National Fish, Wildlife and Plants Climate Adaptation Strategy

Forest Ecosystems

Photo: AFWA

Disclaimer

The information in this Forest Ecosystems Background Paper was developed by the Forest Technical Team of the National Fish, Wildlife and Plants Climate Adaptation Strategy (hereafter *Strategy*), and was used as source material for the full *Strategy* document. It was informally reviewed by a group of experts selected by the Team. While not an official report, this Forest Ecosystems Background Paper is available as an additional resource that provides more detailed information regarding climate change impacts, adaptation strategies, and actions for U.S. forest ecosystems and the species they support. These papers have been edited by the Management Team for length, style, and content, and the Management Team accepts responsibility for any omissions or errors.

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Introduction

Over the past decade, there have been increasing calls for action by government and non-governmental entities to better understand 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 the National Fish, Wildlife and Plants Climate Adaptation Strategy (hereafter *Strategy*).

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*.

A Steering Committee was established to lead this effort and it 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 (representing the states) and Great Lakes Indian Fish and Wildlife Commission to oversee the day-to-day development of the *Strategy*.

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 centered around a major ecosystem type. These teams, which were co-chaired by federal, state, and I most instances, 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 five ecosystem technical teams are: Inland Waters, Coastal, Marine, Forests, and a fifth team comprising four ecosystems: Grasslands, Shrublands, Deserts, and Arctic Tundra.

This Background Paper focuses on forest systems, including information about these systems, existing stressors, impacts from climate change, and several case studies highlighting particular impacts or adaptation efforts. Information from this Background Paper informed discussion of forest impacts and adaptation measures in the full *Strategy*, and was used to develop the Goals, Strategies, and Actions presented in that document and repeated here. This Background Paper is intended to provide additional background information and technical details relevant to forest systems, and to summarize those approaches most relevant to managers of these areas and the species they support. Some of the material presented herein overlaps with that for other ecosystem types, particularly regarding cross-cutting issues.

The ultimate goal of the *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 challenges 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. The *Strategy* also describes mechanisms to foster collaboration among all levels of government, conservation organizations, and private landowners.

Federal, state, and tribal governments and conservation partners are encouraged to look for areas of overlap between this Background Paper, the *Strategy* itself, 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 forest fish, wildlife, and plants.

Description of Forest Ecosystems

Photo: FWS

For 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 10 percent crown closure and attains a height of at least 16 feet (ft) at maturity. This definition encompasses both the matrix forests 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. For the purposes of the *Strategy*, alpine landscapes, which by definition, occur above treeline, are also included with this system.

Ecosystem Services:

Forest systems provide essential ecosystem services to humans; as climate changes, dependence on these services 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 ft^3 of roundwood is harvested (based on 2005 statistics) (Howard 2007). In 2008, 98.8 thousand Americans were directly employed in either logging or forestry (Bureau of Labor Statistics 2010), 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 (NTFPs), such as berries, mushrooms, bark, leaves, and roots that are harvested for personal and commercial use as foods, medicines, and floral products. Many rural economies and communities rely on NTFPs for at least part of their income and regional and product-specific data indicate that NTFPs support multimillion-to-billion dollar industries (Alexander 2003, Draffan 2006, Brinkmann 2008).

Approximately 750 million acres of the United States is forest, both public and private (Heinz Center 2008). To separate forests from grasslands or shrublands, forest definitions generally include minimum canopy cover (or crown area) and dominant vegetation height at maturity. Forests include areas that range from some of the most diverse to the simplest ecosystems on the planet. Moist tropical forests are incredibly species rich, containing perhaps 50 percent of all known organisms, worldwide. In contrast, boreal coniferous (evergreen) forests are often dominated by a single tree species. A vast number of plants and animals are characterized as “forest” species, and the influence of forests on other systems is considerable.

The value of forests often extends beyond the system’s boundaries as well. Because of their structure, trees strongly influence radiant energy and wind speed, tempering grasslands and shading streams. Indeed, the character of many streams and rivers is inseparable from the types of forest through which they flow (e.g., the “black waters” of many coniferous forests). Similarly, forest systems share broad ecotones with shrublands and grasslands. As climate change influences the processes that drive the current biogeography of these systems (namely, fire and water regimes), we can anticipate shifts among these systems' ranges. These "edges" are of particular interest because they are both biologically rich (containing both forest and grassland/shrubland species) and remarkably sensitive to changing climates.

Forests are often broadly classified ecologically into three general biomes corresponding to the broad climatic regimes in which they occur: tropical, temperate, and boreal. Within these general biomes, temperate forests are often classified as coniferous or broadleaf. Tropical forests are highly variable, running the gamut from deciduous coniferous to evergreen broadleaf systems.

Most forests can be divided into easily recognized strata: canopy, subcanopy, midstory, shrub, and groundcover. Forest stands characterized by intact ecological processes often achieve complex structures that provide niches for many plant and animal species. The forest community includes trees, shrubs, vines, grasses, forbs, mosses, liverworts, algae, fungi, mammals, birds, reptiles, amphibians, invertebrates, and soil microorganisms. These biotic components interact with one another and with the abiotic components of soil, water, and minerals as a forest ecosystem.

