Managing and Monitoring Arizona's Wildlife in an Era of Climate Change:
Strategies and Tools for Success



The Heinz Center

Wildlife Conservation Program

Managing and Monitoring Arizona's Wildlife in an Era of Climate Change:

Strategies and Tools for Success

Report and Workshop Summary

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1.0 Report Overview

This report is intended to serve as a tool for wildlife and resource managers in the state of Arizona who are dealing with the current impacts of climate change and are preparing for an increasingly uncertain climatic future.

To assist managers in responding to climate change, this report introduces the concept of an integrated wildlife monitoring program for the state of Arizona. Monitoring programs have the potential to provide information about early effects of climate change on ecosystems, and guide adaptation and mitigation responses. This report explains the steps required to develop an integrated monitoring approach, from conceptual modeling and indicator selection to sampling design and data management. It also includes information about existing monitoring programs in the state of Arizona that are capturing important information about key species and ecosystems of management interest.

This report focuses strongly on climate change, one of the most significant stressors facing wildlife and ecosystems in Arizona and worldwide. Chapter 4 begins with an overview of climate change impacts around the world and in the United States, with the bulk of the chapter devoted to highlighting current and anticipated impacts on species and ecosystems in Arizona.

Throughout the report, the concepts presented are supported by examples drawn from the Heinz Center's Pioneering Performance Measures workshop which was held from September 20-24, 2010 in Phoenix, Arizona. The workshop, co-sponsored with the Bureau of Land Management and the Arizona Game and Fish Department, gathered wildlife and land stakeholders from throughout the state and helped build consensus on shared priorities and common conservation targets. Results from the workshop, including conceptual models for target ecosystems such as the Sonoran Desert, lists of candidate indicators for the target ecosystems, and lists of existing monitoring programs, can be found in the appendices. The workshop provides an important foundation for the development of integrated monitoring approaches for wildlife and ecosystems in the state of Arizona.

2.0 Introduction to Monitoring and Assessment

Arizona has a long history of focused monitoring of its game and fish species. Despite the remarkable ecological diversity of the state, one or more species associated with nearly every land-cover type and vegetation community receive some level of monitoring attention. Time-series data sets for select wildlife species in the state span multiple decades. In recent years, at-risk and imperiled species have increasingly been added to the list of wildlife and fish that are subject to monitoring and assessment. Current assessment activities, including surveys and monitoring, have been essential in guiding management actions for wildlife resources ranging from harvestable mule deer populations to narrowly distributed populations of tiger salamanders.

While wildlife monitoring was once a matter of an ongoing census of Arizona's rich game species diversity, it now includes an increasing obligation to survey for and assess the status and trends of an ever-growing list of protected wildlife species. Today the unprecedented challenges of monitoring game and protected wildlife species are placing significant demands on the resources of the department and its partners. Emerging concerns about the responses of Arizona's wildlife to directional environmental change, especially changes associated with climate trends, pose further challenges for the state's wildlife monitoring programs.

Arizona is already being impacted by climate change. In the future, it is predicted to be "ground zero" for the kind of climate-induced environmental changes that will affect wildlife resources across the American west. Managing wildlife resources in the historical context has proven challenging enough with relatively stable background environmental conditions and dynamic population responses to harvest and other impacts on species from human activities. Overlaying wildlife planning and management actions on a landscape experiencing dramatically shifting ecological conditions demands new types of information to assure that management actions realize intended benefits to Arizona's wildlife and their habitats.

Historically in Arizona, as in its neighboring states, wildlife management and conservation planning has focused on sustaining wildlife species in their current habitats. However, a diverse landscape that is increasingly experiencing (and will continue to experience) rapidly changing environmental conditions requires that planning, management, and monitoring under the CWCS must take new dynamic and anticipatory approaches. The changes in climate predicted for the southwest and intermountain west in coming decades are going to have profound effects on Arizona's desired wildlife. Accordingly, in order for management to sustain and recover wildlife in the state, policies and plans will need to effectively predict future changes in the distributions and abundances wildlife, and the extent and quality of the habitats that support them. To be successful, the CWCS needs to anticipate future impacts on the state's wildlife that will occur with climate change.

2.1 Setting Performance Measures

In setting performance measures for the CWCS, Arizona has elected to explicitly consider the potential impacts on wildlife that will occur as a direct result of climate change. Probably the best known examples of these impacts are the geographic shifts in the distributions of species as individual species adapt to changes in temperature and resource availability. Forced to track suitable physical and biotic conditions, organisms are moving northward in direction and upward in elevation as they experience novel environmental circumstances. Monitoring program design must anticipate such changes by implementing geographically extensive sampling frameworks that will capture evidence of such changes over longer assessment periods. However, many effects of climate change -- such as increased wildfire frequencies leading to proliferation of invasive species – will manifest indirectly. Many of these indirect effects of climate change will predominate in the shorter term and thus need to be considered in monitoring designs.

2.1.1 Monitoring Design

For wildlife management planning to be informed effectively, it is clear that the monitoring schemes and performance measures that service the state's CWCS need to consider the full breadth of environmental changes that will directly and indirectly affect desired species over both shorter and longer terms. Recognizing the diverse types of potential environmental changes and anticipating wildlife responses, this CWCS acknowledges the need to:

- **Integrate ongoing monitoring efforts** that have historically provided essential population status and trend data to wildlife managers;
- Place ongoing monitoring efforts into an **adaptive management framework**; and
- **Enhance sampling and survey designs** to increase the possibility of picking up signals from local ecosystem responses of climate change and other environmental disturbances that put Arizona's desired wildlife more at risk that ever before.

Adaptive management-- also known as "learning by doing" -- under the CWCS will not only require well-designed monitoring schemes, it will also need to integrate those assessment activities with information gathered from directed research and from species and ecosystem models. Integrated monitoring will in many circumstances need to be initiated as pilot studies, with initial sampling programs amended sequentially as accruing data are used to resolve uncertainties in the monitoring design.

2.1.2 Types of Monitoring

Monitoring in support of the CWCS will continue to proceed in the following three categories.

- ***Implementation monitoring***, which is the monitoring of management actions in relation to planned activities; cataloguing the completion of wildlife management projects or habitat restoration activities as they were designed; and documenting compliance with environmental regulations and mitigation obligations in project implementation.

- ***Effectiveness monitoring***, which assesses the effectiveness of management actions in achieving desired wildlife responses and improved habitat conditions.
- ***Status and trend monitoring***, which documents the status and trends of targeted wildlife, their essential habitats and resources, and environmental agents that cause change in both. Status and trend monitoring is the principal data gathering effort that informs management planning about overall environmental and resource conditions relative to established environmental objectives and thresholds. Typically, this type of monitoring serves to track the condition of indicators selected to represent a set of conditions pertinent to environmental objectives in the CWCS.

In order for monitoring to capture environmental and climate change, a new approach is needed that will require adjustments to monitoring programs, including:

- Sustaining ongoing data collection efforts that target desired game and fish species, species that are listed as threatened or endangered, and other valued species, including species that might be useful as early-warning indicators of environmental change.
- Incorporating concurrent data collection of appropriate environmental variables that are known or expected to contribute to landscape occupancy and habitat use by desired wildlife species, including variables that are expected to experience change associated with shifting climatic conditions.
- Sampling widely for wildlife and environmental variables across those geographic and vegetation gradients that provide the template upon which wildlife species distributions and abundances will adjust in response to shifting physical and biological conditions.

2.1.3 Choosing Indicators

The Arizona Game and Fish Department currently fields a diverse group of survey, monitoring, and assessment programs. In combination with other data sets on land cover, soils, climate, and hydrology, data from these programs are being used to help inform ongoing and future management of wildlife and other key natural resources within the state. In particular, analyses of time-series data for species and environmental variables can link changes in population trends to changes in candidate environmental variables. By linking changes in population trends to broader environmental variables, wildlife species have the potential to serve as "indicators" of habitat quality and ecosystem integrity. Wildlife species of particular interest for such analyses include: taxa which

are associated with vegetation communities and land-cover types that are limited in geographic extent, taxa associated with highly fragmented ecological communities, and taxa found along the upper limits of elevational gradients. Monitoring of these species will focus attention on ecological indicators that clearly allow cause-effect interpretations of signal changes in the indicator status or trend. Ultimately, integrated and synthetic monitoring schemes can be implemented in the most extensive vegetation communities and land-cover types, and in highly restricted and at-risk communities and associations. In these locations, prospective sampling will use designs that maximize the likelihood that deterministic changes in wildlife status and trends will be observed and identified, and the environmental determinants of those changes can be assigned.

2.1.4 Indicator Design

Adaptive management and the monitoring that supports it under the Arizona CWCS needs to be highly structured. It should be informed by and designed around a series of requisite elements, including:

- Articulation of **explicitly defined management options** for targeted wildlife species and their habitats;
- Use of **ecological models** that characterize the relationships between desired wildlife or habitat conditions, environmental indicators, and environmental threats and stressors;
- **Data collection in monitoring schemes** that anticipate the application of the information gathered in identifying and directing candidate management actions and prioritizing those actions; and
- Rigorous **evaluation of assessment outcomes**.

A stressor-based approach is one way to meet monitoring program requirements and to identify performance measures under the CWCS.

3.0 A Stressor-Based Approach to Wildlife Conservation and Wildlife Monitoring

One of the essential elements in the Arizona Comprehensive Wildlife Conservation Strategy (CWCS) is a discussion of the threats and stressors that affect wildlife and ecological communities in the state. Threats and stressors obviously have considerable importance for wildlife managers; in fact, Aldo Leopold (1933) traces the development of modern wildlife management back to very early concerns about poaching and the illegal harvesting of game and fish species. Since Leopold's time, advances in ecological science have provided managers with important new understandings of threats and stressors such as invasive species, habitat fragmentation, and unprecedented climatic change.

In this report, we follow a stressor-based approach in order to develop a framework for monitoring the condition of wildlife resources and the effectiveness of wildlife conservation activities in the state of Arizona. The conceptual models in the appendices focus on the interactions between individual threats and stressors and a particular conservation target. The models show causal pathways by which individual threats and stressors affect the target, and show how particular conservation activities are intended to reduce, eliminate, or ameliorate particular threats or stressors. The models thus differ from other ecosystem models that show interactions among individual components (as in food web diagrams) or flows of energy or nutrients through a system.

3.1 The Value of a Stressor-based Approach

For wildlife managers, there are several practical justifications for adopting a stressor-based approach to management and monitoring.

- Much of traditional wildlife management has focused on reducing or ameliorating threats and stressors to individual species or vegetation communities. Methods for controlling many of the most pervasive threats and stressors have been developed (e.g. fire management, invasive species control, erosion control, mine reclamation).
- Threats and stressors are often anthropogenic in nature. It stands to reason that if human activities are responsible for creating the threat or stressor in the first place, then humans may be able to reduce or even undo the adverse effects of the threat or stressor.
- Funding from state and federal government agencies is often focused on specific stressors such as invasive species or climate change. Elimination or reduction of other threats and stressors is commonly recommended as an adaptation strategy for wildlife and ecosystems under altered climate regimes (see discussion in Mawdsley et al. 2009). This strategy is intended to provide wildlife with the maximum flexibility to adapt to changes in climate, unfettered by other stressors and threats.

3.2 Stressors and Threats in Arizona

The general list of threats and stressors for Arizona – as with every state - is necessarily broad and comprehensive. All states, including Arizona, are dealing with pervasive threats such as:

- Invasive species
- Habitat fragmentation
- New energy developments
- Suburban and exurban developments
- Road construction/improvements

- Illegal hunting/collection
- Water pollution

Beyond a general discussion of these threats, it is also important to understand how specific threats and stressors are affecting the individual Species of Greatest Conservation Need and the specific ecosystems of conservation interest within the state. Elsewhere in this edition of the Arizona

Comprehensive Wildlife Conservation Strategy, detailed information about known or potential threats and stressors is listed for each species and community of conservation interest. Such details are critically important for wildlife managers who must then develop more detailed management prescriptions and monitoring frameworks for individual species and ecological communities.

One of the most significant emerging threats for wildlife and ecosystems in Arizona is global climate change. Although there is considerable uncertainty regarding the exact ways in which climate change will play out in Arizona, there is a general scientific consensus that future climatological regimes will likely be very different from those experienced by humans and wildlife in recent centuries.

4.0 Climate Change: A Global Stressor

Change is one thing that is certain about climate. In any given area, the climate will vary from season to season, and from year to year. Around the world, governments, scientists and research groups are monitoring the global climate in order to track changes and compare variations to the historical record.

Though earth's history is dominated by major climatic shifts, the majority of these significant climatic changes occurred before the presence of humans. Recent observed, accelerated changes are challenging modern society's capacity to adapt fast enough to keep pace with the climate. These changes promise to become an even greater challenge into the future.

In particular, changes in temperature and precipitation, along with extreme weather events like severe storms and drought, are alarming government officials, resource managers and businesses that rely on stability in fresh water and food supplies, ecosystems, energy, and socio-economic systems to provide essential goods and services to citizens and consumers.

Today there is debate about whether the changes in our climate are naturally-occurring or human-induced through anthropogenic greenhouse gas emissions (GHGs), which increased by 70% between 1970 and 2004 (IPCC 2007b). Regardless of the cause (or combination of causes), increasingly rapid climate change is well-documented from the global to the local scale.

This section of the report examines climate change, one of the most significant stressors facing wildlife, at multiple scales. First, it offers a broad overview on global impacts of climate change. This overview is followed by an analysis of how climate change is impacting wildlife and ecosystems worldwide. Finally, there's an in-depth look at the impacts of climate change on Arizona's wildlife and ecosystems. The next section, chapter five, discusses of strategies and approaches for mitigating and ameliorating the effects of climate change.

4.1 Impacts Around the World

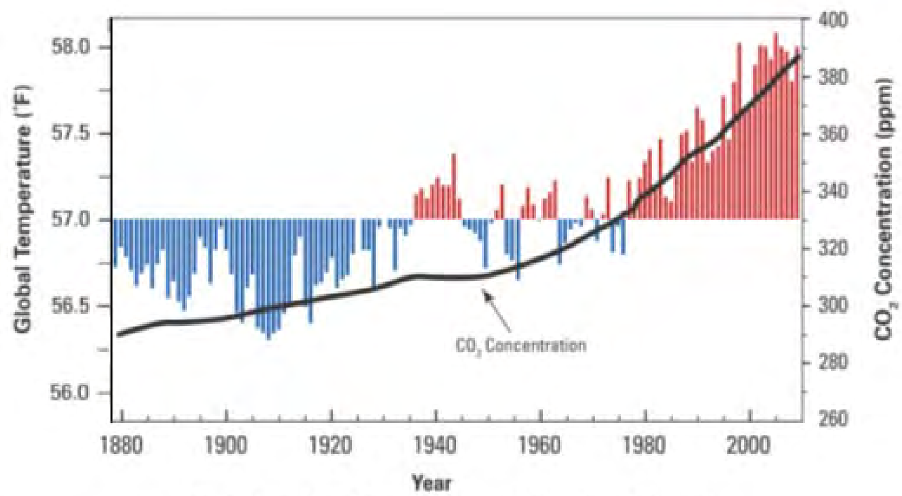
In recent years, numerous scientific and government entities have cited climate change as a major threat to natural systems and biodiversity, and have predicted that in most areas of the world the potential negative impacts on ecosystems will increase dramatically as the earth warms (IPCC 2007b, IASC 2004, US GCRP 2009, US CCSP 2008, NOAA 2009, Union of Concerned Scientists 2010).

In 2007, the Intergovernmental Panel on Climate Change released a synthesis of its peer-reviewed report, which represented the work of thousands of scientists from around the world. The report outlined significant climate change impacts expected by 2020-2050 in regions around the world, including increasing global average temperature, food shortages, sea level rise, health and disease risks, coastal flooding, flash floods, erosion, fires, drought, and heat waves. Simultaneously this group of scientists predicted decreases in agricultural yields, biodiversity, fresh water supplies, and glacial extent. Though some systems and regions will be more impacted by change than others, many of these phenomena are expected to occur in all regions of the world. Among the notable trends are:

- **Changes in Temperature**

Surface temperature data from multiple sources shows that globally the 2000s (2000-2009) was the warmest decade since the instrumental record began in 1850 (NOAA 2009) and preliminary data show that 2010 will likely rank among the three warmest years on record (WMO 2010).

IPCC predictions in 2007 suggested that temperatures would rise between 1.5°C to 4.5°C during the 21st Century. Observations during the years 1990-2007, however, show actual surface temperature were already in the upper range of IPCC predictions (NRC 2009). Global warming is likely to accelerate with increasing GHGs, more melting of sea ice and conversion of tundra to forest, as the ice reflects light and darker, more textured land absorbs more solar radiation (IASC 2004). While the general global trend is toward warming temperatures, some areas will experience cooling, and the degree of change will vary. For example, over the past century temperatures in the Arctic have risen at twice the global average (IPCC 2007b) while in 2010 areas in northern Europe experienced their coolest year in over a decade (WMO 2010).



Global Surface Temperature and Carbon Dioxide

Surface records show global average temperature continuing to rise during the last half century. Natural warming and cooling cycles (of several years to a decade) are also evident. Red (above average) and blue (below average) bars show global temperature compared to the average from 1901-2000.
Source: NOAA/NCDC[1]

- **Changes in Precipitation and Weather Patterns**

Recent extreme weather events are among the most disconcerting and unpredictable impacts of climate change. Multiple changes are being observed in precipitation: when, where and in what form (i.e. snow or rain) it occurs. From 2004-2009 precipitation was above average globally, a trend that began in 1996 and continued in most of the subsequent years (NOAA 2009). In 2010, for example, severe droughts in the Amazon basin and southwestern China contrasted with heavy rains and flooding associated with above-average precipitation over parts of Pakistan, Indonesia, Central Europe, and Australia (WMO 2010). In the future, research shows heavy rainfall events will increase, even in areas where mean rainfall will decrease (IPCC 2007b).

- **Changes in Water Supply**

Along with changing precipitation and weather patterns, the world is entering a time of increasingly uncertain water supply and availability (IPCC 2007b, UCS 2010). Combined with changes in runoff, mountain snow pack, and glaciers, the impact on freshwater availability will be significant (IPCC 2007b). One estimate looking at 130 rivers fed by glacial melt projects a decline in water availability of up to 80% (GEF 2008). Changes in water supply will impact wildlife, humans, agriculture, hydroelectric capacity and more.

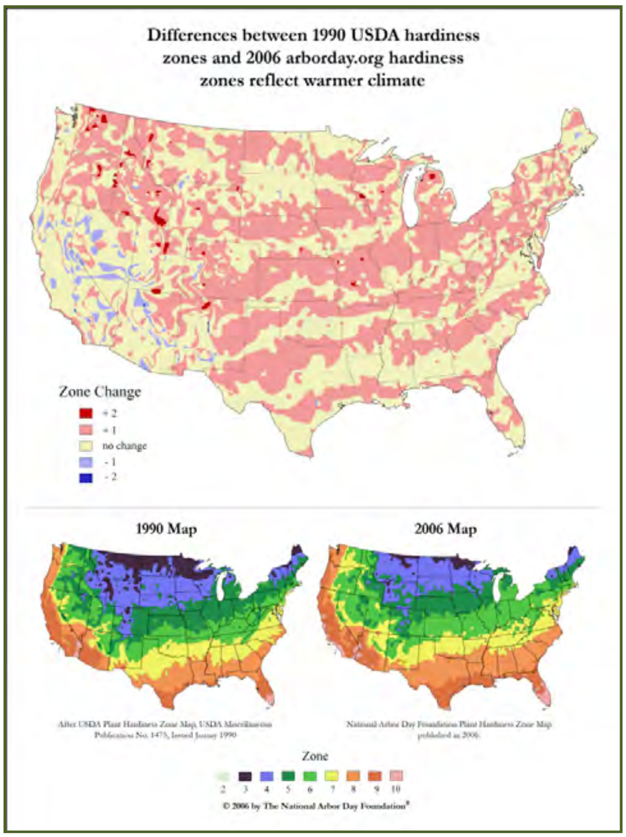
- **Sea level rise**

Oceans cover about 70% of the world's surface and are experiencing significant impacts of climate change, including sea level rise. Projections for future sea level rise during this century due to thermal expansion and glacial melt range from four inches to three feet, which will affect coastal areas globally with impacts like flooding and erosion (IPCC 2007b , IASC 2004).

Though numerous scientific and research entities have documented changes in climate around the world, and the IPCC predicted with confidence levels ranging from "almost certain" to "likely" that these changes will continue or accelerate, it is difficult to anticipate the rate at which change will occur into the future or exactly where (and when) impacts will be experienced at the local level.

4.2 Impacts in the United States

While the United States is relatively modest in size in comparison to the surface area of the globe, the climate in its 50 states varies dramatically, from arid deserts to subtropical forests and Arctic tundra. Likewise a variety of climatic changes are already being observed in the U.S. These changes are already posing challenges for natural resource managers, and are only likely to increase in magnitude in the future. In response to these observed changes and the body of research predicting more dramatic shifts in the coming decades, 38 states have adopted or are preparing climate action plans[1].



Overall trends in the U.S. reveal more unusually hot days and nights, heavy downpours and other extreme weather events, and severe droughts (NRC 2009, US CCSP 2008, IPCC 2007b). Additional warming impacts include a decrease in the number of frost days and earlier snow melt in the western U.S., as well as a northward shift in snowstorms with decreasing frequency in the south and lower midwest and increasing frequency in the upper midwest and northeast (US CCSP 2008).

The U.S. Climate Change Science Program calls the increase in frequency and intensity of heavy precipitation events "one of the clearest trends in the U.S. observational record." The U.S. CCSP also concludes that annual average temperature data for the U.S., Canada and Mexico shows "substantial warming since the middle of the 20th century."

[1] A list of state adaptation plans can be accessed via the Pew Center on Global Climate Change website: http://www.pewclimate.org/what_s_being_done/in_the_states/action_plan_map.cfm

Temperature and precipitation changes in the U.S. are already altering ecological systems. Changing temperatures are affecting the growing seasons of plants and crops, leading to earlier flowering and leaf expansion, and longer growing seasons (USGCRP, USCCSP).

Particularly in the western U.S., higher temperatures, earlier snowmelt and drier vegetation have resulted in an increase in the frequency of large wildfires and the length of fire season, a trend that began in the mid-1980s (USGCRP, USCCSP). Since 1970 the number of acres burned in the North American boreal forest has more than doubled (ACIA). Non-native invasive grasses and other plants thrive in the dryer, warmer conditions brought on by climate change. Recent, ongoing outbreaks of pine bark beetles have destroyed forests throughout North America, including millions of acres in Alaska, Colorado and British Columbia (ACIA, USGCRP). In turn, dead wood provides more fuel for forest fires.

