NATIONAL *fish, wildlife & plants* CLIMATE ADAPTATION STRATEGY

November
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Agency Review **Draft**

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National Fish, Wildlife and Plants Climate Adaptation Strategy

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Preface

The populations of bighorn sheep in the mountains of the American West are in decline. Anglers are finding fewer fish in pristine trout streams from Montana to Maine. Millions of acres in Idaho, Colorado, Wyoming, and other states have become an eerie landscape of dead trees because of devastating attacks from the mountain pine beetle, with major impacts on the timber industry. Across the country, wildflowers are blooming earlier than they used to, while both plant and animal species are changing where they live and when they migrate.

In U.S. lakes and coastal waters, harmful blooms of algae are on the rise. Recent years have brought die-offs of oyster larvae in Washington State, lobster die-offs in Long Island Sound, the disappearance of the mackerel fishery in the Mid-Atlantic, and collapse of ancient coral reefs in Florida and the Caribbean. In the Arctic region, warming temperatures and the loss of sea ice threatens ice seals and other species that depend on ice habitats for feeding and reproduction.

These changes—and countless more like them now being observed in the natural world—have enormous consequences for both the environment and the economy. That's because our nation depends on plants, fish and wildlife for food we eat, water we drink, wood we use to build our homes, natural habitats that buffer our communities from floods and storms, and for a wide range of other vital products and services that affect our lives every day. These products and services provide millions of jobs and create billions of dollars in economic activity. Hunting, fishing and wildlife-related recreation alone add $122 billion to the economy each year. In 2009, commercial marine fisheries generated $116 billion in sales impacts and supported one million jobs in the seafood sectors and across the broader economy. In addition, species and ecosystems are an important part of our identity, our culture and our daily lives.

The shifting patterns now appearing in the natural world are already forcing us to respond and to adapt. Farmers in Iowa are planting corn earlier in the year than in past decades, while seed companies are developing crops that can grow at higher temperatures or when droughts strike. Timber companies are racing to salvage trees from the vast dead forests. Hunters and anglers are beginning to alter when and where they hunt and fish. Wildlife managers are trying to figure out how to keep species and ecosystems healthy as animals and plants move in search of more hospitable climes. Communities that depend on fish and wildlife are considering how these changes will impact their current activities and future plans.

But today's actions only scratch the surface of what is—and will be—needed. Underlying all of the examples of observed effects, each of which can be a complex story, is a common thread: a changing climate. Measurements show unequivocally that average temperatures in the United States have risen two degrees Fahrenheit over the last 50 years. Precipitation has increased five percent. The number and frequency of extreme weather events, such as floods, heat waves, and droughts has climbed. Sea levels have risen eight inches, and oceans and lakes are becoming more acidic. These changes explain why bighorn sheep habitat is being squeezed, why trout streams are threatened, why pests like the pine beetle have been able to expand their range, why marine fish stocks are shifting distribution, and why many other species and the communities that depend on them are being affected.

All of these observed changes in climate, in turn, have been directly linked to the increasing levels of carbon dioxide and other greenhouse gases (GHG) in the atmosphere, which have set in motion a series of changes in the planet's climate system. And far greater changes are already inevitable. Because carbon dioxide (CO_2) stays in the atmosphere for a long time, even if further GHG emissions were halted today, alterations already underway in the Earth's climate will last for hundreds or thousands of years. If GHG emissions continue, as is more likely, the planet's temperature is predicted to rise by four to seven degrees Fahrenheit by the end of the century, with accompanying major consequences for everything from extreme weather events to sea level rise and acidification of our oceans. That would bring huge, unprecedented impacts to our valuable natural resources and the communities and economies that depend on them.

The problem, therefore, is serious and urgent. The nation must prepare for and adapt to a changing climate to safeguard our valuable living resources for current and future generations. This *National Fish, Wildlife and Plants Climate Adaptation Strategy* (*Strategy*) is a call to action–a blueprint for effective steps that can be taken (or at least initiated) over the next five to ten years. It is designed to be a key part of the nation's larger response to a changing climate, and to guide responsible actions by natural resource managers and other decision-makers at all levels of government. The *Strategy* was produced by federal, state and tribal representatives and has been coordinated with a variety of other climate change adaptation efforts at national, tribal, state and regional levels.

The overarching goal of the *Strategy* is a simple one: to inspire, enable and increase meaningful action. Admittedly, the task ahead is a daunting one, especially if the world fails to make serious efforts to reduce emissions of greenhouse gases. But we can make a difference. To do that we must begin now, or we risk serious declines in our fish, wildlife, plants, and in important benefits and services that the natural world provides the nation every day.

Chapter 1: Introduction

The goal of the *National Fish, Wildlife and Plants Climate Adaptation Strategy* (hereafter *Strategy*) is to inspire and enable natural resource professionals, legislators and other decision makers to take action to adapt to a changing climate. Those actions are vital to preserving the nation's ecosystems and natural resources—as well as the human uses and values that the natural world provides. The *Strategy* explains the challenge ahead and offers a guide to sensible actions that can be taken now, in spite of uncertainties over the precise impacts of climate change on living resources. It further provides guidance on longer-term actions most likely to promote natural resource adaptation to climate change. Since climate adaptation cuts across many boundaries, the *Strategy* also describes mechanisms to foster collaboration among all levels of government, conservation organizations and private landowners.

The *Strategy* focuses on preparing for and reducing the most serious impacts of climate change and related non-climate stressors on fish, wildlife and plants. It places priority on addressing impacts for which there is enough information to recommend sensible, effective action over the next five to ten years. But it also identifies key knowledge, technology, information and governance gaps that hamper effective action.

Photo: AFWA

The *Strategy* is not intended to be a detailed assessment of climate science or a comprehensive report of the impacts of climate change on individual species or ecosystems; an abundant and growing literature on those topics already exists (IPCC AR4 2007, GCCIUS 2009, Parmesan 2006). It does not prescribe specific actions to be taken by specific agencies or organizations, or specific management actions for individual species. Rather, this is a broad national adaptation strategy: it identifies major conservation goals and outlines the actions needed to attain those goals.

Because the development of this adaptation plan will only have been worthwhile if it leads to meaningful action, it is directly aimed at several different groups: natural resource management agency leaders and staff; elected officials in both executive and legislative government branches; leaders in industries that depend on natural resources, such as timber, agriculture, and recreation; and private landowners, whose role is crucial because they own more than 60 percent of the land in the United States. The *Strategy* should also be useful for decision-makers in sectors that affect natural resources (such as energy, housing and urban development, transportation and water systems), for international conservation partners, for educators, and for the interested public, whose input and decisions will have major impacts on safeguarding the nation's living resources in the face of climate change.

Federal, state, and tribal governments and conservation partners are encouraged to read this document in its entirety and find areas of overlap between the *Strategy* and other planning and implementation efforts. These groups are also encouraged to identify new efforts that are being planned by their respective agencies or organizations and to work collaboratively to reduce the impacts of climate change on fish, wildlife and plants.

In order for the *Strategy* to be effectively implemented, progress should be periodically evaluated and the plan reassessed and updated every five to ten years. This report proposes that a coordinating body with representation from federal, state, and tribal governments meet quarterly to evaluate implementation and to report progress annually.

The *Strategy* is organized into five chapters, with appendices. The first chapter explains the origins, vision, guiding principles, and development of this effort. It describes the need for action, and explains how to use this document. Chapter 2 describes the major current and predicted impacts of climate change on the eight major ecosystems of the United States, and on the fish, wildlife and plant species those ecosystems support. Chapter 3 then lays out the goals, strategies, and actions that can help fish, wildlife, plants and ecosystems become more resilient in the face of those impacts, enabling natural systems to adapt to and survive climate change. The fourth chapter recommends actions that sectors such as agriculture, energy, transportation and others can take to not make things worse for fish, wildlife and plants, and to ensure that effects on valuable natural resources are considered in their climate adaptation efforts. Chapter 5 discusses implementation and integration, outlining how stakeholders at all levels of government can use this *Strategy* as a resource. Finally, the eight appendices summarize the strategies and actions, including ecosystem-specific actions, for each major natural system of the United States.

Jurisdiction of State, Tribal and Federal Agencies

Jurisdiction for conservation of fish and wildlife in the United States is shared among state, tribal and federal governments. State governments generally have primacy for conservation of resident fish and wildlife. For example, New York State asserts ownership and control of all fish, game, wildlife, shellfish, crustacean and protected insects under its Environmental Conservation Law (11-0105). Other states derive their jurisdiction for fish and wildlife conservation from similar statutes or from their State Constitutions.

Tribes recognized by the United States generally have primacy for conservation of resident fish and wildlife on tribal reservation lands. In some instances, tribes also have reserved rights for subsistence harvest of fish and wildlife on non-tribal lands. Tribal jurisdiction and rights are articulated in treaties between the individual sovereign tribes and the United States.

The federal government jurisdiction for fish and wildlife conservation focuses on migratory birds, threatened and endangered species and inter-jurisdictional fisheries. The authority comes from such federal statutes as the Migratory Bird Treaty Act, the Endangered Species Act, the Marine Mammal Protection Act, the Magnuson-Stevens Fishery Conservation and Management Act and the Coastal Zone Management Act. However, with the exception of the Marine Mammal Protection Act, Congress has affirmed in these statutes that state jurisdiction for fish and wildlife remains concurrent with the federal jurisdiction.

Ownership and jurisdiction for conservation of plants is shared among governments and private landowners. Except in the case of threatened and endangered species, plants are generally owned by the underlying landowner, whether public or private. Many state governments, and the United States, have asserted jurisdiction for conservation of plants listed as threatened or endangered under the federal Endangered Species Act, or various state statutes, regardless of whether the plants are on public or private lands.

1.1 Origins and Development

Over the past decade there have been an increasing number of calls for action by government and non-governmental entities to better understand, prepare for and address the impacts of climate change on natural resources and the communities that depend on them. These calls helped lay the foundation for development of this *Strategy*.

For example, in 2007 the U.S. General Accountability Office (GAO) released a study entitled "*Climate Change: Agencies Should Develop Guidance for Addressing the Effects on Federal Land and Water Resources*," recommending that guidance and tools be developed to help federal natural resource managers incorporate and address climate change into their resource management efforts (GAO 2007). In 2008, the U.S. Global Change Research Program released the report "*Preliminary Review of Adaptation Options for Climate-Sensitive Ecosystems and Resources*" that called for and identified a variety of new approaches to natural resource management to increase resiliency and adaptation of ecosystems and resources (CCSP 2008). In addition, a coalition of hunting and fishing organizations published two reports in 2008 and 2009 on the current and future impacts of climate change on fish and wildlife, and called for increased action to help sustain these resources in a changing climate (Wildlife Management Institute 2008, 2009). These are but a few of the many calls for action to help safeguard the nation's fish, wildlife and plants in a changing climate.

In 2009, Congress asked the Council on Environmental Quality (CEQ) and the Department of the Interior (DOI) to develop a national, government-wide climate adaptation strategy for fish, wildlife, plants, and related ecological processes. This request was included in the Fiscal Year 2010 Department of the Interior, Environment and Related Agencies Appropriations Act Conference Report. The U.S. Fish and Wildlife Service (FWS) and CEQ then invited the National Oceanic and Atmospheric Administration (NOAA) and state wildlife agencies, with the New York State Division of Fish, Wildlife, and Marine Resources as their lead representative, to co-lead the development of the *Strategy*.

The next step was the formation of a 23-person Steering Committee in January of 2011. The Steering Committee includes representatives from 16 federal agencies with management authorities for fish, wildlife, plants, or habitat as well as representatives from five state fish and wildlife agencies and two tribal commissions. The Steering Committee charged a small Management Team including representatives of the FWS, NOAA, Association of Fish and Wildlife Agencies (AFWA, representing the states more broadly) and the Great Lakes Indian Fish and Wildlife Commission to oversee the day-to-day development of the *Strategy*. The Management Team was asked to engage with a diverse group of stakeholders, as well as to coordinate and communicate across agencies and departments.

In March of 2011, the Management Team invited more than 90 natural resource professionals (both researchers and managers) from federal, state and tribal agencies to form five Technical Teams, each centered around a major U.S. ecosystem. These Teams, which were co-chaired by federal, state, and tribal representatives, worked over the next eight months to provide technical information on climate change impacts and to collectively develop the strategies and actions for adapting to climate change. The Management Team worked to identify and distill the primary approaches common across ecosystems into seven overarching goals, which will be discussed further in Chapter 3.

Strategy Goals:

- Goal 1. Conserve, Restore, & Connect Habitat
- Goal 2. Manage Species & Habitats
- Goal 3. Enhance Management Capacity
- Goal 4. Support Adaptive Management
- Goal 5. Increase Understanding
- Goal 6. Increase Awareness & Motivate Action
- Goal 7. Reduce Stresses Not Caused by Climate Change

1.2 The Case for Action

1.2.1 The Climate is Changing

Measurements and observations show unequivocally that the Earth's climate is changing. In the United States, for example:

- Average air temperature has increased two degrees Fahrenheit (°F), and precipitation has increased approximately five percent in the United States in the last 50 years.
- The amount of rain falling in the heaviest storms is up 20 percent in the last century causing unprecedented floods in places like Vermont and Tennessee.

- Extreme events like heat waves and regional droughts have become more frequent and intense, such as the historic 2011 drought in Texas.
- Hurricanes in the Atlantic and Eastern Pacific have gotten stronger in the past few decades.
- Sea levels have risen eight inches globally over the past century and are climbing along most of our nation's coastline.
- Cold season storm tracks are shifting northward.
- Arctic sea ice is shrinking rapidly.
- Oceans are becoming more acidic.

All of these changes have been well documented, as described in the 2009 report of the U.S. Global Change Research Program (GCCIUS 2009). Moreover, the changes are harbingers of far greater changes to come. The science clearly shows that the underlying cause of today's rising temperatures, melting ice, shifting weather and other changes is the accumulation of heat-trapping carbon dioxide and other greenhouse gases (GHGs) in the atmosphere (IPCC AR4 2007). Because GHGs remain in the atmosphere for many years, those that have already been emitted will continue to warm the Earth (and make the oceans more acidic because of the absorption of CO_2) for decades to come (Wigley 2005). Meanwhile, GHG emissions are continuing, increasing the concentrations of the gases in the atmosphere. In some scenarios, this will cause the Earth's average temperature to climb by 10 °F by 2100, and heat waves and droughts will become the norm instead of the exception (IPCC AR4 2007). The future will be unlike the past. Many traditional and proven approaches for managing fish, wildlife, plants and ecosystems may no longer be sufficient.

1.2.2 Fish, Wildlife and Plants Are Already Being Affected by Climate Changes

Given the magnitude of the observed changes in climate, it is not surprising that fish, wildlife and plant resources in the United States and around the world are already being affected. The impacts can be seen everywhere from working landscapes like tree farms and pastures to wilderness areas far from human habitation (Parmesan 2006). As the emissions of GHGs and the resulting climate changes continue to increase in the next century, so too will the effects on species, ecosystems, and their functions (GGCIUS 2009). Furthermore, climate-induced changes are also likely to exacerbate existing stresses like habitat loss and fragmentation, putting additional pressure on our nation's valued living resources (GCCIUS 2009). The changes that have already been observed include:

- Species are shifting their geographic ranges, often moving poleward or upwards in elevation. For instance, geese that used to winter along the Missouri River in Nebraska and South Dakota now seem to migrate only as far south as North Dakota, to the dismay of waterfowl hunters (Wildlife Management Institute 2008).
- The timing of life history events (phenology), such as spring blooming, is changing. This could affect whether or not plants are successfully pollinated (the pollinators might come at the wrong time) or whether food is available when needed by birds.
- Declines in the populations of species, from mollusks off the coast of Alaska to frogs in Yellowstone, have been seen (Maclean and Wilson 2011). Particularly worrisome are the resulting drop in overall biodiversity and the loss of the ecological value that each species brings.

- Different species are responding differently to changes in climate, leading to decoupling of important ecological relationships.
- Habitat loss is increasing due to ecological changes, such as sea level rise, increased fire, pest outbreaks, novel weather patterns or loss of glaciers. The threat to polar bears from reduced Arctic ice cover is well known, but there are numerous examples close to home, such as the potential loss of brook trout.
- Since water absorbs CO_2, the oceans are becoming more acidic, affecting the reproduction of species like oysters.
- The spread of non-native species as well as diseases, pests, and parasites has become more common. For instance, warmer temperatures have enabled a salmon parasite to invade the Yukon River, causing economic harm to the fishing industry (Kocan 2004).

HOTTER SUMMERS THREATEN EASTERN BROOK TROUT

The West Fork of the Kickapoo River in western Wisconsin is an angler's paradise. Its cool, shaded waters and pools abound with native brook trout (*Salvelinus fontinalis*). But brook trout require cold water to reproduce and survive—and temperatures are already rising. By the end of this century, the self-sustaining population in the West Fork could be gone. In fact, up to 94 percent of current brook trout habitat in Wisconsin could be lost with a 5.4 °F increase in air temperature (Mitro et al. 2010).

The threat isn't limited to Wisconsin or to brook trout. Climate change is viewed as one of the most important stressors of fish populations, and cold-water fish species are especially susceptible to rising temperatures. Declining populations would have serious ecological and economic consequences, since these fish are key sources of nutrients for many other species and provide major fishing industries in the Northeast, Northwest, and Alaska (Trout Unlimited 2007). Although climate change has not been proven to have caused the loss of any brook trout populations to date, the warming effects on air temperature is predicted to significantly reduce the current range of brook trout in the eastern United States.

In some cases, adaptation measures may help reduce the threat. The first step is measuring stream water temperatures and flow rates to identify which trout habitats are at risk and which are not. Monitoring efforts have already shown that some trout streams are safe because they have water temperatures far below lethal limits, while other streams are not likely to see increases in water temperatures even when air temperatures rise since adequate amounts of cool groundwater sustain the stream's baseflow in summer. This information enables fisheries managers to focus on the streams and rivers that are at risk from climate change and changing land use that would decrease groundwater discharge rates. In some streams, these deteriorating conditions cannot be reversed. In other streams, adaptation strategies can be implemented to reduce stream water temperatures such as planting trees and other stream bank vegetation for shade, or narrowing and deepening stream channels to reduce solar heating.

Protecting and enhancing water infiltration rates on land is another adaptation strategy that can increase cooler groundwater discharge rates during the critical summer low flow conditions. This stream assessment approach is called "triage" (similar to how accident or battlefield responders work), where efforts are focused on those "individuals" that are most likely to respond to treatment. Thus, limited resources are not spent on streams that are deemed safe from the effects of rising air temperatures, nor are resources wasted on streams that cannot be saved from these effects.

1.2.3 The Value of Fish, Wildlife and Plants to People

As the preceding examples of impacts already occurring from a changing climate suggest, living resources bring immense value and benefits to people. The materials and processes that ecosystems produce that are of value to people are termed "ecosystem services" and can be organized into four general categories (Millennium Ecosystem Assessment 2005):

- *Supporting Services*, such as nutrient cycling, soil formation, plant productivity, and oxygen production, etc.
- *Provisioning Services* including food, water, medicines, wood, etc.
- *Regulating Services*, like climate regulation, flood suppression, disease/pest control, or water filtration, etc.
- *Cultural Services*, such as aesthetic, spiritual, educational, and recreational services.

It's possible to calculate the economic value of some of these uses. Hunting, fishing and other wildlife-related recreation alone is estimated to contribute $122 billion to our nation's economy annually (U.S. DOI 2006), while the world's fisheries, most of which are based on wild, free-ranging species, generate approximately $116 billion a year to the U.S. economy (NMFS 2010). In addition, for many Native Americans and other indigenous peoples around the world, wild species are still essential to their livelihoods. Less obviously, forests help provide clean drinking water for many cities and towns, while coastal habitats such as coral reefs, wetlands and mangroves help protect people and communities from storms, erosion and flood damage (U.S. DOI 2006). The problem is that the value of these so-called indirect ecosystem services is not readily monetized, and so these services are frequently undervalued in decision-making processes. Nevertheless, as climate change influences the distribution, extent and composition of ecosystems, it will also affect the spectrum of services and economic value those ecosystems provide.

Also difficult to measure are the so-called "non-use" values, which include aesthetic, spiritual and intrinsic values many people place on wildlife. For many people, quality of life depends on frequent interaction with wildlife. Others simply take comfort in knowing that the wildlife and natural places that they know and love still survive, at least somewhere. For many Native Americans and rural Americans, wild species and habitats are central to their very cultural identities.

WHAT HAPPENS TO TRIBAL IDENTITY IF BIRCH BARK VANISHES?

Climate change models suggest that by 2100, the paper birch tree may no longer be able to survive in its normal habitat in the upper Midwest and northeastern United States, from northern Wisconsin to Maine (Prasad et al. 2007). That would be not just an ecological loss, but a devastating cultural loss as well. Some species are so fundamental to the cultural identity of a people through diverse roles in diet, materials, medicine, and/or spiritual practices that they may be thought of as cultural keystone species (Garibaldi and Turner 2004). The paper birch (*Betula papyrifera*) is one such species.

Photo: John Zasada

Paper birch bark has been crucial for American Indians throughout the Northeast and Alaska Native tribes since time immemorial. It provided native peoples with transportation, thanks to birch bark canoes. It was used for food storage containers to retard spoilage, earning it the nickname of the "original Tupperware™." It was a material on which fungi was grown for medicines and for tinder in sacred fires. It is an extremely durable material, and is still used as a canvas on which traditional stories and images are etched, contributing to the survival of Native culture and providing a source of revenue. Indeed, birch bark is crucial for the economic health of skilled craftspeople who turn it into baskets and other items for sale to tourists and collectors. And paper birch is central to some of the great legends of the Anishinaabe, or Ojibwe peoples (also known as Chippewa).

These rich cultural and economic uses and values are at risk if the paper birch tree disappears from the traditional territories of many U.S. tribes. Already, artisans in the Upper Midwest are concerned about what they believe is a diminishing supply of birch bark.

1.2.4 Human Actions Can Help Natural Systems and Communities Adapt to Climate Change

Adapting to climate change means taking steps to help people and natural systems prepare for and cope with the effects of a changing climate. That may seem like a daunting task, given the magnitude of potential changes. But effective action by managers, communities and the public is possible. Such action is also crucial. While reducing the causes of climate change (i.e., mitigation) is absolutely necessary, mitigation will not be sufficient to prevent major impacts given the amount of GHGs that have already been emitted into the global atmosphere.

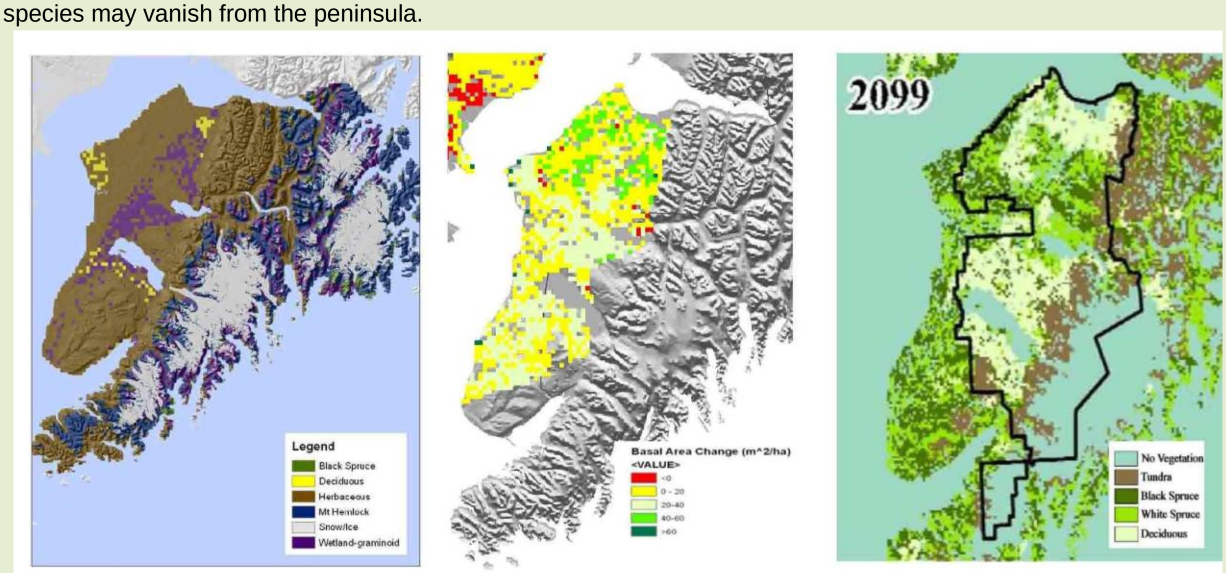
To be more specific, adaptation has been defined as an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC WGII 2007). The science and practice of adaptation to climate change is an emerging discipline that focuses on helping people and natural systems prepare for and cope with the impacts of climate change (Glick et al. 2011). The ability of populations, species, or systems to adapt to a changing climate is often referred to as their adaptive capacity. Adaptive capacity, in turn, is not just the ability to adjust to climate change (including climate variabilities and extremes), but also to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC 2001).

Three general types of adaptation responses illustrate points along a continuum of possible responses to climate change: resistance, resilience and transformation. Resistance is the ability of a system to remain essentially intact or unchanged as climate changes. Resilience is the ability of a system to recover from a disturbance, returning to its original state. Transformation is the change in a system's composition and or function in response to changes in climate or other factors. The adaptation approaches described in *this Strategy* carefully consider whether the desired outcome in any given situation should be to try to increase the resistance of a natural system to climate change, to make it more resilient in the face of climate change, to transform it into a new and different state—or to achieve some combination of all three outcomes (Hansen and Hoffman 2011).

CLIMATE CHANGE IN THE KENAI PENINSULA

For a glimpse of the dramatic changes that a warming climate may bring to the entire nation, look no farther than Alaska's seven million-acre Kenai Peninsula. Here, warmer temperatures have boosted populations of spruce bark beetle, enabling the pest to devastate four million acres of forest on the peninsula and south-central Alaska over a 15-year period. (Berg et al. 2006). Meanwhile, the treeline has risen an unprecedented 150 feet (Dial et al. 2007); the area of wetlands has decreased by six to 11 percent (Berg et al. 2009, Klein et al. 2005, Klein et al. 2011); the Harding Icefield, the largest glacial complex in the U.S., has shrunk by five percent in surface area and 60 feet in height (Adageirsdottir et al. 1998, Rice 1987); and available water has declined 55 percent (Berg et al. 2009). The fire regime is also changing: late summer canopy fires in spruce are being replaced by spring fires in bluejoint grasslands, and a 2005 wildfire in mountain hemlock was far different from any previous fire regime (Morton et al. 2006).

While these changes are already sobering, even greater changes lie ahead, according to predictions from spatial modeling. As the climate continues to warm and dry, the western side of the peninsula could see an almost catastrophic loss of forest. Salmon populations—and the communities that depend on salmon—are predicted to suffer because of higher stream temperatures and increased glacial sediment. Overall, roughly 20 percent of species may vanish from the peninsula.



Future scenarios of the landscape on Kenai National Wildlife Refuge, Alaska using three modeling approaches: climate envelope, fire regime shift, and forest dynamics (USFWS/John Morton)

Is adapting to this rapidly changing climate possible? Some communities are already taking positive steps. For instance, state and local agencies are replanting beetle-killed areas that have become grasslands with white spruce (*Picea glauca*) and non-native lodgepole pine (*Pinus contorta*) to reduce fire hazards for nearby cities and communities. The National Park Service, the Forest Service, the University of Alaska Anchorage and other agencies and groups are also exploring additional adaptation options for the Kenai Peninsula. Kenai National Wildlife Refuge will host a workshop in early 2012 to develop interagency strategies for developing reactive and anticipatory options specifically for the Kenai Peninsula. The geographic discreteness of the peninsula, the substantial lands under federal management, and the documentation of dramatic climate change impacts combine to make Kenai an ideal laboratory to explore the effectiveness of various adaptation measures.

1.3 About the *Strategy*

As discussed previously, species and habitats are already displaying changes consistent with a warming climate (Parmesan 2006). What society can or even should do about these changes is a complicated question, and involves much more than science. Deciding what to do requires considering the way existing conservation institutions describe, classify and value nature and natural resources. It requires examining the institutions, laws, policies and programs that our nation has developed to maintain these resources and the many benefits they provide. It requires evaluating the management techniques that the conservation profession and other sectors (such as agriculture, energy, transportation and urban development) have developed over time, as well as considering new approaches where necessary. Perhaps most of all, it requires communicating our shared social values for wild living things. Those social values can form the basis of cooperative intervention.

This *Strategy* is the first joint effort of three levels of government (federal, state and tribal) that have primary authority and responsibility for the living resources of the United States to identify what must be done to help these resources adapt to a warming climate. The timeframe for this first effort focuses on actions that can be taken in the next decade to help fish, wildlife and plants adapt to changes that are currently predicted by 2050 and 2100. Although there is great certainty about the fact of climate change, uncertainty remains about its scale, pace and regional effects. Because new information will become available in the coming years, this adaptation strategy should be revisited, refreshed, and, as necessary, revised at least every five to ten years.

1.3.1 Purpose, Vision, and Guiding Principles

In 2009, the FWS launched a series of Conservation Leadership Forums to bring together leaders in the conservation community to discuss what a *Strategy* should include and how it should be developed. That effort, and others, produced a purpose and a vision, along with goals and guiding principles, for a national climate change adaptation strategy.

Purpose: The purpose of the *Strategy* is to inspire and enable natural resource professionals and other decision makers to take action to conserve the nation's fish, wildlife, plants and ecosystem functions, as well as the human uses and values these natural systems provide, in a changing climate. The *Strategy* provides a basis for sensible actions that can be taken now, in spite of the uncertainties that exist about precise impacts of climate change. It also provides guidance about what further actions are most likely to promote natural resource adaptation to climate change, and describes mechanisms that will foster collaboration among all levels of government, conservation organizations and private landowners.

Vision: Ecological systems will sustain healthy, diverse and abundant populations of fish, wildlife and plants. Those systems will continue to provide valuable cultural, economic and environmental benefits in a world impacted by global climate change.

Guiding Principles: The *Strategy* adopts the following ten guiding principles:

1. **Build a national framework for cooperative response.** No single sector or level of government can effectively respond to climate impacts alone. An unprecedented commitment to collaboration and communication is required among federal, state, and tribal governments. There must be active engagement with conservation organizations, industry groups, and private landowners.

2. **Respect jurisdictional authorities and foster communication and collaboration rather than prescription.** Jurisdiction for fish, wildlife and plants conservation is shared among many levels of government and, especially for plants, by private landowners. No single entity can tell others what must be done.

3. **Provide a blueprint for collective action that promotes collaboration and communication across government and non-government entities.** This includes creating an environment that supports collaborative approaches to adapting to climate change and provides guidance that all conservation partners can use.
4. **Adopt a landscape/seascape-based approach that integrates best-available science and adaptive management.** Strategies for natural resource adaptation should emphasize: species-habitat relationships; ecological systems and function; strengthened observational systems; model-based projections; risk assessment; and active and passive adaptive management.
5. **Focus actions and investments on natural resources of the U.S. and its Territories.** But at the same time, foster international collaboration and information-sharing, particularly across our borders with Canada and Mexico. International cooperation is important to conservation of migratory resources over broad geographic ranges.
6. **Identify critical scientific and management needs.** These may include new research, information technology, training to expand technical skills, or new policies, programs, or regulations. Resource managers, scientists and decision-makers should work together to identify needs and find creative solutions, such as developing new partnerships, approaches, or funding sources.
7. **Engage the public.** To ensure success and gain support for adaptation strategies, a high priority must be placed on public outreach, education and engagement in adaptation planning and natural resource conservation.
8. **Integrate strategies for natural resources adaptation with those of other sectors.** Adaptation planning in sectors including agriculture, energy, forestry, human health, transportation, and water management may support and advance natural resource conservation in a changing climate. Equally, the conservation of natural resources can be an effective adaptation strategy for these sectors. Managers and decision-makers should work together to identify co-benefits, and integrate planning and actions where possible.
9. **Identify opportunities to integrate climate adaptation and mitigation efforts.** Strategies to increase natural resource resilience and reduce greenhouse gas emissions may directly complement each other to advance current conservation efforts, as well as to achieve short- and long-term conservation goals.
10. **Act now.** Time is of the essence. Immediate planning and action are needed to better understand and address the impacts of climate change to safeguard natural resources now and into the future.

1.3.2 Connecting Science to Policy to Action in an Age of Uncertainty

Climate change presents a new challenge to natural resource managers and other decision makers. The future will be different from the past, so we can no longer rely on the historical record to guide their actions. More is being learned every year about how the climate will change, how those changes will affect species, ecosystems and their functions and services, and how future management and policy choices will exacerbate or alleviate these impacts. This is not a reason for inaction, but rather a reason for prudent action: using the best available information while striving to improve our understanding over time.

Risk Assessment:

A risk assessment is the process of identifying the magnitude or consequences of an adverse event or impact occurring, as well as the probability that it will occur (Jones 2001).

An important approach for dealing with risk and uncertainty is an iterative process called adaptive management. The idea behind adaptive management is to build continual learning into the management process, so that new information to be incorporated into decision-making over time without delaying needed actions. Adaptive management involves defining explicit management goals while highlighting key uncertainties, carefully monitoring the effects of management actions, and then adjusting activities to take the information learned into account (CCSP 2008, Fagre et al. 2009).

There are also tools and approaches to help reduce uncertainty and inform managers about how climate change may affect particular systems or regions. Improved climate modeling and downscaling can help build confidence in predictions of future climate, while climate change vulnerability assessments can help to identify which species or systems are likely to be most affected by climate changes. Well-designed monitoring of how species and natural systems are currently reacting to climate impacts and to adaptation actions will also be a critical part of reducing uncertainty and increasing the effectiveness of management responses. These tools and approaches can all inform scenario planning, which involves anticipating a reasonable range of future conditions and planning management activities around a limited set of likely future conditions. In addition, other approaches aim to identify actions that are expected to succeed across a range of uncertain future conditions, such as reducing non-climate stressors, or managing to preserve a diversity of species and habitats.

Photo: AFWA

Another important component of managing uncertainty is to better integrate existing scientific information into management and policy decisions. This requires that research results be accessible, understandable, and highly relevant to decision-makers. In addition, decision support tools that help connect the best available science to day-to-day management decisions should be developed, and research priorities should be linked to the needs of managers on the ground.

It is important to remember that natural resource management has always been faced with uncertainty about future conditions and the predicted impacts of a particular action. The adaptation strategies and actions in this *Strategy* are intended to help natural resource managers begin making proactive climate change-related decisions today, recognizing that new information will become available over time that can then be factored into future decisions.

Chapter 2: Impacts of Climate Change on Fish, Wildlife & Plants

This chapter summarizes the current and projected impacts of climate change on the nation's fish, wildlife, and plant species, and then provides more detailed information on ecosystem-specific impacts within eight major types of ecosystems in the United States: forest, shrubland, grassland, desert, tundra, inland waters, coastal and marine ecosystems.

2.1 Overview of Climate Changes

The United States has already experienced major changes in climate, and additional changes are expected over time. Their magnitude will depend on the rate of GHG emissions and the resulting atmospheric GHG levels (GCCIUS 2009).