Human use of forests differs from many other terrestrial ecosystems in that harvest of wood products and NTFPs often occur in wild systems and do not demand broad-scale species conversion. Many silvicultural practices rely on natural regeneration of native species. Even in plantation forestry, native trees are commonly chosen for stock, though they may differ from the native species they replace. For this reason, forestlands (particularly in the temperate zone) are much more likely than grasslands or shrublands to be dominated by native species and natural refuges. In both the eastern and western United States, large contiguous forests composed of predominantly native species still exist. This reality makes forests particularly vulnerable to climate change. For many native species, climate change-induced range shifts will occur primarily within forested systems.

Nationwide, ownership of forest lands is fairly evenly divided between public and private owners, with 56 percent of forest lands in private ownership (Smith et al. 2009). Ownership patterns, however, vary greatly by region. In the Rocky Mountain West, for example, 75 percent of forested land is in public ownership (Smith et al. 2009) whereas east of the Mississippi River, the opposite is true. Private land ownership patterns also vary greatly by region. In the Pacific Northwest, the majority of private forest land is corporately controlled whereas in the Northeast and Northcentral regions most (78 percent) of private forest land is non-corporate (Smith et al. 2009). These ownership patterns affect both forest age and composition (Smith et al. 2009) and societal approaches to climate change adaptation.

Forests are interconnected to other ecosystems. There are many linkages with inland water systems such as forested wetlands, mangroves, and other wet forest systems, as well as the lakes, rivers, and streams that often occur within and surrounding forests. Meadows and other grassland landscapes are often found adjacent or within forested systems. Grassland ecosystems can be affected by the amount of shade provided by forest trees as well as the changes in wind patterns they may produce. There are forests in coastal systems as well specifically in Hawaii and other warm tropical areas that may be affected by the impacts of climate change.

Existing Stressors:

Forest systems face a number of existing stressors, such as drought and wildfires. Drought can issue and exacerbate species decline in forested systems. Though controlled burn regimes are important, uncontrolled wildfires can negatively affect ecosystem services garnered from forested systems as well as release large amounts of carbon into the atmosphere that was otherwise stored. The loss of plants and animals due to wildfire can also increase the likelihood of erosion and landslides. In addition, anthropogenic stressors such as deforestation, turning forested systems into land for agricultural use, and air-pollution, which can negatively impact ecological function and forest root systems, are also a challenge to forest ecosystems.

Climate Change Impacts on Forest Systems

Climate-derived effects on forest ecosystems can be divided into four main themes: 1) impacts to forest processes, including tree demographics, productivity, and ecosystem carbon and nutrient cycling; 2) alteration of forest disturbance regimes; 3) shifts in plant and animal species distributions and viability (which may result in novel assemblages and/or extinctions); and 4) economic impacts to managed forests.

Within the global terrestrial biosphere, forests cover 43 percent of the land area but are potentially responsible for 72 percent of the annual net primary productivity (Juday et al. 2005). In addition, forests are important for maintaining the global carbon cycle and act as major sinks of atmospheric carbon (Birdsey et al. 2006, Bonan 2008, Canadell and Raupach 2008). Changing climatic conditions may have significant impacts on forest growth, mortality, reproduction, and eventually, productivity and ecosystem carbon storage (McNulty and Aber 2001, Thomas et al. 2004). Likely impacts are summarized in Table 1.

Table 1: Expected Climate Change Impacts on Forest Ecosystems (USGCRP 2009, IPCC AR4 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/snow:	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

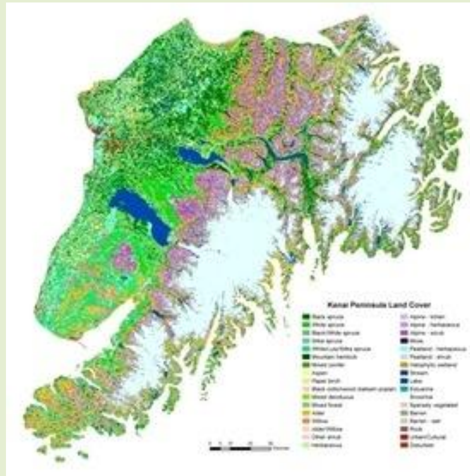
Changes in Air and Water Temperatures:

National and regional scale forest process models suggest that in some areas, elevated atmospheric carbon dioxide (CO_2) concentrations may increase forest productivity by 5-30 percent, and predictions of wetter future conditions may enhance ecosystem carbon sequestration. However, other regions may experience greater than 20 percent reduction in productivity when increasing temperatures and aridity are considered. Drier conditions in the southern United States and elsewhere could lead to increased fire severity and result in decreases in ecosystem carbon stocks (Aber et al. 2001, Westerling et al. 2006, Bond-Lamberty et al. 2007). Similarly, prolonged drought may lead to decreases in primary production and stand water use. Severe drought would increase tree mortality with mature trees less sensitive than younger trees due to established root systems (Van Mantgem et al. 2009). Drought can also alter decomposition rates of forest floor organic materials impacting current fire regimes and nutrient cycling (Hanson and Weltzin 2000).