4.3 Impacts on Ecosystems and Wildlife

4.3.1 Overview

Climate-related environmental perturbations will stress native species and natural ecosystems. The effects of such perturbations will be exacerbated by existing stresses from land and resource development, habitat fragmentation, and the growing presence of non-native invasive species. As changes to habitats occur, species will be forced to adapt or to seek better conditions. Increasingly fragmented habitats combined with limited conservation areas and large-scale human developments will create ecological boundaries that may be impassable to wildlife and may contribute to the extirpation of populations or even species.

Around the world, wildlife are already struggling to adapt to the effects of climate change. (IPCC 2007b, USGCRP 2009, Parmesan 2006, Thomas et al 2004, Walther et al 2002). A study of nearly 1600 species showed that 41% were already showing effects from recent, documented global average warming of 0.6°C, a relatively modest change in global climate (Parmesan 2006).

Climatic variables, like temperature and precipitation, are essential regulators of biological processes in natural systems (US CCSP 2009). Often these processes will continue to occur until a certain temperature or precipitation threshold is met. Climate change has the potential to push many species to the limits of their climate-related ecological thresholds,[2] with the potential for species extirpation or even extinction (Povilitis and Suckling 2010).

[2] An ecological threshold is the point at which there is an abrupt change in an ecosystem quality, phenomenon, or property or where small changes in an environmental driver produce large, persistent responses in an ecosystem. Positive feedbacks or nonlinear instabilities can then drive the domino-like spread of effects in a system that is potentially irreversible (UCCSP 2009, thresholds)

In some cases, climate change will be beneficial for species, for instance by increasing the range of certain plant or animal species that exhibit broad habitat tolerances (EPA 1998). However, the IPCC predicts that the resilience levels of many ecosystems will likely be exceeded this century by a combination of climate change, associated disturbances (e.g., flooding, drought, wildfire, insect outbreaks), and other change agents such as land use conversion, pollution/contaminants, invasive species competition, fragmentation, and resource exploitation (IPCC 2007b). Tree species in the U.S. are expected to shift northward, changing the composition of forests to the extent that spruce-fir forests will disappear completely while oak-hickory forests will expand (USGCRP 2009).

Climate change has the potential to have significant impacts on taxa that are listed as threatened or endangered under the U.S. Endangered Species Act (ESA). Other groups at high risk include species isolated by geographic boundaries or the built environment, those with low population numbers, and/or those with a narrow temperature tolerance range (EPA 1998). In a warming world, the most negatively impacted taxonomic groups are projected to be tropical corals and amphibians, while the most challenged species will be "range restricted" polar and mountain-top taxa. Species extinctions have already been documented among endemic taxa in mountain ranges around the world (USGCRP 2009, Parmesan 2006, Thomas et al 2004).

Phenology - the timing of seasonal activities for plants and animals - will also be significantly affected by climate change (Parmesan 2006). Changes in temperature and precipitation regimes have the potential to radically transform the availability of food, water, and habitat for individual species. Climatic changes also have the potential to alter the synchronization between two or more interacting species, especially in cases where the individual species are responding to different temperature and/or precipitation cues. Climate disruptions have already been noted or predicted to occur between:

- Insect pollinators and flowering plants;
- Life cycles of predators and their prey;
- Herbivorous insects and their host plants;
- Migratory routes for birds, butterflies and other species; and
- Other interactions that affect species survivorship and reproduction (Parmesan 2006).

In addition to these indirect pathways, some species may be impacted by direct physiological responses to temperature or precipitation changes. For example, declines in moose populations in Minnesota have been attributed to temperature increases which in turn are associated with global climate change (USCCSP 2008).

4.3.2 Observed Impacts on Species

Growing evidence shows that both terrestrial and aquatic wildlife are already being affected by climate change (Parmesan 2006; Mawdsley et al. 2009)

4.3.2.1 Terrestrial Species

Studies of terrestrial species in the Northern Hemisphere have showed changes in the timing of spring events, including earlier migrations, egg laying, greening of vegetation in the spring, and a lengthening of the growing season. Decreases in species abundance (including both extirpations and extinctions), changes in the composition of plant and animal communities, and a clear shift of species distributions along latitudinal and elevational gradients have also been observed in many taxa over the past few decades (USCCSP 2009; IPCC 2007b; Parmesan 2006).

4.3.2.2 Aquatic Species

Climate change is also altering aquatic systems through increases in water temperature and changes in salinity, water circulation, and oxygen levels. Effects on aquatic species documented in the literature include shifts in species ranges, changes in fish abundance, and earlier fish migrations (IPCC 2007b). Some aquatic taxa such as coldwater fish are predicted to decline significantly in the coming decades. Losses in trout populations are anticipated to be as much as 90% in North Carolina and Virginia, while certain western states may see declines of up to 50% in native trout populations (USGCRP 2009).

4.3.2.3 Extinction

In a warming world, some species will simply be unable to survive. One study estimated roughly 20 to 30% of plant and animal species will likely become extinct over the coming century if global temperatures continue to rise (IPCC 2007b).[3] In another study, conducted in 2004, scientists considered three different climate change scenarios while looking at extinction rates through the year 2050 for species living on a sample area of 20% of the earth's surface. In the minimum or inevitable change scenario, they projected 15% of species were "committed to extinction," with the number increasing to approximately 37% in a worst case, maximum-change scenario (Thomas et al 2004).

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[3] There is likely to be an increased risk of extinction (20-30 percent) if increases in global average temperature exceed 1.5 to 2.5°C (medium confidence) (IPCC, 2007b)

4.4 Major Impacts in Arizona and the Southwest

A number of studies have reviewed and analyzed the impacts climate change will have on weather patterns and ecosystems within the Southwestern United States, including Arizona. A broad consensus of computerized climate models predicts the region will experience a drier, more arid climate over the 21st Century, and evidence suggests that recent events - including escalation of temperatures, drought severity, and their concomitant impacts - are signs that climate change is already on track with these predictions (USGCRP 2009, Dominguez 2009, IPCC 2007c, Seager et al 2007). Outlined below are some of the predictions for trends in weather (i.e. transformations in temperature and precipitation) over the coming century for this region, along with discussion of major associated stressors that may impact vegetation and wildlife species as a result.

4.4.1 Changes in Air Temperature

According to the U.S. Global Change Research Program, recent warming in the Southwest has been significantly higher than the global average (USGCRP 2009, IPCC 2007c). The global average temperature has risen one degree Fahrenheit (F) over the past 150 years, while in Arizona it has risen by more than two degrees F (AZ FRTF 2010). According to the IPCC's Fourth Assessment report, the Southwestern region of the U.S. will continue to experience warming at a faster rate than most of the U.S. and many parts of the world, with warming likely to be greatest during the summer months, exhibited more through high temperatures than through a rise in the average temperature during that time of year. To date, climate in the Western U.S. has warmed an average of 1.4 degrees F over the past 50 years. IPCC climate models predict these areas will continue to warm a further 3.6 to 9.0 degree F by 2040 to 2069 in the summer months (AZ CCAG 2006). The most extreme climate model scenario suggests that temperatures in the Southwest could rise as much as 14 degree F by the end of this century (AZ CCAG 2006). In urban areas, these changes will be intensified by the urban heat island effect (US GCRP 2009), affecting both humans and wildlife. It is predicted that temperatures currently considered unusually high in Arizona will become more common (Archer and Predick 2008), affecting the frequency and intensity of drought events in the state. This warmer climate may bring along with it:

- **Less winter snowfall, more winter rain, and a faster, earlier snowmelt** in Arizona's mountains (AZ CCAG 2006). Trends over the last 50 years show earlier spring snowmelt and declining winter snowpack (AZ FRTF 2010).

- **Higher summer temperatures and increased rates of water evaporation**, leading to lower levels in reservoirs and lakes, reduced stream flows. These trends are also affecting processes including plant production and soil respiration (AZ CCAG 2006, Weltzin et al 2003).

4.4.2 Changes in Precipitation

It is anticipated that critical changes in precipitation due to climate change - including alterations in the amount, pattern, and type of precipitation (i.e., snow versus rain) - will have a direct effect on ecosystem processes in the Southwest (Archer and Predick 2008), impacting the distribution, composition, and diversity of populations and communities of plant and animal species (Weltzin et al. 2003). However there is less agreement about precipitation projections than other climatic changes.

Despite some uncertainties in the modeling of precipitation changes, the following forecasts for the southwest are generally understood by scientists:

- ***More high intensity storms*** - High intensity storms will likely become common in the southwest during summer months, resulting in longer dry periods punctuated with periodic high intensity rain storms – a combination that means not only more droughts, but more floods (Archer and Predick 2008).
- ***Changes in snowfall and snowmelt*** - Areas historically receiving most of their annual precipitation as snow (i.e., montane areas), will see less snowfall and more rain in winter due to changes in the spatial patterns of precipitation as well as warmer temperatures at higher elevations. This trend was already observed in the Sierra Nevada Mountains where a study by Johnson found that over the last 28 years less snow has been accumulating below 2400 meters. Water storage as snowpack will be markedly reduced, and immediate runoff will increase. The warmer temperatures will likely lead to earlier snowmelt, which will adjust peak runoff in the state's streams and rivers, leaving dry tracks in many areas in summer months, reducing water availability for humans and ecosystems (US CCSP 2008, Solomon et al 2009). Additionally, the combination of more winter rain and rapid snowmelt could also increase flooding in the spring and winter months (AZ CCAG 2006).

- ***Decreased annual precipitation*** -
  - ***Drier months*** - There is a greater agreement among models regarding precipitation amounts during the drier season than the wetter monsoonal season (Dominguez 2009, Christensen et al 2007). In a study by Solomon et al, over 90% of the regional climate models they averaged, including those for the Southwest United States,

showed an increased drying during dry seasons. More specifically, they estimate a 10% decrease in precipitation in the Southwest for every two degrees Celsius warming. Comparatively, the "Dust Bowl" conditions of the 1930s in this region were associated with a similar reduction in rainfall (roughly 10% on average) over 10 to 20 years. If such climate predictions are correct, results similar to the 1930s could be seen with the additional variable of hotter temperatures.

- ***Wetter months (The North American Monsoon System)*** - Approximately 35% of Arizona's precipitation comes during the wet Monsoon season (SWCCN 2008). The Monsoons develop when a seasonal change in prevailing winds over the Gulf of California brings this increased rainfall. It is predicted that less warming over the Pacific Ocean than over North America, as well as "amplification and northward displacement of the subtropical anticyclone," will decrease annual precipitation amounts in the Southwest (Christensen et al. 2007, Dominguez 2009). Long-term rainfall decreases have already been observed in some parts of the Southwest (Soloman et al 2009).

As mentioned, impacts from an increase in temperature and change in precipitation have already been experienced in Arizona. From 2002-2010, two of the worst wildfires in Arizona history occurred: 2002's Rodeo-Chediski fire which burned 500,000 acres and 2005's Cave Creek Complex fire which burned 250,000 acres. During the same eight-year period, the state also experienced its two driest years in over a century and two of the lowest levels of run-off ever recorded, due to decreased snowfall (AZ CCAG 2006). In 2009 a lack of monsoonal rains in the Southwest contributed to Arizona's fifth driest annual period and third driest summer in recorded history (Arndt et al 2010).

4.5 Climate Change Related Stressors in Arizona

As with many complex environmental issues, climate change stressors intertwine in their causes and effects, often overlapping or creating a domino effect from one to the other. Outlined below are some of the major stressors predicted to affect Arizona and its wildlife over the coming years.

4.5.1 Drought

Drought occurs when precipitation is significantly below normal levels, and often has adverse effects on natural resources (IPCC 2007c). Common effects of drought are soil moisture depletion, vegetation stress and die-off, intensified wildfires, and degraded wildlife habitat (SWCCN 2008), all of which have effects that reverberate throughout the environment. Drought impacts are magnified by other climatological processes, including increased evaporation from more sunlight shining down through cloudless skies, as well as high temperatures. Arizona is expected to experience an increased frequency of drought events (AZ CCAG 2006).

Droughts for this region are nothing new, with some of the most remarkable ones on record being the "Dust Bowl" of the 1930s, a record drought in the 1950s, and some the longest documented mega-droughts on the planet experienced in the late 1500s. However, more recent droughts have the added disadvantage of combining rising temperatures with human-induced impacts such as land use changes, invasive species, and habitat fragmentation. Over time droughts will continue to take place, but modeling shows they will become hotter and thus more severe (USGCRP 2009). The natural impacts from them will also become record breaking; already this can be seen in forest die-offs observed in the western United States during droughts earlier this century (SWCCN 2008).

4.5.2 Flooding

Warmer climate and an intensified weather cycle likely mean that the region will also experience the opposite extreme of drought: increased flooding. For instance, winter precipitation in Arizona is becoming increasingly variable, trending towards more frequent extremely dry and extremely wet winters (USGCRP 2009). This change is being seen globally and nationally as well, where precipitation patterns are shifting to more heavy downpours of rain that can lead to flooding. A shift from less snowfall to more rainfall in winter months, combined with earlier and increased snowmelt, in mountain regions can also cause an increased risk of flooding (USGCRP 2009).

4.5.3 Wildfires

Arizona ecosystems are predicted to experience more frequent and intense wildfires under altered climate regimes (UCCSP 2009). A study by Westerling (2006) shows wildfires in the western United States have already "suddenly and markedly" increased since the mid-1980s. Compared to historical fire regimes, these more recent fires are larger, longer lasting, start earlier in the spring, and spread over a longer season (Westerling 2006, AZ FRTF 2010). The National Interagency Fire Center concurs with this finding, stating that there has been a significant increase in wildfires, particularly in the last 10 years (U.S. NPS 2010). This new wildfire regime can be linked to a number of climate change related stressors, including: rising temperatures, spring snowpack reductions, changes in precipitation patterns, decreased soil moisture, and insect outbreaks that weaken trees and other vegetation. The proliferation of invasive species and the anticipated spread of grasslands under altered climate regimes will also likely increase the risk and extent of fires by causing them to burn more swiftly or intensely (USGCRP 2009, U.S. NPS 2010). Other environmental changes less directly associated with climate change, such as over-grazing and fire suppression, are apt to exacerbate the issue (USCCSP 2009).

Like many complex environmental issues it is a combination of factors, such as those mentioned above, that can push a system beyond its threshold. For example, in the late 1990s, forests, woodlands, grasslands, and shrublands in the arid Southwest suffered from extensive dieback due to overgrazing, fire suppression, and climate variability. The weakened vegetation led to massive insect outbreaks, and then finally unprecedented amounts of land area overtaken by fire (USCCSP 2009).

4.5.4 Invasive Species

Invasive species are known to disrupt native ecosystems by altering or overrunning key habitats, displacing native animals and plants, fragmenting native ecosystems, and altering critical aspects of ecosystem function. Climate change may cause certain invasive species to thrive, altering both their impact and distribution. Changes in global climate can also provide opportunity for the establishment of new invasive species. Although evidence suggests that climate change will drive changes in the impacts of invasive species in Arizona, the particular species that will be affected and the magnitude of these changes are poorly understood to

date. Probably the best-studied example is tamarisk, also known as salt cedar (*Tamarix* spp.). Studies anticipate that tamarisk is likely to expand its geographic distribution as a result of global climate change (Bradley et al 2009). This species of shrubs and small trees is considered one of the most aggressive invaders of southwestern riparian ecosystems (Kerns et al. 2009). Tamarisk uses more water than native flora and creates relatively poor habitat for many native plant and animal species. Potential impacts of tamarisk invasion include reductions in species diversity and abundance, reductions in waterway flows, drying of desert springs, and reduction in lake levels (Hellman et al 2007). According to Schneider and Root (2002) increased tamarisk populations will impact wildlife ranging from bighorn sheep and endangered pupfish to the Southwestern Willow Flycatcher (Schneider and Root 2002). In addition to tamarisk, invasive plant species of concern under altered climate regimes include Russian olive, buffel grass, and Lehmann's lovegrass.

4.5.5 Changes in Water Supply and Availability

The IPCC predicts that many arid and semi-arid areas, including Arizona, will experience reductions in water resources in the future due to climate change (IPCC 2007b). According to Dominguez (2009), the Southwest is one of the few regions of the world where there is consistent agreement among climate models that there will be reduction in water sources (Dominguez 2009, see also Christensen et al. 2007). Higher temperatures, changes in precipitation, and increased water evaporation will lead to lower water levels in lakes, reservoirs, rivers, and streams during summer months (AZ CCAG 2006). The changes in snowpack amounts – compounded by increases in winter rain rather than snow - in conjunction with earlier spring snowmelt will mean less spring and summer runoff (AZ CCAG 2006). Aquifers will receive less groundwater recharge, a challenging scenario for a state whose population is already progressively relying on groundwater withdrawals for irrigation and municipal water supplies.

Two studies conducted in the Colorado River Basin show that recent rising water evaporation from higher temperatures lowers river flows and heightens drought conditions throughout the Southwest. One study estimates a 50% probability that live storage in lakes Mead and Powell, the two largest reservoirs in the Colorado system, will be depleted by 2021 (Dominguez 2009, Christensen et al 2007). Also, the Colorado River is predominantly a snowmelt-driven system, so changes in winter precipitation and runoff amounts will likely affect its flow. Conservative estimates predict sizeable impacts to the Colorado River system by the end of the century, including a 15% reduction in annual runoff (AZ CCAG 2006). These declines in seasonal snowpack have already been noted in Arizona in recent years (Folliott and Gottfiend 2010).

Finally, it is important to note that with a burgeoning human population, Arizona may soon face a higher water demand than the state can meet for human activities, which may leave less water for fish and wildlife habitat needs (AZ CCAG 2006, USGCRP 2009, Christensen et al 2007).

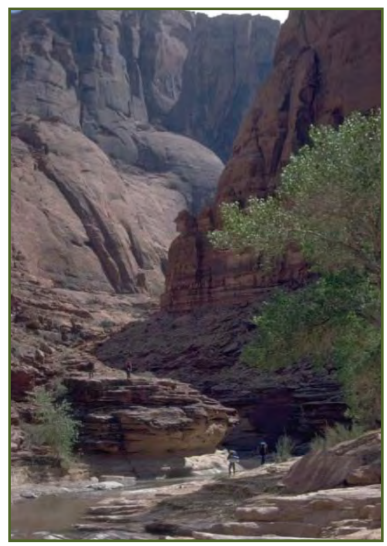
4.6 Climate Change and Arizona Ecosystems

Arizona's major ecosystems will undoubtedly be affected by climate change in a variety of ways.

4.6.1 Coniferous Forests

According to the U.S. Climate Change Science Program, forests of the southwest are already approaching their climate-related threshold (USCCSP 2009). Climate models forecast that these forests will become warmer and drier, experiencing more frequent water stress, undergoing shifts in vegetation types and distributions, and potentially experiencing large forest die-offs (UCCSP 2009, Zugmeyer and Koprowski 2009).

Although most vegetation communities will be affected by climate change, climate impacts are expected to be especially noticeable in coniferous forests (Bentz 2010). In 2002–03, a year-long, region-wide drought caused forests throughout the southwest to lose thousands of acres of trees, including ponderosa pine, piñon pine, and juniper pine (SWCCN 2008). One study showed that after 1.5 years of drought, more than 90% of piñon pine trees were lost at study sites in Arizona (Breshears 2005). While a lack of water was the initial trigger and ultimate underlying cause of the die-back, a chain of climate-related events created additional severe stressors. First, although the drought was not as severe or dry as previous droughts (such as those in the 1950s), it was hotter. Scientists believe this may have resulted in more widespread and extensive die off, over more age classes, and at wetter and higher elevation sites (USCCSP 2009). The intensified heat further dried out the trees and soil via faster evapotransporation. The trees became significantly weakened and more vulnerable to predators, specifically pine bark beetles (SWCCN, 2008).[4] Native to Southwestern ponderosa and piñon-juniper forests, the bark beetle normally attacks diseased or weakened trees. During the drought, however, there were many more weakened trees to attack (USDA FS 2004). It is predicted that outbreaks of bark beetles and other insect pests will become more frequent with global warming (Bentz 2010).[5]



4.6.2 Riparian Systems

Riparian areas along rivers, streams, lakes, and other waterways play an important role in the health of numerous plant and wildlife species. Although the amount of land covered by riparian zones in Arizona is relatively small (approximately 0.4 %), riparian areas are considered one of the most productive natural systems in North America. They are the interface between terrestrial upland areas and aquatic habitats, and one study showed that 70% of Arizona's threatened and endangered vertebrates depend on its habitat. In addition to supporting and enhancing animal and fish habitat, riparian areas improve water quality by filtering sediment and nutrients from runoff, as well as reducing the amount of chemicals that enter a water source. They also stabilize stream banks, reduce floodwater runoff, provide water storage, and recharge aquifers (Zaimes 2006).

[4] Under normal climatic conditions, trees are able to repel bark beetles and other insect invaders through sap flows which force the beetles from the bark. But under these dry conditions, the trees had to conserve water and could not produce the necessary sap (SWCCN 2008).

[5] Although some of this forest die-off is due to lack of fire in fire-adapted ecosystems and other management choices, recent severe and widespread tree mortality in Arizona is due to insect outbreaks which in turn are attributed to higher temperatures (AZ FRTF 2010).

Predicted water level reductions will have a large impact on riparian areas by draining water from these systems. In addition to shrinking their total area and the amount of habitat they can provide, it is anticipated that invasive species will thrive as the climate regime transforms to lower water levels. One reason is that drought and the lower amounts of water will weaken riparian plant species, providing an opportunity for invasive plants to take over, reducing the abundance and richness of plant and wildlife species in these areas. Aggressive plants such as tamarisk and Russian olive are known to thrive in riparian areas with groundwater decline (Archer and Predick 2008).

4.6.3 Arid Desert Systems

Arid desert systems comprise a large amount of Arizona, and as mentioned these areas are predicted to become warmer and drier as a result of climate change. For the plant and wildlife species that rely on arid desert systems, the future is uncertain as many are already approaching their physiological limits for water and temperature stress (Archer and Predick 2008). Even small changes in precipitation, temperature, or the frequency and magnitude of current extreme weather events could dramatically change their distribution, abundance, and composition (Archer and Predick 2008).

The Sonoran desert is the largest arid desert area in Arizona, covering roughly 100,000 square miles. Observed changes in climate in the Sonoran desert include: a warming trend in the winter and spring months, reduced frequency of freezing temperatures, a longer freeze-free season, and higher minimum temperatures in the winter (Weiss and Overpeck 2005, Center for Sonoran Desert Studies 2006). Potential changes that are expected in response to these climatic shifts include shifts of Sonoran desert vegetation along elevational and latitudinal gradients (Weiss and Overpeck 2005). Changes in regional climate are expected to exacerbate infestations of invasive grasses in the Sonoran desert, which in turn can alter fire regimes throughout the system (USGCRP 2009). Additional changes in Sonoran desert vegetation may be driven by reduced frosts, as freezing temperatures in these arid regions are important determinants of plant survival and distribution (Weiss and Overpeck 2005).

