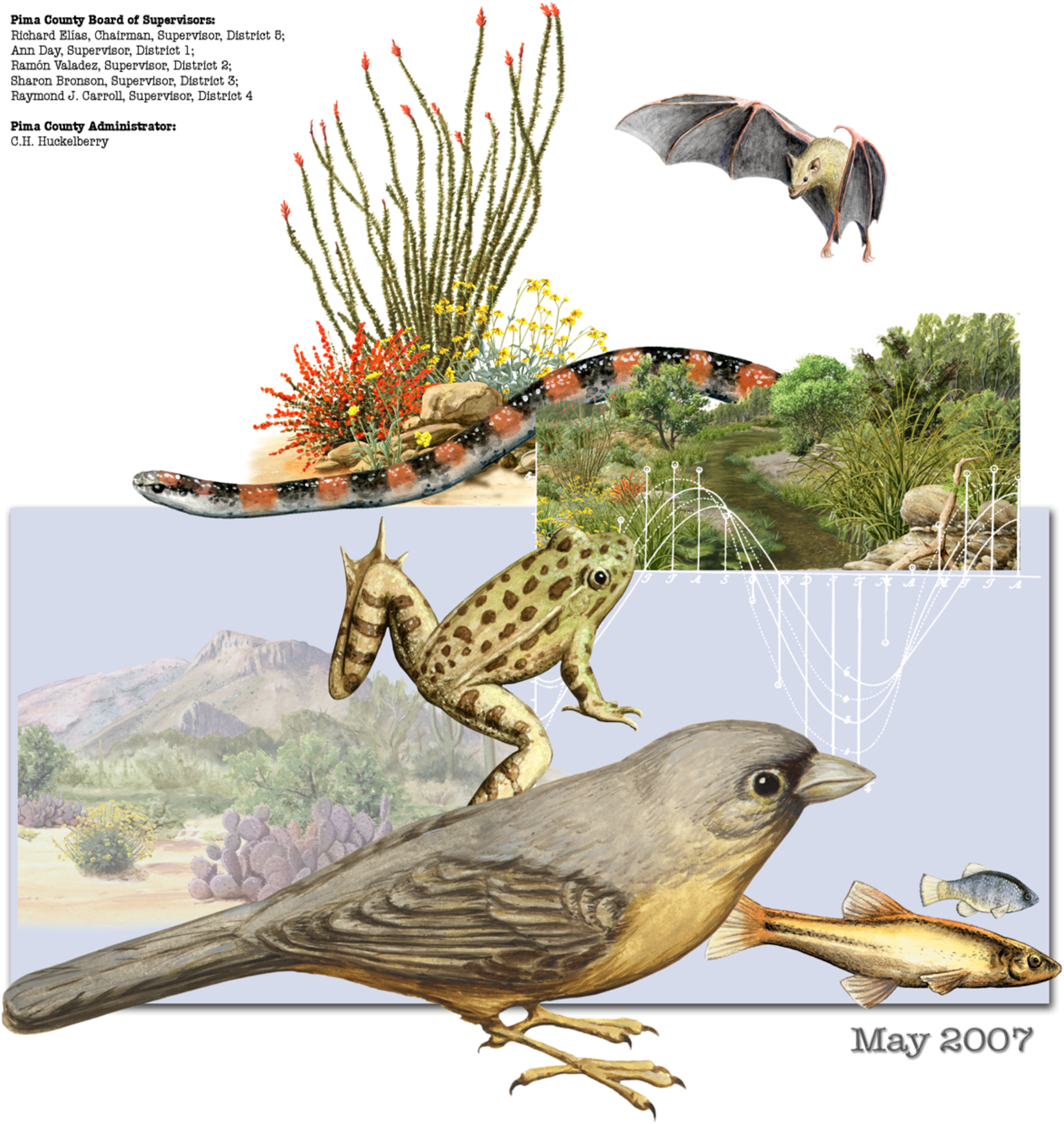

May 2007

Ecological Effectiveness Monitoring Plan for Pima County: Phase 1

Ecological Effectiveness Monitoring Plan for Pima County: Phase I Final Report

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EXECUTIVE SUMMARY

The Pima County Ecological Effectiveness Monitoring Program (Pima County EEMP) is an essential tool for determining the health and condition of key ecosystem components in Pima County, Arizona. The Pima County EEMP is part of a comprehensive conservation effort, known as the Sonoran Desert Conservation Plan (SDCP), which seeks to preserve the biological diversity and cultural heritage of Pima County in response to unprecedented human population growth and its associated impacts. To address ecological health in the context of the Sonoran Desert Conservation Plan (SDCP), Pima County initiated a Multi-species Conservation Plan (MSCP) to ensure both compliance with the Endangered Species Act (ESA), through a Section 10(a)(1)(B) permit, and to aid preservation of the full spectrum of plants and animals indigenous to Pima County. The Pima County EEMP is a required element of the MSCP and this report is the first step in developing the Pima County EEMP

Like most MSCP monitoring programs, the Pima County EEMP will include monitoring a subset of species covered under the Section 10(a)(1)(B) permit. However, there is a growing recognition that monitoring a small suite of species is less informative to managers than monitoring key structural and functional ecosystem parameters. Therefore, Pima County proposes to monitor a broad suite of biotic and abiotic parameters that influence covered species in addition to other species of interest. These additional parameters are linked hierarchically such that changes in one parameter will likely result in changes to other parameters with which they are associated (Figure ES.1). Parameter groups that will be considered for inclusion into the Pima County EEMP

