

Climate Change Adaptation for People and Nature: A Case Study from the U.S. Southwest

Patrick D. MCCARTHY

The Nature Conservancy, Santa Fe 87501, U.S.

Abstract

In the U.S. Southwest, global climate change, acting in concert with extant stressors such as urbanization and over-allocation of water resources, is changing ecosystems in measureable and sometimes dramatic ways. Twenty-first century projections indicate accelerating climate change and cascading ecological consequences. Effects observed to date include large-scale forest dieback, large and severe wildfires, and changes in the flow regimes of rivers and streams with attendant changes to riparian and aquatic ecosystems. Rising temperatures and changing precipitation patterns are pushing ecosystems across physiological and ecological thresholds, causing widespread mortality and, in some cases, major changes in composition, structure and function. These changes have prompted action by the conservation community to reduce the adverse effects of climate change. The Southwest Climate Change Initiative (SWCCI), a project led by The Nature Conservancy, works with local stakeholders in affected landscapes, reduces adverse impacts on ecological and social systems using scientific knowledge and practical tools. The Initiative has learned through practical experience that: 1) managers must embrace change and manage for resilience rather than resistance; 2) strong local science-management partnerships are critical to effective adaptation planning and implementation; 3) planners and managers must broaden the scope and accelerate the pace of conservation activities if ecosystem services are to be sustained; 4) adaptation often does not require radically new or different management practices, rather, conservationists already have many of the tools they need; and 5) rapid documentation and widespread communication of methods and findings can build rapidly regional capacity for climate change adaptation. Our experience suggests that adaptation efforts can be effective if they are focused at the local scale; employ learning networks; and engage in ecosystem-based adaptation: the sustainable management, conservation and restoration of ecosystems so that they continue to provide the services that allow people to thrive in changing environments.

Keywords: climate change adaptation; ecosystem-based adaptation; ecological thresholds; learning networks

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1 Introduction

In the Four Corners states of U.S. Southwest — Arizona, Colorado, New Mexico and Utah — climate change is already changing ecosystems and affecting people in readily measureable ways [Karl *et al.*, 2009]. Rising spring and summer temperatures

and other changes in climate are exacerbating long-standing sources of ecosystem stress such as urbanization, over-allocation of water, and colonization by non-native species. In fact, this arid region has been identified as a bellwether of climate change in North America due to recent ecological changes — uncharacteristically large and severe fires, widespread insect

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Corresponding author: Patrick D. MCCARTHY, pmccarthy@tnc.org

outbreaks, forest dieback, and other signs of ecological degradation — that have been associated with changing temperature, precipitation and stream flow regimes through quantitative scientific analysis [Breshears *et al.*, 2005; Allen, 2007; Karl *et al.*, 2009; Parmesan and Yohe, 2003; Williams *et al.*, 2010]. This suite of ecological changes threatens ecosystem services such as water supply and flood control and could also harm natural resource-based industries including farming, ranching, nature tourism and outdoor recreation, resulting in estimated annual losses of billions of US\$ per year [Hurd and Coonrod, 2008; PCE, 2009; Backus *et al.*, 2010].

These climatological and ecological trends, and projections for accelerating change in ecological and economic systems in the 21st century provide motivation for natural resource managers, conservationists and the public to take action to reduce adverse local and regional effects of global climate change [Rajagopalan *et al.*, 2009; Carter and Culp, 2010; Glick and Stein, 2010; NRC, 2010]. In response, several scientific and conservation organizations created the Southwest Climate Change Initiative (SWCCI), whose goal is to address the threat of climate change to the region's natural areas and the benefits they provide to people. This paper will describe SWCCI's objectives and approach by explaining:

(1) How biodiversity and ecosystem services in arid regions of the Earth like the U.S. Southwest are being affected early, and sometimes severely, by climate change; why we can expect even more change; and why action is necessary now in the most vulnerable places if the natural systems that sustain us are themselves to be conserved.

(2) How the SWCCI is advancing climate adaptation by developing information and tools to understand and address climate impacts in the arid lands of the U.S.

(3) How sharing knowledge and tools in deliberately structured way, site by site and regionally, helps to build capacity for understanding and coping with a changing world.

(4) How conservationists can respond to this challenge by adopting an integrated approach called

ecosystem-based adaptation (EBA), which uses the power of nature to help people adapt to climate change.

2 Rapid ecological transformation in the U.S. Southwest

The U.S. Southwest is a bellwether region of temperate North America. Because of its semi-arid climate, its ecosystems are sensitive to directional and episodic changes in temperature and precipitation [IPCC, 2007]. The region is undergoing three major transformations linked to climate variability and directional climate change: 1) damaging wildfires whose severity and size are outside of the historical range of variability even for the fire-adapted forest types that characterize the region [Westerling *et al.*, 2006; Karl *et al.*, 2009]; 2) widespread and rapid forest dieback resulting from insect outbreaks that occur during droughts of unexceptional depth but exceptional warmth [Breshears *et al.*, 2005; Adams *et al.*, 2008; 2012]; 3) changes in rivers and streams — earlier snowmelt and peak runoff and changing stream and river temperatures, with cascading effects on aquatic and riparian ecosystems and critical water shortages for cities and farms [Stewart *et al.*, 2005; Seager *et al.*, 2007; Rajagopalan *et al.*, 2009; Seager and Vecchi, 2010; WWA, 2010; Overpeck and Udall, 2010; USBR, 2011].