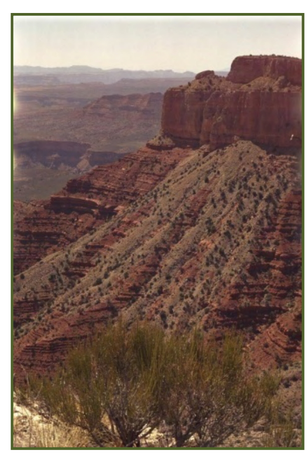
4.6.4 Freshwater Systems

Freshwater systems such as rivers, streams, and lakes will have to face a number of stressors in the future, coming not only from changes in climate but also from rising water demand (linked to Arizona's growing population) and land use changes. With very high confidence, the IPCC states that freshwater biological systems will be strongly affected by rising temperatures; and although less certain, changes in precipitation can cause major effects to the chemical and physical characteristics of these systems as well. For example:

- ***Streams*** - As water temperatures increase, fish species in the desert Southwest will not be able to migrate northward to cooler waters because most of the streams and rivers in this region run west to east (Lovejoy and Hannah 2005). Habitat will also be affected through the surrounding vegetation's reaction to increased droughts. As the vegetation cover and stability of the soil changes, more soil and sediment will run off into the waters, affecting the water quality, riparian zone vegetation and aquatic species (Archer and Predick 2008).
- ***Lakes*** - Lake systems are sensitive to changes in temperature, particularly in terms of their nutrient dynamics. As a result, aquatic organisms in these systems, including fish, will experience changes in their survival, distribution, and growth (US CCSP 2009). Water levels are vulnerable as well. Since 2000, drought has reduced levels in the Lake Powell and Lake Mead reservoirs; and climate models predict Lake Mead will eventually dry up (US CCSP 2009).
- ***Rivers*** –The iconic Colorado River provides water for much of Arizona, as well as other parts of the Southwest. An increase in water demand from rising human population numbers has made the lower portions of the river highly vulnerable to drought. Climate models predict the Colorado River's flow will be reduced by over 20% (US CCSP 2009).
- ***Seasonal Wetlands* -** The timing and size of seasonal wetlands have been and will continue to be affected by decreased snowpacks and earlier snowmelt in the spring. Amphibians are one group that may face population impacts or local extinction if they cannot adapt their breeding patterns to this shift in timing or cannot sustain themselves through multiple dry years (US CCSP 2009).

Historically, these systems have adapted to the natural flow variability of the region, however the harsher and lengthier droughts ahead will likely shift hydrologic regimes potentially beyond their threshold, leading to loss of some entire aquatic systems (Barnett et al 2008, US CCSP 2009).

4.6.5 High Elevation Zones



High elevation zones in Arizona will be particularly susceptible to climate change stressors, including earlier snowmelt, drought, insect infestations, wildfires, and generally warming temperatures. Studies show that temperature changes in these systems have already led to changes in the plant and animal phenology, particularly with flowering, plant growth, and other vegetation-related ecosystem events that have been occurring earlier (Parmesan and Yohe 2003).

Models and empirical data show that temperature increases of as little as a few degrees Celsius could lead to widespread extirpation of high-elevation species. This is particularly true for mountaintop species who often have a limited range or whose sole habitat is located in high elevation zones; they are the first groups where entire species extinctions have been attributed to recent climate change (Parmesan 2006).

4.7 Climate Change and Arizona Species

According to the Southwest Climate Change Network (2008), Southwestern wildlife will face reduced availability of drinking water, food, and habitat. These changes could lead to decreases in reproduction and survivorship, as well as increased mortality, particularly for the most sensitive or range-restricted species (SWCCN 2008). The following sections highlight potential climate change impacts to Arizona wildlife species.

4.7.1 Desert Tortoise

A native of the Southwest, the desert tortoise's habitat range falls within the Mojave and Sonoran Deserts. Desert tortoises were found historically across southern and western Arizona as well as southern California, southwest Utah, and southern Nevada. The Mojave Desert population of the desert tortoise is federally protected as a threatened species under the Endangered Species Act, and the Sonoran Desert population is protected by Arizona state regulations. The listing of the tortoise is due to a combination of anthropogenic stressors such as habitat loss from human encroachment and increased urbanization, grazing, road development, off-highway vehicle use, and illegal collection and poaching; as well as environmental stressors such as drought, disease, wildfires, invasive species, and predators (Reed et al 2009, Galbrieth and Price 2009). Currently a few hundred thousand desert tortoises live across 60,000 square miles of Sonoran desert scrub habitat (Galbrieth and Price 2009).

It is expected that the desert tortoise will physiologically adapt to temperature increases associated with climate change, as the species is already well adapted to live in one of the harshest environments on the planet. Climate-mediated habitat alteration will probably have the most profound effects on the tortoise populations. Climate models project a large change in the vegetation communities in its habitat in southern California, and similar effects are likely for Arizona. It is expected that this habitat loss will greatly reduce tortoise population numbers in the future, and cause further local extirpations of already fragmented populations (Galbrieth and Price 2009). However, there is a chance that increased temperatures could create new habitat for the tortoise in areas north of its current territory, although this is speculative (Galbreith and Price 2009). Increased invasive species encroachment, brought on by climate change, could also become a magnified stressor, replacing the desert plants that the tortoises prefer as a food source (Galbreith and Price 2009).

4.7.2 Birds

Arizona is home to a rich diversity of avian species and studies suggest that birds may be particularly vulnerable to climate change. Individual bird species are known to be sensitive to heat or heat waves due to their diurnal habits, small size, and their limited ability to find microsites to shield them from the heat (McKechnie and Wolf 2009, Hitch and Leeburg 2007). This responsiveness to changes in environmental variables has led scientists to propose that birds may serve as a useful indicator group for measuring the effects of climate. Responses to temperature increases and changes in the geographic distributions and migration patterns of bird species have already been documented in the North American avian fauna (McKechnie and Wolf 2009).

One study of North American birds showed that the northern limit of birds species found in the southern parts of the continent were shifting significantly northward (2.35 km/year) over the past few decades, a trend also seen in Europe and Great Britain. The magnitude of this shift and its correlation with recent global warming trends leads scientists to believe that the shift in distributions is connected to climate change (Hitch and Leeburg 2007). A field study of warbler species has shown that an increase in temperature for birds nesting in hot, arid environments in the southwest can cause individuals to alter their micro-habitat preference (Galbreith and Price 2009).

For migratory bird populations, temperature and weather changes also present a challenge (Fontaine et al 2009). Shifts in the timing of temperature cycles or rainfall events could cause birds to arrive on their breeding grounds either too early or too late for successful reproduction (US CCSP 2008, Cotton 2003).

4.7.3 Mount Graham Red Squirrel

The Mount Graham Squirrel is an endemic mountain-top resident of Arizona’s Pinaleños range. The squirrels live between 8,500 and 10,700 feet in mixed conifer and spruce fir forest. The squirrels feed on pine seeds, which are stashed in middens to protect the seeds from decay and fungal growth. Cool and moist temperatures are required for proper seed storage conditions. In 1987, the Mount Graham red squirrel was listed as Endangered under the Federal Endangered Species Act, and roughly 300 to 500 individuals can now be found in the wild (Galbreith and Price 2009).

This species is threatened by cumulative impacts of drought, wildfires and insect outbreaks, in addition to global climate change (Zugmeyer et al 2009, Koprowski et al 2005, Galbreith and Price 2009). Decreased habitat availability (and associated reductions in food sources) is thought to be the main stressor on the squirrel. Climate-vegetation models predict that evergreen forests, including the mixed conifer and spruce fir preferred by the squirrel, will be eliminated in southern Arizona by warming trends and replaced by either mixed forests or shrub woodland if the average annual temperature increases by five degrees Celsius. Even if the annual temperature does not increase to this extent, smaller increases may nonetheless push the squirrel's habitat farther up Mt. Graham, reducing and fragmenting the species' distribution (Galbreith and Price 2009, McCormack et al 2008). Drought and its related impacts will also affect the Mt. Graham Squirrels survival as trees become weakened and more susceptible to forest fires and insect outbreaks. For example, insect outbreaks in 2002 severely damaged the forest occupied by the squirrels, leaving more open forest with fewer seed trees and decreased cover from predators (Koprowski et al 2005). One study suggests this led to reduced individual fitness and survivorship in the squirrel population (Zugmeyer and Kopowski 2009).

4.7.4 Sonoran Desert Pronghorn

Increases in major drought events are predicted for Arizona and could bring the endangered Sonoran Desert Pronghorn closer to extinction. Found only in protected areas in southwestern Arizona, the Sonoran Pronghorn's main stressor has historically been the competition for food with grazing cattle (US FWS 2002). Although grazing is no longer allowed in Sonoran Pronghorn habitat, today the species faces new problems associated with climate change. Annual reproductive success in Sonoran Pronghorn depends heavily on winter rainfall, and changes in precipitation may result in reduced reproductive success. Drought is also of great concern, as the 2002 drought reduced the Sonoran Pronghorn population in Arizona by 80%. Although the pronghorn are able to obtain much of the water that they need from forbs and other food plants, when these plants die during drought conditions the pronghorn must find a new water source, if possible. During these times, decreased water availability and increased presence of predators at existing watering holes may expose the pronghorn to greater risk of mortality (SWCCN 2008).

5.0 Managing the Effects of Climate Change

The process of adaptive management allows wildlife managers to learn from their past management activities and alter management prescriptions based on the knowledge gained from previous management efforts. Such an approach is ideally suited for situations with high uncertainty, such as the current situation regarding global climate change. Through the adaptive management process (described in more detail elsewhere in this document), managers assess the results of their activities by collecting data through monitoring programs, and in turn use this information to refine their future activities and improve the effectiveness of their programs based on lessons learned. The adaptive management approach is an especially attractive method to help managers monitor and interpret the effects of climate change, and evaluate how best to respond to new and unforeseen challenges.

5.1 Climate Change Monitoring

A well-designed monitoring program has the potential to provide “early warnings” of possible effects of climate change, allowing managers time to take preventive or corrective action if possible before changes become irreversible (Heinz Center 2008). One example is early detection of invasive species outbreaks (US CCSP 2009), which could then be addressed through rapid response and eradication activities. According to the Heinz Center (2008), a climate change monitoring program should combine a few types of indicators and metrics, including:

- ***Leading indicators*** to provide advance warning of climate change effects;
- ***Status indicators*** to measure short- and long-term changes in wildlife populations; and
- ***Effectiveness measures*** to report and assess the effectiveness of climate change adaptation strategies for wildlife and ecosystems.

This dynamic and broader approach recognizes the information management needs of wildlife and natural resource managers who are dealing with a changing climate and an uncertain future for ecosystems (US CCSP 2009).

5.1.1 "Early Warning" Indicator Species and Systems

Certain systems or species may be good “early warning” indicators for ecosystem health, and therefore good targets for monitoring. For instance springs, seeps, and tinajas are important water sources for plants and animals in arid and semi arid regions of Arizona, and are also particularly sensitive to changes in precipitation (e.g. size, duration or frequency of rain events). They are considered the interface between groundwater and surface water. With climate change likely to modify ground and surface water amounts, as well as seasonal flooding and drought patterns, signs of change in the health and persistence of the sensitive springs, seeps, and tinajas systems should be monitored (US NPS 2010). Land birds are another group of species which have the potential to serve as good indicators of environmental change. Despite being highly mobile, many bird species are already being affected by climate change. Climate-mediated shifts in species distributions and changes in migratory patterns have already been observed in many North American bird species (US CCSP 2009).

5.2 Climate Modeling as a Management Tool

Computerized climate models are a very important tool for simulating and understanding climate change, however these models also have a high degree of uncertainty, particularly regarding future changes in precipitation (Archer and Predick 2008, Seager et al. 2007). For some regions of the world, there can be distinct variations from model to model regarding future precipitation changes, as well as underestimation of changes that have already occurred. For instance, in the southwestern United States certain models forecast less precipitation, while others foresee more precipitation (NASA 2008). To improve the predictive ability of these models, researchers are working towards:

- ***Better understanding and simulation of key climatic variables*** such as vertical air movement (e.g. for areas near mountain ranges), jet stream activity, elevation effects, and cloud formation and dynamics (Walther et al 2002, SWCCN 2008). For example, the North American Monsoon System provides a large amount of precipitation for the Southwestern United States. However, in terms of modeling it is also one of the continent's most complicated and least understood large-scale weather circulation patterns (SWCCN 2008). Because it is key to rainfall in the region, better understanding the monsoon's relationship to climate would be invaluable to wildlife managers for planning purposes (SWCCN 2008).
- ***Increased climate model resolution*. ** Climate change projections are most reliable at a global level rather than a regional or local level (SWCCN 2008). It is difficult for a local or regional weather system, such as a monsoon, to be captured in a global climate model because of the difference in scale. The large-scale grids used in many climate models cannot accurately register/formulate the small-scale local processes (e.g. topography and other landscape features) (SWCCN 2008, Weltzin et al. 2003). For instance, in the IPCC 2007 assessment report much of the regional-scale information was deduced from global-scale modeling rather than regional-scale (Arrit and Rummukainen 2010). However, advances in spatial resolution are helping to improve regional scale modeling (IPCC 2007a); and researchers are working to use high resolution satellite observations to improve the accuracy of their models, so that they can have greater confidence in predictions at a local level (SWCCN 2008).

5.3 Combining Climate Modeling and Monitoring

Although modeling studies can provide a range of climate projections, these projections often contain significant uncertainties and differ significantly from model to model. Likewise, the scale or scope of available projections often does not match the scale or scope of a particular management area and/or species of focus. Therefore it is necessary to use both modeling and monitoring information to understand how systems and species may change or adapt with the changing climate. By designing a monitoring program to track the actual effects of climate change, management activities can then be targeted to address specific issues that arise in a particular location, state, or country (Heinz Center 2008). Uniting modeling and monitoring in such as way would better inform decision-making around a broad spectrum of natural resource management topics (Heinz Center 2008).

The effects of climate change will inevitably include a wide array of stresses on individual species. Long before many species shift their distributions to accommodate shifts in habitat conditions, those species may experience phenological shifts which alter resource availability, species mutualisms, disease outbreaks, and habitat suitability. Failure to consider available information related to such essential environmental circumstances and ecological relationships in conservation planning could result in managing the wrong wildlife resources, or the right resources toward the wrong target conditions, or choosing conservation areas of limited longevity. The remaining sections of this report outline strategies to help avoid these undesirable outcomes by selecting potential conservation and monitoring targets. It describes the process and results of an exercise from the September 2010 workshop designed to help multiple stakeholders choose mutually agreed upon highest priority species, ecosystems, or vegetation communities to serve as foci for monitoring.

5.4 Management Approaches to Change

Although climate change is projected to cause significant effects on the wildlife and ecosystems of Arizona, conservation practitioners in the state already have a wide range of tools and approaches that can be used to mitigate or ameliorate these changes. Following the report format established by the Intergovernmental Panel on Climate Change (IPCC), these responses are generally divided into Mitigation and Adaptation approaches. Mitigation approaches are attempts to reduce the anthropogenic drivers of global climate change, mainly by minimizing or mitigating carbon emissions. Adaptation approaches attempt to address and manage the effects of climate change on species, ecosystems, and the built environment. Both types of approaches should be considered as part of an integrated state-wide response to climate change.

5.4.1 Mitigation Strategies

Commonly identified mitigation strategies (The Heinz Center 2008) which might be appropriate for Arizona include:

- Increased efficiency in existing industrial or agricultural processes that create carbon emissions
- Increased vehicle efficiency to reduce carbon emissions
- Use of non-carbon forms of energy, such as wind, solar, or water power
- Reforestation to increase uptake of carbon
- Protection of forests and other natural areas that serve as carbon sinks

5.4.2 Adaptation Strategies

Commonly identified adaptation strategies (The Heinz Center 2008; Mawdsley et al. 2009) which might be appropriate for Arizona include:

- Protect land along key movement corridors for wildlife
- Restore wildlife habitat along key movement corridors
- Promote wildlife-compatible human uses along key movement corridors
- Restore habitat connectivity, especially in riverine and riparian systems
- Reduce other anthropogenic stressors, to give species more flexibility in responding to climate change
- Conduct invasive species control/eradication efforts
- Captive breeding or translocation efforts for species predicted to become extinct
- Improve monitoring programs to track the effects of climate change on key species and ecosystems
- Apply an adaptive management approach to the management of climate change effects, by using monitoring data to track the effectiveness of climate adaptation activities and inform future adaptation efforts

6.0 Shared Priorities for Conservation and Monitoring

6.1 The Challenge of Multiple Conservation Targets

The word "target" is used in many different ways by wildlife and natural resource managers. A "target" can be a desired population size, a land protection goal, a financial or budgetary objective, or the species or area that is itself the focus of management.

Following the lead of groups like The Nature Conservancy and the World Wildlife Fund, many conservation organizations are adopting a more restrictive definition for the word "target" (Heinz

Center 2008). By this definition, a “target” is a particular species, vegetation community, landscape, or defined geographic area which is the subject of conservation management. In this chapter the word “target” is used in this more restrictive sense to develop a preliminary set of performance indicators for the Arizona Comprehensive Wildlife Conservation Strategy.

Even using the more restrictive definition of the word, this Strategy document already lists a large number of potential conservation “targets” in the state of Arizona. Conservation “targets” in this Strategy include all of the species of greatest conservation need and all of the ecosystems or vegetation communities of conservation interest within the state. Each species, ecosystem, and vegetation community listed in this document is a worthy conservation target, deserving careful attention from wildlife and natural resource managers, scientists, and field biologists. At the same time, the state and its partners have limited resources available for conservation activities, including monitoring, and therefore some taxa will necessarily receive attention before others. This is especially true in the case of monitoring activities, where there are extremely limited resources available for monitoring individual species or ecosystem attributes.

Considerable resources are already dedicated to monitoring populations of species that are known to be of conservation interest, such as species listed under the U.S. Endangered Species Act. The monitoring of individual species is a complicated endeavor that requires considerable knowledge of a species’ biology, development and testing of sampling protocols, and a firm understanding of the statistical basis for translating monitoring data into estimates of population trends and other

information needed by wildlife and natural resource managers. Monitoring of individual species is both time- and labor-intensive, with significant commitments of staff and financial resources. In the current funding environment, support for new monitoring programs or projects that are focused on individual species is likely to be extremely limited for the foreseeable future.

In many cases, monitoring of ecosystems or vegetation communities may be more tractable than individual species monitoring. For many communities, such as grasslands, shrublands, and forests, there are readily available metrics of composition and structure that can be applied at the stand or plot level. Many of these same metrics can also be assessed using remote sensing imagery from satellites or aerial photographs. Focusing on ecosystems or vegetation communities as monitoring targets also has the added benefit that the monitoring programs for individual species often fit geographically within particular large-scale ecosystem or vegetation types (for example, sage grouse monitoring efforts occur within sagebrush communities). Furthermore the presence or abundance of individual animal species can provide indirect measures of ecosystem function or vegetation condition (as in the case of species that are sensitive to fire or to the presence of certain invasive species).

Given the limited resources for monitoring species and ecosystems, it is often desirable to select a set of highest-priority species, ecosystems, or vegetation communities that can serve as foci for monitoring. In this initial approach for Arizona, the focus is on large-scale vegetation communities or ecosystems as the primary set of conservation targets for collaborative, multi-agency, multi-jurisdictional monitoring. Each of these broad targets contains within it many individual species and sub-communities which are themselves potential targets of management and monitoring. Monitoring efforts for individual species can help inform efforts to understand the status and trends of the larger system within which these species are embedded. Within a given ecosystem, individual species are often associated with particular habitat variables such as stand density or canopy cover. Such species could potentially serve as "indicators" of their associated aspects of habitat condition. Taken together, trends in the suite of species associated with a particular ecosystem or community can also help measure the overall ecosystem response to environmental stressors.

6.2 Exercise: Identifying Shared Priorities and Targets in Arizona

A group of diverse Arizona stakeholders representing state, federal, and tribal agencies, academia, and non-profit organizations participated in the target selection exercise. Stakeholders are those who have direct management authority for wildlife and/or ecosystems within the state, or those who have direct responsibility for designing or implementing monitoring programs. Each stakeholder typically has their own set of priority conservation targets (i.e. species, ecosystems, vegetation communities, or areas of interest). This exercise is designed to identify shared priorities among the set of stakeholders invited to the meeting. The goal is to identify targets that are viewed by the greatest number of stakeholders as top priorities for conservation and monitoring.

Each stakeholder was asked to identify their top five (5) ecosystem-scale conservation targets within the state. These lists were written on pieces of paper and collected by Heinz Center staff. The lists were then consolidated and presented to the group in rank order according to the number of times each prospective target was mentioned. The top 10 targets from this first round were then listed on poster paper and each participant was assigned 5 stickers with which to vote for their top 5 preferences. Participants were allowed to allocate their votes however they saw fit; voting 5 times for 1 prospective target and voting 1 time each for 5 prospective targets were both acceptable. The shared priority ecosystems selected by partners attending the workshop included: Cottonwood-Willow Riparian, Mixed Conifer/Spruce Fir Forests, Sonoran Desert, Southeastern Grasslands, and Springs/Seeps/Cienegas.

6.3 Exercise Results: Description of Arizona Target Ecosystems

6.3.1 Cottonwood-Willow Riparian

Workshop participants identified riparian areas as an important system in Arizona. During the small break-out group exercise, members identified cottonwood-willow riparian areas as a top priority within riparian systems.

The Arizona Comprehensive Wildlife Conservation Strategy does not specifically outline cottonwood-willow riparian areas as a separate habitat area; rather, it groups all riparian systems under one category ("Streams/Rivers", which includes the associated riparian area). The CWCS notes that Arizona had approximately 267,000 acres of riparian vegetation alongside perennial waters as of 1993 (Valencia 1993). This assessment does not include areas associated with ephemeral streams.

Fremont cottonwood and willows both occur at mid-elevation (3280-6560 feet), along with other vegetation such as the Arizona sycamore, velvet ash, Arizona walnut, and a number of herbaceous plants (CALS 2010). The area where this habitat type can be found has decreased over time. The Paria Canyon is one area where these cottonwood-willow systems still exist. Birds found in this area include bald and golden eagles, swallows and flycatchers, and great blue herons. Coyotes, jack rabbits, and occasional bobcats are also found. Desert bighorn sheep were reintroduced in the 1980s, and some mule deer may also be seen. Lizards and amphibians such as the chuckwalla and the red-spotted toad are commonly observed here as well (BLM 2010).