Increases in atmospheric carbon dioxide (CO_2)

- The concentration of CO_2 in the atmosphere has increased by roughly 35 percent since the start of the industrial revolution (GCCIUS 2009).
- The pH of seawater has decreased from around 8.25 in 1751 to around 8.14 in 2004 (Jacobson 2005), and is projected to drop as much as another 0.3 to 0.4 units by the end of the century as atmospheric CO_2 concentrations continue to increase (Orr et al. 2005).

As a result of human activities, the level of CO_2 in the atmosphere has been rapidly increasing. The present level of approximately 390 parts per million (CO2NOW.org) is more than 30 percent above its highest level over at least the last 800,000 years (GCCIUS 2009). In the absence of strong control measures, emissions projected for this century would result in a CO_2 concentration approximately two to three times the current level (GCCIUS 2009).

Changes in air and water temperatures:

- Average temperatures have increased more than 2 °F in the United States over the last 50 years (more in higher latitudes), and are projected to increase further (GCCIUS 2009).
- Arctic sea ice extent has fallen at a rate of three to four percent per decade over the last 30 years. Further sea ice loss, as well as reduced snowpack, earlier snow melt, and widespread thawing of permafrost, are predicted (GCCIUS 2009).
- Sea level rose by roughly eight inches over the past century, and in the last 15 years it has risen twice as fast as the rate observed over the past 100 years (GCCIUS 2009).

Since 1900, global average temperature has risen approximately 1.5 °F, and it is projected to rise between 2 and 11.5 °F more by 2100 (GCCIUS 2009). Similarly, global ocean temperatures rose 0.2 °F between 1961 and 2003 (IPCC WGI 2007). Future changes for the Arctic are predicted to be especially extreme: for example, the average annual temperature of Alaska's North Slope tundra is projected to rise approximately 13°F by 2100 (SNAP 2008).

Changes in temperature can lead to a variety of ecologically important impacts, affecting our nation's fish, wildlife and plant species. For example, a recent analysis showed that many rivers and streams in the United States have warmed over the past 50 to100 years (Kaushal et al. 2010), and will continue to warm 0.4°F per decade (IPCC AR4 2007). The increasing magnitude and duration of summer water temperatures will increase thermal stratification in rivers, lakes and oceans, and may cause depletion of oxygen for some periods, adversely impacting coldwater fish and other species. Increasing temperature is also a major driver of rising sea levels through thermal expansion. In addition, increasing air and ocean temperatures may have major impacts on ocean currents and stratification of ocean waters.

Changes in timing, form and quantity of precipitation:

- Precipitation has increased approximately five percent in the last 50 years (GCCIUS 2009).
- Models suggest northern (wet) areas will become wetter, while southern (dry) areas will become drier (GCCIUS 2009).

Climate change driven alterations in precipitation patterns, in combination with increasing temperatures, are impacting water quantity, water quality and hydrology on a variety of scales across ecosystems (GCCIUS 2009). These changes vary regionally. The Northeast and Midwest are experiencing higher precipitation and runoff in the winter and spring, while the arid West is seeing less precipitation in spring and summer (GCCIUS 2009). In areas of high snowpack, runoff is beginning earlier in the spring, causing flows to be lower in the late summer. These changes in precipitation combined with increased temperatures are also expected to significantly change the impact of fire on many ecosystems.

Changes in the frequency and magnitude of extreme events:

- Extreme weather events such as heat waves and regional droughts have become more frequent and intense during the past 40 to 50 years (GCCIUS 2009).
- Rain falling in the heaviest downpours has increased approximately 20 percent in the past century. Hurricanes have increased in strength (GCCIUS 2009).

By 2100, tropical storm intensity in the Northern Hemisphere is predicted to increase nine percent. Over the next century, current research suggests a decrease in the total number of extratropical storm events but an increase in number of intense events (Lambert and Fyfe 2006, Bengtsson et al. 2009). According to the GCCIUS (2009), over the past few decades most of the U.S. has been experiencing more unusually hot days and nights, fewer unusually cold days and nights, and fewer frost days. Droughts are also becoming more severe in some regions. These types of extreme events can have major impacts on the distribution, abundance, and phenology of species, as well as on ecosystem structure and function.

2.2 Existing Stressors on Fish, Wildlife and Plants

Fish, wildlife, plants and ecosystem processes are threatened by a number of existing stressors. Many of these stressors will be exacerbated by climate change. Some may reduce a species' ability to adapt to climate change. Resource managers must consider climate impacts in the context of multiple natural and human-induced changes that are already significantly affecting species, habitats and ecosystem services; these include habitat loss, fragmentation and degradation, invasive species, and over-use.

Non-Climate Stressors

In the context of climate adaptation, non-climate stressors refer to those current or future pressures and impacts threatening species and natural systems that do not stem from climate change, such as habitat fragmentation, pollution and contamination, and over-exploitation.

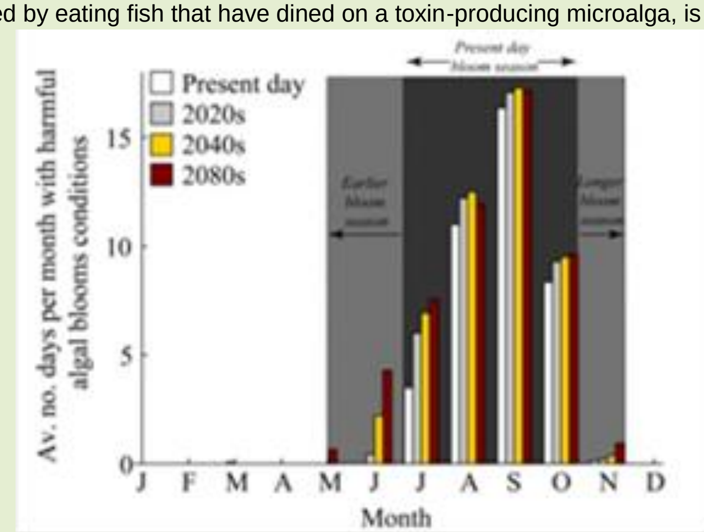
Habitat fragmentation, loss and degradation have been pervasive problems for natural systems and are expected to continue. For example, grasslands, shrublands, and forests are being converted to agricultural uses. Desert systems are stressed by overgrazing. Tundra and marine ecosystems are being affected by energy and mineral exploration and extraction, and coastal ecosystems are experiencing extensive development. Adding changes in climate to habitat fragmentation will put species with narrow ranges and specific habitat requirements at even greater risk. Range reductions and population declines may be severe enough to threaten some species with extinction over all or significant portions of their ranges. For example, Henslow's sparrow (*Ammodramus henslowii*) and the regal fritillary butterfly (*Speyeria idalia*), already declining due to habitat loss, degradation, and fragmentation, may be further threatened by climate impacts (Swengel and Swengel 1998).

HARMFUL ALGAL BLOOMS

In the past three decades, harmful algal blooms (HABs) have become more frequent, more intense, and more widespread in freshwater, estuarine, and marine systems (Sellner et al. 2003). These blooms are taking a serious ecological and economic toll. They consume oxygen in the waterbodies, especially during calm periods when water circulation and reoxygenation from the atmosphere are reduced. When the algae die, the bacteria that eat them use up even more oxygen. The result: an increasing number of massive fish kills. In addition, some blooms, such as those of Cyanobacteria (commonly known as blue-green algae) produce potent nerve and liver toxins that kill fish, seabirds, sea turtles, and marine mammals. These toxins also sicken people and result in lost income from fishing and tourism. The blooms don't even provide a useful food source for the invertebrate grazers that are the base of most aquatic food webs.

The cause of the increasing number of blooms? One of them is climate change. Warmer temperatures are boosting the growth of harmful algae (Jöhnk et al. 2008). More floods and other extreme precipitation events are increasing the runoff of phosphorus and other nutrients from farms and other landscapes, fueling the algae's growth. And the problem is expected to get worse. In Puget Sound, HABs may begin up to two months earlier in the year and persist for one month later compared to today by the end of the 21st century—increasing the chances that paralytic toxins will accumulate in Puget Sound shellfish (Moore et al. 2009). In addition, the ranges of many harmful algal species may expand, with serious consequences. For example, a painful foodborne illness known as ciguatera, caused by eating fish that have dined on a toxin-producing microalga, is already becoming much more common in many tropical areas. Global warming will increase the range of the microalga—and the threat of poisoning.

It is possible, however, to successfully combat this problem. The key strategy is reducing the flow of nutrients into waterbodies. Proven steps include adding buffer strips beside streams or restoring wetlands to absorb nutrient pollution before the nutrients can reach streams, rivers, lakes and oceans. In addition, better detection and warning systems can reduce the danger to people.



Projected changes to the harmful algal bloom season in Puget Sound in a future warmer climate. (NOAA/S. Moore)

Invasive species present another growing problem. The list of species already causing ecological and economic harm includes quagga mussels, Asian carp, and kudzu—and the list grows longer every year. Globalization and the increasing movement of people and goods around the world have enabled pests, pathogens, and other species to travel quickly over long distances and effectively occupy new areas.

These invasions of new species are also getting a boost from land-use changes, the alteration of nutrient cycles and climate change (Vitousek et al. 1996, Mooney and Hobbs 2000). Species that have already colonized new areas in the U.S. may become more pervasive with changing conditions. For example, some invasive species like kudzu or cheatgrass may benefit when CO_2 concentrations increase or historical fire regimes are disturbed (Dukes and Mooney 1999).

Over-use of America's fish, wildlife and plants has also had major impacts. Some species have been lost from certain areas, while others have gone completely extinct. For example, overfishing of commercial and recreational fish stocks in some regions has harmed the resources and the communities and economies that depend on them.

Invasive Species

Invasive species are typically defined as non-indigenous or non-native species that adversely affect the habitats and ecosystems they invade economically, environmentally, and/or ecologically. However, some native species can become invasive in certain ecological contexts, while many non-native species do not negatively affect natural systems. Today climate change may be redefining traditional concepts of native and non-native, as species move into new areas in response to changing conditions,

Of course, resource managers have long been aware of the non-climate stressors on species and ecosystems, and have worked hard to reduce the impact of these stressors in their management strategies. But as climate change will likely exacerbate these existing human-induced pressures on natural systems, one of the most successful strategies for increasing the resilience of fish, wildlife and plants to a changing climate may be reducing the impact of these non-climate stressors. For instance, warmer water temperatures have already caused over half of 36 examined fish stocks off the Northeast coast of the U.S. to shift northward and/or to deeper depths over a 40 year period (Nye 2010). Reducing fishing pressure on these stocks could help ensure that populations are able to thrive even as they move to these new locations.

2.3 Climate Change Impacts on Major U.S. Ecosystems

Climate influences species and ecosystems in many ways. A changing climate can affect growth rates, make food less available, and change rates and patterns of decomposition and nutrient cycling. It can alter the distribution, abundance, phenology, and behavior of species, and the diversity, structure and function of ecosystems. One forecast that seems certain is that the more rapidly the climate changes, the higher the probability of substantial disruption and unexpected events within natural systems (Root and Schneider 1993). The possibility of major surprises, in turn, increases the need for adaptive management strategies—where actions and approaches are flexible enough to be easily adjusted in the face of changing conditions.

Species and populations likely to have greater sensitivities to climate change include those with highly specialized habitat requirements, species already near temperature limits or having other narrow environmental tolerances, currently isolated, rare, or declining populations with poor dispersal abilities, migratory species, and groups especially sensitive to pathogens (Foden 2008). Species with these traits will be even more vulnerable if they have a small population, a low reproductive rate, long generation times, low genetic diversity, or are threatened by other factors. For these reasons, maintaining rare or already endangered species will present significant challenges in a changing climate, because many of these species have limited dispersal abilities and opportunities (CCSP 2008). In addition, migratory species are likely to be strongly affected by climate change, as animal migration is closely connected to climatic factors and migratory species use multiple habitats, sites, and resources during their migrations.

In extreme cases, species have abandoned migration altogether, while in other cases species are now migrating to new areas where they were previously only occasional vagrants (Foden 2008).

Climate impacts will vary regionally and by ecosystem across the United States (see Figures 1 and 2). Understanding the regional variation of impacts and how ecosystems will respond is critical to developing successful adaptation strategies. Current and projected climate change impacts on ecosystems are summarized in Table 1, and discussed in greater details in the following sections.

RANGE SHIFTS IN A CHANGING CLIMATE

Climate is a major driver of the distribution of species and the ecosystems they form. As the climate changes, species are predicted to shift their geographic ranges in response. Increased air and water temperatures, changes in precipitation or snowfall, and reductions in sea ice can all lead to range shifts, as species' physiological thresholds are reached or surpassed in the areas they have historically occupied (Walther et al. 2002). Significant range shifts have already been observed worldwide, as many species move toward the poles or climb upwards in elevation as they track climatic shifts (Parmesan and Yohe 2003). These shifts have been seen around the wolrd, from the Arctic to the Antarctic, in terrestrial, aquatic, and marine systems, and for a variety of species including mammals, birds, butterflies, trees, and many others (Parmesan 2006).

Climate change is already causing range shifts: 80 percent of species analyzed in one meta-analysis moved in accord with climate change predictions (Parmesan and Yohe 2003). For example, in Yosemite National Park, half of 28 species of small mammals (e.g., pinyon mouse (*Peromyscus truie*), California vole (*Microtus californicus*), alpine chipmunk (*Neotamias alpinus*), and others) monitored showed substantial (500 meters on average) upward changes in elevation, consistent with the recent observed 5.4°F increase in minimum temperatures. Formerly low-elevation species expanded their ranges while high-elevation species contracted, leading to changed community composition at mid- and high elevations (Moritz 2008). Mountaintop species and others with narrowly restricted ranges may be especially vulnerable to further climate change (Parmesan 2006). However, these shifts can be quite complicated: recent evidence suggests that some alpine plant species may actually be shifting their distributions "downslope" in response to changes in water availability, rather than changes in temperature (Crimmins et al. 2011).

In addition to terrestrial ecosystems, species ranges are shifting in marine ecosystems. In the Northeast US, over half of 36 examined fish stocks shifted northward and/or to deeper depths over a 40-year time period in response to consistently warm waters (Nye et al. 2009). Atlantic mackerel is now rarely found in Mid-Atlantic waters, such that the fishery in this area no longer exists because it is not cost-effective for fishermen to maintain the infrastructure (nets, boats etc.) to find, catch and process mackerel. Similarly, in the Bering Sea, fish have moved northward as sea ice cover is reduced and the amount of cold water from melting sea ice is reduced (Mueter and Litzow 2008). In the California Current ecosystem, shifts in spatial distribution were more dramatic in species that were heavily fished (Hsieh et al. 2008).

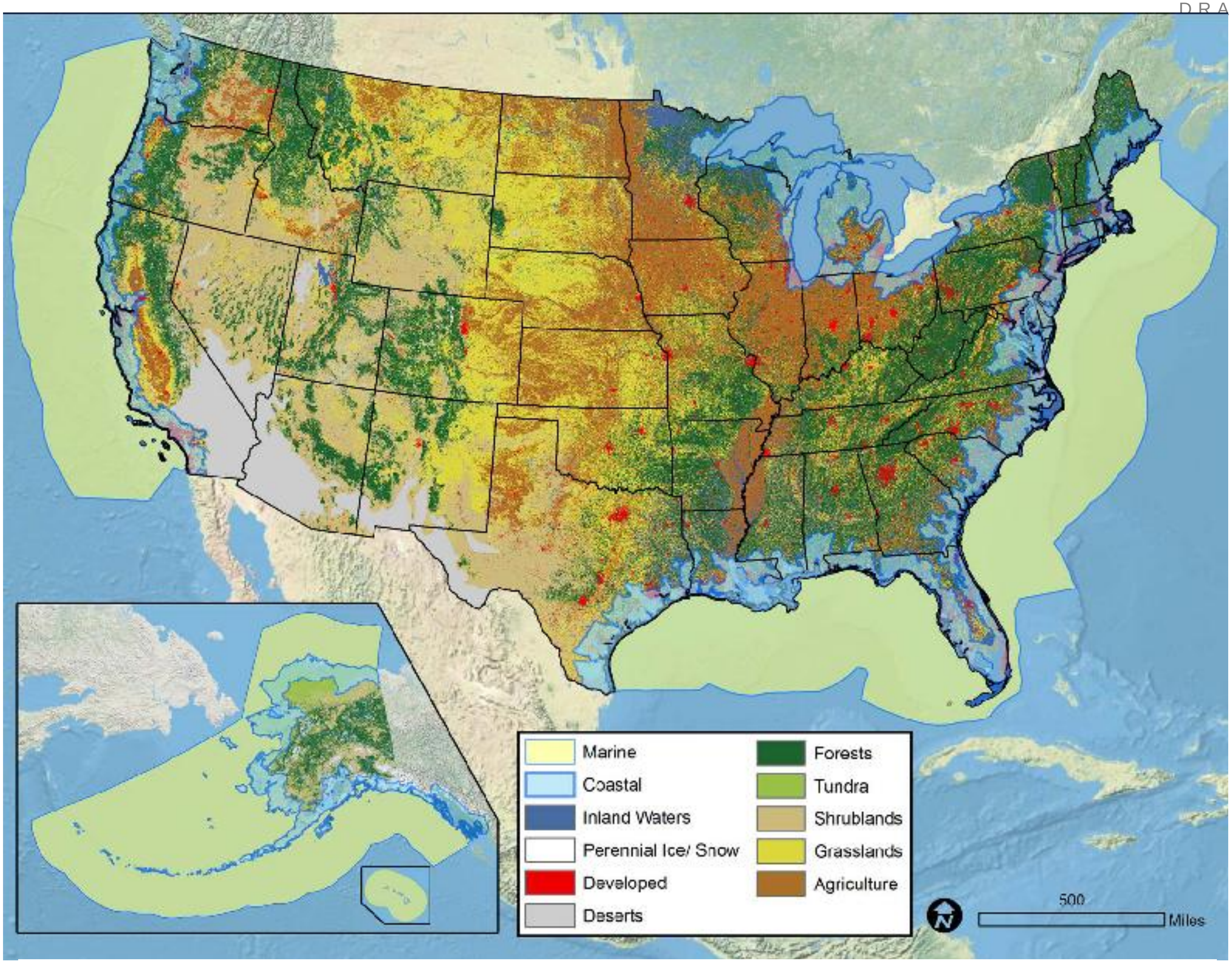
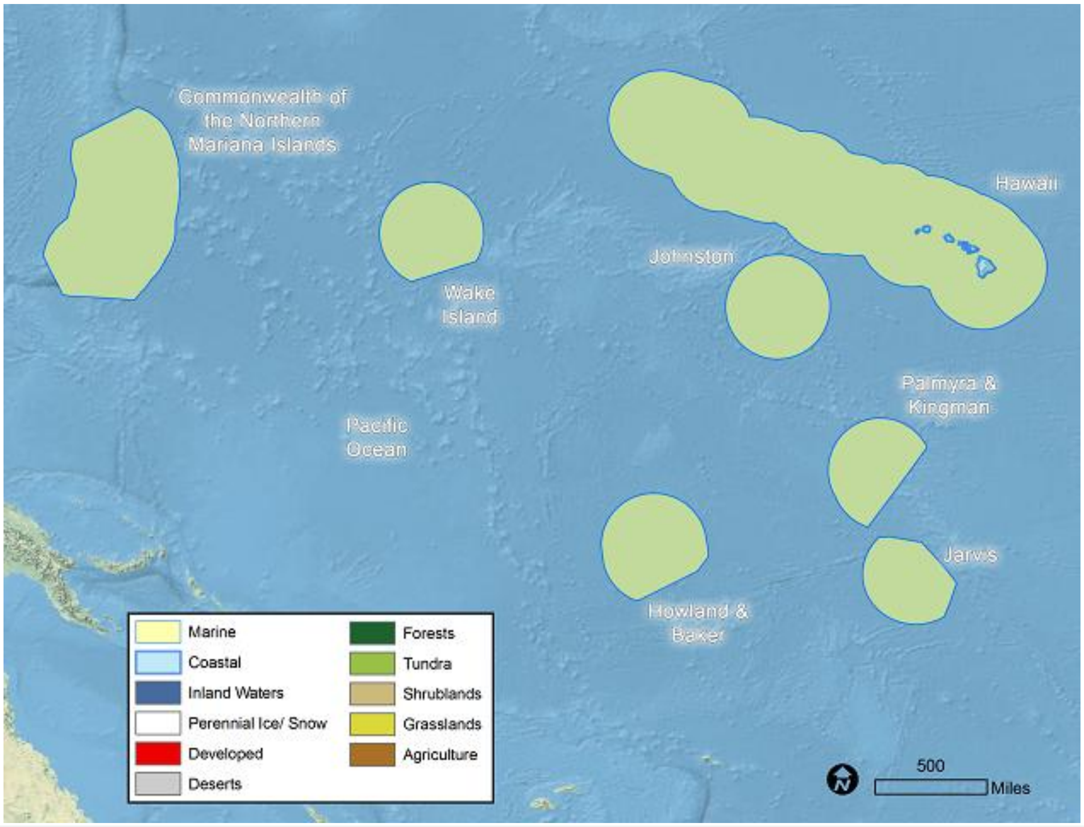


Figure 1: *This image illustrates the distribution of the eight major ecosystems (forests, grasslands, shrublands, deserts, tundra, inland waters, coastal, and marine systems) described in the Strategy. Data source: Multi-Resolution Land Characterization (MRLC) Consortium National Land Cover Database 2001, analysis by USGS EROS data center; NOAA's Coastal Geospatial Data Project and U.S. Maritime Zones, analysis by NOAA; USGS 1;250,000 hydrologic units of the United States.*



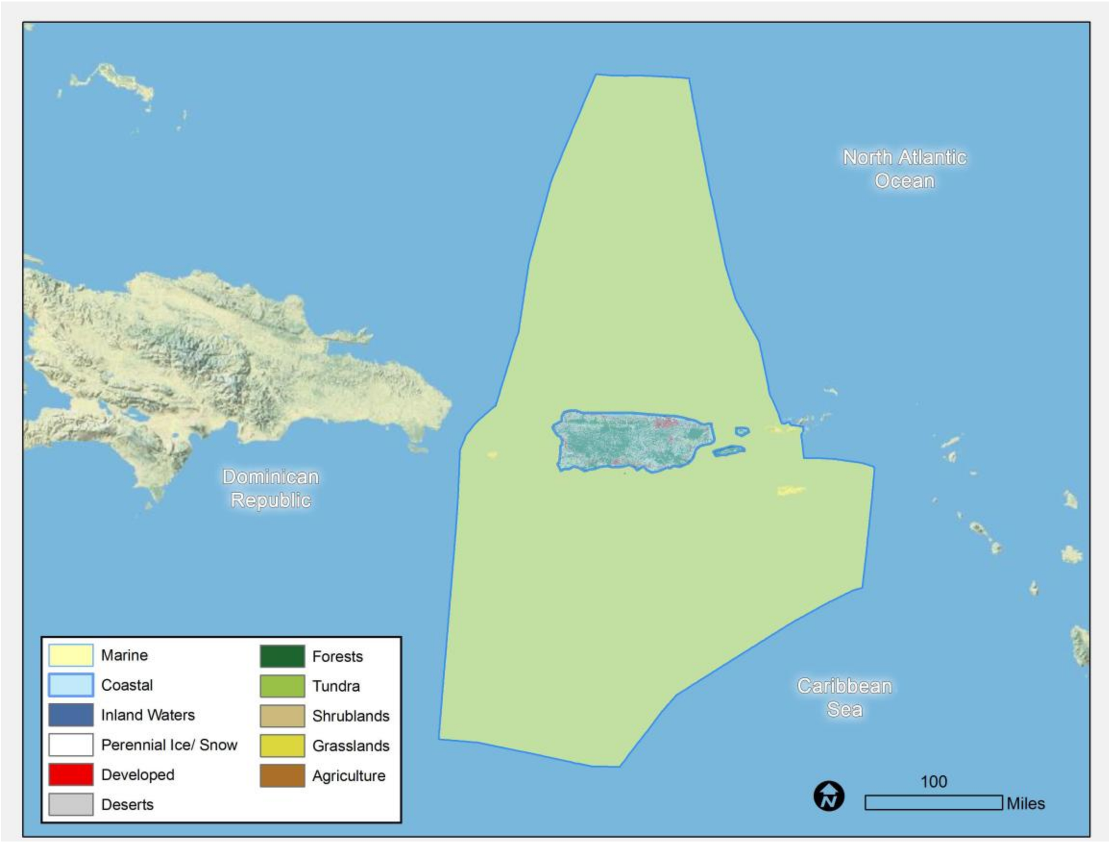


Figure 2: *This image illustrates the distribution of the eight major ecosystems (forests, grasslands, shrublands, deserts, tundra, inland waters, coastal, and marine systems) for the U.S. territories in the Pacific and the Caribbean. See Figure 1 for data sources.*

Table 1: Summary of Major Climate Change Impacts on U.S. Ecosystems*

Major Changes Associated With Increasing Levels of GHGs *(GCCIUS 2009 and IPCC 2007)*	Major Impacts On U.S. Ecosystems (by ecosystem type)							
	Forests	**Shrublands**	**Grasslands**	**Deserts**	**Tundra**	**Inland Waters**	**Coastal**	**Marine**
Increase in atmospheric CO_2: The concentration of CO_2 in the atmosphere has increased by roughly 35 percent since the start of the industrial revolution.	May increase forest productivity and growth in some areas	Increase spread of exotic species such as cheatgrass	Changes in ratios of C3 to C4 plants, increased C:N ratios	Increased productivity of some plants changes communities, fire risk			Increased terrestrial and emergent plant productivity	
Ocean acidification: The pH of seawater has decreased significantly since 1750, and is projected to drop much more by the end of the century if CO_2 concentrations continue to increase.							Declines in shellfish and other species	Harm to corals, shellfish, and others, impacts on early life stages, phenology changes
Increased temperatures: U.S. average temperatures have increased more than 2 °F in the last 50 years, and are projected to increase further. Global ocean temperatures rose 0.2 °F between 1961 and 2003.	Increase in major forest pest damage: tens of millions of acres already affected	Intensified water stress through increased evapo-transpiration	Spread of non-native pests, such as fire ants	Elevated water stress, mortality in heat-sensitive species, possible desert expansion	Water stress, changing plant communities, longer snow-free season, invasion by new species	Increase of warm-water species, depleted O2 levels, stress on cold-water fish	Growth of salt marshes/ forested wetlands, increased stratification, reduced dissolved O2	Coral mortality, range shifts, spread of disease and invasives, new productivity patterns
Melting ice: Arctic sea ice extent has fallen at a rate of 3 to 4 percent per decade over the last 30 years. Further loss as well as reduced snowpack, earlier snow melt, and widespread thawing of permafrost are predicted.	Reduced survival of insulation-dependent forest pests	Reduced snowpack changes water flows	Reduced snowpack changes water flows	Reduced snowpack changes water flows	Thawing permafrost, hydrology changes, terrain instability, species shifts	Affects water temperatures which affect coldwater fish, such as bull trout and salmon	Loss of anchor ice and shoreline protection from storms/waves	Loss of sea ice habitats and dependent species, new productivity patterns
Rising sea levels: Sea level rose by roughly 8 inches over the past century, and in the last 15 years has risen twice as fast as the rate observed over the past 100 years. Sea level will continue to rise more in the future.					Salt water intrusion, loss of coastal habitat to erosion	Inundation of freshwater areas, groundwater contamination	Inundation of coastal marshes, loss of nesting habitat, erosion	Inundation of coastal habitat, negative impacts on many early life stages

Table 1 (cont.): Summary of Major Climate Change Impacts on U.S. Ecosystems*

Major Changes Associated With Increasing Levels of GHGs *(GCCIUS 2009 and IPCC 2007)*	**Major Impacts On U.S. Ecosystems (by ecosystem type)**							
	Forests	**Shrublands**	**Grasslands**	**Deserts**	**Tundra**	**Inland Waters**	**Coastal**	**Marine**
Changing precipitation patterns: Precipitation has increased approximately 5 percent in the last 50 years. Predictions suggest historically wet areas will become wetter, while historically dry areas will become drier.	Fire season length and frequency/ severity of wildfires have increased and will continue	Dry areas getting drier	Invasion of non-native grasses and pests, species range shifting	Loss of riparian habitat and movement corridors	More rain on snow events affect snowpack, hamper mammal movements	Decreased lake levels, changes in salinity, flow	Changes in salinity gradients, reduced Great Lake levels	Changes in salinity, nutrient and sediment flow, new productivity patterns
Drying conditions/drought: Extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.	Decreased forest productivity and increased tree mortality	Decline in prairie pothole wetlands, loss of nesting habitat	Decline in prairie pothole wetlands, loss of nesting habitat, invasion of non-native grasses	May cause water stress and increased susceptibility to plant diseases	Moisture stressed vegetation, loss of coastal wetlands, fish passage issues	Loss of wetlands and intermittent streams, lower summer base flows	Changes in salinity gradients and freshwater input to estuaries	Changes in salinity, nutrient and sediment flow, new productivity patterns
More extreme rain/weather events: Rain falling in the heaviest downpours has increased approximately 20 percent in the past century. Hurricanes have increased in strength. These trends are predicted to continue.	Increased forest disturbance, more young forest stands	Less frequent but more intense rain events may cause more variable soil water content		Higher losses of water through run-off are expected	More landslides/ slumps	Increased flooding, widening floodplains, altered habitat, spread of invasive species	Higher wave heights, storm surges, loss of barrier islands	Reduced salinity, changes in nutrient and sediment flow, impacts to early life stages

**Climate change impacts to ecosystems are discussed in more detail in sections 2.3.1-2.3.8.*

2.3.1 Forest Ecosystems

Photo: FWS

Approximately 750 million acres of the United States is forest, both public and private (Heinz Center 2008), including deciduous, evergreen, or mixed forests. This definition includes the embedded natural features such as streams, wetlands, meadows, and other small openings, as well as alpine landscapes (see Figure 1). Changing climate can affect forest growth, mortality, reproduction, and eventually, productivity and ecosystem carbon storage (Thomas et al. 2004, McNulty and Aber 2001).

Atmospheric CO_2

National and regional scale forest process models suggest that in some areas, elevated atmospheric CO_2 concentrations may increase forest productivity by 5 to 30 percent. Wetter future conditions in some areas may also enhance the uptake of carbon by ecosystems. However, other regions may experience greater than 20 percent reduction in productivity due to increasing temperatures and aridity. In some areas of the U.S., higher atmospheric CO_2 may lead to greater forest water-use efficiency, while in other areas higher evapotranspiration may result in decreased water flow (McNulty and Aber 2001). Species in today's highly fragmented landscape already face unprecedented obstacles to expansion and migration (Thomas et al. 2004), which may magnify the climate change threat to forests.

Temperature Increases and Water Availability

In general, boreal forest and taiga-tundra ecosystems are expected to move northward or upward at the expense of arctic and alpine tundra, and forests in the northwestern and southeastern U.S. might initially expand, although uncertainties remain (Iverson et al. 2008). Within temperate and boreal forests, increases in summer temperatures typically result in faster development and reproductive success of insects as well as changes in timing of development. As a result, these insects may interact with plant and wildlife species in different and sometimes problematic ways (Sharpe and DeMichele 1977, Asante et al. 1991, Porter 1991). Conversely, decreases in snow depth typically decrease overwinter survival of insects that live in the forest litter and rely on insulation by snow (Ayers et al. 2000). Drier conditions in the southern U.S. and elsewhere

Carbon Sequestration

Roughly a quarter of the buildup in greenhouse gases over the past half-century is the result of major global land use changes, especially the destruction and conversion of tropical rainforests (IPCC AR4 2007). Although deforestation rates have eased recently in some areas, such as Southeast Asia, (May 2011), tropical deforestation and other land use changes are expected to continue, especially as the human population grows. Reducing emissions from deforestation and forest degradation (known internationally as REDD) and restoring forested land cover in areas where it has been lost could play a major role in efforts to constrain the further increase of CO_2 in the atmosphere.

Because the most serious losses of forests have occurred in the tropics, the greatest potential for forest protection and restoration as a mitigation measure lies there as well. Opportunities to protect U.S. tropical forests in Hawaii, Puerto Rico, and elsewhere may provide dual benefits of carbon sequestration and habitat protection. In the continental United States, land use management can also be utilized as a means of contributing to greenhouse gas sequestration efforts. For example, the National Wildlife Refuge System has conducted a number of projects restoring forested land cover throughout the system, and there is potential for many more such projects. In addition, no-till agriculture may reduce the emissions of CO_2 from the breakdown of organic matter in soils, and broader utilization of this cropping technique in the American agricultural sector could make a substantial contribution to limiting emissions of CO_2 (Paustian et al. 1999).

could lead to increased fire severity and result in decreases in ecosystem carbon stocks (Westerling et al. 2006, Bond-Lamberty et al. 2007, Aber et al. 2001). Similarly, prolonged drought may lead to decreases in primary production and forest stand water use (van Mantgem et al. 2009). Drought can also alter decomposition rates of forest floor organic materials, impacting fire regimes and nutrient cycles (Hanson and Weltzin 2000). Changes in temperature, precipitation, soil moisture, and relative humidity can also affect the dispersal and colonization success of other forest pathogens (Brassier 1996, Lonsdale and Gibbs 1996, Chakrabbrty 1997, Houston 1998).

BARK BEETLE OUTBREAKS IN WARMER WINTERS

From British Columbia to New Mexico, forests are being devastated at unprecedented levels by an epidemic—a tiny insect called the mountain pine beetle *(Dendroctonus ponderosae*). The beetles lay their eggs under the bark of trees, and in the process, infect the trees with fungus. When the eggs hatch, the combination of fungus and feeding by the beetle larvae kill the trees.

But bark beetles and pine trees have co-existed for eons, causing regular outbreaks of forest death but nothing like those now being seen. So why has the beetle suddenly become so destructive? In the past, sub-zero winter temperatures kept beetle populations in check by directly killing the insects. Cold temperatures also kept the beetle from extending its range farther north and to higher elevations (Amman 1974).

The warming over the last few decades, however, has enabled more beetles to survive the winter and to move to higher elevations and north to regions like British Columbia. They have rapidly colonized areas that were previously climatically unsuitable (Carroll et al. 2003). Because these new areas hadn't previously experienced beetle outbreaks, they contained mature stands of trees, which are particularly susceptible. In addition, warmer summer temperatures have sped up the life cycle of the beetle, enabling it to complete more generations per year (Carroll et al. 2003). Add all these changes together and the result has been unprecedented forest death. The current outbreak in British Columbia, for instance, is ten times larger in area and severity than all previous recorded outbreaks (Kurz et al. 2008).

This massive loss of trees poses major challenges to forest and ecosystem managers. But there are steps that can be taken to reduce the negative impacts and prevent spreading. According to the U.S. Forest Service, the governments of British Columbia and Alberta, in an attempt to avoid further eastward expansion and potential invasion of the boreal jack pine forests, implemented an aggressive control program to suppress beetle populations east of the Rocky Mountains through felling and burning infested trees. Since its inception in 2004, the program has managed to keep beetle populations from expanding (RMRS 2009).

Disturbances and Extreme Events

Disturbances such as wildfires, wind storms, and pest outbreaks are important to forests. Climate change is anticipated to alter disturbance frequency, intensity, duration, and timing, and may cause extreme changes in forest structure and processes (Running 2008, Dale et al. 2000). For example, predictive models suggest that the seasonal fire severity rating will increase by 10 to 50 percent over most of North America, which has the potential to overshadow the direct influences of climate on species distribution and migration (Flannigan et al. 2000). While predictions of hurricane response to climate change are still uncertain, models agree on a dramatic increase in cyclone activity in the western North Pacific (Emanuel et al. 2008), and the intensity of Atlantic hurricanes is likely to increase as well (GCCIUS 2009). If hurricane frequency and intensity increase, then a larger percentage of forests could be set back to earlier successional stages (Lugo 2000).