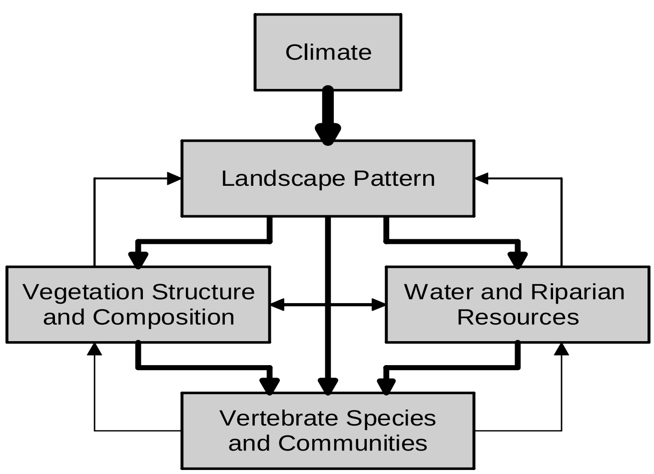

Figure ES.1. Relationships among Parameter Categories in the Pima County EEMP. Line width of the arrows indicates relative influence of categories within Pima County; human-related stressors are not included. Interconnections among categories highlight the importance of creating a comprehensive, multi-category monitoring program are climate, landscape, water and riparian resources, vegetation structure and composition, and vertebrate species and communities. By taking an integrated approach, the Pima County EEMP will have the best chances of anticipating, detecting, and responding to environmental changes resulting from a broad range of stressors at many ecological scales. Ultimately, this approach will also lead to greater cost efficiency, because many of the broader-scale parameters such as land cover and water resources are less expensive to monitor than rare vertebrate species. The design being advocated will also increase the likelihood of understanding the causes of observed trends, offer greater insight and direction to management efforts, and galvanize these efforts in a more timely and therefore more efficient manner. This approach differs markedly from species-based monitoring that emphasizes population parameters for a narrow suite of rare, endangered, or indicator species; yet ultimately is more likely to satisfy requirements of the permit by nature of its integrated design.

The Pima County EEMP is in the initial planning stage (Phase I of III). To inform this effort, RECON Environmental Inc. and Pima County hosted a series of expert workshops in the fall of 2006. Seven workshops were attended by over 50 subject-matter experts and managers who provided important perspectives on what ecosystem components hold the most promise for inclusion into the program. Experts evaluated parameters suggested by an earlier monitoring effort and recommended new parameters to better meet the goals of the SDCP and MSCP. Experts then evaluated parameters based on a series of criteria for ecological relevance, management significance, response variability, and feasibility. From these workshops emerged a prioritized list of parameters, substantial narrative, and discussion points that will be used in the next phases of the program’s development.

Workshops were an invaluable first step in the critical process of evaluating potential monitoring parameters. Phase II development will involve a more detailed evaluation of the many parameters suggested by subject-matter experts. In particular, the process for reducing the list of potential monitoring parameters will involve using information gathered from the workgroup as well as development of conceptual models and evaluation of other monitoring efforts in the region. For a select group of high-ranking parameters, further evaluation will involve estimates of cost and variability, and establishment of measurable objectives. This process will place special emphasis on identifying methods and sampling designs that maximize sampling efficiency (i.e., cost savings). From this process, a ranked list of monitoring parameters will emerge for Phase III, which will primarily involve development of protocols. In addition and as a validation test required for compliance with the ESA, there will be a determination of whether the final list of parameters is adequate for monitoring the status of covered species for the MSCP.

Concurrent with efforts to evaluate parameters will be an effort to foster monitoring partnerships with a host of entities in Pima County that are either actively monitoring or engaged in the planning process (e.g., National Park Service [NPS], Bureau of Land Management [BLM], and U.S. Forest Service). Given the broad scope of the SDCP, Pima County is in a unique position to inform monitoring efforts outside of the area that will be covered under the permit. This approach will broaden the spatial scope of the program, increase efficiencies, enable earlier change detection, and ultimately put the management activities of Pima County into a broader spatial context, thereby better gauging compliance with the terms of the Section 10(a)(1)(B) permit.

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1.0 Program Overview and Setting

1.1 Program Overview

Although the element and importance of monitoring has been subject to frequent discussions during the development of the Pima County Sonoran Desert Conservation Plan (SDCP) and Multi-species Conservation Plan (MSCP), a more focused planning effort for the Pima County Ecological Effectiveness Monitoring Program (Pima County EEMP) was initiated in June 2006 to provide a comprehensive framework for informing managers of the changes to a suite of natural resources in Pima County, Arizona. To accomplish the critical task of creating a meaningful and informative program, the Pima County EEMP will be developed in three phases. Phase I, which is the subject of this report, outlines the conceptual foundation for the program and steps taken to arrive at a list of promising parameters for monitoring. Phase II will use a variety of design tools to evaluate the long list of parameters from Phase I with the goal of establishing an economically efficient and relevant program. The result from Phase II will be a list of parameters that will be monitored, and how, where, and when to monitor them. Phase III will involve the development of detailed monitoring protocols to ensure accurate and consistent data collection and a synthesis of this information to managers.

1.2 Sonoran Desert Conservation Plan and Multi-species Conservation Plan

The Pima County Board of Supervisors initiated the SDCP in 1998 in response to the listing of the cactus ferruginous pygmy-owl (*Glaucidium brasilianum cactorum*) by the U.S. Fish and Wildlife Service (USFWS) as an endangered species and the subsequent designation of the species' critical habitat, much of which was located in Pima County. The listing and critical habitat designation prompted the Board of Supervisors and concerned citizens to seek a comprehensive, long-term strategy for conservation of biological and cultural resources threatened by unprecedented human population growth. The SDCP was the guiding document to help ensure that impacts of human population growth complied with the regulatory requirements of the Endangered Species Act (ESA). The ESA prohibits "take" of threatened or endangered species that is defined by actions that harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect listed species. Section 10(a)(1)(B) of the act allows incidental take of listed species provided that a Habitat Conservation Plan (HCP) is in place. The SDCP was a first step in creating a HCP for Pima County.