In some areas of the United States, higher atmospheric CO_2 may lead to greater forest water-use efficiency, while in other areas, more leaf area and associated evapotranspiration increases may result in decreased water flow. Decreased water flow may be most extreme in the Plains, while western states could experience an increase in water flow due to increased rainfall (McNulty and Aber 2001). Synergistic or antagonistic effects with other factors are likely to affect responses. For example, air pollutants may interact with climate alterations to affect soil respiration, tree growth, species composition and distribution, resiliency, and fuel loads (Bytnerowicz et al. 2006). Similarly, the development of thermokarst, as a direct result of melting permafrost, has indirectly transformed some upland boreal forests into extensive wetlands (Walsh et al. 2005).

CLIMATE CHANGE IN THE KENAI PENINSULA

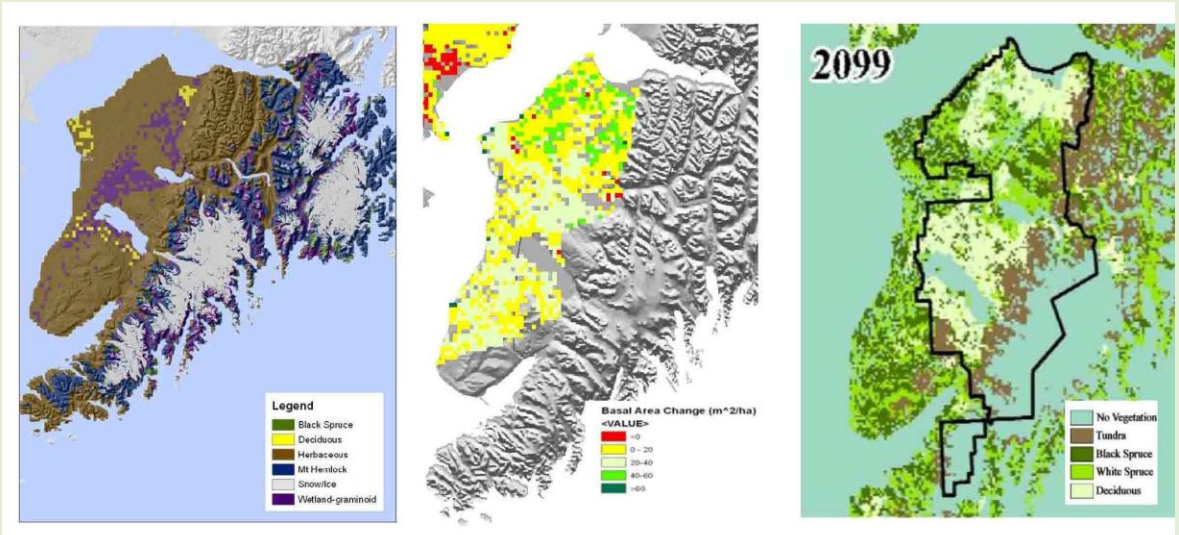
For a glimpse of the dramatic changes that a warming climate may bring to the entire nation, look no farther than Alaska's seven million-acre Kenai Peninsula. Here, warmer temperatures have increased overwinter survival and boosted populations of spruce bark beetle, enabling the pest to devastate four 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 (Klein et al. 2005, Berg et al. 2009, Klein et al. 2011); the Harding Icefield, the largest glacial complex in the United States, has shrunk by five percent in surface area and 60 feet in height (Rice 1987, Adageirsdottir et al. 1998); 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).



Current Kenai Landscape (2006)

While these changes are already sobering, even greater changes lie ahead, according to projections 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 projected to suffer because of higher stream temperatures and increased glacial sediment. Overall, roughly 20 percent of species may vanish from the peninsula.

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 and non-native lodgepole pine 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.



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)

Changes in Disturbance Regimes:

Disturbances are often defining characteristics of forest ecosystems, and important disturbances in forests include wildfires, wind storms, and invasive and pest outbreaks. Climate change is anticipated to alter disturbance frequency, intensity, duration, and timing (Dale et al. 2001). When disturbance regimes are altered by climate change, these stressors can exceed their natural range of variation and cause extreme changes in forest structure and processes (Dale et al. 2000, Running 2008). Predictive models of climate change and forest fires suggest that the seasonal fire severity rating will increase by 10-50 percent over most of North America. This change in fire regime alone has the potential to overshadow direct influences of climate on species distribution and migration (Flannigan et al. 2000).

Wind disturbances (e.g. tornadoes, downbursts, and ice storms) are an important natural forest disturbance. Tornadoes are prevalent in the Southeast and Midwest, while downbursts are more common in forests of the Great Lake region. Impacts to forests from these disturbances include immediate and long-term effects on environmental conditions, density, size structure, species composition, and successional status (Irland 2000, Peterson 2000). These disturbances also influence local climate by altering vegetation, evapotranspiration, and water runoff.

Changes in the Frequency and Magnitude of Extreme Events:

Hurricanes and typhoons are the key large-scale disturbances in many tropical and subtropical forests and result in sudden and massive tree mortality, delayed tree mortality, changes in forest regeneration patterns and succession, faster biomass/nutrient turnover, carbon sink creation, and biodiversity and community shifts that can include substantial expansion of invasive species. Models of hurricane response to climate change are generally uncertain, except in the western North Pacific where models agree on a dramatic increase in cyclone activity (Emmuel et al. 2008). If hurricane frequency and intensity increase, then a larger percentage of forests will be set back to earlier stages of succession; a decrease in hurricane frequency or intensity will result in more mature forest stands (Lugo 2000).

