Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region
April 13-14, 2011, Tucson, Arizona

Workshop Summary Report

Prepared by
Alex Score, EcoAdapt
Lara Hansen, EcoAdapt
Louise Misztal, Sky Island Alliance

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Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region was convened by Sky Island Alliance in partnership with EcoAdapt. Other collaborative partners in development of the workshop series include the University of Arizona Institute of the Environment and School of Natural Resources and the Environment, Climate Assessment for the Southwest, Sonoran Joint Venture, the U.S. Fish and Wildlife Service, the Coronado National Forest, the U.S. Bureau of Reclamation, and the Udall Foundation Institute for Environmental Conflict Resolution. Workshop sponsors included the Coronado National Forest, Saguaro National Park and Arizona Game and Fish Department. This work is funded in part by the Nina Mason Pulliam Charitable Trust and The Kresge Foundation.

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Executive Summary

Sky Island Alliance convened a climate change adaptation workshop in Tucson, Arizona in April 2011. This workshop was the second in a three-part series designed to develop on-the-ground and policy-level adaptation actions to respond to climate change, and to build a regional network of professionals working cooperatively to improve natural resource management under changing conditions. The first workshop was held in September 2010 (www.skyislandalliance.org/adaptationworkshop2010.htm). The workshop series is being developed in collaboration with EcoAdapt, Climate Assessment for the Southwest (CLIMAS), University of Arizona Institute of the Environment, University of Arizona School of Natural Resources and the Environment, Sonoran Joint Venture, US Fish and Wildlife Service, U.S. Bureau of Reclamation, Udall Foundation U.S. Institute for Environmental Conflict Resolution, and U.S. Forest Service. The second workshop built upon the discussions held during the 2010 workshop, where participants discussed climate impacts, natural resource management challenges with climate change, and methods for incorporating climate change into management in the Sky Island region.

This report summarizes the process and outcomes of the workshop and serves as guidance for the Sky Island region to begin developing climate adaptation options. The main objective of this second workshop was to move forward from “planning” to “action.” Workshop goals included: share knowledge about climate change impacts and vulnerabilities; brainstorm individual and collective adaptation strategies; develop pilot projects to begin implementation; and continue to build a diverse network of organizations, natural resource managers, and scientists working to improve natural resource management.

There were approximately 79 participants from 31 organizations, including federal and state agencies, local governments, non-profit organizations, tribal representatives, private landowners, and academic and applied researchers, with the majority having participated in the first climate adaptation workshop held in 2010. During the two days, participants engaged in discussions about key climate vulnerabilities of the Sky Island region and brainstormed adaptation strategies for four of the region’s ecosystems: Madrean forest, semi-desert grassland, desert, and riparian. Participants prioritized strategies and outlined strategic adaptation plans for each ecosystem.

Key Outcomes

The key outcomes of the workshop included: discussion of the climate threats and vulnerabilities for four ecosystems in the Sky Island region; analysis of direct climate change threats, indirect threats, and interacting factors; a list of habitat specific adaptation options for the region; and a plan for adaptation strategies to be implemented. For each habitat, participants fleshed out an adaptation strategy that could be implemented as an action plan for the region. The following are summaries of the threats, vulnerabilities, adaptation options, goal, and action plan for each habitat:

Madrean Forest:

Threats: Increase in temperatures, increase in frequency of warmer and drier winters, increase in summer precipitation variability, and mega droughts.

Vulnerabilities: Forest health and function, increased fire risk, shifts in wildlife and vegetation, loss of soil and potential for forest regeneration, and increased insect infestations.
Adaptation options: Manage for resilience on a landscape scale, manage human uses of public lands, focus resources on maintaining and protecting resilient areas, protect corridors for species connectivity, close sensitive areas to prevent further disturbance, and plan for beetle detection and treatment.

Adaptation goal: Maintain ecosystem services and function of montane forests and woodlands to preserve biodiversity and adaptation potential where possible, or facilitate transition.

Adaptation strategy: Initiate a process to manage the Sky Island region at a landscape scale through the National Environmental Policy Act (NEPA).

Riparian areas:
Threats: Increase in frequency of warmer and drier winters, increase of hotter and longer fore- summers, changes in precipitation during monsoon season, and increase in temperature.

Vulnerabilities: Habitat fragmentation; decreased biodiversity; alterations in physical processes, stream morphology, and water table; decreased recharge; and decreased ecosystem services.

Adaptation options: Capitalize on drought to reduce invasive species, promote restoration, work with planners to build and design infrastructure that helps maintain ecosystem processes, and pursue different water policies.

Adaptation goal: Conserve the function and integrity of riparian systems in a changing climate for the Upper San Pedro basin.

Adaptation strategy: “Stop the Stupid, Start the Smart” outreach campaign that places the value of water and riparian systems in terms that all groups of people can understand.

Semi-Desert Grassland:
Threats: Increasing dry winters, increase in temperatures, variability in precipitation events, and changes in seasonality:

Vulnerabilities: Changes in or inability to continue land use practices, flossing, less viable ranching opportunities, soil loss and erosion, and lack of community concern regarding climate change and effects on grasslands.

Adaptation options: Show communities alternative futures with climatic and landscape changes; incorporate past water, land allocation information, and potential climate changes into future management; harness mass flooding events to increase water reserves, reduce channelization, change grazing time and location; and install stabilizing features.

Adaptation goal: To maintain and restore grasslands and the species in them through community empowerment and engagement.

Adaptation strategy: Work together to cultivate resilient, native seed sources to prepare for likely flooding and soil loss associated with climate change impacts in the region.

Desert:
**Threats:** Increasing temperatures and changes in hydrology.

**Vulnerabilities:** Public disconnect with climate change impacts, changes in land pressure, increased water use, increase in temperature and energy use, and increased invasive species.

**Adaptation options:** Conduct a climate change education and awareness campaign, engage public through citizen science projects, harvest rainwater, increase public transportation and bike lanes, increase energy efficiency, and develop awareness campaign to explain relationship between fire and invasive species.

**Adaptation goal:** Reduce human impact on desert ecosystems through awareness and outreach.

**Adaptation strategy:** Incorporate climate change into the Saguaro National Park BioBlitz event of 2011, specifically into the Biodiversity University.

**Next Steps**
This workshop builds the framework for developing adaptation plans throughout the entire region. The next workshop will build upon these outlined plans, explore further strategies for moving from “planning” to “action,” and continue to develop a climate adaptation implementation strategy for the Sky Island region.
Introduction

Although natural resource managers, scientists, and conservation organizations recognize the need to respond to climate change impacts, there remain many outstanding questions. For example:

- How can existing information be applied?
- What is still uncertain and how do we work with uncertainty?
- What is already being done and what should be done next?

To address these questions, Sky Island Alliance (SIA) is holding a three-part series of workshops designed to develop on-the-ground and policy-level adaptation actions to respond to climate change impacts. The workshops are also designed to build a regional network of professionals working cooperatively to improve natural resource management under changing conditions. SIA convened the first workshop, *Climate Change Adaptation in the Arid Southwest: A Workshop for Land and Resource Management*\(^1\), in September 2010; it focused on developing a shared understanding of the key vulnerabilities of the southwest to climate change and outlining initial adaptation strategies. In April 2011, SIA convened the second workshop, *Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region*\(^2\). This two-day workshop built upon the discussions and findings of the first workshop by exploring the vulnerabilities of, and developing adaptation strategies for, four specific ecosystems within the Sky Island region of southeastern Arizona, southwestern New Mexico, and northern Mexico; focal ecosystems included Madrean forest, semi-desert grassland, desert, and riparian.

The main objectives of *Between a Rock and a Hot Place* were to:

- Review and share knowledge about climate change impacts and management implications specific to four ecosystems in the Sky Island region;
- Identify key vulnerabilities and develop individual and collective adaptation strategies for each ecosystem;
- Engage participants in mechanisms for ongoing sharing, communication, and access to information related to climate change, and continue to build a regional network working cooperatively to improve natural resource management; and
- Develop climate change adaptation pilot projects to begin implementation of adaptation strategies.

The workshop was attended by 79 participants from 31 organizations, including federal and state agencies, local governments, non-profit organizations, tribal representatives, private landowners, and academic and applied researchers. Participants came from a broad range of backgrounds and expertise, including natural systems managers, land use planners, wildlife biologists, forestry scientists, ecologists and policy advocates.

The first half-day of the workshop was dedicated to presenting information about likely climate changes in the region as well as how those changes may affect hydrology, fire, invasive species, and connectivity and corridors. It included several presentations on the vulnerabilities and focal issues in the Sky Island region which are summarized below. This part of the workshop was intended to “set the stage” and ensure that all participants had the background information

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\(^1\)http://www.skyislandalliance.org/adaptationworkshop2010.htm

\(^2\)http://www.skyislandalliance.org/adaptationworkshop2011.htm
necessary to engage in developing adaptation options. The summaries of these presentations below are intended only as a record of the workshop proceedings and should not be used as a source of climate change information. Individual presenters should be contacted for further clarification and accuracy.

A spatial framework for adaptation planning that focused on dealing with uncertainty and detailed examples of regional on-the-ground adaptation projects were also presented. The remainder of the workshop was organized into breakout groups focused on the four main ecosystems. Breakout groups were designed to help participants develop a preliminary adaptation plan for each ecosystem by:

1. Identifying a specific management effort for adaptation planning;
2. Determining specific climate change vulnerabilities;
3. Identifying a suite of potential adaptation responses;
4. Creating a set of adaptation actions and determining next steps.

At the end of the first day, there was an opportunity for each breakout group to exchange information amongst other groups by sharing their progress in “marketplace cross-pollination.” The second day also allowed for an exploration of interactions across ecosystems, landscapes, and stressors to ensure that each breakout group thought about the ways in which different ecosystems and management strategies influence one another. This exercise was included to prevent breakout groups from developing “maladaptive” strategies for their ecosystem that might negatively affect other ecosystems. The concluding session of the workshop included summary presentations by each breakout group, which included their ecosystem goal, top five vulnerabilities, and the expanded adaptation strategy.


**Welcoming Remarks**

*Melanie Emerson, Executive Director, Sky Island Alliance*

Sky Island Alliance (SIA), a non-profit organization focused on restoration and protection of the Sky Island region, has a number of different programs, including conservation policy, landscape restoration, wildlife linkages, wilderness and special designation, northern Mexico conservation and climate change adaptation. SIA is committed to assisting climate adaptation in the region and facilitating collaborative action across jurisdictional boundaries through this workshop series. Several SIA partners were thanked for their support and assistance, including the Sonoran Joint Venture, U.S. Forest Service, National Park Service, U.S. Fish and Wildlife Service, and EcoAdapt.

Ms. Emerson pointed out that approximately 60% of this workshop’s participants had attended the first workshop of the series in September 2010, which included 80 participants from 36 different organizations. Participants in this workshop were directed to collaborate and develop adaptation plans in the Sky Island region by:

- Summarizing potential ecological impacts of climate change and tying them back to projected changes;
- Identifying and sharing useful research;
- Prioritizing vulnerabilities;
- Identifying project planning and implementation processes and opportunities for collaboration;
- Identifying on-the-ground monitoring activities that SIA can support through SIA’s citizen science program.

**Workshop Process Review**

*Lara Hansen, Executive Director and Chief Scientist, EcoAdapt*

Dr. Hansen asked participants to stand if they believed that climate change affects the work they do; all participants stood up. She followed up by asking how many in their daily work believe that something can be done about it; approximately 80% of participants stood up. Dr. Hansen asked participants not to be passive listeners, as the success of the workshop would depend on active participation in the process. The first half-day would mostly consist of information and examples of what is already being done in the region. The following day-and-a-half of habitat-specific breakout sessions and interactions should result in the development of overarching goals to address climate impacts in each habitat, a list of main climate vulnerabilities and impacts, and a series of strategies and actions to address vulnerabilities.
Plenary Sessions: Setting the Stage

Keynote Address: Climate Change and the Southwest
Dr. Jonathan Overpeck, Co-Director and Founder, Institute of the Environment; Professor of Atmospheric Sciences, University of Arizona

Dr. Overpeck provided participants with an overview of climate change and its projected impacts in the southwest United States. He stressed the urgency with which management and policy need to respond to the reality of anthropogenic climate change at global, regional, and local scales. Dr. Overpeck discussed specific impacts, many of which are already occurring and are projected to increase in severity and frequency, including:

- Warmer temperatures, with the highest temperatures projected for the Southwest that will affect both natural and built systems;
- Steady declines in snow, especially in the spring;
- Decreased late winter precipitation;
- Decreased stream flow, especially in the Colorado River basin with the best estimates indicating a 10-20% decrease;
- More intense precipitation, flooding, and drought, with a high risk for a mega-drought in the next century.

These changes are compounded by a huge population influx in the region and the over-allocation of water; for example, the Colorado River is 15-20% over-allocated even without the effects of climate change. These changes require the development of adaptation capabilities in the region and the reduction of greenhouse gas emissions; both will require coordination and collaboration among stakeholders, which may be facilitated by the Southwest Climate Change Network.3

Question and Answer Period

1. Dr. Overpeck discussed the role of the U.S. Department of Interior’s 8 Climate Science Centers4 and 21 Landscape Conservation Cooperatives.5 The Southwest Climate Science Center is expected to be housed in the University of Arizona. A stakeholder advisory committee is being developed by the U.S. Geological Survey to determine what information is needed and prioritize research needs for the region.

2. Uncertainty is high in predicting how climate change will affect the monsoon in the region. Scientists need a better understanding of monsoons in order to be able to simulate them in models at a smaller scale rather than using global models. It should not be long before there is consensus about monsoons. Overpeck believes that there will be more variable but stronger monsoons in the future, including years without any occurrence.

3. Global modelers say that eventually the global models will have regional scale resolution; Overpeck believes we will always have problems where we need finer spatial resolution information. Right now, our best option is to use both global models and regional models. Regional models are not a panacea for problems at a regional scale but can potentially capture regional scale processes. A lot of regional effects are influenced by fine-scale topography that global models are not able to capture.

4. Although public health issues have not generally been the focus of climate change research, there are a growing number of scientists at the University of Arizona who are starting to emerge as national leaders on the subject.

3http://www.southwestclimatechange.org
4http://www.doi.gov/whatwedo/climate/strategy/CSC-Map.cfm
5http://www.doi.gov/lcc/index.cfm
Climate Change, Hydrology, and Sky Islands

Thomas Meixner, Associate Professor, Department of Hydrology and Water Resources, University of Arizona

When looking at climate change effects on hydrology, there are three important questions to consider:

1. **What is hydrology and how is it biologically important?**
   The biological conditions of an area are dependent on hydrology. In the Sky Island region, water percolates through the mountains to recharge the groundwater; surface water that percolates into the groundwater also recharges it. The basin floor may also contribute to groundwater recharge, but not much water percolates to depth. In the San Pedro basin, mountain block, mountain front, and basin floor recharge supply the majority of the water in the region. Approximately 75% of water in the San Pedro basin that supplies the region currently comes from winter precipitation; other sources are flash floods during summer and recharge during monsoon runoff. The legacies of past extreme flood events may be shaping current vegetation trajectories and responses to climate change. In 2006, half of the vegetation near the river was composed of cottonwood and willow, but in the 1940s, it was bare ground, which shows a recent shift towards trees on the very edge of the river. This demonstrates the link between hydrological and biological status; once perennial stream flow is lost, herbaceous species and communities that support wildlife likewise decline.