The SDCP is the product of an iterative process framed in scientific principles and guided by public input. The biological goal of the SDCP is 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.*
> (Fonseca et al. 1999)

This goal has formed the foundation of a visionary process that has earned Pima County over 20 state, national, and international awards. Even though Pima County has yet to formally submit an application for a Section 10(a)(1)(B) permit (herein referred to as "the permit") to the USFWS, implementation of the SDCP has begun through land acquisition as part of the Conservation Land System and bond initiatives, development guidelines as provided for by Comprehensive Land-use Plan policies, and Pima County departmental policies and requirements. To satisfy the requirements of the permit application, Pima County developed a MSCP that embodies the scientific principles of the SDCP biological goal and specifies mechanisms for addressing legal requirements of the ESA (RECON Environmental 2006). The MSCP was guided by the Science and Technical Advisory Team (STAT), a local group of natural resource scientists, who developed a list of Priority Vulnerable Species (PVS) whose habitats were used to identify priority areas for conservation, as reflected by the Conservation Land System. Currently, Pima County proposes to cover 36 PVS under the permit (RECON Environmental 2006; Appendix A).

As part of the permit application, Pima County is required by the USFWS to establish a monitoring program. Given this requirement and the much broader goal of the SDCP, Pima County proposed to expand the level of monitoring beyond PVS to assess trends in a wide range of natural resources in Pima County (Shaw 2006). Expanding the scope of the monitoring program will both enhance its overall effectiveness and continue the diverse base of community support that has been the hallmark of the SDCP planning process.

1.3 Monitoring Program Goal

The Pima County EEMP will be established to determine progress towards meeting the biological goals of the SDCP and MSCP. The STAT Monitoring Subcommittee, which oversees development of the Pima County EEMP, identified the following goal for the program:

> *Detect and quantify changes to select ecosystem components at appropriate spatial and temporal scales to inform adaptive management and to determine if the SDCP biological goal is being achieved.*

The challenge is to design a monitoring program that is both effective at informing managers of ecological change and that is financially sustainable for the proposed 30-year period of the permit. This Phase I plan provides the foundation for addressing these issues. Ultimately, the goal of the Pima County EEMP will be evaluated by parameter-specific monitoring objectives (see Chapter 3.0).

1.4 Monitoring and Adaptive Management

1.4.1 Definitions and Applications

When designing a monitoring program, it is important to articulate the different types of research and monitoring activities that can be accomplished with the plan. *Monitoring* is the repeated measurement of a resource over time with the goal of estimating the magnitude of change in the resources. An *inventory* is a point-in-time effort to determine the status, distribution, or abundance of a resource. Though many monitoring programs begin as inventories, they can not detect trends unless repeated across time. *Research* is a more focused endeavor that seeks to answer questions related to the function or causes of change in a system that may result from management actions or stochastic (random) events. Research studies take many forms from observational studies that seek associations between response and explanatory variables to experimental studies that, through manipulation or by applying treatments, seek to establish causal relationships (see review in Morrison et al. 2001). Research can also be qualitative, such as in historic research (e.g., Bahre 1991; Swetnam et al. 1999; Turner et al. 2003). Beyond these general approaches between research and monitoring there are differences in sampling design choices that ultimately are driven by program goals and financial resources. Therefore, the differences between research and monitoring mean that an optimal design for one is unlikely to be appropriate for the other.

In planning the Pima County EEMP, it is anticipated that research will be used to inform the development of the monitoring plan by providing information on the range of potential parameters or response variables and by addressing components of study design and sampling methods that must be considered prior to initiating monitoring (e.g., Gibbs et al. 1998; Urquhart et al. 1998; Figure 1.1). Once monitoring is initiated (i.e., operational monitoring), research can be employed if a parameter exceeds an *a priori* threshold and the causes of the change are unknown (Figure 1.1). For example, if changes in abundance of a native fish are observed, these changes may be related or compared to changes in parameters thought to influence it, such as water quality and quantity. If these types of analyses do not provide sufficient information to explain changes and research is deemed necessary, a properly designed monitoring program should provide guidance by reducing the number of hypothesized causes of change. In other words, monitoring should aid the efficiency of subsequent research projects.

Where appropriate, quantitative and qualitative research should be incorporated into the program. In particular, restoration efforts are currently not part of the overall Pima County EEMP strategy, but these activities will be carried out by Pima County departments that are responsible for the implementation of the SDCP. As part of SDCP restoration efforts, research should be employed to assess their effectiveness, and added power and efficiencies will be gained by measuring the same parameters at restoration sites and at monitoring sites. For example, restoration of semi-desert grass-