Accordingly, the U.S. Southwest is now being recognized as an epicenter of climate change effects in North America — that is, a place where climate change is changing ecosystems in ways we can see and measure, and that directly affect nature and natural resource-based livelihoods such as farming, ranching and nature-based tourism [Diffenbaugh *et al.*, 2008; Karl *et al.*, 2009; Overpeck and Udall, 2010; Robles and Enquist, 2010; deBuys, 2011]. In an arid region that is subject to rapid population growth, water shortages, proliferation of non-native species, grassland degradation, and uncharacteristically large and severe wildfires, climate change interacts with these stresses such that ecological thresholds are transcended, exacerbating ecosystem degradation and societal stress

[Overpeck and Udall, 2010; deBuys, 2011].

In fact, rapid climate change and its emerging ecological effects are causing ecologists and planners to change the way they think about and carry out nature conservation [Choi, 2007; IPCC, 2007; Millar *et al.*, 2007; Heller and Zavaleta, 2009; Lawler *et al.*, 2010; Sullivan, 2009; Poiani *et al.*, 2011]. Many ecologists are calling for a change in the fundamental goal of conservation from protection and restoration, which generally assume dynamically stable climates and ecosystems, to resilience, defined as the ability to absorb disturbances, to be changed and then to re-organize and still have the same identity (retain the same basic structure and ways of functioning) [Walker and Salt, 2006; Meadows, 2008].

The aim of resilience management and governance is either to keep the system within a particular configuration of states that will continue to deliver desired ecosystem goods and services, preventing the system from moving into an un-desirable regime from which it is either difficult or impossible to recover, or to move from a less desirable to a more desirable regime [Walker and Salt, 2006]. In the case of nature conservation in the U.S. Southwest, this resilience-based approach would have us manage natural ecosystems so that they recover more readily from disturbances, including those whose severity is amplified by rising temperatures and changes in hydrologic processes such as precipitation and evapotranspiration.

2.1 Uncharacteristically large and severe wildfires

In the U.S. Southwest many ecosystem types are adapted to frequent but low-severity fires. For example, the natural fire regime of ponderosa pine-Gambel oak (*Pinus ponderosa-Quercus gambelii*) forests typically involves ground fires (rather than canopy or crown fires) with a point fire return interval of from 2 to 10 years. Such fires keep tree density low, prevent hazardous fuel build-up and maintain forest structural conditions that provide habitat for native species such as the Mexican spotted owl (*Strix lucida occidentalis*) and the northern goshawk (*Accipiter gentilis*). However, due in large part to rising spring and summer temperatures and increased evapotranspiration and drought associated with climate change, wild-

fires have increased dramatically in size (areal extent) and severity (fire-caused mortality and consumption of above-ground vegetation) in past decades [Allen, 2007; Williams *et al.*, 2010]. Recent studies have shown how increases in wildfire frequency, size and severity in western U.S. are correlated with rising spring and summer temperatures [Westerling *et al.*, 2006; Allen *et al.*, 2010; Williams *et al.*, 2010].

These changes have resulted in widespread tree mortality, excessive erosion and sedimentation, and loss of life and property. The summer of 2011 brought yet more extraordinary- and severely damaging-wildfires. The Las Conchas Fire and the Wallow Fire, at 63,370 hm² and 217,740 hm², respectively, are the largest in the recorded history of the states of New Mexico and Arizona. Not only are they threatening endemic species like the Jemez Mountains salamander (*Plethodon neomexicanus*), they are threatening water supplies (ash, radioactive contaminants), irrigated farms, and of course life and property in the communities in and around these mountains, notably two indigenous Indian communities, the Jemez Pueblo and the Santa Clara Pueblo, whose ability to recover is limited by longstanding poverty.

2.2 Forest dieback

The Jemez Mountains of north-central New Mexico have experienced several changes in ecological function and structure consistent with projected climate change effects. During the 2002–2004 regional drought, forest dieback (widespread tree mortality) occurred across more than 1 million hm² [Breshears *et al.*, 2005; Allen, 2007; Allen *et al.*, 2010]. This drought coincided with an exceptionally warm period, exacerbating the effects of a drought that was otherwise unexceptional in historical context [Woodhouse *et al.*, 2010]. More than 90% of all mature pinyon pine trees (*Pinus edulis*), a co-dominant woodland species of a widespread ecosystem type, died from water stress and a bark beetle (*Ips* and *Dendroctonus* species) epidemic during a 3-year drought in the Jemez Mountains. Two recent papers [Breshears *et al.*, 2005; Williams *et al.*, 2010] link this extensive forest dieback to climate change, documenting the role of increased temperature combined with drought- and warming-enhanced outbreaks of native bark beetles

(*Ipsand Dendroctonus* species) as a key driver in this regional dieback event.

Allen *et al.* [2010] have shown that regional drought- and heat-induced forest dieback may be part of a global pattern. Their paper is the first global assessment of recent tree mortality attributed to drought and heat stress, documenting extensive drought- and insect-induced mortality, including examples from four of China's provinces.

2.3 Changes in river and stream flow regime and aquatic ecosystems

Earlier springs and warmer summers are beginning to have significant impacts on the hydrologic regimes of rivers and streams of the western U.S. [Painter *et al.*, 2010; Pierce *et al.*, 2008; USBR, 2011]. With mountain snow melting earlier in spring, the cool meltwater that sustains streams in summer may decline [Mote *et al.*, 2005; Gutzler *et al.*, 2006; Knowles *et al.*, 2006]. For example, in Utah's Bear River Basin, a risk assessment based on thermal imagery shows that summer water temperatures are increasing and some reaches have become too warm for cold water fish species such as the Bonneville cutthroat trout (*Oncorhynchus clarkii utah*) [Williams *et al.*, 2009]. This assessment also indicates that the risk of severe fire in the headwaters of mountain streams is increasing, bringing increased risk of suffocation by catastrophic ash flow.