2. **What might the future of hydrology be in the region?**
   Climate change will cause less winter precipitation in the region, which will decrease stream flow and cause deficits in groundwater availability. Climate projections for the region include warmer and drier winters, hotter and drier summers, and possibly wetter monsoons. All of these impacts could result in less recharge.

3. **What can be done to improve knowledge and response?**
   We may be able to mitigate for some impacts but not with high confidence. We need to decrease uncertainty of the data and models so that we can properly plan for future scenarios (e.g., location of water).

Invasive Species, Altered Wildfires Regimes, and Climate Change

Julio Betancourt, Senior Scientist, U.S. Geological Survey

The arrival times of Utah Juniper and Ponderosa Pine at their northern migrating front in the central Rockies is “fairly recent,” occurring in the late Holocene approximately 2,000 years ago. Woody perennial species like these migrate very slowly, taking centuries to millennia. Generally, herbaceous species are able to spread comparably faster than woody perennials, which are more likely to die fast and spread slowly. For example, throughout the 1900s, red brome, an herbaceous invasive species, spread rapidly across the Southwest; red brome is very dense, burns easily, and was the primary culprit in several large fires in the last few years. Herbaceous invasions such as these are driving large changes in fire regimes throughout the southwest region and are influenced by precipitation changes such as decadal variations in winter precipitation at regional scales (e.g., the Pacific Decadal Oscillation, El Niño, and La Niña). According to 300 years of tree ring records, wet El Niño years generally had less fire activity than dry La Niña years. Currently El Niño years are starting to rival La Niña years as the biggest fire years; winter annual grasses and invasions, during wet El Niño years, are driving huge ignition fronts across the desert valleys and finding dry woody fuels at higher elevations. Fire climatologies of the region may change as desert fires become more prevalent, and during winter wet years, start...
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As climate change influences invasive species and fire, many invasions would have happened regardless.

In the Tucson Basin, scientists are examining the vulnerability and risk associated with buffelgrass invasions, as well as performing priority assessments; this information is being managed through the Southern Arizona Buffelgrass Coordination Center. The USGS is using a state-transition model/dynamic vegetation model, the Markov Chain Model (MCM), to predict buffelgrass invasions, evaluate management actions, and estimate cost/benefits. This model will also be used to predict range shifts of native species in the future.

Managing Fire in the Sky Islands: A Peek into the FireScape Toolbox

Brooke Gebow, Southeastern Arizona Preserves Manager, The Nature Conservancy

Fire plays an important role in the Sky Island region. With climate change, the region is expected to experience more extreme fire behavior and effects, larger wildfires, vegetation type conversions, and more invasive species and insects. The FireScape program was developed by the Coronado National Forest to manage fire at a whole-mountain scale beyond jurisdictional boundaries in southeastern Arizona. The program uses science to help create landscapes that are resilient to fire. The program team works on science, outreach, and compliance in implementing treatments needed for systems with unsustainable fire regimes. FireScape has used progression mapping and is starting to develop ecological mapping to examine the landscape using a common set of units in order to achieve a more consistent approach to managing fire. FireScape is also developing tools that everyone can use to examine fire behavior and effects. They are using fuels models such as Grass 2 and Shrub 1, which convert vegetation into tons per acre of fire fuels, surface-volume ratios, moisture content, and spatial arrangement. FireScape has created a wall-to-wall map of fuels in southeast Arizona and around Coronado National Forest, and has created model transitions based on different scenarios. For example, FlameMap uses flame length as an output for fire predictions under different climate conditions. Fire regimes will change with the advance of climate change; models, predictions, and planning need to incorporate climate change impacts.

Landscape Connectivity and Sky Island Region

Sergio Avila, Northern Mexico Conservation Program Manager, Sky Island Alliance

The Sky Island region is a melting pot of different biological regions including the Rocky Mountains, Sierra Madre Occidental, Sonoran Desert, and Chihuahuan Desert. The region is comprised of isolated mountain ranges surrounded by deserts and grasslands. It supports significant biodiversity and now hosts many species from tropical regions that were not found in Arizona 20 to 30 years ago. Climate changes such as increased temperatures, changes in precipitation, and increased fires are likely to have considerable impacts on the biodiversity and natural resources of the region. Corridors and connected networks of reserves will allow species to move with changing conditions; thus protecting corridors and connectivity is more important.


7www.buffelgrass.org
than ever. The largest threats to connectivity in southern Arizona include development, population growth, and the border wall between the United States and Mexico. Sky Island Alliance is working on several connectivity projects, including mapping border infrastructure, removing barbed wire fences along the border, accommodating wildlife in development planning, landscape and riparian habitat restoration, tracking wildlife movement with remote cameras, and scientific training and expeditions for students.

**Panel Questions and Discussion**

For Thomas Meixner:
Elaborate on how it takes 5,000 years for rain to fall and appear as groundwater in the San Pedro
- Some water from the tap is from the last glacial period; through radiocarbon dating, scientists have demonstrated that the water used today is approximately 2,500 years old.

For Julio Betancourt:
Can the Markov Chain Model (MCM) be used in predicting and treating invasive woody grassland areas (i.e., buffelgrass)?
- The MCM and similar models are useful but also contain a lot of uncertainties. It is more cost effective and efficient to go after newer, smaller invasive populations. Spread rates get slower as you get further away from areas where summer precipitation is less variable. Models can help identify areas where the spread rate is slow, which gives some insight as to where to apply funding (i.e., where treatments would be most effective).

For Full Panel:
How do these issues take into account roads and motorized uses? How is that incorporated into modeling? (question for all panelists)
Brooke Gebow: Roads are effective fire management tools. This is probably not the ideal answer but they are tools and should be considered when looking at fire management.

Julio Betancourt: Roads are also vectors for the spreading of invasive species, and managers are considering them in vulnerability and risk assessments for areas where roads are present. Plant migrations from north to south may be some of the first impacts observed roadside, yet very little research has been done on this to date.

For Full Panel:
There are already many barriers to protecting corridors and migrations pathways. Where then should we place renewable energy sources and utilities? (question for all panelists)
Sergio Avila: Human population growth is the big issue. There are conflicts associated with alternative energy sources and critical lands for wildlife. Priorities should be to protect open space and land for wildlife, and allow humans use of other places.
Jonathan Overpeck: This is a critical issue. The siting of renewable energy projects needs to have everyone at the table so that we can compromise and not give up the ecosystem services that we value – we need to find a way to do both. We have to be a little more open to solving the problem than we might be if we were narrowly focused on a specific priority. Secretary Ken Salazar wants to make renewable energy work,
and we will need to incorporate all kinds of stakeholders in order to reach an agreeable compromise on this issue.

Brooke Gebow: The Nature Conservancy is discussing the issue of site preserves in relation to the siting of renewable energy sources. They are attempting to better coordinate sitings.

Assessing the Vulnerability of Wildlife on the Coronado National Forest to Climate Change

Sharon Coe, U.S. Forest Service, Rocky Mountain Research Station

The System for Assessing Vulnerability of Species (SAVS) tool identifies which species or systems are likely to be most affected by projected climate change impacts and why, and can help set management priorities and guide management strategies. The SAVS tool uses a 25-item questionnaire to calculate an overall vulnerability score for species and systems, and covers habitat, physiology, phenology, and biotic interactions. Each question relates to traits that are expected to reflect vulnerability or resilience to climate change; a negative score indicates resilience while a positive score indicates vulnerability. The SAVS tool helps to identify similarities and differences in vulnerability across species, identifies where there are data gaps, and provides an understanding of where management may be able to increase resilience. Caveats to using the SAVS tool or similar vulnerability assessment tools include: (1) a range of uncertainties still exist; (2) one or more criteria may prove to be disproportionately important to a species’ response; and (3) small differences in the scores may not be meaningful on-the-ground.

The SAVS tool was used to examine the vulnerabilities of 30 species and key habitats on the Coronado National Forest, which includes Madrean woodland, semi-desert grassland, desert scrub, and riparian habitats. Species of interest were selected by staff and included threatened or endangered, sensitive, and management indicator species. Key climate projections by Rehfeldt et al. (2006) — an increase in average annual temperature, an increase in aridity and drought, a reduction in Madrean forest and woodland communities, and an increase in semi-desert grasslands — were used to evaluate vulnerabilities. Overall, 29 out of 30 species were identified as vulnerable. The majority of bird species analyzed were among the most vulnerable, particularly riparian-dependent or associated birds. Slevin’s bunchgrass lizard, a species of interest, was the only species with a slightly resilient range; this was thought to be due to an increase in grassland habitats as a result of climate change. The Rocky Mountain Research Station has developed a website for online access to the SAVS tool.

Projected Changes and Uncertainty

Jennie Hoffman, Senior Scientist and Director of Programs, EcoAdapt

Some uncertainty surrounding climate change will never get reduced, whether it is specific projections of greenhouse gas emissions or changes in laws and policies. Thus, we cannot wait for uncertainty to be resolved in order to take action. Options include using the models that best capture climate processes in the region of interest, or using the average projections from a number of models while keeping in mind areas where there is more or less agreement. Extreme but plausible projections should also be considered in order to give a sense of the range of plausible futures, for example, how much and in what direction (i.e., too much or too little)

9http://www.fs.fed.us/rmrs/#savs
precipitation will change in the southwest. In deciding what information to use, managers need to focus on what their goal is and answer two questions: (1) what kind of information do we use for our work, and (2) how is that information used? Focusing broadly on ecological processes and how the system works can help the project move beyond model uncertainties.

Uncertainty can also be incorporated into a project through scenario planning or adaptive management. Scenario planning can be used to ensure robust decision-making and strategies. For example, the National Park Service (NPS) is using scenario planning for climate change to deal with uncertainty in the models and projections. The NPS is using extreme and average scenarios to identify different planning options, such as core strategies that make sense, regardless of the scenario, versus strategies that should be adopted only under extreme scenarios. Adaptive management is a way of hypothesis testing; for example, what is going to happen, how will it affect the system, what management actions need to be taken and why will they work? The South Bay Salt Pond Restoration Project\(^\text{11}\) used an adaptive management plan that specified key uncertainties and research needed to address them, triggers for action, and necessary science and institutional structures. For each goal the plan listed what to monitor and where, targets for when decisions should be made, what observations would trigger reexamination of the plan, action options once the trigger is tripped, and key knowledge gaps and how to fill them.

**Climate Change Adaptation Case Study Interviews**
Jessica Hitt (EcoAdapt) hosted a short interview session with Gregg Garfin (University of Arizona), Karen Simms (Bureau of Land Management), and Gita Bodner (The Nature Conservancy) to discuss adaptation projects in the Jemez Mountains and Las Cienegas National Conservation Area. Complete case studies can be found in Supplement A: *Climate Change and Land Management Adaptation Case Studies.*

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\(^{11}\)http://www.southbayrestoration.org/
The goals of the breakout groups were to develop a common management goal for each ecosystem in the Sky Island region, assess the vulnerabilities of the goal and actions to address them, and identify resources to implement identified actions. An example of the Florida Reef Tract Action Plan process was introduced to participants as a guide for the breakout groups.

Participants were split into breakout groups by ecosystem with one facilitator, an ecosystem expert who gave an introductory presentation, and a note taker/co-facilitator. Each group was asked to explore vulnerabilities of their selected common management goal, and to identify factors contributing to these vulnerabilities both directly and indirectly (e.g. non-climate stressors affecting vulnerability).

The groups were asked to develop hypotheses of change by answering the following questions:

- How might climate change affect your goal or ecosystem directly?
- How might climate change affect your goal or ecosystem indirectly (e.g. ecological effects, interactions with existing stressors)?
- How might changes outside your ecosystem influence your goal or ecosystem?
- Which interacting factors influence vulnerability to climate change (e.g. other physical stressors)?

Each group was then asked to list a series of adaptation options to make the common management opportunity goal less vulnerable and develop at least one adaptation plan, including outlining needs, necessary resources, partners and a timeline.
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MADREAN FOREST
Facilitators Gregg Garfin, University of Arizona and Alex Score, EcoAdapt

Breakout Group Participants

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<tr>
<th>Name</th>
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<tr>
<td>Adrian Quijada</td>
<td>University of Arizona, School of Natural Resources and the Environment</td>
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<td>Louise Misztal</td>
<td>Sky Island Alliance</td>
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<td>Chris Jones</td>
<td>University of Arizona Cooperative Extension</td>
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<tr>
<td>Carolyn Enquist</td>
<td>USA National Phenology Network, The Wildlife Society</td>
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<td>Craig Wilcox</td>
<td>U.S. Forest Service Coronado National Forest</td>
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<tr>
<td>Larry Laing</td>
<td>Semi-retired, U.S. Forest Service</td>
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<td>Vince Pawlowski</td>
<td>University of Arizona</td>
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<td>Sharon Coe</td>
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<tr>
<td>Brooke Gebow</td>
<td>The Nature Conservancy, Coronado National Forest</td>
</tr>
<tr>
<td>Marcos Robles</td>
<td>The Nature Conservancy</td>
</tr>
<tr>
<td>Cyndi Tuell</td>
<td>Center for Biological Diversity</td>
</tr>
<tr>
<td>Diana Tilton</td>
<td>Arizona Game and Fish Department</td>
</tr>
</tbody>
</table>

Presentation of Madrean forest characteristics– Craig Wilcox, U.S Forest Service, Coronado National Forest

Climate change-induced droughts, increased temperature, and changes in precipitation distribution and seasonality are impacting Madrean forest ecosystem functions and composition. Other interacting, non-anthropogenic impacts, such as wind, fire, and insects, make it difficult to predict what is actually causing some of these changes. Some impacts can also be correlated to changes in land-use management, human-ignited fires, road disturbance, invasive species, and recreational use. Managers have already noticed some shifts in species in the Madrean Encinal oak woodland/semi-desert land boundary. Some forest-managed lands are becoming grasslands, and grasslands are becoming desert grass. Desert grass could eventually invade forest areas. To understand how the habitats will adjust to climate change, there needs to be a better understanding of the different forest zones, succession, and factors that enable disturbance such as insects and roads.

Climate change threats to Madrean forest habitat
During the first day, the group discussed the most significant climate change impacts to Madrean forests’ health, function, wildlife, and fire regimes, including increasing temperatures, frequency of warmer and drier winters, summer precipitation variability (wet summers and dry summers), and mega-droughts.