2.3.2 Shrubland Ecosystems

Photo: NPS

Shrublands of various types and sizes occur throughout the United States and total approximately 480 million acres (Heinz Center 2008) (see Figure 1). Shrublands are landscapes dominated by woody shrub species, often mixed with grasses and forbs (non-woody flowering plants). They provide habitat for numerous native plant and animal species. Sagebrush habitats alone support more than 400 plant species and 250 wildlife species (Idaho National Laboratory 2011), including 100 birds and 70 mammals (Baker et al. 1976, McAdoo et al. 2003). Climate change will increase the risk to shrubland species because many already live near their physiological limits for water and temperature stress.

Atmospheric CO_2

Increased CO_2 can lead to changes in species distribution in the shrublands. For example, the spread of cheatgrass (*Bromus tectorum*) has likely been favored by rising CO_2 concentrations (Larrucea and Brussard 2008, D'Antonio and Vitosuek 1992).

Temperature Increases and Water Availability

Since 1980, western U.S. winter temperatures have been consistently higher than the previous long-term average temperature, and average winter snow packs have declined (McCabe and Wolock 2009). As a result of the warmer temperatures, the onset of snow runoff in the Great Basin is currently 10 to15 days earlier than 50 years ago, with significant impacts on the downstream use of the water (Ryan et al. 2008), though periods of higher than average precipitation have helped to offset the declining snow packs (McCabe and Wolock 2009). Similarly, California has seen an increase in temperature accompanied by an increase in annual precipitation, and a decrease in the climatic water deficit (difference between plant water use and precipitation) from the 1930s to 2005.

Climate changes in shrublands areas can be complex: in areas where both a reduction in total annual rainfall and increased intensity of individual precipitation events are predicted, wet areas are likely to become wetter while dry areas may become drier. More intense rainfall events without increased total precipitation can lead to lower and more variable soil water content, and thus reduce above-ground net primary production (and livestock carrying capacity). Higher temperatures associated with climate change are likely to intensify water stress through increased potential evapotranspiration (Hughes 2003). However, some regions such as the Great Basin region are predicted to become both warmer and possibly wetter over the next few decades (Larrucea and Brussard 2008). The increase in temperature also further benefits invasive cheatgrass, which thrives in hot, open, fire-prone environments and crowds out native shrubland species.

2.3.3 Grassland Ecosystems

Grasslands, including agricultural and grazing lands, cover about 285 million acres of the United States, and occur mostly between the upper Midwest to the Rocky Mountains and from Canada to the central Gulf Coast (CEC 1997, Heinz Center 2008). Vegetation is very diverse and includes many grass species mixed with a wide variety of wildflowers and other forbs. Grassland types include tallgrass, shortgrass, and mixed-grass systems, as well as embedded features such as the shallow, ephemeral wetlands known as prairie potholes and playas that dot the Great Plains and the Eastern grasslands that are openings in the prevailing forest matrix (see Figure 1). Grassland function is tied directly to temperature, precipitation and soil moisture, and therefore climate change is likely to lead to shifts in the structure, function, and composition of this system.

Photo: NPS

Atmospheric CO_2

Increased CO_2 levels may affect the grassland system in multiple ways. For example, forage quality may decline due to increases in the carbon (C) to nitrogen (N) ratios of plant material, resulting in lower crude protein content (Milchunas et al. 2005). In addition, plants that utilize C3-type photosynthesis (e.g., cheatgrass) stand to benefit from increased atmospheric CO_2 (Larrucea and Brussard 2008, D'Antonio and Vitosuek 1992), while C4 species are more efficient at using water under hot, dry conditions, and may respond favorably to increased water stress and lower soil moisture conditions. One CO_2 enrichment experiment on shortgrass prairie showed a 20-fold increase in cover of a C3 shrub over C4 grass cover (Morgan et al. 2007), while other reports show an advantage for C4 over C3 grasses in a CO_2-enriched, warmer environment (Morgan et al. 2011). The future distribution of these species will no doubt be influenced by the interaction of CO_2, available moisture, and temperature, which may produce grassland communities with altered species composition of plants and animals.

Public and Private Lands

Over 60 percent of the land area of the United States is in private ownership (Lubowski 2006). The majority of this land is either in agricultural production or classed as agricultural land (crop, pasture, forest) (Lubowski 2006). In much of the continental United States (especially in the East and Midwest), privately owned lands dominate the landscape and provide valuable habitat for native fish, wildlife and plants.

The vast majority of the nation's publicly owned land is federal, and most of it is located in the eleven western states and Alaska. The bulk of America's federal estate is open to various forms of resource development, such as mining, grazing and timber and energy production, that are not always compatible with the protection of all fish, wildlife, plants or ecological processes. Only about five percent of the land area of the United States falls into the highest categories of protection, aimed primarily at maintaining natural values (IUCN 1998). However, public lands are generally protected from conversion to urban or suburban development, and they are typically more closely managed for conservation purposes than are private lands.

Private lands do and will continue to play a vital role in the conservation of our nation's fish, wildlife and plant resources. For example, many listed threatened and endangered species are only known to occur on private lands. In addition, because most public lands occur in isolated blocks, especially in the East and Midwest, private lands often provide the only connections between protected areas. As the climate continues to change and the geographic distributions of species continue to shift in response, private lands may become even more critical, especially for providing physical connectivity across the landscape.

There are many federal and state programs that provide incentives to private landowners to manage and maintain certain natural values on their lands. Principal among these are the many programs that make up the Conservation Title of the Farm Bill, which constitute an important set of tools for maintaining wildlife values on private lands. Although clearly essential to help manage existing stressors to our fish, wildlife and plant resources, these programs may not be fully adequate to respond to climate change. It is likely that new challenges, especially the increasing need to provide connectivity between protected areas, may demand changes or additions to these existing programs.

LESSER PRARIE-CHICKEN IN A CHANGING CLIMATE

Photo: AFWA

The lesser prairie-chicken (*Tympanuchus pallidicinctus*), which resides mainly in the grasslands of the southern Great Plains region, is a species in trouble. The conversion of native rangelands to cropland, decline in habitat quality due to herbicide use, petroleum and mineral extraction activities, and excessive grazing of rangelands by livestock have all contributed to a significant decline in population leading to it being a candidate for protection under the federal Endangered Species Act (NRCS 1999).

Climate change is expected to make the bird's plight worse. Climate change models predict that temperatures in the lesser prairie-chicken's range will climb by about 5 °F and that precipitation will decrease by more than one inch per year by 2060 (GCCIUS 2009). Such changes would harm the lesser prairie chicken's chances of survival. The good news is that simple management steps can make a big difference. Under existing USDA conservation programs, farmers and ranchers are paid to take land out of production to create wildlife habitat. In fact, a landscape-scale geospatial analysis has shown that restoring native prairie grasses and sagebrush on ten percent of land enrolled in the Conservation Reserve Program, if properly targeted, could offset the projected population decline of prairie chicken from climate change (McLachlan 2011).

Temperature Increases and Water Availability

In recent decades, average temperatures have increased throughout the northern Great Plains, with cold days occurring less often and hot days more often (DeGaetano and Allen 2002). Precipitation has increased overall (Lettenmaier et al. 2008). Future changes projected for the Great Plains include increasing average annual temperatures, from approximately 1.5 to 6 ºF by mid-century to 2.5 to 13 ºF by the end of the century. More frequent extreme events such as heat waves, droughts, and heavy rains; and wetter conditions north of the Texas Panhandle are also predicted (GCCIUS 2009). However, the projected increases in precipitation are unlikely to be sufficient to offset overall decreases in soil moisture and water availability, due to increased temperature and water utilization by plants as well as aquifer depletion (GCCIUS 2009).

Climate change is expected to stress the sensitive prairie pothole habitat with increasing temperatures and changing rainfall patterns, which will alter rates of evaporation, recharge, and runoff in these pond systems (Matthews 2008). Recent modeling predicts that the prairie pothole region of the Great Plains will become a much less resilient ecosystem, with western areas (mostly in Canada) likely becoming dryer and eastern areas (mostly in the U.S.) having fewer functional wetlands. These changes are likely to reduce nesting habitat, and limit this "duck factory" system's ability to continue to support historic levels of waterfowl and other native wetland-dependent species (Johnson et. al 2010). That, in turn, could mean fewer ducks for waterfowl hunters across the United States.

Temperature changes are also likely to combine with other existing stressors to further increase the vulnerability of grasslands to pests, invasive species, and loss of native species. For example, populations of some non-native pests better adapted to a warmer climate are projected to increase, while native insects may be able to reproduce more quickly (Dukes and Mooney 1999).

2.3.4 Desert Ecosystems

Photo: AFWA

Deserts are characterized by temperate climates having low annual rainfall, high evaporation, and large seasonal and diurnal temperature contrasts. The hot desert systems of the United States include the Mohave, Sonoran and Chihuahuan Deserts (note that the so-called "cold deserts" including much of the Great Basin, are covered in this *Strategy* under Shrublands, see Figure 1). This definition includes embedded features such as "sky islands" and mosaics of grasses and shrubs. Desert systems harbor a high proportion of endemic plants, reptiles, and fish (Marshall et al. 2000). Desert ecosystems are particularly susceptible to climate change and climate variability because slight changes in temperature, precipitation regimes, or the frequency and magnitude of extreme events can substantially alter the distribution and composition of natural communities and services that arid lands provide (Archer and Predick 2008, Barrows et al. 2010).

Temperature Increases

Like most of the rest of the United States, the arid west and southwest have been warming over the last century. Climate models predict these areas will continue to warm a further 3.6 to 9.0^{o} F by 2040 to 2069 in the summer months (AZ CCAG 2006), while parts of southern Utah and Arizona have already seen greater than average increases in temperature (e.g., 3 to 5°F; GCCIUS 2009). Most models predict drying, increased aridity, and continued warming in the deserts, as well as increased severity and duration of droughts (GCCIUS 2009). Higher temperatures and decreased soil moisture will likely reduce the stability of soil aggregates, making the surface more erodible (Archer and Predick 2008). Other trends include widespread warming in winter and spring, decreased frequency of freezing temperatures, a longer freeze-free season, and increased minimum winter temperatures (Weiss and Overpeck 2005).

Water Availability

The southwest has experienced the smallest increase in precipitation in the last 100 years of any region in the coterminous United States (CCSP 2008). Precipitation is predicted to increase slightly in the eastern Chihuahuan Desert, but decrease westward through the Sonoran and Mojave Deserts (Archer and Predick 2008). Overall water inputs are expected to decline due to the combined effects of reduced total precipitation, elevated water stress in plants at higher temperatures, and greater run-off losses associated with increased frequencies of high intensity convectional storms (Archer and Predict 2008). Declining rainfall may eliminate wetlands, especially in marginally wet habitats such as vernal pools and in near-deserts. Varied rainfall and higher temperatures will also likely exacerbate existing stressors coming from recreation, residential and commercial development, and improper livestock grazing (Marshall et al. 2000).

Although precipitation-fed systems are most at risk, groundwater-fed systems in which aquifer recharge is largely driven by snowmelt may also be heavily affected (Winter 2000, Burkett and Kusler 2000). Reductions in water levels and increases in water temperatures will potentially lead to reduced water quality, in terms of increased turbidity and decreased dissolved oxygen concentrations (Poff et al. 2002). Decreased water availability and expanded development will also impact desert riverine and riparian ecosystem function and disrupt movement corridors through the desert, which provide critical habitat for arid land vertebrates and migratory birds (Archer and Predick 2008).

Many plants and animals in the desert ecosystem already live near their physiological limits for water and temperature stress. For example, diurnal reptiles may be particularly sensitive due to their sedentary behavior and occurrence in very hot and dry areas (Barrows et al. 2011). When compounded by persistent drought, climate change creates conditions that favor drought-tolerant species, leading to new species compositions of natural communities (CCSP, Fagre et al. 2009). For example, Saguaro density and growth has declined with drought and reduced perennial shrub cover, and the range and abundance of this charismatic species will likely decline as well. Similarly, the abundance and range of nonnative grasses will most likely increase in future climates, including the spread of cheatgrass (*Bromus tectorum*) and buffel grass (*Cenchrus ciliaris*) (Enquist and Gori 2008). These and other non-native species have significantly altered fire regimes, increasing the frequency, intensity, and extent of fires in the American Southwest (D'Antonio and Vitousek 1992, Heinz 2008, Brooks and Pyke 2002).

CACTUS VULNERABILITY

Photo: FWS

Cactus species, an iconic symbol of the American desert, are adapted to hot, dry environments such as those found in the southwestern deserts of the United States. Because they are vulnerable to over-collection, all cactus species are protected under the Convention on International Trade in Endangered Species, and 31 U. S. species are listed under the Endangered Species Act. Cactus species' very specific habitat requirements also make them highly vulnerable to climate change.

NatureServe is developing Climate Vulnerability Indices for over 115 cactus species that are found on Bureau of Land Management (BLM) land in the Sonoran, Mojave, and Chihuahuan deserts. The Vulnerability Index assesses a species' exposure and sensitivity to climate change by evaluating several factors, which are then combined to determine a categorical vulnerability score. Exposure to temperature and moisture (both historical and predicted) were quantified within the species' ranges using GIS analysis. To assess sensitivity to climate change, NatureServe evaluated several natural and life history characteristics. Of 28 Chihuahuan Desert cactus species assessed, most were vulnerable to climate change: 43 percent were moderately vulnerable, 21 percent were highly vulnerable, and four percent were extremely vulnerable. None of the cactus species assessed was predicted to increase in number under climate change, although four percent of species were predicted to be stable.

Though the NatureServe Vulnerability Indices are helpful tools in uncovering which species are the most vulnerable and which might be able to tough it out in a changing climate, there may be instances where there are no viable adaptation measures to be taken to help a given species. These potential losses are lessons on the importance of the range of policies that attempt to stem the occurrence and negative consequences of climate change.

Disturbances and Extreme Events

An increased frequency of extreme weather events such as heat waves, droughts, and floods is predicted (Archer and Predick 2008). For example, climate change is predicted to increase the frequency and intensity of storm events in the Sonoran Desert (Davey et al. 2007). This will result in longer dry periods interrupted by high-intensity rainstorms, and has the paradoxical effect of increasing both droughts and floods. Erosive water forces will increase during high-intensity runoff events, and wind erosion will increase during intervening dry periods (Archer and Predick 2008).

2.3.5 Tundra Ecosystems

Photo: FWS

Arctic tundra is the ecological zone of the polar regions of the earth, occurring mainly north of the Arctic Circle and north of the boreal forest zone. Tundra is characterized by an absence of trees, and occurs where tree growth is limited by low temperatures and short growing seasons. In the United States, Arctic tundra ecosystems represent 135 million acres on the North Slope and west coast of Alaska (Gallant et al. 1995, Heinz Center 2008) (see Figure 1). In most areas soils are underlain by permanently frozen ground, termed permafrost, with a shallow thawed layer of soil that supports plant growth in the summer. Alaska's tundra contains one of the largest blocks of sedge wetlands in the circumpolar arctic (one quarter of global distribution) and provides breeding grounds for millions of birds (more than 100 species). Climate-driven changes in the tundra ecosystem are already being observed, and include: early onset and increased length of growing season, melting of ground ice and frozen soils, increased encroachment of shrubs into tundra, and rapid erosion of shorelines in coastal areas (Hinzman et al. 2005, Richter-Menge et al. 2010).

Temperature Increases

Climate is changing worldwide, but the Arctic has already warmed at a rate almost twice the global average (ACIA 2005). Northern Alaska is one of the fastest-warming regions of the planet, with temperatures in some areas projected to rise approximately 13 °F by 2100 (SNAP 2008). Spring snow melt has been occurring earlier as temperatures increase, leading to an earlier "green-up" of plants. A longer snow-free season also leads to local landscape warming while contributing to further climate change (Hinzman et al. 2005). Historically, fires have been rare on Alaskan tundra, but fire frequency will likely increase as the climate warms. A positive feedback relationship can result, as soils tend toward warmer and drier conditions after fire, promoting shrub growth and a more fire-prone landscape (Racine et al. 2004).

Many tundra plant species in Alaska are already living at the limits of their physiological tolerances, while other species are prevented from moving into the tundra regions only by climate (Martin et al. 2009). Analysis of satellite images has shown an increase in greenness in arctic Alaska over the last three decades indicating increased plant cover (Hinzman et al. 2005). Other studies have documented recent advancement of trees and tall shrubs onto tundra, which is expected to continue (Lloyd et al. 2003, Tape et al. 2006). Similarly, arctic specialist animals may face increased competition as less cold-tolerant species expand their ranges northward (Martin et al. 2009). For example, the arctic fox (*Vulpes lagopus*) may suffer if competitors such as red foxes (*Vulpes vulpes*) continue to increase in abundance.

Water Availability

While precipitation is also expected to increase in the future, models predict a generally drier summer environment due to higher air temperatures, increased evaporation, and increased water use by plants (SNAP 2008). Changes in overall water balance strongly affect this habitat, where water remains frozen most of the year. For example, the vast shallow wetlands of coastal plain tundra are sensitive to changes that could lead to drying. Any intrusion of saline water into formerly fresh systems results in rapid and dramatic change in vegetation (Martin et al. 2009). Contaminants contained within glacial ice, multi-year sea ice, and frozen soil, including persistent organic pollutants and mercury, will almost certainly be released to aquatic ecosystems as the temperature rises (Martin et al. 2009).

Fish will be affected by higher water temperatures and by the changes in precipitation, soil moisture, soil and water chemistry and drainage related to permafrost degradation (Martin et al. 2009). Similarly, changes in water flow, water chemistry, turbidity, and temperature could cause physiological stress to species that cannot adapt to the new conditions. Some Arctic fish species migrate between marine and freshwaters, and will suffer if stream changes prevent fish passage (Martin et al. 2009). If insect production in shallow wetlands declines as these areas dry out during the summer, many birds that are dependent upon these as a food resource may be affected.

ALASKA CLIMATE CHANGE WORKING GROUP

Indigenous communities possess local environmental knowledge and relationships with particular resources and homeland areas, built up through hundreds and even thousands of years of place-based history and tradition, which may make them highly sensitive to and aware of environmental change. Climate change, with its promise of unprecedented landscape-level environmental change, is a threat not only to particular resources or features, but also to the traditions, the culture, and ultimately the very health of the community itself. Indigenous communities lend unique and important perspectives and knowledge about landscapes and climates to the overall effort to respond to climate change, and recognize that they must work together to nurture native environmental knowledge, enhance indigenous capacity to use modern scientific methods, and create indigenous climate-change leadership.

Members of the American Indian Alaska Native Climate Change Working Group represent a broad alliance of indigenous communities working together to empower indigenous climate-change adaptation. They argue that indigenous educational institutions are critical vehicles for nurturing indigenous environmental knowledge and scientific capacity, and can be organizers and leaders of regional indigenous responses to climate change (Upham 2011). Indigenous working groups provide neutral ground that encourages comfort and broad participation, and often lead to consideration of a broader spectrum of resources and issues than externally driven approaches.

Thawing Permafrost

Increasing seasonal melting of ground ice and frozen soils (permafrost) is already measurably altering habitats and water distribution on the landscape, allowing new hydrologic patterns to form (Jorgenson et al. 2006). Because of warming in western Alaska, permafrost has become absent or thin and discontinuous, and more changes are expected. In addition, the thawing of frozen organic material stored in tundra soils will release huge amounts of the greenhouse gases CO_2 and methane to the atmosphere, contributing to climate change (Schaefer et al. 2011).

Large mammals such as caribou (*Rangifer tarandus*) and muskoxen (*Ovibos moschatus*) suffer when access to forage is hampered by deep snow pack or a hard snow crust, caused by winter thawing or rain-on-snow events which are expected to increase in a warmer climate (Martin et al. 2009). Changes in the quantity and quality of forage are also expected to have profound effects on mammal populations, while wildlife pests and diseases are predicted to increase their northern range limits (Martin et al. 2009). Warmer summers, a longer open water season, and delayed freeze-up would likely improve reproductive success for some bird species, though warmer summers could also cause drying of the wetland habitats and aquatic food sources that many birds rely upon. And while birds time their breeding primarily to the solar calendar, increasing water temperature may cause aquatic insects to hatch earlier, resulting in a mismatch in timing.

Sea Level Rise

Summer sea ice has receded dramatically near northern and western Alaska in recent decades. The lack of near-shore ice in summer has made the shoreline more vulnerable to storm-induced erosion, reducing the value of these areas as wildlife habitat (Hinzman et al. 2005). In some areas, erosion rates have doubled since the middle of the last century (Mars and Houseknecht 2007). Particularly in western Alaska, large areas of low-lying coastal plain bird habitat are predicted to disappear within this century, due to sea level rise and storm surges. This degradation will only be partially offset by increased sedimentation rates and tectonic rebound in some areas (Martin et al. 2009). Decreasing sea ice is causing more polar bears (*Ursus maritimus*) to den and forage on land rather than on the sea ice. As a result, they can experience negative encounters with grizzly bears (*Ursus arctos horribilis*) and humans (Martin et al. 2009).

2.3.6 Inland Water Ecosystems

Photo: FWS

Inland waters range from ephemeral pools and intermittent streams to large regional and national features, such as the Great Lakes, Mississippi River, Ogallala aquifer and Everglades. For the purposes of the *Strategy*, inland waters end at the high tide line and include natural as well as artificial and human-altered waterbodies such as ponds, reservoirs, canals and ditches (Coe 1998, see Figure 1). These waters support a broad range of aquatic and terrestrial wildlife. Increasing global air temperatures and changing precipitation patterns are raising water temperatures and changing stream flows, affecting such ecosystem processes as development, productivity and decomposition, and disrupting food web relationships.

Temperature Increases

A recent analysis showed that many rivers and streams in the United States have warmed over the past 50 to 100 years (Kaushal et al. 2010), and will continue to warm up to 0.5 °F per decade, based on greenhouse gas emissions scenarios (IPCC AR4 2007). Water temperature affects the physiology, behavior, distribution, and survival of freshwater organisms, and even slight changes can have an impact (Elliott 1994). Water temperature increases will allow the geographic area suitable for warm-water aquatic species to expand (Rahel and Olden 2008, Eaton et al. 1995, Eaton and Sheller 1996, Poff et al. 2002, Rieman and Isaak 2007, Williams et al. 2009, Pilgrim et al. 1998). The number of streams with temperatures suitable for warm-water fish and other freshwater organisms is predicted to increase by 31 percent across the United States (Mohseni et al. 2003).

These temperature increases will harm some inland water species. For example, one long-term study showed that a 1.2 °F increase in stream temperature caused coho salmon (*Oncorhynchus kisutch*) fry to emerge from the gravel six weeks earlier and move to the ocean two weeks earlier. This causes lower survival rates due to a mismatch in timing with peak prey abundance in the ocean (Holtby et al. 1990). Higher temperatures and more severe droughts also dry up streambeds and wetlands, harming species such as waterfowl (Johnson et al. 2005). Warming temperatures also increase the susceptibility of organisms to disease, and may allow diseases to spread for longer periods and reproduce more quickly. For example, low flows and warmer waters contributed to a massive fish kill from a parasite infestation among spawning Chinook salmon (*Onchorhynchus tshawytscha*) in the Klamath River in September 2002 (CADFG 2004).

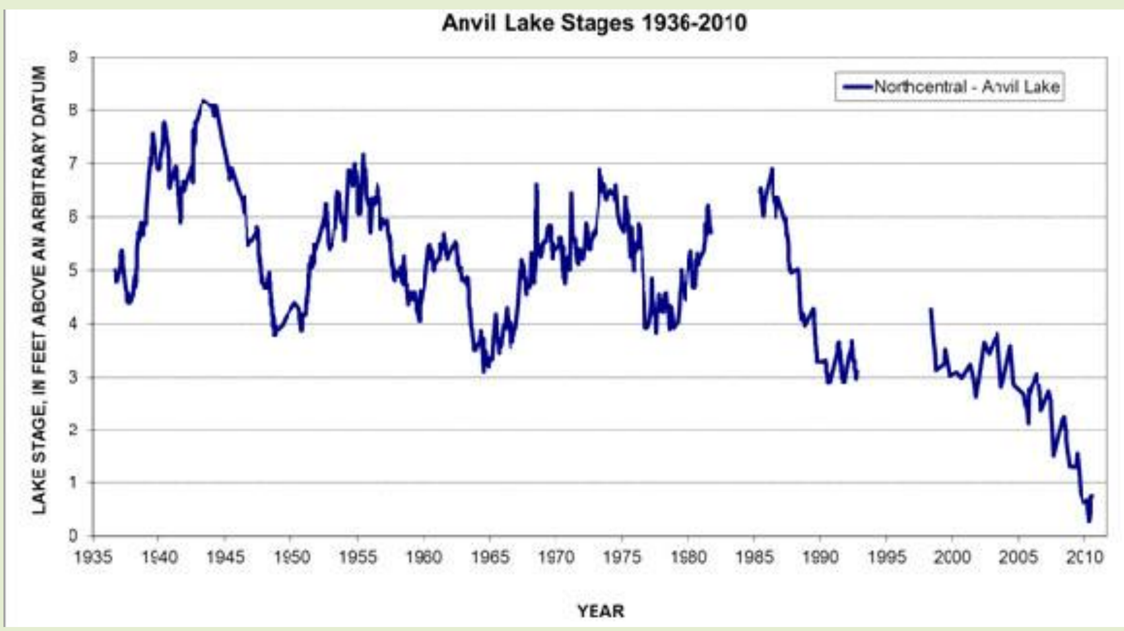
WATER LOSSES UNDER CLIMATE CHANGE

Between 2000 and 2010, the worst drought ever recorded hit the Colorado River Basin. Water levels in Lake Mead dropped to record lows. The drought not only threatened the supply of water to cities like Las Vegas, it also harmed ecosystems throughout the region.

Climate models project that the decade-long drought that gripped the region may become the normal climate instead of the rare exception, perhaps as soon as the end of the 21st century (Rajagopalan 2009, Barnett and Pierce, 2009). The threat is being taken seriously by the Bureau of Reclamation, which has developed a plan that brings all stakeholders together in an attempt to balance human needs for water while providing sufficient flows and habitat for sustainable fish, wildlife, and plant populations.

Similar challenges must be faced around the nation. Long-term records at Anvil Lake, a groundwater-fed lake in northern Wisconsin, highlight the importance of water levels to fish, wildlife and plant species. Over centuries, the lake's water level has risen and fallen. However, Anvil Lake's water level became progressively lower during each succeeding dry period, especially during the most recent dry period (WICCI 2011). In the future, any water loss through evapotranspiration associated with warmer temperatures would be expected to exacerbate any drought effect in similar aquatic systems.

These examples hold an important lesson for adaptation strategies. To help plants, wildlife and ecosystems adapt to a changing climate, it's not enough to focus just on the natural world. Ensuring that ecosystems have enough water in regions expected to experience more droughts will require working with farmers, municipalities, energy industries, among others, to reduce the overall demand for the increasingly scarce water.



Water levels for Anvil Lake in North central Wisconsin, 1936-2010 (WICCI 2011; USGS lake stage data)

Water Availability

Precipitation changes are predicted to vary regionally. Higher precipitation and runoff in the winter and spring are expected in the Northeast and Midwest, and decreasing precipitation and runoff are expected in the arid West in spring and summer (GCCIUS 2009). In areas of high snowpack, runoff is beginning earlier in the spring and flows are lower in the late summer. This affects flow-dependent species and estuarine systems and reduces habitat area and connectivity while increasing water temperature and pollution levels. In contrast, higher flows and frequent storms can create wider floodplains, alter habitat, increase connectivity, displace riparian and bottom-dwelling species, or further distribute invasive species (Le Quesne et al. 2010). Changing flood and freshwater runoff patterns can impact critical life events, such as the spawning and migration of salmon. Increased evaporation of seasonal wetlands and intermittent streams can also destabilize permanent waterbodies and cause a loss of habitat or a shift in species composition (Le Quesne et al. 2010).

Lake Stratification

Ice cover on freshwater systems is sensitive to climate changes (Magnuson, 2002). Higher air and water temperatures shorten lake ice cover seasons, increase evapotranspiration and thermal stratification, and increase winter productivity of lake systems. These changes will favor predator fish, such as northern pike (*Esox lucius*), over a diverse community of fish species adapted to depleted oxygen levels in shallow lakes (WICCI 2011). In contrast, deeper, less productive lakes in the northern U.S. could face lower oxygen levels in bottom waters during the summer. Prolonged warm weather would lengthen thermal stratification periods and deplete oxygen throughout the entire zone of bottom waters, harming coldwater fish such as lake trout (*Salvelinus namaycush*) and cisco (*Coregonus artedi*).

Disturbance and Extreme Events

As the climate warms, altered precipitation patterns may manifest as heavy storms that punctuate extended periods of hot, dry weather, yielding floods. Increased tidal/storm surges will also affect freshwater ecosystems, especially with increases in hurricane and typhoon intensities (IPCC WGII 2007). Tidal and storm surges can cause oxygen depletion, changes in salinity, mud suffocation, and turbulence (Tabb and Jones 1962).

2.3.7 Coastal Ecosystems

Photo: NOAA

The Pacific, Atlantic, Arctic, Gulf of Mexico and Great Lakes coastal systems, as defined for the *Strategy*, extend seaward to mean lower-low water and landward to all lands that drain directly into an estuary, ocean (including the entirety of off-shore islands), or Great Lake (see Figure 1). They include the waters and sub-tidal zones of estuaries, semi-enclosed bays, and lagoons, as well as emergent and wooded wetlands, open water and aquatic beds, and unconsolidated and rocky shorelines. In addition to increases in air and water temperature, coastal ecosystems will experience climate impacts that include: sea and lake level changes; alterations in precipitation patterns and subsequent delivery of freshwater, nutrients, and sediment; changes in intensity of coastal storms; changes in water chemistry; and changes in sea ice.

Ocean Acidification

Ocean acidification will cause changes to many key biological processes in coastal systems. For example, increased acidity in estuaries will affect shellfish species that use carbonate minerals to build their shells, as these minerals are more readily dissolved in lower pH environments (GCCIUS 2009). Elevated CO_2 concentrations are also expected to increase photosynthesis and productivity for many plants, such as mangroves and emergent and submerged vegetation. These increased growth rates may be reduced in areas that experience additional stress due to coastal pollution, which can also exacerbate the effects of ocean acidification (Adam 2009).

Temperature Increases

Global ocean temperatures rose 0.2 ° F between 1961 and 2003 (IPCC 2007). Temperature changes affect flora and fauna phenology, including key events such as the spring phytoplankton bloom, plant germination and turtle nesting. Changes in temperature also can cause species range shifts (Hoegh-Guldburg and Bruno 2010, Harley et al. 2006). While warmer temperatures could cause increased growth of coastal salt marshes and forested wetlands, they could also cause expansion of invasive species and disease pathogens. Extreme changes may also stress organisms to the point of mortality. In estuarine environments, increased water temperature will affect water column stratification and eutrophication; and could cause range shifts. In addition, warmer temperatures will exacerbate low summer oxygen levels (such as those in mid-Atlantic estuaries and the Gulf of Mexico) due to increased oxygen demand and decreased oxygen solubility (Najjar 2000). In Alaska, rapid warming has led to severe shoreline erosion due to longer seasons without ice cover as well as to land subsidence due to permafrost melt and sea level rise. These changes have made the coast far more vulnerable to wind and wave damage (Larsen and Goldsmith 2007).

Sea Level Rise

As water warms, it expands, and the ocean surface rises. Additional sea level rise is caused by the melting of inland glaciers and continental ice sheets, including those in Greenland and Antarctica. Sea level is projected to increase 16 to 79 inches by 2090 (IPCC AR4 2007, Rahmstorf 2010). However, sea level change is highly variable regionally. It depends on the relative increase in water levels as well as local land elevation changes caused by subsidence or uplift, and local rates of sediment accumulation. Relative sea level rise refers to a local increase in the level of the ocean due to the interaction of these factors.

Changes in Sea Ice

Changes in the extent, thickness, condition, and duration of sea ice are direct impacts of changes in global temperature. Warming triggers loss of sea ice, creating open water conditions. These conditions in turn allow higher wave energy to reach the shoreline (particularly during storms), accelerating the rate of coastal erosion (GCCIUS 2009). Retreat of sea ice will result in loss of critical habitat for species that depend on the ice, such as polar bears and walrus. Similarly, the timing of the spring phytoplankton bloom is directly tied to the location of the sea ice edge over the Bering Sea shelf (Stabeno et al. 2001). In addition, warmer temperatures could change food web dynamics by allowing for the migration of different predator and prey species in the Arctic (Forbes 2011). Changing ice conditions are threatening lifestyles and subsistence economics of indigenous peoples as well, by making trips to hunting grounds more hazardous (Forbes 2011).

Sea Level Rise

Sea level rise is a key driver of coastal geomorphologic change. The immediate effects of sea-level rise are the submergence and increased inundation of coastal land and increased salinity in estuaries. Additional physical effects include increased erosion, changes in geomorphology, and saltwater intrusion in groundwater. Sea level rise will also exacerbate flooding events ranging from spring tides to tropical or extratropical storms, and will cause inland penetration of storm surge into areas not accustomed to inundation. These areas will likely experience flooding more often. While sea-level changes have occurred repeatedly in the geologic past, the accelerated pace of sea level rise in the 20th and 21st centuries raises questions about how coastal ecosystems will respond (GCCIUS 2009).

A rising sea level also means that tidal wetlands need space to migrate inland. However, the success of inland migration is dependent on the availability and slope of an upland corridor, the pace of the rise, erosion rates, and the potential for wetland accretion (CCSP, Titus et al. 2009). In populated coastal areas, wetland migration is often constrained by land development and shoreline stabilization measures. These conditions can result in the crowding of foraging and bank-nesting birds and the loss of critical coastal habitat for certain species, such as the diamondback terrapin, which requires both marsh and beach habitats (Shellenbarger Jones et al. 2009). Marsh islands are already being lost in the Mid-Atlantic due to sea level-related flooding and erosion, which threatens island nesting bird species (Shellenbarger Jones et al. 2009). In addition, the degradation and loss of tidal marshes affect fish and shellfish production and flood attenuation, key ecosystem services for coastal communities.

PIPING PLOVER HABITAT CONSERVATION

Photo: Bill Byrne

The piping plover (*Charadrius melodus*) is a small sandy-colored bird with yellow orange legs and a black band on its forehead. It runs along beaches in search of worms, insects and other invertebrates, and lays its eggs on beaches from Maine to North Carolina. The species prefers wide, gently sloping ocean beaches—precisely those that will go underwater first if sea levels rise. As a result, climate change will bring a major new threat to the piping plover, which is already listed as an endangered species.

Helping the piping plover adapt to climate change will be a complex task. It requires understanding how various coastal management decisions, such as whether to stabilize beaches, nourish them with new sand, or allow them to retreat, will affect the bird's habitat as sea levels climb. But in a promising approach for addressing such complexities, federal and state agencies, conservation organizations, and academic institutions are collaborating to couple a model of piping plover habitat evolution with a model of piping plover nest density and distribution. The habitat evolution model explores how changes in sea level and storminess will affect such physical habitat features as topography, shoreline position and vegetation (Gutierrez et al. 2011). This approach, known as a Bayesian network model, is well suited to understanding and responding to climate change because of its ability to handle uncertainty. It also can be validated and improved by empirical data.

