# Pima County Ecological Monitoring Program: Phase II Monitoring Plan Summary

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# 1 Introduction

This report summarizes the Phase II planning process that has identified a suite of ecological monitoring parameters that are being proposed for inclusion into the Pima County Ecological Monitoring Program (PCEMP). This report builds on the Phase I report, written by RECON Environmental Inc. (2007) and is a summary of a report by Powell (2010c) and Steidl et al. (2010), which summarize the design process in greater detail, including information about the rationale for choosing specific program elements and parameters, where they will be monitored, and by what methods. Ultimately, this summary report and associated documents will be superseded by a Phase III monitoring plan that will be developed after the program is operational and after issuance of a Section 10 permit (see next section).

## 1.1 The Sonoran Desert Conservation Plan and Pima County Multiple Species Conservation Plan

Pima County has embarked on a broad-scale ecological planning and implementation effort known as the Sonoran Desert Conservation Plan (SDCP). The SDCP seeks to address multiple conservation needs in the rapidly urbanizing Pima County, including cultural resource protection, ranch conservation, and maintenance of wildlife habitat (see Pima County 2000). The SDCP is now being implemented through a host of measures including a land acquisition program and mitigation measures such natural open-space set asides on private development. In the early planning stage of the SDCP, members of the public and scientific community articulated an important and ambitious biological goal for the SDCP:

> *"To ensure the long-term survival of the full spectrum of plants and animals that are indigenous to Pima County through maintaining or improving the habitat conditions and ecosystem functions necessary for their survival"*
> (Pima County 2000)

To help realize this goal and to provide regulatory certainty, Pima County has drafted a Multi-species Conservation Plan (MSCP; a type of Habitat Conservation Plan [HCP]) that embodies the scientific principles of the SDCP biological goal and specifies mechanisms for addressing the legal requirements of the Endangered Species Act. The county's MSCP covers 49 species that are proposed for coverage in County's forthcoming Section 10(a)(1)(B) permit application (herein "the permit" or "Section 10 permit") from the U.S. Fish and Wildlife Service (USFWS). These species are known as the *Covered Species*. The purpose of the permit is to provide regulatory coverage to the County and its development community by covering otherwise lawful activities that result in the "take" of species on the Endangered Species Act list or in the destruction of critical habitat. In exchange for this coverage, the USFWS requires that Pima County avoid, minimize, or mitigate—to the maximum extent practicable—the effects of Covered Activities on these species through the protection, management, and monitoring of a suite of lands that are used to offset (i.e., mitigate for) these effects. Prior to issuance of a Section 10 permit, Pima County must have a monitoring plan. The plan and its supporting documents are the foundation of the MSCP monitoring plan.

## 1.2 What is Monitoring?

The term *monitoring* is used to represent a wide array environmental sampling efforts designed to provide information to evaluate the status or condition of natural resources at a single point in time or, more commonly, to evaluate trends in attributes of these resources through time. Although monitoring programs are most effective when designed to evaluate the consequences of specific management actions (Nichols and Williams 2006; see the next section), monitoring is often necessary to assess whether broad conservation and management goals are being met, such as has been proposed for the MSCP.

## 1.3 Monitoring and Adaptive Management

Much of the monitoring for the PCEMP will be trends (or "surveillance") monitoring; in other words observing trend in a host of parameters (measures; e.g., density of vegetation) over time. Monitoring programs are most successful when there is an active interplay between monitoring and management, which is facilitated by providing data to managers in a timely and relevant manner. Ideally, this active process would employ *adaptive management*. Adaptive management involves feedbacks between information gained through monitoring and management actions. In essence, adaptive management is an iterative learning process that identifies gaps in understanding, facilitates action, and modifies management based on new information (Walters 1986). Adaptive management involves applying management treatments as randomized experiments so that the results of these actions can be continuously assessed and refined to bring about the desired objective (i.e., learning by doing). Adaptive management places an emphasis on recurrent decisions for which there is considerable uncertainty. For example, eliminating shrubs from semi-desert grasslands can involve different treatment types (e.g., manual removal, fire, and herbicides) and times of treatment; this is an ideal application for adaptive management.

Adaptive management may be ideal, but there are other ways to apply monitoring and research information to management. Sometimes called passive adaptive management, or responsive management actions, this is equated with traditional management philosophy that uses new data opportunistically and as it becomes available. An example would be the discovery of a new non-native species or opening of a "wildcat" road. These data can still provide an extraordinary opportunity for learning, because monitoring data on the spatial and temporal scales advocated for the PCEMP are rare or not available in the region. In addition to simply observing change, other opportunities to learn will be available throughout the term of the permit, because monitoring sites will be impacted by unpredicted events, such as floods and wildland fire. These quasi-experiments can provide an opportunity to compare impacted sites with those not experiencing impacts (Green 1979).

## 1.4 PCEMP Goal and Core Elements

The PCEMP is being developed to determine if the County's conservation measures, such as MSCP mitigation, are proving effective at meeting the USFWS requirements of the MSCP, as well as addressing SDCP goals. Therefore, the goal of the PCEMP is to:

*Detect and quantify changes to select ecosystem components at appropriate spatial and temporal scales to inform adaptive management, satisfy Pima County's Section 10 permit monitoring requirements, and to determine if the SDCP biological goal is being achieved.*

This monitoring plan seeks to address this goal by integrating five program elements:

- Species monitoring seeks to detect changes in the status and/or trend in the presence, abundance, or occupancy of a select set of Covered Species.

- Habitat monitoring focus on monitoring environmental features that are thought to control the distribution and abundance of Covered Species and other target species in Pima County. Habitat monitoring will be conducted in lieu of (or in addition to) monitoring for some species that are widespread and/or difficult to monitor.

- Landscape pattern monitoring relates to the spatial configuration of major community types and human-made features and is a critical leading indicator of changes to the distribution of species and other threats. Landscape pattern parameters include land cover type and fragmentation (e.g., configuration of undeveloped lands and conversely, roads).