6.3.2 Mixed Conifer/Spruce Fir Forests

Mixed conifer and spruce fir forests were identified as an important habitat type. While not specifically delineated, this broad forest type is mentioned throughout the State CWCS, and is captured in the Montane Conifer and Alpine Conifer habitat type descriptions. At lower elevations (Montane, 6000-9000 ft.), ponderosa pine is the dominant species. Other fir and pine species are also found at lower elevations along with deciduous tree species such as Douglas fir, white fir, and limber and southwestern white pine. At higher elevations (Alpine, 8000-9000 ft.), Englemann and blue spruce can be found, along with corkbark, white, and Douglas firs, mixed in with bristlecone and limber pine. As of 1999, there were 19.4 million acres of forested land in Arizona, with 56% of that area classified as piñon-juniper or juniper stands, 16% as ponderosa pine, about 1% each of Douglas-fir and Engelmann spruce, and the remaining acreage included a number of other deciduous trees and miscellaneous tree types (O'Brien 2002).

These forests are found in several ecoregions across the state, including: the Colorado Plateau (e.g., Kaibab Plateau) in the northern part of the state; in the Arizona-New Mexico Mountains area (e.g., higher elevations of the White Mountains and San Francisco peaks); in higher elevations within the Apache Highlands North ecoregion (Northeastern Arizona); and small areas within the Apache Highlands South ecoregion in southeastern Arizona (e.g., Sky Islands).

A number of important species depend on conifer and spruce fir forests for habitat, including: the Mexican spotted owl, northern goshawks, Clark's nutcracker and other bird species; Chiricahua leopard frog and tiger salamanders; tassel-eared and red squirrels, and other small mammals; ocelot and jaguars; and talussnails.

6.3.3 Sonoran Desert

The Sonoran Desert was identified as a system of particular concern in Arizona. The Arizona CWCS identifies 12 habitat types which are found within the Sonoran Desert ecoregion: Lower Colorado Sonoran Desertscrub, Upland Sonoran Desertscrub, Chihuahuan Desertscrub, Mojave Desertscrub, Semidesert Grassland, Chaparral, Madrean Evergreen Forest, Great Basin Conifer Forest, Human-dominated landscapes, Wetlands/Springs, Streams/Rivers, and Lakes/Reservoirs.

According to the CWCS, this complex and diverse ecoregion covers 22.3 million acres and ranges in elevation from 70 to 5900 feet. Several major metropolitan areas (including Phoenix and Tucson) occur in this ecoregion. Saguaro and cholla cactus vegetation are abundant, and depending on the specific habitat area are joined by creosote bush and bursage (lowland Sonoran), leguminous trees and succulents (upland Sonoran), as well as small pockets of grasslands, chaparral, and woodlands. A number of bird Species of Greatest Conservation Need (SGCN) utilize riparian areas within the Sonoran ecoregion, including: Swainson's Thrush, the Western Yellow-billed Cuckoo, the Red-naped sapsucker, and the Cactus Ferruginous Pygmy-Owl. Several amphibian, mollusk, bat, and reptile SGCN species are also found throughout the area. Examples of these species include the Lowland Leopard Frog, several species of tallusnails, the Mexican Long-Tongued bat, and the Sonoran Desert Tortoise. Desert bighorn Sheep and the Sonoran Pronghorn can also be found in the Sonoran Desert.

6.3.4 Southeastern Grasslands

Workshop participants identified grasslands as a broad shared priority. Rather than selecting a specific grassland type (e.g., Plains and Great Basin, semidesert, subalpine), participants in the small break-out group exercise chose to identify a specific geographical region, Southeastern Arizona, as the area of focus. This area includes some steep elevational gradients, and distinct animal and plant species.

In the CWCS, the Apache Highlands South ecoregion appears to coincide with southeastern Arizona. The two grassland habitat types present in this ecoregion, as identified in the CWCS, include semidesert grassland (61.0% of acreage) and Plains and Great Basin Grassland (2.0%). Other habitat areas found in the Apache Highlands South, some of which either historically and/or currently contain some remnant grassland, include the Madrean Evergreen Woodland (18.1%), Chihuahuan Desertscrub (15.3%), Interior Chaparral (2.1%), Montane Conifer Forest (1.3%), and some Great Basin Conifer Woodland (0.2%) and Subalpine Conifer Forest (0.05%). This region has been and continues to be under a number of pressures, and therefore the current-day grassland system in Southeastern Arizona no longer appears as it once did.

In the semidesert grassland habitat, invasion of non-native species such as Lehmann lovegrass has replaced many native grass species. Some SGCN species for semi-desert grasslands outlined in the CWCS include the Chiricahua Leopard frog, numerous bird species (e.g., Crested Caracara), bats (e.g., Lesser Long-nosed bat), ocelots and desert bighorn sheep, and a variety of snakes, lizards and turtles (e.g. Desert Box Turtle). The Plains and Great Basin Grassland, although small in acreage in this region, is important for pronghorn and grassland birds. Bird species of greatest conservation need noted in the CWCS include Botteri's Sparrow, Baird's Sparrow, Arizona and Western Grasshopper Sparrows, Sprague's Pipit, Ferruginous hawks, Olive-sided Flycatcher, the American Peregrine Falcon, Bald Eagle, Sage Thrasher, and the Azure Bluebird. According to the CWCS, the Madrean Evergreen Woodlands historically contained open oak woodlands with native grasses, and some work is being done to restore sustainable grazing and natural fire regimes to the area, which should encourage some grassland recovery. Currently, vegetative species such as juniper that are not adapted to the natural fire regime are present. Numerous SGCN species are found here, including amphibians (e.g., Sonoran Tiger Salamander), birds (e.g., Apache Northern and Northern Goshawks), bat and small mammal species, jaguars, and reptiles (e.g., Arizona and Yellow Mud Turtles).

6.3.5 Springs and Cienegas

Workshop participants identified wetlands / springs / seeps as an important system in Arizona. Furthermore, in the small break-out group exercise, members identified springs / seeps/ cienegas as a more specific priority.

The CWCS describes wetlands / springs / seeps as a broad system category that occurs throughout the state of Arizona. This broad category includes perennial and intermittent wetlands, free-flowing springs and seeps, natural cienegas (marshes), tinajas (ephemeral pools), and stock tanks. According to the CWCS, these areas are thought to be greatly reduced from their prehistoric conditions; there are approximately 6,400 mapped springs in the state, and only a few remnant cienegas. Diversions for livestock and human use and drought are two major contributors to lost habitat.

The condition and quantity of springs, seeps, and cienegas, and the plants and animals they support, vary by ecoregion and are described in the CWCS. In the Apache Highlands South ecoregion, wetland, spring, and seep areas are rare but important. For example, the Arivaca Cienega and Creek area located within the Buenos Aires National Wildlife Refuge supports over 300 bird species, 50+ reptile and mammal species, and nearly 60 mammal species including mule deer, pronghorn, and javelina (USFWS 2010). Riparian habitat in this ecoregion provides needed corridors for migratory birds, pollinating insects and bats. In the Apache Highlands North, the CWCS notes that long-term drought and poor watershed condition have contributed to dry spring and seep areas. In the Arizona-New Mexico Mountains, the condition of springs, seeps and wetlands condition varies; some are protected while others are severely degraded. In the Colorado Plateau, springs and seeps are associated with major canyon systems, although few major wetlands still exist in this region. Remaining areas provide habitat for federally-listed plants, and invertebrates such as springsnails and ambersnails. In the Mojave Desert, springs and seeps are still common in the major mountain ranges but development and grazing pressures are generally forcing this habitat type to decrease in area. In the Lower Colorado River area of the Sonoran Desert, cattail and bulrush marshes are present and provide habitat for marsh species such as the Yuma clapper rail and California black rail.

7.0 Conceptual Modeling

7.1 Introduction

Previous sections of this report have discussed how stakeholders can work together to identify priority conservation targets, and why adaptive management is essential to managing wildlife in an uncertain climate future.   Once shared priority conservation targets have been identified, conceptual models can be used to show linkages between the targets, threats and stressors, and conservation actions. Such conceptual models can be important tools in conservation planning, in the development of assessment and monitoring programs, and in the identification of opportunities for future management and research activities.

Conceptual models document a specific version of the hypotheses about how wildlife survive and persist and how the ecological systems that they depend on function. They describe in graphical or narrative form the ecological system subject to management, allowing inference about how that system works. A model of riparian vegetation function on the Colorado or Salt Rivers, for example, describes the relationships between vegetation and the wildlife that depend on it, the hydrological and other physical processes that affect those relationships, and the role of human activities in disturbing and sustaining the system. The Arizona CWCS uses conceptual models to illustrate the relationships between ecosystems, threats, and actions that have been observed by state wildlife biologists and their conservation partners. The models thus represent the current status of knowledge among state wildlife managers regarding these conservation targets.

Conceptual models that explicitly link targeted wildlife species to essential resources and environmental stressors naturally lead to the identification of ecological factors that need to be targeted by management actions and candidate environmental parameters that should be measured by monitoring efforts. In the formulation of a conceptual model, the combinations of environmental influences that drive ecological systems often become apparent. This in turn allows planners to rank the importance of different attributes in determining system function, affecting the status and trends of wildlife populations. Using conceptual models helps us to assure that our current and future management actions target the correct ecosystem features and attributes, and to maximize the likelihood that management under the CWCS will produce desired outcomes. In utilizing conceptual models, this CWCS seeks a clear articulation of what is known about wildlife and the ecological systems that support them, systems which are subject to management, assessment, and monitoring. These activities produce explicit descriptions of how the state's land and wildlife managers believe their targeted ecosystems and wildlife operate. The process of developing species- and ecosystem-specific conceptual models has proven to be an effective way of exposing differences of opinion regarding the essential relationships between desired wildlife species and the diverse environmental drivers that influence them, as well as the management actions that are intended to benefit them. The models also highlight interactions between species on the planning landscape.

Conceptual models serve to identify key system elements, including targeted species, the structure and composition of the ecosystem in which they exist, and the processes that link those species with other biotic elements and physical attributes of the system. The models describe how the system may be impacted by environmental stressors (e.g. disturbances, perturbations) generated by both natural and anthropogenic sources, and how management can intervene to reverse undesirable ecological conditions or wildlife population trends. These descriptions variously take one or more forms, which include box and arrow diagrams, cartoons that are accompanied by narrative descriptions, simple linear pathway illustrations, or straightforward text descriptions.

Several important principles were considered in the formulation of the conceptual models contained in this report. First, because we do not fully understand how the ecosystems that support our wildlife operate, our models are nearly always incorrect in one or even a number of ways. Repeated refinement of our models is necessary as new information or new understandings of ecological interactions becomes available. Nonetheless, each iterative model tends to reduce uncertainties that confound our management efforts. Second, as adaptive management efforts become increasingly effective, the conceptual models will improve. As we learn more about how systems function, our management will become more effective and efficient. Third, the conceptual models that we generate are essential to learning under the CWCS; they are making our understanding of Arizona's natural systems work available for review and discussion, thus they help us to identify areas of key uncertainty, thereby stimulating efforts to gain the information necessary to make better management decisions. In addition, our conceptual models appear to be serving as a gateway to the development the predictive quantitative wildlife and ecosystem models that we need to provide essential management decision support.

7.2 Exercise: Conceptual Modeling in Arizona

7.2.1 Threats and Stressors on the Targets

The group used a simple exercise to develop a series of conceptual models for the set of high-priority monitoring targets that they had identified earlier from the Arizona Comprehensive Wildlife Conservation Strategy. For each target, workshop participants brainstormed lists of potential threats and stressors for that particular target. *Threats* are actions or processes that have the potential to cause direct harm to a particular target, while *stressors* are actions or processes that cause stress to the target. Next, lists of potential *conservation actions* were brainstormed that either directly benefit the target or counter one or more of the threats and stressors.

Threats and stressors were then sorted into two groups: *direct threats and stressors*, which operate directly on the target; and *indirect threats and stressors*, which operate on the target through an intermediary. For example, off-highway vehicles (OHVs) act directly on the landscapes of the Sonoran Desert, and would therefore be considered a direct threat to the Sonoran Desert. By comparison, recreation policies and human attitudes towards the desert would operate indirectly through their influence on OHV users, and thus would be seen as indirect. The stakeholder working groups agreed by consensus on the classification of individual threats and stressors into the direct or indirect categories.

For purposes of constructing the conceptual model, the threats and stressors were written on small "Post-It" notes and arranged around a central "Post-it" note listing the conservation target which was placed at the center of a large sheet of poster paper.

The next step was to draw arrows between threats/stressors and the conservation target, and between the various threats and stressors to show patterns of interactions between the threats/stressors and the target. The arrows indicate causal pathways, with the item on the straight end of the arrow causing some form of change in the item on the pointed end of the arrow. Reciprocal relationships are possible (arrows pointing in both directions between two stressors, for example), as are loops. Arrows were drawn by the facilitators once the project stakeholders achieved consensus regarding the direction and placement of each arrow.

The group identified the three to five most significant threats/stressors for each target, recognizing that different threats and stressors operate at different temporal and spatial scales and that certain threats are likely to be more significant for particular conservation targets than others.

In the last step of model construction, the individual conservation activities were written on "Post-It" notes and these notes were added to the model, with arrows showing how those conservation activities would affect particular threats/stressors or the target itself. Most conservation activities map to one or more of the threats/stressors; a few map directly onto the target itself. An example of a conservation activity that addresses a threat or stressor would be the removal of invasive vegetation. An example of a conservation activity that addresses the target directly would be the augmentation of a population of a particular fish species through translocation, when the fish species itself is the target.   Again, the arrows were drawn between conservation activities, threats/stressors, and the conservation target once the project stakeholders had achieved consensus on the direction and placement of each arrow.

7.2.2 Desired Condition Statements for the Targets

For each target, the group developed a statement of desired condition through a brainstorming exercise. The description was aimed at field biologists who would need to be able to assess through site visits the relative condition of a particular site or area of conservation/management interest. Attributes that were commonly listed for ecosystem-scale targets include:

- Soil type and condition

- Characteristic vegetation (e.g. presence, composition, age structure, density, patchiness)
- Intact understory or herbaceous layer
- Full suite of associated vertebrate species, with emphasis on birds
- Absence of key stressors (invasives, roads, vehicle traffic)
- Disturbance regimes within expected parameters (fire, flooding, etc.)

7.3 Conceptual Models for Priority Ecosystems in Arizona

During the September 2010 workshop, five conceptual models (Figures 1-5), one for each target ecosystem identified by the group, were developed through the exercise described above. As outlined, each model includes a target system, a suite of threats or stressors (direct and/or indirect), and possible conservation actions to alleviate the threats or stressors.

The conservation target is shown in a circle at the center of each model. Around the circle is a ring of boxes containing the names of stressors or threats affecting the system, and ovals containing possible conservation actions. The arrows indicate cause-and-effect relationships; the factor at the blunt end of the arrow affects the target or factor at the pointed end of the arrow. A key to understanding components of the conceptual models:

- ***Direct stressors*** (square-shaped and typically placed closest to the target) have a solid arrow leading from them. The thickest arrowheads indicate the most impactful or priority stressors/threats to the target.
- ***Indirect stressors*** (square-shaped typically placed farther from the target) have a dashed line leading from them.
- ***Conservation actions*** (oval-shaped and typically placed on the outer ring of the circle) have a solid line with an open arrowhead leading from them.

Note that some stressors can have both *indirect* and *direct* effects. For example, in Figure 1 drought has a direct affect on the Mixed Conifer/Spruce Fir system as well as *indirect* affects through the stressors fire and insects/disease.

7.3.1 Mixed Conifer-Spruce Fir System

The first model (Figure 1) depicts the direct and indirect threats, as well as conservation actions for the mixed conifer-spruce fir system. Before disbanding into smaller breakout groups, the full group worked together to create a sample conceptual model for this system. They brainstormed 11 major threats and stressors, of which six have direct impacts to the system including: ungulate grazing, insects/disease, temperature and precipitation changes, drought, and fire. Of these, fire and drought were considered the most impactful or priority threats. Possible conservation actions were suggested for some but not all of these threat/stressors (i.e., seven of the 11) including recreation management to address OHV use and dispersed camping, Integrated Pest Management to address insect outbreaks, and fuels reduction to address erosion and fire.

7.3.2 Cottonwood-Willow Riparian System

The second model (Figure 2) illustrates the relationships between Cottonwood-Willow riparian ecosystems, their major threats/stressors, and potential conservation actions. Workshop participants identified 18 threats to this system, a majority which are direct impacts including fire, invasive species, and drought. This model also highlights the significant, direct impacts of insufficient water quantity and/or quality on the system, resulting from activities such as water diversion and damming, hydrological modifications, and groundwater pumping. Participants felt strongly that human population growth exacerbates and indirectly impacts all of the stressors to this system. The group discussed 14 conservation actions that are being taken or could be taken to ameliorate the threats/stressors, including the need for a general increase in public education efforts.

7.3.3 Springs and Cienegas

Figure 3 illustrates the complex relationship between threats/stressors affecting Springs and Cienegas ecosystems and possible conservation actions. Of the 12 threats/stressors identified in the small breakout group, groundwater pumping, grazing (both wildlife and livestock), invasive species, and development and diversion of springs were considered most influential on the system. Conservation actions of note that are being taken or could be taken included fencing, spring restorations (returning springheads to their natural state), and land acquisition. Others suggested revising management strategies for recreation, water, grazing, fire, forest and woodlands, and invasive species. Participants also felt public education should be used to address all threats/stressors.

7.3.4 Sonoran Desert

Figure 4 shows the many stressors and threats on the Sonoran Desert ecosystem, which occupies much of southern Arizona and is home to a high percentage of the human population in the state. Stressors that were highlighted during the workshop as having the most influence in this system included: climate change, fragmentation, land conversion (development), invasives (which is coupled with fire, but with invasives serving as the primary stressor), and groundwater pumping. Border activities were also discussed, as were mining, energy, and land development. Conservation actions that are being taken or could be taken to ameliorate these stressors included invasives control, grazing management, and maintenance of connectivity between protected areas. The group identified better land use planning as a priority activity that would help address issues with agriculture, mining, energy and urban development. Other critical conservation actions that would benefit the Sonoran Desert as a whole included public outreach, enforcement, and public/private partnerships.

7.3.5 Southeastern Grasslands

Though grasslands are found throughout Arizona, the group decided to focus on the Southeastern Grasslands (Figure 5) in part because the region already has an ongoing, multi-agency partnership, the Southeastern Arizona Grasslands Working Group. Altered fire cycle, over-grazing and fragmentation were among the leading stressors identified by the small breakout group. Most of the stressors listed were direct rather than indirect. Conservation actions that were highlighted included grazing and fire management, treatments for vegetation, fencing, wildlife corridors, water rights protection and acquisition, land use planning, conservation easements, and border activity and migration. Discussion in the small group regarding stressors and actions was rooted in a desire to preserve the system as it is currently, as opposed to trying to return it to its historical appearance and structure. It was noted that the area, a key habitat for many species, has a decent water cycle and a good capacity to recover. Ownership of southeastern grasslands was discussed as a barrier to management action because much of the land is privately owned. Similarly, limiting access was discussed as a potential conservation action. However, the group noted that border issues are complicated and extend beyond the jurisdiction of wildlife managers to other state and federal agencies charged with law enforcement and border control.

8.0 Indicator Selection

8.1 Overview

The use of indicators to assess the performance of this CWCS is not a shortcut – it is necessity. Given resource constraints, only a relatively small number of wildlife species and ecosystem parameters can be monitored, assessed, or measured. The default for monitoring efforts is data collection that targets a subset of the species, habitat attributes, and landscape features and vegetation conditions of conservation concern. Monitoring under the CWCS requires identification of a subset of candidate ecological features that are useful surrogates for, or indicators of, the greater array of organisms and other environmental attributes and processes that wildlife action planning seeks to manage.

This plan seeks reliable, cost-effective measures of the status or trend of wildlife and environmental phenomena that are scientifically or logistically challenging to measure directly. An effective indicator species is recognized here as a species "so intimately associated with particular environmental conditions that its presence indicates the existence of those conditions" (see Patton 1987). Indicator species more generally meet the definition from Fleishman and Murphy (2009) as a “scientifically reliable, cost-effective measure of the status or trend of an environmental phenomenon, which is not scientifically or logistically tractable to measure directly.” Bringing necessary rigor to the indicator selection process is challenging; it requires a clear articulation of the purposes for identifying an indicator or indicators, the assumptions used in the indicator selection process, and the exacting circumstances for which the indicator will be used.

An emphasis on direct measures of wildlife abundances and habitat conditions will inevitably dominate monitoring in wildlife action planning. A comprehensive monitoring program will use some limited number of wildlife species for purposes of guiding management actions targeting a larger group of species. And, monitoring will include indicators that collectively measure compositional, structural, and functional attributes of vegetation and other components of ecological systems at a variety of spatial scales (see Lindenmeyer et al. 2000, Noon and Dale 2002). The monitoring parameters that are directly measured may include aspects of the demography, life history, or behavior of an indicator species. These indicator measures are prototypical “fine-filter” measures of ecosystem health or integrity (Hunter et al. 1988, Haufler et al. 1996, Noon 2003).

Some species selected for measurement are intended as "coarse-filters" -- or broad measures -- to provide insights into the status or trends of species that are not measured. ***Structure-based indicators*** are measured at local and landscape scales. Structure-based indicators include ecosystem elements, such as vegetation structural complexity, inter-patch heterogeneity, and connectivity at the landscape level. ***Function-based indicators*** rely on direct measures of processes and their rates, including primary productivity, nutrient cycling, water flows, and similar ecosystem process parameters. Both structure and function indicators serve as “coarse filter” measures of ecosystem condition.

8.2 Purpose

In service to the CWCS, indicators can be viewed as serving at least three purposes:

1) ***Early warning indicators***, which provide early warning of specific stressors that are impacting key ecosystem processes;
2) ***Population surrogate indicators***, drawn from species whose status and trends are indicative of the status and trends of other species; and
3) ***Biodiversity indicators***, a species or taxonomic group that serves as a surrogate for multiple other taxonomic groups.

Characteristics of effective indicator species include their sensitivity to environmental change, variability in responses, degree of ecological specialization, residence status, population dynamics, and more (Landres et al. 1988).

8.3 Process

Several sequential steps are necessary to inform a defensible indicator selection process, and are being employed in developing target-directed monitoring program:

1) Programmatic goals and planning criteria that are used to determine whether those goals are explicitly stated; from the overarching goals explicit, quantifiable objectives are identified.
2) Conceptual model or models are built describing the target ecosystem and its wildlife, illustrating the species involved, the essential ecosystem attributes that affect those species, emphasizing stressors, both natural and human-generated, which impact the targeted species and their habitats and will require management responses.
3) Opportunities and options for management actions are listed.
4) A comprehensive candidate indicators list is drawn from the list of wildlife species that are supported by the targeted ecosystem and from the landscape features and ecological attributes of the system that contribute to habitat for those species. Candidate indicators are drawn from available ecosystem attributes at multiple spatial scales. These are inclusive, such as physical environmental parameters and biotic parameters, including potential structural, compositional, and process variables.
5) Indicator measures are chosen using explicit criteria that are consistent with assessment goals. These measures are those for which a causal chain can be identified that link the parameter to the environmental phenomenon of immediate concern. Measures can be found in any component (e.g. drivers, linkages, outcomes, and endpoints) of the conceptual models.
6) Sampling schemes are developed using estimates of expected values (or trends) of selected performance measures to assess the state of those measures following management actions.