The predictions of the model will be used to develop habitat conservation recommendations for the piping plover. The model's results also may improve habitat management for other sensitive beach-strand species, such as least terns (*Sternula antillarum*), American oystercatchers (*Haematopus palliates*), Wilson's plovers (*Charadrius wilsonia*), and seabeach amaranth (*Amaranthus pumilus*) (a federally threatened plant species).

Sea level rise may also result in the inland movement of seawater, shifting the tidal influence zone of streams and rivers upstream and permanently inundating downstream riparian/coastal portions with brackish water (Riggs and Ames 2003). In the U.S., these impacts are already apparent in freshwater swamps along Louisiana and Florida (IPCC 1997, Bowman et al. 2010, Migeot and Imbert 2011). In Florida, mangroves have advanced 0.93 miles inland over the last 50 years (Rivera-Monroy et al. 2011), and another 10 to 50 percent of the freshwater sawgrass prairie will be transformed to salt marsh or mangroves by 2100 (Kimball 2007). Salinity increases in formerly fresh or brackish surface waters and saltwater intrusion of shallow coastal groundwater aquifers will also result from sea level rise. This may threaten systems such as tidal freshwater forested wetlands that support a variety of wildlife species and critical drinking water sources, especially in island ecosystems such as Hawaii. Sea level rise also threatens small and low-lying islands with erosion (GCCIUS 2009, Baker et al. 2006, Church et al. 2006), many of which support high concentrations of rare, threatened and endemic species (Baker et al. 2006).

Lake Level Change

Photo: USGS

Great Lakes water levels are expected to decrease significantly due to climate-driven changes in precipitation and evapotranspiration (GCCIUS 2009, Angel and Kunkel 2010). Lower water levels will lead to desiccation of coastal habitats that do not (or cannot) migrate with retreating shoreline, likely stressing fish species that rely on wetlands as nursery habitat. Shorebirds may also experience a loss of nesting habitat as beaches may become overrun by opportunistic invasive species, such as *Phragmites.* At the same time, new wetlands may be formed as a result of accretion in other areas. A decrease in the extent and duration of lake ice will also affect lake species and habitats. For example, lake ice enhances the overwinter survival of fish eggs and protects shoreline habitat from erosion during winter storms (ASCE 1999). Longer periods without lake ice cause greater evaporation, and can increase lake-effect snows if air temperature is favorable for snow (Lofgren et al. 2002).

Water Availability

Changes in precipitation will primarily impact coastal systems through changes in quantity, timing, intensity, and quality of freshwater flow into estuarine systems. The quantity of freshwater will affect salinity gradients and nutrient inputs, while changes in peak flow timing could affect phenology and migration cues. Changes in the timing and amount of freshwater, nutrient, and sediment delivery will also impact estuarine productivity. For example, changes in flow regimes may affect the abundance and distribution of suspension feeders, such as mussels, clams, and oysters, which could in turn alter food web dynamics as well as water clarity (Pratt 2008). Increases in flow, turbidity, and eutrophication could also impact submerged aquatic vegetation due to reduced light penetration (Najjar 2000), as well as organisms that rely on this habitat for food and shelter. These impacts of precipitation changes in estuaries will likely be exacerbated by non-climate stressors such as freshwater demand and extraction, eutrophication and hypoxia.

Disturbances and Extreme Events

Increased storm wind strength due to elevated sea surface temperatures could lead to increases in wave height and storm surge (Scavia et al. 2002), and would be magnified by a higher sea level. The primary impacts associated with more intense storm systems include increased flooding and erosion. More intense storms, coupled with common manmade ecosystem alterations such as shoreline stabilization measures that impede or eliminate long-shore transport, could lead certain barrier islands (and their habitats) to fragment and disappear instead of migrating and rebuilding. Impacts to coastal and estuarine beaches would affect biota such as: microscopic invertebrates that are critical to the food web; horseshoe crabs (*Limulus polyphemus*) that rely on beaches for egg deposition; and migratory shorebirds that feed on the eggs, such as the red knot (*Calidris canutus*) (Shellenbarger Jones et al. 2009). Shifts in the seasonal distribution of major storm events could also affect plants, wildlife, and fish; for example, an increase in the number or intensity of storms during the spring and early summer could substantially affect breeding success of coastal birds such as the piping plover (*Charadrius melodus*). More infrequent but intense precipitation events can also lead to scouring of sediment and vegetation during peak flows, redistribution of sediment, as well as increased pollutants from events such as more frequent sewer overflows.

2.3.8 Marine Ecosystems

Photo: NOAA

For the purposes of the *Strategy*, marine ecosystems extend from the coastline to 200 miles seaward (see Figure 1). This area, generally referred to as the U.S. Exclusive Economic Zone (EEZ), spans 3.4 million square nautical miles of ocean, encompassing 1.7 times the land area of the continental U.S. The *pelagic* (open water) and *benthic* (bottom) habitats support species ranging from microscopic planktonic organisms that comprise the base of the marine food web through kelp and eel grass beds to a wide range of invertebrates and vertebrates. Higher temperatures and CO_2 levels have significant impacts on marine species and ecosystems. Marine systems and taxa respond physically, chemically, and biologically to both increases in ocean temperatures and the absorption of atmospheric CO_2. This leads to changes in nutrient availability, biological productivity, reproductive success, the timing of biological processes, distributions, migrations, community structure, predator-prey relationships, and entire biomes.

Temperature Increases

Between 1961 and 2003, global ocean temperatures rose by 0.2°F, with much greater changes observed in some locations (IPCC WGI 2007). The physical consequences of such warming include sea level rise, increases in storm frequency and intensity, increased stratification of the water column, and changes in ocean circulation. Warming sea temperatures also boost the energy available to initiate and intensify hurricanes and typhoons, and storm intensity is expected to increase as sea surface temperatures rise (IPCC WGI 2007).

Altered patterns of wind and water circulation in the ocean environment will influence the vertical movement of ocean waters (i.e., upwelling and downwelling). This coupled with increased stratification of the water column resulting from changes in salinity and water temperature will change the availability of essential nutrients and oxygen to marine organisms throughout the water column.

Increasing ocean temperatures and the other associated changes in ocean conditions have a variety of impacts on fish, wildlife and plants at multiple levels. These impacts range from changes in metabolic rates and energy budgets of individuals to changes in ecological processes such as productivity, species interactions, and even toxicity of compounds found in marine systems (Schiedek et al. 2007). Increasing air temperatures can also affect the growth and survivorship of early life history stages of some marine species whose larvae or juveniles use estuaries and other

Ocean Acidification

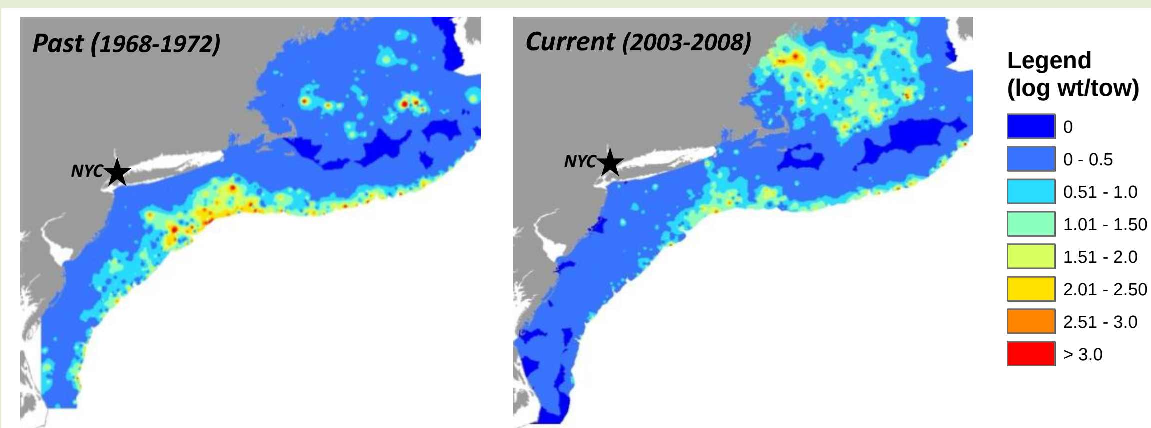
The oceans act as a buffer to changes in atmospheric CO_2, providing a sink for one-fourth of all anthropogenic CO_2 emissions (Sabine et al. 2004; Le Quéré et al. 2009; IPCC WGI 2007). In the past, it was believed that the oceans would offset the effects of greenhouse gas emissions by absorbing CO_2 (Orr et al. 2005, Fabry 2010). It is now understood that while absorption of CO_2 by the ocean slows the atmospheric greenhouse effect, CO_2 reacts with seawater to fundamentally change the chemical environment in which living marine resources reside. These changes include not only a reduction in pH (hence the term "ocean acidification"), but also changes in the availability of a range of chemical compounds, many of which are tightly linked with biological processes, such as productivity, respiration, and calcification. A doubling of the atmospheric CO_2 concentration, which could occur within the next 50 years, would cause a rapid change in marine chemistry and could lead to significant marine extinctions (McLeod et al. 2008, Herr and Galland 2008).

near-shore habitats as nursery areas (Hare and Able 2007). For example, increasing winter temperatures along coastal areas could increase the juvenile survivorship of these estuarine dependent species resulting in northward shifts in their distribution.

SHIFTING SPACIAL DISTRIBUTIONS OF US FISH STOCKS

The US is fortunate to have several multispecies fish monitoring programs in its large marine ecosystems where the abundance and location of important fish and macroinvertebrate species are consistently documented each year. Without these long time series of data, shifts in spatial distribution of US fish stocks would never have been detected. Several studies using these data have detected large distributional shifts in marine fish in the California Current Ecosystem (Hsieh et al. 2008), Bering Sea (Mueter and Litzow 2008) and the Northeast US (Nye et al. 2009).

In the Northeast, over half of 36 examined fish stocks shifted northward and/or to deeper depths over a 40-year time period in response to consistently warm waters. The figure below shows the past and present spatial distribution of a commercially important fish species, silver hake, as an example of shifts that have been observed in this area. The Atlantic mackerel fishery is a good example of how these warming-induced shifts have affected the US fishing industry. Atlantic mackerel is now rarely found in Mid Atlantic waters, such that the fishery in this area no longer exists because it is not cost-effective for fishermen to maintain the infrastructure (nets, boats etc.) to find, catch and process mackerel. Surf clams in this area also suffered higher mortality in recent warm years and are now found only at deeper depths. Similarly, in the Bering Sea, fish have moved northward as sea ice cover is reduced and the amount of cold water from melting sea ice is reduced. In both cases, fishermen have to travel further and set their nets to deeper depths, increasing the costs associated with fishing. In both ecosystems, fish stocks are shifting closer to the borders of neighboring Canada and Russia, requiring coordinating monitoring and assessment of key stocks. In the California ecosystem, shifts in spatial distribution were more dramatic in species that were heavily fished. Combined, these studies stress the importance in preventing overfishing in healthy stocks to enhance recovery of those at low abundance such that these shifts in spatial distribution and the resilience of these species will not be exacerbated by climate change.



Silver hake distribution in the past as compared to its present distribution (Nye et al. 2011).

One species which may benefit from marine climate change and a conservative management regime is the Atlantic croaker (*Micropogonias undulatus*) which inhabits the coastal Atlantic of the United States and supports a commercial and recreational fishery worth approximately $9M per year. Annual fish surveys along the East Coast have recorded croaker populations expanding northward since 1975. Recent research suggests that its range expansion is due to combination of increasing sea surface temperature and a constant fishing pressure or catch level by anglers. Spawning occurs in the coastal waters during the late summer, fall and winter. Between 30-60 days after spawning, larvae enter the estuaries of the Mid-Atlantic region to overwinter and grow to juveniles. Juvenile survival during the winter is determined by water temperature with cold water adversely affecting recruitment to the fishery. Using sea surface temperature forecasts from an ensemble of global climate models, researchers have projected increased recruitment of juveniles in estuaries leading to more adult fish (Hare et al. 2010). As sea surface temperature increases the range and if fishing pressure remains relatively low, the croaker fishery is expected to shift northward 100-400 km as new estuarine habitat becomes available recruitment from larvae into juveniles.

Species are adapted to specific ranges of environmental temperatures. As temperatures change, species can respond by 1) migrating poleward or deeper, 2) reducing their climate niche within the existing range, 3) evolve, or 4) going extinct (Mueter and Litzow 2008, Nye et al 2009, Cheung et al. 2009, Overholtz et al. 2011). These individual responses lead to new combinations of species that will interact in unpredictable ways. In addition, changes in ocean circulation patterns will change larval dispersal patterns and the geographic distributions of marine species (Block et al. 2011). Between 2000 and 2100, warming in the North Pacific is projected to result in a 30% increase in the area of the subtropical biome, while areas of the equatorial upwelling and temperate biomes will decrease by 28% and 34%, respectively (Polovina et al. 2011). Some species may benefit from climate change, such as the Atlantic croaker (*Micropogonias undulates*). Also, some warmer water marine fishes may grow bigger or more rapidly (Nye et al. 2009).

Melting of sea ice and seabed permafrost is also a consequence of atmospheric and ocean warming, and will produce associated physical, chemical, and biological changes, including increased stratification in the water column. Species are particularly vulnerable in the Arctic, where shrinking ice cover reduces habitat and increases adult and juvenile mortality in some species. Variation in the spatial extent of sea ice and timing of the spring retreat has strong effects on the productivity of the Bering Sea ecosystem. For example, the timing of the spring phytoplankton bloom is directly tied to the location of the sea ice edge over the Bering Sea shelf (Stabeno et al., 2001). And in 2008 the polar bear (*Ursus maritimus*) was listed as a threatened species under the Endangered Species Act (ESA) because of a projected decline in abundance. The main cause of this projected decline is malnutrition and reduced survival resulting from the projected loss of sea ice habitat required by polar bears and their prey (e.g., ring seals).

Ocean Acidification

Increased ocean acidification will directly and indirectly impact physiological and biological processes of a wide variety of marine organisms such as growth, development and reproduction (Le Quesne and Pinnegar 2011). Even the most optimistic predictions of future atmospheric CO_2 concentrations (such as stabilization at 450 parts per million) could bring levels high enough to cause coral reefs to no longer be sustainable (Hoegh Gulberg et al. 2007, Veron et al. 2009), bivalve reefs to slow or even stop developing, and large areas of polar waters to become corrosive to shells of some key marine species. There also are expected to be major effects on phytoplankton and zooplankton that form the base of the marine food chain. These effects will then have cascading impacts on productivity and diversity throughout the ocean food web.

WEST COAST OYSTER PRODUCTION

In 2007 and 2008, two of the three major West Coast oyster hatcheries discovered that their Pacific oyster (*Crassostrea gigas*) larvae were dying. It didn't happen all the time, so researchers set out to understand why. Was something wrong in the water pumped from the sea into the hatcheries? By testing the water, researchers discovered a telltale pattern. The larvae died only when upwelling off the coast brought deep, cold water to the surface—and into the hatcheries (Feely et al. 2008).. This cold water was low in calcium carbonate, the basic material in oyster shells. Without enough dissolved calcium carbonate (in a form known as aragonite), the oyster larvae struggled to survive.

The finding pointed to the ultimate culprit—the same rising CO_2 levels in the atmosphere that cause climate change. When CO_2 concentrations increase in the air, the ocean absorbs more CO_2. That increases the acidity of the water. Higher acidity (lower pH), in turn, means that the water can't hold as much dissolved calcium carbonate. And since cold water can't dissolve as much calcium carbonate as warmer water can, the cold water is more harmful to the oyster larvae.

The hatcheries figured out ways around the problem. One of them measured concentrations of dissolved CO_2 in the seawater and pumped in water only when its acidity was low (typically late in the day after plankton had lowered water CO_2 levels because of their photosynthesis). The other hatchery moved its intake from deep to shallow water.

But these steps don't solve the larger, far more ominous problem—the increasing acidification of the oceans. Over the last six years, the difficulties faced by the hatcheries in rearing Pacific oyster larvae have been paralleled by poor supplies of naturally produced seed oysters in Willapa Bay, Washington—the most important oyster-producing bay on the West Coast. That's already having a serious effect on the West Coast's $80 million per year oyster industry, which employs thousands of people in economically depressed coastal communities (PCSGA 2010). If the acidification of the oceans is the cause, then the problem will just get worse. And not just oysters will be at risk, but also the basic food webs in the oceans because so many species use calcium carbonate to build shells and skeletons.

Ocean Currents

Ongoing warming of the atmosphere and the ocean could cause major changes for key water masses and the processes they control. A change in the intensity and location of winds, such as the Westerlies moving northward in the Atlantic, will change surface ocean circulation. Currents such as the thermohaline circulation, which is driven by temperature and salinity gradients, can also be significantly affected by the warming climate. For instance, the circulation of deep ocean currents in the Atlantic and Pacific Oceans could slow. These large scale changes in circulation could have localized impacts such as increased ocean stratification and alterations to upwelling and coastal productivity, which in turn will change the availability of essential nutrients and oxygen to marine organisms throughout the water column. In addition, changes in ocean circulation patterns will change larval dispersal patterns and the geographic distributions of marine species (Block et al. 2011).

CORAL REEF BLEACHING

Photo: NOAA/Eakin

Coral reefs are one the most productive ecosystems on Earth. At the heart of the coral reef's success is a symbiotic relationship between coral and microscopic protozoa (zooxanthellae) within the living coral. The coral provides the nutrients that the protozoa need to capture carbon dioxide through photosynthesis. The protozoa, in turn, provide coral with the carbon they need to build their skeletons—and thus the reef itself.

But a changing climate is threatening this symbiotic relationship and the whole coral reef ecosystem. When sea temperatures rise too much, the coral expel their protozoa, a process called bleaching (since the coral become whiter without their symbionts). In 2005, up to 90 percent of shallow-water corals in the British Virgin Islands bleached in response to increased water temperatures (Wilkinson and Souter 2008).

Bleaching has profound effects on corals and can ultimately kill the organisms. In addition, the problem is being exacerbated by ocean acidification, which makes it harder for the coral to build their skeletons.

An effort is underway to try to protect coral reefs by making them more resilient to climate change. The Nature Conservancy has started a Reef Resilience program, working in the Florida Keys in partnership with the State of Florida, NOAA, and Australia's Great Barrier Reef Marine Park Authority, to understand the non-climate factors that adversely affect coral reefs, such as damage from charter and private vessels and improper erosion control. The hope is that by reducing these non-climate stressors, the coral will be better able to resist being bleached when sea temperatures increase. A related approach, being studied by scientists at the University of Miami, Australia Institute of Marine Science, and elsewhere, is actively inoculating corals with algal symbionts that are resistant to higher water temperatures. Early results are promising (Strat and Gates 2011).

2.4 Impacts to Ecosystem Services

Natural resources provide a wide range of important products and services to the nation, including food, clean water, protection from storms, recreation, and cultural heritage. These products and services support millions of jobs and billions of dollars in economic activity. As a result, the impacts from climate change on species and ecosystems are expected to have significant implications for America's communities and economies. For example, changes in distribution and productivity of forests will have direct consequences for both global carbon sequestration and the forest products industry, and will also influence other socioeconomic uses of forested ecosystems, such as recreation and non-timber products.

Agriculture is a fundamental component within the grassland system matrix, and is also sensitive to climate changes. The same stressors that affect grasslands affect agriculture, and can decrease crop yields (Ziska 2004). In the case of crop production, research suggests that crop plant responses to increasing CO_2 are varied, and therefore it is difficult to determine winners and losers (Taub 2010). The benefits from increased CO_2 (a longer growing season) may not be sufficient to offset losses from decreasing soil moisture and water availability due to rising temperatures and aquifer depletion. Decreasing agricultural yields per acre could also increase pressure for the conversion of more acres of native grasslands to agriculture (GCCIUS 2009).

Some benefits provided by well-functioning inland water and coastal ecosystems will also change or be lost due to climate change impacts, especially when compounded with other stressors such as land use change and population growth. For example, there may be fewer salmon for commercial and recreational harvest, as well as for traditional ceremonial and cultural practices of indigenous peoples. Coastal marshes and mangroves provide natural buffers against storms, absorbing floodwaters and providing erosion control with vegetation that stabilizes shorelines and absorbs wave energy. If those habitats are degraded and/or destroyed, then adjacent inland communities will have less protection from sea level rise, and may experience more direct storm energy and flooding (NC NERR 2009). Tidal marshes and associated submerged aquatic plant beds are important spawning, nursery, and shelter areas for fish and shellfish, including commercially important species like blue crab (*Callinectes sapidus*); nesting habitat for birds; and invertebrate food for shorebirds.

In marine systems, shifts of fish stocks to higher latitudes and deeper depths may force fishermen to travel further and spend more time in search of fish, or to undertake the costly task of updating infrastructure to effectively harvest the changing mixture of fish stocks. Fishery agencies will also have to update regulatory measures to conform to these new stock boundaries. Melting sea ice is also changing transportation routes, oil and gas exploration and extraction, fishing, and tourism in the Arctic, which in turn could impact the fish, wildlife and plants in this region.

Chapter 3: Climate Adaptation Strategies and Actions

Studies of past periods of climate change and their effects on the species and ecosystems help us understand what may happen in the future. The major lesson from the recent fossil record of the transition from the last Ice Age to the current inter-glacial period is that when climate changes, each species responds in its own way. Species found living together in one climate may not live together in another, and vice versa. Thus, the natural community types recognized today, such as spruce-fir forests of the North, hemlock-beech forests of the Northeast, or tallgrass prairie of the Midwest, will not simply move northward or upslope. Instead, the species composition of these communities will change.

This observation has many implications for our conservation efforts in the current period of climate change. For example, many existing protected areas, such as Joshua Tree National Monument or the National Elk Refuge, were established largely to protect specific natural communities or species. As the climate continues to change and each species responds individually, these areas may lose the specific communities or species they were established to protect. They will also gain new species, including perhaps species equally in need of conservation. The management challenge will not be to keep current protected areas as they are, but rather to complete a network of habitat conservation areas that maximizes the chances that all species will have sufficient habitat somewhere.

3.1 Goals, Strategies and Actions

This *Strategy* identifies seven Goals to help fish, wildlife, plants and ecosystems cope with the impacts of climate change. As discussed in the Introduction, these Goals were developed collectively by diverse teams of federal, state, and tribal technical experts, based on existing research and understanding regarding the needs of fish, wildlife and plants in the face of climate change. They are listed in the order of their ultimate importance, rather than the sequential order in which they would be undertaken.

Strategy Goals:

- Goal 1. Conserve, Restore, & Connect Habitat
- Goal 2. Manage Species & Habitats
- Goal 3. Enhance Management Capacity
- Goal 4. Support Adaptive Management
- Goal 5. Increase Understanding
- Goal 6. Increase Awareness & Motivate Action
- Goal 7. Reduce Stresses Not Caused by Climate Change.

Each Goal identifies a set of initial strategies and actions that should be taken or initiated over the next five to ten years. “National Actions” were compiled from Technical Team submissions determined to be broadly applicable to the eight major U.S. ecosystems considered in this document. In addition, more detailed “Ecosystem-Specific Actions” developed by the Technical Teams are also presented, in order to illustrate how these approaches could be carried out in particular ecosystems. A complete set of Actions most relevant to each ecosystem is presented in Appendices 1-8.

A short-term progress check list is offered under each goal. Each of the items in these lists could be achieved over the next five to ten years by pursuing the strategies and actions under each goal. Accomplishing these items will show real progress in implementing the *Strategy*. While adaptation planning for biological resources is still a very new endeavor, it is important to recognize that work on all of these Goals is already underway. This *Strategy* attempts to build on the excellent work of pioneering state governments, federal agencies, tribes, conservation partners, private landholders, and others who have been leading the way on adaptation.

Goal 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate. Sustaining a diversity of healthy populations over time requires conserving a sufficient variety and amount of habitat and building a well-connected network of conservation areas to allow the movement of species in response to climate change.

Goal 2: Manage species and habitats to protect ecosystem functions and to provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate. Incorporating climate change information into fish, wildlife and plant management efforts is essential to safeguarding these valuable natural resources.

Goal 3: Enhance capacity for effective management in a changing climate. Climate change adaptation requires new ways of assessing information, new management tools and professional skills, increased collaboration across jurisdictions, and a review of laws, regulations and policies.

Goal 4: Support adaptive management through integrated observation and monitoring and improved decision support tools. The impacts of climate change are uncertain. Coordinated observation, information management, and decision support systems can help management strategies to be adaptive and adjust to changing conditions.

Goal 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate. Research must be targeted to address key knowledge gaps and needs, and findings must be rapidly incorporated into decision support tools available to natural resource managers.

Goal 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate. Adaptation efforts will be most successful if they have broad political and popular support and if key groups and people (such as private landowners) are motivated to take action.

Goal 7: Reduce stresses not caused by climate change. Reducing such existing threats as habitat degradation, fragmentation, and invasive species can help fish, wildlife, plants and ecosystems better cope with the additional stresses caused by a changing climate.

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Many of our nation's imperiled species do not occur in protected conservation areas. Indeed, the major threat to many of species on the Endangered Species list is the loss of habitat caused when the environment they depend on is converted to a different use. Climate change will make the problem worse—and will make the need for new conservation areas more urgent. The most robust approach to helping fish, wildlife and plants adapt to climate change is to conserve enough variety and amount of habitat to sustain diverse and healthy populations as landscapes and seascapes are altered by climate change. We will need well-connected networks of conservation areas to allow for the movement of species in response to climate change. Selecting areas that will be both resilient and able to capture the broadest range of species will be an important challenge.

The first step to meeting this challenge is identifying the best candidates for conservation areas. The areas can be selected through the use of inventories, mapping (including geophysical as well as biological features), vulnerability assessments, and geophysical and biological modeling. Geographic Information Systems (GIS) techniques, climate models, and inventory data can assist federal, state, tribal and private land owners in setting collective priorities for conservation, restoration, and connectivity. Coordinating the efforts of many agencies and landowners will be a daunting process, but is a critical part of doing the job effectively and efficiently.

Increasing the number, quality and size of conservation areas can increase the opportunities for individual species to adapt to climate change, and also make it more likely that native biodiversity will be conserved. Healthy and biologically diverse ecosystems are likely to better withstand or adjust to the impacts of climate change. Increasing the number (redundancy) and distribution of protected fish, wildlife and plant populations is important for the same reason. Establishing larger and more hospitable conservation areas for species to transition to will also increase opportunities for species to create new assemblages that are better able to persist in a dynamic climate.

But simply creating new networks of conservation areas or acquiring more land to be protected in perpetuity won't be enough. Biologists and conservation land managers also must manage these conservation areas in innovative and flexible ways, as species and ecosystems respond and adjust (often in unpredictable fashion) to climate change. Flexible tools such as re-designation or exchanges of some existing public lands and the creation of conservation easements, leases and incentives for private landowners will be essential.

Another challenge will be providing corridors between conservation areas so that species can freely move to new locations with suitable habitat. Protecting and restoring large blocks of habitat and using linkages and corridors to develop networks for movement will facilitate connectivity. In addition, appropriate transitory or "stopover" habitat for migrating species can promote biological connectivity between non-physically connected areas. Private landowners and government agencies such as energy, transportation, and water resources agencies will be critical partners in creating these ecological connections. At the same time, managers must also guard against enabling movement of invasive species, pests and pathogens.

Because human development in the United States has been so extensive, some of the habitat necessary for a comprehensive network of conservation areas will need to be restored. In the context of a period of climate change, ecological restoration will not necessarily be about attempting to restore specific species or combinations of species, but rather about restoring the conditions that favor healthy, diverse and productive communities of species. Key components of such restoration can include promoting or mimicking natural disturbance regimes like fire; managing issues like in-stream flows, water withdrawals, and stormwater runoff; and addressing poorly-sited infrastructure in floodplains and sensitive coastal areas. Effective restoration will require applying protocols and techniques that anticipate a range of future conditions caused by climate change and that facilitate adaptation.

Overall, single jurisdiction or single interest approaches to land and water protection are not sufficient to deal with the landscape scale changes being driven by climate change and in some instances may even be counter-productive. Fish, wildlife and plant conservation agencies and private conservation interests must work together in a coordinated way to build an ecologically connected network of conservation areas.

MAKING SALMON POPULATIONS MORE RESILIENT

Photo: Amy Gulick

As a species that requires cold, fast flowing streams for spawning, salmon could be hard hit by climate change. Indeed, climate models predict widespread, large increases in air and stream temperature in Washington State (Mantua et al. 2009), where much of the nation's key salmon habitat is located. Combined with anticipated declines in stream flows, higher temperatures would threaten not just the salmon, but also the immensely valuable industries, cultural traditions and ecosystems that depend on the species.

As a result, there is a need to map streams throughout the salmon's range to figure out which ones are mostly likely to stay cold with sufficient water flow (Mantua et al. 2009). The assessment also describes steps that can be taken to maintain good salmon habitat even in a changing climate. Those steps include:

- limiting the amount of water that can be withdrawn from streams for irrigation or other purposes, especially in times of high temperatures and low stream flow;
- protecting undercut banks and deep stratified pools, where water temperatures are lower;
- restoring vegetation along streams, which cools the water and reduces sediment and pesticide levels;
- releasing cold water from large storage reservoirs during summer, and
- removing dams and other barriers so that cooler, protected headwaters flow more swiftly downstream, and salmon can swim upstream farther and faster.

Some of these strategies are already being implemented as part of the effort to protect and restore endangered salmon species. For example, two aging dams on the Elwha River are being removed, giving salmon access to 60 miles of high elevation, coldwater rivers and streams in Olympic National Park. The diversity of that habitat will increase salmon resilience (Waples et al. 2009).

Meanwhile, the Columbia Basin Water Transactions Program is tackling the problem of low stream flows. By taking such actions as acquiring water rights and leasing water, the program is able to reduce water withdrawals at critical times. And in another example, the USDA Conservation Reserve Enhancement Program and NOAA's Pacific Coastal Salmon Recovery fund are helping to restore vegetation in riparian zones. That not only helps protect streams from rising temperatures and sediment, it also provides greater inputs of leaf litter and large logs that support stream food webs and create habitat diversity.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

National Actions:

— 1.1.1: Identify high priority areas for protection using species distributions, habitat classification, land cover, and geophysical settings (including areas of rapid change and slow change).

— 1.1.2: Identify and prioritize areas currently experiencing rapid climate impacts (such as the coastline of Alaska, low-lying islands, and high alpine areas).

— 1.1.3: Establish and maintain a comprehensive, inter-jurisdictional inventory of current and candidate high priority conservation areas in order to coordinate future protection efforts.

Ecosystem Specific Actions:

— 1.1.4 Tundra: Produce a detailed land cover map of the Alaskan tundra, using satellite imagery, Digital Elevation Models, and ancillary spatial data such as surface geology.

— 1.1.5 Inland Water/Coastal: Identify and prioritize groundwater sources, recharge and discharge sites, and areas that provide sediment resources necessary for ecosystem processes.

— 1.1.6 Coastal: Assess the migration potential of coastal habitats and species, and prioritize areas for highest migration potential, considering ecosystem functions and existing and future physical barriers.

— 1.1.7 Marine: Assess current Marine Managed Areas (MMA) for value in protecting against and/or building resilience to climate change impacts on the local, regional, national and international level, and identify important gaps.

— 1.1.8 Marine: Create geo-referenced depiction of the current U.S. MMAs compatible with the Multipurpose Marine Cadastre, and the National Information Management System under development for Coastal and Marine Spatial Planning.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

National Actions:

— 1.2.1: Conserve areas that provide habitats under current climate conditions and are likely to provide habitat in the future.

— 1.2.2: Conserve areas representing the range of geophysical settings, including various bedrock geology, soils, topography and projected climate, in order to maximize future biodiversity.

— 1.2.3: Build redundancy into the network of conservation areas by protecting multiple examples of the range of existing habitat types and geophysical settings.

— 1.2.4: Work with partners to maximize use of existing conservation programs (e.g., easement, management), particularly the conservation titles of the Farm Bill, to protect private lands of high conservation value, enhance habitats and maintain working landscapes under climate change.

— 1.2.5: Identify and pursue opportunities to increase conservation of priority lands and waters by working with managers of existing public lands such as military installations or state lands managed for purposes other than conservation.

Ecosystem Specific Actions

— 1.2.6 Forest: Identify and conserve large blocks of contiguous, unfragmented forest and aim for representation and redundancy of all forest types, vegetation mosaics, and natural disturbance regimes (coarse filter' conservation approach).

— 1.2.7 Inland Water: Protect and restore transitional habitats between ecosystem types (e.g., riparian areas, mangrove forests).

— 1.2.8 Coastal: Protect coastal wetlands including those that may function for relatively short periods during species and ecosystem transition and migration.

— 1.2.9 Coastal: Incorporate climate change into land acquisition plans (e.g., Coastal and Estuarine Land Conservation Program, state acquisition plans).

— 1.2.10 Coastal: Capitalize on unique opportunities and funding sources (e.g., FEMA's Repetitive Loss and Severe Repetitive Loss programs) to acquire coastal lands.

— 1.2.11 Marine: Identify other marine spatial management tools besides Marine Management Areas (MMA) that are useful for addressing climate change impacts, and ensure wide distribution to managers of the type, authority for and best application of each type of tool.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

National Actions:

— 1.3.1: Develop and implement restoration protocols and techniques that promote ecosystem resilience and facilitate adaptation under a range of possible future conditions.

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.

— 1.3.3: Restore or enhance areas that will provide essential habitat and ecosystem services during climate change ecosystem transitions.

— 1.3.4: Restore natural disturbance regimes wherever possible, including instituting human-assisted disturbance (e.g., prescribed fire) to augment natural processes and mimic natural patterns and recurrence for specific ecological systems.

Ecosystem Specific Actions:

— 1.3.5 Forest: Develop market-based incentives that encourage reforestation where appropriate.

— 1.3.6 Coastal: Explore alternative environmental engineering options (e.g., dredged material as wetland fill, beach re-nourishment) to restore or enhance coastal habitats.

BUILDING CONNECTIVITY IN NEW JERSEY

If current low-lying coastal areas in New Jersey are flooded by spring high tides, as expected with sea level rises caused by climate change (Titus and Richman, 2001), many amphibians will no longer be able to migrate up the Cape May Peninsula. That could threaten the viability of species like the state-endangered eastern tiger salamander (*Ambystoma tigrinum*), Cope's gray treefrog (*Hyla chrysoscelis*) and the threatened frosted elfin (*Callophyrus irus*).

That's why the New Jersey Division of Fish and Wildlife is working to provide more habitat for these amphibians—and to better connect habitats to allow migration. Such migration prevents small populations from becoming isolated, thus preserving genetic diversity for key species (Marsh and Trenham 2001, Cushman 2006).

For amphibians, the key habitat is the vernal pool, a temporary pond that's typically deepest in the spring. So the state has been both working to preserve existing vernal pools—and looking for sites where it could create new pools. The sites were picked based on such criteria as elevation above anticipated sea-level rise, vicinity to other vernal pools and upland habitat, location on state protected land, proper soil characteristics, and use by a variety of species,

When the effort is complete, the state will have established a connected network of vernal pool "strongholds" that will give New Jersey's amphibians a far better chance to adapt and survive when sea levels rise.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

National Actions:

— 1.4.1: Identify species with special connectivity needs (i.e. those that are area-limited, resource-limited, dispersal-limited, or process-limited).