- Threats monitoring focuses attention on possible underlying causes of potential decline of species and/or habitat components. In the context of the PCEMP, threats monitoring can include landscape pattern parameters in addition to other parameters such as off-road vehicle use, wildlife diseases, and pollution.

- Climate monitoring entails collecting weather data (primarily precipitation) at long-term monitoring plots. Climate is an important driver of biodiversity and therefore changes to climate variables such as temperature and precipitation can have far-reaching impacts on species and their habitat.

The specific parameters associated with each of these program elements, the justification for their inclusion into the program, and where and how often parameters within each element will be monitored is the subject of the Phase II plan.

## 1.5 Location of PCEMP Activities

Most on-the-ground monitoring activities will take place on lands on which Pima County has acquired for the purposes of mitigating for Covered Activities, and other properties owned by Pima County such as Tucson Mountain Park. Collectively, these properties are known as the County Preserve System and they encompass approximately 230,000 acres. At this time, ground-based monitoring is not being planned for privately owned natural open-space set asides—those undeveloped lands within subdivisions for which Pima County is seeking mitigation for the MSCP—because of the difficulty in getting permission to visit these sites.

Monitoring activities such as for landscape-pattern monitoring using remote-sensing methods can take place at larger spatial scales such as all of eastern Pima County, including private lands.

# 2 Species Monitoring

Species are the most fundamental unit in conservation and plant and vertebrate species, in particular, have a long history of being used for conservation planning activities (Morrison et. al. 1998: p 3-10), in large part due to their public appeal and because they are widely believed to be indicators of changing environmental conditions (Belnap 1998, Canterbury et. al. 2000, Niemeijer and de Groot 2008). The SDCP relied heavily on plant and animal species to develop key features of the plan, such as identification of biologically important areas that were subsequently used to inform the County's planning and rezoning process. The MSCP was an outgrowth of the SDCP planning process, and as such it is a species-centered plan.

The monitoring approach of most HCPs, such as Pima County's, usually rely almost entirely on species-specific monitoring, and for good reason; species monitoring is the "gold standard" for any HCP because species are used as "currency" in establishing program impacts and mitigation. In recognition of this, Pima County's Science and Technical Advisory Team (STAT) believe that some species-level monitoring is justified for a subset of Covered Species, particularly for those species that are restricted to a small number of individuals or populations within the MSCP Permit Area. Though other program elements (habitat, threats, landscape pattern, and climate) were also advocated for inclusion into the plan, Pima County will commit to directly monitoring a subset of species.

## 2.1 Covered Species to Be Monitored

The PCEMP will directly monitor 18 species (Table 1). Most species are aquatic or riparian obligate species and are restricted to a few sites in both eastern Pima County and in the County Preserve System, but others are more widespread. Table 1 includes information about the proposed monitoring protocol to be used, where and how often monitoring will take place, and what issues—if any—remain to be resolved before Pima County can commit to monitoring. Additional information about each species and Pima County's monitoring commitments can be found in Supplement A. (Note, all Supplements can be found on the SDCP monitoring website: http://www.pima.gov/cmo/sdcp/Monitoring/index.html)

**Table 1. Covered Species that will receive direct monitoring as part of the PCEMP. Additional information about the connection between the species and other program elements (e.g., habitat and threats monitoring) can be found in Supplement A, which also includes information on the current distribution of each species in Pima County. Many of the Covered Species that are not in this table will receive some measure of monitoring, at least through incidental observations.**

| Taxon group | Species | Key Information |
|---|---|---|
| Plants | Pima pineapple Cactus | Pima County will monitor numbers and survival of a suite of known individuals on County-owned and maintained mitigation banks every 2-3 years. Additional surveys for recruitment and additional individuals will take place every four years. Pima County will work with USFWS to establish monitoring on other sites within the Preserve system (e.g., Altar Valley near Aravaca). Pima County will use line transect surveys (Roller 1996) but Pima County will work the USFWS to refine the sampling protocol to possibly incorporate the use of occupancy models that account for imperfect detectability. In addition, Pima County may employ an adaptive cluster sampling design for this species. Finally, Pima County will develop a database for incidental observations of this species so that County staff and cooperators can record observations made while performing other functions. |
| | Huachuca water umbel | Presence at known locations (Cienega Creek and Bingham Cienega preserves) will be monitored every 2-3 years and in accordance with the methods used by Engineering and Environmental Consultants Inc. (2001). Additional surveys for presence in the Cienega Creek Preserve will be conducted every four years. Pima County will facilitate and encourage research on this species, particularly improved methods for detection of this difficult-to-survey species. |
| Mammals | Lesser long-nosed bat | Pima County has determined that species-level monitoring is warranted for this species because ongoing monitoring of roost sites is being implemented and provides local information on lesser long-nosed bat use patterns and occupancy. Therefore, Pima County will: (1) participate in coordinated exit counts at sites that contain bats that use the Permit Area and in coordination with other agency personnel; (2) visit known cave, mine, and adit roost sites within the County Preserve System every 2-3 years to observe presence of this and other bat species. Exit counts should use infra-red video cameras, and Pima County will provide technical assistance to the USFWS to develop a more detailed protocol. Pima County will develop a cave visitation protocol (including what kinds of equipment to be used) to minimize disturbance to this and other species. Surveys will take place at appropriate times of year (June-August) to ensure the greatest chance of recording occupancy. Additional monitoring of populations through the employment to passive detectors (e.g., Duchamp et. al. 2006) will be reviewed periodically to determine application of this technology to the County's needs. Pima County may participate in species-level monitoring for this and other bat species as part of Arizona Game and Fish Department's bat monitoring plan; that plan is not complete. Finally, with funding from the USFWS, Dr. Robert Steidl (University of Arizona) and a graduate student are developing a regional monitoring program for this species. Pima County will evaluate a role in that program after it is complete. |
| | Mexican long-tongued bat, Allen's big-eared bat, California leaf-nosed bat, Pale Townsend's big-eared bat | Pima County will monitor for the presence of these species while conducting surveys of known cave, mine, and adit roost sites in the County Preserve System, as well as periodic checks of habitat improvement (stabilization) projects, such as along Cienega Creek. Monitoring will take place every 2-3 years. Pima County will develop a cave visitation protocol (including what kinds of equipment to be used) to minimize disturbance to these species. This is particularly important because many of these species are sensitive to disturbance. As a result, abundance estimation at roost sites may not be appropriate. Surveys will take place at appropriate times of year to ensure occupancy by this species. Additional monitoring of populations through the employment to passive detectors (e.g., Duchamp et al. 2006) will be reviewed periodically to determine application of this technology to the County's needs. Pima County may participate in species-level monitoring for this and other bat species as part of Arizona Game and Fish Department's bat monitoring plan; that plan has not yet been released. |

