National Fish, Wildlife and Plants Climate Adaptation Strategy

Desert Ecosystems

Photo: AFWA

Disclaimer

The information in this Desert Ecosystems Background Paper was developed by the Grassland, Shrubland, Desert, and Tundra 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 Desert 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. desert 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 desert 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 desert 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 desert 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 desert fish, wildlife, and plants.

Desert Ecosystem Description

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 Mojave, Sonoran, and Chihuahuan Deserts, which are located in the Basin and Range Province (Bailey 1998) of the western United States between the Rocky Mountains in the east and the Sierra Nevada in the west. The so-called "cold deserts," including much of the Great Basin, are covered in this *Strategy* under Shrubland systems.

The Mojave Desert occurs within an isolated, inland drainage basin that includes a significant portion of southeastern California and smaller parts of central California, southern Nevada, southwestern Utah, and northwestern Arizona (Bailey 1998). Mean annual precipitation ranges between 1.4 and 12.2 inches (Hastings and Turner 1965). Phenological events in the Mojave Desert are triggered by heavy rains (more than one inch), with the most predictable and consequential of these occurring between September and early December (Beatley 1974).

The Mojave Desert's boundaries are also generally defined by the presence of Joshua trees (*Yucca brevifolia*). While this desert is believed to support between 1,750 and 2,000 species of plants, the landscape is dominated by a few perennial plants, primarily creosote (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*) (MacMahon and Wagner 1985). The Mojave is rich in annuals. Of the 250 species, at least 80 are endemic (Quinn 2009). Most are winter annuals responding to September through December rainfall, but summer annuals also occur. The time of rain is critical in determining which species germinate. The Mojave Desert has not historically supported a fire regime because of low fuel loads and connectivity. However, in the last few decades, invasive annual plants (e.g., *Bromus spp.*, *Schismus spp.*, *Brassica spp*.) have facilitated fire, which has significantly altered many areas of the desert. At higher elevations, fire regimes are regular but infrequent.

Mammals of the Mojave are similar to those of the other North American hot deserts including desert bighorn sheep (*Ovis canadensis nelson*), mountain lion (*Puma concolor*), coyote (*Canis latrans*), kit fox (*Vulpes macrotis*), mule deer (*Odocoileus hemionus*), and bobcat (*Lynx rufus*) (Quinn 2009). Except for the coyote and mule deer, these large mammals live only at the edges of the desert because of the sparse desert vegetation. Most lizards and snakes in the Mojave are subspecies of more widespread species. While not endemic, many lizard and snake species are distinctive in the Mojave, such as the regal horned lizard (*Phrynosoma solare*), Mojave patchnose snake (*Salvadora hexalepis mojavensis*), and Mojave rattlesnake (*Crotalus scutulatus*) (Quinn 2009). Chuckwallas (*Sauromalus spp.*) are also characteristic. The federally threatened subspecies Agassiz's desert tortoise (*Gopherus agassizii*) occurs in alluvial fans, washes, and canyons of the desert where more suitable soils for den construction might be found (NABCI 2011). Kelso Dunes in Mojave National Preserve is a distinct community with seven endemic insects (Quinn 2009).

The Sonoran Desert is the warmest and most tropical of the three North American deserts. The Sonoran Desert consists of approximately 55 million acres and covers parts of Arizona, California, and the Mexican states of Sonora and Baja, California (Marshall et al. 2000). The Sonoran Desert is perhaps the most accessible of the three deserts with its close proximity to major population centers in the United States. It therefore receives high visitor use on numerous federal reserves, monuments, and eleven National Park Units within its boundaries (Davey et al. 2007).

The Sonoran Desert has a bi-modal rainfall pattern receiving frequent low-intensity winter rains and intense summer "monsoon" thunderstorms. These distinct rainy seasons support a broad assemblage of warm- and cool-season species, giving the Sonoran Desert its unique diversity. The desert harbors a high proportion of endemic plants, reptiles, and fish (Marshall et al. 2000). Vegetation is sparse, with bare ground between individual plants. Cacti and thorny shrubs are most prevalent. The creosote bush, arborescent cacti or cholla (*Opuntia spp.*), Joshua tree, and saguaro cacti (*Carnegiea gigantean*) are common. Honey mesquite (*Prosopis glandulosa*) is less widespread and grows only along washes and watercourses (Bailey 1998). Large ungulates are almost absent from the desert with only desert mule deer (*Odocoileus hemionus crooki*), collared peccary (*Pecari tajacu*), and the federally endangered Sonoran pronghorn antelope (*Antilocapra americana sonoriensis*) present (Bailey 1998). Many birds including Gila woodpecker (*Melanerpes uropygialis*), elf owl (*Micrathene whitneyi*), Gambel's quail (*Callipepla gambelii*) cactus wren (*Campylorhynchus brunneicapillus*) and purple marten (*Progne subis*) nest in tall cacti. Various reptiles, snakes and lizards, are common on the desert floor along with more notable species, the Gila monsters (*Heloderma suspectum*) and desert tortoise (*Gopherus agassizii*) (Bailey 1998). The area near the Mexican border is vital habitat for the only jaguars (*Panthera onca*) living within the United States.