DANGERS OF SMOKE

Photo: NPS

Fires create smoke, which threatens greenhouse gas budgets, carbon stocks, and air quality, because smoke contains potentially toxic particles and gases, precursors to ozone, and greenhouse gases converted from biomass by fire. However, fire is also a natural process, in some places unavoidable, that responds to climate. In the West, fires are becoming larger, more frequent, and severe (i.e., consuming or killing a greater proportion of the forest) likely due to a warming climate.

Fighting fire with fire is a well-worn but apt cliché that may apply to climate change response simply because managers control so few other processes that operate at the large, landscape scales in question. Yosemite and Sequoia and Kings Canyon National Parks are studying the frequency and severity of fires as key elements that can be manipulated by fire management, and that by facilitating frequent, moderately growing, mixed severity fires, managers can reduce the impact and severity of forest fires and maximize the resilience and stability of ecosystems and carbon stocks, especially in fire dependent forest ecosystems.

Invasive species:

Introduced species, pathogens, and herbivores are pervasive disturbances in forest ecosystems. Impacts include herbivory, predation, disease, parasitism, competition, habitat destruction, hybridization, and changed disturbance regimes and nutrient cycles. Pathogens and herbivores exert strong impacts within every major forest type (Ayers and Lombardero. 2000). Several global processes, including climate and land-use change, economic globalization, and alteration of nutrient cycles, are contributing to escalating rates of species invasions and impacts (Vitousek et al. 1996, Mooney and Hobbs 2000). Within temperate and boreal forests, increases in summer temperatures result in faster development of insects, thereby increasing reproductive success (Sharpe and DeMichele 1977, Asante et al. 1991, Porter 1991). Conversely, decreases in snow depth may decrease overwinter survival of insects that live in the forest litter and rely on insulation by snow (Ayers and Lombardero 2000). Changes in temperature, precipitation, soil moisture, and relative humidity can also influence the dispersal and colonization success of other forest pathogens (Brassier 1996, Lonsdale and Gibbs 1996, Chakrabbrty 1997, Houston 1998). The biogeographical ranges of many species are directly influenced by climate, but assessing species dispersal and impacts to forests is complicated and not well studied (Simberloff 2000). Pimentel et al. (2000) estimate the damage caused by non-indigenous insect species to U.S. forests is $2.1 billion annually. There are approximately 50,000 foreign species in the United States and the number is increasing. About 42 percent of the species on the Threatened or Endangered species lists are at risk primarily because of alien-invasive species (Pimentel et al 2005). The United States has about 2,000 non-native invasive plant species (i.e., weeds), which are especially prevalent in California, Florida, and Hawaii (Mitchell 2000). An estimated 138 alien tree and shrub species have invaded native U.S. forest and shrub ecosystems (Campbell 1998). Approximately 360 non-indigenous insect species are found in U.S. forests (Liebhold et al. 1995).

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. 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 fungal infection and feeding by the beetle larvae kill the trees.

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 northward to regions like British Columbia. They have rapidly colonized areas that were previously climatically unsuitable (Carroll et al. 2003). Because these new areas had not 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). All these changes have resulted in unprecedented forest death. The current outbreak in British Columbia, for instance, is 10 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).

Shifts in Species Distributions:

Species respond negatively to climate change through population declines or local extinction, or positively through increases and expansion into new areas. Collectively, such individual responses can drive dramatic shifts in forest distribution and composition and produce novel species assemblages (Lenihan and Neilson 1995, Huntley et al. 1997). Observations over recent decades document many forest species responses to climate change, and long-term datasets from natural archives (e.g., lake-sediment cores) reveal dramatic species migrations and major landscape-level changes in forest distribution and composition over millennia (Davis 1981, Lenihan and Neilson 1995, Huntley et al. 1997, Hupy and Yansa 2009).

These observations – and the simulations they inform – suggest that forest responses to 21st century climate change will be substantial. In general, boreal forest and taiga-tundra systems/communities are expected to move northward or upward at the expense of arctic and alpine tundra, and warmer scenarios suggest that forests in the northwestern and southeastern United States might initially expand although very substantial uncertainties remain (Iverson et al. 2008). Such predictions should be evaluated carefully and in context – for example, pronounced warming in the high-elevation tropics suggests that the upper limit of cloud forest will move uphill, but climate change is strengthening a sharp vertical climatic discontinuity (the trade wind inversion; Diaz et al. 2011) that may preclude such a response. Elsewhere, anticipated responses may await disturbance as a trigger or be limited by seed dispersal or other limits on migration capacity (Cramer and Steffen 1997), chronological mismatch between pollinators and flowering events, and non-uniform vegetation shifts. Different species assemblages may appear and disappear over time (Lenihan and Neilson 1995, Huntley et al. 1997) and their composition will be strongly affected by changes in disturbance regimes.

CLIMATE CHANGE AND THE WISCONSIN ENVIRONMENT

Wisconsin's northern forests have warmed noticeably in winter and spring over the past half-century, and have become drier in summer (WICCI 2011). Plant and animal phenology has already shifted in response to 20th century warming (Bradley et al. 1999), and accelerating climate change in the coming decades will alter species' abundances and distributions across the state.