| Taxon group | Species | Key Information |
|---|---|---|
| Birds | Cactus ferruginous pygmy owl | Pima County will assist with the delineation and mapping of high-quality habitat within the Permit Area. Once that map is complete, Pima County will conduct surveys for abundance and/or occupancy at a subset of those lands within the County Preserve System according to a survey protocol that is acceptable to the USFWS. The number of monitoring sites and revisit pattern will be determined after the habitat model has been developed. Pima County may also continue surveys for this species prior to construction of Capital Improvement Projects. |
| | Southwestern willow flycatcher | Pima County will monitor biennially for abundance and/or occupancy at Cienega Creek Preserve and at the A7 Ranch along the San Pedro River. Pima County will use the survey method in Sogge (2010), which calls for three surveys per year during the nesting season. |
| | Western yellow-billed cuckoo | Pima County will monitor for abundance and/or occupancy every other year at the Cienega Creek Preserve using a standardized protocol by Wiggins (2005) that uses a broadcasted call of the species to elicit a response. Pima County will survey suitable habitat within the Preserve at least twice during June. |
| Fishes | Gila chub | Pima County will monitor abundance and/or relative abundance of this species using backpack shocker and/or passive sampling at the Cienega Creek Preserve. Monitoring will take place within pools and runs, and multiple-pass depletion sampling will be used for deeper pools. Monitoring will take place every other year, as recommended by Bodner (2007) when monitored in combination with other species for which different methods are used (e.g., seine netting; Gila topminnow). By alternating seining and electroshocking (for Gila chub) each year, Pima County minimizes sampling impacts to the species and maximizes opportunities for finding invasive species. The location of monitoring sites will be chosen using simple random sampling. |
| | Gila topminnow and Longfin dace | Pima County will monitor abundance and/or relative abundance of these species using seine nets and employing depletion sampling at the Cienega Creek Preserve. Monitoring will occur every two years. At the Cienega Creek Preserve, monitoring will take place at $\geq$ 10 pools that are randomly chosen from the all potential pools. The number of monitoring sites at other locations will be determined prior to permit issuance. By alternating seining and electroshocking (for Gila chub) each year, Pima County minimizes sampling impacts to the species and maximizes opportunities for finding invasive species. |
| Amphibians | Lowland leopard frog | Pima County will monitor for occupancy at least two times in late spring and early summer (pre-monsoon) every other year at select sites. Monitoring will be for any stage of the species' life cycle (eggs, tadpoles, adults) using a visual encounter survey (Heyer 1994) that has been modified by the Arizona Game and Fish Department for the Chiracahua leopard frog (U. S. Fish and Wildlife Service 2007). Don Swann (Saguaro National Park) has also developed a survey protocol for this species and Pima County will investigate the use of that protocol, which includes a rapid assessment of habitat conditions (mostly water availability) during each visit. Pima County will develop a database for incidental observations of this species so that County staff and cooperators can record observations made while performing other functions. Pima County will also note other aquatic species such as the Sonoran mud turtle and canyon treefrog. Pima County may also work with researchers at the UA to test populations for *Chytridiomycosis*. |
| | Chiricahua leopard frog | No known populations of this species currently exist within the County Preserve System. However, Pima County will inventory new acquisitions and leased lands for new populations. For populations that are found within the County Preserve System, Pima County will monitor for occupancy at least two times in late spring and early summer (pre-monsoon) at least every other year. Monitoring will be for any stage of the species life cycle (eggs, tadpoles, adults) using a visual encounter survey (Heyer 1994) that has been modified by the Arizona Game and Fish Department for this species (U. S. Fish and Wildlife Service 2007). Don Swann (Saguaro National Park) has also developed a survey protocol for the lowland leopard frog and Pima County will investigate the use of that protocol, which also includes a rapid assessment of habitat conditions during each visit. Pima County will also note other aquatic species such as the Sonoran mud turtle and canyon treefrog. Pima County may also work with researchers at the UA to test frog populations for Chytridiomycosis. |

| Taxon group | Species | Key Information |
|---|---|---|
| Reptiles | Desert tortoise | Pima County will commit to monitoring occupancy for the desert tortoise at approximately 15 sites, which will be surveyed every other year according to the field protocol used by Zylstra (2008). This protocol suggests at least 4 visits to sites each season. Of course, monitoring this species would best be accomplished at a larger spatial scale than the County's preserve network. To this end, Pima County awaits the development of a long-term monitoring protocol to be developed by the Arizona Game and Fish Department. Once that plan is released, Pima County will decide if the plan is appropriate for Pima County to be involved. Pima County will develop a database for incidental observations of this species so that County staff and cooperators can record observations made while performing other functions. |
| | Mexican garter snake | Pima County will monitor occupancy of this species every three years at Cienega Creek Preserve using either visual encounter surveys (Heyer 1994) or minnow traps, which have been successful for capturing this species (Rosen and Caldwell 2004). Because of the low detectability of this species, Pima County will survey a select set of sites at least four times within a seasonal period of peak activity for this species. |
| Invertebrate | Arkenstone Cave pseudoscoprion | Recent sightings of this species in Colossal Cave may represent an opportunity to monitor presence without entering Arkenstone Cave. Pima County will work with park staff to determine the feasibility of this approach. |

For most of the species, the location of monitoring will occur within occupied habitat or those areas known or suspected to be occupied in the recent past. This approach will not provide information on their expansion to other areas, which would likely be documented if monitoring were to take place throughout their potential habitat (as defined by modeled habitat (Pima County 2001)], Priority Conservation Area, or by other means). However, monitoring areas that have a low probability of being occupied is difficult to justify given the high cost of monitoring for these species. Many of the species proposed for restricted monitoring are conspicuous species and any sightings within the County Preserve System will be investigated. Similarly, reintroductions of species to County-managed conservation lands will also be monitored to determine success of reintroduction efforts.