The Chihuahuan Desert is the largest North American desert and one of the most biologically rich deserts in the world (Dinerstein et al. 2001, Holt 2002, Archer and Predick 2008). It extends from southwestern New Mexico and western Texas south into Mexico, covering an area of about 140,000 square miles. The climate is distinctly arid; spring and early summer are extremely dry, while summers are characteristically long and hot with short winters (Bailey 1998). The terrain mainly consists of basins broken by numerous small mountain ranges such as the Sacramento and Guadalupe Mountains. These create "sky islands" such as the Madrean Archipelago in Arizona, where cooler, wetter, climates within the desert and higher elevations combine to support both coniferous and broadleaf woodlands, and even forests along drainages and favored exposures.

The Chihuahuan Desert is one of the most biologically diverse deserts on Earth, and has been recognized by the International Union for the Conservation of Nature as one of the most important arid eco-regions for both its freshwater and terrestrial biodiversity (Olson and Dinerstein 1998). Typical desert species including tulip prickly pear (*Opuntia phaecantha*) and lechuguilla (*Agave lechuguilla*) as well as conifer forest, oak woodlands, grasslands, sand dunes, and spring fed pools are present (Bailey 1998, Dinerstein et al. 2001, Archer and Predick 2008). Grasslands comprise 20 percent of this desert, often in mosaics of grass and shrub including side-oats grama (*Bouteloua curtipendula*), black grama (*Bouteloua eriopoda*), and purple three-awn (*Aristida purpurea*) (Bailey 1998, Dinerstine et al. 2001). Species diversity is represented by approximately 2263 species of vascular plants, over 100 species of mammals, over 100 species of reptiles, 250 bird species, 20 to 25 amphibian species, and 250 species of butterflies (Dinerstein et al. 2001). However, the region has been heavily degraded over time, primarily by inappropriate grazing. Many native species have been replaced with creosote bush, currently the dominant native plant species throughout the Chihuahuan Desert.

Existing Stressors:

Threats from water mismanagement, overgrazing, and overbrowsing 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 (Dinerstine et al. 2001). Human population growth and its distribution across the desert will be one of the most important issues that will be faced during the next century.

The spread of non-native species in desert systems can also lead to higher fuel levels and more frequent fires, which can significantly impact native species that evolved with infrequent, low-intensity fires. For example, non-native buffelgrass (*Pennisetum ciliare*) and other African grasses now common in much of the Sonoran Desert provide elevated fuel levels that could threaten cactus species with increased fire frequency and severity (Williams and Baruch 2000). In the Chihuahuan Desert, the prevalence of invasive species such as cheatgrass (*Bromus tectorum*) similarly increases the frequency and intensity of fires over what has historically occurred (Archer and Predick 2008). In the Mojave Desert and Great Basin, highly flammable species such as exotic annual brome grasses (*Bromus sp*.) and Arabian Schismus (*Schismus spp.*) cover millions of acres and spread rapidly after fires. Among the many charismatic species at risk are saguaro cactus, Joshua tree, and desert tortoise (Cole et al. 2011).

Desert systems have not been converted to agriculture as extensively as grasslands and shrublands, largely due to their aridity. However, urban expansion will affect these areas through increasing human demand for water and energy, further reducing water availability for wildland ecosystems. Decreased water availability and development will impact desert riverine and riparian ecosystem function and disrupt wildlife movement corridors through the desert. Although these areas comprise a small fraction of arid lands, they provide critical habitat for arid land vertebrates and migratory birds (Archer and Predick 2008). Climate change will offer further challenges for natural resource managers to maintain adequate supplies of water to achieve wildlife management objectives (Mawdsley 2011). Lands currently under protection or managed for species resiliency, where demand already exceeds supply or in those regions highly dependent upon groundwater or seasonal flows from snowmelt appear especially vulnerable. (Marshall et al. 2000, Enquist and Gori 2008, Mawdsley 2011). As more private lands are developed in the United States 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, and groundwater.