Throughout the Colorado River Basin, climate projections for mid-century involve declines in total discharge of up to 20%, making it challenging for water managers to meet targets for water supply to farms, cities and ecosystems [Stewart *et al.*, 2005; Seager *et al.*, 2007; Seager and Vecchi, 2010; Overpeck and Udall, 2011].

2.4 Climate change vulnerability of arid regions

Why is the U.S. Southwest showing the effects of climate change so soon and so dramatically? The natural systems of these areas tend to be water-limited and are frequently susceptible to rapid step-wise change due to the crossing of physiological and ecological thresholds [Adams *et al.*, 2008]. These ecosystems are sensitive to warming-driven amplifica-

tion of the effects of the natural disturbances that have been shaping the region for millennia: fire, drought, and insect outbreaks. The schematic diagram shown in Figure 1, for example, shows how rising temperatures superimposed upon normal drought cycles can lead to deeper, more prolonged droughts that will transform our natural land scapes through forest dieback and stream drying [Robles and Enquist, 2010]. Figure 2 shows how directional changes in mean precipitation and temperature can cause increased mortality rates for species populations at single sites or regions [Allen *et al.*, 2010] when climate changes "push" species and ecosystems across physiological thresholds.

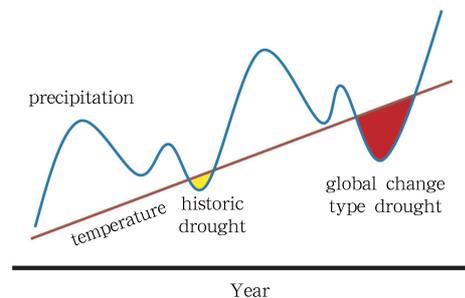


Figure 1 Conceptual diagram showing how rising temperatures superimposed upon normal drought cycles can transform natural landscape through forest dieback and stream drying [Robles and Enquist, 2011]

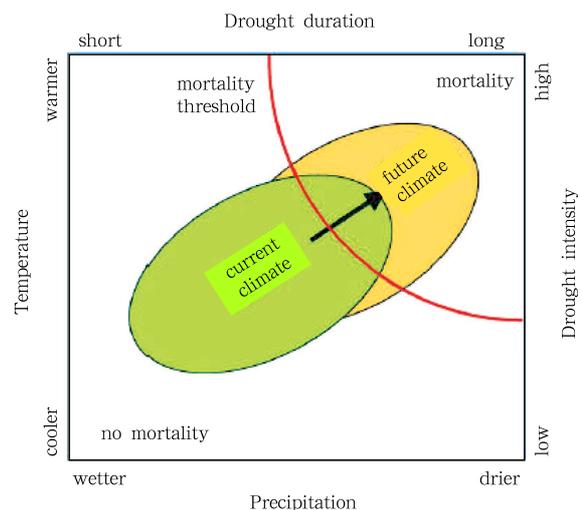


Figure 2 Directional changes in mean precipitation and temperature may increase mortality rates for species populations at single sites or regions [Allen *et al.*, 2010]

Changes in disturbance regimes (e.g., fire, flooding, drought, and insect outbreaks), when combined

with climate-induced range shifts and phenological changes, can trigger widespread changes in species distribution and in ecosystem composition, structure and function [Parmesan *et al.*, 2000; Parmesan and Yohe, 2003; Crimmins *et al.*, 2009]. Some such changes will be gradual, others stepwise and threshold-dependent. Yet others will be counterintuitive and surprising, such as frost damage to alpine plants exposed prematurely to cold early spring temperatures due to early snowmelt [Inouye *et al.*, 2000].

2.5 Threat multiplication and exacerbation

Climate change may also interact with extant stresses such as habitat fragmentation and isolation, exacerbating them such that vulnerable species may be lost. An example is the Mexican spotted owl (*Strix occidentalis lucida*), which has been facing habitat degradation, fragmentation and small population size for decades. Some climate projections suggest that more than 40% of the bird's ponderosa pine forest habitat will die off and be replaced by other natural communities in the 21st century [Smith *et al.*, 2011]. Large and severe wildfires like this summer's 300,000 hm² Wallow Fire further threaten the bird's viability. A species-specific vulnerability assessment suggests that much of the current habitat of the Mexican spotted owl in northern Arizona may become unsuitable because of climate change and its ecological effects by the close of the 21st century [Friggens *et al.*, 2010].

Physiological and ecological thresholds are difficult to define quantitatively, and therefore scientists cannot reliably predict when or how climate change will transcend these limits and cause widespread change in ecosystem structure, composition and function. However, single- or multi-year events can trigger sudden ecological change when an ecosystem and a species are subject to many interacting stresses, as evidenced by the forest dieback resulting from the 2002–2004 regional drought and the mega-fires of 2011.