Monitoring program designers identify indicator measure values that will trigger management responses, and fully consider issues of spatial context (including heterogeneity), temporal resolution and extent, and sample size and units of measure. Monitoring design elements reference back to program and project goals, and conceptual models are necessary tools for developing a sampling scheme that will detect pertinent changes in performance measure and ecosystem attributes. Sampling frequency and replication needed to detect trends in indicators should be based on historical data where possible and power analyses that interrelate the percentage change that can be detected, variance of the parameter, and replication in space and time.

8.4 Exercise: Selecting Indicators in Arizona

In this exercise, stakeholders identified potential indicators (key rates, states, or processes) that could be monitored by managers in “real time.” These indicators would allow managers to track the condition of each priority conservation target, the effects of the threats and stressors on the target, and the effectiveness of various conservation activities intended to benefit the target.

For each box in the conceptual model (targets, threat/stressors, actions), the stakeholder working groups brainstormed lists of potential indicators (e.g. metrics of status, trends, or key processes and rates). An initial question was posed to the group: "What would you want to know about this target/stressor/action in an ideal world?" This exercise resulted in a lengthy list of potential indicators (i.e. targets, threats/stressors, actions) for each of the boxes in the conceptual model. [For each of the potential actions, we also asked whether or not there was anyone in the state actually pursuing that course of action, and listed the names of agencies and/or programs engaged in the specific types of activities identified in the conceptual model.]

For each potential indicator, participants had a brainstorming session to identify group(s) (e.g. state agencies, federal agencies, tribes, NGOs, or academic biologists) that are currently collecting pertinent data within the state at appropriate temporal and spatial scales to adequately inform land and wildlife managers about the condition of the target or the effects of stressors and the effectiveness of conservation activities. This first filter served as an important criterion for reducing the number of prospective indicators to a more manageable number.

After the workshop concluded, the Heinz Center used information gathered during this brainstorming session to create a series of charts listing a series of potential indicators for each of the conceptual models. The charts also include information about monitoring programs that are currently collecting data associated with these indicators. By collecting and combining data from these various sources, the state of Arizona will be able to develop a robust picture of overall ecosystem health in each of these high priority ecosystems. These charts are included in the Appendix.

9.0 Towards an Integrated Sampling Design

Because resources for monitoring are extremely limited within every state and federal agency, it is essential for managers to attempt to derive as much benefit as possible from existing monitoring programs. Current monitoring activities in the United States are a patchwork quilt of projects and programs, each of which has been designed to answer a specific set of questions at particular spatial and temporal scales. Monitoring programs run the gamut from satellite-based approaches that examine changes in continental-scale variables such as ecosystem extent and landscape pattern, to very small-scale approaches focused on a single species at a particular site.

At the state level, many of the existing monitoring programs are narrowly focused on individual species. Among other reasons, this narrow focus can be a result of legal mandates, funding constraints, and state and federal programmatic requirements. Given the limited nature of monitoring resources, managers at both state and federal levels must begin to ask pertinent questions such as:

- How could we integrate and combine data across monitoring programs to tell us more about the factors affecting all species of conservation interest? or
- What other variables could I add for little or no cost to my existing monitoring program that would give me extra insights into the species and ecosystems that I manage? or
- How can we integrate data across multiple monitoring programs to provide us with a broader, large-scale picture of wildlife and ecosystem health?

One approach to improve efficiency and effectiveness of monitoring is the concept of an integrated monitoring framework. This concept has already been pilot-tested at a variety of scales by the USDA Forest Service and other conservation agencies. An integrated monitoring framework combines data from multiple independent monitoring efforts that are focused on tracking a diversity of species as well as monitoring ecosystem attributes such as vegetation condition, climate, and hydrology. Such a framework can take a variety of different forms depending on the questions that it is intended to address and the spatial and temporal scales at which managers need data in order to make decisions.

9.1 Basic Building Blocks

Integrated monitoring approaches are built using existing monitoring or sampling activities as basic elements or "building blocks." Some of the elements that are commonly mentioned by wildlife managers and monitoring experts as essential components of an integrated monitoring approach include:

- Vegetation monitoring (composition, extent, structure)
- Monitoring of key vertebrate species, especially species that track important processes, states, and rates
- Monitoring of water quantity and quality (for aquatic systems)
- Monitoring of climatic variables
- Monitoring of the frequency and magnitude of disturbance events

Other building blocks can be added depending on the particular system of interest (e.g. a component measuring fluvial geomorphology could be added to monitoring efforts focused on riparian/riverine systems).

It is worth noting that information about animal populations, both vertebrate species as well as invertebrates, could potentially provide managers with data about any of the other basic "building blocks." Certain bird species, for example, only nest in areas that have a particular vegetation structure or species composition. Likewise, benthic macroinvertebrates are commonly used as indicators of the quality of aquatic systems, with certain species characteristic of intact systems while other species are characteristic of degraded systems. Changes in the phenology or timing of life history events in animal species (and plant species too) are frequently discussed in the scientific literature as "early warning" indicators of global climatic change. And many animal species are sensitive to various forms of disturbance and are found in reduced numbers in disturbed areas. Similar arguments can also be advanced for plant species, many of which are also sensitive to various environmental threats and stressors.

9.2 Moving from Disparate Monitoring Efforts to Integrated Sampling

In Arizona, the Department of Game and Fish and its partners already have a large number of individual species- or taxon-specific monitoring efforts deployed across the state. Such efforts could potentially serve as building blocks for an integrated approach. However, since these monitoring programs were generally designed to assess status and population trends in individual species or suites of closely related species, there may be incompatibilities between the individual monitoring programs (for example having different temporal or spatial sampling schemes) which could in turn lead to problems with comparing data across multiple monitoring programs. To build a more robust picture of ecosystem health and environmental condition, managers will want to improve coordination across the existing programs and move towards compatible data collection efforts.

9.2.1 Steps to Integrate Monitoring

Though improving coordination may seem like a daunting task to agencies already strained in their capacity, the process can be made easier by using systems already in place. The literature on integrated sampling suggests that there is a series of steps by which multiple disparate monitoring activities can become better integrated across a broader landscape, including:

- **Define the landscape of interest**. Generally the landscape of interest can be defined by a large-scale vegetation community, ecosystem, watershed, or by a unit of human geography such as a county, region, or major municipality.
- **Map the existing monitoring activities**. The agency and its partners can map the localities at which data are currently being collected using paper maps or, better yet, Geographic Information Systems (GIS). For each point, sampling transect, or sampling array, it is useful to know what data are being collected at that site and at what frequency.
- **Identify areas of overlap** where monitoring activities might be combined or integrated. Look for areas on the map where monitoring activities are already

occurring within close physical proximity. Determine whether or not there might be efficiencies in combining monitoring efforts at these sites.

- **Identify the desired temporal sampling frequency** and ideal spatial sampling density for each element, and for the system as a whole.
- Take the steps needed in order to **bring activities into a standard temporal and spatial sampling frame**.

9.2.2 Steps in Action

9.2.2.1 Mapping Existing Monitoring in Arizona

During the Heinz Center's September 2010 workshop in Phoenix, Arizona, a collaborative, stakeholder approach was used to identify existing monitoring sites for fish, wildlife, and plant resources within the Arizona portion of the Sonoran Desert, one of the five priority ecosystems chosen earlier in the workshop. Participants placed dots on a large map of the Sonoran Desert to indicate the location of monitoring sites in the Desert and its constituent communities in the southern portion of Arizona. Specific monitoring programs which were mapped included the sampling of fish and aquatic resources by Arizona Department of Game and Fish, monitoring of vegetation condition through the BLM Range Assessments, state and federal desert tortoise monitoring sites, and transects for the federal Breeding Bird Survey.

Mapping these sites is the first step towards determining the degree of overlap between the various monitoring programs and identifying portions of the landscape that are already being adequately sampled for key fish, wildlife, and plant resources.

9.2.2.2 Identifying Areas of Overlap

The next step involves determining whether any of these monitoring programs are in fact sampling at the same sites or same areas of the landscape, and whether it might make sense to integrate monitoring activities at these particular sites. Such comparisons can be done in the first approximation by simply inspecting the map of monitoring sites. Beyond this initial analysis, in-depth conversations are needed between program managers to discuss whether joint data collection activities are feasible. Targeted meetings between the individual monitoring program managers in the state would be a valuable next step towards assessing the possibility of joint data collection by the staff of particular monitoring programs.

9.2.2.3 Identifying Desired Spatial and Temporal Scales

Since we are interested in making larger-scale inferences about the condition of key species and resources across the broader Sonoran Desert landscapes, it is also necessary to determine whether the existing monitoring programs in the Sonoran Desert are collecting data at adequate spatial and temporal scales so that we can make these inferences. A statistical power analysis can be used to determine whether there are adequate numbers of sampling sites for each of the key species or ecosystem elements across the broader Sonoran Desert landscape, and whether sampling is being conducted at appropriate temporal intervals in order to provide managers with the information they need. In designing a spatially and temporally explicit sampling approach, managers are usually asked to start by identifying the degree or percentage of change they wish to detect, the level of error in measurements they are willing to accept, and also provide some basic information about the probability of detection for each species or resources. Bayesian statistical analysis can then be used to specify the number of sampling sites and the frequency of sampling that is needed in order to achieve the level of precision in measurements that is desired. This form of analysis is helpful if an agency or its partners has the capacity to add additional monitoring sites. Such an analysis can also be useful even when additional sites cannot be added, because it can help managers determine exactly what magnitude of change in species, resources, and ecosystems can actually be detected by existing monitoring efforts. Assistance in designing and implementing such an analysis can be provided by statisticians or USGS wildlife biologists.

Even in the absence of a formal statistical analysis, managers can make significant strides towards integrating monitoring programs simply by increasing the communication and coordination between administrators of individual monitoring programs within a defined geographic area. Significant steps forward can be made with simple activities such as adopting a compatible temporal sampling frame for monitoring activities. By bringing the timing of monitoring programs into alignment, managers can compare population trends across multiple species and begin to investigate how factors such as drought or changes in weather patterns may be affecting entire suites of species. Managers could also attempt to correlate patterns in species composition and abundance with the temporal and spatial distribution of known stressors. Such correlations can help identify the specific stressors that are directly or indirectly affecting species.

9.3 Putting the Elements Together: Site-specific Integrated Sampling Design for Multiple Taxa and Ecosystem Variables

Another way to combine multiple monitoring activities is to develop a site-based integrated “monitoring frame” that allows managers to collect data on a suite of species and ecosystem attributes at a single site. By combining multiple sampling activities at a single site, managers can directly compare data on species population trends across multiple taxa and compare these trends directly to other ecosystem attributes at the level of the individual site. The individual monitoring frames can also be deployed as repeated units using some statistically robust sampling approach (e.g. randomized design) across broader landscapes, which would allow managers to make inferences about changes in species and processes at the landscape or ecosystem scale. Monitoring frames can also be deployed across elevational and latitudinal gradients in order to investigate changes in species distribution and/or abundance that could be the result of climate change.

Components of a monitoring frame can also be incorporated into existing sampling efforts, for example by adding a vegetation monitoring component to existing avian species monitoring sites, or by adding riparian vegetation monitoring and avian species monitoring to existing fish monitoring sites. In the case of existing Arizona Department of Game and Fish monitoring programs, much of the sampling for riparian birds and native fish diversity occurs at the same site or sites which are in relatively close physical proximity to each other. Addition of riparian vegetation monitoring, water quality monitoring, and fluvial geomorphological analyses at these same sites would nicely complement the existing data collection efforts and provide managers with the ability to draw inferences about the effectiveness of management activities across multiple data sources. Such comparisons are essential for managers who wish to understand the relationships between changes in key ecosystem variables resulting from active management and species population trends.

Figure 6 shows a simple integrated monitoring frame which was originally designed for grassland or sagebrush communities in Utah. This frame incorporates a variety of data collection activities for different vertebrate taxa and vegetation structure at a single site. The green lines are vegetation sampling transects, based on the Bureau of Land Management's range assessment protocols which assess species composition, ground cover, and vegetation structure along a set of intersecting linear transects. The red lines are sampling transects for breeding birds and for large mammal scat sampling. The orange boxes are sites where Sherman traps could be deployed for small mammal sampling. And the blue circles are large-diameter pitfall traps for live amphibian and reptile sampling. With minor modifications, this sampling frame could potentially be adapted for monitoring a wide variety of terrestrial ecosystems. In forest ecosystems, for example, managers may wish to incorporate more traditional measures of stand density and structure as part of the vegetation monitoring component. Other forms of sampling could also be added to the basic framework (for example, small-diameter pitfall traps for ants and terrestrial beetles, or yellow pan traps for solitary bees).

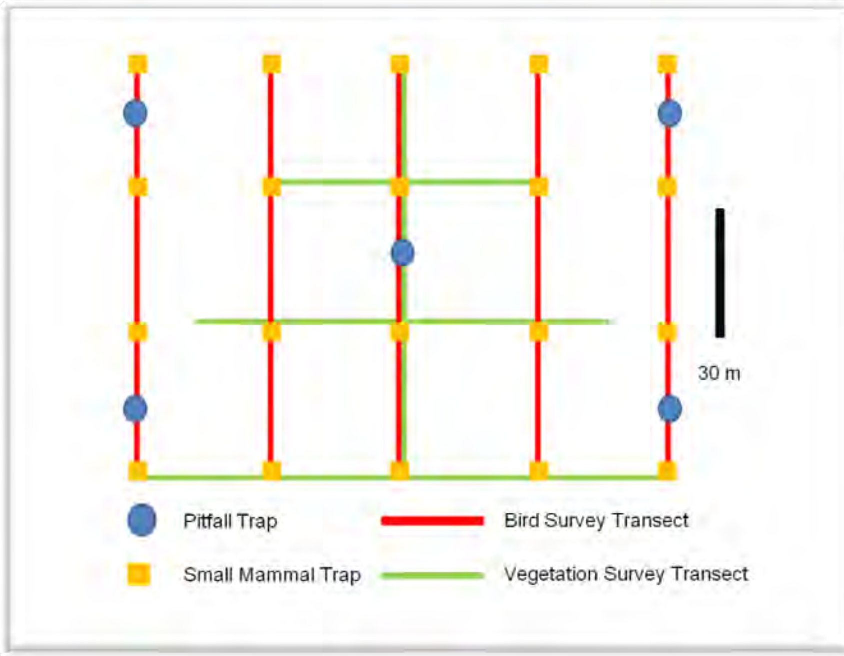


Figure 6: Integrated sampling design that includes sampling activities for multiple plant and animal taxa at a single site. This basic sampling unit may be replicated across broader landscapes or across elevational or latitudinal gradients in order to collect data at appropriate spatial and temporal scales necessary for answering particular questions related to wildlife and ecosystem management.

9.4 Towards More Robust Sampling

As monitoring programs in the state of Arizona continue to develop and mature, program managers will undoubtedly have opportunities to build stronger connections with other monitoring programs at the state, federal, and local levels, thereby enhancing their own sampling efforts in a variety of ways. The literature on monitoring of wildlife and ecosystems provides a set of general guiding principles that are worth considering whenever the opportunity to improve a monitoring program arises. Managers should be encouraged to "think outside the box" and explore creative ways to enhance and expand existing monitoring efforts. The following activities are some practical suggestions for improvements from the literature on monitoring programs.

9.4.1 Identify opportunities for collaboration and coordination across existing monitoring programs.

Managers may be able to achieve efficiencies by identifying specific sites and areas where multiple taxa of management interest could be sampled by a single field crew. Training an existing field crew to collect additional data may be less expensive than deploying an entirely new field crew to sample the same sites. Under certain circumstances it may be possible to add simple yet informative monitoring protocols to existing data collection efforts (e.g. protocols for assessing vegetation structure could be added to terrestrial bird monitoring efforts, or water quality monitoring could be added to existing fish sampling activities) which greatly improve the ability of managers to tell meaningful stories using their data. Even the simple act of synchronizing the timing of data collection can be beneficial. By collecting samples at similar times, managers can compare responses of species to known stressors and determine which species are most strongly affected by particular stressors. Managers can also track the effects of management activities across multiple species and determine which management actions are most valuable for addressing the effects of particular stressors on particular species.

9.4.2 Use statistical methods to identify under-sampled areas within the broader landscape.

Statistical approaches can be used to identify areas of the landscape that are currently being under-sampled by existing monitoring programs. New monitoring activities for the species in question could then be directed towards sites in the under-sampled areas. Such sites should contribute important new data on species distributions and population size, and also enhance our ability to make inferences about one or more species across the broader landscape. By adding additional sites, managers may be able to improve their ability to detect overall population trends, correlate species trends with trends in other environmental variables, and measure quantitatively the effectiveness of management activities. This form of analysis can be extremely valuable in identifying specific sites where new monitoring activities could take place if/when additional resources became available.

9.4.3 Add sites along elevational and latitudinal gradients, in order to track the effects of climate change on wildlife and other important natural resources.

Current projections suggest that the distributions of many wildlife species are expected to shift northward and upward along latitudinal and elevational gradients. By ensuring that a given sampling design includes sites distributed along these gradients, managers should be able to determine whether or not the distributions of species of management interest are in fact shifting, and whether these shifts might be associated with global climate change.

9.4.4 Invest in permanent "sentinel sites" where long-term monitoring will occur.

There is great value for wildlife and natural resource managers in establishing long-term monitoring programs that will give managers information about trends in species populations and key ecosystem variables. Long-term data sets have been very helpful in analysis of large-scale phenomena such as global climate change or changes in vegetation communities. Managers may wish to establish permanent "sentinel sites" in their state where a variety of monitoring data will be collected over long-term (decadal or longer) scales.

9.4.5 Add new monitoring targets sparingly and only when there is a clear management imperative or other compelling reason to do so.

New monitoring programs are expensive and require significant investments of staff time and resources. Whenever possible, managers should look for efficiencies in existing monitoring programs. This means attempting to address new and emerging concerns using existing resources (staff time and funding). A good example of this approach would be the incorporation of climatic monitoring data into existing programs for riparian birds and riparian vegetation.

10.0 Data Management

A variety of agencies and organizations use different methods for wildlife management and monitoring activities. The data captured through these activities is ideally meant to inform management in an adaptive management context. However, through their discussions at the Arizona workshop, wildlife managers identified a number of challenges in using data in an adaptive management context. This chapter provides an overview of various data collection and data sharing efforts described by Arizona workshop participants, as well as a discussion of some of the challenges participants face.

10.1 Review of Existing Methods for Data Management

The final day of the workshop included important discussions on data-related issues, including data use, archiving of data, and data sharing. Workshop participants were asked to describe the data collection and data sharing efforts carried out within their agency or organization. Responses shared during this session are described below.

10.1.1 USDA Forest Service

The type of data collected by USDA Forest Service staff in Arizona is in some ways driven by the need for a management response; however specific interests and project-level needs are also factored into the program development. Data collected is stored on a main corporate database in DRO. Data is shared with regional offices and other Arizona forest managers, partners, and biologists; and the Agency also provides data upon request. In addition they have a formal data sharing agreement for terrestrial and aquatic data with ENRIS.

10.1.2 Arizona Bureau of Land Management (AZ BLM)

Data collection at the Arizona Bureau of Land Management office is issue-specific, relevant to a Resource Management Plan (RMP), use permit, or National Environmental Policy Act (NEPA) process or determination for resources managed by BLM. In addition to this, some opportunistic data gathering occurs when possible. The agency is working to address its data collection priorities, which have historically been influenced by individual agency biologists who steer data collection based on their specialties or interest areas. This can allow for inconsistencies in monitoring activities and goals when staff or monitoring needs change. BLM is working to identify core data that should always be collected and maintained regardless of personnel changes and personal interest.

Agency wildlife data is compiled in both paper and electronic format, and they are gradually converting to an entirely electronic format. For example, the Safford field office has entered roughly half of its data into the Vegetation Monitoring Analytical Program (VMAP) database system.

BLM stores and maintains wildlife data locally at their individual field offices (e.g., for instance their Rangeland and Fire groups each have individual databases). However, BLM is working to bring data together, for instance the Desert Managers Group is attempting to pool landscape-level data; and Frank Quammen at the BLM Data Center in Denver, Colorado is working to combine BLM databases that contain a variety of environmental information. The Arizona BLM anticipates that the new BLM Assessment, Inventory, and Monitoring (AIM) Strategy, intended to standardize data collection and retrieval so that it is comparable over time, will be a useful tool for synthesizing and aggregating data from the field office level to regional, state, and even national levels.   Currently, the agency's National Operations Center (NOC) is looking at a platform to house the data through the AIM program.

BLM shares its data with federal partners, and also participates in a data sharing agreement with the Arizona Game and Fish Department (AZGFD), for example by submitting data to AZGFD's Heritage Data Management System. BLM also provides data to the BugLab, a cooperative venture between the U.S. BLM and Utah State University, that processes and houses data from watershed monitoring programs on public land for multiple states. Generally the data shared by AZ BLM does not go beyond sensitive species or threatened and endangered species information.

10.1.3 Arizona Game and Fish Department (AZGFD)

Much of the data collection for the Arizona Game and Fish Department is driven by its sources of funding, so the extent of collection varies. Certain programs have a large amount of data, while other newer programs have less. In many cases, AZGFD data is housed within individual work units rather than a central database, although the agency is working towards centralized data management as a goal.

The agency shares certain data with outside partners, including data submitted to the Integrated Wildlife and Sport Fish Database (Southwest ReGAP); as well as data shared through internal AZGFD databases such as the Heritage Data Management System, which receives input from all partner agencies for certain species (HTMS), and the CWCS tool, an Enterprise, geo-referenced database system currently in development that includes documentation of threats, landscapes, species, and vulnerability criteria. Additional AZGFD databases include:

Database	Description
Big Game Database	Houses big game species data from annual flight surveys, and is used to generate hunting recommendations (e.g. hunting limits). Because it uses GPS it could eventually be utilized to look at ecosystem health.
Bat Database	The bat database is a three–year effort by AZGFD to compile regional bat data into one master database.
Breeding Bird Database	A ten-year effort that is frequently used by partners.
Coordinated Bird Monitoring Projects Database	Access database containing data from coordinated bird monitoring projects. Currently not accessible to partners.
Important Bird Areas (IBA) Database	Developed in partnership with The Audubon Society, this is a publicly accessible database often used by land managers that houses over 100,000 records representing various sites across the IBA network in Arizona.
Invertebrate Database	Forthcoming IMS database that will bring together existing spreadsheet data on: Spring and amber snails, including presence/absence, abundance, habitat associations, water quality, etc. Crayfish, including trapping data, sites, presence/absence, measurements, gender, habitat associations, etc. Currently more extensive for historical information (1995-2002).
Project-specific Databases	A number of project specific databases exist within AZGFD, for example one for telemetry work on elk road crossings and corridor projects run internally or with external partners.
Raptor Database	Workshop participants regarded it as a useful database however they had limited knowledge of its specific details.
Riparian/Herp Database	With an emphasis on frog data, this mature database also contains literature and museum records added to help understand historical patterns of change. The database was developed for inventory rather than adaptive management purposes, which presents difficulties when using it for management decisions (e.g. when evaluating what constitutes a frog population based on the data currently collected).
Road Kill Database	Contains data on animals killed along roadways

Sonoran Tiger Salamander Database	This database was designed specifically to inform management actions and to address threats and needs of the species. It is considered a flagship adaptive management database. Because there are limited resources, field staff are unable to visit all 300 Sonoran Tiger Salamander sites (i.e., they can only cover roughly 80 of 300); and the database helps AZGFD determine the best sampling schemes each year for the species. Field staff enter data directly into this database, including presence/absence, other species occurrence, and tiger salamander life history.
Turtle Database	This database is currently in development.