Large-scale habitat conversion for renewable energy development has the potential to exacerbate existing and anticipated climate stressors and inhibit species adaptation options by limiting movement between remnant habitats (Lovich and Bainbridge 2003, Boardman and Kristan 2006). In the California Desert, applications for solar energy facilities in 2007 total nearly 500,000 acres due to the emphasis on advancing alternative energy sources. In Nevada, habitat lost through energy development is also a potential threat, where various energy development projects have been proposed and applications have been submitted for solar power facility right-of-ways on over 133,000 acres of potential desert tortoise habitat. In 2010, the Nevada Department of Wildlife reviewed and commented on 20 proposed solar energy projects located within the Mojave Desert of southern Nevada, primarily on lands administered by the Bureau of Land Management.

Impacts of Climate Change on Desert Systems

Like most of the rest of the United States, the arid west and southwest has been warming over the last century. Parts of southern Utah and Arizona have had greater than average increases in temperature (e.g., 3 to 5 °F) (USGCRP 2009), and the Southwest has experienced the smallest increase in precipitation in the last 100 years of any region in the coterminous United States (CCSP 2008). Climate models project drying and continued warming in the arid ecoregions, which could have significant effects on desert habitats (CCSP 2008), as well as increased severity and duration of droughts (USCGRP 2009). Aridity of some deserts such as the Chihuahuan Desert is predicted to increase, which together with pumping of groundwater for irrigation combined with over-grazing which reduced aquifer recharge rates, has resulted in the loss of many springs in the U.S. portion of the eco-region (Kelley and Contreas 2002). Current predictions include fewer frost days; warmer temperatures; greater water demand by plants, animals, and people; and an increased frequency of extreme weather events such as heat waves, droughts, and floods (Archer and Predick 2008). Likely impacts are summarized in Table 1.

Table 1: Expected Climate Change Impacts on Deserts Ecosystems (USGCRP 2009 and IPCC AR4 2007)

Major Changes Associated With Increasing Levels of Greenhouse Gases (GHGs)	Major Impact on Deserts
Increased temperatures:	Elevated water stress, mortality in heat-sensitive species, possible desert expansion
Melting ice/snow	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

Precipitation is predicted to increase slightly in the eastern Chihuahuan Desert but decrease westward through the Sonoran and Mojave Deserts (Archer and Predick 2008). 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. Higher temperatures and decreased soil moisture will likely reduce the stability of soil aggregates, making the surface more erodible (Archer and Predick 2008).

While rainfall events are expected to decrease in occurrence, they may increase in intensity, and intense storms will likely become more common. 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 rain storms, and have 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). Increased moisture in some areas may create wetlands where none existed before, whereas declining rainfall may eliminate prairie potholes or other significant wetlands, especially in marginally wet habitats such as vernal pools and near-deserts.

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 (Burkett and Kusler 2000, Winter 2000). Reductions in water levels and increases in water temperatures will potentially lead to reduced water quality, in terms of increased turbidity and decreases in dissolved oxygen concentrations (Poff et al. 2002). Increased productivity, driven by increased temperature, may lead to increases in algal blooms and more frequent so-called dead-zone (aquatic areas without any dissolved oxygen) conditions (Allan et al. 2005).

Varied rainfall and higher temperatures will likely exacerbate existing stressors coming from recreation, residential, and commercial development, and improper livestock grazing (Marshall et al. 2000). In addition, the abundance and range of non-native grasses will most likely increase in future climates, including the spread of cheatgrass and buffelgrass (Enquist and Gori 2008). This 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, Brooks and Pyke 2002, Heinz Center 2008).

Arid desert ecosystems of the western and southwestern United States are particularly susceptible to climate change and climate variability. 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 (Fernandes et al. 2010). Slight changes in temperature or precipitation regimes or a change in the frequency and magnitude of extreme climatic events could substantially alter the distribution and abundance of species, the composition of natural communities, and the ecosystem services that arid lands provide (Archer and Predick 2008, Barrows et al. 2010). Further alterations to species composition and ecosystem structure may result from widespread warming trends in winter and spring, decreased frequency of freezing temperatures, lengthening of the freeze-free season, and increased minimum winter temperatures (Weiss and Overpeck 2005).