It should be noted that species monitoring does not preclude habitat monitoring, threats monitoring, landscape-pattern monitoring, and climate monitoring. Instead, for some of these species, the combination of these monitoring approaches will help ensure that important changes are detected and properly addressed.

# 3 Habitat Monitoring

Habitat is a species-specific term that refers to resources that a species needs to perform life-history functions such as foraging, nesting, mating, and seeking refuge (Morrison et al. 1998). Habitat monitoring will be a critical component of the PCEMP, which is a different approach to monitoring than most other HCPs, which often focus on species monitoring. There are a number of reasons for this. First, HCPs (such as Pima County's) that contain as many species and cover such a broad geographic area (>700,000 acres for this HCP) are essentially ecosystem conservation programs. This scale suggests that monitoring take a broader view of change by moving from species to the next level of biological organization: the environmental features that are necessary for their survival. This is habitat monitoring. The second, and related, justification for this approach is that changes to a species' habitat are most likely to affect

populations of the species themselves and in some cases may predict these changes in advance, thereby providing an opportunity to enact management actions to improve habitat quality (e.g., Krueper et. al. 2003). This is the reason why most successful species conservation projects focus resources on improving a species' habitat and in reducing threats and only revert to direct, species-level reintroductions as a method of last resort or in combination with habitat improvement.

Putting Pima County's monitoring program in the broader conservation context provides further justification for this approach. In the case of Pima County's MSCP, the suite of Covered Activities (i.e., a subset of development activities in eastern Pima County that are covered under the permit) is likely to have a minor influence on the populations of Covered Species in Pima County as compared to other sources of impact, including past land use in Pima County, development activities (including mining) not covered under the permit, climate change, invasive species, and off-road vehicle use. In this context, Pima County's focus on acquisition and long-term conservation of undeveloped land provides greater conservation than most other large-scale HCPs. As the County turns attention to monitoring, it is logical to place a significant amount of the County's effort toward habitat monitoring. Finally, it should be noted that while Pima County is developing a habitat-based monitoring effort that will be applied by Pima County to the County Preserve Network, Pima County sees this effort as having application to areas outside of the preserves and Pima County will encourage our partners (e.g., Bureau of Land Management and National Park Service) to adopt these methods if they address the goals and objectives of the respective programs.

## 3.1 Summary of the Design Process

Pima County's focus on habitat monitoring prompts a critical question: what constitutes habitat and how do we monitor it? The response to this question has been a two-year planning process, and which is detailed in the attached supplement by Steidl et al. (2010; Supplement B). We refer the reader to that document for full details on the design process and results. But in short, the design process considered a host of potential environmental features (i.e., habitat features used by many different species) and compared environmental features based on different objectives that focused on issues of management, importance of Covered Species relative to other species considered in the planning process, etc. Some environmental features emerged as the most important to monitor regardless of the weighting scheme used. Most notably, vegetation characteristics were among the most important because of their importance as habitat to many of the vertebrates included in the planning process. In fact, of the top 12 Environmental Features, ten are related to vegetation. Not surprisingly, water was another critical feature that emerged and together, these two groups of parameters will form the foundation of the habitat-based monitoring effort for the PCEMP. Though not part of the design process in Steidl et al. (2010), caves and mines will be a part of habitat monitoring for the PCEMP.

### 3.1.1 Vegetation

Two aspects of vegetation were consistently chosen in the design process, no matter the weighting scheme used: (1) *structure* is the physical formation, arrangement, and physiognomy

of vegetation and is often measured as density or volume of vegetation; and (2) *composition* refers to the plant species present on a site and includes measures of stem density, abundance, or frequency. The emergence of vegetation features as top-ranked parameters is not surprising: plants are fundamental aspects of many species' habitat and vegetation is an indicator of site characteristics, past disturbance events, climate patterns, and in the case of some annual vegetation, the timing and intensity of weather events.

#### 3.1.1.1 Co-Location Plot Design for Vegetation and Other Monitoring Parameters

As part of the parameter selection process (Supplement B), Pima County determined that monitoring a host of parameters at the same location has inherent advantages over designs that monitor only one or a few resources at a site. Co-location of monitoring plots is common (e.g., National Biological Service 1995, Manley et. al. 2006), particularly when the resources of interest have an important effect on—or are influenced by—each other. Sampling for multiple parameters at the same location has two primary advantages over strategies that establish sampling locations for parameters independently. First, co-locating measurements will allow for assessments of interactions among parameters and provide data that can be used as covariates in analyses of trends. For example, changes in the abundance of a Covered Species can be explored to assess whether these changes are associated with parameters such as vegetation structure and composition. Second, costs are reduced when sampling sites are co-located because several parameters can be measured at a site during a single visit. Conversely, there are two primary disadvantages of co-location. First, parameters for uncommon resources may not be sampled sufficiently to generate estimates of sufficiently high precision. This can be overcome by increasing the number of locations where those resources are sampled. Second, consistent surveys on a plot may damage some resources, and therefore careful attention must be paid to ensure protection of a site from trampling by surveyors.