10.1.4 U.S. Fish and Wildlife Service Migratory Birds Joint Ventures Program

A number of joint ventures under the U.S. Fish and Wildlife Program's Migratory Bird Joint Ventures Program are advanced in their data handling. For instance, the Sonoran Joint Venture (SJV) Program across the Southwestern United States and Northwestern Mexico submits data to the Avian Knowledge Network (AKN)[6], a publicly available, open access database managed by Cornell University. SJV partners collect data using paper field sheets, and then transfer the information onto a spreadsheet form created by the AKN. The AKN also receives data from numerous bird monitoring projects such as the North American Breeding Bird Survey, Audubon Society's Christmas Bird Count, and other large programs. Cumulatively, this data sharing provides joint ventures access to more extensive monitoring information with which to inform their annual management plans. This is a model for adaptive management. Partners in Flight (PIF) Joint Venture is one such program that uses the shared information to create multi-national plans, as well as to inform individuals in the field, decision-makers, and director-level staff.

Another process in development is AKN's development of Decision Support Systems (DSS), which are interactive tools that integrate monitoring data, models, GIS information, and other related information. DSS are the next step in the adaptive management process, moving beyond simply data sharing toward a combined data and planning application for decision making. Bird observatories, PIF, and others are beginning to apply these tools, and Landscape Conservation Cooperatives (LCCs) are also discussing the use of decision support tools for their population objectives.

10.1.5 The Tohono O'odham Nation Department of Natural Resources

The Tohono O'odham Nation Department of Natural Resources Wildlife Program has been in existence for 10 years. They do not have data electronically stored, and are in the process of

[6] For AKN's point count module, they usually go through a node first like Great Basin Bird Observatory or the Rocky Mountain Bird Observatory, before sending data to AKN.

converting paper data sheets into electronic spreadsheets, with the goal of establishing a database within the next six months. Overall there is limited wildlife monitoring that occurs on their lands, although some species-specific monitoring (e.g., pygmy owls, lesser long nosed bats) has taken place, at times annually.

Data sharing is complicated due to tribal sovereignty issues, and typically data is only shared if obtained through a federally funded project. However, the Nation's Department of Natural Resources is developing a data sharing policy in the hopes of sharing data in the future. Currently, they work with the Arizona Department of Transportation on tortoise and pygmy owl surveys; and anticipate working with USDA FWS and the University of Arizona in 2011 when they begin an inventory project in the Baboquivari region. Also, the Cypress Copper Mine conducts pygmy owl surveys and lesser long-nosed maternity roost counts on Tohono O'odham lands, collecting data once per year.

10.2 Using Data in an Adaptive Management Context

The Arizona workshop discussions highlighted a number of challenges related to the actual use of wildlife and ecosystem data in an adaptive management context. These challenges are widespread and systemic in many agencies and organizations, and range from lack of funding, lack of staff, lack of appropriate technology, and a lack of understanding and support at higher levels within the organization.

In the past, technological limitations and database incompatibilities prevented organizations and agencies from combining or sharing data sets. However, current developments in web and database technologies are reducing or eliminating these impediments. Advances in technology are creating exciting new opportunities for wildlife and natural resource managers to implement adaptive management approaches. As new projects are funded, all data could be housed in a central database, so that the information remains accessible beyond the life of individual projects. Such a database might include information about habitat, species, and human dimensions data (e.g., recreational surveys). Analyses could then be based on a cumulative body of information and apply cross-cutting data analysis techniques to best inform program planning.

Policy changes are also needed at higher levels outside of the state. For instance, the regulatory apparatus of the National Environmental Policy Act (NEPA) and the funding mechanisms of the North American Wetlands Conservation Act (NAWCA), either do not require or pay for monitoring. Identifying dedicated streams of funding for wildlife monitoring, data archiving, and data analysis has the potential to benefit wildlife managers at local, state, and federal levels.

Workshop participants discussed the use of data for management and design of monitoring activities. Participants noted that monitoring activities are often the first casualties of reduced budgets. When decisions are made that affect monitoring programs, it is important to rely on whatever institutional knowledge may be available. By learning from previous experience and reviewing existing data and results, staff can identify the most (and least) successful techniques or strategies and avoid replicating past problems. Other identified roadblocks to successful monitoring included a lack of baseline data for certain key species or ecosystems. Even if data do exist, the data may be incomplete or insufficient to meet the manager's needs. Because of inadequate information, managers may be put in a position where they must follow their own knowledge and intuition rather than the accumulated institutional knowledge.

Improved reporting to high-level decision-makers at state and federal levels is critically important for the success of wildlife and natural resource management. It is important that managers understand what information the decision-makers above them are most interested in and try to collect data that will meet those needs.

Participants also recognized that many decisions in wildlife and natural resource management are not driven by data and information, and that politics and/or personal preferences often drive policies forward. Despite this reality, participants nonetheless recognized the importance of collecting scientifically credible data about the condition, status, and trends of wildlife and ecosystem resources. By collecting scientifically credible data on the condition of wildlife and natural resources, and monitoring the effectiveness of conservation activities, managers will be able to learn about "what works" from past conservation actions and use this information to develop sound management policies into the future.

11.0 References and Additional Resources

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Southwest Climate Science Center – The Southwest Climate Center is the fourth of eight planned regional Climate Science Centers—or CSCs-to be established by the Department. In October of 2010 it was announced it will be launched with the University of Arizona in Tucson.

The Southwest Climate Change Network - http://www.southwestclimatechange.org/

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Fire http://cals.arizona.edu/pubs/natresources/az1425.pdf

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Appendices

Appendix 1: Conceptual Models

Appendix 2: Lists of Potential Indicators and Monitoring Programs

Appendix 3: Workshop Participants List

Appendix 1:

Conceptual Models

Figure 1: Conceptual Model of Stressors/Threats and Conservation Actions for the Mixed Conifer and Spruce Fir System in Arizona

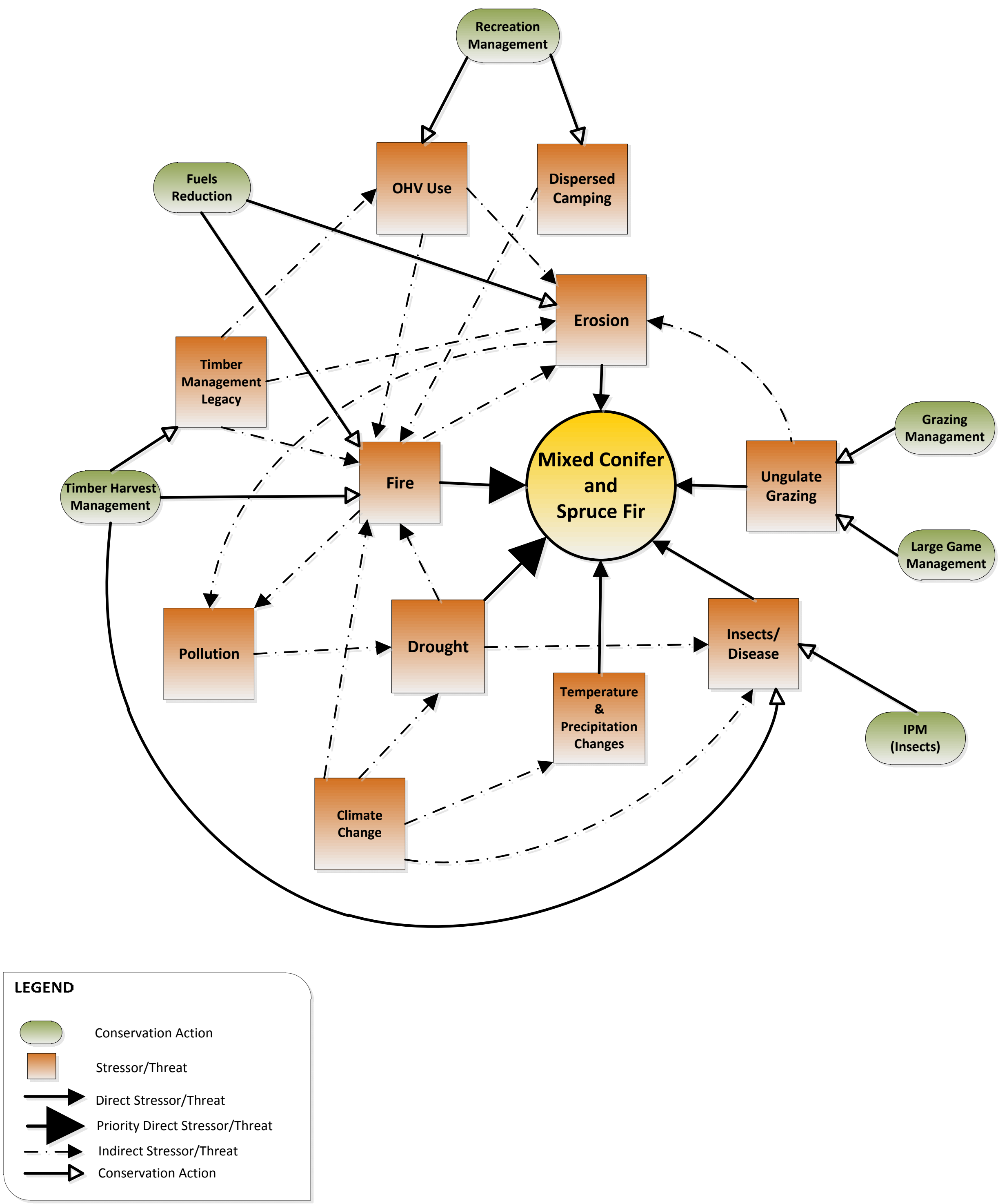


Figure 2: Conceptual Model of Stressors/Threats and Conservation Actions for the Cottonwood-Willow Riparian System in Arizona

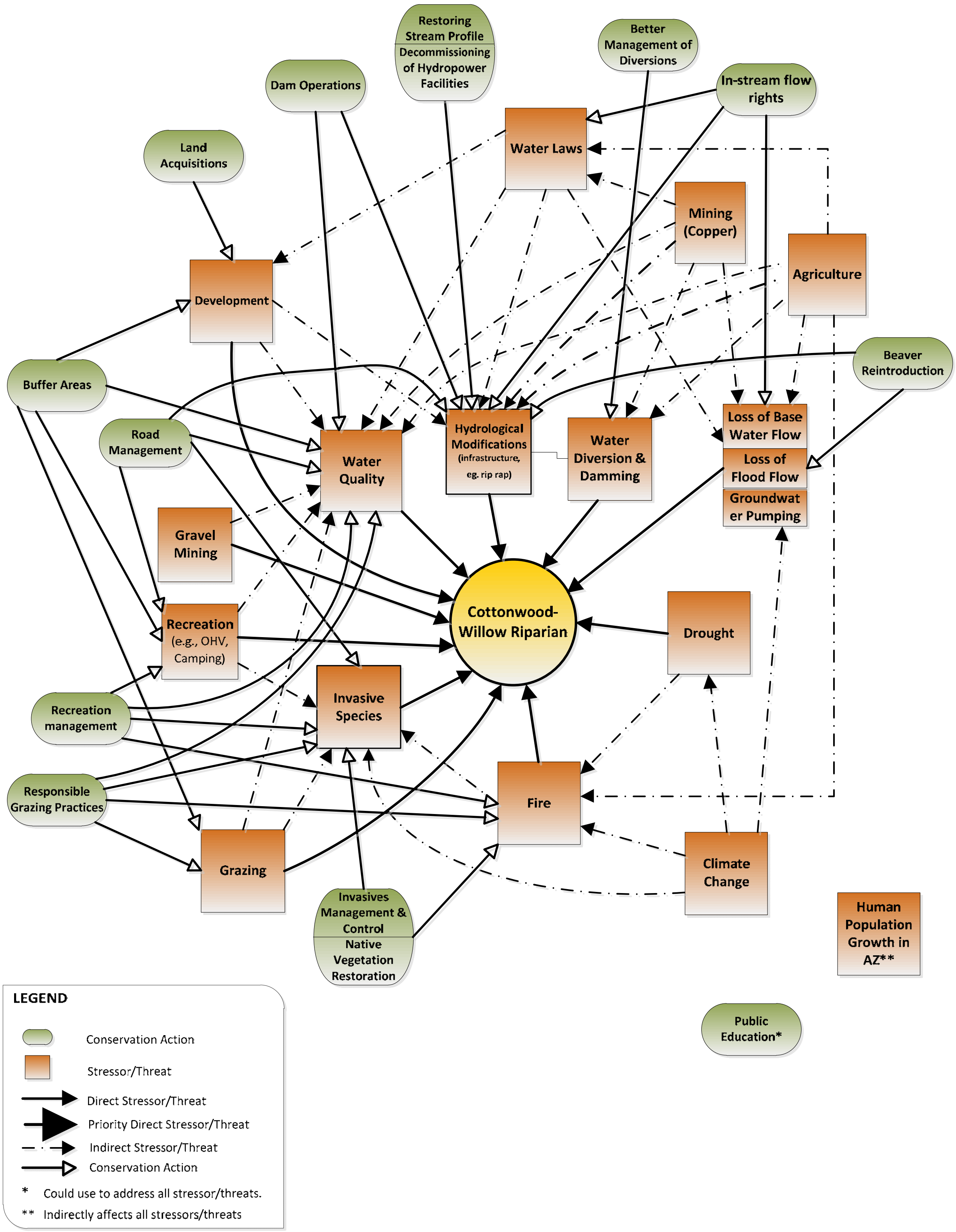


Figure 3: Conceptual Model of Stressors/Threats and Conservation Actions for the Springs and Cienegas System in Arizona

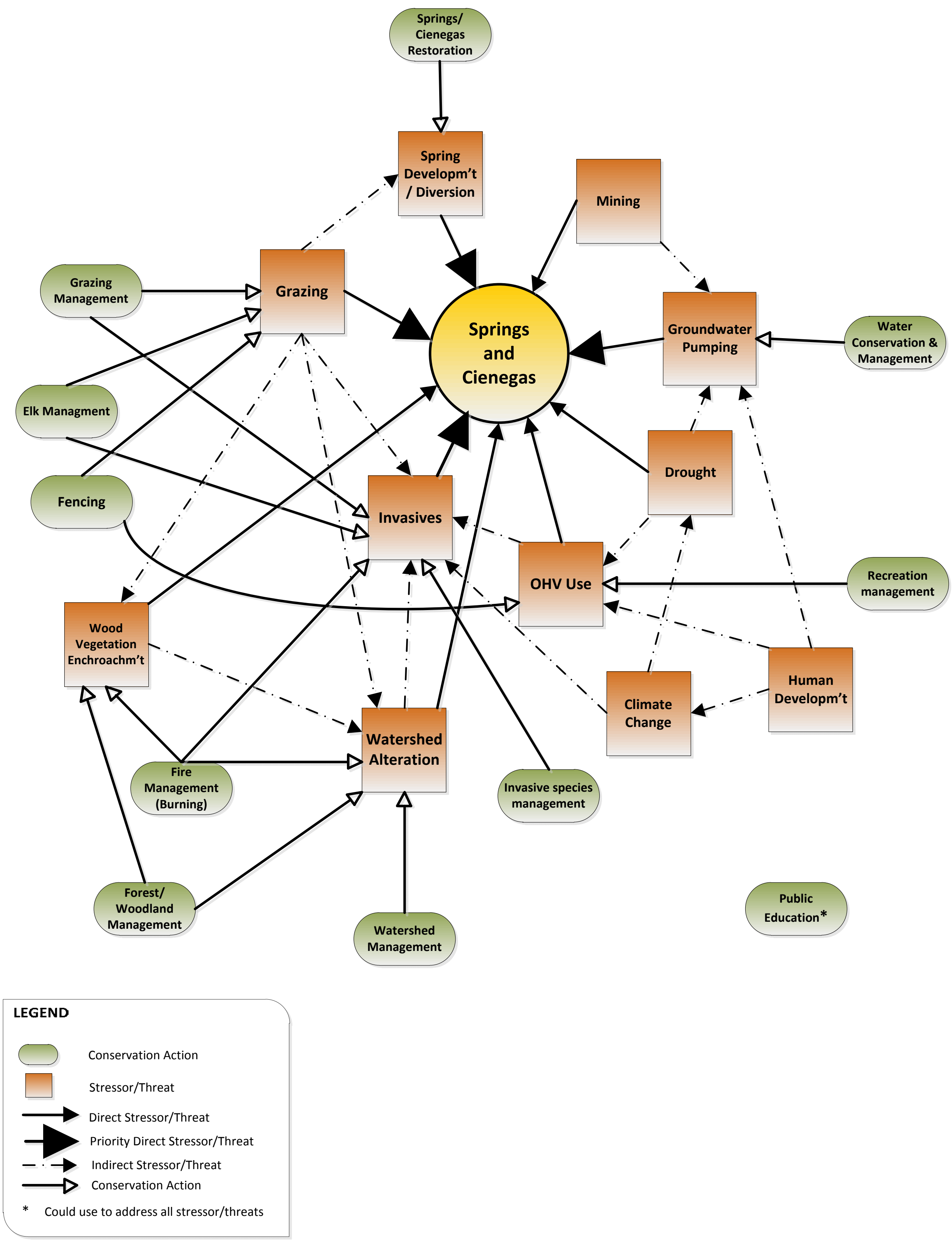


Figure 4: Conceptual Model of Stressors/Threats and Conservation Actions for the Sonoran Desert System in Arizona

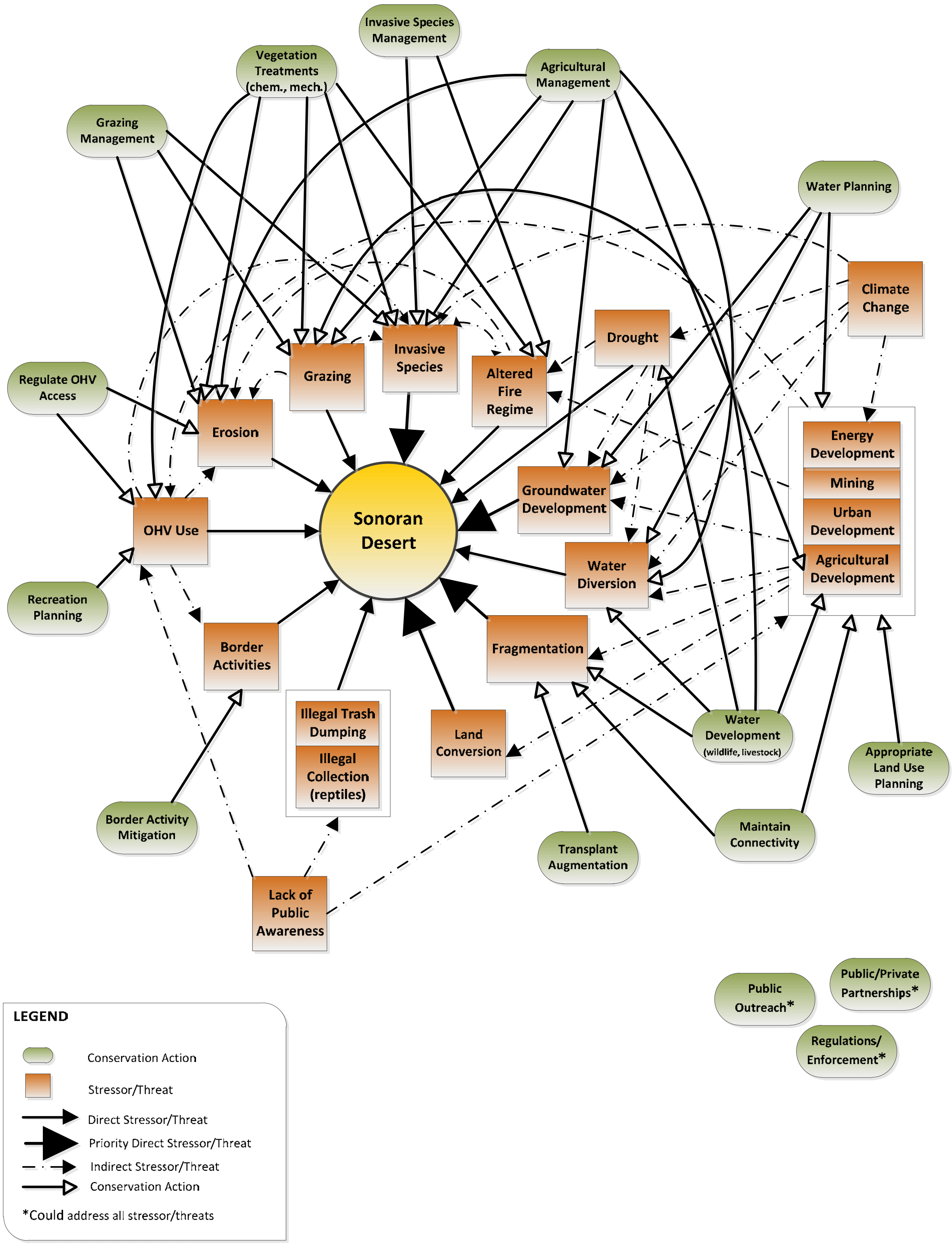
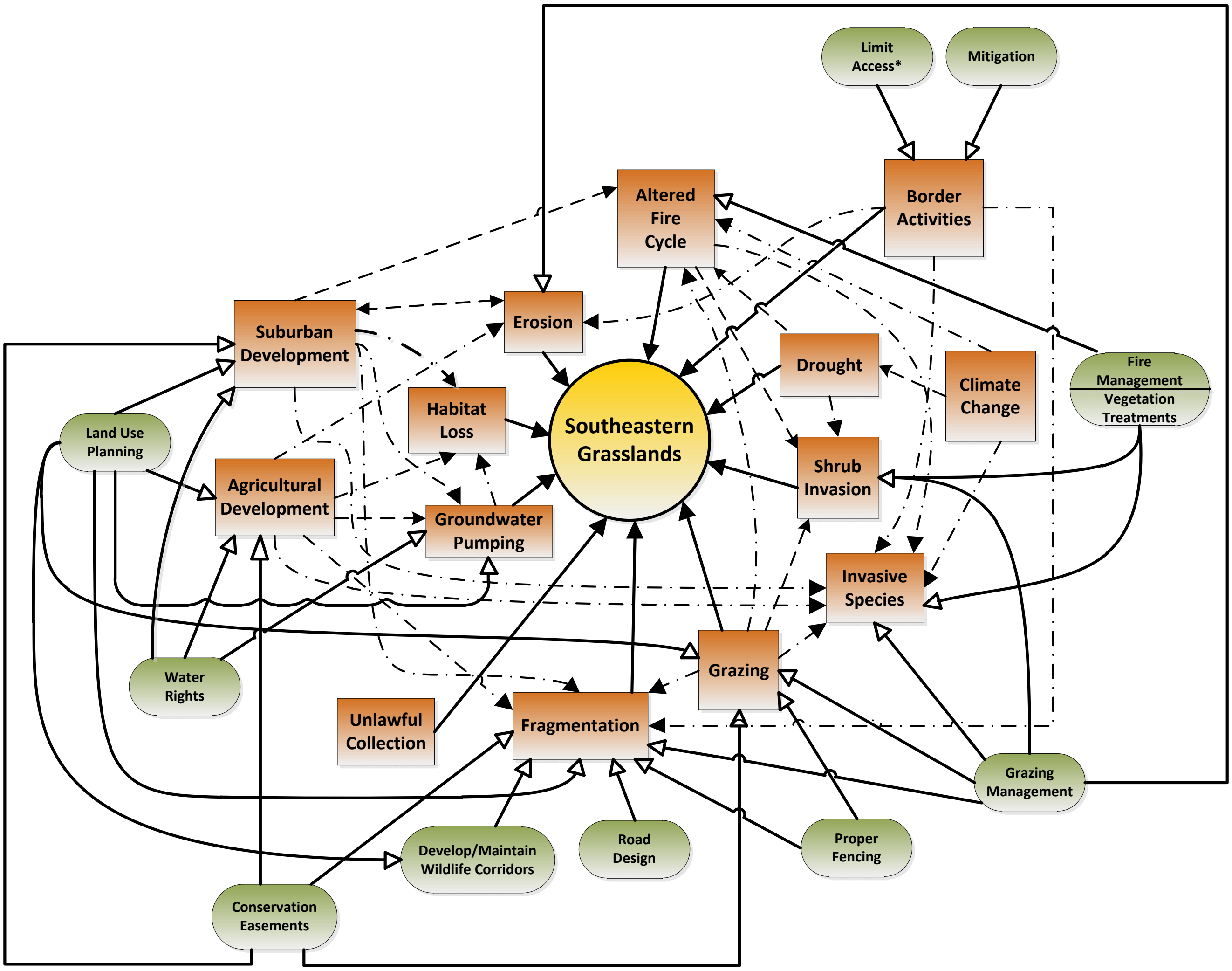