Increasing temperatures, which may result in:

- **Direct impacts:**
  - Decrease in vegetation health due to heat stress
  - Increase in viability of insect pests
  - Enhanced fire risk due to longer fire season
  - Altered soil biophysical characteristics
  - Temperature stress on wildlife leading to ecophysiological changes, direct mortality, and/or migration
  - Species range shifts
Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region

- **Indirect impacts**
  - Insect invasions from outside the forest habitat
  - Altered forest regeneration/productivity due to soil changes
  - Endemic insects pose a more active threat
  - Expanded fire regime from other ecosystems affecting forests
  - Increased wildlife urban interface
  - Increased fires
  - Soil erosion following catastrophic/uncharacteristic fires

- **Interacting factors**
  - Increased human pressures on landscape
  - Recreation (e.g. off road vehicle use, hunting, and off trail hiking) causing habitat fragmentation and stress
  - Forest treatment to increase water yield

**Increasing frequency of warmer and drier winters**, which may result in:

- **Direct impacts**:
  - Altered snow hydrology
  - Diminished moisture watershed retention
  - Increase in insect invasions
  - Increased fires
  - Ecosystems shifts (e.g. woody species expected to decrease with less winter rain)

- **Indirect impacts**:
  - Increased grazing pressures
  - Phenological shifts (aquatics, seeps, and springs)

- **Interacting factors**:
  - Cloud seeding

**Increasing summer precipitation variability**, which may result in:

- **Direct impacts for wet summer**:
  - Reduced heat stress for certain species
  - Flooding and erosion

- **Indirect impacts for wet summer**:
  - Phenological shifts
  - Extend breeding season for some species
  - Ecosystem shifts

- **Interacting factors for wet summer**:
  - Soil loss through floods

- **Direct impacts for dry summer**:
  - Woody species decrease
  - Less water for wildlife
  - Decreased recharge

- **Indirect impacts for dry summer**:
  - Decreased soil moisture retention
  - Decreased water recharge
  - Increased advantage for invasive species and pests

- **Interacting factors for dry summer**:
  - Winds bringing in more invasive species
**Mega-droughts**, which may result in:

- **Direct impacts:**
  - Tipping point/threshold change
  - Increased insect/pest infestation
  - More fires/erosion
  - Mortality of Madrean forest species

- **Indirect impacts:**
  - Increased pressure of herbivorous plants trying to establish
  - Species extirpation from high elevations
  - Ecosystem shifts and collapse
  - Loss of species refugia

- **Interacting factors:**
  - Significant changes to forest habitat
### Madrean forest Top vulnerabilities and adaptation options

Breakout group participants discussed the vulnerabilities of the Madrean forest and possible adaptation options.

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Adaptation Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased forest health and ecosystem services</td>
<td>• Adjust NEPA assessments to scale, time and space appropriate for landscape level</td>
</tr>
<tr>
<td></td>
<td>projects rather than site specific. FireScape[^12] is already doing this on the</td>
</tr>
<tr>
<td></td>
<td>Coronado National Forest.</td>
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<tr>
<td></td>
<td>• Evaluate where forest and woodland function can be maintained and manage</td>
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<tr>
<td></td>
<td>transitions of forest to other ecosystems (e.g to woodland savannah or grassland)</td>
</tr>
<tr>
<td></td>
<td>to avoid drastic changes.</td>
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<tr>
<td></td>
<td>• Restore appropriate fire regimes at the landscape-level.</td>
</tr>
<tr>
<td></td>
<td>• Place fire damage liability on property owners within the Wildland Urban</td>
</tr>
<tr>
<td></td>
<td>Interface.</td>
</tr>
<tr>
<td></td>
<td>• Survey for and manage invasive grasses.</td>
</tr>
<tr>
<td></td>
<td>• Focus resources on maintaining and protecting resilient areas.</td>
</tr>
<tr>
<td>Catastrophic fire leading to abrupt change</td>
<td>• Decrease human caused fire ignition by managing human uses of public lands:</td>
</tr>
<tr>
<td></td>
<td>- Increase fire prevention/closure programs</td>
</tr>
<tr>
<td></td>
<td>- Perform mountain range assessment to prioritize closure to human use</td>
</tr>
<tr>
<td></td>
<td>- Ensure adequate enforcement of closure orders</td>
</tr>
<tr>
<td></td>
<td>- Focus ecological restoration work in areas of high human use</td>
</tr>
<tr>
<td></td>
<td>• Increase prescribed burns and forest thinning to restore historic fire regime:</td>
</tr>
<tr>
<td></td>
<td>- Prepare in advance for expected post-fire erosion</td>
</tr>
<tr>
<td></td>
<td>• Manage invasive grass species that are carrying uncharacteristic fire into forests.</td>
</tr>
<tr>
<td></td>
<td>• Break the continuity between invasive grass species that are moving upward in</td>
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<tr>
<td></td>
<td>elevation to forested areas through fire break management and surveys/monitoring</td>
</tr>
<tr>
<td></td>
<td>to detect and eradicate upstart populations.</td>
</tr>
<tr>
<td></td>
<td>• Engage in community education focused on prevention of human ignitions and the</td>
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<tr>
<td></td>
<td>natural role of fire in ecosystems to promote public acceptance of the need for</td>
</tr>
<tr>
<td></td>
<td>fire.</td>
</tr>
<tr>
<td></td>
<td>• Collect tree cones and seeds with volunteers in advance of fire.</td>
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<tr>
<td></td>
<td>• Manage fires started by natural causes to benefit the resources – wildland fire</td>
</tr>
<tr>
<td></td>
<td>use.</td>
</tr>
<tr>
<td>Wildlife and vegetation shifts</td>
<td>• Increase habitat and wildlife protection.</td>
</tr>
<tr>
<td></td>
<td>• Protect corridors for species connectivity.</td>
</tr>
<tr>
<td></td>
<td>• Manage the landscape for resilience.</td>
</tr>
<tr>
<td></td>
<td>• Manage invasive species.</td>
</tr>
<tr>
<td>Loss of soils, decreased forest regeneration potential</td>
<td>• Develop habitat restoration programs to prevent erosion.</td>
</tr>
<tr>
<td></td>
<td>• Prepare in advance of prescribed burns for erosion and actively build control</td>
</tr>
<tr>
<td></td>
<td>measures:</td>
</tr>
<tr>
<td></td>
<td>- Closures of sensitive areas to prevent further disturbance</td>
</tr>
<tr>
<td></td>
<td>- Survey potential of invasive species and develop triage treatment</td>
</tr>
<tr>
<td>Increased insect infestations and tree vulnerability to</td>
<td>• Develop tools for early detection of beetle infestation and treat:</td>
</tr>
<tr>
<td>insects</td>
<td>- Pheromone treatments and insecticides</td>
</tr>
<tr>
<td></td>
<td>• Maintain forest resilience through treatments like prescribed burning.</td>
</tr>
</tbody>
</table>

[^12]: http://www.azfirescape.org/
After analyzing the climate vulnerabilities and adaptation options, participants were asked to develop one adaptation plan that would fulfill the agreed-upon goal, to “maintain ecosystem services and function of montane forests and woodlands to preserve biodiversity and adaptation potential where possible, or facilitate transition.” Many possible plans were discussed, including prescribed fires and wildlife protection; education on climate change, fires, and carbon; and shifting fire damage liability to private landowners. The group decided to focus on landscape-scale management to increase the system’s resilience to climate change.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Maintain ecosystem services and function of montane forests and woodlands to preserve biodiversity and adaptation potential where possible, or facilitate transition.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategy:</td>
<td>Initiate a process to manage the Sky Island region at a landscape scale through the National Environmental Policy Act (NEPA). Use the Statewide Forest Strategy as a framework and model process after the Four Forest Restoration Plan. Conduct a landscape vulnerability assessment, define project areas, and use a facilitated process with a conflict resolution expert.</td>
</tr>
<tr>
<td>Rationale:</td>
<td>Because of climate change, managers need to start considering a landscape scale, instead of single places in specific jurisdictions. The region needs to develop a programmatic NEPA analysis on how to manage for resilience, which is not currently done by the U.S. Forest Service. A program based on the FireScape model might be able to inform management at a landscape scale if built into the NEPA analysis. The NEPA analysis would need to be updated with new climate models or predictions.</td>
</tr>
<tr>
<td>Resources Needed:</td>
<td>Working group for coordination Funding</td>
</tr>
<tr>
<td>Potential Partners:</td>
<td>• State agencies • Government agencies • Counties • Non-profit organizations, such as Sky Island Alliance • Land Conservation Trusts • Tribes • Coronado Planning Partnership • Sonoran Joint Venture • Universities, such as the University of Arizona • State forestry groups • Private land owners</td>
</tr>
<tr>
<td>Lead:</td>
<td>U.S. Forest Service</td>
</tr>
<tr>
<td>Timeline:</td>
<td>• 6-9 Months: define the landscape using FireScape as a tool, conduct landscape assessment, identify resources, and build partnerships. • 6 months-2-years: Organize and engage the working group to develop the landscape NEPA analysis. • 2-3 years: Draft a programmatic NEPA analysis, conduct stakeholder outreach, implement public comments, and prepare final release.</td>
</tr>
<tr>
<td>Monitor Success:</td>
<td>Track the timeline and process in getting the NEPA decision adopted in the region. Track implementation and revise if necessary.</td>
</tr>
</tbody>
</table>
Riparian
Facilitators: Eric Mielbrecht & Jessi Kershner, EcoAdapt

Breakout Group Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phil Rosen</td>
<td>U.S. Geological Survey, Southwest Biological Science Center</td>
</tr>
<tr>
<td>Emily Brott</td>
<td>Sonoran Institute</td>
</tr>
<tr>
<td>Trevor Hare</td>
<td>Sky Island Alliance</td>
</tr>
<tr>
<td>Sage Goodwin</td>
<td>Conservation Rancher</td>
</tr>
<tr>
<td>Lisa McDonough</td>
<td>University of Arizona</td>
</tr>
<tr>
<td>Jony Cockman</td>
<td>Bureau of Land Management</td>
</tr>
<tr>
<td>Matt Killeen</td>
<td>The Nature Conservancy</td>
</tr>
<tr>
<td>Salek Shafiqullah</td>
<td>U.S. Forest Service, Coronado National Forest</td>
</tr>
<tr>
<td>Debbie Sebesta</td>
<td>U.S. Forest Service, Coronado National Forest</td>
</tr>
<tr>
<td>Tom Meixner</td>
<td>University of Arizona, Department of Hydrology and Water Resources</td>
</tr>
<tr>
<td>Mark Briggs</td>
<td>World Wildlife Fund</td>
</tr>
<tr>
<td>Larry Norris</td>
<td>National Park Service Saguaro National Park</td>
</tr>
<tr>
<td>Ken Boykin</td>
<td>New Mexico State University</td>
</tr>
<tr>
<td>Amy Markstein</td>
<td>U.S. Bureau of Land Management</td>
</tr>
<tr>
<td>Terry Hill</td>
<td>White Mountain Apache Tribe</td>
</tr>
<tr>
<td>Ben Lomeli</td>
<td>U.S. Bureau of Land Management</td>
</tr>
<tr>
<td>Ron Tiller</td>
<td>The Nature Conservancy</td>
</tr>
<tr>
<td>Brian Powell</td>
<td>Pima County Office of Conservation Science and Environmental Policy</td>
</tr>
</tbody>
</table>

Presentation of Riparian characteristics – Ron Tiller, The Nature Conservancy

Riparian areas are dynamic and constantly changing in response to climate, hydrology, fire, and other factors. Mountain block recharge, ephemeral stream channels, and flood recharge along the river influence stream flow regime. Ongoing changes in riparian ecosystems indicate declines in aquifer levels and stream flow discharge. Predicted future conditions through scenario modeling indicate there will be continued water table decline, vegetation change, and species response in complex riparian ecosystems. The Nature Conservancy (TNC) and other groups in the region are currently managing for change in riparian systems to improve the conditions in the watershed. Projects include reintroduction of beaver in the mid-1990s, which improved bird diversity and habitat heterogeneity; incentive grants for water conservation; promoting and implementing groundwater recharge projects; installing dry wells to capture rainwater; prescribed fire and vegetation management to help reduce groundwater use; land use planning restrictions near rivers; and establishing conservation easements to retire active agriculture and preclude future development.

Climate change threats to Riparian

During the first day, the group discussed a variety of climate changes of importance to riparian habitat, including warmer and drier winters, variability in monsoons, and increasing temperatures.

Increasing frequency of warmer and drier winters, which may result in:

- **Direct impacts:**
  - Less water available for the system
  - Recharge decreases
- **Indirect impacts:**
Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region

- Decreased recruitment of cottonwood and willow
- Riparian vegetation subject to more booms and busts
- Phenological shifts
  - **Interacting factors:**
    - Potential shift to bare ground in upland-grassland habitats leading to increased erosion and decreased infiltration
    - Decreased invasive aquatic species due to less aquatic habitat

**Increasing frequency of hotter, drier and longer fore-summers**, which may result in:
  - **Direct impacts:**
    - Decreased dissolved oxygen in water bodies
    - Longer, more severe droughts
    - Distance between wet islands increasing and connectivity decreasing
  - **Indirect impacts:**
    - Desertification
    - Increased flooding
    - Effects on migrating birds that rely on wet islands and riparian vegetation
    - Population extirpation or extinction due to decreases in genetic exchange
  - **Interacting factors:**
    - Less grassland or more non-native grassland in upland habitats

**Changes in timing and amount of precipitation during monsoon season**, which may result in:
  - **Direct impacts:**
    - Parts of the river basin experiencing no-flow times for the first time, and fewer areas having perennial flow
    - Parts of river basins that currently experience no-flow times experiencing those times for longer
    - Increased flooding
    - Decreased water availability
  - **Indirect impacts:**
    - Impacts to soils, plants, and recharge ultimately influencing riparian areas
    - Changes in species recruitment and stream morphology due to flood events
    - Potential for increased recharge with increased summer flooding
  - **Interacting factors:**
    - Changes in rainfall sequencing significantly impacting grasslands, which feed into riparian areas
    - Decreases in some species, including invasive upland species changing riparian areas
    - Changes in fire regime

**Increases in temperature**, which may result in:
  - **Direct impacts:**
    - Decreased dissolved oxygen
  - **Indirect impacts:**
    - Aquatic species declines such as trout, native fish (e.g., dace), Chiricahua leopard frog, and the Huachuca frog
    - Possibly some species increases such as the lowland leopard frog
    - Decrease in native grass cover in uplands
  - **Interacting factors:**
- Drier conditions

**Riparian vulnerabilities and adaptation options**
During the second day, participants identified eight different vulnerabilities of riparian habitat. From this list, the group chose the top five vulnerabilities, and participants then divided up into three smaller groups – places, species, and process/features – to identify ways to reduce potential impacts through various adaptation options. Many of the strategies developed were applied to more than one vulnerability.

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Adaptation Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitat fragmentation due to increased patchiness or isolation of wet islands</td>
<td>• Capitalize on drying of wet islands and drought to eradicate aquatic invasive species populations.&lt;br&gt;• Use restoration and other work to keep water in the system (e.g., check dams, rock dams, rooftop engineering solutions).</td>
</tr>
<tr>
<td>Decreased biodiversity</td>
<td>• Prioritize areas for conservation and/or development.&lt;br&gt;• Use restoration and other work to help keep water in the system for plants and wildlife (e.g., check dams, rock dams, rooftop engineering solutions).&lt;br&gt;• Actively create aquatic and riparian habitat such as stock ponds in urban and rural settings.&lt;br&gt;• Capitalize on drying of wet islands and drought to eradicate or reduce invasive species populations.</td>
</tr>
<tr>
<td>Changes or alterations in physical processes, stream morphology, and water table</td>
<td>• Work with planners and engineers to build and design infrastructure that helps maintain ecosystem processes.&lt;br&gt;• Use restoration and other work to help keep water in the system.</td>
</tr>
<tr>
<td>Decreased recharge and less water in the system</td>
<td>• Use restoration and other work to help keep water in the system and available for recharge.&lt;br&gt;• Figure out where, when, and how water will concentrate and develop strategies to slow the water down to keep it in the system.&lt;br&gt;• Pursue different water policies to ensure water is saved for the environment and ecosystems.</td>
</tr>
<tr>
<td>Decreased ecosystem services, increased pressures and conflicts (e.g. water for the ecosystem vs. for the people)</td>
<td>• Pursue different water policies to ensure water is saved for the environment and ecosystems.&lt;br&gt;• Public engagement to build eco-values in voters, legislators and society to conserve water and reduce usage and increase management dollars.&lt;br&gt;• Work with planners and engineers to build and design infrastructure in a way that is effective for both ecosystems and people.</td>
</tr>
</tbody>
</table>
Riparian Adaptation Plan
After discussing a range of adaptation strategies and possibilities for implementation post-workshop, participants focused on a specific adaptation plan to put into action. The table below summarizes the group’s adaptation plan.