Biological responses will be heterogeneous (Davis 1981, Hotchkiss et al. 2007), and so effective management must distinguish between forest communities and species ranges that will change dramatically and those that will not. Sediment cores from lakes and bogs, which contain records of long-term vegetation response to climate and fire (Lynch et al. 2011), can make powerful contributions towards scientifically based conservation and management by expanding our perspective over a much broader range of changes in climate, fire, and vegetation than has been observed in recent decades (e.g., Davis et al. 2000, Willis et al. 2007, Froyd and Willis 2008, Pearman et al. 2008).

The Wisconsin Department of Natural Resources has joined with two UW-Madison research labs to form an innovative partnership that uses an array of paleoecological records to train LANDIS forest process models (Mladenoff 2004, 2005, Scheller and Mladenoff 2005) over several thousand years of changing climate, fire, and vegetation. The models will be used with newly available downscaled climate projections to predict future habitat changes. These analyses will identify and describe likely scenarios for 1) habitats most sensitive to climatic variation; and 2) rare bird and mammal species dependent on particular habitats that are most likely to be affected by climate changes in Wisconsin. Findings will inform landscape-level climate change adaptation strategies, as well as species-specific rare bird and mammal species conservation efforts.

Habitat Fragmentation:

Some climate models indicate extensive fragmentation of the eastern temperate mixed forests, which are very sensitive to changes in available water and thus, to any positive effect of elevated CO_2 (Butchart et al. 2004). Human land use can influence forest distribution and composition, and therefore species in today's highly fragmented landscape face unprecedented obstacles to expansion and migration (Hansen et al. 2001, Thomas et al. 2004). These anthropogenic influences may magnify the climate change species-extinction threat to forests, and could generate species-poor forests and disequilibrium ecosystem dynamics. The only forecast that seems certain is that the more rapidly the climate changes, the higher the probability of substantial disruption and surprise within natural systems (Root and Schneider 1993).

Economic Impacts:

Climate change impacts on the distribution and productivity of forests will have direct consequences for the forest products industry, notably through impacts to the supply of wood to sawmills and paper mills. However, adaptation in U.S. timber and wood-product markets may offset some of the potential negative effects of climate change (Sohngen and Mendelsohn 1998, Sohngen and Sedjo 1998, Winnett 1998, Sohngen and Alig 2000). Industry responses to climate change may include selecting and planting alternative tree species, changing the nature or location of capital and machinery, changing reliance on imports or exports, or adopting new processing technologies. In addition, climate change will influence other socioeconomic uses of forested ecosystems, including recreation and non-timber product availability and harvest. Weather and climate are major deterministic factors in the demand for outdoor recreation. Seasonality influences both cold and warm weather forest-based recreation and recreational and tourism patterns are predicted to increase in areas with warm season activities and to shift to higher latitudes and altitudes (Morris and Walls 2009).

Areas with lengthened warm periods will experience shifts in recreational demand toward warm season outdoor activities (e.g., camping, fishing), increasing the intensity and duration of these forest-based activities, as well as pressure on local infrastructures and resultant environmental impacts (e.g., pollution, water use) (Irland et al. 2001, Morris and Walls 2009). Just as climate change will exacerbate the impacts of drought, insect infestations, and wildfire on the forests themselves, so too will they impact forest-based recreation. Wildfires can lead to unexpected forest closures; disease-ridden areas diminish the aesthetic quality of forests. Reduced habitat quality impacts the density, composition, and presence of animal species, which serve as a major draw to recreationists (Morris and Walls 2009).

The changing presence and abundance of valued NTFPs will impact rural households that rely on harvesting, processing and exchange of these products to provide them with a critical economic safety net (Mclain et al. 2008). Harvest pressures on NTFPs increase in the face of local economic downturns (e.g., layoffs) as an increasing number of people turn to NTFPs as a source of income (Bailey 1999, Mclain et al. 2008, Shackleton et al. 2011). In response to the changing availability of forest resources, market forces may drive species substitutions that could shift manufacturing and processing infrastructure and lead to changes in imports and exports of goods (Irland et al. 2001). As an integral forest-based land-use activity, the complexities of NTFP production systems will present unique challenges in forest adaptation strategies and policies (Laird et al. 2010).

WHAT HAPPENS TO TRIBAL IDENTITY IF BIRCH BARK VANISHES?

Photo: John Zasada

Climate change models suggest that by 2100, the paper birch tree may no longer be able to survive in its habitat in the upper Midwest and northeastern United States, from northern Wisconsin to Maine (Prasad et al. 2007). This 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 is one such example.

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. 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.

Climate Adaptation Strategies and Actions for Forest Systems

The *Strategy* identified seven primary 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. Each Goal identifies a set of initial Strategies and Actions that should be taken or initiated over the next five to ten years.

Actions listed here were derived from those Technical Team submissions determined to be most applicable to forest systems. Numbers that correspond to the full *Strategy* document are designated by *Strategy* (S) and the Action number (e.g., 1.1.1).

GOAL 1: Conserve 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:

— A: Identify and map high priority forest areas for conservation using information on species distributions (current and projected), habitat classification, land cover, and geophysical settings (including areas of rapid change and slow change). (**S 1.1.1**)

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

— C: Establish and maintain a comprehensive, inter-jurisdictional inventory of current conservation areas and candidate high priority conservation areas in order to coordinate future conservation efforts. (**S 1.1.4**)

— D: Protect and maintain existing seed orchards and establish new orchards for priority species and geographic areas.