These types of shifts could result in dramatic changes in wildlife communities in the affected areas. Overall, we may see a reduction in the number of desert species and an increase in species that inhabit dry grasslands, shrublands, and woodlands (CCSP 2008). For example, Saguaro cacti 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. Conversely, limited available data suggest that increases in atmospheric carbon dioxide concentrations could promote Joshua tree seedling survival and result in an increase of this native species’ range. However, both of these species are likely to decline in abundance if subjected to fires resulting from establishment of non-native grasses (Archer and Predick 2008).

CLIMATE CHANGE AND DESERT BIGHORN SHEEP

The desert bighorn sheep (*Ovis canadensis nelsoni*), occurs in isolated desert mountain ranges of the Sonoran, Mojave, and Great Basin deserts of the southwestern United States. Although this species is currently the most common of California’s three subspecies of bighorn sheep, hunting, loss of food from livestock grazing, and disease from domestic livestock has had devastating impacts on these sheep populations over the past century. Habitat

Photo: CA DFG

loss and fragmentation has further contributed to declining numbers of the desert bighorn sheep which occur in small populations scattered throughout the deserts. Essential to desert bighorn sheep survival is the need to maintain movement between other mountain ranges in order to preserve genetic diversity across metapopulations and to allow new colonization of available and suitable habitat in adjacent mountain ranges.

A study led by researchers at the University of California, Berkeley (Epps et al. 2004), linked population declines of California's desert bighorn sheep to the effects of climate change. Epps et al. (2004) predicts many of the state's remaining bighorn sheep populations could face extinction if climate change increases as forecasted over the next 60 years. The study also showed how interactions between climate and other factors like precipitation, elevation, and the presence of natural springs strongly correlate with population persistence. In contrast, lower, drier elevations that are exposed to areas where domestic sheep graze had a negative correlation to population persistence over time.

Ultimately, survival of the species may hinge on the ability of individual sheep to move between mountain ranges having higher elevation habitats. New obstacles to such movement are, however, now becoming more limited in the California deserts with broad scale development of renewable energy facilities and infrastructure on the desert floor.

In the last century, most of the water from Southwest river systems has been harvested for human use, leaving many streams totally or partially dewatered. Future decreases in precipitation and increases in human population present major challenges for maintaining adequate supplies of water for ecosystem persistence. Dams have reduced the base flows of major rivers and in some areas, groundwater pumping has reduced or eliminated spring and stream flow or allowed the infiltration of saline water into fresh water zones (Kelly and Contreras 2002). When compounded by persistent drought, ecosystem vegetation will be pushed toward the limits of their physiological tolerance to water stress, creating conditions that favor drought-tolerant species, leading to system change (CCSP 2009).

Many plants and animals in the desert ecosystem already live near their physiological limits for water and temperature stress. Among vertebrates, diurnal reptiles occurring in arid regions may be particularly sensitive to climate change, due to their relative sedentary behavior and occurrence in areas where high temperatures and drought drive species to their physiological limits (Barrows et al. 2010). Maintaining endangered aquatic species, such as the Devil's Hole pupfish (*Cyprinodon diabolis*) (which occurs naturally in a single cave in Ash Meadows National Wildlife Refuge in Nevada), will present even more challenges because most have limited dispersal abilities and opportunities (CCSP 2008).

Climate Adaptation Strategies and Actions for Desert Systems

The *Strategy* identifies 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 desert 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 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**)

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: Conserve desert areas identified in Action 1.1.1 that provide high-priority habitats under current climate conditions and are likely to be resilient to climate change and/or support a broad array of species in the future. (**S 1.2.1**)

— B: Identify and pursue opportunities to increase conservation of priority desert lands 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**)

Strategy 1.3: Restore habitat features where necessary and practicable to maintain ecosystem function and processes and resiliency to climate change.

Actions:

— A: Restore degraded habitats as appropriate to support diversity of species assemblages and ecosystem structure and function. (**S 1.3.2**)

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 desert conservation areas. (**S 1.4.2**)

- B: Conserve corridors and transitional habitats between ecosystem types through both traditional and non-traditional (e.g., land exchanges, rolling easements) approaches. (**S 1.4.3**)
- C: Assess existing barriers or structures that impede movement and dispersal within and among habitats to increase natural ecosystem resilience to climate change, and where necessary, consider the redesign or mitigation of these structures. (**S 1.4.5**)

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: Incorporate climate change considerations into existing and new management plans and practices using the best available science regarding projected climate changes and trends, vulnerability and risk assessments, and scenario planning. (**S 2.1.1**)
- B: Review and revise as necessary existing species and habitat impact avoidance, minimization, mitigation, and compensation standards and develop new standards as necessary to address impacts associated with climate change. (**S 2.1.6**)