Because of the overwhelming influence of vegetation on vertebrate species and in consideration of the methods used to monitor it, we determined that the best approach for establishing long-term monitoring plots is to establish a *primary sampling unit* as a circular plot with a radius of approximately 150 m (17.5 acres) to support measurement of all vegetation and other parameters that will be included in the PCEMP. Within each plot will be 12 subplots where measurements of vegetation and groundcover will occur. This plot size and arrangement of subplots will facilitate precise estimates of vegetation and other parameters within the plot, but is not so large as to make sampling inefficient. Though long-term monitoring plots are optimized for vegetation monitoring, additional parameters will be monitoring at long-term monitoring plots including precipitation, threats such as off-road vehicle use and presence of select invasive species.

In the spring of 2010, Pima County developed and pilot tested a field-based protocol to monitor vegetation and other resources at long-term monitoring plots (Supplement C). The 150m radius plot was used as a first approximation during the field trial and may be modified based on an analysis of those data. The results from the 2010 field season will also be used to provide a basis for developing an appropriate stratification strategy and establishment of the number of

plots necessary to monitor vegetation and other environmental features effectively during the 30-year permit period.

Once the program is fully implemented, Pima County will establish plots throughout the County Preserve System using a randomized design. We will revisit the same plots every 3-5 years, but may adjust this schedule based on the results of the second visit to each plot. That is, if we observe very little change between the first few sampling periods, the time between subsequent visits may be expanded, whereas if significant changes are observed, we would want to revisit plots more often. These decisions will be made in consultation with STAT or another scientific advisory group.

### 3.1.2 Water Resources

Water drives most ecological patterns and processes, especially in arid environments. In riparian areas, water availability determines the extent, composition, and structure of the vegetation community and has profound effects on biodiversity in general (Stromberg et. al. 1996, Eby et. al. 2003). In the southwestern U.S., more than 70 percent of vertebrate species use riparian areas during some stage of their life cycles (Knopf et. al. 1988), and in Pima County many Covered Species occur in riparian areas, especially hydo-riparian and meso-riparian communities. In addition to supporting high biodiversity, naturally functioning riparian areas improve water quality and provide important floodplain functions (Leopold et. al. 1964, Stromberg et al. 1996, Naiman and Decamps 1997). Water monitoring is therefore an essential component of the PCEMP, especially given the increasing demand for water by humans and the likelihood of reduced natural water resources as a result of climate change (Powell 2010a).

Three primary water resources will be monitored as part of the PCEMP: (1) seeps and springs, (3) shallow groundwater in select systems, and (3) perennial streams. Table 2 provides details of the approach and methods that Pima County will employ for this program element.

### 3.1.3 Caves and Mines

Caves and mines were not a part of the design process developed by Steidl et al. (2010) because this abiotic resource does not change in the same manner as vegetation or water resources. However, they are key habitat components for a number of Covered Species, most importantly bats, and therefore will be an important part of the habitat monitoring element.

**Table 2. Water resources that will be monitored as part of the Pima County Ecological Monitoring Program. Precipitation monitoring is covered in Chapter 6.**

| Water Resource | Parameter(s) | Monitoring Approach and Commitments |
|---|---|---|
| Spring and Seeps | Presence of water and relative flow | Observation and measurement of all springs in the County Preserve System. Pima County will monitor each spring at least once every two years. Pima County will engage other land management agencies (especially the U.S. Forest Service) in the development of regional spring monitoring protocol. Pima County may employ citizen scientists to visit springs and evaluate conditions. |
| Perennial and intermittent creek flow | Proportion of stream with water | Pima County will conduct wet/dry mapping of select creeks (e.g., Cienega Creek, Youtcry, Edgar, Davidson, and Posta Quemada) using the protocol used by the Pima Association of Governments along Cienega Creek. Monitoring will take place at least once per year and will likely be conducted in combination with aquatic species surveys. Surveys should be conducted during the driest parts of the year. |
| Shallow groundwater | Level in relation to established threshold | Groundwater monitoring will continue at sites along Cienega Creek, but the application of monitoring to other systems has not been determined. Fonseca (2008a) provides an in-depth analysis and discussion of this topic and we refer the reader there for more information. |
| Water Quality | Total dissolved solids, temperature, conductivity, and pH | Data being collected at Cienega Creek Preserve by Pima Association of Governments (Pima Association of Governments 2009). Data also collected on the Santa Cruz River as part of the operations for Pima County's wastewater operations. Additional water quality monitoring may take place as part of fish and amphibian monitoring using a multi-parameter meter. |

As noted in the species-specific monitoring effort for cave-dwelling bats (see Table 1) caves and mines on County preserves will be visited every 2-3 years. Initial site visits to lesser-known caves (i.e., all caves except at Colossal Cave Mountain Park) will entail a detailed survey of conditions including size and dimensions of the cave, recent evidence of vandalism, and any structural issues that may cause deterioration of the cave or preclude subsequent visits, as well as a determination about the potential for installing bat-friendly gating. Don Carter, program manager at Pima County Natural Resources, Parks, and Recreation is currently updating the inventory of caves and mines within the County Preserve System and conducting site visits to most caves. He anticipates completing this project by late fall 2010. Subsequent visits will document changed conditions since the last visit, such as evidence of collapse and vandalism.

## 3.2 Potential for Using Remote Sensing Tools to Monitor Vegetation Change and Stream Channel Morphology

Habitat monitoring need not be restricted to on-the-ground measurements of resources at long-term monitoring plots. The PCEMP can also take advantage of advancements in remote sensing technologies to monitoring habitat features such as vegetation structure and composition. In particular, the use of light detection and ranging technology (LiDAR), combined with multi-spectral imagery is a powerful new tool for monitoring vegetation structure change as well as changes in stream channel morphology. (Stream channel morphology was not

chosen for inclusion into the program, in part because of the expense of collecting on-the-ground monitoring data, but it can be monitored easily and inexpensively using LiDAR). As part of the planning effort for the Section 6 grant, Swetnam and Powell (2010; Supplement D) conducted a pilot study of the effectiveness of LiDAR for characterizing vegetation along the Cienega Creek Natural Preserve. The pilot study found that vegetation monitoring using LiDAR is feasible, particularly in areas with significant amounts of vegetation, such as in riparian systems.