<table>
<thead>
<tr>
<th>Goal:</th>
<th>Conserve the function and intactness of riparian systems in a changing climate for the Upper San Pedro River basin.</th>
</tr>
</thead>
</table>
| Strategy: | Stop the Stupid, Start the Smart Campaign  
There is a need to put the value of water and riparian systems in terms that all groups of people can understand. Strategies that may help include discussions on money savings, human health and well-being, scientific vs. practical needs, and myth busting. In addition, when talking to people it is important to respect their values, find common ground, and be flexible. |
| Rationale: | Education and outreach are critical in order to help people in the region understand the value of water and riparian systems. There is a need for developing methods to communicate effectively with engineers, cattlemen’s associations, decision makers, youth, consumptive users (e.g., agriculture, mining, forestry), and the general public to drive decision support in protecting and conserving water resources. |
| Resources Needed: | • Funding/financial resources  
• Shared network of knowledge  
• Communication tools  
• Marketing campaign  
• Build off efforts by the Arizona Riparian Council, Arizona Hydrologic Society, and Arizona Floodplain Managers Association |
| Potential Partners: | • Respected experts in the field as bridge to fields (Natural Resources Conservation Service or National Resource Directory folks are key partners for this)  
• Communication experts or a professional communication organization  
• Political and social leaders and allies (need a respected decision-maker on your side to influence another decision maker)  
• Conservation ranchers  
• Educators  
• Operators (e.g., floodplain managers)  
• Media/marketing  
• Pima Association of Governments clearinghouse  
• Land, water and wildlife managers  
• Professional associations  
• Other key stakeholders |
| Lead: | The Nature Conservancy, Sky Island Alliance, or the Sonoran Institute |
| Timeline: | • 1-4 weeks: develop strategies  
• 6 months: launch program/campaign |
| Monitor Success: | • Public surveys  
• Public attitude change  
• Water conservation success |
SEMI-DESERT GRASSLAND

Facilitators: Lara Hansen & Rachel M. Gregg, EcoAdapt

Breakout Group Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jessica Lamberton</td>
<td>Sky Island Alliance</td>
</tr>
<tr>
<td>Eva Sargent</td>
<td>Defenders of Wildlife</td>
</tr>
<tr>
<td>Sheridan Stone</td>
<td>Department of Defense Ft. Huachuca</td>
</tr>
<tr>
<td>Mary Hunnicutt</td>
<td>U.S. Fish and Wildlife Service, Buenos Aires National Wildlife Refuge</td>
</tr>
<tr>
<td>Dan Cohan</td>
<td>U.S. Fish and Wildlife Service, Buenos Aires National Wildlife Refuge</td>
</tr>
<tr>
<td>Jeff Williamson</td>
<td>Arizona Zoological Society</td>
</tr>
<tr>
<td>Karen Simms</td>
<td>U.S. Bureau of Land Management, Las Cienegas National Conservation Area</td>
</tr>
<tr>
<td>Gita Bodner</td>
<td>The Nature Conservancy</td>
</tr>
<tr>
<td>Wolfgang Grunberg</td>
<td>Arizona Game and Fish Department</td>
</tr>
<tr>
<td>Larry Jones</td>
<td>U.S. Forest Service, Coronado National Forest</td>
</tr>
<tr>
<td>Valer Austin</td>
<td>Cuenca los Ojos Foundation</td>
</tr>
<tr>
<td>Jennie Duberstein</td>
<td>Sonoran Joint Venture</td>
</tr>
<tr>
<td>Lacrecia Johnson</td>
<td>U.S. Fish and Wildlife Service</td>
</tr>
<tr>
<td>Roger Cogan</td>
<td>Appleton-Whittell Research Ranch, Arizona</td>
</tr>
<tr>
<td>Rem Hawes</td>
<td>U.S. Bureau of Land Management</td>
</tr>
<tr>
<td>Ron Pulliam</td>
<td>Biophilia Foundation</td>
</tr>
<tr>
<td>Jennifer Ruyle</td>
<td>U.S. Forest Service, Coronado National Forest</td>
</tr>
</tbody>
</table>

Presentation of Semi-Desert Grassland characteristics – Dan Cohan, Buenos Aires National Wildlife Refuge

Semi-desert grasslands in the Sky Islands are dominated by grasses interspersed with desert shrubs and succulents. Summer and winter grasses are low in organic matter, often high in calcium carbonate, and have a long growing season (over 300 days/year). The abundance and composition of grasses, shrubs, and other species are determined by water availability, soils, the occurrence of fire, and land use practices. Approximately 80% of the Buenos Aires National Wildlife Refuge, primarily established to protect the critically endangered Masked Bobwhite Quail, is classified as semi-desert grasslands. Key management issues within this habitat include climate change, land use practices, invasive species, and altered fire regimes.

Climate change threats to Semi-Desert Grassland

During the first day, the group discussed a variety of climate changes of importance to semi-desert grassland, including increasing dry winters, increased temperatures, variability in precipitation events, and changes in seasonality.

Increasing frequency and intensity of dry winters, which may result in:

- **Direct impacts:**
  - Less spring green-up
  - Increased number of invasive species
  - Possibly more perennial grass mortality
  - Species range shifts of grass species
  - Decreased availability of prey

- **Indirect impacts:**
  - Less primary productivity because of increased erosion rates during monsoon
- Intensification of fire events leading to more habitat destruction (e.g., fire may burn roots)
- Changes in composition and number of key charismatic species
  - **Interacting factors:**
    - Higher tree mortality in woodlands surrounding grasslands
    - More catastrophic fires in woodlands may cause increased sedimentation
    - Biotic conflicts with desertification
    - Increased water availability, which may lead to increased water extraction and allocation for surrounding human communities

**Increasing variability**, which may result in:
  - **Direct impacts:**
    - Greater extremes in precipitation
    - Drier dry years
    - Increases in fire events
    - Altered seasonality and timing of precipitation
  - **Indirect impacts:**
    - Dryness may lead to loss or alteration of vegetation community
    - Erosion
    - Decreased ability to retain moisture
    - More variable production, leading to changes in food availability
  - **Interacting factors:**
    - Subdivision of ranches which could cause change in economic base
    - Ranching will become more marginal

**Changes in seasonality**, which may result in:
  - **Direct impacts:**
    - Earlier and longer spring
    - Longer arid summer
    - Earlier and longer fire season
    - Longer potential growing season
    - Possibly more frost damage
  - **Indirect impacts:**
    - Increasing grass mortality
    - Extinctions and problems with lizards, birds, bees/pollinators because of asynchronies
    - Possible influx of competing desert species
    - Changes in species migration timing
  - **Interacting factors:**
    - Potentially higher than expected impacts from grazing
    - Increased grazing pressure from surrounding habitats
    - Increasing asynchronies between livestock management cycles and growing seasons
    - Increasing desertification

**Increasing intensity and frequency of precipitation**, which may result in:
  - **Direct impacts:**
    - Increasing erosion
    - Decreasing recharge
Increasing runoff
- Changes in grass productivity
- More competitive invasive species

**Indirect impacts:**
- Shifts in species composition
- Changes in hydrologic regime
- Increasing fluctuation in carrying capacity for native and non-native species
- Drainage and ditching may affect recharge back into grasslands

**Interacting factors:**
- If trees die-off upslope, may cause more runoff and flood flows, exacerbating grassland erosion
- May be increased hard structure responses (e.g., rip rapping) to protect human systems
- Fluctuations in grazing capacity

**Increasing temperatures**, which may result in:

**Direct impacts:**
- Drier conditions
- Less surface water
- Increasing transpiration
- Increasing mortality for certain species (e.g., temperature sensitive species)

**Indirect impacts:**
- Lower productivity
- Food chain effects
- Increasing fire frequency
- Increasing invasive species

**Interacting factors:**
- Increasing energy needs for cooling
- Increasing water use/allocation for human communities
- Increasing alternative energy needs leading to habitat and landscape fragmentation
## Semi-desert Grassland vulnerabilities and adaptation options
During the second day, participants identified 17 different vulnerabilities of semi-desert grassland. From this list, the group chose the top five vulnerabilities and identified ways to reduce potential impacts through various adaptation options.

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Adaptation Options</th>
</tr>
</thead>
</table>
| Changes in or inability to continue historic land use practices (ranching, agriculture, tourism, development) | • Show communities alternative futures with climatic and landscape changes through technological means like Google and other mobile-type applications (e.g., Farmville equivalent) to engage stakeholders.  
• Reach out to public by soliciting community participation in tracking climate changes through monitoring:  
  ▪ Rainlog, a cooperative rainfall monitoring network for Arizona to inform drought planning and watershed management ([www.rainlog.org](http://www.rainlog.org))  
  ▪ National Phenology Network ([www.usanpn.org](http://www.usanpn.org))  
• Support recreational uses that are sustainable, including stewardship programs and citizen monitoring.  
• Incorporate past water and land allocation information and potential climate changes into future management. |
| Flooding and mass flow events because of changes in hydrologic regime | • Harness mass flow and flooding events to increase water reserves in the region by installing berms or swales, and providing incentives to people who dedicate land to groundwater recharge (e.g., water ranching as a new industry).  
• Reduce urban channelization.  
• Plant vegetation that can provide sponge effect to protect the built environment. |
| Less viable ranching opportunities | • Change grazing time and location. For example, move cattle grazing north and cooperate with other ranchers to avoid increased costs of irrigation.  
• Increase reserve seed allotments to increase flexibility and options in the future.  
• Value and reward land occupancy and use by providing incentives for those areas that provide water and soil retention and maintain native species and grassland habitats (e.g., paying for ecosystem services).  
• Increase diversification of land use to provide ranchers with alternative options for future employment (e.g., recreational uses, dude ranching). |
| Soil loss, decreased ground cover, and decreased seed availability | • Install stabilizing features (rocks, berms) to “catch” seed and soil during runoff.  
• Improve monitoring techniques and practices for soil loss (e.g., consider soil physics) and track erosion patterns across large landscapes (e.g., LiDAR). |
| Lack of community concern regarding climate change and its effects on grasslands | • Conduct educational workshops for the public in order to overcome denial.  
• Actively engage young people in environmental stewardship by including climate change in school curriculum (e.g., Children of Nature Network) or alternative outlets (e.g., *Tucson Weekly* interview with children and older generations can address climate changes in the region).  
• Engage public through citizen science monitoring activities, like tracking changes through Rainlog and the National Phenology Network.  
• Conduct scenario planning (climate and management scenarios) with local communities through programs like Oregon State University’s Integrated Landscape Assessment Project. This program is working with Coronado National Forest and FireScape to examine ecological conditions.  
• Solicit input from diverse community members, including tribes’ cultural stories (e.g., through Buenos Aires National Wildlife Refuge). |
**Semi-Desert Grassland Adaptation Plan**

After discussing a range of adaptation strategies and possibilities for implementation post-workshop, participants focused on a specific adaptation plan to put into action. The table below summarizes the group’s adaptation plan.

<table>
<thead>
<tr>
<th>Table 6. Semi-Desert Grassland Adaptation Plan</th>
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<tbody>
<tr>
<td><strong>Goal:</strong></td>
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<td><strong>Rationale:</strong></td>
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<td><strong>Resources Needed:</strong></td>
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<td><strong>Potential Partners:</strong></td>
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</table>
| | • Climate Adaptation Knowledge Exchange (www.cakex.org), to promote and
engage participants and publicize project
- Department of Transportation
- Seeds of Success (www.nps.gov/plants/sos)
- Water companies
- Key individuals to engage:
  - Dan Robinette (Natural Resource Conservation Service)
  - Peter Gierlach (aka Petey Mesquitey)

**Lead:** Steering Committee
- Karen Simms, U.S. Bureau of Land Management
- Dan Cohan, U.S. Fish and Wildlife Service
- Heather Dial, Natural Resource Conservation Service
- Gita Bodner, The Nature Conservancy
- David Hodges (works for Valer Austin)
- Jennifer Ruyle, Coronado National Forest/U.S. Forest Service
- U.S. Department of Agriculture representative (still needed)
- Sky Island Alliance representative (still needed)

**Timeline:**
- May–August 2011
  - Steering Committee meetings to determine roles and responsibilities
  - Development of business plan
- September 1, 2011
  - Pre-proposal (3 page narrative and budget) due to National Fish and Wildlife Foundation Keystone Initiatives Program
- November 1, 2011
  - Full proposal due
- March 31, 2012
  - Notification

**Monitor Success:**
Seed has to be grown within Sky Island region with quality control measures in place (e.g., not contaminated with buffelgrass) in order to meet demand. Seeds should be tested for drop tolerance, possibly on test plots from the Tucson Plant Materials Center. Feedback mechanisms need to be created to gather information on what is working.
DESERT SUMMARY

Facilitators: Jennie Hoffman & Jessica Hitt, EcoAdapt

Breakout Group Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Affiliation</th>
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<tbody>
<tr>
<td>Sergio Avila</td>
<td>Sky Island Alliance</td>
</tr>
<tr>
<td>Barbara Warren</td>
<td>Physicians for Social Responsibility</td>
</tr>
<tr>
<td>Adam Springer</td>
<td>National Park Service, Saguaro National Park</td>
</tr>
<tr>
<td>Dana Backer</td>
<td>National Park Service, Saguaro National Park</td>
</tr>
<tr>
<td>David Schaller</td>
<td>Westmoreland Associates</td>
</tr>
<tr>
<td>Curt Bradley</td>
<td>Center for Biological Diversity</td>
</tr>
<tr>
<td>Jeff Wallner</td>
<td>National Park Service, Saguaro National Park</td>
</tr>
<tr>
<td>Christa Weise</td>
<td>Bat Conservation International</td>
</tr>
<tr>
<td>Eleonora Demaria</td>
<td>University of Arizona, Department of Hydrology and Water Resources</td>
</tr>
<tr>
<td>Helen Rowe</td>
<td>Arizona State University</td>
</tr>
<tr>
<td>Christina Vojta</td>
<td>Desert Landscape Conservation Cooperative</td>
</tr>
<tr>
<td>Dave Bertlesen</td>
<td></td>
</tr>
<tr>
<td>Zack Guido</td>
<td>U.S. Geological Survey, Southwest Biological Science Center</td>
</tr>
<tr>
<td>Cecil Schwalbe</td>
<td></td>
</tr>
<tr>
<td>Julio Betancourt</td>
<td>University of Arizona</td>
</tr>
<tr>
<td>Robert Mesta</td>
<td>Sonoran Joint Venture</td>
</tr>
</tbody>
</table>

Presentation of Desert characteristics – Cecil Schwalbe, U.S. Geological Survey Southwest Biological Science Center

The Sky Island region is home to the confluence of two of the four major hot and dry deserts in North America: the Chihuahuan and Sonoran. The Chihuahuan Desert is higher in elevation than the Sonoran Desert, which results in differences in precipitation and temperature. The Sonoran Desert has bi-seasonal rainfall, whereas the Chihuahuan Desert receives the majority of its rainfall during the monsoon season of late summer. Both deserts are characterized by ground-hugging shrubs and short woody trees, including creosote bush, tarbush, palo verde, and acacia. The Sonoran Desert is also home to the iconic saguaro cactus. Many of the region’s endemic reptiles and amphibians are being dramatically affected by changes in precipitation and temperature. While some species are pre-adapted to move up slopes, others lack the ability to shift their range as their ideal habitat shifts up the latitudinal and altitudinal gradient. Also, species with temperature-dependent sex determination are threatened by increasing regional temperatures. Cattle grazing, urban sprawl, invasive species, and climate change are the main management issues in the region.