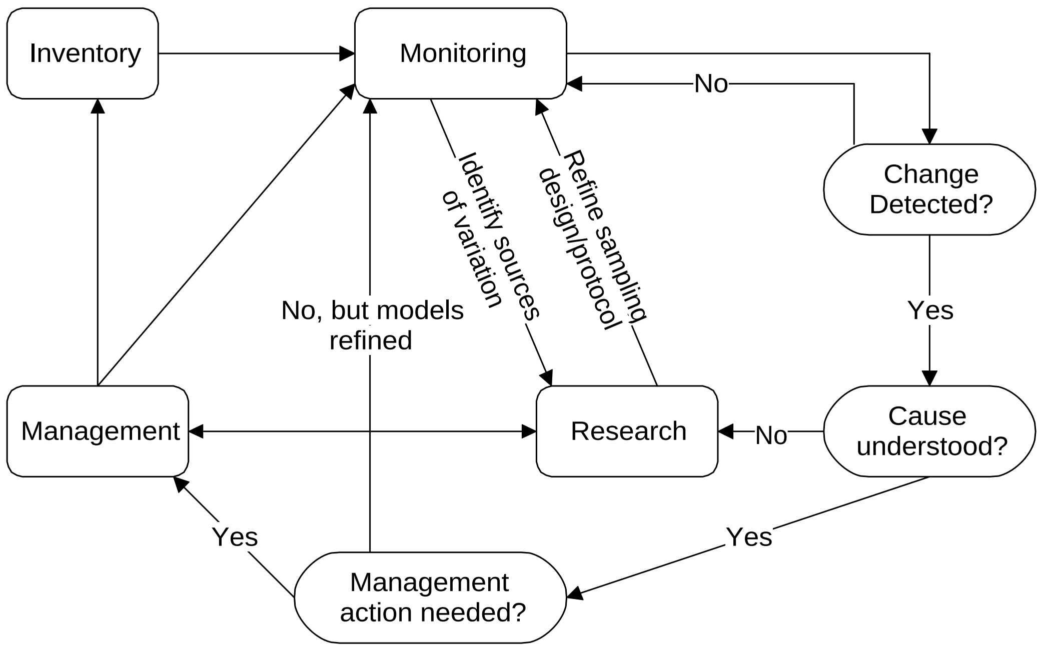

Figure 1.1. Information Pathways and Relationships among Inventories, Monitoring, and Research. Figure 1.1 illustrates how each affects natural resource management (modified from Jenkins et al. 2003).

lands is an objective of the SDCP (Fonseca and Connolly 2002), and large-scale management activities related to this goal, such as the experimental use of fire or mechanical treatments, will likely take place both on and off the Pima County EEMP sites. This example also illustrates how monitoring data can be applied toward research and *vice versa* by informing researchers of the range of natural responses and variability that are invaluable when planning a project (Steidl et al. 1997). Finally, monitoring results can provide data for investigating ecological patterns and processes that can refine conceptual models of how natural systems operate and identify environmental characteristics of high conservation value (e.g., Brown et al. 1997; Holmes and Sherry 2001; Sauer et al. 2003).

1.4.2 Monitoring and Adaptive Management

It has been a guiding principle throughout the SDCP process that sound stewardship of natural resources requires managers to base decisions on the best available information (Pima County 2001a). 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 typically takes one of two forms: passive and active (Walters and Holling 1990). Passive adaptive management uses observational data to infer causation based on observed patterns (i.e., learning by watching). Active adaptive management is more powerful and 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).

Active adaptive management may be the ideal form of adaptive management, but it is rarely employed in non-consumptive applications because of budgetary and environmental constraints to manipulating resources (Stankey et al. 2003). Therefore the use of active adaptive management in the Pima County EEMP will be limited. Later in the development of the program, active adaptive management may be employed if monitoring results indicate that a parameter has exceeded an *a priori* threshold, thereby necessitating management activities to restore desired conditions, such as reintroductions of native species or removal of non-native or invasive species.

Though less informative than active adaptive management, passive adaptive management can still provide an extraordinary opportunity for learning, because monitoring data on the spatial and temporal scales advocated for the Pima County EEMP are rare or not available in the region. This will provide managers with an unprecedented opportunity to evaluate data that have direct application to assessing program progress towards meeting the SDCP and MSCP goals. 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 stochastic and planned 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).

1.4.3 Adaptive Monitoring

An essential objective of the Pima County EEMP is to provide timely information to managers. To enable this feedback process (Figure 1.1), it is essential that the program be broad in scope, flexible in design, and responsive to unforeseen management issues and stressors as they arise (Ringold et al. 1996). Examples of unanticipated stressors include chytrid fungus that is suspected to be among the leading causes of decline of amphibian populations throughout the world, yet virtually unknown until 1999 (Lips et al. 2006). Similarly, a large influx of human immigrants crossing into the U.S. from Mexico was not considered a management issue in the early 1990s, but today it is perhaps the most debated social and environmental issue in the region, in part because of the environmental damage caused by border crossers and associated law enforcement activities (NPS 2003; Segee and Neeley 2006). Future threats that may impact vertebrate communities include diseases such as avian influenza (Kou et al. 2005). These examples highlight the importance of a flexible program that can include and address additional parameters or expand the spatial scope of monitoring to address needs for new information.

1.5 Program Setting

Pima County is located in southern Arizona and is over 5,800,000 acres in size (Figure 1.2). Elevations range from 1,200 feet in the western deserts to over 9,000 feet in the Rincon and Catalina Mountains in eastern Pima County. The county is located in the Basin and Range physiographic province and contains a diverse range of landforms and ecological communities including the easternmost portion of the Sonoran Desert (Figure 1.3). Vegetation communities within Pima County range from lowland deserts of the Lower Colorado Subdivision, with majestic columnar cacti, to highland mixed-conifer forests in the Santa Catalina and Rincon Mountains. The greater Sonoran Desert Ecoregion, in which Pima County lies, has the highest diversity of plants and animals of any desert in the U.S. (MacMahon 1985) resulting from a subtropical climate, continental physiography, a bimodal precipitation pattern, varied geology and topography, and the intersection of four major biogeographical provinces (Figure 1.3; Brown 1982; Sellers et al. 1985; McLaughlin and Bowers 1999). These factors make the Sonoran Desert globally significant for conservation (Olsen and Dinnerstein 1999; Marshall et al. 2000).

The Tohono O'odham Nation is the single largest land holder, with approximately 42 percent of lands within Pima County under their ownership (Figure 1.4). Federal ownership in Pima County is 27 percent, State of Arizona ownership is 15 percent, and private land ownership is 14 percent (Figure 1.4). Pima County owns approximately 82,000 acres, or about 1.4 percent of the county. Although not a dominant land owner, Pima County plays an important role in land management through ownership of grazing leases (approximately 80,000 acres), by establishing zoning and land-use regulations, and by managing large-scale public works projects.

The Permit Area, a subset of Pima County to which the MSCP permit applies, is approximately 607,700 acres (Figure 1.5). Lands in the Permit Area comprise county and private lands that are under the ownership or jurisdiction of the Pima County. Excluded from the Permit Area are tribal, federal, state, and local lands that are under separate jurisdictions and ownership. Almost all of the Permit Area is below approximately 4,000 feet elevation, where the majority of the impacts associated with growth has and will continue to occur. Though this plan focuses on these lower-elevation lands, it is not intended to be restricted in its scope of inference to Pima County and private lands. Rather, there will be an attempt to integrate monitoring results from state and federal lands, as well.