Despite its potential as a long-term monitoring tool for vegetation, additional pilot testing and research must be done before Pima County will commit to its use in the PCEMP. For example, its utility for monitoring change in the desert uplands and semi-desert grassland communities needs further exploration. To advance this process, Pima County hopes to pilot test a small LiDAR flight to collect data in a way that is optimal for vegetation monitoring. That flight is likely to take place in 2011. If that effort is successful, Pima County will develop a detail protocol and develop cost estimates for employing this promising new tool. It is important to note that LiDAR will complement—and not replace—long-term monitoring plots, which would be used to attribute the date collected as part of the LiDAR effort.

# 4 Landscape-pattern Monitoring

Landscape pattern is a broad category describing the spatial configuration and extent of land-cover and land-use parameters. *Land cover* is the observed biophysical state of the earth's surface and immediate subsurface (McConnell and Moran 2000) and is typically delineated into major categories such as types of natural vegetation (e.g., forest and grassland) and human uses such as urban development, agricultural fields, mine sites, and roads. *Land use* involves both the manner that land is manipulated and the intent of that manipulation (Turner et. al. 1995). The difference between land cover and land use can best be explained by example. Classification of an area by land cover may assign it as semi-desert grassland, but the land use there may vary from protected area to active ranchland with very different and important conservation implications such as the potential for future subdivision of the ranchland. This example illustrates why land use is considered an excellent leading indicator of environmental condition and a major determinant of land cover (Meyer and Turner 1994). Further, the type, distribution, and extent of major land uses can foreshadow changes to the distribution and abundance of plant and animal species (Blair 1999) or other parameters such as water quality (e.g., Soranno et. al. 1996) that have important implications for maintenance of biodiversity and ecological health in Pima County.

## 4.1 Proposed Monitoring Approach

Throughout the development of the SDCP and PCEMP, the STAT has recommended monitoring landscape-level parameters. Fortunately, there are a host of tools that Pima County can use for this element, as suggested by Fonseca (2008b). To monitor landscape pattern, Pima County will use tools: 1) that are produced as part of the County's day-to-day operations to measure and

forecast development-related activities and 2) remote-sensing tools including, but not limited to, products such as the National Land Cover Dataset and Regional GAP.

### 4.1.1 Retrospective Monitoring of Landscape Patterns

The objective of retrospective monitoring is to document changes in the type and location of conversion activities such as new roads and sewers, and land use that took place in a previous time period (unusually every year, but sometimes longer depending on the data source). Retrospective monitoring will be completed using two primary methods: using the County's internal data and using freely available information from other governmental sources (Table 3). Information gained from this analysis will be useful in understanding regional trends affecting species and inform other regional conservation and monitoring effort such as other HCPs and the National Park Service's Inventory and Monitoring Program.

During the 30 years of the monitoring program we expect new tools will be at our disposal to obtain a more accurate footprint of roads and development activities. For example, we will encourage the acquisition of additional high-resolution, multispectral imagery (from outside the current extent of image acquisition; primarily defined by the urban boundary) being acquired by Pima Association of Governments. Using these data we would be able to quantify the location and footprint of development within parcels for which we have only limited data. Using freely available datasets, we will monitor changes in land cover over longer time periods as the tools become available (usually every 3-5 years). For this we will use the National Land Cover Dataset (NLCD) and the Southwestern ReGAP. NLCD mapped Arizona in 1992 and 2001, and has summarized changes in land cover over that time period. Pima County and its partners can use the NLCD to understand conversion of natural cover to urban, agricultural and mining land uses, and to understand regional changes in the distribution and extent of bare soil, rock, and riparian forests (primarily mesquite bosques, broadleaf deciduous forests, and wetlands combined). Data is acquired at a resolution of 30 meters at a time interval of approximately every 10 years. Change can be resolved at a minimum of 1 acre (http://www.mrlc.gov/changeproduct.php). For more information on this approach, see Fonseca (2008b).

### 4.1.2 Prospective Monitoring

Prospective monitoring will *forecast* the location of development by monitoring pre-construction permits and processes such as Comprehensive Plan amendments, rezonings, and plat and subdivision approvals by the Pima County Board of Supervisors (Table 2).

# 5 Threats Monitoring

Threats are any past, present, or future anthropogenic activity that degrades or destroys a conservation target (i.e., Covered Species and/or its habitat). Many threats result from past human actions, but which no longer require such actions for the threat to be significant, such as the introduction of an invasive species. Threats are widely recognized as being an important component of broad-scale monitoring programs (Salafsky and Margoluis 1999).

**Table 3. Retrospective and prospective approaches that will be employed to monitor changes in landscape pattern. Changes in these monitoring parameters will be reported each year or as new information is received. See text of the document for more discussion on retrospective versus prospective monitoring.**