Climate change threats to Desert

Throughout the first day, the desert breakout group discussed a range of climate change impacts that threaten the Sonoran and Chihuahuan Deserts as well as how these impacts would affect human communities and their behavior. Conversation primarily focused around regionally-increasing temperatures and changes in hydrology. Breakout group participants placed a particular emphasis on how these climate changes would influence human behavior and the ability of ‘climate advocates’ to communicate their message to the public.

Increasing temperatures, which may result in:

- Direct impacts:
  - Increasing mortality for temperature sensitive species
Between a Rock and a Hot Place: Climate Change Adaptation and Resource Management for the Sky Island Region

- Drier conditions
- Less surface water and reservoir water
- Decrease in frequency of freeze events
- Increased heat waves
- Changes in the growing season
- Species range shifts
- Increased fire frequency and intensity

- **Indirect impacts:**
  - Increasing energy needs for cooling
  - Increasing water use and allocation for human communities
  - Increased urban heat island effect
  - Climate-related human migration
  - Increased public health impacts
  - Decreased use of public transit
  - Decreased outdoor recreation
  - Increased disease and pests

- **Interacting factors:**
  - Increasing alternative energy needs leading to habitat and landscape fragmentation
  - Increase in human reproduction rates
  - Increase in invasive species
  - Decrease in agriculture potential
  - People becoming complacent about change that is happening
  - Cost of stopping climate change might be deemed too high
  - Increased use of herbicides and other chemicals to fight invasive species

### Changes in precipitation, which may result in:

- **Direct impacts:**
  - Decrease in precipitation
  - Increased intensity and frequency of precipitation events
  - Decrease in surface water
  - Increasing mortality for temperature sensitive species
  - Drier winter and spring
  - Changes in the monsoon
  - Changes in summer and fall precipitation
  - Changes in snowpack
  - Increase in frequency and intensity of mega-droughts

- **Indirect impacts:**
  - Infrastructure projects to bring water to the region
  - Shifts in species composition
  - Erosion
  - Decreased ability to retain moisture
  - Changes in sex-ratio of species with temperature-driven egg determination

- **Interacting factors:**
  - Management of invasive species
  - Conflict over water use priorities (municipal, mining, solar, nature)
  - Increased pressure for wind derived energy and other low-water energy sources
  - Increased public awareness about climate threats
Conflicts over what we are ‘saving’ or what is native
Increased use of herbicides and other chemicals to fight invasive species

Other Climate Factors:
  o Changes in monsoons
  o Changes in dust storms
  o Changes in regional fire regime
Desert top vulnerabilities and adaptation options

During day two, participants discussed a range of vulnerabilities to desert habitat. Participants narrowed down the conversation, selected the top five vulnerabilities, and discussed ways to reduce their impact through adaptation strategies.

<table>
<thead>
<tr>
<th>Vulnerability</th>
<th>Adaptation Options</th>
</tr>
</thead>
</table>
| Public disconnect or confusion over causes and impacts of climate change | • Stop talking about the causes of climate change and start focusing on the impacts the region is experiencing or will experience.  
• Conduct an education and awareness campaign around the region possibly in conjunction with ongoing efforts.  
• Conduct advertising and marketing campaign including PSAs and billboards.  
• Engage public through citizen science projects and campaigns.  
• Use members of various communities to communicate the issues to their own constituents.  
• Attend local meetings to get climate change incorporated into local municipal planning projects. |
| Change in land use pressures, policies, and opportunities | • Encourage multi-use land strategies (e.g., installing solar on lands already disturbed by mining).  
• Use in-filling to reduce urban sprawl.  
• Plant drought-resistant crops.                                                                                                                                      |
| Increased water use by humans                           | • Harvest rainwater.  
• Support policies to mandate grey water use for gardening and other non essential water functions.  
• Design water storage for more intermittent use.  
• Changes in water rate structure to incorporate climate change and future conditions.  
• Cover canals with solar panels to reduce evaporation.  
• Plant drought-resistant crops.  
• Redefine floodplain zones based on future conditions instead of historic conditions.                                                                                       |
| Increase in temperatures and energy use                 | • Increase public transportation and bike lanes.  
• Mandate showers at work.  
• Implement flexible workdays (can bike to work when cooler).  
• Encourage cultural shift of energy use in home life (turning up/down the thermostat).  
• Support/suggest energy initiatives with lower impact including energy cooperatives.  
• Institute policy to cover roofs and parking lots with solar panels.  
• Cover canals with solar panels.  
• Increase energy efficiency standards for new construction.                                                                                                               |
| Increase in invasive species                            | • Create awareness campaign to explain relationship between fire and invasive species.  
• Develop and promote safe methods of invasive species control.                                                                                                           |
**Desert Adaptation Plan**

After discussing a range of vulnerabilities and adaptation strategies for implementation post-workshop, participants focused on devising an outreach and education campaign that they felt addressed all their ecosystem’s vulnerabilities. The table below summarizes the group’s adaptation strategy.

<table>
<thead>
<tr>
<th><strong>Goal:</strong></th>
<th>Reduce human impact on desert ecosystems by awareness and outreach.</th>
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<tbody>
<tr>
<td><strong>Strategy:</strong></td>
<td>Incorporate climate change into the Biodiversity University events that are part of the Saguaro National Park BioBlitz event.</td>
</tr>
<tr>
<td><strong>Rationale:</strong></td>
<td>There needs to be a better understanding of climate change impacts in the region. Incorporating climate change into an already existing and successful event would help increase the awareness and understanding in the region. The BioBlitz and Biodiversity University is a two-day event to showcase national parks close to urban areas and will be held in October 2011. The event features numerous field trips and opportunities for outreach that could easily be changed to incorporate climate change with little or no budget but high impact.</td>
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<td><strong>Resources Needed:</strong></td>
<td>Ambassadors, scientists, volunteers, students, university, high schools, buy-in from BioBlitz steering committee</td>
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<td>Education materials:</td>
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<td></td>
<td>• Talking points for field trip leaders</td>
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<td></td>
<td>• Creative slogans with climate lens</td>
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<tr>
<td></td>
<td>• Take-home materials for attendees with list of to-dos</td>
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<tr>
<td><strong>Potential Partners:</strong></td>
<td>National Geographic</td>
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<td></td>
<td>Sky Island Alliance</td>
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<td>Saguaro National Park</td>
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<td>Arizona Sonoran Desert Museum</td>
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<td>Desert breakout group participants</td>
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<tr>
<td><strong>Lead:</strong></td>
<td>Jeff Wallner, Saguaro National Park</td>
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<tr>
<td><strong>Timeline:</strong></td>
<td>Next two weeks (end of April 2011) Jeff will speak to folks to get climate change incorporated into Biodiversity University, next few months meeting to plan incorporation, BioBlitz-Oct 21-22nd</td>
</tr>
<tr>
<td><strong>Monitor Success:</strong></td>
<td>Climate change inclusion in BioBlitz: number of organizations, speakers, and performers that incorporate climate change.</td>
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</tbody>
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Cross-cutting Issues – Marketplace and Exploration of Interactions

Interactions across ecosystems, landscapes, and climate stressors will influence the region’s overall vulnerability to climate change. Each ecosystem breakout group was instructed to mix with members of other groups in order to consider climate stressors, activities in other ecosystems, outside influences, and the four cross-cutting issues: fire, invasive species, hydrology, and connectivity. Some common issues included:

Upland management
- Riparian areas are adjacent to or embedded in the other three habitats (forests, grasslands, deserts). Activities and disturbances in these upland habitats (e.g., water extraction, erosion, and sedimentation) will affect riparian areas downstream/down slope.

Invasive species
- May move in different ways across different habitats, which may change the outcomes of fire events in the region.
- May cause community shifts within specific habitats; for example, buffelgrass from semi-desert grasslands may invade forests as temperatures increase.

Hydrology
- Will become a huge issue as drier climates, aridity, and more intense precipitation events affect the region.
- May be affected by dust and atmospheric pollution (thereby affecting water retention and availability).
- Ways to slow water down to retain it in the system as well as water rights are important to consider.
- Use highways to direct water during monsoon season to capture it as long as there is a retention basin.

Fire
- Fire and disturbance regimes in riparian and other areas are normal and are a useful tool for watershed health, but resource and user conflicts remain.
- May need to burn grasslands to maintain desert habitats, but need to be careful not to let the fire escape into the Sonoran Desert

A watershed-based approach to climate change may be necessary in order to coordinate fire, water, land, and wildlife management.

Public understanding of ecosystem services provided by the four ecosystems is limited and needs to be improved. Need to improve people’s behaviors through social education and outreach including using someone within a group or community to deliver the message, utilizing citizen science, using a community orientation rather than an individual focus, and possibly bringing social engineers or ecopsychologists to the table.

Maladaptive approaches need to be addressed immediately! Engineered solutions can be maladaptive; practitioners should encourage and promote ecosystem-based solutions.
Long-term drought (e.g., 25-yr droughts) and other similar surprises (e.g., extreme rain, extreme fire) will need to be addressed.

Species migration is an issue, especially for species we want to conserve; we will need to anticipate where they can go and how they can get there, and be sure to communicate across jurisdictions to support species movement.

Long-term scientific studies and monitoring are needed for all ecosystems.

Harnessing storms for greater human and ecological benefits. What natural processes can be harnessed to help the landscape?

Land use issues
  o Important across all four ecosystems, including grazing, urban development, mining, recreation and tourism, and water use planning and management.
  o Engage communities and economic interest groups in scenario planning to show where different land uses stop becoming viable and to present alternatives.
  o Engage the community to ask when they feel their interests are compromised and what they want to do, and encourage alternative ideas and thoughts.
Conclusions

Each breakout group presented the results of their discussion during the closing plenary on day two, *Mission Not Impossible – Reflection and Projection*. Lara Hansen (EcoAdapt) encouraged participants to follow through on the ideas and plans developed in the breakout groups and to utilize the Climate Adaptation Knowledge Exchange (CAKE; [www.cakex.org](http://www.cakex.org)) to share progress and find adaptation resources.

Melanie Emerson and Louise Misztal (Sky Island Alliance) gave some concluding thoughts and directions for next steps:

2. Change “could” to “will” to spur climate change action.
3. Sky Island Alliance is available to help by providing a trained citizen science corps of volunteers and facilitating connections among workshop participants.
4. Join the Arizona Climate Change Network ([http://www.skyislandalliance.org/aznetwork.htm](http://www.skyislandalliance.org/aznetwork.htm)) – it is only effective with your input and involvement.

Next Steps

This workshop builds the framework for developing adaptation plans throughout the entire Sky Island region. It also builds upon the Sky Island Alliance formed Arizona Climate Change Network, to foster the sharing of climate change information and findings, and promote collaborations in the region. Information and discussions during the first two workshops will be used as the source of information for planning the third workshop, the last of the climate adaptation workshops in the series. The next workshop will build upon these outlined plans, discuss further strategies for moving from “planning” to “action,” and develop a climate adaptation implementation strategy for the Sky Island region.

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13[http://www.skyislandalliance.org/aznetwork.htm](http://www.skyislandalliance.org/aznetwork.htm)
Acknowledgements

Organizing and Convening the Workshop
We would like to extend a huge thank you to everyone who participated in the workshop. Special acknowledgement goes to those organizations and agencies who invested considerable time and effort into organizing this workshop: Sky Island Alliance, EcoAdapt, University of Arizona Institute of the Environment, University of Arizona School of Natural Resources and Environment, CLIMAS, Sonoran Joint Venture, U.S. Forest Service Coronado National Forest, The Biophilia Foundation, U.S. Fish & Wildlife Service, and the U.S. Institute for Environmental Conflict Resolution.

Speakers and Panelists
We would like to extend our sincere gratitude to all of the speakers and panelists who contributed their time and expertise to make this workshop possible.

Volunteers and Sky Island Alliance Staff
The event ran smoothly and effectively due to the excellent work of numerous Sky Island Alliance volunteers and the efforts of many of Sky Island Alliance’s staff members, including, Melanie Emerson, Jenny Neeley, Caroline Patrick, Sergio Avila, Trevor Hare, and Acasia Berry.

Sponsors
We would like to thank Saguaro National Park, the Coronado National Forest, and the Arizona Game and Fish Department for their sponsorship of the event.

This Climate Change Adaptation workshop series is made possible in part through generous support from the Nina Mason Pulliam Charitable Trust and The Kresge Foundation.
Supplement A: Climate Change and Land Management Adaptation Case Studies

Prepared by: Jenny Neeley (Sky Island Alliance), and Jessica Hitt (EcoAdapt)

Cuenca Los Ojos

Overview
The Cuenca los Ojos Foundation (CLO) is a bi-national non-profit organization working in the United States and Mexico, with major land-holdings in both countries that total more than 200,000 acres of privately-owned and managed lands. The CLO works to preserve and restore the biodiversity of the borderlands region through land protection, habitat restoration to enhance ecosystem services, and wildlife reintroduction. The CLO supports these programs through scientific research and sustainable resource management practices. Josiah and Valer Austin, the founders of CLO, have been involved with conservation projects in this region for the past 30 years.

Properties managed by CLO are strategically located in both the United States and Mexico at the headwaters of the Rio Yaqui watershed, a major north-south migration corridor along the western flank of the Sierra Madre. CLO-managed lands encompass multiple ecological zones and countless biotic communities, including conifer forests, oak savannahs, desert grasslands, and riparian and cienega systems. Located in the heart of the Sky Island region and considered a global ‘hotspot’ for biodiversity, this area is home to more than 70 mammal species, 400 bird species, 50 reptile and amphibian species, 11 native fish species, and 600 bee species, and this includes numerous species that are federal and/or state-listed as threatened or endangered, or are species of conservation concern. Despite centuries of overexploitation, this region remains one of the most biologically diverse due to the convergence of four great biogeographic domains and the intermingling of their unique floras and faunas. Plants and animals from the lowlands of the

Contact Information
Fundacion Cuenca Los Ojos
El Coronado Ranch
vaustin@elcoronadoranch.net

Photo Courtesy of Cuenca Los Ojos Foundation
Sonoran Desert to the west meet the equally rich but less known biota of the Chihuahuan Desert to the east. Dividing these two great deserts are highlands stemming both from the Rocky Mountains to the north and the Sierra Madre Occidental to the south. The elevation and climatic heterogeneity of the region allows for mixing of species from different biogeographic regions, and an unusually high number of species reach their geographic distributional limits here. Named a global hotspot for biodiversity, the Sky Island region hosts trogons and parrots, four species of native cats, twice as many mammal species as Yellowstone Park, and the greatest diversity of bees, ants, reptiles, and sparrows in temperate North America.