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current conservation areas.
— 1.4.3: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches.
— 1.4.4: Identify and remove or mitigate physical barriers to movement and dispersal within and among habitats (e.g., high fences, major highways, dams).
— 1.4.5: Assess, and take steps to reduce, risks of facilitating movement of undesirable non-native species, pests and pathogens.
— 1.4.6: Provide landowners and stakeholder groups with incentives to maximize use of existing conservation easement programs, such as the conservation titles of the Farm Bill, to protect private lands of high connectivity value under climate change.

Ecosystem Specific Actions:

— 1.4.7 Forest: Protect transitional areas between connected forests and forests fragmented by human land use to limit further habitat loss or degradation.
— 1.4.8 Coastal: Assess and where necessary redesign or remove existing legacy structures (e.g., dams, hardened shorelines) to increase natural ecosystem resilience and allow for ecosystem function and species response to climate change.
— 1.4.9 Coastal: Assess, redesign, or remove existing legacy structures to increase natural ecosystem resilience (e.g., allow for ecosystem and species response) to climate change; including water and sediment processes.
— 1.4.10 Marine: Identify and protect habitats important for maintaining connectivity and supporting robust populations of marine species including areas likely to serve as refugia in a changing climate.

☑ **PROGRESS CHECK LIST FOR GOAL 1:**

- ☐ Areas resilient to climate change identified;
- ☐ Range of geophysical settings (particular combinations of geology, soils, topography, etc.) classified and mapped;
- ☐ Gap analysis of geophysical settings completed and priority candidate areas identified.
- ☐ Desired ecological connectivity among conservation areas identified;
- ☐ Baseline comprehensive inventory of conservation areas completed;
- ☐ Suite of land protection tools (designations, exchanges, acquisitions, easements, leases, incentives) evaluated and updated;
- ☐ Land conservation plans updated;
- ☐ Funding allocations reviewed/revised in light of climate change priorities.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

As described in Chapter 1, humans depend upon and derive multiple benefits from fish, wildlife and plants. Our living resources are vital for ceremonial, spiritual, and subsistence practices by indigenous peoples; recreational activities such as sport fishing, waterfowl hunting, birding and nature photography; and commercial interests such as fisheries, wood products, and food production. They are part of the core fabric of America, providing livelihoods, cultural identity and boundless opportunities.

The United States has a highly developed set of management agencies and authorities that maintain our existing living resources and the many uses and benefits they provide. Virtually all of these agencies have sophisticated management plans for the species and areas under their jurisdiction. However, the vast majority of these plans do not yet take account of climate change. This deficiency must be addressed, because managing for the *status quo* is no longer sufficient. We must begin to integrate climate adaptation strategies and actions into existing species and conservation area management plans if species and ecosystems are to survive and thrive in an uncertain future.

Management plans and programs must consider species' abilities to adapt, including maintaining a full range of genetic diversity across managed plant and animal populations. Some species may need more direct management, such as captive breeding. In other cases, managers may need to consider whether human interventions such assisted migration or translocation are appropriate. Because some of these actions may be new and potentially controversial, collaborative, deliberative and flexible decision making will be critical.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

National Actions:

- 2.1.1: Incorporate climate change into management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.
- 2.1.2: Develop and implement best management practices to support habitat resilience in a changing climate.
- 2.1.3: Identify transitional species and habitats particularly vulnerable to climate impacts (e.g., cool season to warm season grasslands or cool-water to warm-water fisheries) and develop management strategies and approaches for adaptation.
- 2.1.4: Review and revise as necessary techniques to maintain or mimic natural disturbance regimes and to protect vulnerable habitats.
- 2.1.5: Review and revise as necessary existing species and habitat impact minimization, mitigation and compensation standards (e.g., under NEPA) and develop new standards as necessary to address impacts associated with climate change.

Ecosystem Specific Actions:

- 2.1.6 Forest: Conduct treatments such as prescribed burning, planting, and thinning to reduce excessive fuel loads, to select stress-tolerant species and genotypes, to manage age classes, and to reduce competition where appropriate.
- 2.1.7 Forest: Create landscape patterns with many age classes and diverse species and seed sources
- 2.1.8 Shrubland/Grassland: Develop cattle grazing practices that function in ecosystems with reduced rainfall and increasing temperature.
- 2.1.9 Shrubland/Grassland: Participate in USDA/NRCS state technical committees to encourage incorporation of climate change into species status assessments and into future federal Farm Bill programs.
- 2.1.10 Inland Water/Coastal: Develop basin-specific integrated water management plans that address in-stream flows, inter-basin water transfers, and surface and groundwater withdrawals while promoting water conservation and ecosystem function.
- 2.1.11 Coastal: Develop strategic protection, retreat, and abandonment plans for areas currently experiencing rapid coastal climate change impacts (e.g., coastline of Alaska and low-lying islands).
- 2.1.12 Marine: Incorporate information about climate variability, change and uncertainty into the marine fisheries stock assessment process and Fishery Management Plans.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

National Actions:

- 2.2.1: Use vulnerability and risk assessments to design and implement management actions at species to ecosystem scales.
- 2.2.2: Actively manage populations (e.g., using harvest limits, seasons, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions.
- 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

SEED BANKING IN A CHANGING CLIMATE

Climate change may bring the loss of major populations of plants—or even entire species. One of the key approaches for boosting a species' chances of surviving on a changed planet is maintaining the species' genetic diversity.

Bureau of Land Management 2009. Native Plant Materials Development Program: Progress Report for FY2001-2007.

Both of these issues can be addressed by collecting and banking seeds and other plant materials. An extensive seed bank can save species that go extinct in the wild, preserve the genetic diversity needed for other species to cope with a changed environment, and provide the seed needed for restoration projects.

Such a preservation effort is now underway. In 2001, Congress directed the Bureau of Land Management (BLM) to establish an Interagency Native Plant Materials Development Program. Working with hundreds of partners in federal, tribal and state agencies, universities, conservation groups, native seed producers and others, the program has now collected seeds from more than 3,000 native plant species in the United Sates. The BLM also has increased the capacity of its storage facilities to 2.5 million pounds of seed.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

National Actions:

- 2.3.1: Protect and maintain high quality wildland seed sources including identifying areas for seed collection across elevational and latitudinal ranges of target species.
- 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.

Ecosystem Specific Actions:

- 2.3.3 Forest: Conduct treatments, such as planting, girdling, prescribed burning, and thinning to select stress-tolerant species and genotypes, manage age classes, and reduce inter-tree competition.
- 2.3.4 Shrubland/Grassland/Desert: Seed bank, develop and deploy as appropriate plant materials that will be resilient in response to climate change.
- 2.3.5 Marine: Develop and implement approaches for assessing and maximizing the genetic diversity of marine species.

☑ **GOAL 2 PROGRESS CHECK LIST:**

- ☐ Co-managers (state, federal, tribal, local, international) identified and engaged;
- ☐ Risk assessments and scenario planning used to guide species management decisions;
- ☐ Species and area management plans updated;
- ☐ Fire and other disturbance regimes managed to better simulate natural conditions;
- ☐ State Wildlife Action Plans updated to include climate adaptation;
- ☐ Agency specific climate change adaptation plans developed;
- ☐ Agency specific climate adaptation plans and regional plans integrated;
- ☐ Species requiring active intervention identified;
- ☐ Use of artificial propagation evaluated;
- ☐ Criteria and guidelines developed for translocation and assisted migration;
- ☐ Genetic conservation issues identified.

GOAL 3: Enhance capacity for effective management in a changing climate.

Climate change adaptation requires new ways of assessing information, new management tools and new professional skills. Natural resource agency professionals need accessible opportunities to learn about climate-related species, habitat, and ecosystem changes as well as how to identify the most promising strategies to conserve fish, wildlife and plant populations and functioning ecosystems. While well-trained in ecology and applied resource management, many managers have not yet had the opportunity to learn about and understand how climate change “changes the rules” about conservation of fish, wildlife and plants. These professionals require training to enhance their capacity and confidence to understand the impacts of climate change and to design and deliver effective climate adaptation programs.

Climate change impacts are occurring at scales much larger than the operational scope of individual organizations and agencies, and successful adaptation to climate change demands a strong collaboration among all jurisdictions charged with fish, wildlife and plant conservation, both domestic and international. Collaborative efforts will result in more informed, relevant, and creative solutions for all stakeholders. Federal, state, and tribal resources managers should work together with their partners across jurisdictions and regional scales (including international borders) to provide context and coordination for species and conservation area management in the context of climate change scenarios. Current institutional disconnects and barriers can hamper our ability to manage fish, wildlife, plants and ecosystems across jurisdictions. Landscape Conservation Cooperatives, Climate Science Centers, National Fish Habitat Partnerships and other emerging partnerships provide a useful forum for multiple jurisdictions and partners to work better together to define, design, and deliver sustainable landscapes at a regional scale.

Nearly all fish, wildlife, and plant conservation laws, regulations and policies were developed when climate was thought to be constant. Now that the climate is changing, these legal foundations need to be reviewed and updated as necessary. This review process should also aim to assure that these legal foundations assist, and do not impede, adaptation efforts. It is also essential that programs are reviewed to maximize the utility of existing conservation funding and to increase the priority of climate change adaptation work.

SEA LEVEL RISE IN DELAWARE

Photo: NOAA

A rising sea combined with sinking land creates a watery future. The state of Delaware is experiencing both, with relative sea levels to rise at the rapid rate of one inch every eight years (NOAA 2009). That's a big problem in a state where more than ten percent of the land lies less than eight feet above sea level and no spot is farther than 35 miles from the Atlantic Ocean, Delaware Bay, or Delaware River, and residences, communities, and industries are at risk. In fact, the state is already experiencing worrisome coastal flooding. Breaches in the Prime Hook National Wildlife Refuge (NWR), for instance, have allowed saltwater into freshwater marshes that provide critical waterfowl habitat.

Keenly aware of the threat, the state of Delaware has created a Sea-Level Rise Initiative to understand the impacts of sea-level rise, prepare for future inundation, respond where necessary, and keep the public informed. Prime Hook is collaborating with the State of Delaware to implement short-term adaptation strategies to address inundation and saltwater intrusion into freshwater impoundments by stabilizing the shoreline.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

National Actions:

— 3.1.1: Build on existing needs assessments to identify gaps in climate change knowledge and technical capacity among natural resource professionals.

— 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.

— 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).

— 3.1.4: Develop a web-based clearinghouse of training opportunities and materials addressing climate change impacts on natural resource management.

— 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop inter-agency communities of practice about climate change adaptation.

— 3.1.6: Support and enhance web-based clearinghouses of information (e.g., www.CAKEX.org) on climate change adaptation strategies and actions targeted towards the needs of resource managers and decision makers.

Ecosystem Specific Actions:

— 3.1.7 Forest: Foster interaction among landowners, local experts and specialists to identify opportunities for adaptation and to share resources and expertise that otherwise would not be available to many small forest landowners.

— 3.1.8 Shrubland/Grassland/Desert/Tundra: Increase scientific capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to species.

— 3.1.9 Marine: Develop regional downscaling of Global Climate models to conduct vulnerability assessments of marine living marine resources.

— 3.1.10 Marine: Evaluate the effectiveness of adaptation strategies by explicitly incorporating mechanisms of change into policies.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

National Actions:

— 3.2.1: Use regional venues such as Landscape Conservation Cooperatives (LCCs) to collaborate across jurisdictions and develop conservation goals and landscape/seascape scale plans capable of sustaining fish, wildlife and plants.

— 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.

— 3.2.3: Integrate individual agency climate change adaptation programs with other regional conservation efforts such as the National Fish Habitat Action Plan, Landscape Conservation Cooperatives (LCCs), and the Northeast Association of Fish and Wildlife Agencies regional application of State Wildlife Grant funds.

— 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.

— 3.2.5: Engage with international neighbors, including Canada, Mexico, Russia, and nations in the Caribbean Basin, Arctic Circle, and Pacific Ocean to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

National Actions:

— 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.

— 3.3.2: Review and seek to change as appropriate federal and state laws and regulations that govern floodplain mapping, flood insurance and flood mitigation to discourage development and construction of infrastructure in floodplains and sensitive coastal areas

— 3.3.3: Continue the ongoing work of the Joint State Federal Task Force on Endangered Species Act Policy to ensure that policies guiding implementation of the Endangered Species Act provide appropriate flexibility to address climate change impacts on listed fish, wildlife and plants and to integrate the efforts of federal, state, and tribal agencies to conserve listed species.

- 3.3.4: Initiate a dialogue among all affected interests about revising the federal Coastal Zone Management Act and the Clean Water Act, and state coastal tidal wetland protection programs to address impacts of sea level rise on coastal habitats.

Ecosystem Specific Actions:

- 3.3.5 Coastal: Modify policies and programs to create or strengthen disincentives for long-lived coastal development (infrastructure) and armoring (seawalls, revetments, etc.) to protect areas vital to fish, wildlife and plant adaptation.
- 3.3.6 Coastal: Alter current policy and zoning in coastal areas to anticipate migratory nature of coastal habitats and prevent development in potential refugia and corridors.
- 3.3.7 Coastal: Clarify legal authority to manage new and future habitat areas, particularly in areas where jurisdiction migrates with landscape features (e.g., shorelines).

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

National Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
- 3.4.3: Collaborate with state and tribal agencies and private conservation partners to sustain authorization and appropriations for the State and Tribal Wildlife Grants program.
- 3.4.4: Collaborate with agricultural interests (e.g., American Farm Bureau Federation) to seek increased priority for funding of the conservation titles of the Farm Bill.
- 3.4.5: Review existing conservation related federal grants to tribal agencies and revise as necessary to provide apportioned funding for tribal climate adaptation activities.
- 3.4.6: Develop a web-based clearinghouse of funding opportunities available to support climate adaptation efforts.

☑ **GOAL 3 PROGRESS CHECK LIST:**

- ☐ Natural resource professional training needs identified;
- ☐ Climate adaptation training collaboratives established;
- ☐ Core curricula for climate adaptation established;
- ☐ Training opportunity and accessibility increased;
- ☐ Interagency personnel assignments expanded;
- ☐ Landscape Conservation Cooperative (LCC) Network engaged as primary venue for inter-jurisdictional collaboration;
- ☐ Floodplain maps, insurance laws and regulations updated;
- ☐ Policies regarding key conservation statues reviewed and, as necessary updated;
- ☐ Dialogue initiated to identify changes to Coastal Zone Management Act, Clean Water Act and state wetland protection programs needed to deal with sea level rise;
- ☐ Funding and resource needs for climate adaptation identified;
- ☐ Criteria to include climate adaptation in existing conservation grant programs developed.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

As discussed previously, uncertainty will always exist about the specific impacts of climate change on fish, wildlife and plants, as well as about the effectiveness of management actions. To minimize such uncertainty, decision-making should employ long-term data series, information systems, decision support tools, best professional judgment and stakeholder involvement to design and implement management approaches to promote climate change adaptation. The principles of adaptive management should be used to monitor the response to management actions, evaluate effectiveness, gain new knowledge and improve and inform future management decisions.

Coordinated inventory, monitoring, and observation systems should be developed to enable resource managers to monitor and identify changes in ecological baselines from the species to the ecosystem level, and to prioritize and develop adaptation plans and actions. The National Ecological Observatory Network (NEON) represents such an effort to deploy instrumentation at sites to measure key ecosystem variables arrayed across important environmental gradients. Such systems allow managers and other decision-makers to evaluate the efficacy of management actions.

While observation systems provide critical data for resource managers, those data have far greater utility when processed, analyzed, and made available as readily useable information. The need for information management and increased access to information is well-documented (Glick et al. 2011). A multi-disciplinary approach, to link and make available data currently developed by separate agencies or groups, will increase access to and use of this information by resource managers, planners and decision-makers.

In addition, decision support tools such as risk assessments and scenario planning can inform and enable management planning and decision making under uncertainty. Identifying, developing, and employing these types of tools will help managers facilitate adaptation of individual species and build habitat resilience.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

National Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation.

— 4.1.3: Promote a collaborative approach to acquire, process, archive, and disseminate essential geospatial and satellite-based remote sensing data products (e.g., snow cover, green-up, and surface water) needed for regional-scale monitoring and land management.

— 4.1.4: Develop sentinel site networks for integrated climate change inventory, monitoring, research, and education.

— 4.1.5: Define national indicators that can be used to monitor the response of fish, wildlife, plants and ecosystems to climate change.

— 4.1.6: Collaborate with the National Phenology Network and others and create a National Population Network to facilitate monitoring of phenology and changes in distribution and abundance of fish, wildlife and plants that have been identified as most vulnerable to climate change.

Ecosystem Specific Actions:

- 4.1.7 Forest: Develop, refine, and implement monitoring protocols that provide key information needed for managing forest systems (e.g., expand Forest Inventory and Analysis sampling to include additional variables).
- 4.1.8 Forest: Inventory and evaluate conservation value of existing ex situ forest germplasm resources to target underrepresented forest areas or species that should be prioritized in light of climate change.
- 4.1.9 Tundra: Establish observational capacity on the North Slope to collect integrated hydrological, climate, biological, and geophysical data.
- 4.1.10 Inland Water: Monitor and assess functionality of created wetlands and restored wetlands, streams, and lakes.
- 4.1.11 Coastal: Monitor and assess water levels in shallow coastal aquifers that support freshwater-dependent ecosystems.
- 4.1.12 Marine: Employ and enhance marine data collection systems and platforms (such as the Integrated Ocean Observing System or IOOS), existing protected area networks, and other research sites) to monitor climate change and its impacts.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems) via dialogue with scientists, managers (of natural resources and other sectors) and stakeholders.

National Actions:

- 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for fish, wildlife and plants.
- 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact fish, wildlife and plants.
- 4.2.3 Identify actions that can be implemented by a variety of sectors, and that are beneficial given a range of climate futures and desired future conditions (“no regrets” options).
- 4.2.4 Ensure the availability of and provide guidance for decision support tools (e.g., NOAA’s Digital Coast) that assist federal, state, local and tribal resource managers and planners in effectively managing fish, wildlife and plants in a changing climate.
- 4.2.5: Use observation, information, assessment and decision support systems to monitor and determine the effectiveness of specific management actions to analyze the potential for maladaptations and adapt management approaches appropriately.

Ecosystem Specific Actions:

- 4.2.6 Tundra: Establish long-term observatories on the North Slope to collect integrated hydrological, climate, and geophysical data regarding the response of permafrost, hydrologic, and ecological systems to changes in thermal and precipitation regimes.

☑ GOAL 4 PROGRESS CHECK LIST:

- ☐ Public/private collaborative to build nationally integrated climate change inventory, monitoring, observation and information systems convened;
- ☐ Existing public and private inventory, monitoring, observation and information systems assessed for use in detecting climate change.
- ☐ Existing public and private, inventory, monitoring, observation, and information systems linked and interoperable;
- ☐ Data collection standards for common set of climate change metrics established;

- ☐ Coordinated sentinel sites identified, linked, and, as necessary established to monitor climate change impacts and responses;
- ☐ Targeted monitoring of fish, wildlife, plants, and their habitats for the effects of climate change initiated;
- ☐ Federal, state, and tribal managers provided with access to natural resources information and other necessary data;
- ☐ Evaluation of existing and new climate adaptation plans linked to integrated observation and information systems.
- ☐ Framework of tools for managing under uncertainty developed and utilized.
- ☐ New adaptive management actions developed in response to data and information from observation and information management systems.

SENTINEL SITE MONITORING

Crafting an effective climate adaptation strategy is difficult without having good data on the impacts of climate change. Collecting that vital information, in turn, requires observing and measuring what's happening at specific locations over many years. In 2008, the National Estuarine Research Reserve System (NERRS) began establishing such so-called `sentinel sites' to learn how habitats respond to sea level change.

One of those sentinel sites is the Elkhorn Slough Reserve in California's Monterey Bay. The area began losing some of its tidal wetlands more than 50 years ago after an inlet was built to Moss Landing harbor, creating a permanent connection to the open ocean. Now, sea level rise is further threatening this valuable estuarine ecosystem. At the same time, the Reserve is under stress from eutrophication, groundwater withdrawals, and other factors.

To understand the complex effects of these stressors, the NERRS is intensely monitoring the ecosystem. Researchers are recording surface and groundwater levels, testing water quality, and charting the changes occurring in mangrove trees, tidal marsh plants, and submerged aquatic vegetation. They are also monitoring the climate, the amounts of sediment reaching the wetlands, and changes in land elevation.

So far, the project has documented a worrisome trend. The combination of rising sea levels and the loss of marshes is increasing the vulnerability of a railroad line, a power plant, and a number of adjacent farms to flooding and coastal erosion.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Designing and delivering effective fish, wildlife and plant climate change adaptation programs has been hampered by lack of detailed knowledge about the impacts of climate change on fish, wildlife, plants and habitats and their adaptive capacity to respond. Existing research collaborations such as the USGCRP can enable natural resource managers to focus and prioritize research. New findings should be rapidly incorporated into decision support tools and made available to managers, as well as into climate change adaptation planning, delivery and evaluation.

Vulnerability assessments are important tools that inform adaptation planning by helping to identify those species, habitats, or systems likely to be most affected by climate change. Vulnerability is generally defined as a combination of sensitivity to change, exposure to changing conditions, and the capacity to adapt to those changes over time (IPCC 2007). These types of assessments can help managers develop and prioritize adaptation strategies as well as inform management approaches.

The use of models to project potential changes in weather patterns and natural systems has already generated a great deal of useful information to help us plan for future climate impacts, especially at large scales. Additional and more refined models, at temporal and spatial scales appropriate to climate adaptation objectives established by natural resource managers, are required. Development of models to predict changes in climate variables, habitat and fish, wildlife and plant abundance and distribution is a priority and should initially focus on processes that are already occurring and that act on short (i.e. decadal) time scales.

Most Americans appreciate the aesthetic values that healthy populations of fish, wildlife, and plants offer, and many have a cultural, recreational, or economic association with wildlife and wild places. Few, however, fully understand the services that well-functioning ecosystems provide to society or what the full cost of replacing those services would be. Methods should be developed to objectively quantify the value of ecosystem services and to understand potential impacts from climate change to these important services.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

National Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change.

— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., low-lying islands and glaciated areas) or highly vulnerable species.

Ecosystem Specific Actions:

— 5.1.4 Tundra: Participate in research planning for programs such as NSF, NOAA, NASA, NEON, CAFF, and DOE to ensure inclusion of research relevant to missions of agencies and resource managers.

PLANTS AND THEIR POLLINATORS

More than 75 percent of flowering plants, which provide a bounty of fruits, seeds, nuts and nectar for wildlife, depend on pollinators. As the climate changes, plants will grow in different places and shift when they bloom. That raises a high-stakes question: Will pollinators follow? If they can't, then vital ecological relationships could be severed.

The U.S. Fish and Wildlife Service's Arizona Ecological Services Field Office and the Merriam-Powell Center for Environmental Research Center at Northern Arizona University are trying to answer this question. In the mountains of San Francisco Peaks north of Flagstaff, Arizona, teams of researchers are conducting extensive surveys of plant-pollinator relationships at five different sites.

The initial results show that bees are the major pollinators at lower elevations, while flies are more important at higher elevations. The researchers also discovered a greater than expected diversity of bees. There are at least 85 species at the five plots, including five species found at all elevations. This is significant given the differences in vegetation of lower altitude deserts compared to higher altitude mixed conifer and aspen forests.

Strategy 5.2: Work through existing partnerships or build new collaborations as needed across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

National Actions:

- 5.2.1: Address priority climate change knowledge gaps and needs.
- 5.2.2: Support basic research on life histories of fish, wildlife and plants to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.3: Work with funding entities to support priority climate change research topics.
- 5.2.4: Increase coordination of research across entities such as USGCRP, CSCs, RISAs, and the academic and private sector.
- 5.2.5: Assess potential success, and consider unanticipated consequences, of assisted migration and translocation for species at risk from climate change.
- 5.2.6 Quantify the value of ecosystem services and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.

Ecosystem Specific Actions:

- 5.2.7 Forest: Investigate how key species move through forest landscapes (permeability) for key species.
- 5.2.8 Forest: Increase research on pollination, dispersal, food web dynamics, and other species interactions to better understand ecological interrelationships among forest-dependent fish, wildlife, and plants.
- 5.2.9 Shrubland/Grassland/Desert: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change.
- 5.2.10 Shrubland/Grassland/Desert/Tundra: Increase understanding of the adaptive capacity of communities and species under climate change.
- 5.2.11 Tundra: Conduct research into how ground ice influences a landscape's susceptibility to warming and predict the extent and magnitude of habitat change and sedimentation rates into marine and fresh water systems.
- 5.2.12 Inland Water: Conduct research to determine the impacts of temperature increases and glacial melting on water temperatures, evapotranspiration rates, flow characteristics, stream channel processes and aquatic species.
- 5.2.13 Inland Water/Coastal: Conduct research to determine flows required to support sustainable populations of vulnerable species, such as during prolonged drought.
- 5.2.14 Coastal/Marine: Conduct research to better understand fish, wildlife, plant, and ecosystem responses to ocean acidification and saltwater intrusion.
- 5.2.15 Marine: Produce regional to subregional projections of future climate change impacts on physical, chemical and biological conditions for all U.S. marine ecosystems.
- 5.2.16 Marine: Increase research on early life histories, food web dynamics, and other species interactions to better understand implications of climate change on ecological interrelationships among marine dependent fish, wildlife, and plants.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

National Actions:

- 5.3.1: Define national standards and criteria to identify fish, wildlife, plants and ecosystems most vulnerable to climate change impacts.
- 5.3.2: Conduct vulnerability assessments for priority species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.3: Define the suite of physical and biological variables and ecological processes for which predictive models are needed via a collaborative process among state, federal and tribal resource managers, scientists and model developers.
- 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
- 5.3.5: Model climate change impacts on vulnerable species, including future distributions and the probability of persistence.

Ecosystem Specific Actions:

- 5.3.6 Forest: Develop climate sensitive growth and yield models for tree species to predict long-term sustainability of forest habitats.
- 5.3.7 Inland Water: Update hydrologic statistics and stream channel characteristics needed to delineate areas prone to flooding and channel migration as a result of climate impacts.
- 5.3.8 Coastal: Model sea level rise and physical and biological responses at relevant scales.
- 5.3.9 Marine: Develop models to provide predictions of physical atmospheric and oceanographic climate changes for the marine waters of the U.S. Exclusive Economic Zone.
- 5.3.10 Marine: Develop regional downscaling of Global Climate models to conduct vulnerability assessments of marine living marine resources.

☑ **GOAL 5 PROGRESS CHECKLIST:**

- ☐ Inventory of knowledge gaps completed;
- ☐ Research agenda developed with priorities and initial projects for research into adaptive capacity;
- ☐ Criteria to identify species sensitive to climate change and response indicators developed;
- ☐ Working groups are developed that share data, expertise, and responsibilities for addressing research needs;
- ☐ Funding for climate change related research on impacts and adaptive strategies increased;
- ☐ Novel anticipatory strategies for adapting to climate change developed;
- ☐ Approaches to improve validity of predicting scenarios under future climate conditions developed;
- ☐ Number of regional and consistent climate change scenarios increased;
- ☐ Protocols and metrics for valuing ecosystem services developed.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Adaptation efforts will be most successful if they have broad political and public support, and if key groups and people are motivated to take action themselves. Limited resources should be targeted toward elected officials, public and private policy makers, publics that are already interested in climate change issues, large private landowners, and natural resource user groups.

Engaging stakeholders early and repeatedly to increase awareness of the threats from climate change, to gather input in developing appropriate, integrated adaptation responses, and to motivate their participation and action is key to making this *Strategy* work.

The concept of ecosystem services is gaining traction among elected officials and policy makers, but not enough is being done to translate the concept into action. Communicating science-based information on the socio-economic value of ecosystem services to public and private decision makers and opinion leaders should be accomplished by using real examples.

Development and implementation of effective adaptation policies and practices requires that interested constituencies and key stakeholders understand the fundamentals of climate change adaptation. Practical education and outreach efforts and opportunities for participation should be developed and implemented whenever possible.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

National Actions:

— 6.1.1: Develop focused outreach efforts aimed at local, state and federal elected officials on climate impacts to fish, wildlife, plants and ecosystems, and on the importance of adaptation planning

— 6.1.2: Target outreach approaches to other key audiences, such as the private sector (e.g., agriculture, forestry), cultural leaders, and large private land managers.

— 6.1.3: Identify and partner with key stakeholder groups (e.g., conservation and environmental organizations; hunting and angling groups, trade associations) to help develop and distribute key climate change and adaptation messages tailored for their interest groups as well as the broader public.

— 6.1.4: Develop and distribute effective educational curricula and materials that increase understanding of climate change and steps to lessen impacts to fish, wildlife and plants.

— 6.1.5: Incorporate information about potential climate change impacts to ecosystem services in education and outreach activities.

— 6.1.6: Use case studies as story telling tools to provide interested publics with real world examples of impacts of climate change on fish, wildlife and plants, and of efforts to promote adaptation.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

National Actions:

— 6.2.1: Use public access points, nature centers, and hunting and fishing regulation guides to inform tourists, visitors and recreational users of climate impacts to and adaptation strategies for fish, wildlife and plants.

— 6.2.2: Develop specific programs to engage citizens in monitoring impacts of climate change on the landscapes (e.g., citizen science monitoring, nature center programs)

— 6.2.3: Make research and monitoring information regarding climate impacts to species and natural systems accessible to the public.

— 6.2.4: Develop educational materials and teacher trainings for K-12 classrooms on impacts and responses to climate change in marine ecosystems.

- 6.2.5: Develop collaborations with museums, aquariums and other organizations to increase communication and awareness of impacts and responses to climate change.
- 6.2.6: Promote opportunities for citizens to engage in assessment and adaptation science.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

National Actions:

- 6.3.1: Provide access to tools (web-based and others) that promote improved collaboration, interactive dialog and resource sharing and minimize duplication of effort across jurisdictions.
- 6.3.2: Engage agency employees in key climate change issues by expanding existing forums for information sharing and idea exchange like the Landscape Conservation Cooperatives, and create new forums and channels as needed.
- 6.3.3: Develop and implement communication efforts with States, Tribes to increase awareness of the impacts and responses to climate change.

Ecosystem Specific Actions:

- 6.3.4 Marine: Develop and implement communication efforts between NOAA and Department of the Interior to increase awareness of the impacts and responses to climate change in marine ecosystems.

☑ GOAL 6 PROGRESS CHECKLIST:

- ☐ Climate change considerations incorporated into existing and ongoing communications to the public regarding natural resource issues;
- ☐ Stakeholder representatives engaged in working groups related to climate change messaging;
- ☐ Improved messaging and targeting of climate change information to key audiences developed;
- ☐ Agency-produced educational and interpretive materials and papers are developed and distributed;
- ☐ Targeted attempts made to inform popular press coverage of climate change adaptation;
- ☐ Traffic to the *Strategy* web site and other electronic climate change adaptation resources increase;
- ☐ Workshops and communication programs increasing awareness of climate change related issues regarding fish, wildlife and plants developed;
- ☐ Programs designed to engage citizens in monitoring impacts of climate change developed.

GOAL 7: Reduce stresses not caused by climate change to make fish, wildlife, plants and ecosystems less vulnerable to a changing climate.

This *Strategy* identifies actions that natural resource managers can take to address the impacts of climate change on fish, wildlife and plants and the human uses and benefits that living systems provide. In addition, natural resource managers must continue to work to reduce other negative impacts to ecosystems, which has been done for decades with notable successes. While this *Strategy* does not attempt to catalog all of those critical efforts, it is important to note that some of these existing stressors (such as habitat fragmentation, degradation, and invasive species) are likely to interact with climate change to magnify negative impacts on fish, wildlife and plants.

The importance of protecting, restoring and connecting suitable habitats as a way to enhance fish, wildlife and plant resiliency has been discussed previously, and reducing and mitigating the ongoing degradation associated with human development such as pollution is also critical. Opportunities for collaboration with land use planners, as well as major sectors such as agriculture, transportation and water resource interests, to identify common concerns and shared solutions should be actively pursued.

Invasive species are pervasive in our environment and becoming more so every day. Historic invaders such as chestnut blight, Dutch elm disease, kudzu and cheatgrass changed forever the character of our natural, rural and urban landscapes. Climate change has already enabled range expansion of some invasive species, such as hemlock woolly adelgid (*Adelges tsugae*), and will likely create welcoming conditions for new invaders. There are no easy ways to combat invasive species, but coordinating efforts across jurisdictions and between terrestrial and aquatic resource managers, stepping up efforts at prevention, enhancing early detection and rapid response programs and avoiding accidental movement of invaders can help.

Strategy 7.1: Slow and reverse habitat loss and fragmentation.

National Actions:

— 7.1.1: Work with local land-use planners to identify shared interests and potential conflicts in reducing and reversing habitat fragmentation and loss through comprehensive planning and zoning.

— 7.1.2: Work with farmers and ranchers to apply the incentive programs in the conservation titles of the Farm Bill to minimize conversion of habitats, restore marginal agricultural lands to habitat, and to increase riparian buffer zones.

— 7.1.3: Work with water resource managers to enhance design and siting criteria for water resources infrastructure to reduce impacts on floodplains and to restore connectivity in aquatic habitats.

— 7.1.4: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts and to promote habitat restoration in desirable locations.

Ecosystem Specific Actions:

— 7.1.5 Forest: Bridge the gap between ecosystem conservation and economics, and consider market-based incentives that encourage afforestation in forested systems.

— 7.1.6 Shrubland/Grassland: Support land trusts and farmland and ranchland preservation programs as a way to sustain habitats on working landscapes.

— 7.1.7 Shrubland/Grassland/Desert/Tundra: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded shrubland and grassland areas.

— 7.1.8 Forest/Shrubland/Desert/Tundra: Reduce the footprint of energy development and mining activities in desert and tundra systems.

— 7.1.9 Inland Water/Coastal: Work with local and regional water management districts to evaluate historical water quantities and base flows and develop flow release agreements to approximate natural flows.

— 7.1.10 Coastal: Protect natural dunes and dune vegetation from removal and trampling.

— 7.1.11 Coastal: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).

— 7.1.12 Coastal: Fully incorporate risks associated with coastal development into property owners' insurance rates to enlist market forces in the effort to minimize loss of coastal habitat.

— 7.1.13 Marine: Bridge the gap between ecosystem conservation and economics, and consider market-based incentives that encourage actions that foster resilience and adaptation in marine systems.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

National Actions:

- 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize ecosystem degradation resulting from development and land-use change.
- 7.2.2: Work with farmers and ranchers to develop and implement livestock management practices to reduce and reverse habitat degradation and to protect regeneration.
- 7.2.3: Work with water resource managers to identify, upgrade, or remove outdated sewer and stormwater infrastructure to reduce water contamination.

Ecosystem Specific Actions:

- 7.2.4 Forest: Regulate ungulate herbivory populations to promote and protect regeneration.
- 7.2.5 Forest: Promote urban forestry practices that provide multiple ecosystem services and benefits - including improved air quality, habitat connectivity, and recreational.
- 7.2.6 Grassland/Tundra: Reduce existing pollution and contaminants and increase monitoring of air and water pollution.
- 7.2.7 Tundra: Address and improve best management practices for freshwater withdrawals used for ice road construction.
- 7.2.8 Inland Water: Develop or improve best management practices, incentives, and legislation to reduce thermal, sediment, nutrient, and chemical loading in aquatic habitats.
- 7.2.9 Inland Water/Coastal: Increase restoration, enhancement and preservation of riparian zones and buffers in agricultural and urban areas to minimize non-point source pollution.
- 7.2.10 Inland Water/Coastal: Reduce impacts of impervious surfaces and stormwater runoff in urban areas to improve water quality, groundwater recharge and hydrologic function.
- 7.2.11 Marine: Work with ocean-use planners to identify potentially conflicting needs and opportunities to minimize marine ecosystem degradation resulting from development and ocean-use change.