| Approach | Parameter | Data sources used in analysis |
|---|---|---|
| Retrospective | Miles of new roads and other ground-disturbing Capital Improvement Projects | Three types of information will be used for this parameter. First, additions to highways, roads, streets, and sewers are updated nightly by the Pima County Department of Transportation after roadway parcels are dedicated to the County or incorporated area. Second, Pima County Development Services issues grading permits and in some cases this is a proxy for road building, particularly in more rural areas where a parcel is undeveloped. Finally, "wildcat" roads on public lands are occasionally mapped and monitored by the Sky Island Alliance and we will use satellite imagery to periodically monitor County preserves for new, unauthorized roads. Completed CIP projects by the County or unincorporated jurisdictions are updated once projects are complete. |
| | Extent and location of the built environment | A number of measures will be used to monitor this parameter. 1) Grading and/or building permits issued would be considered to be developed, 2) for improvements to a parcel outside of the sewer service area, changes in the tax assessor's records from "unoccupied" to "occupied" would be noted as developed, and 3) approved applications to Development Services for "Notice of Intent to Discharge" and "Discharge Authorization through Pima County's Department of Environmental Quality. |
| | Changes in land cover type and location | Pima County will use data from a variety of free sources as they become available. The National Land Cover Dataset and Southwestern ReGAP are two products that will be used—as they become available—to monitor changes from one time period to the next. |
| Prospective | Extent and location of future development | Pima County collects the following information and stores it in a GIS that can be summarized periodically: (1) Comprehensive Plan Amendments. Any changes to the Comprehensive Plan, as it relates to future patterns of growth, is analyzed for how it might affect the type and location of future development. This is effort is often a best guess, but can be very useful in forecasting. (2) Rezoning. Most development activity in eastern Pima County happens after the approval of rezoning applications. Pima County will track the location and type of rezoning and report separately changes in land use codes, such as from ranchlands to agriculture or mining. (3) Plat or Subdivision Approvals. After rezoning approval by the Pima County Board of Supervisors, subdivision or plat plans are submitted to Development Services for approval. Approvals in the planning period will be mapped. (4) Building permits issued but without taxable improvements. In these cases, construction is either ongoing or has not yet begun. (5) Grading permits. Location of permit. (6) Planned CIP Projects. Any proposed and approved (but not started) county or incorporated jurisdiction CIP project such as roads, sewers, and bank stabilization. |

## 5.1 Threats to be Included in the PCEMP

Given the importance of threats to the long-term maintenance of biodiversity in Pima County, its inclusion into the monitoring program is essential, but choosing the right parameters is also important. The suite of chosen parameters is listed in Table 4, which provides a summary of threats and how they will be monitored as part of the PCEMP. Threats were chosen for a variety of reasons, including their importance in the SDCP planning process, direction from technical advisors (the STAT and during the Phase I scoping sessions; RECON Environmental Inc. 2007), and because of ongoing efforts to collect the information. For some threats that are not included as part of the PCEMP (e.g., water quality, hunting pressure), other entities are

collecting this information and Pima County can periodically query the entity for relevant information. Similarly, some threats are not currently being considered for inclusion into the program, but may be monitored in the future by employing collaborations that are not currently in place.

# 6 Climate Monitoring

*Climate* is the average weather over a long time period. Parameters used to describe an area's climate include precipitation, temperature, humidity, cloud cover, atmospheric pressure, and wind speed. Climate is fundamental to ecosystem patterns and processes and as such is the broadest-scale category for inclusion into the PCEMP. Especially in arid regions, the amount and timing of precipitation has an overwhelming influence on distribution and abundance of plants and animals in both space and time, and is an important determinant of regional biodiversity.

**Table 4. Threats that will be monitored as part of the PCEMP.**

| Threat | Justification, Parameters and Approach |
|---|---|
| Development and fragmentation | Justification: Development-related activities is the leading cause of habitat destruction and fragmentation in Pima County and is the reason for the County's acquisition of a Section 10 permit. Parameters: Location and area of development (buildings, roads, sewer, bank stabilization, etc.) resulting from the private and public sectors. |
| Cave and mine modification, closure, and vandalism | Justification: Caves and mines are important habitat for a number of Covered Species and changes to this resource is likely to impact the species. Parameters: Number, location, and extent of closure, modification or vandalism. Monitoring Approach: Monitoring all caves in County preserves 2-3 years as part of species-specific monitoring and habitat-based effort. |
| Shallow groundwater levels | Justification: Shallow groundwater supports hydro-riparian and meso-riparian systems and therefore is fundamental to maintaining habitat for a number of Covered Species. Parameter: Depth to water levels in select shallow groundwater areas of Pima County. Monitoring Approach: Groundwater monitoring will continue at sites along Cienega Creek, but the application of monitoring to other systems has not been determined and this is discussed in depth by the Groundwater protocol developed by (Fonseca 2008a) |
| Motorized off-road vehicle impacts | Justification: Off-road vehicles (from road recreation, drug smuggling, and law enforcement) are an increasing threat to a variety of resources including Covered Species, soils, and vegetation. Parameters: Location, extent, and condition of new roads. Monitoring Approach: Yet to be determined, but is likely to be anecdotal and qualitative within County preserves. Data is likely to be recorded while County staff performs other functions. |
| Invasive aquatic vertebrates and crayfish | Justification: Bullfrogs, invasive fish, and crayfish can significantly impact aquatic Covered Species. In areas where they are not currently present, early detection will be critical. Parameters: Presence and relative abundance. Monitoring Approach: Monitored concurrently with fish, leopard frogs, and presence of water along key perennial riparian areas within County preserves. Surveys will be conducted using visual encounter surveys and enrolling citizen scientists in the effort will be important. |
| Invasive plants | Justification: Invasive plants can out-compete native plants and alter ecosystem structure and function and therefore threaten habitat of Covered Species. Of particular concern are buffelgrass, fountaingrass, Lehmann's lovegrass, and African sumac. Parameters: Variable depending on the species, but the number of new individuals in an area (i.e., early detection) is critical. Monitoring Approach: Pima County will develop a database for recording incidental observation of any species and in any location on County preserves. Pima County will develop a list of the 15 or 20 most important invasive species that all appropriate County staff and cooperators must be able to indentify. These invasive species will be surveyed for in and around all long-term monitoring plots at the same time as vegetation monitoring (see Chapter 3). Buffelgrass mapping and monitoring efforts are ongoing and being coordinated by the Southern Arizona Buffelgrass Coordination Center; Pima County will assist with this effort. Lehmann's lovegrass will be monitored at most long-term monitoring plots that occur in semi-desert grassland communities. |

## 6.1 Proposed Approach

Many parameters are used in monitoring climate, most importantly temperature, humidity, wind speed, and precipitation. The PCEMP will focus only on monitoring precipitation because this parameter is more spatially variable and has such an important control over the biota of the County. Fortunately, many of the other important climate parameters are being collected by other entities within the County (Flood Control District) and Pima County will periodically obtain data on temperature, humidity, and wind speed from these entities, including:

- Arizona Automated Local Evaluation in Real Time Network,
- Arizona Meteorological Network,
- National Weather Service Cooperative Observer Program,
- Colorado River Basin Forecast Center,
- Rainlog.org volunteer network, and
- Remote Automated Weather Station Network

In addition, Pima County will benefit from broader-scale syntheses of climate that are being conducted by researchers and Pima County will continue to keep abreast of the most current findings.