Figure 1.2. Location of Pima County, Arizona.

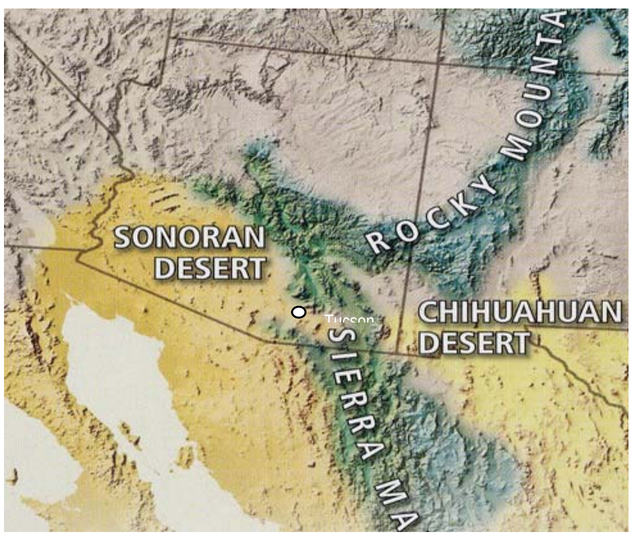

Figure 1.3. Location of the Sonoran Desert in relation to Other Biogeographical Provinces Contributing to High Biodiversity.
Image courtesy of the National Park Service.

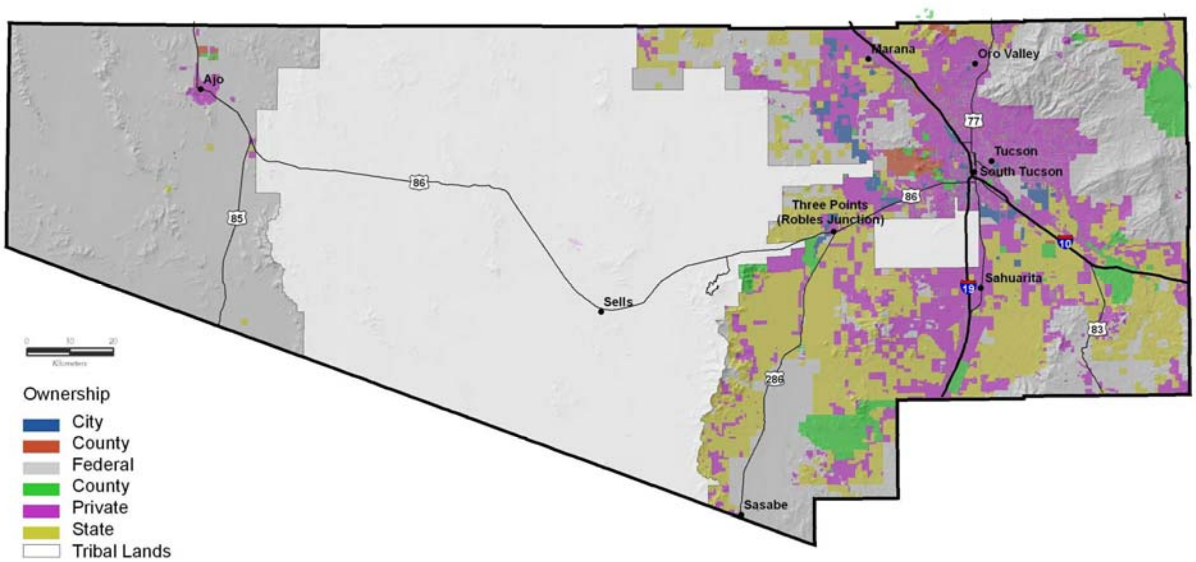

Figure 1.4
Land Ownership in Pima County

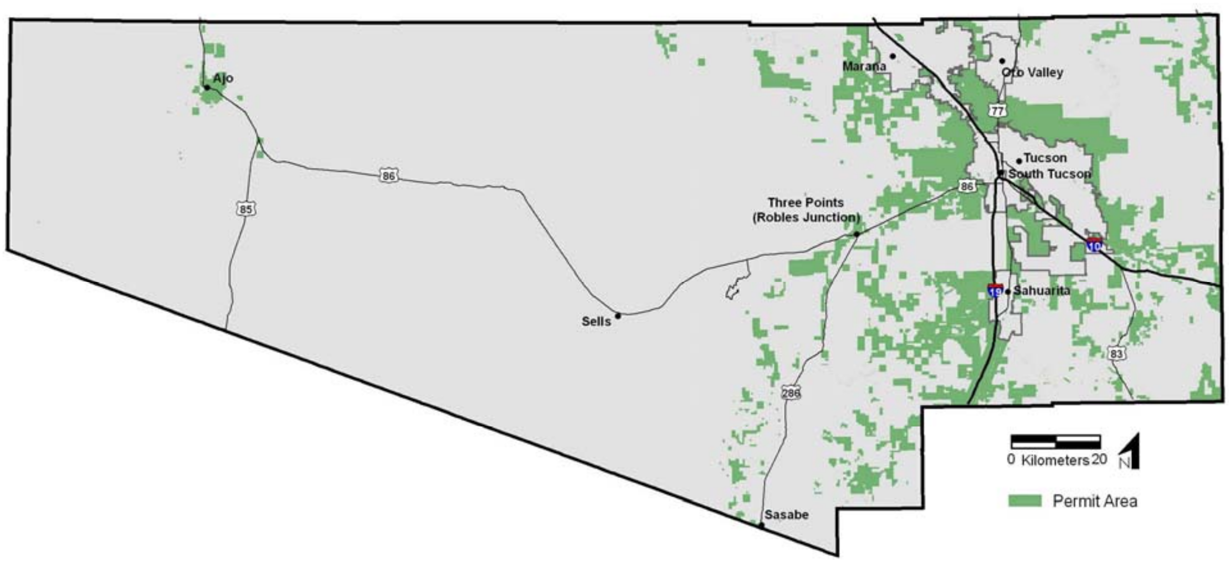

Figure 1.5
Pima County MSCP Permit Area (607,000 acres)

1.6 Ecological Communities of Interest in the SDCP

Throughout the SDCP planning process, Pima County focused attention on three low-elevation communities that together comprise most of the Permit Area: Sonoran Desert upland, semi-desert grasslands, and riparian woodland and forest (RECON Environmental 2006). Other important resources, known as Special Elements, are more spatially restricted but have received attention throughout the SDCP planning process because of their importance for PVS. Special Elements include: talus slopes, limestone outcrops, caves and adits, and bridges for bats (Fonseca and Connolly 2002).