REDUCING STRESS ON KELP FORESTS

Good management strategies do work. That's the lesson from the forests of giant kelp (*Macrocystis pyrifera*) off the coast of southern California. These underwater forests provide habitat for more 1,000 species of marine fishes and invertebrates, from tiny snails and starfish to leopard sharks and endangered sea otters. But long-term ecological monitoring that began at the Channel Islands National Park in 1982 spotted signs of trouble. Normally, predators like spiny lobsters, sheephead and sea otters keep sea urchin populations in check. That prevents the kelp-loving urchins from chewing off too many of the anchors that hold kelp in place, which causes kelp to drift off and die. What the monitoring revealed, however, was that overfishing of lobsters and sheephead, plus declines in sea otter numbers, was allowing the sea urchin population to explode, turning kelp forests into sea urchin barrens.

To tackle the problem, the California Fish and Game Commission and the National Oceanic and Atmospheric Administration established a network of marine protected areas (MPAs) in state and federal waters near the Channel Islands. Preventing fishing of lobsters and sheephead in these areas has allowed the predators to return and thrive—and to resume their control of the sea urchin population. Studies show that the kelp forests in these areas are denser and healthier than in non-protected areas (CA DFG 2008)—and should also be able to better cope with the impacts of climate change.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

National Actions:

— 7.3.1: Use observation and monitoring networks for early detection of invasive species.

— 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to natural ecosystems.

— 7.3.3: Develop strategies for rapid response to contain, control and where possible eradicate new invasive species.

— 7.3.4: Develop national standards for collecting and reporting invasive species data to facilitate information sharing and management response.

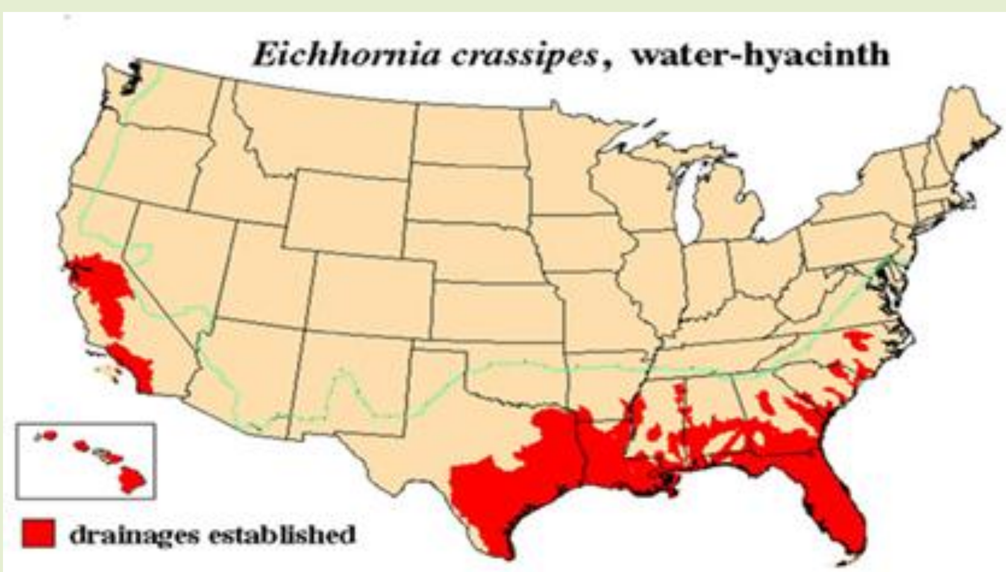
— 7.3.5: Employ a multiple barriers approach to detect and contain incoming invasive species, including monitoring at points of origin and points of entry for shipments of goods and materials into the United States and for trans-shipment within the country.

— 7.3.6: Monitor pathogens associated with fish, wildlife and plant species for increased understanding of distributions and to minimize introduction into new areas.

FIGHTING THE SPREAD OF WATER HYACINTH

Water hyacinth (*Eichhornia crassipes*) is already a major pest. Introduced into the United State in the late 1890’s from South America, this floating plant has spread rapidly across the southeastern United States. It produces vast, thick mats that clog waterways, crowding out native plants and making boating, fishing and swimming almost impossible.

Climate change will make the problem worse by allowing this pest to invade new areas. That’s because water hyacinth can’t survive when winter temperatures drop below freezing. So if temperatures rise, as predicted, the plant will spread north. Fortunately, there are effective measures for fighting invasions of water hyacinth. But these steps must be taken before the plant gets established, emphasizing the vital importance of planning for invasions predicted in a changing climate and constantly monitoring vulnerable ecosystems for the first telltale signs of such invasions.



The red areas indicate the range of water hyacinth as of 1999. The Green line is potential expansion if average winter temperature increase by 9 °F (USGS).

Ecosystem Specific Actions:

— 7.3.7 Forest: Apply integrated pest management practices, share innovative control methodologies, and take corrective actions (e.g., silviculture changes, suppression or eradication) when necessary to manage forest diseases and insect pests.

— 7.3.8 Forest/Shrubland/Grassland: Avoid use of potentially invasive species in biomass/biofuels energy production in sensitive areas.

— 7.3.9 Coastal/Marine: Implement best management practices to reduce the spread of invasive species through ballast water.

— 7.3.10 Marine: Apply integrated management practices, share innovative control methodologies, and take corrective actions when necessary to manage marine diseases and invasives.

— 7.3.11 Marine: Avoid use of potentially invasive species in aquaculture and other areas.

☑ **GOAL7 PROGRESS CHECKLIST:**

- ☐ Regional and local land-use planners engaged;
- ☐ Collaborative partnerships with land trusts and private landowners established;
- ☐ Collaboration with farmers and ranchers to review/revise livestock management practices begun;
- ☐ Nationwide inventory of outdated legacy infrastructure completed;
- ☐ Disruptive floodplain infrastructure reduced/removed;
- ☐ Coordinated invasive species and diseases monitoring system established;
- ☐ Multiple barriers to invasive species introduction in place.

Chapter 4: How Climate Adaptation Can Benefit Multiple Sectors

4.1 Overview

Climate change doesn't just pose significant challenges for our nation's ecosystems. Its impacts also are being increasingly felt in cities and towns, in industry, in agriculture—and in our daily lives. Farmers are being forced to cope with droughts and higher temperatures that stunt crops. Communities in Iowa, Tennessee, Vermont and many other places have been hit by unprecedented deluges that overwhelm storm sewers, flood basements and businesses, and sweep away bridges, culverts and roads. Utility companies are struggling to keep the power on during more severe heat waves and after bigger storms. And water managers, especially in the Southwest, are facing the prospect of a drier, hotter future with far less water available for thirsty cities (USGCRP 2009).

These threats have already prompted important adaptation efforts. Chicago is installing 'green' roofs and 'cool' pavement to tamp down anticipated heat waves (Hayhoe and Wuebbles 2010).Keene, NH, has upgraded stormwater systems and other infrastructure after being hit by devastating floods (City of Keene, New Hampshire 2007). Native Americans are moving entire villages in Alaska and making trout habitat more resilient in Michigan (Buehler 2011). Overall, at least 17 states have climate adaptation plans. At the federal level, adaptation efforts are being coordinated by the Interagency Climate Change Adaptation Task Force (ICCATF) and are described in the October 2012 Progress Report to the President on climate change adaptation.

Sometimes adaptation efforts taken by these other sectors can clash with the needs of ecosystems (maladaptation). For example, southwestern cities diversifying their water supplies may take vital water away from wildlife and farmers. But far more often, climate change adaptation can benefit multiple sectors. Restoring wetlands to provide more resilient habitats also works to improve water quality and slow floodwaters, for instance, helping downstream cities. Protecting coastal ecosystems also helps protect communities and industries along the coast. Moreover, research on the economics of climate adaptation shows that it can be far cheaper to spend some money now to become more resilient than to pay for damages caused by climate change later (ECA 2009).

In working to reduce climate change impacts on fish, wildlife, and plants, therefore, it is important to consider not only the impacts of other sectors, such as agriculture and industry, on these species and their ecosystems, but also to look for opportunities for coordinated adaptation strategies. Other sectors can also take actions that reduce non-climate stressors on ecosystems. For instance, precisely matching fertilizer amounts to the differing needs of each section of a field can cut overall fertilizer use and nutrient runoff, thus reducing the toxic algal blooms that stress aquatic ecosystems and increase their vulnerability to climate change.

It is outside the scope of this *Strategy* to describe in detail either the climate change impacts on other sectors or the sectors' adaptation needs. Instead this chapter simply summarizes those impacts and recommends actions for managers in these sectors to ensure that the needs of fish, wildlife and plants are considered in their climate adaptation efforts. For the reader's utility and quick reference, the corresponding National Actions from Chapter 3 are identified in parentheses along with the sector-specific recommendations.

Eight overarching climate adaptation strategies have been identified that are common to all sectors:

1. **Improve understanding and communication of impacts to fish, wildlife and plants from sectoral climate adaptation options.**

2. **Enhance coordination between sectors and natural resource managers, land use planners, and decision makers regarding climate change adaptation.**
3. **Use integrated planning to engage all levels of government (local, state, federal, and tribal) and multiple stakeholders in multi-sector planning (e.g., coastal and marine spatial planning).**
4. **Make best available science on the impact of climate change on fish, wildlife and plants accessible and useable for planning and decision-making across all sectors.**
5. **Explicitly incorporate fish, wildlife, and plants into sector-specific climate adaptation planning.**
6. **Improve, develop and deploy decision support tools, technologies, and best management practices that incorporate climate change information to reduce sector impacts on fish, wildlife, and plants.**
7. **Focus linear development (e.g., energy transmission, water pipelines, transportation) along corridors already developed for those purposes.**
8. **Expand compensatory mitigation activities for projects that reduce ecosystem resilience.**

4.1.1 Agriculture

Agriculture is expected to be most affected by changes in temperature and precipitation in a changing climate. Livestock and crops will experience stresses similar to those experienced by wild species. Shifting precipitation patterns will bring drought to certain areas and excess rainfall to others, likely reducing crop yields. Temperature and precipitation changes will cause shifts in the distributions of traditionally harvested crops. Many crops grow faster with small increases in temperature, but as temperatures climb more, growth and yields are predicted to drop. Livestock productivity will likely decrease due to heat stress, disease, and declining forage quality. CO_2 levels will likely have mixed effects on agriculture and aquaculture. Some crops grow faster with increased CO_2 levels, but not to the extent initially anticipated. Increased CO_2 in the marine environment will result in acidification and adversely impact aquaculture (Cooley et al. 2009).

How the agricultural sector responds to climate change will have an impact on ecosystems and species. More land is expected to be converted to agriculture due to increasing demand for food and biofuels. The changes in where crops are grown will also alter the locations of agricultural pests and pesticide usage. While the reduction of pesticide use in some areas can help fish, wildlife and plants, the increased presence of pests and pesticides in other areas may negatively affect populations. Excess runoff in areas with increased precipitation from storm events will lead to sediment and nutrient concerns for natural systems (such as eutrophication and hypoxia). Areas that experience drought will expect increased demand for irrigation, stressing already depleted water resources and habitat.

Sector Specific Actions:

— Agriculture 1: Develop and communicate key objectives for fish, wildlife and plants management under climate change to land owners, farmers, and managers in agricultural sectors. (see also National Action 3.1.4; 6.1.2)

— Agriculture 2: Revisit and update incentive structures for agriculture production in light of impacts to fish, wildlife and plants in a changing climate to ensure that the incentives encourage the behavior needed to safeguard fish, wildlife and plant resources. (see also National Action 7.2.2)

— Agriculture 3: Revisit and update Farm Bill conservation programs to ensure they are adequately addressing the new challenges for fish, wildlife and plants presented by climate change. (see also National Actions 1.2.4, 1.4.3, 1.4.4. 1.4.6, 7.1.2, 7.1.4)

Ecosystem Specific Actions:

— 2.1.8 Shrubland/Grasslands: Develop cattle grazing practices that function in ecosystems with reduced rainfall and increasing temperature.

— 7.1.6 Shrubland/Grassland: Support land trusts and farmland and ranchland preservation programs as a way to sustain habitat values on working landscapes.

— 7.2.9 Inland Waters/Coastal: Increase restoration and preservation of riparian zones and buffers in agricultural areas to minimize non-point source pollution.

— 7.3.7 Forests: Apply integrated pest management practices, share innovative control methodologies, and take corrective actions (e.g., silviculture measures, suppression or eradication) when necessary to manage forest diseases and insect pests.

COASTAL HABITAT CONSERVATION ON AGRICULTURAL LANDS

Enhanced management of agricultural wetlands along our coasts may represent the best opportunity to accommodate waterbirds displaced by wetland loss from sea-level rise.

The Texas-Louisiana Gulf Coastal Plain is one of three major rice growing regions in the United States. Extensive conversion of wet coastal prairie to agriculture began in the early 20th century; rice and crops or livestock produced in rotation with rice have become a major component of the contemporary landscape of the region. The 1.5 to 2 million acres of farmland in coastal Louisiana and Texas operated in rice-crayfish-fallow, rice-fallow, or rice-pasture rotational schemes simulate wet, early successional habitats that are highly attractive to wetland-associated wildlife. The economic value of Louisiana rice fields as habitat for waterbirds ($100 to $1028 per acre per year), may exceed net income derived from agricultural production ($55 to $208) per acre per year. Sea level rise threatens to inundate many of these lands.

In response to the Deepwater Horizon explosion in the Gulf of Mexico and the threat of massive oil contamination of coastal habitats critically important to resident and migratory birds, the Natural Resource Conservation Service launched the Migratory Bird Habitat Initiative (MBHI) to provide alternative habitats for waterbirds potentially impacted by the oil spill. The MBHI was tailored to address priority groups of birds identified by regional joint ventures and their conservation partners. Conservation programs authorized under the Farm Bill such as the Wildlife Habitat Incentives Program (WHIP), Environmental Quality Incentives Program (EQIP), and Wetlands Reserve Program (WRP) were adapted to compensate landowners willing to amend tillage and flooding practices to accommodate targeted waterbirds such as fall-migrating shorebirds and wintering and spring-migrating waterfowl. Almost one-half million acres of rice fields and crawfish and catfish ponds have been enrolled in MBHI at a cost of $40 million.

In Pacific Northwest estuaries, Ducks Unlimited and others are working to ensure that salt marsh birds and other species have adequate habitat in the future. The adaptation strategy is to target farmland adjacent to tidal wetlands for sea-level rise induced marsh migration, and protect these lands through easements. In this approach, conservation groups buy the development rights from a willing farmer, ensuring that no other land use except farming is allowed. At any point in the future, the property can then be sold for wetland restoration purposes. Restoring wetlands on lands like farmlands that have not been filled and developed with buildings and hard infrastructure is a cost effective and feasible approach.

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4.1.2 Energy Development

As the climate changes, people are expected to change the amount and type of energy they use. Human populations will also shift, requiring adjustments in power generation and delivery. Warming will decrease energy demand for heating (primarily fossil fuels) while increasing demand for cooling (primarily electricity). In addition to changes in consumer demand, changes in the physical environment will affect where renewable energy can be located. Changing precipitation patterns will affect renewable hydroelectric power and changing wind patterns will dictate the locations of wind turbines. Power infrastructure may become threatened by climate change impacts such as coastal inundation and river flooding as sea level rises and precipitation increases in some areas (IPCC AR4 2007).

Decisions made within the energy sector will affect fish, wildlife, and plants in a changing climate. Demand for renewable energy has increased and is expected to increase further as the use of solar, wind, and biofuels expands. As energy development expands to new areas, it will compete directly with fish, wildlife and plant resources. Development of access roads and transmission lines may cause habitat fragmentation and create avenues for pest infestation, disease, and colonization of invasive species. In the marine and coastal environment, increased energy generation, transportation and transmission may further stress fish, wildlife, and plant populations. Hydropower generation can create barriers to fish passage.

Sector Specific Actions:

— Energy Development 1: Provide incentives for energy production that facilitates or allows fish, wildlife and plant climate adaptation and remove subsidies that discourage or prevent fish, wildlife and plant climate adaptation. (see also National Actions 1.4.3, 1.4.4)

— Energy Development 2: Site new energy projects in disturbed areas or areas of least importance to fish, wildlife and plant climate adaptation; avoid areas of high importance or high vulnerability.

— Energy Development 3: Research alternative energy technologies that are climate adaptation-friendly to fish, wildlife, and plants.

— Energy Development 4: Promote adequate preparedness and response capacity for catastrophic events.

— Energy Development 5: Use native species and systems that mimic the natural system structure and use diverse taxa in biomass energy production.

Ecosystem Specific Actions:

— 1.4.8 Coastal: Assess and redesign or remove existing legacy structures (e.g., dams, hardened shorelines) to increase natural ecosystem resilience and allow for ecosystem function and species response to climate change.

— 7.1.11 Coastal: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).

— 7.2.11 Marine: Work with ocean-use planners to identify potentially conflicting needs and opportunities to minimize marine ecosystem degradation resulting from development and ocean-use change.

— 7.3.8 Forest/Grassland/Shrubland: Avoid use of potentially invasive species in biomass/biofuels energy production.

4.1.3 Society and Urbanization

Since U.S. cities, towns and communities developed during a period of relatively stable climatic conditions, many municipalities and urban centers are at risk of climate change. Sea level rise and changes in temperature and precipitation will have the greatest impact on society and urban centers.

Physical damage from storms, flooding, and sea level rise will threaten coastal infrastructure and development. Changing temperatures and precipitation patterns will affect the built environment and water resource availability. Increased temperatures and forest fires will reduce air quality and threaten life and property (McMahon 1999).

Human responses to climate change are expected to affect fish, wildlife, and plants in a number of ways. Human populations will shift to areas with ample resources while people that remain in areas without necessary resources will exert more effort to import those resources. The shifts in human population and the use of resources will strain the ecosystem services provided by the natural environment. Increased human demand for water resources will reduce water availability for fish, wildlife, and plants. The availability of culturally, commercially, and recreationally important species for human uses (e.g., fishing, hunting, watching) will change as species distributions respond to a changing climate and human population pressures. Availability and human use of those species will ultimately affect subsistence and commercial use, recreation, tourism and the economy. Also affecting the economy will be the response of harvestable resources (e.g., timber, fish) to a changing climate. Decisions made regarding development will affect fish, wildlife, and plant populations by reducing habitat availability, fragmenting habitats, and increasing multiple stressors. Development will be affected by the presence of species listed under the Endangered Species Act, and the number of listings will likely grow due to climate change.

STORMWATER RUNOFF

A major nonpoint source of pollution related to development along the coastline is stormwater runoff. Runoff degrades water quality, making it an important stressor affecting resilience and sustainability of coastal habitats and species. As a result of increasing development, impervious surfaces that do not allow rain to penetrate the soils (such as parking lots, roads and rooftops) increase the amount and peak flow of stormwater runoff. Changing precipitation patterns predicted with climate variability and change, especially increased frequency and intensity of heavy rains, will have a compounding effect on the amount of stormwater released into surrounding ecosystems

NOAA's Hollings Marine Laboratory has developed a stormwater runoff-modeling tool to predict the local impacts of development in a changing climate. Urbanized watersheds were compared with less-developed suburban and undeveloped forested watersheds to examine the relationship between land-use change and stormwater runoff and how this will be amplified under climate change.

This user-friendly and flexible tool provides a mechanism to quantify the volume of runoff and peak flow estimates under different land use and climate change scenarios. It provides an improved understanding of the impacts of development on stormwater runoff as well as the potential impacts associated with climate change in urbanized communities. Moreover, this research provides coastal resource managers with a tool to protect coastal habitat resiliency from both non-climatic stressors such as development as well as climate-associated stressors such as changing patterns of precipitation.

Sector Specific Actions:

— Society and Urbanization 1: Provide opportunities to engage many stakeholders in land use and resource use decisions that incorporate climate change considerations.

— Society and Urbanization 2: Anticipate changes in human demographic patterns in response to climate change, identify potential conflicts with the protection of fish, wildlife and plants, and develop possible solutions.

— Society and Urbanization 3: Incorporate habitat migration potential into land use planning and protect key corridors for species movement. (see also National Action 1.2.5)

- Society and Urbanization 4: Restore native habitats and species and promote use of native species in development standards. (see also National Action 7.1.4)
- Society and Urbanization 5: Change federal disaster relief and flood insurance programs to emphasize buyouts versus rebuilding in areas vulnerable to climate change impacts. (see also National Action 3.3.2)
- Society and Urbanization 6: Educate the public about ecosystems, ecosystem services, and anticipated climate changes and prepare the public for projected changes. (see also National Action 6.1.2)

Ecosystem Specific Actions:

- 3.3.5 Coastal: Modify policies and programs to create or strengthen disincentives for long-lived coastal development (infrastructure) and armoring (seawalls, revetments, etc.) necessary to protect areas vital to fish, wildlife and plant adaptation.
- 3.3.6 Coastal: Alter current policy and zoning in coastal areas to anticipate migratory nature of coastal habitats and prevent development in potential refugia and corridors.
- 7.1.11 Coastal: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).
- 7.1.12 Coastal: Fully internalize risks associated with coastal development into property owners' insurance rates to minimize loss of coastal habitat.
- 7.2.10 Inland Waters/Coastal: Reduce impacts of impervious surfaces and storm water runoff in urban areas to maintain and improve water quality, groundwater recharge and hydrologic function.
- 7.2.11 Marine: Work with ocean-use planners to identify potentially conflicting needs and opportunities to minimize marine ecosystem degradation resulting from development and ocean-use change.

4.1.4 Transportation and Infrastructure

Sea level rise and storm surge will increase the risk of flooding of coastal infrastructure. Flooding from increasingly intense rain events and snow melt will increase the risks of disruptions and delays in transportation and damage infrastructure. Increased intensity of hurricanes will lead to more evacuations, infrastructure damage, and transportation interruptions. Arctic warming will reduce sea ice, lengthening the ocean transport season but also causing greater coastal erosion from waves. Permafrost thaw in Alaska will damage infrastructure and make previous modes of transportation impossible in some areas.

Climate impacts to transportation and infrastructure that are particularly relevant to fish, wildlife, and plant climate adaptation include coastal and riparian flooding, which will also impact species and habitats. Damage to infrastructure from increasingly severe storms will exacerbate the release of pollutants and debris into ecosystems. Melting sea ice in the Arctic, and the associated opening of new areas to transportation, increases the risk of oil spills and injuries to whales from ships. Transportation and other infrastructure can fragment habitats and disrupt desirable connections between habitats. For example, roads and transmission lines can fragment habitats, preventing the movement of species and disrupting ecosystem functions. Meanwhile, transportation and other infrastructure can create unwanted habitat connectivity, facilitating the movement of predatory or invasive species. Shipping delivers invasive species in cargoes, such as food, in ship ballast water and attached to ships' hulls.

Sector Specific Actions:

- Transportation 1: Plan concurrently for inland or upslope migration of species and habitats and relocation of infrastructure in response to coastal inundation, riparian flooding, and loss of permafrost.

- Transportation 2: Avoid adaptation options, such as armoring of infrastructure, that prevent inland or upslope migration of species and habitats.
- Transportation 3: Site transportation corridors and infrastructure where it will have the least impact on species and ecosystem processes and provide opportunities for species migration (see also National Action 1.4.3).
- Transportation 4: Consider the full breadth of ecosystem services provided by habitats including carbon sequestration, and strive to retain habitats and habitat connectivity that build resilience for fish, wildlife, and plants. (see also National Action 1.2.5)
- Transportation 5: Consider collaborative development of design standards for fish, wildlife, and plant passage.
- Transportation 6: Identify and prioritize the removal of outdated and legacy infrastructure including dams. Provide financial incentives for upgrading or replacing outdated infrastructure that might impede ecosystem resiliency to climate change. (see also National Action 1.4.4)
- Transportation 7: Restore native species along highway corridors to build ecosystem resilience.
- Transportation 8: Reduce the potential of transportation corridors to serve as conduits for predators and invasive species that could harm ecosystem resilience. (see also National Action 1.4.5 and 7.2.5)
- Transportation 9: Develop strategies that minimize impacts of increased transportation in the Arctic marine environment, including assessing alternative routes to reduce potential impacts on fish, wildlife, and plants.

Ecosystem Specific Actions:

- 1.4.8 Coastal: Assess and where necessary redesign or remove existing legacy structures (e.g., dams, hardened shorelines) to increase natural ecosystem resilience and allow for ecosystem function and species response to climate change.
- 7.1.11 Coastal: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).
- 7.2.7 Tundra: Address and improve best management practices for freshwater withdrawals used for ice road construction.
- 7.2.10 Inland Waters/Coastal: Reduce impacts of impervious surfaces and storm water runoff in urban areas to maintain and improve water quality, groundwater recharge and hydrologic function.
- 7.3.9 Coastal/Marine: Implement best management practices to reduce the spread of invasive species through ballast water.

4.1.5 Water Resources

The availability of water resources depends on temperature and precipitation distributions that will shift in a changing climate. Drought will reduce surface water availability, thus increasing the use of groundwater. But drought will also reduce groundwater recharge, and increase the potential for water diversion. Areas that have traditionally relied on snowmelt as a water source are expected to receive less snowmelt, along with changes in the timing and amount of water delivery from melting snow. Other areas may receive higher amounts of precipitation, stressing existing retention and transport features and infrastructure and increasing flooding. Coastal areas will experience saltwater intrusion into aquifers as a result of sea level rise. Salinity and tidal regimes will move inland as sea level rises and coastal areas become inundated. In addition to affecting the amounts of available water, climate change can be expected reduce water quality, decreasing supplies of clean water (IPCC 2001).

Water resources are shared by fish, wildlife, and plants and many different human interests (e.g., agriculture, drinking water, manufacturing and energy). The balance of use and consumption will ultimately determine the quantity and quality of water available for fish, wildlife, and plants. Already under stress from climate change, fish, wildlife, and plant populations will be further stressed by the lack of available, high quality water resources.

Climate change impacts and adaptation needs for the water resources sector are described in much more detail in the recently published *National Action Plan: Priorities for Managing Water Resources in a Changing Climate*, which establishes 24 priority actions for federal agencies in managing freshwater resources in a changing climate. The recommended actions below draw from that work and identify key actions for the water resources sector to ensure the continued protection of fish, wildlife and plant resources.

Sector Specific Actions:

— Water Resources 1: Identify, protect, and restore key elements of watershed connectivity (e.g., streams/ floodplains, riparian areas, wetlands) to increase resilience and protect species movements. (see also National Actions 1.4.3, 1.4.4, 7.1.3).

— Water Resources 2: Conduct integrated water resources management and planning that considers climate change influences on aquatic ecosystems (see also National Action 3.3.4).

— Water Resources 3: Improve operation of water infrastructure projects to ensure that the quantity, quality, and timing of water flows needed for fish, wildlife, and plant resources are maintained under a changing climate. (see ecosystem specific actions below).

— Water Resources 4: Examine, and revise as needed, floodplain and coastal zone management practices to ensure that they provide incentives for protection of ecosystem services and that they increase ecosystem resilience to climate change (see also National Action 7.1.4).

— Water Resources 5: Identify, upgrade, or remove outdated sewer and stormwater infrastructure to reduce water contamination.

Ecosystem Specific Actions:

— 1.1.5 Inland Waters/Coastal: Identify and prioritize groundwater sources, recharge and discharge sites, and areas that provide sediment resources necessary for ecosystem processes.

— 1.4.8 Coastal: Assess and where necessary redesign or remove existing legacy structures (e.g., dams, hardened shorelines) to increase natural ecosystem resilience and allow for ecosystem function and species response to climate change.

— 2.1.10 Inland Water/Coastal: Develop basin-specific integrated water management plans that address in-stream flows, inter-basin water transfers, and surface and groundwater withdrawals while promoting water conservation and ecosystem function.

— 4.1.11 Coastal: Monitor and assess water levels in shallow coastal aquifers that support freshwater-dependent ecosystems.

— 5.2.13 Inland Water/Coastal: Conduct research to determine flows required to support sustainable populations of vulnerable species, such as during prolonged drought.

— 7.1.9 Inland Waters/Coastal: Work with local and regional water management districts to evaluate historical water quantities and base flows and develop flow release agreements to approximate natural flows.

— 7.1.11 Coastal: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).

Chapter 5: Integration and Implementation

5.1. How Federal Agencies, States, Tribes, and Other Partners Can Use this *Strategy*

As noted earlier, this *Strategy* is the first national-scale effort across all levels of government with authorities for fish, wildlife and plants to jointly identify the major strategies and initial actions needed to help our valuable living resources and the communities that depend on them deal with the challenges of climate change. Although the *Strategy* identifies some of the essential actions that can be taken or initiated in the next five to ten years, this is not a comprehensive action plan. Additional planning and action by federal, state and tribal governments and many partners is essential to realize the goals and strategies laid out here.

The *Strategy* builds upon and complements many existing climate adaptation efforts. Continuation and expansion of these efforts is critical to achieving the goals of this *Strategy*. First, many local governments and states have already begun to develop plans and adapt to climate change, either within their state fish and wildlife agencies, or more broadly within state government. For example, in February 2011, Washington State released the Washington State Integrated Climate Change Response Strategy, which explains the climate change adaptation priorities and potential strategies and actions to address those concerns. Additionally, the California Climate Adaptation Strategy was released in 2009, and Alaska's Climate Change Strategy was released in 2010. The number of state resource agencies with climate vulnerability and adaptation efforts underway is increasing, and this *Strategy* can serve as a resource for states and local governments.

Second, many multi-governmental and non-governmental partnerships already conduct sophisticated resource management planning that can incorporate climate change. Two examples are Joint Ventures and the National Fish Habitat Action Plan,[1] a partnership of federal agencies, states, tribes, conservation organizations and industry that's working to protect fish habitats in the United States. These efforts offer ideal opportunities to bring climate change information into existing resource management planning to ensure management actions advance adaptation in a changing climate. Such efforts can also draw upon a growing number of important tools and approaches for adaptation planning and action. For example, the non-profit organization Climate Adaptation Knowledge Exchange (CAKE)[2] provides detailed information and access to information, tools and case studies on adaptation to climate.

Many tribal governments and organizations are already experiencing the impacts of climate change on species, habitats and ecosystems that are vital to their cultures and economies. They understand the need to adapt. For example, the Swinomish Tribe in the Pacific Northwest, which depends on salmon and shellfish, has developed the Swinomish Climate Change Initiative. This effort seeks to assess local impacts, identify vulnerabilities, and prioritize planning areas and actions to address the impacts of climate change, and can serve as an example for other tribal governments.

A number of inter-agency climate adaptation efforts at the federal level are also underway. The U.S. Global Change Research Program[3] is responsible for publishing a National Climate Assessment every four years describing the extent of climate change in the United States and its impacts. The most recent

[1] http://fishhabitat.org/

[2] http://www.cakex.org

[3] http://www.globalchange.gov

national assessment was published in 2009 and provides the scientific foundation for this *Strategy*. The next assessment in 2013 will provide new information about impacts, opportunities, and vulnerabilities. It will also provide a basis for evaluating the effectiveness of the adaptation actions in this *Strategy* and determining next steps. In addition, the USGCRP has produced a series of 21 Synthesis and Assessment Products (SAPs)[4] on the current information regarding the sensitivity and adaptability of different natural and managed ecosystems and human systems to climate and related global changes. These reports address topics such as sea-level rise (SAP 4-1), ecosystem change (SAP 4-2), agriculture, biodiversity, land and water resources (SAP 4-3), adaptation options for climate-sensitive systems and resources (SAP 4-4), energy production (SAP 4-5), human health (SAP 4-6) and transportation (SAP 4-7).

Another important entity is the Interagency Climate Change Adaptation Task Force,[5] which was established in 2009 to help the federal government and partners understand, prepare for, and adapt to the impacts of climate change. The Interagency Task Force has launched several efforts to advance climate adaptation that both inform this *Strategy* and provide opportunities for the *Strategy's* implementation. One of these is the *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate* (Freshwater Action Plan). Released in October of 2011, the Freshwater Action Plan describes the challenges that a changing climate presents for the management of the nation's freshwater resources, and recommends a set of actions federal agencies can take to help freshwater resource managers reduce the risks of climate change. In addition, the National Ocean Council (NOC) is creating a *Resiliency and Adaptation to Climate Change and Ocean Acidification Strategic Action Plan* (Ocean SAP) to respond to the challenges posed by climate change and ocean acidification. A draft Ocean SAP was released for public comment in November of 2011; the final plan is expected by the spring of 2012. This *Strategy* has been developed in coordination with both the Freshwater Action Plan and the Ocean SAP so that the three strategies support and reinforce each other.

In addition, following direction from Presidential Executive Order 13514 and the Interagency Task Force, the Council on Environmental Quality issued guidance to all federal agencies to launch climate change adaptation planning. This presents many opportunities for the resource management agencies involved in the development of this *Strategy* to develop their own agency-specific plans (if they have not already done so) and to interact with other agencies whose programs may influence their prospects for success. Many federal agencies have already conducted assessments of their vulnerability to climate change, and are developing adaptation plans to reduce risks, respond to impacts and take advantage of possible beneficial changes of a changing climate. This *Strategy* can serve as a useful resource to all these efforts.

5.2 Strategy Implementation

This *Strategy* is a call to action and blueprint to meet the challenges of safeguarding the nation's fish, wildlife and plants and the communities and economies that depend on them in a changing climate. To position the nation for action, this *Strategy* identifies seven major goals, then offers strategies and actions that government and conservation partners can implement (or initiate) over the next five to ten years.

Federal, state, and tribal governments and conservation partners are encouraged to read the document in its entirety to identify areas of overlap between the *Strategy* and their mission areas and activities. These entities are encouraged to identify existing and new efforts that help advance the goals and strategies in this document. Successful implementation of this *Strategy* will take commitment and resources by

[4] http://www.globalchange.gov/publications/reports

[5] http://www.whitehouse.gov/administration/eop/ceq/initiatives/adaptation

government and non-government entities, and must include steps to evaluate, learn and adjust our course of action as needed to achieve our goals in changing world. To ensure effective coordination, implementation, tracking and updating of the *Strategy*, this report proposes the following steps:

1. Federal, state and tribal governments and conservation partners will incorporate appropriate elements of the *Strategy* (goals, strategies and actions) into their plans and actions at national to local levels (e.g., development of implementation plans by federal, state, tribal governments).
   - Landscape Conservation Cooperatives (LCCs), Climate Science Centers (CSCs) and other regional collaborative efforts will use the *Strategy* as a resource for guiding their future science and assessment agendas and adaptation strategies.
   - State wildlife action plans will use this *Strategy*, the Association of Fish and Wildlife Agencies' publication, *Voluntary Guidance for States to Incorporate Climate Change into State Wildlife Action Plans and Other Management Plans*, and other appropriate resources to design and deliver programs and actions that advance adaptation of fish and wildlife resources in a changing climate.
2. Federal agencies with programs that affect fish, wildlife and plants and the habitats they depend on will incorporate appropriate elements of the *Strategy* into the agency adaptation plans they are developing under EO 13514.
   - Federal members of the Strategy Steering Committee will assign lead roles and implementation timelines for implementation of the *Strategy* across the federal sector. These assignments will be incorporated into each agency's climate adaptation plan.
3. A new coordinating body with representation from federal, state, and tribal governments will be established by June 30, 2012. This body will meet on a quarterly basis to evaluate implementation of the *Strategy* and will report progress to Congress, CEQ and federal, state and tribal fish and wildlife agencies on an annual basis, with the first report due in June 2013.
   - This coordinating body will be tasked with promoting awareness, understanding and use of the *Strategy* as a key tool in addressing climate change.
   - Starting in June 2017, the coordinating body, with support from DOI and CEQ, will start a revision of the *Strategy*, to be completed by June 2018.
   - The coordinating body will establish a FACA-chartered advisory committee with representatives of conservation partners, natural resource industries, and private landowners to assist with Strategy implementation and revision.