Strategy 1.2: Secure appropriate conservation status on areas identified in Action 1.1.1 to complete an ecologically-connected network of public and private conservation areas that will be resilient to climate change and support a broad range of species under changed conditions.

Actions:

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

— B: 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 habitat features where necessary and practicable to maintain ecosystem function and processes and resiliency to climate change.

Actions:

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

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

— C: Develop market-based incentives that encourage reforestation in forested systems where appropriate. (**S 1.3.6**)

— D: Expand restoration seedbanks and build nursery and agronomic capacity for native plant materials, including development of seed zones and transfer guidelines, validation of seed transfer tools, and providing training for deployment of native plant material that will be adapted to current and future environments.

SALMON IN THE TREES

Photo: Amy Gulick

To adequately prepare for change, resource managers must consider how climate influences the reciprocal relationships within and among ecosystems and plan adaptation strategies accordingly. The interaction of salmon and forest ecosystems illustrates this complexity. A major ecological role of salmon is to transport marine-derived nutrients and organic matter to riparian forests and wildlife, which in turn, has the potential to feed back into the growth and survival of the next generation of salmon.

Salmon nutrients are deposited in riparian forests by predator and scavenger excreta, partially eaten salmon and skeletons, and floods that transport carcasses upslope, decay, and are transported to the forest by subsurface flow (Drake et al. 2006). Studies of salmon consumers such as eagles, bears, and mustelids suggest that salmon play an integral role in population dynamics (Hansen 1987, Ben-David 1997, Hilderbrand et al. 1999). Further, the ecological benefits of salmon influence multiple trophic levels, including increased invertebrate biomass and songbird abundance and diversity adjacent to salmon streams (Gende and Wilson 2001, Christie and Reimchen 2008).

Studies have also significantly linked salmon abundance and annual escapement (from predators) to tree-ring growth in riparian forests (Drake et al. 2006); and salmon nutrients to shifts in plant communities towards nutrient rich species and lower plant community diversity (Hocking and Reynolds 2011). Riparian forests contribute to salmon stream habitat through shading, sediment, and nutrient filtration, and production of large woody debris that shelters young salmon. As trees and shrubs near spawning streams show significant growth due to nitrogen inputs from salmon, scientists posit that this fertilization subsidy may act as a positive feedback mechanism for spawning and rearing habitat for future generations of salmon (Helfield and Naiman 2001).

Terrestrial anthropogenic stressors such as deforestation, habitat degradation, logging roads built in riparian areas, and urbanization have contributed to the degradation of many salmon streams. Riparian buffer strips that are too narrow to accommodate the activities of bears and other salmon predators can severely disrupt the salmon nutrient transfer from water to land. The importance of forests for fish goes beyond conventional consideration of water temperatures, sedimentation, and pool creation using woody debris. Aquatic and terrestrial ecologists need to cooperatively study this two-way coupling of land and water ecosystems for salmon recovery efforts (Willson et al. 1998).

Additionally, effective adaptation strategies must take into consideration a holistic view of these complex relationships at a landscape scale through a climate change lens. Certainly, research on understanding the linkages, how they interact with one another, and how they are collectively affected by stressors is a start (Mote et al. 2003). Protecting, maintaining, or restoring adequate riparian forest buffers that shade streams *and* support salmon predators might be another strategy to consider, especially riparian forests on valley floors and alluvial terraces (Willson et al. 1998, Naiman et al. 2005). Forests managed beyond the buffers for timber, should be planted with trees well-suited to thrive in climate projected for an area including insect pest and invasive scenarios. Finally, protecting springs and large groundwater seeps within the forest matrix will also be necessary as subterranean water sources will become more important as surface flows are altered by climate change (Naiman et al. 2005). Land management strategies that strengthen the climate change resilience between salmon and all the ecosystems they inhabit will have the best chance of insuring that the linkages between salmon and forests remain intact and functional for future generations of salmon, bears, and people.

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

Actions:

- A: Assess and prioritize critical connectivity gaps and needs across current forest conservation areas, including areas likely to serve as refugia in a changing climate. (**S 1.4.2**)
- B: Conserve transitional areas between connected forests and forests fragmented by human land use to limit further habitat loss or degradation. (**S 1.4.3**)
- C: Assess and take steps to reduce risks of facilitating movement of undesirable non-native species, pests, and pathogens. (**S 1.4.4**)

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

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

Actions:

- A: Review and revise as necessary techniques to maintain or mimic natural disturbance regimes and to protect vulnerable habitats. (**S 2.1.5**)
- B: 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.
- C: Create forest landscape patterns with many age classes and diverse species and seed sources, including genetically diverse, older-aged seed trees.

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

Actions:

- A: Use vulnerability and risk assessments to design and implement management actions at species to ecosystem scales. (**S 2.2.1**)
- B: Develop criteria and guidelines for the use of translocation, assisted migration, and captive breeding as climate adaptation strategies. (**S 2.2.2**)
- C: Where appropriate, actively manage populations of vulnerable species as part of timber and NTFP management activities (e.g., harvest limits, seasons, and supplementation) to maintain biodiversity, human use, and other ecological functions. (**S 2.2.3**)
- D: Increase plant adaptive capacity through expansion of traditional breeding programs to new species or traits or new biotechnologies.