1.6.1 Sonoran Desert Upland Communities

The Sonoran Desert upland typifies the Sonoran Desert and comprises the majority of the Permit Area. Dominant plants include a variety of short trees and shrubs, succulents, and cacti including large columnar saguaros (*Carnegiea gigantea*). Annual plants are common, particularly following sufficient winter rainfall. Historically the Sonoran Desert upland vegetation did not experience frequent wildfire. Recently, however, invasion of non-native species (African buffelgrass [*Pennisetum ciliare*], red brome [*Bromus rubens*], crimson fountain grass [*Pennisetum cetaceum*], and others) have increased fire frequency resulting in (1) high mortality of native vegetation (McLaughlin and Bowers 1982; Wilson et al. 1996; Franklin et al. 2006), (2) likely greater subsequent invasion (D'Antonio and Vitousek 1992), and (3) alterations to soil, water, net primary productivity, and vertebrate communities (Esque et al. 2003; Franklin et al. 2006). PVSs inhabiting the Sonoran Desert upland community include cactus ferruginous pygmy-owl, rufous-winged sparrow, Sonoran Desert tortoise, and Tucson shovel-nosed snake (see Appendix A for scientific names).

1.6.2 Semi-desert Grasslands Communities

Semi-desert grasslands occur at higher elevations than Sonoran Desert uplands and are more limited geographically to valley bottoms and bajadas in Pima County. Semi-desert grasslands were once dominated by stands of native perennial bunchgrasses and had low shrub density, conditions that are increasingly rare in southern Arizona (Gori and Enquist 2003; Finch 2004). Invasive (native) shrubs have become common in semi-desert grasslands in the deserts of southwestern U.S and adjacent Mexico due to cumulative interactions among drought, overgrazing, suppression of wildland fire, and introduction of non-native grasses, especially Lehmann lovegrass (*Eragrostis lehmanniana*) (Anable et al. 1992), influences that began to degrade these areas significantly by the end of the 19th century (Bahre 1991; Van Auken 2000). Semi-desert grasslands have been the focus of a number of conservation efforts through the SDCP, in part because of the importance of preserving ranches from exurban development

(Pima County 2000a). PVS inhabiting semi-desert grasslands include Pima pineapple cactus, lesser-long nosed bat, Swainson's hawk, and desert box turtle (see Appendix A for scientific names).

1.6.3 Riparian Communities

Broadleaf riparian woodlands in the region cover a small percentage of the landscape, yet support a high density and diversity of native vertebrates, including many PVS (Pima County 2000b). Mesoriparian and hydroriparian areas are characterized by shallow ground water and in some situations by persistence of surface water (hydoriparian), which provides conditions for dense stands of deciduous trees such as Fremont cottonwood (*Populus fremontii*), Arizona sycamore (*Platanus wrightii*), and velvet ash (*Fraxinus velutina*). Xeroriparian communities are also an important resource in Pima County; they are characterized by dense stands of velvet mesquite (*Prosopis velutina*) and netleaf hackberry (*Celtis reticulata*), and found primarily along ephemeral washes, although connection to groundwater resources is common in mesquite forests (bosques). Despite their profound value, the extent and condition of riparian resources (water, plants, and animals) have decreased as a result of water diversion, groundwater pumping, woodcutting, and drought (Bahre 1991; Betancourt and Turner 1991; Stromberg et al. 2004). The SDCP has placed the highest conservation priority on hydroriparian and mesoriparian communities (Harris et al. 2000; Pima County 2000b, Pima County 2001b) in part because most PVS occur primarily there including western Huachuca water umbel, Gila topminnow, yellow-billed cuckoo, western red bat, and lowland leopard frog (see Appendix A for scientific names).

1.7 Stressors and Threats to Biodiversity in Pima County

Pima County's permit application is focused primarily on the impacts of residential and commercial development and associated activities on PVS. Urbanization impacts such as infrastructure (e.g., buildings and roads) and groundwater pumping are leading causes of species' decline via habitat loss, fragmentation, and degradation in the region (Nabhan and Holdsworth 1999; Pima County 2000c), especially in the Tucson metropolitan area. Human population growth in and around Tucson is projected to more than double in the next 25 years (Pima Association of Governments 2005). This increase will expand the footprint of current human activity as natural areas are developed and natural vegetation, soils, and hydrologic, energy, sediment, and nutrient cycles are altered (Stromberg et al. 2004; Grimm et al. 2004; Kaye et al. 2006).

Impacts of urbanization on plant and animal communities involve both direct removal, local extinction, and indirect impacts such as creation of conditions that are favorable for the establishment of non-native species that are increasingly common in urban and adjacent natural areas (Germaine et al. 1998; Bowers et al. 2006; Powell et al. 2006a). Increased urbanization will reduce biodiversity, which can lead to reduced ecosystem resilience and health (Hooper et al. 2005; Faeth et al. 2005). Native terrestrial vertebrates are disproportionately impacted, and those that are not extirpated from urban areas are subject to higher rates of mortality (Rosen and Lowe 1994; Trombulak and Frissell 2000), reduced movements (Edwards et al. 2004), and harassment by humans (Wilshire 1983; Mann et al. 2002) and free-roaming pets (Coleman and Temple 1993).

