reconnecting, and restoring landscapes will have significant benefits for human communities. Protecting high elevation drinking water supplies will reduce water filtration costs. Reconnecting rivers to floodplains will reduce downstream flooding costs. Restoration activities such as thinning unnaturally dense forest stands near communities will provide high paying, family-wage jobs while insulating communities from the effects of intense wildfires. Use of this harvested cellulosic biomass can also enhance our reliance on renewable energy, thus further reducing carbon emissions.

As the Senate develops comprehensive climate and energy legislation, your leadership is needed to get the job done this year. Please ensure that the climate legislation you consider in the Senate both reduces greenhouse gas emissions and safeguards natural resources, fish, wildlife and our own communities threatened by the changes already set in motion by changing climate effects. Specifically, any Senate bill should establish a national policy framework to help protect, reconnect, and restore public and private lands; provide increased scientific capacity; identification of wildlife migration corridors; coordination and information sharing; and dedicate an adequate amount of the total allowance value to federal, state and tribal agencies to implement identified actions needed to conserve natural resources in a climate change bill. We are appreciative of the natural resource adaptation funding levels in the House-passed bill, and urge you to increase those funding levels if at all possible. We further acknowledge the advocacy of other sportsmen's groups for consideration of the need for and role of other low-carbon based energy sources in a comprehensive climate and clean energy bill.

Thank you for your consideration of this most important issue.

BOONE AND CROCKETT CLUB * FOUNDATION FOR NORTH AMERICAN WILD SHEEP * QUALITY DEER MANAGEMENT ASSOCIATION * ARCHERY TRADE ASSOCIATION * CAMPFIRE CLUB OF AMERICA NATIONAL WILD TURKEY FEDERATION * PUBLIC LANDS FOUNDATION * WILDLIFE FOREVER * HOUSTON SAFARI CLUB * DALLAS SAFARI CLUB * POPE & YOUNG CLUB * NATIONAL TRAPPERS ASSOCIATION * CATCH-A-DREAM FOUNDATION * MULE DEER FOUNDATION

September 15, 2009

The Honorable Barbara Boxer
Committee on Environment and Public Works
United States Senate

The Honorable James M. Inhofe
Committee on Environment and Public Works
United States Senate

The Honorable Blanche Lincoln
Committee on Agriculture Nutrition and Forestry
United States Senate

The Honorable Saxby Chambliss
Committee on Agriculture Nutrition and Forestry
United States Senate

The Honorable Max Baucus
Committee on Finance
United States Senate

The Honorable Chuck Grassley
Committee on Finance
United States Senate

The Honorable Jeff Bingaman
Committee on Energy and Natural Resources
United States Senate

The Honorable Lisa Murkowski
Committee on Energy and Natural Resources
United States Senate

The Honorable Jay Rockefeller
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable Kay Bailey Hutchison
Committee on Commerce, Science, and Transportation
United States Senate

The Honorable John F. Kerry
Committee on Foreign Relations
United States Senate

The Honorable Richard G. Lugar
Committee on Foreign Relations
United States Senate

Our organizations share a common mission of wildlife conservation. Through the hard work and financial contributions of millions of Americans, we have built a system of wildlife conservation in North America that has restored wildlife populations and habitat, and is a model for the entire world. Part of this tradition is that we work together for common results across our diverse interests and views. As such, we believe in order for a climate change policy to succeed, it must protect and build on America's investment in wildlife and habitat, address forest and rangeland health, conserve water resources, and maintain a strong economy while reducing greenhouse gases. Although we do not have consensus on a climate change bill, we do agree on the following principles:

- Fund habitat mitigation and wildlife population adaptation;
- Accelerate conservation and restoration of forests and rangelands (including grasslands and native prairie) to sequester carbon and prevent uncharacteristic wildfires;
- Invest in energy conservation and technologies that reduce emissions with minimal habitat footprint; and
- Maintain affordable energy sources; ensure that private and public land fragmentation does not result from higher input costs.

We also recommend Congress' attention to several specific considerations.

Wildlife and habitat conservation agencies and organizations have the track record of success on the ground to justify a strong role in delivering the land management that will play a vital role in any climate policy. Funding for conservation efforts should be delivered through existing programs. Furthermore, these conservation programs require greater funding to keep pace with other challenges as state fish and wildlife agencies have been called upon to manage greater diversity of wildlife in more crowded landscapes. On this point, and subject to our principle of maintaining affordable energy sources, we welcome the calls from other sportsmen's groups that are committed to advocating for new Federal revenue raised through climate legislation.

America's agricultural lands and private forests sequester much of our country's annual carbon emissions. Prairies and grasslands are highly effective at sequestering carbon as biomass. The vast wildlife and fish habitats of the American West must be protected as renewable energy becomes the latest new use of multiple-use public lands, requiring new power lines and installations. Habitats on private land must be conserved through incentives and education for landowners. Known problems such as invasive species should be priorities.

Energy development and rising costs of electricity have a significant impact on wildlife and habitat. Climate legislation should promote energy conservation and clean and renewable energy sources to meet growing demand for electricity. New nuclear generation, funding for research of clean coal technology and carbon capture and storage, responsible growth of biomass energy, including renewable biomass from forests, and faster and better regulatory approval processes, will help meet this challenge.

Edited by the Wildlife Management Institute and the Theodore Roosevelt Conservation Partnership in cooperation with the following sportsmen's organizations:

- Ducks Unlimited
- Trout Unlimited
- BASS/ESPN Outdoors
- Izaak Walton League of America
- Association of Fish and Wildlife Agencies
- Coastal Conservation Association
- American Sportfishing Association
- Pheasants Forever
- Boone and Crockett Club

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