3 Climate change assessment and adaptation for people and nature: The SWCCI

After experiencing ecologically-transformative

wildfires, droughts, and insect-induced forest dieback, all of them consistent with changes projected to occur under global change, southwestern North America's nature conservation community recognizes that climate change may undermine more than a century's worth of conservation by unraveling the fabric of nature in the U.S.'s existing network of nature reserves. The community is calling for acceleration in the pace of conservation, and the revision of conservation goals so that they are attainable and practical in the context of a rapidly changing climate [Poiani *et al.*, 2011]. To be sustainable, climate adaptation solutions must be based in sound science and carefully planned for effectiveness under a range of possible climate scenarios.

How shall we, as conservationists who believe in the sustainability of nature and the human enterprise, respond? In the 16th century humankind learned that the Earth is not the center of the universe. In the 19th century, Darwin demonstrated that the fabulous diversity of life was not fixed but, rather, ever evolving, and that humans were but one in a line of ever-changing kinds. Now, in the 21st century, the evidence tells us that the stable climate that has sustained us for millennia is no more, and that we must prepare for more change or risk losing nature and the economies that support our way of life.

Organizations and individuals in the Southwest have begun working in earnest on climate change assessment and adaptation. Federal agencies have integrated climate change and climate adaptation into their operations [USFS, 2008; NPS, 2010; USFWS, 2010]. The executive branch of the U.S. Government is requiring that all federal agencies develop and implement climate adaptation plans by 2013 [CEQ, 2011]. An adhoc group of federal scientists and managers called the Western Mountain Initiative is developing and interpreting climate assessments for land and water managers in the western U.S. At the level of state government, the Association of Fish and Wildlife Agencies has produced guidance for incorporating climate change into regional, state and local wildlife management plans [AFWA, 2010]. Non-governmental associations have developed detailed guidance for climate change adaptation for natural resource conservation organizations [Glick and Stein, 2010].

The response of The Nature Conservancy, a leading conservation organization that works in more than 30 countries around the world, has been to band with others to create the SWCCI, a public-private partnership developed in 2009 with the University of Arizona Climate Assessment for the Southwest, Wildlife Conservation Society, National Center for Atmospheric Research, and Western Water Assessment. The initiative's goal is to provide information and tools to conservation practitioners in the southwestern U.S. to build the resilience of the ecosystems on which all life depends. Its objectives are threefold: 1) Build regional and local understanding of climate change and its effects: conduct regional assessments of vulnerability and resilience that identify what is most at risk and where to take action first. 2) Take action: use scientific assessments to develop and implement adaptation plans to reduce adverse climate change impacts on nature and people. 3) Build regional capacity for climate adaptation: document and share knowledge, tools and methods through a dedicated learning network.

The latter objective is perhaps the most important because, while there are hundreds of vulnerable areas in southwestern North America that call out for climate adaptation planning and implementation, the SWCCI has the capacity to work at only a small number of places. Adapting to climate change in the region requires development and broad dissemination of robust, flexible methods and tools^①.

To achieve these objectives, the SWCCI operates regionally and at four focal landscapes selected because of the vulnerability of species and ecosystem services to climate change (taking into account both observed and projected ecological effects). These include the Bear River Basin in Utah, the Gunnison Basin in Colorado, the Jemez Mountains in New Mexico and the Four Forest Restoration Initiative area (which includes four units of the National Forest System) in

Arizona (Fig. 3a & 3b).

3.1 Methods

The SWCCI uses the Adaptation for Conservation Targets (ACT) framework^②, a method developed by a working group of the National Center for Ecological Analysis and Synthesis for rapidly but rigorously assessing vulnerability and identifying adaptation strategies for particular places. The framework takes advantage of scientist-manager working groups to develop scientifically sound and practical ways to reduce the degradation or loss of ecological and economic productivity. The products of the ACT framework are testable hypotheses about local climate change effects, and practical, local solutions to managing those effects. The SWCCI modified the ACT framework for use at focal landscapes by integrating certain elements of The Nature Conservancy's framework for climate adaptation planning [Poiani *et al.*, 2011].

The SWCCI conducted two-day adaptation planning workshops in each of the four landscapes in 2009 and 2010. These workshops were designed to: a) promote cross-jurisdictional learning and dialogue about climate change and local implications for natural resource management; b) identify management actions to reduce the adverse impacts of climate change; c) spur local adaptation action; and d) provide opportunities to test and refine a structured approach to adaptation planning and action. Using participant input, we selected two or three conservation features (species, ecological processes or ecosystems) as the focus of adaptation planning at each landscape. Each workshop included introductory presentations, small-group adaptation planning exercises, and plenary discussions regarding challenges, opportunities and next steps for implementation of priority actions. Climate and hydrology experts from the region prepared future climate and hydrological scenarios for each workshop. During each workshop, scientists and managers

^①Wall, T., and G. Garfin, in prep: Evaluating our capacity: A discussion of capability for ongoing climate assessment in the Colorado River Basin. Proceedings of a National Climate Assessment workshop held in Boulder, Colorado, June 6–8, 2011

^②Cross, M. S., E. S. Zavaleta, D. Bachelet, et al., in review: Adaptation for conservation targets (ACT) framework: A tool for incorporating climate change into natural resource conservation and management. *Environmental Management*

worked in small groups through the ACT framework's steps 1 to 5 (Fig. 4). This initial planning set the stage for sustained engagement of stakeholders in the implementation phase of the ACT framework during subsequent meetings and workshops.