The San Bernardino Valley in southeast Arizona and northeast Sonora is currently a key restoration focus of CLO and remains one of the most important corridors for the migration of plants and wildlife on the continent. In both the U.S. and Mexico, CLO partners with state and federal land and wildlife management agencies, universities and other researchers, non-governmental organizations, other private landowners, and ejidos. CLO has a lengthy history of success in land protection, including designation of private reserves in Mexico, species reintroductions, restoration of grasslands and wetlands, and education.

**Project Background**
The goal of CLO is to preserve and restore the native biological diversity in the headwaters region of the Rio Yaqui that stretches across the international boundary. CLO lands in Mexico span over 30 miles of the international border in an area that serves as a major migratory corridor for many species moving between Mexico and the U.S. These lands provide quality wildlife habitat for foraging, movement, and breeding, as well as unfettered access between federal, state and private lands in the U.S. and the protected grassland, riparian, and wetland systems in Mexico. CLO properties in Mexico are adjacent to the Malpai Borderlands Group’s ranches in Arizona and New Mexico, connecting these U.S. conservation lands to Mexico’s Sierra San Luis and south into the spine of the Sierra Madres.

CLO uses a number of strategies, including land preservation, habitat restoration, native wildlife conservation and reintroduction, and protection of migratory corridors. The organization is heavily engaged in on-the-ground scientific research that is constantly informing its restoration activities, and conducts workshops and other education opportunities to share its knowledge of the landscape with others.

Climate change is a growing threat to the livelihood of the people of the region and to biodiversity and other market and non-market goods and services provided by the regional ecosystems. However, climatic shifts are not new to the region and have contributed to major shifts in regional ecology and the collapse of indigenous cultures over thousands of years. Climate variations coupled with severe overgrazing in the past two centuries have resulted in severely eroded uplands, increased sedimentation of streambeds, increased flooding frequency and intensity, and dropping of the regional water tables. Though quantitative climate data are sparse in the region, the drought in the southwest US and northern Mexico in the 1950s resulted in marked socioeconomic and ecosystem services impacts in the Sonoran highlands. Researchers have used piecemeal local weather records, demographic data, and oral histories to document the disruption of traditional subsistence patterns, alterations of land tenure patterns, and human migration to the Sonoran lowlands and the U.S.
The preservation and restoration goals of CLO are likely to be affected by the current and predicted effects of climate change in this region, including increasing temperatures, decreasing precipitation and ongoing drought conditions. CLO’s ongoing restoration efforts serve to increase the resiliency of the landscape and will facilitate adaptation to the predicted impacts resulting from climate change.

**Project Implementation**

The San Bernardino Valley once supported permanently flowing creeks, springs, wetlands, and healthy grassland. Dependable sources of water and grass made the area invaluable to a huge diversity of plants and wildlife, and a center of human activity for millennia. When CLO founders Josiah and Valer Austin acquired the properties here in the late 1990s, they found the land suffering from severe erosion and almost completely devoid of grass and water, a result of drought conditions, poor range management practices, and intensive farming.

CLO’s wetland restoration efforts include constructing berms, trincheras (small rock walls), and gabions (larger rock and wire structures) in order to repair damage caused by severe erosion. This historic method of harvesting water on the landscape works by slowing run-off that is otherwise accelerated by lack of vegetation allowing silt to deposit and building up the once-barren riparian areas. This makes CLO lands more resilient in the face of drought-flood cycles by increasing the land’s ability to absorb intense rain events, which in turn increases the ability of vegetation to persist through drought conditions.

CLO has cultivated strong working relationships with many other land owners and agencies who look to the ecological improvements on CLO lands to guide their own work, from leading erosion-control workshops for neighboring ejidos to providing a demonstration site for a bi-national effort to align the grassland classification and management guidance of the U.S. Natural Resources Conservation Service (NRCS) with that of CONAFOR and CONABIO, Mexican agencies similar to the U.S. Forest Service, U.S. Fish and Wildlife Service, and the U.S. Geological Survey. CLO is also currently working with The Nature Conservancy to establish a protected native fish preserve in Cajon Bonito. Other conservation partners include the World Wildlife Fund, CEMEX Green Division, Naturalia, Malpai Borderlands Group, Northern Jaguar Project, and Sky Island Alliance.

Because lands managed by CLO in Mexico are privately owned (as are most in the US) and managed primarily for conservation rather than commodity production, there is a tremendous opportunity for restoration activities that can be done quickly and have a degree of permanence not found with many other restoration projects. This is particularly true for those projects where restoration activities are often followed by agency management actions in both countries which return those lands to the very uses that caused the negative impact and need for restoration in the first place.

**Project Outcomes and Conclusion**

To date, CLO has constructed more than 30,000 trincheras in washes and adjacent hillsides, more than 500 berms to slow erosion and capture water, and more than 50 large wire and rock
gabions. CLO has restored more than 9,000 acres of grasslands with native grasses and planted more than 2,500 riparian trees.

Scientific research on CLO lands has focused on many species including fish, grassland sparrows, turtles, spring snails, birds, fireflies, moths, native cats (ocelot, jaguar, mountain lion, and bobcat), black bear, beaver, plants, hummingbirds, bees, ants, and aquatic insects.

CLO works to restore native wildlife populations, and has partnered with other science-based organizations to reintroduce native species in areas where habitat and prey base have been restored to the point where wildlife populations can be supported. The reintroduction of rare species on CLO lands include several species of native fish in the U.S., Gould’s turkeys and thick-billed parrots in the U.S. and Mexico, and white-tailed deer, a prey species, in Mexico.

CLO has worked to increase pollinators on their lands with a current focus on several species of hummingbirds, and has begun growing and planting thousands of flowering and fruiting plants in an effort to make this area a more productive stopover for humming birds as they migrate north and south. Plantings will also provide strong ancillary benefits for many other pollinators, and other species that utilize these plants.

As part of its restoration efforts, CLO has integrated sustainable resource management into its cattle operations, continually monitoring the condition of grasses and the amount of time cattle spend in one area, and in some cases removing cattle altogether when the condition of the land is not suitable to sustain cattle. Currently, CLO only has cattle on lands it manages in the United States.

CLO works closely with scientists from the U.S. and Mexico to study the region’s natural systems and the native species. CLO regularly hosts researchers and organizations whose work dovetails with its mission, often providing accommodations for scientists conducting field studies on its lands. It uses the information gathered to inform restoration efforts, and shares this information with other land managers in the area. It also conducts workshops where it teaches others the restoration techniques that have proven to be successful.

CLO’s ongoing efforts to restore the grasslands and riparian areas of the San Bernardino Valley have created a thriving natural system on an upward trajectory. Restoration efforts at the San Bernardino Valley cienega (wetlands) have increased the size of this rare wetland community from 3% to 20% of the total historic acreage. Additional work in adjacent riparian areas has reconnected downcut streams with their historic floodplains. Most impressive, these important accomplishments have been realized during the most significant drought of the past 60 years.

Long-term photo documentation of conditions before and after the implementation of restoration efforts confirm that CLO’s methods are having a significant impact on the health and integrity of the San Bernardino Valley, increasing the resiliency of the landscape and allowing it to better adapt to the predicted impacts to this area resulting from climate change. Continuing on-the-ground research and monitoring, as well as remote sensing and GIS and GPS technologies, inform CLO’s ongoing restoration efforts.
Links
http://cuencalosojos.org/
The Four Forest Restoration Initiative

Overview
The Four Forest Restoration Initiative (4FRI) is a broad-based, collaborative effort to restore the ponderosa pine forest ecosystems of northern Arizona across portions of the Apache-Sitgreaves, Coconino, Kaibab and Tonto National Forests. A multi-decade restoration program, 4FRI will treat up to 1 million acres over a 20-year period through strategically-placed mechanical thinning, prescribed burning, road obliteration, exotic species management, hand thinning, recreation management and Wildland Fire Use techniques.

In April 2010, agencies and stakeholders involved with 4FRI held a workshop to address the increased vulnerabilities of ponderosa pine ecosystems resulting from climate change that, in some cases, are already being observed on the landscape, and are very likely to impact the larger goals of the 4FRI over the long-term. The goal of the workshop was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for implementation of the 4FRI larger strategies. To achieve these goals, the workshop participants first selected three conservation or management features associated with this ecosystem on which to focus their discussions: the ponderosa pine fire regime, ponderosa pine forest watershed function, and the Mexican spotted owl.

For each of these features, the impacts of future climate scenarios were assessed, and potential strategic actions were identified in light of plausible climate change impacts. Strategic actions were then prioritized according to factors such as cost, social and political feasibility, potential

Contact Information
Henry Provencio
USFS Team Leader
(928) 527-3600
hprovencio@fs.fed.us

Edward Smith
Stakeholder Chairperson
(928) 774-0831
esmith@tnc.org

Photo Courtesy of Sky Jacobs
for positive effects or risk of unintended negative consequences for other features or objectives, and in light of uncertainty surrounding future climate scenarios.

**Project Background**

The 4FRI restoration effort focuses on ponderosa pine forest ecosystems of northern Arizona, which stretch almost continuously from the south rim of the Grand Canyon across the Mogollon Rim to the White Mountains in eastern Arizona, and include embedded wetlands, riparian areas, grasslands, and aspen and pine-oak forests.

The overarching goals of 4FRI are to provide for fuels reduction, forest health, and wildlife and plant diversity in a way that will create sustainable ecosystems in the long-term. Appropriately-scaled businesses play a key role in the initiative by harvesting, processing, and selling wood products, which will reduce treatment costs and provide restoration-based job opportunities.

The diverse coalition of groups currently working together on 4FRI includes state and federal agencies, timber industry representatives, conservationists, recreation groups, local government, and scientists. In March 2011, more than 20 organizations signed a Memorandum of Understanding (MOU) between the 4FRI Collaborative Stakeholder Group and the Apache-Sitgreaves, Coconino, Kaibab and Tonto National Forests. The Collaborative Stakeholder Group includes:

- Arizona Forest Restoration Products
- Arizona Game and Fish Department
- Arizona State Forestry Division
- Arizona Eastern Counties Association
- Center for Biological Diversity
- Coconino County
- Coconino Natural Resources Conservation District
- Coconino Rural Environment Corps
- Ecological Restoration Institute
- Flagstaff Fire Department
- Forest Energy Corporation
- Gila County Graham County
- Grand Canyon Trust
- Greater Flagstaff Forests Partnership
- Greenlee County
- Mottek Consulting
- National Wild Turkey Federation
- Navajo County
- Northern Arizona Logging Association
- Northern Arizona Natural Resources Working Group
- Northern Arizona University
- Forest Ecosystem Restoration Analysis
- Northern Arizona Wood Products Association
- Pioneer Association
- Rocky Mountain Elk Foundation
- Sierra Club
- Southwest Sustainable Forests Partnership
- The Nature Conservancy
- U.S. Fish and Wildlife Service

The first phase of 4FRI will treat 750,000 acres in the Coconino and Kaibab National Forests over a 10-year period, with about 300,000 acres treated mechanically for tree thinning. The proposed restoration activities include thinning trees using methods that improve forest structure and wildlife habitat, conducting prescribed burns to reduce the potential for high-intensity fires and reintroduce natural fire regimes into the ecosystem, and restoring dry ephemeral channels to improve watershed function.
The health and resiliency of the ponderosa pine ecosystems of northern Arizona have been compromised by unsustainable historical land uses and fire exclusion, as well increasing temperatures, decreasing precipitation and ongoing drought associated with climate change, which will likely have significant impacts on the ponderosa pine ecosystem. The vulnerabilities created by climate change will exacerbate the already severe threats posed by the landscape’s reduced resiliency, including large-scale, high-intensity, and high-severity wildfires, insect and disease outbreaks, and the flooding and erosion that follows fires.

Project Implementation
In April 2010, agencies and stakeholders involved with 4FRI held a workshop to address the increased vulnerabilities of ponderosa pine ecosystems resulting from climate change that, in some cases, are already being observed on the landscape, and are very likely to impact the larger goals of the 4FRI over the long term. The goal of the workshop was to identify management strategies that will help native plants, animals and ecosystems adapt to a changing climate and lay the groundwork for implementation of the 4FRI’s larger strategies.

To achieve these goals, the group first selected three conservation or management features associated with this ecosystem on which to focus their discussions: the ponderosa pine fire regime, watershed function in ponderosa pine forests, and the Mexican spotted owl. For each of these features, the impacts of future climate scenarios were assessed using conceptual models that illustrate how all the different climatic, physical, ecological, and socio-economic drivers affect the selected feature. From there, potential strategic actions were identified in light of plausible climate change impacts and then prioritized according to such factors as cost, social and political feasibility, potential for positive effects or risk of unintended negative consequences for other features or objectives, and in light of uncertainty surrounding future climate scenarios.

Ponderosa Pine Fire Regime: Impacts to this conservation feature expected to result from climate change include increased wildfire frequency, intensity and severity due to a longer fire season, drier fuels, and changes in fuel loads and types. Decreased precipitation in winter and summer may lead to increased drought- and bark beetle-related ponderosa pine mortality, increased risk of uncharacteristically high-severity fire, decreased productivity of native understory plants, and increased success of drought and fire-adapted native and exotic invasive understory plants. Under a more extreme climate change scenario, it is possible that a significant portion of the 4FRI area might experience more dramatic declines in ponderosa pine acreage. Also expected is a stronger transition towards a system more dominated by shrubs and other drought- and fire- prone vegetation types and species.

The overarching management objectives for 4FRI include reducing hazardous fuels and risk of large-scale uncharacteristic fire, reintroducing fire as a natural process, restoring forest composition, structure and species, and providing sufficient certainty in biomass flow to invite appropriately-scaled industry, which will provide economic sustainability. However, due to the projected impacts of climate change on ponderosa pine distribution and abundance, several aspects of these objectives may need to be revisited. In particular, restoring forest composition and structure may be incompatible with the effects of climate change on species assemblages in the region.
In light of these projected impacts, several sub-objectives were considered for the 4FRI project, including: 1) maintaining native understory by preventing the take-over of invasive species; 2) building social acceptance around fire and smoke, and 3) promoting current native plant community in the short-term and provide a smooth transition to a desirable alternate state in the longer term.

Five high priority adaptation actions were identified that together will address fuels management, education, and vegetation management. First, to address fuel management, the following priority strategies were identified: (1) thinning to create a mosaic of clumpy, groupy tree distribution and openings, (2) treating more acres with prescribed burns, and (3) allowing more wildland fire to burn. For vegetation management, (4) engaging in management actions that encourage recruitment of drought- and fire-prone trees will address vegetation changes, including reduced abundance and distribution of ponderosa pine forests in the 4FRI area. Finally, (5) increasing social acceptance for appropriate forest management, including thinning, prescribed fire and wildland fires for resource benefit will address the education needs related to the likelihood of longer fire seasons, drier fuels, and changes in fuel loads and type, all of which are expected to increase wildfire frequency, intensity, and severity.