Figure 5: Conceptual Model of Stressors/Threats and Conservation Actions for the Southeastern Grasslands System in Arizona



LEGEND

Conservation Action

Stressor/Threat

Direct Stressor/Threat

Indirect Stressor/Threat

Conservation Action

* See model description in text for discussion

Appendix 2:

Lists of Potential Indicators and Monitoring Programs

List of Potential Indicators and Monitoring Programs:
Mixed Conifer/Spruce Fir Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Desired Condition				
Clark's Nutcracker present	Presence/absence	US Geological Survey (USGS)	Breeding Bird Survey	
Dead/down timber present	Density of down timber; tons per acre	USDA Forest Service (USDA FS)	Various, including fuels program and Forest Plan	The fuels program work includes fuel loads. There are also guidelines in the Forest Plan for the Mexican spotted owl and the Northern grousehawk.
Diverse age classes present	Diverse age class	USDA FS	Stand inventories; Forest Inventory and Analysis Program (FIA)	USDA FS programs in mixed conifer systems include fuels reduction and stand inventories. Remote sensing is part of the FS FIA Program.
Dusky Grouse present		USGS	Breeding Bird Survey (BBS)	
Evening Grosbeak present		USGS	Breeding Bird Survey (BBS)	
Forest patchiness		USDA FS/US Department o the Interior (DOI)	LANDFIRE	
Healthy aspen component	Red sap-sucker presence/absence (in the Northern Forests); Bluebirds and woodpecker diversity presence/absence; bats, squirrels presence/absence; rim draws.	USDA FS	Regional offices - forest health annual inventory; Unit level - habitat mapping or forest-wide and pre-project monitoring; Breeding Bird Survey	In the Northern forests, red naped sap-sucker is included in management indicators surveys/MIS surveys, and there may be related research projects at Universities. Long-term work is being done in Aspen forest, including research projects with rim draws. (finding that Aspen is declining across Western, US.)
Healthy streams/riparian areas	High elevation riparian obligate birds (e.g. bald eagle) presence/absence; Macroinvertebrates (to indicate stream health)	AZ Game and Fish Department (AZGFD)	Cooperative Bird Monitoring Program; fisheries surveys in streams	
		AZ Dept of Environmental Quality (DEQ)	Water Quality program	
		Multi-agency collaboration	Proper function conditioning (PFC) analysis through multiple agencies (BLM, US FWS, AZ Riparian Council)	

	Indicator	Monitoring Program: Agency	Monitoring Program: Program Name	Notes
		SW Riparian Cadre		
		USDA FS	stream surveys	There are variations in USDA FS stream survey methodology.
Lack of fire distribution	Presence of fire	USDA FS; Land management agencies	LANDFIRE	Possible other sources include Don Faulk at the University of Arizona, and Tom Swettnum who can provide a historical perspective. Also, the TNC did BLM's statewide fire plan and may be a resources as well.
Meadow cienegas present	Presence/absence of Meadow cienegas; Tiger salamander, sniped soras, rails (presence absence); Water springs present	USDA FS	Forest soil; Threatened, Endangered, & Sensitive (TES) Species Program;	
		AZGFD	Cooperative Bird Monitoring Program; Fisheries program	
Mexican spotted owl present	Presence/absence	USDA FS; USGS	Project basis; ESA	There is some nesting data, however it is not measured annually. Also, the Mexican Spotted Owl is not a species monitored as part of the Breeding Bird Survey. USGS projects vary (e.g. by area, Department of Defense installation, national park)
Moist soil		USDA FS	Project level assessments; post-fire assessments	Data through the TES program is existing, but monitoring is not ongoing.
	Soil moisture regime	NOAA	Soil moisture program	NOAA tracks soil regimes.
	Sentinel plant species	Bureau of Land Management (BLM)	Inventory Assessment of seeps and springs (fauna and vegetation information)	Sentinel plant species
	Mushroom communities	Amateur naturalists		Mushroom communities
		Interagency (including BLM)	Southwest Riparian Cadres (PFC protected)	Mushroom communities
Montaine Voles present	Presence/absence			
Least Chipmunk present	Presence/absence			
Golden Mantled Squirrels present	Presence/absence			
Least Weasel present	Presence/absence			

List of Potential Indicators and Monitoring Programs:
Mixed Conifer/Spruce Fir Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Olive Side Flycatcher present	Presence/absence	USGS	Breeding Bird Survey	
Mt. Graham Red Squirrel present	Presence/absence	USDA FS; AZGFD Region 5 in cooperation with US Fish and Wildlife Srvice (FWS) & National Park Service (NPS)	Mt. Graham Red Squirrel Recovery Program	USDA FS collects presence/absence data. AZGFD et al's Mt. Graham study captures density, fire effects, presence/absence data, etc. Other possible data resources include academia (Karpowsky), or a local Arizona squirrel expert.
Snags	Hairy woodpecker	USDA FS	Integrated pre-project monitoring/ MIS monitoring	In Northern Arizona the hairy woodpecker is an indicator species.
Tiger salamander present	Presence/absence	Arizona State University		Jim Collins is believed to be conducting a study.
Stressors/Threats				
Climate change				
Development/fragmentation	Miles of road per meter squared; status/distribution of roads	USDA FS	Watershed monitoring; mapping other development (i.e. ski areas); Forest plans (designations for development)	The watershed monitoring is for invasive species.
		Counties	Zoning/development information	zoning, watershed, roads.
Dispersed camping				
Erosion				
Fire	Fire frequency, intensity, and extent	USDA FS	Interagency Fire Center; LANDFIRE	
Herbivory (insects, large and small mammals)				
Insects/disease				
OHV				
Timber management				
Ungulate grazing				

List of Potential Indicators and Monitoring Programs:
Mixed Conifer/Spruce Fir Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Conservation Actions			**Conservation Program**	
Fuels reduction in the WUI (wildland/urban interface)		AZ State Forestry (Counties, Cities & Communities); USDA FS; BLM	Fuels reduction programs	
Grazing management		AZ State Land Department; USDA FS; BLM	Grazing management programs	USDA FS and BLM programs occur on their lands
Integrated Pest Management (insects)				
Large game management				
Prescribed fire				
Recreation management				
Timber harvest/salvage/thinning				
Travel management				

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Desired Condition				
Flood plain re-connection	Fluvial geomorphology [inundated flood plains, active flood plain width; degree of entrenchment (i.e. low equals good)]	Bureau of Reclamation (BOR)	Fluvial geomorphology program	
		PFC Agencies		
		USDA Forest Service (USDA FS)	Healthy soil and watershed program	
Habitat connectivity	Distance between cottonwood-willow communities; width of riparian areas; brown headed cow bird	Sonoran Institute		
		Land management agencies, including:		
		Bureau of Land Management (BLM)	San Pedro	
		USDA FS	Riparian program, fish program	
		The Nature Conservancy (TNC)	Preserve plans	
		Audubon		
		AZGFD	Cooperative Bird Monitoring Program	
Heterogeneity in system	Multi-layer canopies; Species composition; Varying age structure.	Audubon/BLM	Pilot aquifer project (Agua-Fria National Monument)	
		AZGFD	Cooperative Bird Monitoring Program (vegetation and birds)	
		BLM	RBC (species composition)	
		Sonoran Institute		
		USDA FS	Riparian monitoring program	

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	**Program Name**	
Native aquatic communities	Native fish presence, abundance, species diversity (Jila chub, Roundtail chub); Demography; Relationship between native leopard frog, native fish, and garter snake	AZGFD	Various fish, snake, and leopard frog monitoring	
		Arizona State University	CAP (Central Arizona Project)	
		BLM	Fish Program (through CAP)	
		Bureau of Reclamation (BOR)	CAP (Central Arizona Project)	
		FWS		
		TNC/AZGFD		
		Northern Arizona University		
		USDA FS	Aquatic restoration program (e.g. Tonto National Park)	
		University of Arizona		
Native/riparian obligate species (nesting and migratory)	Native birds (presence/absence, breeding ability, density, frequency (e.g. Lucy's warbler, yellow-billed cuckoo, etc.)	Audubon	Bird surveys	
		AZGFD	Bird surveys	
		BLM	Bird surveys	
		FWS	Bird surveys	
		SGS	Bird surveys	
		TNC	Bird surveys	
		USDA FS		
		USGS	Breeding Bird Survey	
		US National Park	Bird surveys (Cuckoo, etc.)	
	Native obligate plant species (species composition, proportion of native plants); herptofauna presence/absence, breeding ability, density, frequency (e.g., narrow-headed and Mexican garter snakes, etc.)	AZGFD	Vegetation data on bird monitoring plots	
		Arizona State University		
		BLM		
		USDA FS		

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Natural water flow and disturbance regimes	Cottonwood-Willow regeneration and recruitment; base flow, flood flow, natural hydrographs	AZ Department of Water Resources		
		BOR		
		County Flood Control Department		
		USGS	Natural hydrographs	
		USDA FS	Stream monitoring and trend data	
Recruitment of Cottonwood-Willow occurring	Recruitment of Cottonwood-Willow occurring	Audubon/BLM partnership	Pilot aquifer project (Agua-Fria National Monument)	
		AZGFD	CGM (vegetation and birds)	
		BLM	RBC (species composition)	
		Sonoran Institute		
		Universities (e.g. Arizona State University)		
		USDA FS	Riparian monitoring program	
Water quality that meets beneficial use standards	Beneficial use standards	AZGFD	Aquatic wildlife surveys	
		AZ Department of Environmental Quality (AZDEQ)		
		BLM	Aquatic wildlife surveys; recreation	
		USDA FS	Aquatic wildlife surveys; watershed program	

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Better educated public		Audubon; AZGFD; BLM; NPS; Sonoran Institute; Sky Islands Alliance; TNC; USDA FS; University of Arizona		
Stressors/Threats				
Agriculture	Acres lost (conversion)	Sonoran Institute		
		Land management agencies, including:		
		Audubon		
		AZGFD	CBM program	
		BLM	San Pedro program	
		TNC	Preserve plans	
		USDA FS	Riparian program, Fish program	
	Water quality	AZGFD	Aquatic wildlife surveys	
		ADEQ		
		BLM	Aquatic wildlife surveys; recreation	
		USDA FS	Aquatic wildlife surveys; Watershed program	
	Surface water extent, discharge amounts	USGS		
		Arizona State University	CAP (Central Arizona Project)	
		Audubon	Bird surveys	
		AZGFD	Bird surveys Various fish, snake, and leopard frog monitoring	

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Climate change	Vegetation Species composition Wildlife/fish species composition	BLM	Bird surveys, etc. Fish program through CAP	
		BOR	CAP (Central Arizona Project)	
		FWS	Bird surveys	
		Northern Arizona University		
		NPS	Bird surveys (Cuckoo, etc.)	
		TNC	Bird surveys, etc.	
		TNC/AZGFD		
		University of Arizona		
		USDA FS	Aquatic restoration program (e.g. Tonto National Park Service)	
		USGS	Breeding Bird Survey	
Development	Immediate loss of cottonwood-willow coverage; compaction (i.e. physical alteration of cottonwood-willow because of anthropogenic activities); fragmentation	Cities and counties		
		Sonoran Institute	Limited monitoring (1 river)	
		TNC		
		USDA FS	Recreation monitoring programs (e.g. number of existing campgrounds etc.)	
Drought	Cottonwood-Willow acres of mortality; dieback	Arizona State University		
		Counties	e.g. Pima County	
		Sonoran Institute		
		University of Arizona		
		USDA FS		
Fire	Acres of habitat burned	Counties		
		University of Arizona	Studies of Riparian zone fires	
		USDA FS	Fire suppression program	
	Cottonwood-Willow recruitment	AZGFD	Cooperative Bird Monitoring Program	

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Grazing	Cottonwood-Willow presence/absence	USDA FS	Riparian monitoring program	
	Presence/absence of trespassing cattle	BLM	River range	
	Presence/absence of brown headed cow bird	Audubon		
	Riparian obligate birds (Lucy's Warbler, Yellow breasted chat, etc.)	USDA FS	Miscellaneous monitoring	
		Audubon	Important Bird Areas Project	
	Utilization of plant materials			
	Soil/ground compaction			
	Bank stability			
	Area			
Groundwater pumping	Surface flow wells	AZ Dept. of Water Resources	Salt River Project	
		USDA FS		
	Water discharge meter	AZGFD	Hatcheries Program	
Human population growth	Amount of recreational use	Overarching through many organizations		
Hydrological modifications/infrastructure ***(e.g. riprap, channelization, etc.)***	Miles of hardened banks; rip rap; channelization (miles of channelized/ entrenched streams)	Army Corps of Engineers		
		BOR		
		Counties		
		USDA FS		
Invasive species	Presence/absence; acres; percent vegetation; species composition; crayfish; bullfrogs; exotic fish; "some"	AZGFD		
		BLM		
		BOR		
		FWS		

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
	non-native sport fish; non-native plant species	TNC		
		USDA FS		
Mining	Groundwater draw down; acres of lost habitat; water quality issues (standard water quality chemistry e.g., contamination)	Army Corps of Engineers		
		BLM	Mining and Minerals Program	
		USDA FS	Mining and Minerals Program	
Recreation ***(e.g. OHV, camping, etc.)***	Soil compaction; lack of vegetation regulation; OHV use (miles of unauthorized tracks); soil erosion; number of dispersed campsites/fire rings; number of dump sites	BLM	Recreation program	
		USDA FS	Riparian program (e.g., Tonto National Park), Recreation program	
Water diversion	Depth of groundwater; diversion structures; flow rate/amount; alteration of natural flow regime.	Irrigation District; Army Corps of Engineers		
	Plant mortality; species composition changes.	USDA FS	Riparian monitoring program	
	Riparian birds species	AZGFD		
		Audubon		
Conservation Actions			**Conservation Program**	
Beaver re-introduction		AZGFD		
		BLM		
Better management of diversions		Army Corps of Engineers		
		BOR		
		Salt River Project		
Buffer areas		BLM		

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
		Counties		Pima is buying land
		NRCS		
		TNC		
		USDA FS		
Dam operations		BOR		
		Salt River Project		
		USDA FS		For Tonto National Park at least
		West Area Power Administration (WAPA)		
Decommissioning of hydro-power facilities		None		
Environmental education		Audubon, AZGFD, BLM, Counties, NPS, Sonoran Institute, Sky Islands Alliance, TNC, USDA FS, University of Arizona, Watershed Groups		

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Fire Restrictions		AZ State Land Department BLM Counties USDA FS		
In-stream flow rights		ADWR AZ Water Trust AZGFD Salt River Project TNC USDA FS		
Invasive species management/control ***(e.g. salt cedar, cray fish)***		ARP Audubon AZGFD BLM Counties/cities FWS National Park Service (NPS) Resource Conservation Districts SIA University of Arizona USDA FS Watershed groups		
Land acquisition		Audubon AZGFD BLM Cities/ municipalities		

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
		NPS TNC USDA FS		
Native vegetation restoration		Audubon, AZGFD, BLM, Counties, NPS, Sonoran Institute, Sky Islands Alliance, TNC, USDA FS, University of Arizona, Watershed Groups		
Recreation management		AZGFD BLM FWS NPS USDA FS		
Responsible grazing practices		BLM USDA FS		
Reterracing stream profile		AZGFD USDA FS BOR		e.g. Tonto National Park
Road management ***(e.g. closures, etc.)***		AZ State Land Department BLM Counties USDA FS		

List of Potential Indicators and Monitoring Programs:
Cottonwood-Willow Riparian Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Public Education		Audubon, AZGFD, BLM, Counties, NPS, Sonoran Institute, Sky Islands Alliance, TNC, USDA FS, University of Arizona, Watershed Groups		

Cottonwood-Willow Riparian Ecosystem
List of Prospective Indicators
September 2010

Landscape Measures

- Acres burned
- Acres lost to conversion
- Acres lost to cottonwood-willow mortality
- Distance between cottonwood-willow communities
- Miles of channelized and unchannelized stream
- Miles of hardened banks
- Miles of unauthorized roads
- Width of riparian area

Geological and Geomorphological Measures

- Active floodplain width
- Bank stability
- Degree of stream entrenchment
- Inundated floodplains
- Presence of rip-rap
- Soil compaction

Hydrological and Water Quality Measures

- Base Flow
- Flood Flow
- Groundwater measures
- Presence of water diversion structures
- Standard water quality monitoring measures
- Surface water extent, discharge

Site Disturbance/Human Use Measures

- Number of dispersed camp sites
- Number of dump sites
- Number of fire rings
- Presence of ORV tracks

Vegetation Measures

- Age structure
- Cottonwood and willow recruitment, regeneration
- Presence of multi-layered canopy

Presence of native plant understory
Proportion of native plants
Species composition

Invasive or Disruptive Species

Bullfrog
Cattle and cattle sign
Crayfish
Exotic fishes

Tamarisk
Russian Olive
Chinese Elm
Tree of Heaven
Giant Cane/Giant Reed
Fountain Grass

Native Vertebrate Species

Gila Chub
Sonora Sucker
Headwater Chub
Roundtail Chub
Lowland Leopard Frog
Chiricahua Leopard Frog
Mexican Garter Snake
Narrow-headed Garter Snake
Sonoran Mud Turtle

Birds

Brown-headed Cowbird
Lucy’s Warbler
Yellow-billed Cuckoo
Yellow breasted Chat
Summer Tanager
Yellow Warbler
Bell's Vireo
Song Sparrow
Albert's Towhee
Grey Hawk

Mammals

- Beaver
- Mesquite Mouse
- Red Bats
- Honry Bats

Invertebrates

- Salt Cedar Beetle

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona

September 22, 2010

Desired Condition	Indicator	Monitoring Program: Agency	Monitoring Program: Program Name	Notes
Appropriate vegetation age class distribution	Multiple age classes present (of appropriate vegetation); layered canopy when appropriate (woody vegetation)	USDA Forest Service (USDA FS)	Proper Functioning Condition (PFC)	
		Bureau of Land Management (BLM)	La cienega Program; future seeps/springs monitoring (awaiting funding)	
		The Nature Conservancy (TNC)	Soil and vegetation monitoring program (cienegas)	
Healthy hydric soils	Present where appropriate	BLM	Definition issues; lentic Proper Functioning Condition (PFC) (some attributes)	
		TNC	Soil and vegetation monitoring program for cienegas they manage	
		UDSA FS	PRC method	opportunistic/project level observations
Heterogeneity of water level	Depth to groundwater	US Geological Survey (USGS)	Wetlands delineation	
High water quality	Standard water quality chemistry (contamination, etc.)	AZ Department of Environmental Quality (AZ DEQ)	Drinking water program (springs)	
		AZ Game and Fish Department (AZGFD)	Leopard frog monitoring program; Fisheries/ invertebrate monitoring (springs and seeps); Hatcheries program (many spring fed)	
		USDA FS	Leopard frog monitoring program	
		US Fish and Wildlife Service (FWS)	Water quality information	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
		AZ Mining and Minerals	Mine footprint; water quality data	
		Interagency (BLM, etc.)	AML (Abandoned mine labs)	
Native fauna	Marsh birds (presence/absence/abundance)	AZGFD	Marsh Bird Monitoring Program (ACBM)	Data stored in USGS National Database
	Forest species (e.g. Cinnamon Teal)	BLM	Older data sets (hardcopy)	
	USDA FS Management Indicator Species	USDA FS	Management Indicator Species Program	
	Chiricahua Leopard Frog and Northern Leopard Frog	Audubon	Frog monitoring program	
		AZGFD	Frog monitoring program	
		USDA FS	Frog monitoring program	
		University of Arizona	Frog monitoring program	
	Lowland Leopard Frogs	BLM	Frog monitoring program	This species is considered less of an indicator than other frog species mentioned here.
		TNC	Frog monitoring program	
	Species abundance	AZGFD and FWS partnership	Waterfowl surveys	
	Gila chubs	AZGFD; BLM; FWS; TNC; USDA FS	Monitoring	
	Gila top minnow/pup fish (Presence/absence, abundance, invasive species, water quality cattail count)	AZGFD; BLM; FWS; TNC; USDA FS	Monitoring	
	Spring snails (presence/absence, abundance, density, water quality, and habitat)	AZGFD	Monitoring	
		USDA FS	Monitoring	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
	Amber snails (presence/absence, abundance, density, water quality, and habitat)			
	Butterflies	None	None	
	Dragonflies	None	None	
	Tiger Salamander (mountains, meadows) (presence, absence)	Audubon; AZGFD; BLM; TNC; University of Arizona; USDA FS	Opportunistic monitoring through frog surveys	Note: Academia have had tiger salamander monitoring programs in the past.
Native vegetation	Bebb's willow presence/abundance	TNC		
		USDA FS	Native Plants Program	
	Water Umble; Ladies tress	BLM		
		FWS		
		TNC		
		USDA FS		
	Other rare plants	USDA FS	Opportunistic monitoring	
	Vegetation cover and others	AZGFD	Marsh Bird Surveys	Limited information/sites
	Species, coverage, percentage living/dead, areas established	AZGFD	Amber snails survey	Limited information/sites
	Native Vegetation Presence	USDA FS	Proper Functioning Condition (PFC) Survey	
Natural disturbance regime	Lady Tress Presence (cienegas)	FWS; TNC	Regular distribution monitoring	
	Water Umble Presence (cienegas)	FWS; TNC	Regular distribution monitoring	
	Obvious periodic disturbances			
	Limited distribution in other habitat types (i.e., other than cienegas)			