Workshop discussions, findings and decisions were documented in detailed reports [Degiorgio *et al.*, 2010; Enquist *et al.*, 2009; Neely *et al.*, 2010; Smith *et al.*, 2011]. Workshop organizers also gathered post-workshop feedback through written exit surveys, and organized numerous follow-up meetings at three of the four pilot landscapes to support implementation

of strategies identified during the initial workshops. A new report by the SWCCI[Ⓢ] summarizes workshop outcomes and assesses evaluates their efficacy in accelerating climate adaptation at the landscape or site scale.

In total, 190 natural resource managers, scientists and conservation practitioners from 43 local, state and federal agencies and organizations participated in the four workshops. As of winter 2011, the SWCCI continues to support climate adaptation at the four landscapes, moving from assessment and planning to implementation.



Bear River Basin, Utah/Wyoming
 · Bonneville cutthroat trout (*Oncorhynchus clarki utah*)
 · abandoned ox-bow wetlands



Four Forest Restoration Initiative, Arizona
 · Mexican spotted owl (*Strix occidentalis lucida*)
 · ponderosa pine (*Pinus ponderosa*) fire regime
 · ponderosa pine forest-watershed function



Jemez Mountains, New Mexico
 · natural stream flow regime
 · natural fire regime



Gunnison Basin, Colorado
 · Gunnison sage-grouse (*Centrocercus minimus*)
 · Alpine wetlands
 · natural hydrologic function

Figure 3a Focal landscapes and conservation features of the SWCCI in the U.S. states of Arizona, Colorado, New Mexico and Utah

[Ⓢ] Cross, M. S., P. D. McCarthy, G. Garfin, et al., in review: Accelerating climate change adaptation for natural resources in the southwestern United States. *Conservation Biology*

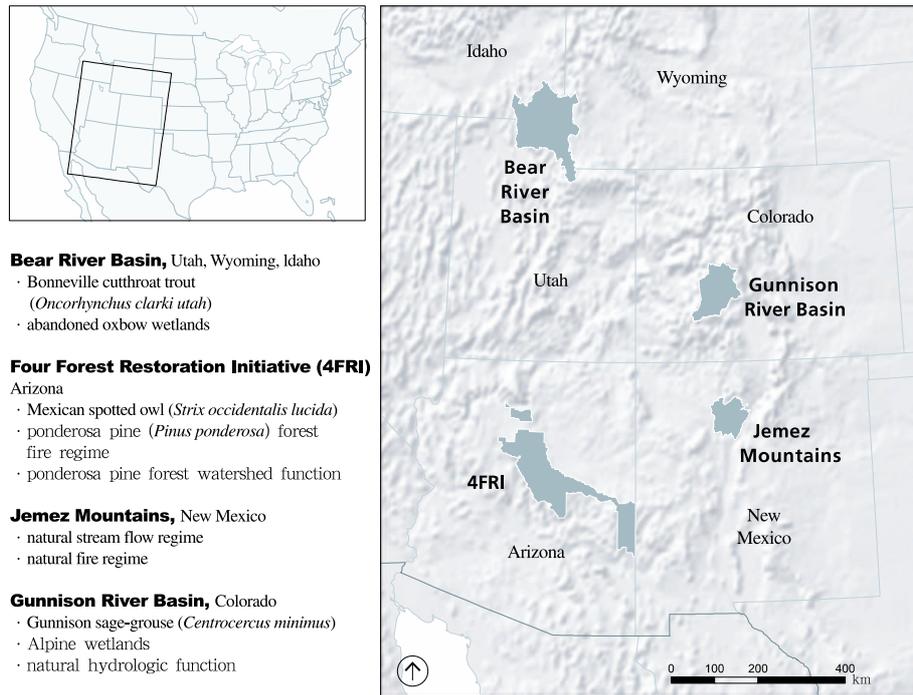


Figure 3b Locator map for focal landscapes and conservation features of the SWCCI

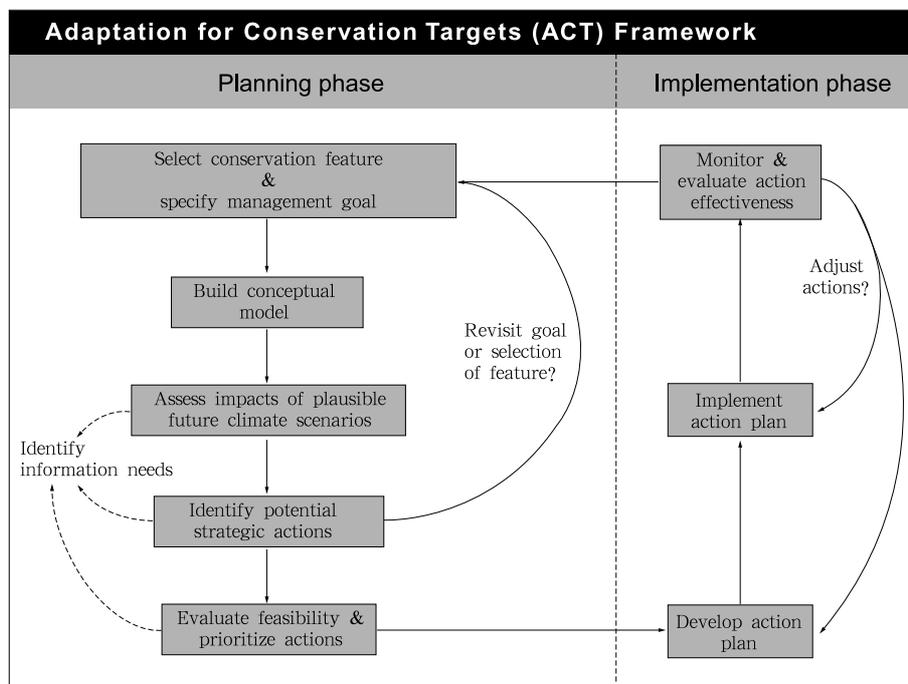


Figure 4 The Adaptation for Conservation Targets (ACT) framework for climate change adaptation planning used by the SWCCI

3.2 *Results: Practical strategies and action to build resilience*

The ultimate goal of the ACT framework and the SWCCI is simple to state but difficult to achieve: implementation of strategies that reduce the adverse effects of climate change under multiple plausible climate scenarios — that is, in a range of possible future climates, depending on future greenhouse gas emissions. Such strategies have been termed “robust” or “no-regrets” strategies.