The rapidly increasing human population of the southwestern U.S. has also led to severe degradation of the region's hydrological systems and riparian resources (Judd et al. 1971; Cooper 1994). Alterations to the amount, timing, and distribution of water have resulted in declines of aquatic- and riparian-obligate vertebrate species, most of which are now restricted to small and geographically isolated populations (Minckley and Deacon 1991; Hall and Steidl *In Press*).

Design and implementation of the Pima County EEMP will both consider and be sensitive to a full range of known or potential stressors within the Permit Area. By taking an approach that considers related sets of parameters, the Pima County EEMP should be able to both detect and respond to changes in parameters and their interactions that result from a variety of stressors. This approach differs from one that seeks to address potential causes that result from one or a few (currently) known stressors.

1.8 Overview of Monitoring in Pima County and Adjacent Areas

There are a number of monitoring-related activities in Southern Arizona that have provided information on changes to natural resources. Observations of plants and animals by early European explorers and settlers provide a wealth of information on the distribution of plants and animals of those times and provide a baseline for gross assessments of change (e.g., Minckley 1999; Fischer 2001). Recent efforts to compare current conditions to earlier ones provide a powerful tool for conveying ecological change (e.g., Turner et al. 2003). Repeat inventory efforts have been used as a more quantitative long-term monitoring tool by comparing current species lists and collections to historical specimen collections and observations to assess changes in species composition (e.g., Bowers and McLaughlin 1987; Shaffer et al. 1998; Powell et al. 2006a).

The longest-running ecological monitoring plots in the world were established in 1903 at the Desert Laboratory (originally called the Carnegie Desert Botanical Laboratory), located west of Tucson (Goldberg and Turner 1986). The nineteen permanent plots and subsequent additions have produced a wealth of information on the dynamics of vegetation communities in the Sonoran Desert (Pierson and Turner 1998; Bowers et al. 2006). In fact, the creation of the nearby Tucson Mountain District of Saguaro National Part (west of Tucson) in 1961 resulted from documented declines in saguaro cacti at the Desert Lab and other areas in the region (McAuliffe 1993). Also established in 1903, the Santa Rita Experimental Range, located in southern Pima County, is the longest-running rangeland research facility in the United States. Although primarily focused on rangeland dynamics and cattle production, the Santa Rita Experimental Range has significantly influenced knowledge of successional processes in rangelands, primarily as a result of resurveys of long-term vegetation transects, many dating back 50 years (McClaran 2003). Those transects continue to be resurveyed every three years, and the data are readily available. The other consistent, long-term monitoring in the region has been climate (temperature and precipitation) monitoring sites, some of which were established late in the 19th Century (Sellers et al. 1985).

In recent decades there have been a proliferation of monitoring programs and projects in the region (see Appendix B for complete list). The National Park Service (NPS) has been a leader in this regard by institutionalizing comprehensive long-term monitoring in Pima County. The Ecological Monitoring Program at Organ Pipe Cactus National Monument in western Pima County is the longest-running program dedicated to ecological monitoring of vertebrates, in particular, in Pima County. The program began in 1984 with baseline surveys of plants and animals, and was expanded in 1991 with the development and implementation of monitoring protocols for a variety of parameters (National Biological Service 1995). The NPS also recently funded the creation of the Sonoran Desert Network Inventory and Monitoring Program, one of 32 national monitoring networks of the NPS. The Sonoran Desert Network is currently developing detailed monitoring protocols for a wide range of parameters that have application to the Pima County EEMP (Appendix B). These protocols are freely available to be used by other entities.

Notable individual monitoring projects include 30+ years of fish monitoring data from Aravaipa Canyon (Eby et al. 2003); 16 years of fish monitoring along Cienga Creek (Simms et al. 2006); and deer (*Odocoileaus* spp.), javelina (*Pecari tajacu*), desert bighorn sheep (*Ovis canadensis nelsoni*), and pronghorn (*Antilocapra americana spp. americana and sonoriensis*) population monitoring by the Arizona Game and Fish Department. Also, approximately 40 North American Breeding Bird routes have been surveyed in southern Arizona, some dating back to the mid-1960s (Sauer et al. 2006). The utility of these and other monitoring efforts to inform the development of the Pima County EEMP will be investigated in Phase II (see Chapter 3.0).

There are numerous examples in Pima County of monitoring data used to inform adaptive management. For example, Gori and Schussman (2005) resurveyed vegetation transects at the Las Cienegas National Conservation Area in southeast Pima County. They found changes in ecological parameters of interest to the Bureau of Land Management (BLM), who manage the land and permit livestock grazing. Presented with the monitoring results, the BLM and the lessee revised the livestock grazing management plan to improve site conditions. This example illustrates the importance of monitoring data in natural resource management. As the science of monitoring is advanced to more reliably detect change, commitment to these programs will increase among land managers and decision makers. It is in this spirit of dedication to reliable and timely information that the Pima County EEMP is being developed.

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2.0 Initial Parameter-selection Process

2.1 Introduction

Selecting an appropriate set of monitoring parameters is an essential component in the long-term success of a monitoring program; yet choosing among the hundreds of potential parameters is a challenging task (Noon 2003). To address the monitoring goals of the Pima County EEMP, the STAT Monitoring Subcommittee identified five categories of parameters to be considered for inclusion in the program (see Figure ES.1):

- Climate
- Landscape pattern
- Vegetation structure and composition
- Water and riparian resources
- Vertebrate species and communities

These parameter categories are discussed in the following section; they represent a wide range of biotic and abiotic metrics of environmental condition that, if considered simultaneously, would provide a comprehensive approach to ecosystem monitoring in Pima County. This approach differs markedly from most multi-species conservation plans that emphasize only a narrow suite of "indicator" species, whose changes are thought to reflect ecological conditions (see critiques in Landres et al. 1988; Noss 1990; Simberloff 1998). The following sections provide a brief introduction to each category and reasons why it is being considered for the program.