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
	Habitat change over time	AZGFD	Habitat photos over time as part of Amber snails monitoring	
	Presence and amount of distribution	USDA FS	Exclosure monitoring	
Natural flow regime	Flow discharge, flow cubic feet/second (cfs), PAGG	USGS	Real time flow data set	
		BLM	Long term data set for springs	
	Stream flow quantity, etc.; Water flow rights, etc	USDA FS; AZGFD	Hatcheries monitoring	
	Springs and seeps discharge	National Park Service (NPS)/academia/ Museum of Northern Arizona collaboration	Grand Canyon Natives Restoration Program	
		AZ DWR	Northern Arizona study	
	Qualitative observational information (low water, high water, etc.)	AZGFD	Fish surveys	
No invasive species ***(e.g. crayfish, bull frogs, exotic fish, salt cedar, Russian olive, non-native grasses)***	No invasive species (presence/absence of non-natives)	Audubon; AZDWR; AZGFD; BLM; NPS; TNC; USDA FS; USFWS; USGS	Invasive species monitoring program	
		USDA FS	Forest fish program; Proper Functioning Condition (PFC) methods (invasives)	
		AZGFD	Crayfish surveys; bullfrog surveys; crayfish citizen science effort/reporting	
No OHV tracks	Presence/absence of OHVs	USDA FS	Travel management process	

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
No overgrazing	Multiple age class present of appropriate vegetation.	BLM	La Cienegas Program; future seeps/springs monitoring (awaiting funding)	
		TNC	Soil and vegetation monitoring program (cienegas)	
		USDA FS	Proper Functioning Condition (PFC) methods	
	Appropriate fauna	*Note: See "Native Fauna" section under Desired Conditions above*		
	Appropriate vegetation cover	USDA FS	Enclosure monitoring; range monitoring	
Educated public	No OHV tracks; increased compliance; positive landscape changes	None	None	
Stressors/Threats				
Climate change	Temperature, precipitation	National Weather Service	Various monitoring programs	
	Depth to soil moisture; discharge levels	AZGFD	Hatcheries	
		USGS		
	Phenology of plants	National phenology network	Just beginning, so nothing at the moment	
	Phenology of fauna (breeding, nesting hatching)	National phenology network	Just beginning, so nothing at the moment	
	Wet time (length)			
	Dry time (without surface water)			
	Precipitation	National Weather Service	Various monitoring programs	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Drought	Dryness			
	Presence/absence of plant and animal species (spring seep obligates)	*Note: See "Native Fauna" section and "Native Vegetation" sections under Desired Conditions above*		
	Soil wetland colors			
Encroachment (native, woody veg.) ***(e.g. Ponderosa Pine, Cheatgrass)***	Acres of encroachment	USDA FS	Project level	
	Presence/absence			
Grazing	Compacted soils; water quality; presence of native plants; shoreline integrity	BLM	Riparian program	
		USDA FS	Exclosure monitoring work	
	Presence/absence: song sparrow, common yellow throat	AZGFD	Marsh Bird Survey; Riparian program	
Groundwater pumping	Surface flow wells	AZ Dept of Water Resources	Salt River Project	
		USDA FS		
	Water discharge meter	AZGFD	Hatcheries Program	
Human development	Acquisition of exchange of land; impervious surfaces; presence of spring boxes and piped springs; stream flow persistence; lack of discharge; aquatic water flow discharge	Arizona Geological Survey	Groundwater monitoring	
		Bureau of Reclamation (BOR)		
		USDA FS	Riparian program	
		USGS	Groundwater monitoring	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Invasive species	No invasive species (presence/absence of non-natives)	Audubon; AZDWR; AZGFD; BLM; NPS; TNC; USDA FS; USFWS; USGS	Invasive species monitoring program	
		USDA FS	Forest fish program; Proper Functioning Condition (PFC) methods (invasives)	
		AZGFD	Crayfish surveys; bullfrog surveys; crayfish citizen science effort/reporting	
Mining	Runoff; acidification	USDA FS	Mining and Minerals Program - Environmental effects	
	Water quality issues (standard water quality chemistry e.g. contamination etc,)	AZ Mining and Minerals	Mine footprint; water quality data	
		AZDEQ	Drinking water program (springs)	
		AZGFD	Leopard frog monitoring program; fisheries/ invertebrate monitoring (springs and seeps); Hatcheries program (many spring fed)	
		FWS	Water quality information	
		Interagency (BLM, etc.)	AML (Abandoned mine labs)	
		USDA FS	Leopard frog monitoring program	
OHV use	Presence/absence of OHVs	USDA FS	Travel management process	
		AZ Geological Survey	Groundwater monitoring	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program: Agency	Monitoring Program: Program Name	Notes
Spring development/diversion	Presence of spring boxes	BOR		
		USDA FS	Riparian/surface water rights; Great Range Program	
		USGS	Groundwater monitoring	
Watershed alteration	Density; percent cover in uplands (re: overstocked forest/too many trees)	USDA FS	Forest restoration	
	Southern Arizona - percent bare ground	BLM	Range studies	
		USDA FS	Soil surveys	
Conservation Actions			**Conservation Program**	
Big game management (Elk)			AZGFD	
Fire management			Audubon; AZGFD; BLM; NPS; TNC; USDA FS; USFWS; USGS	
Forest/woodland management			BLM; USDA FS	
Grazing management			AZ State Land Department: BLM; USDA FS	
Invasive species management			Audubon; AZGFD; BOR; National Park Service; TNC; USDA FS	

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Land acquisition			AZGFD; BLM; TNC; USDA FS	
Physical protection/fencing			BLM: AZGFD; US FWS; TNC; USDA FS	The US FWS monitoring is through terms and conditions or biological opinions records.
Public education			Audubon; AZGFD; BLM; National Park Service; Sonoran Institute; Sky Islands Alliance; TNC; USDA FS; University of Arizona	
Recreation management			AZGF BLM (in selected areas) USDA FS (fencing for OHVs)	
Spring restoration			AZGF Sky Islands Alliance USDA FS; USDA FS and TNC Partnership	The USDA FS does fencing at springs, and is also working in partnership with TNC to restore cienegas (e.g. Huachuca)
Water conservation and management			Natural Resources Conservation Service (NRCS); NGOs - Watershed Groups; Resource Conservation Districts (RCDs); Salt River Project; University of Arizona USDA FS	NRCS has an Equip and Whip Program; Examples of watershed groups include the Little Colorado River Plateau and Con. Val. Plan. Partnership; University of Arizona has a NEMO program; USDA Forest Service does Tonto fencing and issue may also overlap with spring testing.

List of Potential Indicators and Monitoring Programs:
Springs and Cienegas Communities in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Water rights			AZGFD; AZ Land and Water Trust; BLM; Salt River Project; USDA FS	
Watershed management (e.g. soil condition, productivity, channelization, etc.)			ARP; BLM; Counties; TNC; NGOs (smaller ones); NRCS Groups (Soil and Water Conservation Districts); USDA FS	

List of Potential Indicators and Monitoring Programs: Sonoran Desert in Arizona

September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Desired Condition				
Maintain existing or revert to historic compostition of plant/vegetation/ species/geomorphology	Presence of native vegetation/species; vegetation measures (condition, composition, height, utilization); Percent bare ground; soil health (presence of microbiotic crusts);	BLM; AZGFD; Audubon; NPS; USFS	Rangeland survey/Veg monitoring; Species-specific monitoring programs including Big Game surveys & LTMP's; Tribes; Monarch Watch; Thrasher Working Group; Flat Tail Lizard Working Group; Desert Wash Bird Protocol; PRBO Alliance (BLM, AZGFD,CA OHV; U of Arizona); Burro/herd management; Central Arizona Long Term Ecological Research (CAPLTER); Maricopa County	See full species list in appendix. **Animals:** Some sheep and mountain lion are radio-collared. Desert tortoise has long-term monitoring plots since 1980s, with data collected at same sites every 3-5 years, documents: mammals, birds, reptiles, plants, P/A data, human uses inclu. OHV). Flat tail working group is a 2 year project with 4 years additional funding. AZGFD 3 year study of sonoran toads started in 2010. Various bats monitored (28 species total in AZ). **Plants:** Native perennial grasses measured in NRCS range data.
Minimal disturbance (outside of "natural")	Soil health (condition & extent); Presence/absence of non-natives; percent bare ground; Site disturbance/human use measures (Campfire rings; presence of trash);	BLM, Border Patrol	Veg surveys; road mapping; Activity data (number of crossings, group size);	
Natural/historical fire regime	Fire temperature, duration, extent; percent bare ground; minimal change post-fire; localized impacts	DOD; BLM;LANDFIRE; Land agencies; counties/cities & municipalities	fire maps; post-fire monitoring	

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Healthy hydrological systems	Heath of mequite bosques; species diversity/ composition along washes (ironwood, mesquite, palo verde); absence/reduction in non-natives; Percent of bare groun approriate to site	DWR; BLM; Bureau of Reclamation; Local governments; NRCS; NPS; USFS; TNC?	Veg surveys; BLM invasives/noxious weed surveys; stream monitoring; Colorado River monitoring; Pima County monitoring (part of Sonoran Desert Conservation Plan); NRCS soil mapping	
Landscape supports appropriate multiple uses				
Connectivity	Heterogenity (along evelational gradients); Extent; large continuous blocks of habitat; road mortality; Presence/absence data for species (especially birds)	AZGFD; DOT; Audobon	Remote sensing data; Travel corridor information; road kill data; GIS landscape models; Breeding Bird Survey; AZ Bird Conservation Intiative;	BBS has 40 sites in AZ. Birds include: Bendire's thrasher, costa's hummingbird, elf owl, gilded flicker, LeConte's thrasher, rufous-winged sparrow
Healthy Dunes	Extent & condition; presence of invertabrates (beetles, bees, wasps)	DOD		
Healthy Desert Pavement	Soil health (condition & extent); presence of macrobiotic crusts; diverse native species present (sheep, deer, tortoise)	AZGFD; BLM; NAU; DOD; ASU?	Big game survey; Desert Tortoise monitoring program	
Healthy Bajadas	Presence of native vegatation/species	AZGFD; BLM; NAU; DOD; ASU?	Veg surveys; NAU Remote sensing surveys; species-specific monitoring; BBS; Burro/herd management surveys	Native plant species include: ironwood, blue palo verde, cactus, saguaro. Native animal species include: desert tortois, desert sheep (seasonal), rugus-wing sparrow, gilded flicker, pollinators, Townson's Bat, California Leaf-nose Bat, Mexican Long-tongue Bat

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Healthy Desert Washes	Presence of native vegetation/species	AZGFD; PRBO?; Desert Washes Bird Monitoring Alliance; DOD; Border Patrol;	Desert Wash Bird Protocol; Disturbance data; species specific monitoring; Sonoran Desert National Monument Veg surveys	Native plant species include Desert Hackberry, smoke trees. Native animal species include: Tortoise, Black-tailed Gnatcatcher, Lucy's Warbler
Stressors/Threats				
Energy development (especially renewable)	New energy developments (siting and density); transmission corridors (siting and density)	BLM; NREL; WGA; RECO; AZ state land office; AZGFD; private/developers	Western renewable energy zones; ARTIS (state model siting study)	
Dewatering/Groundwater Development	Heath of mequite bosques; species diversity/ composition along washes (ironwood, mesquite, palo verde); absence/reduction in non-natives; Percent of bare groun approriate to site	DWR; BLM; Bureau of Reclamation; Local governments; NRCS; NPS; USFS; TNC?	Veg surveys; BLM invasives/noxious weed surveys; stream monitoring; Colorado River monitoring; Pima County monitoring (part of Sonoran Desert Conservation Plan); NRCS soil mapping	
Fragmentation	Road/travel corridors - siting & density; fencing	AZ DOT; AZGFD; county governments		
Invasive/introduced species	Presence of invasives	BLM; USFS; conservation districts; AZ Invasive Species Group	Veg study; "Highway map"; invasives monitoring; Invasives species interagency working group	
Altered fire regime	Fire temperature, duration, extent; percent bare ground; minimal change post-fire; localized impacts	DOD; BLM;LANDFIRE; Land agencies; counties/cities & municipalities	fire maps; post-fire monitoring	

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Urban/suburban development	Present of urban/suburban development	AZ state land department; county/city planning & zoning; land management agencies	LANDSAT	
Water diversion	Presence of dams, canals, flood/water control structures	AZ irrigation districts; DWR; NRCS; county governments		
OHV use	Presence/proliferation of roads and trails	USFS; BLM; State lands agency; other land agencies	Route management	
Illegal dumping of trash	Presence of trash	AZ land department; USFS; NPS; USFWS: ADOT; BLM; counties & cities	Border refuges; adopt-a-ranch;	
Illegal collection (eg reptiles)	Habitat destruction	AZGFD		
Border activities				
Grazing		BLM; USFS; state Land office; ASLD		
Mining	Presence and extent of mining activities	State Department of Mines; BLM; USFS		
Land conversion				
Agricultural development	Presence of agricultural development	NRCS; AZ State Land Dept; Farm Security Administration; land management agencies; county planning & zoning;	LANDSAT	

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Climate change	Drought; change in vegetation; Precipitation; temperature; floral phenology; presence of invasives/noxious weeds;	Phenology Network; TNC	Palmer Drought Index; Phenology Network; Hummingbird Monitoring Network; AZ Sonoran Desert Museum	Species as indicators of phenology: White-winged dove, Lesser Nighthawk, Costa's Hummingbird
Erosion	Stream wash measures (arroyo downcutting, sedimentation in streams); sedimentation; particulate matter in air	AZ DEQ; BLM;		
Lack of public awareness				
DOD activities		DOD; FWS		
Drought	Palmer Drought Index; Precipitation	NOAA; NWS	PRISM	
Conservation Actions			**Conservation Program**	
Appropriate siting of renewable energy		AZGFD; WGA; land management agencies; USFWS; TNC		
Water planning		Governor's Water Group; irrigation districts; DWR; Army Corps of Engineers; U of A; SRP; ASU	ASU Decision Theater	
Water development (wildlife & livestock)		AZGFD; FWS; BLM; USFS; state landholders; ranchers		

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Approriate land use planning		Counties; municipalities; Fed & State land agencies; Tribes; Sonoran Institute; DOD; state parks; ADPT; DOE; Federal highways		
Maintain connectivity				
Public outreach				
Recreation planning/regulate OHV-quad use		BLM; USFS; AZGFD; all federal landholders; municipalities (run state parks)		
Enforcement (eg dumpling, border activity, OHV use)		AZGFD; law enforcement; state, federal and county governments; tribes	Native Plant Act; signage	
Control invasives (mechanical & chemical)		NPS; USFS; Counties/municipalities; ADOT	Preserves (Maricopa, Pima, Phoenix, Scottsdale); approved plant lists	
Agricultural management		AZ Dept of Agriculture; BLM; USDA - NRCS; private landholders	U of Arizona Ag Extension; conservation districts	

List of Potential Indicators and Monitoring Programs:
Sonoran Desert in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Grazing management		BLM; Livestock association; AZ cowgrowers; private ranching consortiums		
Border activity mitigation		Border Patrol; USFWS; NPS?		
Transplant augmentation		AZGFD; FWS; land management agencies; private landholders	Desert Big Horn, Pronghorn	
Native Plant Act				
Public/private partnerships				

Sonoran Desert Ecosystem
List of Prospective Indicators
September 2010

Climatological/Meteorological Measures

Palmer drought index
Particulate matter in air
Precipitation
Temperature

Landscape Measures

Large contiguous blocks of vegetation
New energy developments – siting and density
Presence of agricultural development
Presence of dams, canals, flood/water control structures
Presence and extent of mining activities
Road/travel corridors – siting and density
Road kill data
Transmission corridors – siting and density

Site Disturbance/Human Use Measures

Campfire rings
Presence of trash

Stream/Wash Measures

Arroyo down-cutting
Sedimentation in streams

Vegetation Measures

Changes in composition, structure, diversity post-fire
Fire temperature, duration, and extent
Floral phenology
Percent bare ground
Presence of invasives/noxious weeds
Presence of mesquite bosques along floodplains, bajadas, and arroyos
Presence of microbiotic crusts
Presence of native vegetation
Vegetation condition
Vegetation composition
Vegetation height

Vegetation utilization

Plant Species

Desert Hackberry
Desert Ironwood
Mesquite
Palo Verde
Saguaro

Bur Sage (responsive to drought, winter precipitation)
Flat Top Buckwheat
Jojoba (cattle, mule deer grazing)
Caliendra (cattle, mule deer grazing)
Saharan Mustard (invasives)
Buffel Grass

Elephant Tree
Native Perennial Grasses
Blue Palo Verde

Amphibians

Desert-breeding Anurans (responsive to local rainfall, temperature)
Sonoran Toads

Reptiles

Desert Tortoise
Horned Lizard
Chuckwalla
Sidewinder
Shovel-nosed Snake
Desert Iguana
Desert Spiny Lizard

Mammals

Bighorn Sheep
Kit Fox
Mountain Lion
Mule Deer
Sonoran Pronghorn

Lesser Long-nose Bat
California Leaf-nose Bat
Mexican Long-tongue Bat
Townsend's Big-eared Bat

- Desert Pocket Mice
- Rock Pocket Mice
- Mesquite Mice
- Desert Kangaroo Rat
- Desert Grasshopper Mouse

Birds

- Black-tailed Gnatcatcher
- Lucy's Warbler
- Black-tailed Sparrow
- Purple Martin
- White-winged Dove
- Lesser Nighthawk
- Cactus Ferruginous Pygmy Owl (CFPO)
- Bendire's Thrasher
- Costa's Hummingbird
- Elf Owl
- Gilded Flicker
- LeConte's Thrasher
- Rufous Winged Sparrow
- Aztec Thrush

Invertebrates

- Sphinx Moth
- Monarch Butterfly
- Dragonflies
- Damselflies
- Native Bees

List of Potential Indicators and Monitoring Programs:
Southeastern Grasslands in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Desired Condition				
Fewer/no invasive species				
Good connectivity (large, extensive)				
Good structure				
Native species				
Natural fire cycle				
Natural hydrologic functioning				
"Proper" mix of species, plant & wildlife (robust, diverse, in mosaic of landscape)				
Reduced woody component in upland (account for appropriateness in patches)				
Stressors/Threats				
Agricultural development				
Altered fire cycle				
Border activities				
Climate change				
Drought				
Erosion/soil loss				
Fragmentation (roads & fencing)				
Grazing				
Groundwater pumping (due to agriculture, urban growth)				
Habitat loss				
Increased human uses				
Invasive species (mainly plants)				
Land conversion				
Shrub invasion (natives)				
Suburban development				
Unlawful collection				

List of Potential Indicators and Monitoring Programs:
Southeastern Grasslands in Arizona
September 22, 2010

	Indicator	Monitoring Program		Notes
		Agency	Program Name	
Conservation Actions			Conservation Program	
Conservation easements				
Grazing management				
Implementing fire management strategies (prescription, educating public)				
Land use planning (road design, proper fencing; protect vegetation & habitat from conversion)				
Limit access				
Manage water rights				
Mitigation related to borderland patrol activities				
Woody vegetation treatments				

Southeastern Grasslands:
Overview of Small-Group Discussion on Potential Indicators and Monitoring Programs
Pioneering Performance Measures Workshop
Phoenix, Arizona - September 2010

On day two of the workshop, the terrestrial ecosystem breakout group had a robust and lengthy discussion about grasslands, one of the priority ecosystems selected by the full group. The group began by talking about the many types and locations of grasslands in Arizona: Great Basin, semi-desert, alpine meadows (particularly in the Sky Islands), Chihuahan, Sonoran, and great plains. Overall they noted that grasslands are associated with big washes and other drainage areas, and that they are plagued by a number of invasive shrub and grass species.

After some discussion, the group decided to focus on the Southeastern Grasslands, which are noted for their distinctive fauna and flora. The group considered the historic degradation of grassland communities and whether or not the trend toward desert scrub has been an invasion or degradation.

The group consensus was that there was a potential for restoration or management within the Southeastern Grassland systems, and that properly managed areas had a good capacity to recover. Although there are persistent problems with invasive species, native grass species continue to dominate in many areas, and the area has an adequate hydrological cycle to maintain the dominant native grass communities.

Group members also acknowledged that a high percentage of the Southeastern Grasslands are currently in private ownership. Consequently any conservation activities and monitoring efforts would need to be undertaken in partnership with private landowners. Also it was noted that public opinion in the area might not be supportive of efforts to return the grasslands to pre-settlement condition. Finally given the small public land base in the region, it was questioned whether or not the Southeastern Grasslands should be a management priority for state and federal wildlife agencies.

The group's extensive discussion resulted in a list of desired conditions, stressors/threats, and management actions for Southeastern Grasslands. These conservation items are contained in the attached spreadsheet, which could be populated by Arizona wildlife partners. The members of the breakout group had limited expertise in the Southeastern Grasslands ecosystem, so they did not complete the indicator selection exercise for this ecosystem. Instead, they focused efforts on the complex and higher priority Sonoran Desert ecosystem.

Of particular note for future conservation efforts in the area was a newly formed monitoring partnership called the Southeastern Grasslands Working Group. The partners in this collaborative include: BLM, AZGFD (lead in Tucson field office), The Audubon Society, The Nature Conservancy, the Sky Island Alliance, Altar Valley Conservation Alliance, USFWS, NRCS, and DOD (Fort Huachuca).

Appendix 3:

Workshop Participants List

Arizona Workshop Participants

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