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

Actions:

- — A: Protect and maintain high quality native seed sources including identifying areas for seed collection across elevational and latitudinal ranges of target species. (**S 2.3.2**)
- — B: Develop protocols for use of propagation techniques to rebuild abundance and genetic diversity for particularly at-risk species. (**S 2.3.3**)
- — C: In degraded areas (e.g., post fire or insect infestation), 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, taking care to prevent the introduction and spread of invasive species.
- — D: Bank seed and develop and deploy as appropriate forest plant materials (including understory species) 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 awareness and capacity of natural resource managers and enhance their professional capacity to design, implement, and evaluate fish, wildlife, and plant adaptation programs.

Actions:

- — A: Build on existing needs assessments to identify gaps in climate change knowledge and technical capacity among natural resource professionals. (**S 3.1.1**)
- — B: Develop training on the use of existing and emerging tools for managing under uncertainty (e.g., vulnerability and risk assessments, scenario planning, decision support tools, and adaptive management). (**S 3.1.3**)
- — C: Encourage use of interagency personnel agreements and interagency (state, federal, and tribal) joint training programs as a way to disperse knowledge, share experience and develop interagency communities of practice about climate change adaptation. (**S 3.1.5**)
- — D: Increase scientific and management capacity (e.g., botanical expertise) to develop management strategies to address impacts and changes to forest species. (**S 3.1.7**)

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:

- — A: 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. (**S 3.2.1**)
- — B: Collaborate with tribal governments and native peoples to integrate traditional ecological knowledge and principles into climate adaptation plans and decision-making. (**S 3.2.4**)
- — C: 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 shared trans-boundary areas and for common migratory species. (**S 3.2.5**)
- — D: 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. (**S 3.2.6**)

Strategy 3.3: Review existing federal, state and tribal legal, regulatory and policy frameworks that provide the jurisdictional framework for conservation of fish, wildlife, and plants to identify opportunities to improve, where appropriate, their utility to address climate change impacts.

Actions:

— A: Review existing legal, regulatory and policy frameworks that govern protection and restoration of habitats and ecosystem services and identify opportunities to improve, where appropriate, their utility to address climate change impacts. (**S 3.3.1**)

— B: Continue the ongoing work of the Joint State Federal Task Force on Endangered Species Act (ESA) Policy to ensure that policies guiding implementation of the ESA 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. (**S 3.3.6**)

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

Actions:

— A: Prioritize funding for land and water protection programs that incorporate climate change considerations. (**S 3.4.1**)

— B: 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. (**S 3.4.2**)

— C: Collaborate with state and tribal agencies and private conservation partners to sustain authorization and appropriations for the State and Tribal Wildlife Grants Program and include climate change criteria in grant review process. (**S 3.4.3**)

GOAL 4: Support adaptive management in a changing climate through integrated observation and monitoring and use of 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:

— A: Develop consensus standards and protocols that enable multi-partner use and data discovery, as well as interoperability of databases and analysis tools related to fish, wildlife, and plant observation, inventory, and monitoring. (**S 4.1.2**)

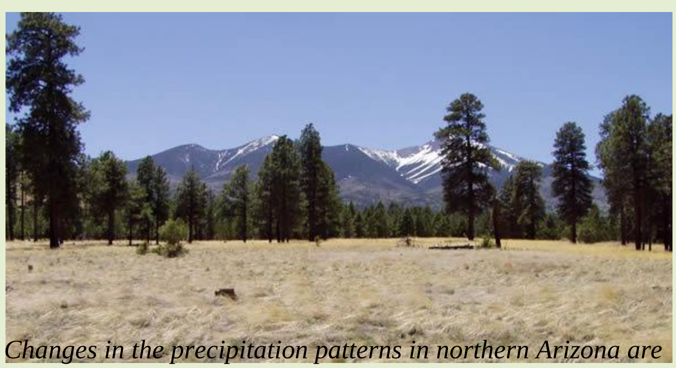
— B: Develop, refine, and implement monitoring protocols that provide key information needed for managing forest systems (e.g., expand Forest Inventory and Analysis sampling to include additional variables). (**S 4.1.7**)

— C: 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.

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 cannot, then vital ecological relationships could be severed.

The FWS's Arizona Ecological Services Field Office and the Merriam-Powell Center for



Changes in the precipitation patterns in northern Arizona are affecting Ponderosa pine in the highest elevations of the San Francisco Peaks. Photo: David Smith/USFWS

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

Actions:

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

— B: Conduct vulnerability and risk assessments for priority species (threatened and endangered species, species of greatest conservation need, species of socioeconomic, and cultural significance). (**S 4.2.4**).

— C: Use observation, information, assessment, and decision support systems to monitor and determine the effectiveness of specific management actions to analyze the potential for maladaptation and adapt management approaches appropriately. (**S 4.2.8**)

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

Strategy 5.1: Identify knowledge gaps and define research priorities via a collaborative process among federal, state, and tribal resource managers and research scientists working with the National Science Foundation (NSF), USGCRP, National Climate Assessment (NCA), USDA Extension, Cooperative Ecosystem Study Units (CESUs), Climate Science Centers (CSCs), LCCs, Migratory Bird Joint Ventures (JVs), and Regional Integrated Sciences and Assessments (RISAs).