3.2.1 *Strategies*

Following is a sample of the climate adaptation strategies that emerged from the four SWCCI workshops and that are now being implemented at the pilot sites.

(1) Bear River Basin (Utah): sustain the native Bonneville cutthroat trout (*Oncorhynchus clarki utah*), riverside vegetation and floodplain agriculture, hydropower generation and nature-based recreation and tourism by restoring natural flows, reconnecting stream reaches, and releasing cool water from reservoirs.

(2) Jemez Mountains (New Mexico): build resilient forests, protect the birds and fish that depend on them, and protect life and property from severe wildfire by conducting controlled burns and careful thinning of forest density.

(3) Gunnison Basin (Colorado): restore wetlands and streams to build resilience of the Gunnison sage-grouse (*Centrocercus minimus*) and sustain surface water and groundwater for livestock grazing and downstream agriculture. (Landowners, ranchers, scientists and government natural resource managers have taken an additional step, forming a permanent working group that is committed to developing local climate change solutions.)

(4) Four Forests Restoration Initiative (Arizona): sustain aquatic habitats and water supplies by increasing capture and infiltration from snowmelt through protection of groundwater recharge areas and carefully designed forest treatments; protecting forest-dependent animals through restoration practices that reduce the risk of high-severity fire; and rebuild-

ing local forest products businesses by making small-diameter timber (from the aforementioned treatments) available at low cost as a raw material for value-added products.

3.2.2 *Actions and outcomes*

Scientists, planners and managers at the four SWCCI landscapes have begun to implement many of the strategies identified at the workshops. Though it will take many years to determine whether these activities are effective in mitigating the adverse effects of climate change, these strategies are already producing tangible benefits.

For example, in the Jemez Mountains, forest planners and managers are using the workshop’s down-scaled climate change scenarios to develop guidelines for managing the forested habitat of the endemic Jemez Mountains salamander (*Plethodon neomexicanus*). Moreover, several of the climate adaptation strategies identified during the SWCCI workshop are being integrated into the Southwest Jemez Strategy, a 10-year, 90,000 hm² forest and watershed restoration project supported by the U.S. Forest Service’s Collaborative Forest Landscape Restoration Program at a cost of 10M US\$. The Southwest Jemez Strategy, if successful, will protect lives and property from uncharacteristically severe wildfire, and help sustain the local forest-based economy.

In the Gunnison Basin, the U.S. Bureau of Land Management, U.S. Forest Service, Gunnison county, National Park Service, The Nature Conservancy and others formed the Gunnison Climate Working Group (GCWG). Since the initial workshop, this diverse group, which represents this site’s most important economic sectors, has produced a comprehensive climate change vulnerability assessment and has funded (at approximately 300,000 US\$) and initiated a climate adaptation demonstration projects to build the resilience of montane wetlands, Gunnison sage-grouse and other priority habitats and species. Following the planned completion of a socioeconomic climate vulnerability assessment, the GCWG plans to take steps to diversify its economy in preparation for climate change.

Partners in the Four Forest Restoration Initia-

tive have designed a landscape conservation program that addresses climate change and its effects through adaptive management, allowing for rapid response to change and surprise. Climate change scenarios developed for the SWCCI workshop are being integrated into the Four Forest Restoration Initiative, helping the collaborators manage risks to forests, water supply and wildlife through an integrated program of forest thinning, prescribed fire, and diversification of the forest products economy.

Northern Arizona's Wallow Fire of 2011, one of the new "mega-fires" of unprecedented size and severity that have been linked to global change, provides an example of the effectiveness of the SWCCI-promoted adaptation strategies. In several areas where ponderosa pine (*Pinus ponderosa*) forest restoration treatments had been performed, fire behavior was less severe, allowing forest stands and nearby homes to survive [USFS, 2012]. Strategic use of such forest treatments, as described in the SWCCI workshop report for this landscape, could sustain forests and protect lives and property on a large scale, buffering communities from the effects of a changing climate.

In the Bear River Basin, The Nature Conservancy, Trout Unlimited and private landowners are removing stream diversions and restoring natural flows and streamside vegetation to sustain Bonneville cutthroat trout habitat in river reaches that are projected to remain cool enough to support the trout. The landscape conservation plan previously developed for the area by these and other groups are being updated and revised by integrating the climate change scenarios and strategies developed at the Bear River workshop.

3.3 *Lessons for effective climate adaptation planning and implementation*

Climate change adaptation is a new and developing discipline and there is much to learn about how to most efficiently and effectively develop and implement strategies for helping people and nature cope with a rapidly changing climate [Hansen and Hoffman, 2010]. The SWCCI members learned much in the course of four workshops and the ensuing implementation work.