**Ponderosa Pine Forest Watershed Function:** Direct and indirect effects of changes in temperature and precipitation associated with climate change may result in cascading ecosystem impacts, including increased drought-induced tree mortality due to soil moisture stress and stress caused by insects and disease. This will lead to decreased canopy cover, reduced tree density and changes to the understory. In the short-term, increased herbaceous cover and reduction in tree water use will lead to greater fraction of available water for recharge, with reduced baseflows and increased water temperatures also expected. Climate-induced changes to evapotranspiration, snowpack dynamics, human water demands and development patterns are likely to have effects on watershed vegetation, runoff, base flows, groundwater recharge and flood regimes. In addition, vegetation disturbance regimes, such as severe intensity fires, drought, and insect and disease outbreaks, are likely to have cascading impacts on tree density, herbaceous vegetation cover, groundwater recharge, runoff, soil erosion and water quality.

The overarching management objective for this conservation feature is to maintain or improve watershed function in ponderosa pine-dominated systems. To achieve this objective, several sub-objectives were identified, including: (1) maintaining or improving water quality, quantity and timing of flow for surface and ground water; (2) maintaining or improving soil productivity; and (3) promoting adequate soil moisture and recharge by maintaining or improving the recharge-to-runoff ratio.

A series of priority adaptation strategies were then identified that address the overall need of coping with less water in ponderosa pine watersheds as well as changes in ecosystem disturbance regimes under moderate and extreme climate scenarios. To reduce fire risk and drought-induced tree mortality, increase herbaceous ground cover and improve watershed health by enhancing infiltration, soil moisture and groundwater recharge, as well as to maximize snowpack accumulation and minimize sublimation losses, priority strategies include: (1) thinning, (2) prescribed burning, and (3) use of naturally-ignited fires for resource benefit. To address
expected increased erosion in watershed, the priority strategies include: (1) optimizing road density for multiple uses, (2) decommissioning and restoring unnecessary roads, and (3) upgrading existing roads with enhanced drainage measures, culverts and hardened stream crossings. Finally, purchasing or leasing in-stream flow water rights and other surface water rights will ensure adequate stream flows in the face of increasing human water demands and reduced future supply.

**Mexican Spotted Owl**: The most significant known or likely climate change impacts include changes in the frequency, severity and size of fires, increased frequency and extent of bark beetle outbreaks, and changes in landscape configuration, such as patch size, fragmentation, dispersion and connectivity of habitats that support the owl. These changes will likely lead to changes in spatial distribution, areal extent, composition and structure of nesting/roosting and foraging habitat, which in turn will lead to decreases in the amount of available habitat, change in prey abundance, increases in predation, and consequently an increased risk of extirpation of the Mexican spotted owl across the region.

Establishment of measurable, quantifiable management objectives for the Mexican spotted owl are problematic if not impossible due to the lack of data describing the location, numbers and movement of the owl in the 4FRI region. Moreover, wildlife biologists and managers cannot determine whether any objective has been met without much more comprehensive and extensive description and monitoring of the owl’s habitat. In light of these considerations, the management objective for the owl is to maintain and/or enhance existing (restricted/protected) habitat and foster development of new habitat such that the total amount of habitat is stable or increasing.

Priority strategies that are most likely to increase the viability of the owl in the face of climate change include: (1) landscape strategic planning that integrates objectives for owl survival and viability, specifically identifies priority areas for forest restoration treatment (in a spatially explicit way), evaluates trade-offs and sets priorities, shares draft maps and plans with the public to garner support, identifies key linkages, and proposes a patch linkage design to provide landscape connectivity; (2) forest thinning and ecological restoration that includes developing and maintaining large trees, identifying refugia microclimates (fire, north facing slopes, soil types) for management of owl nesting/roosting habitat, and identifying, managing and maintaining key linkages across the landscape to assist and provide landscape connectivity; (3) economic development, including developing markets for woody biomass for energy, design and implementation of large-scale contracts, and development of other small-diameter wood markets; and (4) fire management, including conducting low intensity planned fires to reduce fuels, increase understory vegetation, restore natural fire regimes, and break up fuel continuity; reducing suppression by using unplanned fires where feasible to meet resource objectives; and design objectives that incorporate owl habitat considerations.

**Project Outcomes and Conclusion**

Work has begun designing treatments to increase snowpack and its retention through silvicultural practices. Mexican spotted owl Protected Activity Centers (PAC) are being assessed for allowable treatments, including silvicultural and controlled burning activities in restricted habitat to connect occupied habitat and increase connectivity to provide for refugia. An adaptive
management and monitoring plan is in development to address measuring ecological response to management practices.

The identified strategic actions reinforce current management direction, and will need further refinement to reduce the impacts to ponderosa pine forests, processes and wildlife in light of the plausible climate scenarios assessed at the workshop. Some of the next steps identified include: (1) the need to understand more fully the plausible climate change scenarios for this region; (2) more in-depth discussion, testing and confirmation of the groups conclusions and recommendations; (3) a commitment to research; (4) system-wide monitoring to determine the effects of adaptation strategies; and (5) dedicated efforts to raise funds and rally managers around a shared program of work.

Continued collaboration will also be needed across the 4FRI landscape to plan for climate change adaptation and continue to explore new strategies as conditions shift. Recommended steps include:

• Incorporating workshop strategies into 4FRI planning and analysis,
• Implementing “no-regrets” strategies for the three conservation features, that is, strategies that have clear, beneficial effects with broad social acceptance,
• Convening a small group of key stakeholders, including federal and state land management agencies, county, scientists, and non-governmental organizations, to continue the climate adaptation dialogue and determine strategies for working together,
• Conducting further analyses of climate change and its ecological effects in northern Arizona, e.g., further interpretation of the moderate and extreme climate scenarios,
• Refining the identified strategic actions, especially for the more extreme scenario,
• Developing a communications plan related to these activities, emphasizing public outreach and education, and
• Encouraging research of priority needs to better understand the biological responses to climate change and to assist land managers in making land management decisions,

Links
http://www.fs.usda.gov/4fri

http://www.4fri.org
Developing Adaptation Strategies for the Jemez Mountains: A Southwest Climate Change Initiative Effort

Overview
The Jemez Mountain Climate Change Adaptation Workshop brought together over 50 managers, conservation practitioners, scientists, and others working in the Jemez region to:

- Learn basics on regional climate change impacts;
- Using professional judgment, identify the key effects of climate on two important ecological processes;
- Use an adaptation planning framework to develop strategies to address impacts; and
- Collaborate with other regional managers.

This two-day workshop, held in April 2009, was the first of four workshops held by The Nature Conservancy’s (TNC) Southwest Climate Change Initiative (SWCCI), Wildlife Conservation Society, U.S. Forest Service, University of Arizona, and University of Washington.

Project Background
SWCCI’s aim is to increase regional capacity in the four-corner states of Colorado, New Mexico, Arizona, and Utah to address climate change by providing the information and tools needed through regional adaptation workshops. The SWCCI project’s objective is to expand impact assessment activities into all four-corner states, provide the tools needed to prepare and respond to climate change, and to create a regional learning network to ensure continuous learning and advancement in the field.

The Jemez Mountains, located at the southernmost tip of the Rockies, consists of nearly one million acres of forest, woodlands, and rivers and streams. The region contains many rare and endemic species that have been geographically isolated from other species, many of which are dependent on high elevation areas for survival. The Jemez Mountain range is managed and maintained by many stakeholders, including private landowners, and federal, tribal, and state land managers. The region is rich with scientific information, thanks in large part to two place-based scientists who have studied the area for many years. The Jemez also has a history of regional collaboration developed through interagency fire management.
In 2009, the New Mexico chapter of TNC completed a statewide vulnerability assessment that identified the Jemez landscape as a priority area for conservation due to its climate change “exposure”, e.g. trend in elevated temperatures and moisture deficit, and a concentration of vulnerable and endemic species. Regional climate change impacts are already evident and recent decades have been marred by severe wildfires, extensive mortality of pinyon pine, decreases in snowpack, and declines in high elevation-sensitive species. The Jemez Mountains were also identified in TNC’s Southern Rockies ecoregional assessment and the New Mexico Department of Game and Fish’s Comprehensive Wildlife Conservation Strategy as a priority habitat.

Project Implementation
In April 2009, with funding from the Doris Duke Foundation, TNC convened a two-day workshop in Los Alamos, New Mexico. Prior to the workshop, organizers convened a science team to help define the scientific needs of the workshop and prepare what information would be required for a successful meeting. Invited workshop participants were surveyed ahead of time to identify ecological processes of interest that would determine the adaptation planning focus during the meetings. The survey overwhelmingly pointed toward fire and water, specifically instream flow, as the processes of interest.

Workshop organizers also worked with Los Alamos National Laboratory to put together two climate change scenarios, moderate and high emission scenarios, which would frame the discussion of impacts and adaptation actions. Scenario 1, the moderate scenario, looked at a 10-30 year planning horizon with 2-4°C increases in annual temperature that would result in increased drying and extreme drying events as well as reduced precipitation with fewer but more extreme events. Scenario 2, the high scenario, looked at a planning horizon beyond 30 years with a 2-6°C increase in annual temperature. Scenario 2 was similar in temperature range to Scenario 1 but with only 67% of the precipitation.

At the beginning of the workshop, participants received background information on climate change, an explanation of the two scenarios and the projected impacts, and an overview of the adaptation planning process that would be used during the workshop. Participants were separated into two groups based on their ecological process of interest – either fire or water – and worked over the course of the workshop to construct conceptual models of drivers, including climatic, ecological, social, and economic drivers; find management intervention points; and identify potential adaptation strategies.

Largely, both groups discovered that the adaptation strategies they would employ under Scenario 1 were similar to what they were already using; however, the difference was how and when these strategies should be applied. Both groups noted that normal management strategies would need to be adjusted in scale, sequencing, and priority to mitigate climate change effects. The fire group identified thinning as an example of this needed shift in how and when thinning strategies should be employed. Thinning is a common management strategy but it could be adjusted to leave greater diversity of trees to ensure survival of a stand from a pest outbreak or fire, or altered to provide more shade for a stressed stream system.

Participants found identifying strategies to employ under Scenario 2 considerably more challenging. Participants concluded that under Scenario 2, many of their current efforts would
not be sufficient to address the changes that their system would be facing, and a realignment of management would be needed. Management strategies discussed to address Scenario 2 included responses with increased human intervention, such as assisted migration, or new species mixes to facilitate future species compositions in the face of severe fires, and the use of mechanical features to compensate for the loss of vegetation structures given a mega-drought. Workshop participants concluded that Scenario 2 required more planning and thinking to develop appropriate responses, as well as a public awareness campaign to explain the drastic impacts region could experience.

At the end of the meeting, the two breakout groups returned together to share adaptation strategies identified in their groups, discuss barriers and opportunities to implementing the strategies, highlight the gaps in research, and outline monitoring needs (see workshop summary report, Jemez Mountains Climate Change Adaptation Workshop: Process, Outcomes and Next Steps). Overall, the workshop provided participants with the opportunity to gain information on climate change and its impacts on the region, learn and practice implementing an adaptation planning framework, and collaborate with colleagues across jurisdictions.

**Project Outcomes and Conclusion**
The Jemez workshop had a number of successful outcomes. The workshop served as a trial run for the SWCCI project and helped shape future efforts with lessons learned on how to run a successful meeting on climate adaptation for practitioners. Following the workshop, a number of projects were developed, including an effort focused on building resilience for the rare endemic Jemez mountain salamander. Climate change was integrated into a large landscape restoration strategy developed by the Santa Fe National Forest, the Valles Caldera National Preserve, Jemez Pueblo, New Mexico Forest and Watershed Institute, and TNC. The partnership used products developed during the workshop to put together a proposal to the national competitive Collaborative Forest Landscape Restoration Fund to implement the restoration strategy on a 210,000 acre watershed in the Southwest Jemez over a ten year period. The proposal was successfully funded in 2010. The SWCCI has since held three successful adaptation workshops in Utah, Colorado, and Arizona.

**Links**

[http://nmconservation.org/dl/Jemez%20Workshop%20Report%202009%20FINAL.pdf](http://nmconservation.org/dl/Jemez%20Workshop%20Report%202009%20FINAL.pdf)

**Overview of Regional Climate Impacts in the Southwest** - Dr. Todd Ringler

**Ecological Trends and Consequences of Climate Change in the Jemez Mountains** - Dr. Bob Parmenter

**Implementing a Framework for Adaptation Planning** - Dr. Molly Cross

**An Integrated Climate Change Assessment & Adaptation Framework for Conservation Planning & Management in the Southwestern US** - Dr. Carolyn Enquist
From Adaptive Management to Climate Adaptation at The Las Cienegas National Conservation Area: Starting Where You Are

Overview
At the core of a 300,000-acre watershed southeast of Tucson, Arizona’s Las Cienegas National Conservation Area (LCNCA) includes nearly 50,000 acres of public land administered by the U.S. Bureau of Land Management (BLM). The Las Cienegas Resource Management Plan is based on an adaptive management approach that allows the BLM and regional stakeholders to monitor and evaluate management actions, and adjust actions based on what they learn. This process builds the knowledge and flexibility needed to manage lands in a changing climate. The BLM and partners are examining how they can further incorporate climate adaptation by modifying monitoring protocols, implementing no regrets actions, and engaging in scenario planning.

Project Background
The LCNCA is located in the Sonoita Valley, about 50 miles southeast of Tucson. The landscape encompasses much of the upper Cienega Creek watershed, which is vital to Tucson for flood control and aquifer recharge, as well as upper watersheds of Sonoita Creek and the Babocomari River. The landscape’s natural resources also continue to support a thriving rural community. Long-renowned for its archeological and more recent western cultural heritage, LCNCA and the Sonoita Valley also support several threatened and endangered species and five of the rarest plant communities in the Southwest: cienega wetlands, cottonwood-willow riparian forests, sacaton grasslands, mesquite bosques, and semi-desert grasslands. The landscape’s grasslands and woodlands connect several of the region’s sky island mountain ranges and play a vital role in regional connectivity. Management of the LCNCA is multi-use and includes active livestock grazing as well as a number of recreational activities.

The Sonoita Valley community has a long history of collaboration in both protecting and managing lands. In addition to the BLM and The Nature Conservancy, regional partners include the U.S. Forest Service, U.S. Fish and Wildlife Service, Natural Resource Conservation Service, Agricultural Research Service, Arizona Game and Fish Department, Arizona State Land

Contact Information
Gita Bodner
The Nature Conservancy
GBodner@tnc.org

Karen Simms
Bureau of Land Management
ksimms@blm.gov

Photo Courtesy of Sky Island Alliance
Department, Pima County, Sonoran Institute, Sky Island Alliance, National Audubon Society – Appleton Whittell Research Ranch, Vera Earl Ranch, Phoenix Zoo, Huachuca Hiking Club, Sonoita Crossroads Community Forum, Empire Ranch Foundation, and many other stakeholders in the Sonoita Valley Planning Partnership (SVPP). As an ad-hoc group of regional stakeholders, the SVPP worked with the BLM from 1995-2003 to develop the site’s Resource Management Plan. Many of these stakeholders continue to engage in the site’s adaptive management process through its Biological Planning teams. The Cienega Watershed Partnership, a 501(c)(3) non-profit, formed as an alliance of partner groups including the SVPP, now focuses on securing resources to implement management and protection plans throughout the basin.