This *Strategy* is the beginning of an historic, unprecedented effort to safeguard the nation's fish, wildlife, plants and the communities and economies that depend on them in a changing climate. Lying ahead is an immense and challenging task, and much remains to be learned about the specific impacts of climate change and the responses of plants, wildlife and ecosystems. New climate change and adaptation science is coming out almost daily, and will help guide the way. But we know enough now to begin taking effective action to reduce risks and increase resiliency of these valuable natural resources – and we can't afford to wait to respond to the changes we're already seeing, or to prepare for those yet to come. Unless the nation begins a serious effort to undertake this task now, we risk losing priceless living systems—and the countless benefits and services they provide—as the climate inexorably changes. This *Strategy* offers a common blueprint for action to start the nation down the path to a meaningful adaptation response, and will help ensure that the nation's valuable fish, wildlife, plants and ecosystems continue to provide important products and services to communities all across the country.

Appendix 1: Forest Ecosystems

What's at Risk?

Forests systems are of tremendous value in the United States both for the fish, wildlife and plants they support and the ecosystem services they provide to humans. For the purposes of the *Strategy*, forests include all areas within the United States and US-affiliated Pacific and Caribbean islands typified by deciduous, evergreen, or mixed vegetation that exceeds ten percent crown closure and attains a height of at least five meters at maturity. This definition encompasses both forested areas as well as the embedded natural features within those landscapes, such as streams, meadows, cliffs, talus, barrens, wetlands, windthrow gaps, caves, sinkholes, and other small openings. Alpine landscapes, where they occur above treeline, are also included with this system.

As the climate changes, the dependence of humans on essential ecosystem services provided by forests will likely increase. Forests regulate the timing and flow of surface and groundwater discharges to streams, rivers, reservoirs, and bays; improve and protect water and air quality; store and sequester carbon; control stormwater runoff and prevent flooding; reduce stream temperature; reduce urban heat and provide energy savings; provide wildlife habitat; maintain pollinator communities; protect aquatic resources such as fisheries; provide recreational opportunities; and offer cultural, health, and historic connections between humans and the environment.

Every year, to meet U. S. demand, about 17 billion square feet of roundwood is harvested (based on 2005 statistics).[i] In 2008, 98.8 thousand Americans were directly employed in either logging or forestry,[ii] and this is a small proportion of the total employment associated with milling, transportation, retail sales, paper production, and the plethora of dependent industries ranging from furniture manufacture to home construction, to the publication of books and magazines. Forests are also an important source of non-timber forest products (NTFP), such as berries, mushrooms, bark, leaves, and roots that are harvested for personal and commercial use as foods, medicines, and floral products. Surveys suggest that nearly one-quarter of the U.S. population may participate in at least casual gathering of NTFPs.[iii]

Many species depend on large unfragmented blocks of forest habitat for purposes of migration as temperatures change. Native forest species also depend on habitat that is not overwhelmed by invasive species that may cause disruption to normal ecosystem processes.

Impacts of Climate Change

Appendix Table 1: Major Climate Change Impacts on Forest Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Forests
Increased atmospheric CO_2:	May increase forest productivity and growth in some areas
Increased temperatures:	Increase in major forest pest damage: tens of millions of acres already affected
Melting ice:	Reduced survival of insulation-dependent forest pests
Changing precipitation patterns:	Fire season length and frequency/severity of wildfires have increased and will continue
Drying conditions/drought:	Decreased forest productivity and increased tree mortality
More extreme rain/weather events:	Increased forest disturbance, more young forest stands

Summary of Adaptation Goals, Strategies and Actions – Forest Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority forest areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change)[6]

— 1.1.2: Identify and prioritize forest areas currently experiencing rapid climate impacts (e.g., high alpine areas).

— 1.1.3: Establish and maintain a comprehensive, inter-jurisdictional inventory of current and candidate high priority conservation areas in order to coordinate future protection efforts.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.5: Identify and pursue opportunities to increase conservation of priority forest lands by working with managers of existing public lands such as military installations or state lands managed for purposes other than conservation.

— 1.2.6: Identify and conserve large blocks of contiguous, unfragmented forest and aim for representation and redundancy of all forest types, vegetation mosaics, and natural disturbance regimes (coarse filter' conservation approach).

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.1: Develop and implement restoration protocols and techniques that promote forest ecosystem resilience and facilitate adaptation under a range of possible future conditions.

— 1.3.4: Restore natural disturbance regimes wherever possible, including instituting human-assisted disturbance (e.g., prescribed fire) to augment natural processes and mimic natural patterns and recurrence for specific ecological systems.

— 1.3.5: Develop market-based incentives that encourage reforestation in forested systems where appropriate.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

[6] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current forest conservation areas.
— 1.4.5: Assess and take steps to reduce risks of facilitating movement of undesirable non-native species, pests and pathogens.
— 1.4.7: Protect transitional areas between connected forests and forests fragmented by human land use to limit further habitat loss or degradation.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.4: Review and revise as necessary techniques to maintain or mimic natural disturbance regimes and protect vulnerable habitats.
— 2.1.6: Conduct treatments such as prescribed burning, planting, and thinning to reduce excessive fuel loads, select stress-tolerant species and genotypes, manage age classes, and reduce competition where appropriate.
— 2.1.7: Create forest landscape patterns with many age classes and diverse species and seed sources.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement forest species-specific management actions.
— 2.2.2: Actively manage populations of vulnerable species as part of timber and non-timber forest product management activities (e.g., harvest limits, seasons, and supplementation) to maintain biodiversity, human use, and other ecological functions.
— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

— 2.3.1: Protect and maintain high quality wildland seed sources including identifying areas for seed collection across elevational and latitudinal ranges of target species.
— 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.
— 2.3.3: Conduct treatments, such as planting, girdling, prescribed burning, and thinning to select stress-tolerant species and genotypes, manage age classes, and reduce inter-tree competition.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

- 3.1.1: Build on existing needs assessments to identify gaps in climate change knowledge and technical capacity among natural resource professionals.
- 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).
- 3.1.7: Foster interaction among landowners, local experts and specialists to identify opportunities for adaptation and to share resources and expertise that otherwise would not be available to many small forest landowners.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

- 3.2.1: Use regional venues such as Landscape Conservation Cooperatives (LCCs) to collaborate across jurisdictions and develop forest conservation goals and landscape scale plans capable of sustaining fish, wildlife and plants at desired levels.
- 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.
- 3.2.5: Engage with international neighbors, including Canada and Mexico, to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

- 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.
- 3.3.3: Continue the ongoing work of the Joint State Federal Task Force on Endangered Species Act Policy to ensure that policies guiding implementation of the Endangered Species Act provide appropriate flexibility to address climate change impacts on listed fish, wildlife and plants and to integrate the efforts of federal, state, and tribal agencies to conserve listed species.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
- 3.4.3: Collaborate with state and tribal agencies and private conservation partners to sustain authorization and appropriations for the State and Tribal Wildlife Grants program.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.7: Develop, refine, and implement monitoring protocols that provide key information needed for managing forest systems (e.g., expand Forest Inventory and Analysis sampling to include additional variables).

— 4.1.8: Inventory and evaluate conservation value of existing ex situ forest germplasm resources to target underrepresented forest areas or species that should be prioritized in light of climate change.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for fish, wildlife and plants.

— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact forest fish, wildlife and plants.

— 4.2.5: Use observation, information, assessment and decision support systems to monitor and determine the effectiveness of specific management actions to analyze the potential for maladaptations and adapt management approaches appropriately.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

- 5.2.2: Support basic research on life histories of forest species to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.6: Quantify the value of ecosystem services and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.
- 5.2.7: Investigate how key species move through forest landscapes (permeability) for key species.
- 5.2.8: Increase research on pollination, dispersal, food web dynamics, and other species interactions to better understand ecological interrelationships among forest-dependent fish, wildlife and plants.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

- 5.3.2 Conduct vulnerability assessments for priority forest species (e.g., threatened and endangered species, species of greatest conservation need, and species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.3 Define the suite of physical and biological variables and ecological processes for which predictive models are needed via a collaborative process among state, federal and tribal resource managers and model developers.
- 5.3.4 Develop climate sensitive growth and yield models for tree species to ensure long-term sustainability of forest habitats.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

- 7.1.1: Work with local land-use planners to identify shared interests and potential conflicts in reducing and reversing forest habitat fragmentation and loss through comprehensive planning and zoning.
- 7.1.5: Bridge the gap between ecosystem conservation and economics, and consider market-based incentives that encourage afforestation in forested systems.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

- 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize forest ecosystem degradation resulting from development and land-use change.
- 7.2.4: Regulate ungulate herbivory populations to promote and protect regeneration.
- 7.2.5: Promote urban forestry practices that provide multiple ecosystem services and benefits - including improved air quality, habitat connectivity, and recreational.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

- 7.3.1: Use observation and monitoring networks for early detection of invasive species.
- 7.3.7: Apply integrated pest management practices, share innovative control methodologies, and take corrective actions (e.g., silviculture, suppression or eradication) when necessary to manage forest diseases and insect pests.
- 7.3.8: Avoid use of potentially invasive species in biomass/biofuels energy production in sensitive areas.

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[i] Howard, J.L. 2007. U.S. timber production, trade, consumption, and price statistics 1965 to 2005. Research Paper FPL-RP-637. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 91 p

[ii] Bureau of Labor Statistics; http://www.bls.gov/oco/cg/cgs001.htm#emply

[iii] Cordell, H.K. and M.A. Tarrant. 2002. Forest-based outdoor recreation. In: Wear, D.N.; Greis, J.G., eds. Southern forest resource assessment. Gen. Tech. Rep. SRS–53. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 269-282.

Appendix 2: Shrubland Ecosystems

What's at Risk?

Shrublands of various types and sizes occur throughout the United States, totaling approximately 480 million acres.[iv] For purposes of the *Strategy*, shrublands are landscapes dominated by woody shrub species, often mixed with grasses and forbs (non-woody flowering plants). Major shrubland systems include the intermountain sagebrush steppe, California chaparral, as well as Texas Tamaulipan Thornscrub and Edwards Plateau regions.

Shrublands provide habitat for numerous native plant and animal species. Sagebrush habitats alone support more than 400 plant species and 250 wildlife species,[v] including 100 birds and 70 mammals.[vi] In addition to supporting livestock grazing on millions of acres of public lands in the west, shrublands also provide the public with recreational opportunities, which serve as an important source of jobs and income in the U.S.[vii] and particularly benefit rural communities.[viii] Shrubland ecosystems also provide critical regulating and supporting services tied to water quality and quantity, including watershed protection, erosion control, flood protection, and groundwater recharge.

In addition to agricultural conversion, livestock grazing has drastically altered remaining shrubland communities, decreasing abundance of associated herbaceous species, increasing sagebrush density and cover as well as bare ground, and shifting community composition and structure to favor exotic herbaceous species such as cheatgrass, yellow star thistle, and knapweed.[ix] Almost one-fifth of native grassland and shrubland animal species are already considered to be at risk, making them even more vulnerable to the impacts of climate change.[x] Climate change will increase the risk to shrubland species because many already live near their physiological limits of water and temperature stress.

Impacts of Climate Change

Appendix Table 2: Major Climate Change Impacts on Shrubland Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Shrublands
Increased atmospheric CO_2:	Increase spread of exotic species such as cheatgrass
Increased temperatures:	Intensified water stress through increased evapotranspiration
Melting ice	Reduced snowpack changes water flows
Changing precipitation patterns:	Dry areas getting drier
Drying conditions/drought:	Decline in prairie pothole wetlands, loss of nesting habitat
More extreme rain/weather events:	More variable soil water content

Summary of Adaptation Goals, Strategies and Actions – Shrubland Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority shrubland areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change).[7]

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.4: Work with partners to maximize use of existing conservation easement programs, particularly the conservation titles of the Farm Bill, to protect private shrublands of high conservation value and to maintain working landscapes under climate change.
— 1.2.5: Identify and pursue opportunities to increase conservation of priority shrublands by working with managers of public lands such as military installations or state lands managed for purposes other than conservation.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.
— 1.3.4: Restore natural disturbance regimes wherever possible, including instituting human-assisted disturbance (e.g., prescribed fire) to augment natural processes and mimic natural patterns and recurrence.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current shrubland conservation areas.
— 1.4.3: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches.
— 1.4.4: Identify and remove or mitigate physical barriers to movement and dispersal within and among habitats (e.g., high fences, major highways).

[7] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem..

— 1.4.6: Provide landowners and stakeholder groups with incentives to maximize use of existing conservation easement programs, such as the conservation titles of the Farm Bill, to protect private lands of high connectivity value under climate change.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into shrubland management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.

— 2.1.4: Review and revise as necessary techniques to maintain or mimic natural disturbance and protect vulnerable habitats, including working with National Interagency Fire Center to determine appropriate fire regimes.

— 2.1.8: Develop cattle grazing practices that function in ecosystems with reduced rainfall and increasing temperature.

— 2.1.9: Participate in USDA/NRCS state technical committees to encourage incorporation of climate change into species status assessments and within future federal Farm Bill programs.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement species-specific management actions for shrubland species.

— 2.2.2: Actively manage populations (e.g., harvest limits, seasons, and supplementation) of vulnerable species to maintain biodiversity, human use, and other ecological functions.

— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

— 2.3.1: Protect and maintain high quality wildland seed sources including identifying shrubland areas for seed collection across elevational and latitudinal ranges of target species.

— 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.

— 2.3.4: Bank seed and develop and deploy as appropriate shrubland plant materials that will be resilient in response to climate change.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

- 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.
- 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).
- 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop inter-agency communities of practice about climate change adaptation.
- 3.1.7: Increase scientific capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to shrubland species.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

- 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.
- 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

- 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
- 3.4.4: Collaborate with agricultural interests (e.g., American Farm Bureau Federation) to seek increased priority for funding of the conservation titles of the Farm Bill.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation.

— 4.1.4: Develop sentinel site networks for integrated climate change inventory, monitoring, research, and education.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for shrubland fish, wildlife and plants.

— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact shrubland species.

— 4.2.4: Ensure the availability and provide guidance for decision support tools that assist federal, state and tribal resource managers as well as local governments in effectively managing shrubland species in a changing climate.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address shrubland management objectives under climate change.

— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., glaciated areas) or highly vulnerable species.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

- 5.2.2: Support basic research on life histories of shrubland fish, wildlife and plants to increase understanding of how these species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.5: Assess potential success and unanticipated consequences of assisted migration and translocation for species at-risk from climate change.
- 5.2.6: Quantify the value of shrubland ecosystem service and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.
- 5.2.9: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change.
- 5.2.10: Increase understanding of the adaptive capacity of shrubland communities and species under climate change.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

- 5.3.2: Conduct vulnerability assessments for priority shrubland species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
- 5.3.5: Model climate change impacts on vulnerable shrubland species, including future distributions and the probability of persistence.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

- 7.1.2: Work with farmers and ranchers to apply the incentive programs in the conservation titles of the Farm Bill to minimize conversion of shrubland habitats, restore marginal agricultural lands to habitat, and to increase riparian buffer zones.
- 7.1.4: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts to shrublands, and to promote habitat restoration in desirable locations.
- 7.1.6: Support land trusts and farmland and ranchland preservation programs as a way to sustain habitat values on working landscapes.

— 7.1.7: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded shrubland areas.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

— 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize shrubland degradation resulting from development and land-use change.

— 7.2.2: Work with farmers and ranchers to develop and implement livestock management practices to reduce and reverse habitat degradation and protect regeneration.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

— 7.3.1: Use observation and monitoring networks for early detection of invasive species

— 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to shrubland ecosystems.

— 7.3.8: Avoid use of potentially invasive species in biomass/biofuels energy production in sensitive areas.

[iv] Heinz Center (The H. John Heinz III Center for Science, Economics and the Environment). 2008. Heinz Report: Grasslands and Shrublands. The State of the Nations Ecosystems. Island Press, Washington, D.C.

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[vi] Baker, M.F., R.L. Eng, J.S. Gashwiler, M.H. Schroeder, and C.E. Braun. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bull. 88:165-171.,
McAdoo, J.K., B. W. Schultz, and S.R. Swanson. 2003. Habitat management for sagebrush-associated wildlife species. Fact Sheet -03-65. University of Nevada Cooperative Extension.

[vii] U.S. DOI (U.S. Department of the Interior), Fish and Wildlife Service, and U.S. Department of Commerce, U.S.Census Bureau. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation.

[viii] Lal et al. 2011

[ix] Chambers JC, BA Roundy, RR Blank SE Meyer. 2007. What makes Great Basin sagebrush ecosystems invasible by Bromus tectorum? Ecological Monographs 77(1):117-145.

[x] Heinz Center. 2008.

Appendix 3: Grassland Ecosystems

What's at Risk?

Grasslands of various types and sizes occur throughout the United States covering much of the interior of the continent between the upper Midwestern states to the Rocky Mountains, and from Canada to the central Gulf Coast.[xi] For the purposes of the *Strategy*, grassland ecosystems are areas dominated by grasses and forbs (broad-leafed herbaceous plants). This definition includes tallgrass, shortgrass, and mixed-grass systems, as well as embedded features such as the shallow, ephemeral wetlands known as prairie potholes and playas that dot the Great Plains.

Grasslands support a diverse number of species, including many that are dependent on this habitat. They play an exceptionally important role in the provisioning of our national economy, as grasslands form the heart of our nation's agricultural landscape. Tallgrass and mid-grass prairie in particular serve as the American breadbasket, while shortgrass prairie is also used for livestock grazing. A substantial majority of U.S. grasslands are privately held, and agriculture is by far the dominant use of these lands. Grasslands also provide an array of functions important to human health and well-being, such as their ability to store carbon. Increases in the amount of carbon stored in grassland soils may help offset some emissions of carbon dioxide that drive global warming. Grasslands ecosystems are also important for maintaining hydrological and nutrient cycling services for both terrestrial and aquatic ecosystems.

The greatest existing stressors for grassland ecosystems in the United States is land conversion, primarily for agricultural production, as well as the spread of invasive species through various mechanisms. Climate change is likely to combine with other existing stressors to further increase the vulnerability of grasslands to pests, invasive species, and loss of native species. Grassland function is tied directly to temperature, precipitation, and soil moisture, and changes in carbon dioxide concentrations, temperature, and water availability are likely to lead to shifts in structure, function, and composition of this system.

Impacts of Climate Change

Appendix Table 3: Major Climate Change Impacts on Grassland Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Grasslands
Increased atmospheric CO_2:	Changes in ratios of C3 to C4 plants, increased C:N ratios
Increased temperatures:	Spread of non-native pests, such as fire ants
Melting ice	Reduced snowpack changes water flows
Changing precipitation patterns:	Invasion of non-native grasses and pests, species range shifting
Drying conditions/drought:	Decline in prairie pothole wetlands, loss of nesting habitat

Summary of Adaptation Goals, Strategies and Actions – Grassland Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority and important core grassland areas for protection using satellite imagery, species distributions, vegetation classification, land cover, and geophysical settings (including areas of rapid change and slow change).[8]

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.4: Work with partners to maximize use of existing conservation easement programs, particularly the conservation titles of the Farm Bill, to protect private grasslands of high conservation value and to maintain working landscapes under climate change.

— 1.2.5: Identify and pursue opportunities to increase conservation of priority grasslands by working with managers of public lands such as military installations or state lands managed for purposes other than conservation.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.

— 1.3.4: Restore natural disturbance regimes wherever possible, including instituting human-assisted disturbance (e.g., prescribed fire) to augment natural processes and mimic natural patterns and recurrence.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current grassland conservation areas.

— 1.4.3: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches.

— 1.4.4: Identify and remove or mitigate physical barriers to movement and dispersal within and among habitats (e.g., high fences, major highways).

[8] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

— 1.4.6: Provide landowners and stakeholder groups with incentives to maximize use of existing conservation easement programs, such as the conservation titles of the Farm Bill, to protect private lands of high connectivity value.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into grassland management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.

— 2.1.3: Identify transitional species and habitats (e.g., cool season to warm season grasslands) and develop management strategies and approaches for adaptation.

— 2.1.4: Review and revise as necessary techniques to maintain or mimic natural disturbance and protect vulnerable habitats, including working with National Interagency Fire Center to determine appropriate fire regimes.

— 2.1.8: Develop cattle grazing practices that function in ecosystems with reduced rainfall and increasing temperature.

— 2.1.9: Participate in USDA/NRCS state technical committees to encourage incorporation of climate change into species status assessments and within future federal Farm Bill programs.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement species-specific management actions for grassland species.

— 2.2.2: Actively manage populations (e.g., using harvest limits, seasons, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions.

— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

— 2.3.1: Protect and maintain high quality wildland seed sources including identifying grassland areas for seed collection across elevational and latitudinal ranges of target species.

— 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.

— 2.3.4: Bank seed and develop and deploy as appropriate grassland plant materials that will be resilient in response to climate change.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

— 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.

— 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).

— 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop inter-agency communities of practice about climate change adaptation.

— 3.1.8: Increase scientific capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to grassland species.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

— 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.

— 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

— 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

— 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.

— 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.

— 3.4.4: Collaborate with agricultural interests (e.g., American Farm Bureau Federation) to seek increased priority for funding of the conservation titles of the Farm Bill.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation.

— 4.1.4: Develop sentinel site networks for integrated climate change inventory, monitoring, research, and education.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for grassland fish, wildlife and plants.

— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact grassland species.

— 4.2.4: Ensure the availability and provide guidance for decision support tools that assist federal, state and tribal resource managers as well as local governments in effectively managing grassland species in a changing climate.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address grassland management objectives under climate change.

— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., glaciated areas) or highly vulnerable species.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

- 5.2.2: Support basic research on life histories of grassland fish, wildlife and plants to increase understanding of how these species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.5: Assess potential success and unanticipated consequences of assisted migration and translocation for species at-risk from climate change.
- 5.2.6: Quantify the value of grassland ecosystem service and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.
- 5.2.9: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change.
- 5.2.10: Increase understanding of the adaptive capacity of grassland communities and species under climate change.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

- 5.3.2: Conduct vulnerability assessments for priority grassland species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
- 5.3.5: Model climate change impacts on vulnerable grassland species, including future distributions and the probability of persistence.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

- 7.1.2: Work with farmers and ranchers to apply the incentive programs in the conservation titles of the Farm Bill to minimize conversion of grassland habitats, restore marginal agricultural lands to habitat, and to increase riparian buffer zones.

- 7.1.4: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts to grasslands, and to promote habitat restoration in desirable locations.
- 7.1.6: Support land trusts and farmland and ranchland preservation programs as a way to sustain habitat values on working landscapes.
- 7.1.7: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded grasslands areas.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

- 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize grassland degradation resulting from development and land-use change.
- 7.2.2: Work with farmers and ranchers to develop and implement livestock management practices to reduce and reverse habitat degradation and protect regeneration.
- 7.2.6: Reduce existing pollution and contaminants and increase monitoring of air and water pollution.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

- 7.3.1: Use observation and monitoring networks for early detection of invasive species
- 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to grassland ecosystems.
- 7.3.8: Avoid use of potentially invasive species in biomass/biofuels energy production in sensitive areas.

[xi] CEC (Commission for Environmental Cooperation). 1997. Ecological regions of North America: toward a common perspective. Commission for Environmental Cooperation, Montreal, Quebec, Canada. 71p. Revised 2006.,
Heinz Center (The H. John Heinz III Center for Science, Economics and the Environment). 2008. Heinz Report: Grasslands and Shrublands. The State of the Nations Ecosystems. Island Press, Washington, D.C.

Appendix 4: Desert Ecosystems

What's at Risk?

Deserts are characterized by temperate climates having low annual rainfall, high evaporation, and large seasonal and diurnal temperature contrasts. The hot desert systems of the United States include the Mohave, Sonoran and Chihuahuan Deserts, located in the Basin and Range Province of the western U.S. between the Rocky Mountains on the east and the Sierra Nevada on the west.[xii] This definition includes embedded features such as "sky islands" and mosaics of grasses and shrubs.

Desert systems play a role in regulating and supporting ecosystem processes and providing cultural and recreational services in addition to dust control, biodiversity, aesthetic value, and habitat connectivity.[xiii] As more private lands are developed in the U.S for human uses, public lands will play an even larger role in biodiversity conservation serving as refugia for species and natural vegetation communities, and for providing ecosystem services such as flood protection, water purification, groundwater recharge, pollination, and nutrient cycling, among others.[xiv] Desert systems also harbor a high proportion of endemic plants, reptiles, and fish.

Threats from water mismanagement, inappropriate grazing by livestock, agricultural expansion, a lack of law enforcement, and introduced and exotic species are expected to result in further loss of desert species and habitats.[xv] Arid desert ecosystems are particularly susceptible to climate change and climate variability, as slight changes in temperature, precipitation regimes, or the frequency and magnitude of extreme events could substantially alter the distribution and composition of natural communities and disrupt the services that arid lands provide.[xvi]

Impacts of Climate Change

Appendix Table 4: Major Climate Change Impacts on Deserts Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Deserts
Increased temperatures:	Elevated water stress, mortality in heat-sensitive species, possible desert expansion
Melting ice	Reduced snowpack changes water flows
Changing precipitation patterns:	Loss of riparian habitat and movement corridors
Drying conditions/drought:	Water stress and increased susceptibility to plant diseases, increased soil erosion
More extreme rain/weather events:	Higher losses of water through run-off

Summary of Adaptation Goals, Strategies and Actions – Desert Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority desert areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change).[9]

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.1: Conserve desert areas that provide habitats under current climate conditions and are likely to provide habitat in the future (including thermal refugia).

— 1.2.5: Identify and pursue opportunities to increase conservation of priority desert areas by working with managers of public lands such as military installations or state lands managed for purposes other than conservation.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current desert conservation areas.

— 1.4.3: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches.

— 1.4.4: Identify and remove or mitigate physical barriers to movement and dispersal within and among habitats (e.g., high fences, major highways).

[9] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into desert management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.

— 2.1.5: Review and revise as necessary existing species and habitat impact minimization, mitigation and compensation standards (e.g., under NEPA) and develop new standards as necessary to address impacts to desert systems associated with climate change.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement species-specific management actions for desert species.

— 2.2.2: Actively manage populations (e.g., using harvest limits, seasons, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions.

— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

— 2.3.1: Protect and maintain high quality wildland seed sources including identifying desert areas for seed collection across elevational and latitudinal ranges of target species.

— 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.

— 2.3.4: Bank seed and develop and deploy as appropriate desert plant materials that will be resilient in response to climate change.

GOAL 3: Enhance capacity for effective management in a changing climate. .

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

— 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.

— 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).

— 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share

experience and develop inter-agency communities of practice about climate change adaptation.
- 3.1.8: Increase scientific capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to desert species.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

- 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.
- 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.
- 3.2.5: Engage with international neighbors including Mexico and others to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

- 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

- 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.
- 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment) to support integrated national observation and information systems that inform climate adaptation.

— 4.1.4: Develop sentinel site networks for integrated climate change inventory, monitoring, research, and education.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for desert fish, wildlife and plants.
— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact desert species.
— 4.2.4: Ensure the availability and provide guidance for decision support tools that assist federal, state and tribal resource managers as well as local governments in effectively managing desert species in a changing climate.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.
— 5.1.2: Bring managers and scientists together to prioritize research needs that address desert management objectives under climate change.
— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., glaciated areas) or highly vulnerable species.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

— 5.2.2: Support basic research on life histories of desert fish, wildlife and plants to increase understanding of how these species are likely to respond to changing climate conditions and identify survival thresholds.
— 5.2.5: Assess potential success and unanticipated consequences of assisted migration and translocation for species at-risk from climate change.
— 5.2.6: Quantify the value of desert ecosystem service and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.
— 5.2.9: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change.
— 5.2.10: Increase understanding of the adaptive capacity of desert communities and species under climate change.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

— 5.3.2: Conduct vulnerability assessments for priority desert species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
— 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
— 5.3.5: Model climate change impacts on vulnerable desert species, including future distributions and the probability of persistence.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

— 7.1.4: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts to deserts, and to promote habitat restoration in desirable locations.
— 7.1.7: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded desert lands.
— 7.1.8: Reduce the footprint of energy development and mining activities in desert systems.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

— 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize desert degradation resulting from development and land-use change.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

— 7.3.1: Use observation and monitoring networks for early detection of invasive species

— 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to desert ecosystems.

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Barrows, C.W., Rotenberry, J.T., & Allen, M.F. 2010. Assessing sensitivity to climate change and drought variability of a sand dune endemic lizard. Biological Conservation 143:731-736.

Appendix 5: Tundra Ecosystems

What's at Risk?

Arctic tundra is the ecological zone of the polar regions of the earth, occurring mainly north of the Arctic Circle and north of the boreal forest zone. Tundra is characterized by an absence of trees, and occurs where tree growth is limited by low temperatures and short growing seasons. In the United States, Arctic tundra ecosystems represent 135 million acres on the North Slope and west coast of Alaska.[xvii]

Alaska's tundra contains one of the largest blocks of sedge wetlands in the circumpolar arctic (one quarter of global distribution) and provides breeding grounds for millions of birds (more than 100 species). These include species from all 50 U.S. states and 6 continents, including ducks, shorebirds, songbirds, raptors, and several species of geese, loons, and swans. Tundra ecosystems also provide habitat for large numbers of free-roaming large mammals, including over 700,000 caribou, as well as grizzly bears, muskoxen, wolves, foxes, ground squirrels, lemmings, voles, and wolverines.[xviii] As the last major ecoregion of the U.S. that has not been extensively altered by humans, the tundra has value for research and monitoring of unaltered natural processes and for its wilderness qualities.[xix]

Existing stressors such as oil and gas development and mining of metal sulfide ores of lead, zinc, and iron has resulted in alteration or loss of tundra habitat.[xx] Climate-driven changes in the tundra ecosystem are already being observed, and include: early onset and increased length of growing season, melting of ground ice and frozen soils, increased encroachment of shrubs into tundra, and rapid erosion of shorelines in coastal areas.[xxi] Northern Alaska is one of the fastest-warming regions of the planet, with temperatures in some areas projected to rise approximately 13°F (7°C) by 2100.[xxii]

Impacts of Climate Change

Appendix Table 5: Major Climate Change Impacts on Tundra Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Tundra
Increased atmospheric CO_2:	Disproportionate Increased productivity of some plant species will change plant community composition
Increased temperatures:	Moisture stressed vegetation, changing plant communities, longer snow-free season, increased wildfire, invasion by plant and animal species from the south
Melting ice	Thawing of permafrost and soil ice changes hydrology and leads to terrain instability and vegetation change
Rising sea levels	Salt water intrusion, loss of coastal habitat to erosion
Changing precipitation patterns:	More winter thaws and rain-on-snow events harden snowpack, hampering mammal movements and foraging
Drying conditions/drought:	Moisture stressed vegetation, reduction in coastal plain wetlands, fish passage issues in streams
More extreme rain/weather events:	More landslides/slumps

Summary of Adaptation Goals, Strategies and Actions – Tundra Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority tundra areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change).[10]

— 1.1.2: Identify and prioritize areas currently experiencing rapid climate impacts (e.g., coastline of Alaska, etc.)

— 1.1.4: Produce a detailed land cover map of the Alaskan tundra, using satellite imagery, Digital Elevation Models, and ancillary spatial data such as surface geology.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.1: Conserve tundra areas that provide habitats under current climate conditions and are likely to provide habitat in the future (including thermal refugia).

— 1.2.5: Identify and pursue opportunities to increase conservation of priority tundra areas by working with managers of public lands or state lands managed for purposes other than conservation.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current tundra conservation areas.

— 1.4.3: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches.

— 1.4.4: Identify and remove or mitigate physical barriers to movement and dispersal within and among habitats (e.g., pipelines, raised roads through wetlands).

[10] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into tundra management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.

— 2.1.5: Review and revise as necessary existing species and habitat impact minimization, mitigation and compensation standards (e.g., under NEPA) and develop new standards as necessary to address impacts to tundra systems associated with climate change.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement species-specific management actions for tundra species.

— 2.2.2: Actively manage populations (e.g., using harvest limits, seasons and supplementation) of vulnerable species to maintain biodiversity, human use, and other ecological functions.

— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

— 2.3.1: Protect and maintain high quality wildland seed sources including identifying tundra areas for seed collection across elevational and latitudinal ranges of target species.

— 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.

GOAL 3: Enhance capacity for effective management in a changing climate. .

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

— 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.

— 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).

— 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and Alaska Native) joint training programs as a way to disperse knowledge, share

experience and develop inter-agency communities of practice about climate change adaptation.
- 3.1.8: Increase scientific capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to tundra species.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:
- 3.2.2: Identify and address conflicting management objectives within and between federal, state, and Alaska native conservation agencies and seek to align policies and approaches wherever possible.
- 3.2.4: Collaborate with Alaska native governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.
- 3.2.5: Engage with international neighbors, including Canada, Russia, and others to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:
- 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:
- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and Alaska native grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
- 3.4.5: Review existing conservation related federal grants to Alaska native agencies and revise as necessary to provide apportioned funding for Alaska native climate adaptation activities.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:
- 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation. Conform to accepted international monitoring procedures of circumpolar Arctic Council.
— 4.1.3: Promote a collaborative approach to acquire, process, archive, and disseminate essential geospatial and satellite-based remote sensing data products (e.g., snow cover, green-up, and surface water) needed for regional scale monitoring and land management.
— 4.1.4: Develop sentinel site networks for integrated climate change inventory, monitoring, research, and education.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for tundra fish, wildlife and plants.
— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact tundra species.
— 4.2.4: Ensure the availability and provide guidance for decision support tools that assist federal, state and Alaska native resource managers as well as local governments in effectively managing tundra species in a changing climate.
— 4.2.6: Establish long-term observatories on the North Slope to collect integrated hydrological, climate, and geophysical data regarding the response of permafrost, hydrologic, and ecological systems to changes in thermal and precipitation regimes.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and Alaska native resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.
— 5.1.2: Bring managers and scientists together to prioritize research needs that address tundra management objectives under climate change.
— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., coastal Alaska) or highly vulnerable species.
— 5.1.4: Participate in research planning for programs such as NSF, NOAA, NASA, NEON, CAFF, and DOE to ensure inclusion of research relevant to missions of agencies and resource managers.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

- 5.2.2: Support basic research on life histories of tundra fish, wildlife and plants to increase understanding of how these species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.6: Quantify the value of tundra ecosystem service and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.
- 5.2.10: Increase understanding of the adaptive capacity of tundra communities and species under climate change.
- 5.2.11: Conduct research into how ground ice influences a landscape's susceptibility to warming, to predict the extent and magnitude of habitat change and sedimentation rates into fluvial systems.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

- 5.3.2: Conduct vulnerability assessments for priority tundra species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
- 5.3.5: Model climate change impacts on vulnerable tundra species, including future distributions and the probability of persistence.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

- 7.1.4: Consider application of offsite habitat banking linked to climate change habitat priorities as a tool to compensate for unavoidable onsite impacts to tundra, and to promote habitat restoration in desirable locations.
- 7.1.7: Minimize impacts from alternative energy development by focusing siting options on lands already disturbed or degraded.
- 7.1.8: Reduce the footprint of energy development and mining activities in tundra systems.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions

— 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize tundra degradation resulting from development and land-use change.