First, we learned that sustaining valued elements of natural systems requires that we embrace change and manage for resilience rather than to resist climate change by attempting to maintain current structure and composition. This may require that natural resource managers abandon goals that may not be attainable, such as the viability of a particular plant or animal species in places where the future climate will no longer be suitable. Many goals related to ecosystem structure and composition, which might have been appropriate in relatively stable 20th century climates, may become unattainable or obsolete as climate envelopes shift and novel climates appear [Saxon *et al.*, 2005].

Another important lesson is that climate adaptation plans are perhaps most effective if they are developed by local science-management partnerships rather than being developed independently by off-site experts. Using workshops to investigate and document local climate change effects, and to identify management practices that can help build resilience, builds local understanding and implementation capacity [Lemos and Morehouse, 2005]. Workshop participants who live and work in vulnerable landscapes offer valuable experiential knowledge, commitment and technical skills and are often the same people who will be funding or implementing adaptation strategies [Kloprogge and van der Sluijs, 2006].

Thirdly, the SWCCI members learned that climate adaptation does not necessarily require radically new or different management practices (although it sometimes does). Rather, conservation practitioners already have many of the tools they need. Examples include planting streamside vegetation to provide shade and cool water temperatures for fish in habitats denuded by livestock overgrazing, and mechanical thinning and controlled burning to reduce forest density, increase precipitation infiltration, and reduce the risk of destructive canopy fires in fire-adapted forests.

We also learned that, in order to sustain certain ecosystem processes and functions in the face of rapid climate change, planners and managers must broaden the scope and accelerate the pace of conservation activities such as designation of conservation areas

(parks, conservation easements, etc.), reintroduction or relocation of native species, and restoration of degraded rivers and streams. For example, restoration of fire-adapted forest ecosystems of the U.S. Southwest under a changing climate may require increasing the pace of scale of forest thinning and controlled burning far beyond what had previously been considered necessary [Enquist *et al.*, 2009; Smith *et al.*, 2011]. Novel, even radical, approaches to conservation, such as assisted migration of species, may be necessary to meeting conservation goals in areas, like the arid Southwest, that undergo rapid climate and ecological change.

Finally, the SWCCI workshops demonstrated that rapid documentation and widespread communication of methods and findings among adaptation projects can help build capacity in the conservation sector rapidly, and should be built into the design of regional and national adaptation programs. In particular, learning networks — groups of project teams organized specifically for developing and sharing practical information and tools — offer a way to accelerate development and implementation of new conservation methods that respond to emerging challenges like climate change [Goldstein and Butler, 2010].

4 Discussion: Building capacity

In closing, I offer three ideas that might help frame the dialogue about how to build capacity for developing and implementing climate change adaptation strategies.

4.1 *Use global and regional assessments, but work at the landscapes scale*

First, the examples from the four SWCCI pilot sites show why the landscape scale — that is, from about 100,000 to several million hm^2 — can be an effective scale for climate adaptation planning and implementation. Global and regional research, such as global climate model and downscaled regional climate model output and regional vulnerability assessments, are essential for understanding broad climate change risks and setting priorities among regions and sites. But most conservation activities are initiated locally

and driven by stakeholder interest in conserving natural resources and ecosystems and the communities that depend on them. Local collaborative projects that develop cohesive planning and implementation teams composed of scientists and managers can build understanding of climate change effects and accelerate climate adaptation activity [Kloprogge and van der Sluijs, 2006; Lemos and Morehouse, 2005].

4.2 *Develop learning networks to build capacity for climate change adaptation*

Second, the global scope and rapid pace of climate change demand new approaches to conservation planning and practice. Learning networks [Goldstein and Butler, 2010] offer a way to rapidly and effectively build capacity regionally for climate adaptation, through structured workshops and exchange of information among project teams working to protect vulnerable landscapes.

The SWCCI was modeled after the U.S. Fire Learning Network, a highly successful initiative that rapidly built the capacity of multiple public and private organizations across the country to restore fire-adapted ecosystems. The SWCCI, as in other learning networks, involved the development of carefully structured project teams that worked through a stepwise, logical framework to devise practical solutions. The SWCCI project teams are committed to these solutions because they developed them. Accordingly, they are motivated to fund and implement them over the long term. Completing an adaptation workshop is thus not the end of the project, but rather the beginning of a long-term, community-driven effort.

One vision for how to build capacity nationally as well as regionally, as modeled by the U.S. Fire Learning Network, is to exchange information and methods among regional networks. The information produced by landscape project teams and the network can inform both practice and policy. An example of the latter is the passage of new federal forest restoration legislation, the Collaborative Forest Landscape Restoration Act of 2010, whose design draws upon knowledge developed by the U.S. Fire Learning Network.

4.3 *Build support by collaborating across sectors*

Thirdly, I suggest that working across sectors — agriculture, water supply, energy production, and natural ecosystem conservation, for example — can lead to more effective, better informed and better funded climate adaptation action than working in a single sector, isolated from other actors and stakeholders.^④

Many climate change vulnerability indicate high risk of economic loss or environmental degradation. These cross-sector assessments are useful in making the case for adaptation action, but they provide little guidance to planners and managers. To better address the adaptation challenge, society needs more collaboration across sectors to identify strategies for practical matters such as managing water supplies, growing food, and conserving natural areas. Examples include PlaNYC Update 2011: a greener, greater New York, an adaptation plan that addresses climate change impacts to the City of New York and its environment in an integrated way [CNY, 2011]. Likewise, the California Climate Adaptation Strategy drew on the expertise and ideas of hundreds of experts and citizens to find ways to keep people, the economy and the environment healthy in a changing world [CNRA, 2009]. The principal U.S. water management agency, the Bureau of Reclamation, is planning for water shortages and developing strategies such as water banks, environmental flow prescriptions and interstate and international water allocation agreements through the innovative SECURE Water Act [USBR, 2011].