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 (e.g., using harvest limits, seasons, translocation, captive breeding, and supplementation) of vulnerable species to ensure sustainability and maintain biodiversity, human use, and other ecological functions. (**S 2.2.3**)

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

- 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: Seed bank, develop, and deploy as appropriate plant materials for restoration that will be resilient in response to climate change. (**S 2.3.4**)

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 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. (**S 3.1.2**)
- 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 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: Identify and address conflicting management objectives within and among federal, state, and tribal conservation agencies and private landowners, and seek to align policies and approaches wherever possible. (**S 3.2.2**)
- 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 Mexico, to help adapt to and mitigate climate change impacts in shared trans-boundary areas and for common migratory species. (**S 3.2.5**)

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**)

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**)

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: Work through existing distributed efforts (e.g., the National Climate Assessment (NCA)) to support integrated national observation and information systems that inform climate adaptation. (**S 4.1.4**)
- C: Expand and develop as necessary networks of places for integrated climate change inventory, monitoring, research, and education. (**S 4.1.5**)

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: Conduct risk assessments to identify key climate change hazards and assess potential consequences for desert fish, wildlife and plants.
- B: 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: Ensure the availability of and provide guidance for decision support tools that assist federal, state, local, and tribal resource managers and planners in effectively managing fish, wildlife, and plants in a changing climate. (**S 4.2.7**)

CACTUS VULNERABILITY

Photo: FWS

Cacti may be an iconic symbol of the arid American desert, but this symbol faces an increasingly uncertain future. Adapted to hot, dry environments such as those found in the southwestern deserts of the United States, most cacti species have very specific habitat requirements that also make them highly vulnerable to climate change and susceptible to small changes in their environment. Another key vulnerability is potential disruption of associated species interactions under climate change. For example, many cacti depend on other species for pollination, to provide habit, or to protect them from herbivores. Changes in climate may result in mismatches in time or space between the cacti and other species upon which they depend.

While helping these species adapt will be challenging, the first key management step is figuring out which species are the most vulnerable and which might be able to survive or even thrive in a climate-changed world. One such assessment is already underway. NatureServe is seeking to develop Climate Vulnerability Indices for over a hundred cactus species found in the Sonoran, Mojave, and Chihuahuan deserts. This process includes assessing a species’ exposure and sensitivity to climate change through several factors, which are combined into a categorical vulnerability score. For example, in the Chihuahuan Desert, most cactus species assessed were either moderately (43 percent), highly (21 percent) or extremely (four percent) vulnerable to climate change (Hernández et al. 2010).

These types of vulnerability indices highlight the need for continued research on how climate change is likely to impact particular species and can help to establish priorities for adaptation activities. They are also tools to better inform management plans and conservation activities. In addition, vulnerability assessments may also help us identify those instances when viable adaptation measures simply may not be available.

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), Landscape Conservation Cooperatives (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**)

— C: Prioritize research on questions relevant to managers of near-term risk environments or highly vulnerable species. (**S 5.1.6**)

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 desert 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: Identify and address priority climate change knowledge gaps and needs (e.g., species adaptive capacity; risk/rewards of assisted migration; climate change synergy with existing stressors; etc.). (**S 5.2.3**)

— C: Accelerate research on establishing the value of ecosystem services and potential impacts from climate change such as loss of pollution abatement. (**S 5.2.4**)

— D: Conduct research on the propagation and production of native plant materials to identify species or genotypes that may be resilient to climate change. (**S 5.2.5**)

— E: Increase understanding of the adaptive capacity of desert communities and species under climate change.

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

Actions:

— A: Develop and use models of climate-impacted physical and biological variables and ecological processes at temporal and spatial scales relevant to conservation.

— B: Improve modeling of climate change impacts on vulnerable species, including projected future distributions and the probability of persistence. (**S 5.3.2**)

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: 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 conservation or restoration in desirable locations. (**S 7.1.5**)

— B: Minimize impacts from alternative energy development by focusing siting options on already disturbed or degraded areas. (**S 7.1.7**)

— C: 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/ocean-use planning, water resource planning, pollution abatement, and the implementation of best management practices.

Actions:

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

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

Actions:

— A: Employ a multiple barriers approach to detect and contain incoming and established 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. Utilize education, regulation, and risk management tools (e.g., the Hazard Analysis and Critical Control Point process) to address. (**S 7.3.1**)

— B: Apply risk assessment and scenario planning to identify actions and prioritize responses to invasive species that pose the greatest threats to desert ecosystems. (**S 7.3.3**)

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