Many of these same partners also worked to secure congressional designation for Las Cienegas as a National Conservation Area in 2000. These stakeholders continue to promote ecological and cultural values of the landscape in a variety of other ways, including protecting lands to maintain connectivity and watershed function across public and private ownership. As a result, protected lands in this valley run east-west from the 9,500-foot forested peaks of the Santa Rita Mountains, down through oak woodlands and grassy valley bottoms of Las Cienegas some 5,000 feet lower, and back up the scrub and forest slopes of the Whetstone Mountains. Additional investments are gradually securing latitudinal connectivity from Saguaro National Park in the Rincon Mountains to the north, and south to the Patagonia Mountains and into Mexico. All together, these connected lands include terrain managed by the BLM, U.S. Forest Service, National Park Service, Pima County, Fort Huachuca, Arizona State Parks Department, The Nature Conservancy, and many private landowners.

In recent decades, however, the region has experienced increased temperatures, prolonged drought, increased fire activity, and changes in hydrological processes. In addition, the area is anticipating climate-related increased erosion and decreased groundwater and ephemeral recharge, range shifts and species die-offs, and more. Non-climate stressors include poorly planned development, mining, invasive species, and border related activities.

**Project Implementation**

Adaptive management and collaboration across jurisdictions are often cited as vital strategies for climate adaptation. Yet both can take years to develop, with many potential pitfalls along the way. This project starts with 20 years of ongoing investments into gathering ecological information into an adaptive management framework, and building relationships among managers and stakeholders so they can respond effectively to changes they see on the ground. In the last several years, partners have begun to recognize climate change as a potentially game-changing dynamic, and are now working to adapt existing structures to respond explicitly to this new challenge.

**Collaboration and adaptive management:** In 2003, the BLM and stakeholders completed the Las Cienegas Resource Management Plan. The plan was formed around shared goals, and translated these goals into ecologically-based and measureable objectives. The plan also articulated an adaptive management approach that uses both collaboration and data to inform recurrent decisions about grazing management, grassland restoration, and aquatic and riparian restoration. In this approach, BLM and partners track conditions of key watershed resources. Management actions are monitored to determine if they are achieving their intended goals and if
adjustments are needed. As part of the adaptive management approach, the plan established a “Biological Planning” process that engages panels of stakeholders to review monitoring results and provide feedback to inform management decisions. In addition to participating in bi-annual review meetings, stakeholders now convene technical teams to enhance understanding of changes in particular resource areas such as grassland and riparian ecosystems.

Since 2005, The Nature Conservancy’s main role has been helping BLM refine the science components of its adaptive management program by making sure monitoring BLM and stakeholders whether they are meeting their management objectives, enhancing power to detect change around critical ecological thresholds, and making sure relevant data is available when and where decisions are being made. Such robust monitoring and evaluation processes are crucial for enabling managers to respond to the changes they see on the ground, in part because stakeholders that are engaged in documenting changes are much more likely to support agency attempts to modify management in response to these changes.

Funding for adaptive management has been provided primarily through the BLM, with considerable cost-share investment by TNC. Many other partners contribute substantial time and resources. Several partner organizations have obtained foundation grant funds to implement restoration projects. The LCNCA also utilizes citizen science and volunteers that make the robust monitoring program and restoration actions possible.

Some monitoring protocols are now being modified to better track climate parameters themselves. For example, the partnership recently installed an array of more accurate rain gauges to help understand drought impacts across the landscape, a project funded by a small climate adaptation grant from BLM to TNC. Sensors are being added that will record temperature and humidity, essentially creating mini-climate stations that may help tease apart climate impacts from other ecological changes.

**No-regrets actions:** In order to make this project more climate-smart, partners are examining existing activities that will have adaptation benefits and looking for areas that may need to be adjusted. They are currently focused on “no-regrets actions”, including:

- Building resilience into floodplains through restoration and enhancement activities; this includes restoring riparian sacaton grasslands and reducing erosion in arroyos. Boosting the capacity of floodplains to capture sediment and slow release of runoff water benefits people and wildlife regardless of climate change; predicted increases in intensity of droughts and floods may make floodplain health even more critical for buffering streams from watershed-wide impacts.

- Ramping up monitoring of groundwater changes to detect impacts of human activities as well as droughts. Recognizing the climate threats posed to southwestern streams, this new data is feeding efforts to improve modeling of the basin’s dynamic water resources. A primary goal of this monitoring and modeling is to identify management actions that could reduce the impacts of projected declines in the regional water budget; and

- Continuing to protect landscape connectivity, particularly along elevational and latitudinal gradients. Purchases of land and easements are also targeting areas that protect key water resources.
Scenario planning: The partnership has recognized that in some cases, making adjustments to existing activities may not be enough to buffer the watersheds that human communities and wildlife depend on from effects of rapid change. Las Cienegas staff and partners asked internationally-renowned scholars and managers to help brainstorm climate adaptation solutions at a Collaborative Adaptive Management Network (CAMnet) conference in 2010. Suggestions included blending adaptive management with scenario planning approaches that explore a larger range of potential futures, and that generate indicators that help managers identify which trajectories of change a system appears to be on. The partnership recently brought scenario planning experts to a community science forum to begin exploring options for scenario planning.

Project Outcomes and Conclusion
BLM and partners have a long history of collaboration on management of the LCNCA, and an equally long history of protecting landscape connectivity across many public and private jurisdictions. As it became clear it was essential to incorporate climate change into their activities, project leads determined that they did not need to start from scratch, but rather could examine their existing work through a climate lens – a “starting where you are, but not stopping there” strategy. This approach has enabled managers to start implementing some adaptation solutions while planning and evaluating others. Getting started on no-regrets strategies and tracking changes is particularly valuable since it may take many years of data to separate climate-related or management-related changes from natural variability, e.g. with groundwater fluctuations. Inevitably, some actions will yield better results than others. The partnership has already demonstrated a commitment to learning from results as they emerge. But we will learn much more if we can track both inherent benefits of restorative management actions and any additional benefits from climate-savvy modifications of time-tested practices.

Links
http://azconservation.org/projects/las_cienegas
http://sites.google.com/site/lcncaadaptivemanagement/
http://www.skyislandalliance.org/misc/Collaborative%20Management%20LCNCA.pdf
http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/arizona/howwework/tracking-changes-at-las-cienegas.xml
Appendix A: Workshop Agenda

WEDNESDAY, APRIL 13

Morning: Climate Change Impacts and Adaptation Case Studies

7:30  Registration in Lower Lobby
Continental Breakfast and Poster & Table Display Setup in Grand Ballroom Foyer

8:30  Welcome from Sky Island Alliance and EcoAdapt in Central Ballroom

8:45  Keynote Address: Climate Change and the Southwest
Jonathan Overpeck, Co-Director, Institute of the Environment
A Professor of Geosciences and Atmospheric Sciences, Jonathan Overpeck has published over 130 papers in climate and the environmental sciences, and recently served as a coordinating lead author for the Nobel Prize-winning UN Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment (2007).

9:30  Setting the Stage: Focal Issues for the Region
  • Hydrology, Thomas Meixner, Associate Professor, Department of Hydrology and Water Resources, University of Arizona
  • Invasive Species, Julio Betancourt, Adjunct Professor, University of Arizona
  • Fire, Brooke Gebow, Southeastern Arizona Preserve Manager, The Nature Conservancy and FireScape Program Lead, Coronado National Forest
  • Landscape Connectivity, Sergio Avila, Northern Mexico Conservation Program Manager, Sky Island Alliance
  • Panel discussion and questions

10:40  BREAK and Poster Viewing in Grand Ballroom Foyer

10:55  Assessing the Vulnerability of Wildlife on the Coronado National Forest to Climate Change, Sharon Coe, U.S. Forest Service, Rocky Mountain Research Station and University of Arizona School of Natural Resources and the Environment

11:10  Projected Changes and Uncertainty
Jennie Hoffman, Senior Scientist and Director of Programs, EcoAdapt

11:30  Climate Change Adaptation Case Study Interviews
  • Jemez Mountains Climate Adaptation Workshop, Gregg Garfin, Assistant Professor and Extension Specialist in Climate, Policy and Natural Resources, School of Natural Resources and the Environment
  • Las Cienegas Adaptive Management Planning
    Karen Simms, Ecosystem Planner, BLM Las Cienegas National Conservation Area
    Gita Bodner, Conservation Ecologist, The Nature Conservancy

11:55  Directions for Workshop and Breakout Groups

12:15  LUNCH in East Ballroom
**WEDNESDAY, APRIL 13**

**Afternoon: Ecosystem Breakout Groups**

<table>
<thead>
<tr>
<th>Room</th>
<th>Madrean Forests</th>
<th>Semi-Desert Grasslands</th>
<th>Desert Communities</th>
<th>Riparian</th>
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<tbody>
<tr>
<td>Presenter</td>
<td>Craig Wilcox, Coronado National Forest</td>
<td>Dan Cohan, Buenos Aires National Wildlife Refuge</td>
<td>Cecil Schwalbe, USGS Southwest Biological Science Center</td>
<td>Holly Richter, The Nature Conservancy</td>
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<tr>
<td>Facilitation Team</td>
<td>Gregg Garfin, Lara Hansen, Jennie Hoffman, Eric Mielbrecht</td>
<td>Alex Score, Rachel Gregg, Jessica Hitt, Jessi Kershner</td>
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**1:15 Breakout Session 1 in Breakout Rooms**

*Ecosystem Case Study and Identification of Management Effort for Adaptation Planning*

<table>
<thead>
<tr>
<th>Goals</th>
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<tbody>
<tr>
<td>1) Identify a common management opportunity, effort or approach on which to focus as a group over the ensuing breakout sessions.</td>
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<td>2) Explore the vulnerabilities of the selected opportunity/effort/approach to climate change.</td>
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<tr>
<th>Methods</th>
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<tr>
<td>1) Presentation by habitat experts, including a case study.</td>
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<td>2) Sharing of participant activities, approaches, knowledge of opportunities, and change.</td>
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<tr>
<th>Deliverables</th>
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<tr>
<td>1) Agreement on common management opportunity, effort, or approach for group focus, with defined goal/objective to be achieved.</td>
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<tr>
<td>2) Rough hypotheses of change for the system and key components.</td>
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**2:45 BREAK and Poster Viewing in Grand Ballroom Foyer**
3:00  Breakout Session 2 in Breakout Rooms
Vulnerabilities to Climate Change

| Goals | 1) Continue to explore vulnerabilities of selected opportunity, effort, or approach to climate change.
|       | 2) Identify factors contributing to vulnerability both directly and indirectly (e.g. non-climate stressors affecting vulnerability). |
| Methods | Use hypotheses of change to inform understanding of vulnerability. |
| Deliverables | Assessment of the vulnerability of the management opportunity/goal/objective to climate change. |

4:20  Marketplace in Central & West Ballroom
Cross pollination of ideas and findings

| Goals | Exchange information among the groups. |
| Methods | Each group selects two people to stay at one table and explain their group’s work to others, and other participants rotate between groups to exchange information and discuss progress. |

4:50  Overview of the Day and Preview of Thursday

5:00  ADJOURN
Poster Viewing in Grand Ballroom Foyer

5:30 – 7:30  Reception in Downtown Tucson at La Cocinca Restaurant at Old Town Artisans
Please join us for tasty hors d'oeuvres, good conversation and a cash bar.
See walking map to the reception in your packet.
THURSDAY, APRIL 14  
*Morning: Ecosystem Breakout Groups and Focal Issues* 

### 7:30  
Registration in Lower Lobby and Continental Breakfast in Grand Ballroom Foyer

### 8:30  
Breakout Session 3 in Breakout Rooms  
*Developing Responses to Climate Change*

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<td>Gregg Garfin</td>
<td>Redwood</td>
<td>Jennie Hoffman</td>
<td>Eric Mielbrecht</td>
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<td>Sagewood</td>
<td>Lara Hansen</td>
<td>Ironwood</td>
<td>Cottonwood</td>
<td>Jessica Hitt</td>
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<td>Cottonwood</td>
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**Goals**

1) Reflect on what was learned in yesterday’s cross pollination session.  
2) Identify ways to reduce the vulnerabilities identified during Day One and how to implement those in existing or new approaches to achieve desired outcomes.

**Methods**

Using the assessments from breakout session #2, each group develops actions, approaches or strategies to improve the likelihood of maintaining their goals in the face of climate change.

**Deliverables**

- Categorized summary of options for ways to make the common management opportunity/goal/objective less vulnerable/more robust given reality of climate change.

### 10:30  
BREAK and Poster Viewing in Grand Ballroom Foyer

### 10:45  
Exploration of Interactions in Breakout Rooms  
Participants will rearrange into four groups according to the numbers on their name tags to create a mix of people from each of the earlier breakout groups. The breakout rooms will be numbered.

**Goals**

Identify how interactions across and among habitat types, landscapes, and stressors can influence vulnerability to climate change, and by doing so, ensure their plan addresses or at least anticipates all important factors.

**Methods**

Each group considers interactions across habitat types and between crosscutting issues (fire, invasives, hydrology or connectivity) and climate stressors, and develops approaches that ideally are actionable.

**Deliverables**

1) Table of how interacting factors influence vulnerability to climate change.  
2) Updated “hypotheses of change” table.  
3) Categorized, annotated list of approaches to reducing vulnerability by addressing interactions among stressors and across scales.

### 12:00  
LUNCH in East Ballroom
THURSDAY, APRIL 14
Afternoon: Ecosystem Breakout Groups and Conclusions

1:00 Breakout Session 4
Developing Responses to Climate Change

| Goals | 1) Explore a diversity of adaptation options.  
|       | 2) Develop set of criteria for evaluation of options and types of tradeoffs encountered.  
|       | 3) Initiate partnerships between participants, if necessary. |
| Methods | Reflect on list of actions developed during breakout session #3 and the ideas generated in the “Exploration of Interactions” sessions. |
| Deliverables | 1) Annotated list of possible adaptation actions.  
|           | 2) Complete adaptation planning worksheet for at least one action, including outline of what needs to happen when, and necessary resources/partners. |

2:30 BREAK in Grand Ballroom Foyer
(Groups will break individually as needed, with refreshments available beginning at 2:30.)

4:00 Concluding Plenary in Central Ballroom
- Discuss shared actions to be taken forward post-workshop with audience feedback.
- Discuss next steps and engagement between now and the next workshop.

5:00 ADJOURN: Thank you for your participation!

Acknowledgements
We would like to extend a huge thank you to everyone who participated in the workshop. Special acknowledgement goes to those organizations and agencies who invested considerable time and effort into organizing this workshop: Sky Island Alliance, EcoAdapt, Institute for the Environment, University of Arizona School of Natural Resources and Environment, CLIMAS, Sonoran Joint Venture, Coronado National Forest, The Biophilia Foundation, US Fish & Wildlife Service, and the US Institute for Environmental Conflict Resolution.

We would also like to thank the Nina Mason Pulliam Charitable Trust and The Kresge Foundation for their generous support in making these workshops possible.

Finally, we would like to thank Saguaro National Park, the Coronado National Forest, and Arizona Game and Fish for their sponsorship of the event.