4.4 *Employ ecosystem-based adaptation: Integrated strategies to protect people and nature*

Ecosystem-based adaptation (EBA), the use of natural ecosystems to build the resilience of people and nature as the climate changes, can bring communities of interest together around shared values, building a constituency for ecologically and economically smart preparation for climate change [Colls et al., 2009; Vi-

gnola et al., 2009; WB, 2010]. Figure 5 shows how protecting forests, wetlands and other natural systems can help sustain services — such as flood control, water supply and soil fertility — that people depend on. By joining forces in an integrated approach to adaptation, the agriculture, water management and conservation communities can make scarce funds go farther, avoid conflict, and sustain ecological and economic health. Moreover, nature-based approaches to adaptation can be more cost-effective than conventional approaches that require expensive “gray infrastructure” such as sea walls and dams. Examples of “green infrastructure” for ecosystem-based adaptation include the use of natural wetlands for flood protection, mangroves for protection from extreme storms, and forests for protection of groundwater and surface water supplies [WB, 2008; Hale et al., 2009; Opperman et al., 2011].

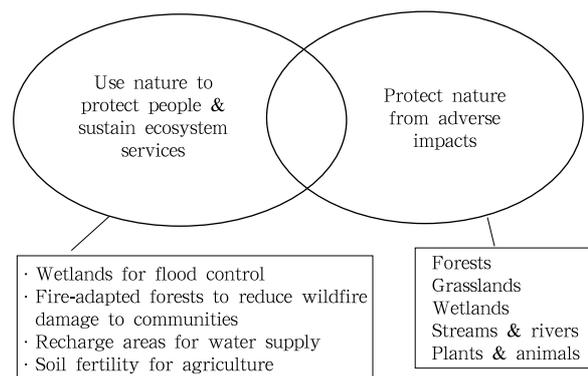


Figure 5 Conceptual diagram illustrating ecosystem-based adaptation: Use of natural ecosystems to reduce the adverse effects of climate change on people and nature

4.4.1 *Ecosystem-based adaptation example: Santa Fe Water Source Protection Fund*

An example of ecosystem-based adaptation from the U.S. Southwest is the Santa Fe Water Source Protection Fund. This program uses public grants to support watershed restoration activities that reduce the risk of climate-driven catastrophic wildfire and subsequent disruption of the city’s water-supply infrastructure, including reservoirs, water treatment plants, and conveyances [CSF, 2011; TNC, 2011; Taylor, 2011].

^④ Wall, T., and G Garfin, in prep: Evaluating our capacity: A discussion of capability for ongoing climate assessment in the Colorado River Basin. Proceedings of a National Climate Assessment workshop held in Boulder, Colorado, June 6–8, 2011

These activities include non-commercial mechanical thinning of small-diameter trees, controlled burns to reintroduce the low-severity ground fires that historically maintained forest health, and comprehensive ecological monitoring to determine effects of these treatments on forest and stream habitats, plants, animals, habitats and soils.

The Santa Fe Water Source Protection Fund prepares city residents for climate change by managing wildfire risk, securing water supplies and conserving nature in an integrated fashion. Supported by a strong local science-management partnership and based on extensive ecological research, this project is an instructive example of how ecosystem-based adaptation can benefit people and nature in a cost-effective way (this is represented by the center of the ecosystem-based adaptation diagram in Figure 5).

4.4.2 *Ecosystem-based adaptation examples from Mexico and Vietnam*

Schroth et al. [2009] describe threats to biodiversity and livelihoods in Chiapas, Mexico, from irregular rainfall extreme events (hurricanes, landslides and wildfires) whose severity and frequency may be increasing because of global climate change. They group proposes a comprehensive strategy to sustain the biodiversity, ecosystem services and livelihoods of the Sierra Madre in the face of climate change that includes the promotion of biodiversity friendly coffee growing and processing practices; payments for forest conservation and restoration from existing government programs complemented by private initiatives; diversification of income sources to mitigate risks associated with unstable environmental conditions and coffee markets; integrated fire management; development of markets that reward sustainable landuse practices and forest conservation; crop insurance programs that are accessible to smallholders; and the strengthening of local capacity for adaptive resource management.

The Community-based Mangrove Reforestation and Disaster Preparedness Programme is a mature ecosystem-based adaptation effort that has been implemented by Viet Nam Red Cross since 1994 [*IFR-CRCS*, 2011]. This project aims to protect dikes and

coastal communities from typhoons and floods in the eight northernmost coastal provinces of Vietnam by planting and protecting mangroves on a large scale. Complementing the planting activities, the project takes several measures to enhance the disaster preparedness of communities. The project has demonstrated that restoring and protecting natural ecosystems brings significant protective benefits as well as direct economic benefits (livelihood improvements) to coastal communities.

4.5 *Conclusions*

The U.S. Southwest is not alone as a region transformed by climate change. This starkly beautiful region serves as a bellwether for the powerful impacts that much of the rest of the world has begun to — or will soon — experience [*deBuys*, 2011]. Only by working together, within and across similarly affected regions of the Earth, can we hope to sustain the lands and waters that sustain us.

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