The PCEMP will collect precipitation data at all or most long-term monitoring plots that will be established throughout the County Preserve System. We will employ a combination of manual rain gauges and multi-function weather stations with data loggers. Monitoring will be performed by paid staff or volunteers who will check manual rain gauges or download data from automatic data loggers twice per year (September and May).

# 7 Other Program Elements

## 7.1 Data Management

Data management will play an important role in the PCEMP and considerable resources will be devoted to the effort. As a first step, Pima County completed a data management plan (Powell 2010b; Supplement E), which is a strategy for ensuring that data are documented, secure, accessible, and useful for decades by future managers and members of the public. The data management plan is based on a set of core principles:

- **Quality:** Ensure that appropriate quality assurance measures are taken during all phases of data development: acquisition, processing, summary and analysis, reporting, documenting, and archiving.
- **Interpretability**: Ensure that complete documentation accompanies each data set so that users will be aware of its context, applicability, and limitations.
- **Security**: Ensure that both digital and analog data are maintained and archived in a secure environment that provides appropriate levels of access to project leaders, technicians, network staff, and other users.
- **Longevity:** Ensure that data sets are maintained in an accessible and interpretable format, accompanied by sufficient documentation.

- **Availability**: Ensure that the data are made available and easily accessible to managers and other users.

### 7.1.1 Covered Species Information Database

The annual monitoring activities for the PCEMP will form the foundation of the program and will be used to determine permit compliance and effectiveness. Yet the program stands to benefit from the fact that Tucson is a regional center for ecological research and monitoring activities, much of which could contribute to an understanding of the distribution and abundance of Covered Species. To provide an effective means of collecting and summarizing this information, Pima County will develop the Covered Species Information Database (CSID). Each year Pima County will query researchers and other governmental entities and non-governmental organizations regarding any data collected on Covered Species in the preceding year. Information would include a diverse range of information such as reports, sightings, or emergence of new threats. Information from these sources would be part of the annual report to the USFWS. Participating researchers and government and non-governmental entities would be encouraged to participate through public outreach activities, but the program would be on a voluntary basis. Pima County would be careful to ensure that no sensitive information, such as locations of Threatened or Endangered species, be released without permission of the research entity and the relevant landowner. Data from this project will be stored using appropriate protocols that include metadata.

This database will also have direct application to habitat monitoring because information on species can be used to update species accounts as they relate to habitat. To this end, the Pima County IT department has begun to create this database.

## 7.2 Engaging the Public: Promoting Citizen-based Monitoring Projects and Outreach

Pima County is fortunate to have a citizenry that is active in conservation, research, and education. This interest has been demonstrated by citizen engagement in large-scale planning efforts such as the SDCP, as well as their participation in many volunteer opportunities such as the Tucson Bird Count and Sky Island Alliance's tracking and road monitoring programs. A important objective of the PCEMP will be to engage citizens in monitoring activities and products.

### 7.2.1 Citizen-science monitoring

Opportunities for citizen-science monitoring will be explored, such as for monitoring streamflow length. This has been done to great effect in Cienega Creek since 1999. These outings have been an extraordinary educational opportunity for participants and have contributed critical information for understanding the response of Cienega Creek to drought conditions. As a result of this success, monitoring the presence of surface water in several key riparian areas in eastern Pima County (Sabino Creek, Tanque Verde Wash, Agua Caliente Spring, and Arivaca Creek) using trained observers is a high priority for the PCEMP. Pima County may also partner with the National Phenology Network to provide interested Pima County citizens

with the opportunity to monitor changes in phenological events such as initiation of flowering, nesting, or migration (see http://www.usanpn.org for more information). Other opportunities for citizens might include reporting sightings of invasive species, and location and extent of off-road vehicles.

Though volunteers can be an effective model for achieving program goals, it does require more cost for oversight and management than most realize (Brudney 1990). It is often difficult to quantify, but some studies estimate that volunteers can cost organizations from $300-1,000 per year per volunteer (Public/Private Ventures 2002). For some PCEMP projects, most volunteer opportunities will have to be in and around where most volunteers live (i.e., mostly Tucson), but getting volunteers to more remote sites for projects such as wet/dry mapping may require that the County pay for travel expenses. Cost associated with recruiting, training, retaining, and recognizing volunteers will be factored into all protocols that will consider the use of volunteers.

### 7.2.2 Project Communication

The primary function of the PCEMP will be to collect, analyze, and archive long-term monitoring data. Another key element of the program will be in communicating program results to managers, the general public, and the media. An import step in the development of the PCEMP will be for Pima County to develop a communications plan that identifies target audiences and appropriate products (e.g., reports and presentation) for each of the audiences. Other items for the communication plan include standardizing data reporting formats, and outlining data sharing protocols. Based on discussions with other monitoring program managers, Pima County can expect to devote approximately 10% of the program's budget to communicating program results.

## 7.3 Program Duration and Phasing

The PCEMP is being developed as part of the County's Section 10 permit, and as such monitoring will not get underway until after permit issuance. Because the Section 10 permit will be for 30 years, the PCEMP will also be for 30 years, though some program elements will likely continue after permit expiration. The PCEMP will be fully implemented within approximately five years of obtaining a Section 10 permit and the monitoring program will be implemented in three phases. Within one year of permit issuance the County will enact an implementation plan to guide program development. The reason for the phasing, rather than starting all program elements and parameters at once, is to provide sufficient time to develop each piece with the appropriate care and attention. In this way, each program phase builds on the success and lessons learned from the previous phase(s).

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