— 7.2.6: Reduce existing pollution and contaminants and increase monitoring of air and water pollution.

— 7.2.7: Address and improve best management practices for freshwater withdrawals used for ice road construction.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

— 7.3.1: Use observation and monitoring networks for early detection of invasive species

— 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to tundra ecosystems.

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[xxii] SNAP (Scenarios Network for Alaska Planning). 2008. Validating SNAP climate models. Accessed May 2011.

Appendix 6: Inland Water Ecosystems

What's at Risk?

Inland Water Systems encompass a wide range of surface and underground physical, hydrological and biological systems and include, ponds and lakes; aquifers, springs, streams, rivers, and wetlands. These waters range from small or ephemeral (e.g., seasonal pools and intermittent streams) to large regional and national features such as the Great Lakes, Mississippi River, Ogallala aquifer, and Everglades. These diverse ecosystems host a broad range of aquatic life from microscopic plants and animals to large trees and major predators, and can include rare, endemic species.

Water temperature controls the physiology, behavior, distribution, and survival of freshwater organisms, and even slight temperature changes can affect these functions (Elliott, 1994). Increasing global air temperatures and changing precipitation patterns are raising water temperatures and shifting stream flow regimes in inland waters of the United States, which effect habitat, connectivity, water temperature levels, pollution levels, native species, and invasive species. In addition to these climate effects, more than a century of land use practices have degraded inland water ecosystems and the goods and services they provide to society.

Changing flood and freshwater runoff patterns can impact critical life stages that are attuned to the timing of stream flows, such as the spawning and migration of salmon. Increased evaporation of seasonal wetlands and intermittent streams can destabilize permanent water bodies, causing a loss of habitat or a shift in species composition. Major shifts in species composition, diversity and ecological function are more likely to occur for species with narrow thermal tolerances in smaller, fragmented or isolated habitats. Diseases, parasites and chemical toxicity in water bodies are also influenced by rising temperatures. The toxicity of some substances, such as lead, copper and ammonia, becomes more potent at higher temperatures (Lovett, Heugens *et al.* 2003, Piper *et al.* 1982). Warming temperatures also increase the susceptibility of organisms to disease. Diseases may also spread for longer periods and reproduce faster, threatening larger populations.

Intact inland water ecosystems offer four types of goods and services: provisional services (e.g., food and, water), regulating services (e.g., water purification), supporting services (e.g., climate regulation and nutrient cycling), and cultural services (e.g., aesthetic values and sense of place)[xxiii]. They generate value when people enjoy them directly (e.g., fishing and water sports) or indirectly when they support other things people enjoy (e.g., instream flows that support fish). Some benefits provided by well-functioning inland waters ecosystems will change or be lost due to climate change impacts compounded with other stressors such as land use change and population growth. For example, there may be fewer salmon for commercial and recreational harvest, as well as traditional ceremonial and cultural practices for indigenous peoples. The water needs of humans for such uses as hydropower, navigation, municipal, industrial, agricultural and recreational purposes must be balanced with the aquatic ecosystem needs and adaptively managed based on an uncertain changing climate and integrated with all natural resource management strategies.

Impacts of Climate Change

Appendix Table 6: Major Climate Change Impacts on Inland Water Systems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Inland Waters
Increased temperatures:	Increase of warm-water species, depleted oxygen levels, stress on cold-water fish
Melting ice:	Affects water temperatures which affect coldwater fish, such as bull trout and salmon
Rising sea levels:	Inundation of freshwater areas, groundwater contamination
Changing precipitation patterns:	Decreased lake levels, changes in salinity, flow
Drying conditions/drought:	Loss of wetlands and intermittent streams, lower summer base flows
More extreme rain/weather events:	Increased flooding, widening floodplains, altered habitat, spread of invasive species

Summary of Adaptation Goals, Strategies and Actions – Inland Water Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority inland water areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change).[11]

— 1.1.3: Establish and maintain a comprehensive, inter-jurisdictional inventory of current and candidate high priority conservation areas in order to coordinate future protection efforts.

— 1.1.5: Identify and prioritize groundwater sources, recharge and discharge sites, and areas that provide sediment resources necessary for ecosystem processes.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.1: Conserve inland water areas that provide habitats under current climate conditions and are likely to provide habitat in the future.

— 1.2.4: Work with partners to maximize use of existing conservation programs (e.g., easement, management), particularly the conservation titles of the Farm Bill, that protect private lands of high conservation value, enhance inland water habitats and maintain working inland water landscapes under climate change.

[11] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

— 1.2.7: Protect and restore transitional habitats between ecosystem types (e.g., riparian areas, mangrove forests).

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.1: Develop and implement restoration protocols and techniques such as instream flows and water management plans that promote inland water ecosystem resilience and facilitate adaptation under a range of possible future conditions.
— 1.3.2: Restore degraded habitats as appropriate to support diversity of inland water species assemblages and ecosystem structure and function.
— 1.3.3: Restore or enhance inland water areas that will provide essential habitat, hydrologic function, and ecosystem services during climate change ecosystem transitions, even for relatively short periods.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current inland water conservation areas.
— 1.4.4: Identify, prioritize, and improve, remediate or remove thermal, physical, or chemical barriers to connectivity in aquatic habitats.
— 1.4.5: Assess and take steps to reduce risks of facilitating movement of undesirable non-native species, pests and pathogens.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into inland water management plans, programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.
— 2.1.3: Identify transitional inland water species and habitats (e.g., cool-water to warm-water fisheries) and develop appropriate management approaches.
— 2.1.10: Develop basin-specific integrated water management plans that address in-stream flows, inter-basin water transfers, and surface and groundwater withdrawals while promoting water conservation and ecosystem function.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1: Use vulnerability and risk assessments to design and implement inland water species-specific management actions.

— 2.2.2: Actively manage populations (e.g., using harvest limits, seasons, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions.
— 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

— 3.1.2: Build on existing training courses and work with professional societies, academicians, technical experts, and natural resource agency training professionals to address key needs, augment adaptation training opportunities, and develop curricula and delivery systems for natural resource professionals and decision makers.
— 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).
— 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop inter-agency communities of practice about climate change adaptation.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

— 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.
— 3.2.3: Integrate individual agency climate change adaptation programs with other regional conservation efforts such as the National Fish Habitat Action Plan, Landscape Conservation Cooperatives (LCCs), and the Northeast Association of Fish and Wildlife Agencies regional application of State Wildlife Grant funds.
— 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

— 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.
— 3.3.2: Review and seek to change as appropriate federal and state laws and regulations that govern floodplain mapping, flood insurance and flood mitigation to discourage development and construction of infrastructure in floodplains.

— 3.3.3: Continue the ongoing work of the Joint State Federal Task Force on Endangered Species Act Policy to ensure that policies guiding implementation of the Endangered Species Act provide appropriate flexibility to address climate change impacts on listed fish, wildlife and plants and to integrate the efforts of federal, state, and tribal agencies to conserve listed inland water species.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

— 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
— 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
— 3.4.3: Collaborate with state and tribal agencies and private conservation partners to sustain authorization and appropriations for the State and Tribal Wildlife Grants program.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools. Adjust and improve management strategies based on new observations and information.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.
— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation.
— 4.1.10: Monitor and assess functionality of created wetlands and restored wetlands, streams, and lakes.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for fish, wildlife and plants in inland water systems.
— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact inland water fish, wildlife and plants.
— 4.2.4: Ensure the availability and provide guidance for decision support tools that assist federal, state and tribal resource managers, as well as local governments, in effectively managing fish, wildlife and plants in a changing climate.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, Landscape Conservation Cooperatives and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change.

— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., low-lying islands and glaciated areas) or highly vulnerable species.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

— 5.2.6: Quantify the value of inland water ecosystem services and identify potential impacts (e.g., loss of pollution abatement or flood attenuation) from climate change.

— 5.2.12: Conduct research to determine temperature increases and glacial melt impacts on water temperature, evapotranspiration rates, flow characteristics, stream channel processes and aquatic species.

— 5.2.13: Conduct research to determine flows required to support sustainable populations of vulnerable species, such as during prolonged drought.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

— 5.3.2: Conduct vulnerability assessments for priority inland water species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.

— 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.

— 5.3.7: Update hydrologic statistics and stream channel characteristics needed to delineate areas prone to flooding and channel migration as a result of climate impacts.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

— 7.1.2: Work with farmers and ranchers to apply the incentive programs in the conservation titles of the Farm Bill to minimize conversion of habitats, restore marginal agricultural lands to habitat, and to increase riparian buffer zones.
— 7.1.3: Work with water resource managers to enhance design and siting criteria for water resources infrastructure to reduce impacts on floodplains and restore connectivity in aquatic habitats.
— 7.1.9: Work with local and regional water management districts to evaluate historical water quantities and base flows and develop flow release agreements to approximate natural flows.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

— 7.2.3: Work with water resource managers to identify, upgrade, or remove outdated sewer and stormwater infrastructure to reduce water contamination.
— 7.2.8: Develop or improve best management practices, incentives, and legislation to reduce thermal, sediment, nutrient, and chemical loading for aquatic habitats.
— 7.2.9: Increase restoration, enhancement, and preservation of riparian zones and buffers in agricultural and urban areas to minimize non-point source pollution.
— 7.2.10: Reduce impacts of impervious surfaces and stormwater runoff in urban areas to maintain and improve water quality, groundwater recharge and hydrologic function.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

— 7.3.1: Use observation and monitoring networks for early detection and rapid response of invasive species.
— 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to inland water ecosystems.
— 7.3.6: Monitor pathogens associated with fish, wildlife and plant species for increased understanding of distributions and to minimize introduction into new areas.

[xxiii] Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being. Synthesis. Island Press. Washington, D.C.

Appendix 7: Coastal Ecosystems

What's at Risk?

Coastal ecosystems exist at the interface between land-based and oceanic influences, creating an inherently dynamic and productive environment that can be reformed under short and episodic timeframes (days to decades). For this *Strategy*, coastal ecosystems include all lands that drain directly into an estuary, ocean, or Great Lake (i.e. estuarine, coastal, and Great Lakes drainage areas) and the waters of estuaries, lagoons, and semi-enclosed bays. Globally, at least 600 million people, or 10% of the world's population, lives between zero and 10 m elevation along coastlines[xxiv]; in the United States an estimated 53% of the US population lives in coastal counties[xxv].

Coastal ecosystems provide many different types of ecosystem services. Coastal areas provide millions of jobs and billions of dollars in economic activity through tourism, recreation, fishing, and shipping. Coastal ecosystem services include erosion control, providing habitat for both aquatic and terrestrial animals and plants, improving water quality, storm protection, eco-tourism and recreation, and carbon sequestration.

U.S. coastal ecosystems support a rich diversity of fish, wildlife and plants. There are approximately 600 species or groupings of fish and shellfish that rely on estuaries during at least one life stage. This list includes commercially important species, with estuarine species representing more than $11 billion in commercial landings nationwide from 2000 to 2004[xxvi].

Many migratory and non-migratory birds, marine and terrestrial mammals, reptiles (especially turtles), and invertebrates depend on coastal ecosystems for survival. The coastal system includes important parts of bird migratory pathways (Pacific flyway, central, and Atlantic) and coastal habitats comprise some of the most important wintering, breeding, or stop-over habitat for many migratory species. Resident species often use both terrestrial and aquatic environments and many of these species are rare, threatened, or endangered due to human impacts on the coast.

Impacts of Climate Change

Appendix Table 7: Major Climate Change Impacts on Coastal Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Coastal Systems
Increased atmospheric CO_2:	Increased terrestrial and emergent plant productivity
Ocean acidification:	Declines in shellfish and other species
Increased temperatures:	Phenological changes, increased growth of salt marshes and forested wetlands, stronger estuarine stratification, lower dissolved oxygen levels
Melting ice:	Loss of anchor ice, decreased shoreline protection from storms/waves, increased shoreline erosion
Rising sea levels:	Inundation of coastal marshes, loss of nesting habitat, erosion, saltwater intrusion
Changing precipitation patterns:	Changes in salinity gradients, reduced Great Lake levels
Drying conditions/drought:	Changes in salinity gradients and freshwater input to estuaries
More extreme rain/weather events:	Higher wave heights, storm surges, loss of barrier islands

Summary of Adaptation Goals, Strategies and Actions – Coastal Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority areas for protection using species distributions, vegetation classification, land cover, and geophysical settings (including both areas of rapid change and slow change)[12]

— 1.1.5: Identify and prioritize groundwater sources, recharge and discharge sites, and areas that provide sediment resources necessary for ecosystem processes.

— 1.1.6: Assess the migration potential of coastal habitats and species and prioritize areas for highest migration potential, considering ecosystem functions and existing and future physical barriers.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

— 1.2.8: Coastal Protect coastal wetlands including those that may function for relatively short periods during species and ecosystem transition and migration.

— 1.2.9: Incorporate climate change into land acquisition plans (e.g., Coastal and Estuarine Land Conservation Program, state acquisition plans).

— 1.2.10: Capitalize on unique opportunities and funding sources (e.g., FEMA's Repetitive Loss and Severe Repetitive Loss programs) to acquire coastal lands.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.2: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.

— 1.3.3: Restore or enhance areas that will provide essential habitat and ecosystem services during climate change ecosystem transitions, even for relatively short periods.

— 1.3.6: Explore alternative environmental engineering options (e.g., dredged material as wetland fill, beach re-nourishment) to restore or enhance coastal habitats.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

[12] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

Actions:

- 1.4.2: Assess and prioritize critical connectivity gaps and needs across current conservation areas.
- 1.4.8: Assess and where necessary redesign or remove existing legacy structures (e.g., dams, hardened shorelines) to increase natural ecosystem resilience and allow for ecosystem function and species response to climate change.
- 1.4.9: Assess, redesign, or remove existing legacy structures to increase natural ecosystem resilience (e.g., allow for ecosystem and species response) to climate change; including water and sediment processes.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

- 2.1.1 Incorporate climate change into coastal management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments.
- 2.1.10: Develop basin-specific integrated water management plans that address in-stream flows, inter-basin water transfers, and surface and groundwater withdrawals while promoting water conservation and ecosystem function.
- 2.1.11: Develop strategic protection, retreat, and abandonment plans for areas currently experiencing rapid coastal climate change impacts (e.g., coastline of Alaska and low-lying islands).

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

- 2.2.1: Use vulnerability and risk assessments to design and implement species-specific management actions.
- 2.2.2: Actively manage populations (e.g., using harvest limits, seasons, and supplementation) of vulnerable species to maintain biodiversity, human use, and other ecological functions.
- 2.2.3: Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

- 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).
- 3.1.4: Develop a web-based clearinghouse of training opportunities and materials addressing climate change impacts on natural resource management.
- 3.1.5: Encourage use of inter-agency personnel agreements and inter-agency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop inter-agency communities of practice about climate change adaptation.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

- 3.2.2: Identify and address conflicting management objectives within and between federal, state, and tribal conservation agencies and seek to align policies and approaches wherever possible.
- 3.2.3: Integrate individual agency climate change adaptation programs with other regional conservation efforts such as the National Fish Habitat Action Plan and the Northeast Association of Fish and Wildlife Agencies regional application of State Wildlife Grant funds.
- 3.2.5: Engage with international neighbors, including Canada, Mexico, Russia, and nations in the Caribbean Basin, Arctic Circle, and Pacific Ocean to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

- 3.3.4: Initiate a dialogue among all affected interests about revising the federal Coastal Zone Management Act and the Clean Water Act, and state coastal tidal wetland protection programs to address impacts of sea level rise on coastal habitats.
- 3.3.5: Modify policies and programs to create or strengthen disincentives for long-lived coastal development (infrastructure) and armoring (seawalls, revetments, etc.) necessary to protect areas vital to fish, wildlife and plant adaptation.
- 3.3.6: Alter current policy and zoning in coastal areas to anticipate migratory nature of coastal habitats and prevent development in potential refugia and corridors.
- 3.3.7: Clarify legal authority to manage new and future habitat areas, particularly in areas where jurisdiction migrates with landscape features (e.g., shorelines).

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.

— 3.4.6: Develop a web-based clearinghouse of funding opportunities available to support climate adaptation efforts.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

— 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.

— 4.1.2: Work through existing distributed efforts (e.g., National Climate Assessment, National Estuarine Research Reserve System system-wide monitoring program) to support integrated national observation and information systems that inform climate adaptation.

— 4.1.11: Monitor and assess water levels in shallow coastal aquifers that support freshwater-dependent ecosystems.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

— 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for fish, wildlife and plants.

— 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact fish, wildlife and plants.

— 4.2.4: Ensure the availability and provide guidance for decision support tools (e.g., NOAA's Digital Coast) that assist federal, state and tribal resource managers as well as local governments in effectively managing fish, wildlife and plants in a changing climate.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment, USDA extension, LCCs and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

— 5.1.1: Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.

— 5.1.2: Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change.

— 5.1.3: Prioritize research on questions relevant to managers of near-term risk environments (e.g., low-lying islands and glaciated areas) or highly vulnerable species.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

— 5.2.2: Support basic research on life histories of fish, wildlife and plants to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds.
— 5.2.13: Conduct research to determine flows required to support sustainable populations of vulnerable species, such as during prolonged drought.
— 5.2.14: Conduct research to better understand fish, wildlife, plant, and ecosystem responses to ocean acidification and saltwater intrusion.

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

— 5.3.2: Conduct vulnerability assessments for priority species (e.g., threatened and endangered species, species of greatest conservation need, species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
— 5.3.4: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.
— 5.3.8: Model sea-level rise and physical and biological responses at relevant scales.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

— 7.1.9: Work with local and regional water management districts to evaluate historical water quantities and base flows and develop flow release agreements to approximate natural flows.
— 7.1.10: Protect natural dunes and dune vegetation from removal and trampling.
— 7.1.11: Assess and prioritize the redesign or removal of existing structures that currently inhibit natural sediment processes and/or flows (e.g., dams, bulkheads, revetments).
— 7.1.12: Fully internalize risks associated with coastal development into property owners' insurance rates to minimize loss of coastal habitat.

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land-use planning and the implementation of best management practices.

Actions:

- 7.2.3: Work with water resource managers to identify, upgrade, or remove outdated sewer and stormwater infrastructure to reduce water contamination.
- 7.2.9: Increase restoration and preservation of riparian zones and buffers in agricultural areas to minimize non-point source pollution.
- 7.2.10: Reduce impacts of impervious surfaces and stormwater runoff in urban areas to maintain and improve water quality, groundwater recharge and hydrologic function.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

- 7.3.1: Use observation and monitoring networks for early detection of invasive species
- 7.3.2: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to natural ecosystems.
- 7.3.9: Implement best management practices to reduce the spread of invasive species through ballast water.

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Appendix 8: Marine Ecosystems

What's at Risk?

Marine ecosystems are the largest systems on the planet, covering over 70 percent of the Earth's surface and constituting over 99% of the living space on the planet by volume. These vast ecosystems are composed of many different habitats which extend seaward from nearshore regions to continental shelves and the deep ocean.

For the purposes of this report, the marine ecosystems under U.S. jurisdiction extend from the shore to 200 miles seaward, spanning an area 1.7 times the land area of the continental U.S (3.4 million square nautical miles) that is divided into 11 different large marine ecosystems (LMEs) based on the unique physical, chemical and biological features of these regions.

Marine ecosystems are home to millions of species and provide food, jobs, income, economic activity, recreation, coastal protection and many other vital ecosystem services to billions of people in the U.S. and around the world. These services include: (1) Food, jobs and income from the harvest of fish and shellfish; (2) Jobs, economic activity and health services from recreation and tourism; (3) Key components of many products including animal feed, fertilizers for crops, additives in foods and pharmaceuticals to fight diseases and promote human health; (4) Protection of coastal communities from storms, waves and erosion by coastal habitats (e.g., coral reefs, mangroves, marshes); and (5) Cultural identity and spiritual values to coastal communities, as well as many tribes and indigenous people whose ties to the water and the species living there are integral to their histories and way of life.

Marine ecosystems support a rich diversity of fish, wildlife, plants and other species ranging from microscopic planktonic organisms that comprise the base of the marine food web (i.e., bacteria, phytoplankton and zooplankton) through kelp and eel grass beds to a wide range of invertebrates (e.g., corals, crustaceans, mollusks) and vertebrates (e.g., fish, turtles, birds and marine mammals). Marine systems are connected to all other ecosystems, the most obvious linkages existing between Coastal and the Inland Waters ecosystems that numerous marine species inhabit during parts of their life cycles. But on the broader scale, the ocean moderates the Earth's climate by transporting heat from the equator to northern latitudes and vice versa. Until recently, the ocean has buffered the effects of climate change by absorbing carbon dioxide from the atmosphere. Changes in the marine environment will have positive or negative feedbacks on the global climate.

Impacts of Climate Change

Appendix Table 8: Major Climate Change Impacts on Marine Ecosystems (GCCIUS 2009 and IPCC 2007)

Major Changes Associated With Increasing Levels of GHGs	Major Impact on Marine Systems
Ocean acidification:	Negative impacts on corals, shellfish, and other species (particularly early life stages and organisms at base of food chains), changes in biogeochemical processes that may reduce the ability of the ocean to absorb excess CO_2, creating a positive feedback to climate change
Increased temperatures:	Mass mortalities of corals and other species, changes in organism phenology, distribution, growth and mortality rates, changes in timing and magnitude of primary and secondary productivity, spread of diseases and invasive species
Melting ice:	Changes in timing, magnitude of primary productivity and fish productivity. Loss of habitats critical to foraging and reproduction of ice-dependent species

Rising sea levels:	Inundation of coastal marshes, loss of marine bird nesting habitat, erosion, saltwater intrusion affects early life history stages of many marine species
Changing currents:	Changes in phenology, dispersal, distribution and growth rates of fish stocks and other species, changes in timing and magnitude of primary and secondary productivity, changes in spread of diseases and invasive species
Changing stratification:	Changes in nutrient distributions in water column and timing and magnitude of primary and secondary productivity, altered predator-prey interactions
Changing precipitation patterns:	Changes in salinity, nutrient and sediment flow to coastal waters affects near-shore productivity and early life stages of many marine species, especially those who use freshwater and estuarine habitat for part of their life cycle
Drying conditions/drought:	Increased salinity, changes in nutrient and sediment flow to coastal waters affects near-shore productivity and early life stages of many marine species (particularly anadromous species)
More extreme rain/weather events:	Reduced salinity, changes nutrient and sediment flow to coastal waters affects near-shore productivity and early life stages of many marine species (particularly anadromous species)

Summary of Adaptation Goals, Strategies and Actions – Marine Ecosystems

GOAL 1: Conserve adequate habitat to support healthy fish, wildlife and plant populations and ecosystem functions in a changing climate.

Strategy 1.1: Identify areas for an ecologically connected network of terrestrial, freshwater, coastal and marine conservation areas that are likely to be resilient to climate change and to support a broad range of fish, wildlife and plants under changed conditions.

Actions:

— 1.1.1: Identify high priority marine areas for protection using species distributions, habitat classification and geophysical settings (including both areas of rapid change and slow change)[13]

— 1.1.2: Identify and prioritize marine areas currently experiencing rapid climate impacts (e.g., Arctic, tropical reef ecosystems).

— 1.1.3: Establish and maintain a comprehensive, inter-jurisdictional inventory of current and candidate high priority conservation areas in order to coordinate future protection efforts.

— 1.1.7: Assess current Marine Managed Areas (MMA) for value in protecting against and/or building resilience to climate change impacts on the local, regional, national and international level, and identify important gaps.

— 1.1.8: Create geo-referenced depiction of the current U.S. MMAs compatible with the Multipurpose Marine Cadastre, and the National Information Management System under development for Coastal and Marine Spatial Planning.

Strategy 1.2: Complete an ecologically connected network of public and private conservation areas that will facilitate fish, wildlife and plant climate adaptation.

Actions:

[13] Numbering corresponds with actions from Chapter 3: Climate Adaptation Strategies and Actions. Some wording has been adapted for each ecosystem.

— 1.2.1: Conserve areas that provide habitats under current climate conditions and are likely to provide habitat in the future.
— 1.2.3: Build redundancy into the network of conservation areas by protecting multiple examples of the range of existing habitat types and geophysical settings.
— 1.2.11: Identify other marine spatial management tools besides Marine Managed Areas (MMA) that are useful for addressing climate change impacts and ensure wide distribution to managers of the type, authority for and best application of each type.

Strategy 1.3: Restore habitats where necessary to enhance ecosystem function and processes and resiliency to climate change.

Actions:

— 1.3.1 Develop and implement restoration protocols and techniques that promote marine ecosystem resilience and facilitate adaptation under a range of possible future conditions.
— 1.3.2 Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function.
— 1.3.3 Restore or enhance areas that will provide essential habitat and ecosystem services during climate change ecosystem transitions.

Strategy 1.4: Protect, restore, and, as appropriate, build new ecological connections among conservation areas to facilitate fish, wildlife and plant migration, range shifts, and other transitions caused by climate change.

Actions:

— 1.4.2: Assess and prioritize critical connectivity gaps and needs across current marine conservation areas.
— 1.4.5: Assess and take steps to reduce risks of facilitating movement of undesirable non-native species, pest and pathogens.
— 1.4.10: Identify and protect habitats important for maintaining connectivity and supporting robust populations of marine species including areas likely to serve as refugia in a changing climate.

GOAL 2: Manage species and habitats to protect ecosystem function and provide sustainable cultural, subsistence, recreational, and commercial use in a changing climate.

Strategy 2.1: Update current or develop new species and habitat management plans, programs and practices to consider climate change and support adaptation.

Actions:

— 2.1.1: Incorporate climate change into management plans programs and practices using the best available science regarding projected changes, trends and vulnerability assessments. 2.1.2: Develop and implement best management practices to support resilience of marine species and habitats in a changing climate.
— 2.1.3: Identify transitional species and habitats particularly vulnerable to climate impacts and develop management strategies and approaches for adaptation.

Strategy 2.2: Develop and apply species-specific management approaches to address critical climate change impacts where necessary.

Actions:

— 2.2.1 Use vulnerability and risk assessments to design and implement management actions at species to ecosystem scales.

- 2.2.2 Actively manage populations of vulnerable species as part of fisheries, protected species or other management activities to maintain biodiversity, human use, and other ecological functions.
- 2.2.3 Develop criteria and guidelines for the use of translocation, assisted migration and captive breeding as climate adaptation strategies.

Strategy 2.3: Conserve genetic diversity by protecting diverse populations and genetic material across the full range of species occurrences.

Actions:

- 2.3.1: Identify, protect and maintain areas/sources of genetic diversity among marine species across ranges of target species.
- 2.3.2: Develop protocols for use of artificial propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species.
- 2.3.5: Develop and implement approaches for assessing and maximizing the genetic diversity of marine species.

GOAL 3: Enhance capacity for effective management in a changing climate.

Strategy 3.1: Increase the climate change literacy of natural resource managers and enhance their professional capacity to design, implement and evaluate fish, wildlife and plant adaptation programs.

Actions:

- 3.1.1: Build on existing needs assessments to identify gaps in climate change knowledge and technical capacity among natural resource professionals.
- 3.1.3: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability assessments, risk assessments, scenario planning, decision support tools, and adaptive management).
- 3.1.6: Support and enhance web-based clearinghouses of information and tools on climate change impacts and adaptation strategies in marine and coastal ecosystems.
- 3.1.9: Develop regional downscaling of Global Climate models to conduct vulnerability assessments of marine living marine resources.
- 3.1.10: Evaluate the effectiveness of adaptation strategies by explicitly incorporating mechanisms of change into policies.

Strategy 3.2: Facilitate a coordinated response to climate change at landscape, regional, national and international scales across state, federal and tribal natural resource agencies and private conservation organizations.

Actions:

- 3.2.1: Use regional venues such as Regional Fishery Management Councils, Regional Ocean Partnerships, Landscape Conservation Cooperatives to collaborate across jurisdictions and develop marine conservation goals and seascape scale plans capable of sustaining marine resources at desired levels.
- 3.2.4: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge (TEK) and principles into climate adaptation plans and decision-making.
- 3.2.5: Engage with international neighbors, including Canada and Mexico, to help adapt to and mitigate climate change impacts in trans-boundary habitat areas and for migratory species.

Strategy 3.3: Review existing state, federal and tribal policies, laws and regulations that provide the jurisdictional framework for conservation and habitat protection and seek any necessary improvements to address climate change impacts.

Actions:

- 3.3.1: Review and seek to change as appropriate laws, regulations and policies in order to facilitate the protection or restoration of habitats and ecosystem services impacted by climate change.
- 3.3.3: Continue the ongoing work of the Joint State Federal Task Force on Endangered Species Act Policy to ensure that policies guiding implementation of the Endangered Species Act provide appropriate flexibility to address climate change impacts on listed fish, wildlife and plants and to integrate the efforts of federal, state, and tribal agencies to conserve listed species.

Strategy 3.4: Optimize use of existing fish, wildlife and plant conservation funding sources to design, deliver and evaluate climate adaption programs.

Actions:

- 3.4.1: Prioritize funding for land and water protection programs that incorporate climate change considerations.
- 3.4.2: Review existing federal, state, and tribal grant programs and revise as necessary to support funding of climate change adaptation and include climate change considerations in the evaluation and ranking process of grant selection and awards.
- 3.4.3: Collaborate with state and tribal agencies and private conservation partners to sustain and strengthen collaborative efforts to conserve living marine resources and their habitats.

GOAL 4: Support adaptive management through integrated observation and monitoring and improved decision support tools.

Strategy 4.1: Support, coordinate, and where necessary develop distributed but integrated inventory, monitoring, observation and information systems to detect and describe climate impacts on fish, wildlife, plants and ecosystems.

Actions:

- 4.1.1: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools.
- 4.1.2: Strengthen and expand efforts to support integrated observations on climate change impacts on ocean habitats and living marine resources.
- 4.1.4: Develop sentinel site networks to provide integrated early warning and tracking of climate change impacts on marine habitats and living marine resources for decision makers.
- 4.1.6: Collaborate with the National Phenology Network and others to increase access to information on changes in phenology, distribution and abundance of marine fish, wildlife and plants.

Strategy 4.2: Identify, develop and employ decision support tools for managing under uncertainty (e.g., risk assessments, scenario planning approaches, and adaptive management evaluation systems).

Actions:

- 4.2.1: Conduct risk assessments to identify key climate change hazards and assess potential consequences for fish, wildlife and plants.

- 4.2.2: Engage scientists, resource managers, and stakeholders in climate change scenario planning processes, including identification of a set of plausible futures (scenarios) associated with climate phenomena likely to significantly impact marine species.
- 4.2.5: Use observation, information, assessment and decision support systems to monitor and determine the effectiveness of specific management actions, to analyze the potential for maladaptations and adapt management approaches appropriately.

GOAL 5: Increase knowledge and information on impacts and responses of fish, wildlife and plants to a changing climate.

Strategy 5.1: Work with the National Climate Assessment and others to identify knowledge gaps and define research priorities via a collaborative process among federal, state and tribal resource managers and research scientists.

Actions:

- 5.1.1 Increase coordination and communication between resource managers and researchers through existing forums (e.g., Regional Ocean Observing Partnerships, Climate Science Centers, Regional Integrated Science and Assessment Partnerships, Landscape Conservation Cooperatives) to ensure research is connected to management needs.
- 5.1.2 Bring managers and scientists together to prioritize research needs that address resource management objectives under climate change.

Strategy 5.2: Work through existing partnerships and across jurisdictions (e.g., USGCRP, National Climate Assessment, CSCs, RISAs, and others) to conduct research into ecological and socioeconomic aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems.

Actions:

- 5.2.2: Support basic research on life histories of marine species to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds.
- 5.2.6: Quantify the value of ecosystem services and identify potential impacts (e.g., loss of pollution abatement) from climate change.
- 5.2.15: Produce regional to subregional projections of future climate change impacts on physical, chemical and biological conditions for all U.S. marine ecosystems.
- 5.2.16: Increase research on early life histories, food web dynamics, and other species interactions to better understand implications of climate change on ecological interrelationships among marine dependent fish, wildlife, and plants

Strategy 5.3: Apply existing information and knowledge gained through research to develop vulnerability assessments, predictive models, and other decision support tools for designing and evaluating fish, wildlife and plant climate adaptation strategies.

Actions:

- 5.3.2 Conduct vulnerability assessments for priority marine species and habitats (e.g., threatened and endangered species, species of greatest conservation need, and species of cultural and socioeconomic significance) under a standard set of climate change scenarios.
- 5.3.3 Define the suite of physical and biological variables and ecological processes for which predictive models are needed via a collaborative process among state, federal and tribal resource managers and model developers.
- 5.3.4: Develop climate sensitive growth and yield models for marine species to ensure long-term sustainability of marine species and habitats.

— 5.3.9: Marine: Develop models to provide predictions of physical atmospheric and oceanographic climate changes for the marine waters of the U.S. Exclusive Economic Zone.
— 5.3.10: Develop regional downscaling of Global Climate models to conduct vulnerability assessments of marine living marine resources.

GOAL 6: Increase awareness and motivate action to safeguard fish, wildlife and plants in a changing climate.

Strategy 6.1: Increase public awareness and understanding of climate impacts to natural resources and ecosystem services and the principles of climate adaptation at regionally and culturally appropriate scales.

Strategy 6.2: Engage interested publics through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

— 6.3.4: Develop and implement communication efforts between NOAA and DOI to increase awareness of the impacts and responses to climate change in marine ecosystems.

GOAL 7: Reduce impacts of non-climate stressors to reduce the vulnerability of fish, wildlife, plants to climate change.

Strategy 7.1: Slow and reverse where feasible habitat loss and fragmentation.

Actions:

— 7.1.1: Work with fisheries managers and other marine resource users to identify shared interests and potential conflicts in reducing and reversing marine habitat fragmentation, degradation and loss through comprehensive planning and zoning.
— 7.1.13: Bridge the gap between ecosystem conservation and economics, and consider market-based incentives that encourage actions that foster resilience and adaptation in marine systems

Strategy 7.2: Slow, mitigate, and reverse where feasible ecosystem degradation from anthropogenic sources through land and ocean-use planning and the implementation of best management practices.

Actions:

— 7.2.1: Work with local land-use planners to identify potentially conflicting needs and opportunities to minimize marine ecosystem degradation resulting from development and land-use change.
— 7.2.11: Work with ocean-use planners to identify potentially conflicting needs and opportunities to minimize marine ecosystem degradation resulting from development and ocean-use change.

Strategy 7.3: Use, evaluate and as necessary improve existing programs to control and eradicate invasive species and manage pathogens.

Actions:

— 7.3.1: Use observation and monitoring networks for early detection of invasive species.
— 7.3.10: Apply integrated management practices, share innovative control methodologies, and take corrective actions when necessary to manage marine diseases and invasives.
— 7.3.11: Avoid use of potentially invasive species in aquaculture and other areas.

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