Actions:

— A: Increase coordination and communication between resource managers and researchers through existing forums (e.g., NSF, USGCRP, NCA, USDA, CESUs, CSCs, LCCs, JVs, RISAs, and others) to ensure research is connected to management needs. (**S 5.1.1**)

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

Strategy 5.2: Conduct research into ecological aspects of climate change, including likely impacts and the adaptive capacity of species, communities and ecosystems, working through existing partnerships or new collaborations as needed (e.g., USGCRP, NCA, CSCs, RISAs, and others).

Actions:

— A: Support basic research on life histories and food web dynamics of fish, wildlife, and plants to increase understanding of how species are likely to respond to changing climate conditions and identify survival thresholds. (**S 5.2.2**)

— B: Accelerate research on establishing the value of ecosystem services and potential impacts from climate change such as loss of pollution abatement or flood attenuation, etc. (**S 5.2.4**)
— C: Investigate how key species move through forest landscapes (permeability) for key species.
— D: Increase research on pollination, dispersal, food web dynamics, and other species interactions to better understand ecological interrelationships among forest-dependent fish, wildlife and plants.
— E: Monitor changing timber and NTFP harvest levels and management activities to support sustainable populations of vulnerable species and habitats in response to shifts in economic use and opportunities of forests resulting from climate change.
— F: Develop unique partnerships with entities not traditionally engaged in conservation, but which impact on forest health (e.g., USDA-National Organic Program (Wild Crop Certification) has biodiversity requirements, conducts monitoring and audits).

Strategy 5.3: Advance understanding of climate change impacts and species and ecosystem responses through modeling.

Actions:

— A: 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.
— B: 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. (**S 5.3.1**)
— C: Develop models that integrate the potential effects of climate and non-climate stressors on vulnerable species. (**S 5.3.3**)

SOUTHWEST CLIMATE CHANGE INITIATIVE

Natural landscapes in the Southwest have changed—80 percent of the habitats and 70 percent of the watersheds in the Southwest have warmed significantly over the last half century. Ecological and hydrologic transformation is occurring in up to half of these areas which has resulted in changes to species behavior, snowpack, stream-flow regime, invasive species infestation and natural disturbance intervals and intensity.

Native Southwestern habitat types of intensifying conservation concern include subalpine forests, piñon-juniper woodlands, sage shrublands, and Colorado Plateau canyonlands and grasslands. At least 119 plant and animal species within these habitats have been affected by climate change.

A public-private partnership initiated in 2008, the Southwest Climate Change Initiative (SWCCI) was established to engage conservation practitioners and land managers in local-scale climate change adaptation planning and implementation. As designed, the SWCCI project intends to:

- Develop and expand impacts assessment activities in each of the Southwest's Four Corners states (AZ, CO, NM, and UT);
- Apply a vulnerability assessment tool being developed by the U.S. Forest Service; and
- Implement an adaptation planning framework developed by the Wildlife Conservation Society and National Center for Ecological Analysis and Synthesis working group to a series of case-study sites in the four states.

The case studies will provide opportunities to further test and refine each component of the overall framework, by building on new research, strengthening existing partnerships, and laying the foundation for future innovation, including on-the-ground application and testing of adaptation strategies.

SWCCI Partners:

National Center for Atmospheric Research
The Nature Conservancy
University of Washington
USDA Forest Service
Western Water Assessment
Wildlife Conservation Society

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 the public through targeted education and outreach efforts and stewardship opportunities.

Strategy 6.3: Coordinate climate change communication efforts across jurisdictions.

GOAL 7: Reduce non-climate stressors to help fish, wildlife, plants, and ecosystems adapt to a changing climate.

Strategy 7.1: Slow and reverse habitat loss and fragmentation.

Actions:

— A: 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. (**S 7.1.1**)

— B: Bridge the gap between ecosystem conservation and economics, and consider market-based incentives that encourage conservation and rehabilitation of ecosystems for the full range of ecosystem services including carbon storage. (**S 7.1.6**)

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

Actions:

— A: Work with local and regional land-use, water resource, and coastal and marine spatial planners to identify potentially conflicting needs and opportunities to minimize ecosystem degradation resulting from development and land and water use. (**S 7.2.1**)

— B: Regulate ungulate herbivory populations to promote and protect regeneration.

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.

Due to climate warming impacts such as coastal erosion, increased storm effects, sea ice retreat, and permafrost melt, the village of Newtok, home to the Qaluyaarmiut people for at least 2,000 years, has begun relocation plans. The Qaluyaarmiut are avid fishermen and depend on the natural environment for subsistence. With an average erosion rate of 68 feet per year from 1953 to 2003 and the combination of all the climate warming impacts it is enduring, Newtok is no longer a sustainable long-term home for the Qaluyaarmiut people (Feifel and Gregg 2010).

Members of the American Indian Alaska Native Climate Change Working Group represent a broad alliance of indigenous communities, tribal colleges, scientists, and activists, who recognize the significance of situations like Newtok, 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 in a relaxed setting that promotes broad participation, and often lead to consideration of a broader spectrum of resources and issues than externally driven approaches.

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