2.1.1 Climate

Climate is the average weather over a longer time period, usually 30 years or more. 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 Pima County EEMP (see Figure ES.1). 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. In the Sonoran Desert ecoregion, patterns of annual precipitation are bi-modal and include both summer and more protracted winter rainy seasons that, when combined with varied topography and extreme temperature, make the region especially sensitive to variation in rainfall (Woodhouse 1997; Swetnam and

Betancourt 1998). In the recent past, events such as heavy rainfall and subsequent flooding during the 2006 monsoon season and drought conditions that have prevailed since 1998 have had a strong influence on the environment (e.g., Breshears et al. 2005). Overall, temperature and precipitation are expected to increase and become more variable in the future (Sprigg and Hinkley 2000) and are likely to have profound effects on the water, vegetation, and animal resources of the region.

2.1.2 Landscape Pattern

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. Areas of natural cover provide important ecological services such as reprocessing and reclamation of waste and pollutants, carbon sequestration, and improvements to water quality, all of which are diminished when natural cover is modified by human activities (Forman and Alexander 1998; Wissmar et al. 2004; Linderman et al. 2005). Land cover can also influence patterns of biodiversity at various spatial scales, because it influences biological processes such as habitat selection (Hutto 1985), movements patterns, and gene flow (Edwards et al. 2004; Riley et al. 2006), all of which increase extinction risk (Wilcox and Murphy 1985; Soulé 1986).

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; Hope et al. 2003; Hansen et al. 2005) or other parameters such as water quality (Soranno et al. 1996) that have important implications for maintenance of biodiversity and ecological health (Hansen et al. 1993) in Pima County.

2.1.3 Vegetation Structure and Composition

Vegetation structure refers to the physical formation, arrangement, and physiognomy of vegetation. Parameters include growth form, canopy and herbaceous cover, height, foliage volume, and biomass. *Vegetation composition* refers to the plant species that compose a community and often includes measures of abundance or frequency.

Structural and compositional parameters can be combined as a measure of species dominance or importance relative to other species in a community in space or their phenology across time (Krebs 1999). Functional species groups, such as life forms (e.g., trees or grasses), may also be delineated and monitored when they are relevant to specific ecological processes such as the frequency and potential extent of fires.

Vegetation features are fundamental to assessing ecological condition. Vegetation captures energy from the sun and makes it available to higher trophic levels. Vegetation is also an indicator of site characteristics, past disturbance events, climate patterns, and even weather events. Vegetation provides physical cover and food to terrestrial vertebrates including birds, mammals, and herpetofauna that respond directly to changes in vegetation structure and composition (Holmes and Sherry 2001; Alcock 2005). Vegetation along watercourses also affects habitat suitability of aquatic vertebrates and invertebrates by controlling erosion and sediment, reducing pollutants, and providing cover that mitigates water temperature and increases dissolved oxygen (Naiman and Decamps 1997).

Monitoring vegetation parameters is particularly important because rapid changes in these parameters result from a variety of interrelated stressors including human activities and climate change (see Chapter 1.0). These stressors are pervasive and generally increasing in riparian, semi-desert grassland, and Sonoran Desert upland communities, which are of particular interest to the SDCP. Monitoring vegetation parameters also has application to the county's adaptive management goals, because they are often evaluated in terms of these parameters (Falk et al. 2006). For example, restoration of semi-desert grasslands throughout the county reserve system will focus on controlling mesquite and other shrubs from invading uplands, whereas mesoriparian restoration will focus on establishing cottonwood, willow, and mesquite woodlands (Pima County 2001b).

2.1.4 Water and Riparian Resources

Water resources refer to the physical and chemical characteristics of water including groundwater depth, surface-water quantity (surface flow and spring discharge), and water quality (e.g., dissolved oxygen, turbidity, temperature, nutrient loading, and pollutants). *Riparian areas* occur along rivers, washes, seeps, springs, and ponds where availability of water is greater than in uplands (Naiman and Decamps 1997). Riparian vegetation monitoring is highlighted in Section 2.1.3, and riparian vertebrate species are discussed in Section 2.1.5.

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 (e.g., 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 PVS species occur in riparian areas, especially hydroriparian and mesoriparian communities (RECON Environmental 2006). In addition to supporting high biodiversity, naturally functioning riparian areas improve water quality and provide important floodplain functions (Leopold 1994; Stromberg et al; 1996, Naiman and Decamps 1997). Water monitoring is therefore an essential component of the Pima County EEMP, especially given the increasing demand for water by humans and associated public health concerns.

Another parameter group critical to understanding water and riparian resources is *stream-channel morphology*. Parameters in this group include slope of the water surface, channel profile, bankfull stage, and condition of the floodplain and terraces. Channel morphology parameters are an important indicator of riparian health and watershed condition; they influence groundwater recharge, surface flows, deposition, and determine habitat for plants and animals (Naiman and Bilby 1998; Woodsmith et al. 2005). Changes in stream-channel morphology due to channelization may harm functions such as overbank flood storage (Leopold et al. 1964).

2.1.5 Vertebrate Species and Communities

Vertebrate species are important components of ecosystems, because they influence a wide range of ecosystem functions such as decomposition, seed dispersal, pollination, and disturbance (Sekercioglu et al. 2004). Because of their high trophic positions, some vertebrate species can be good indicators of conditions upon which they depend (Rich 2002). In turn, the distribution and abundance of vertebrates are influenced by a myriad of ecological parameters including those discussed in previous sections. Vertebrates are often the focus of monitoring efforts, because they are highly valued by society for their aesthetic and cultural appeal; humans place great intrinsic value on biodiversity, and vertebrates are the most recognized and appealing expression of these values. The use of vertebrate species as targets for conservation efforts is highlighted by the SDCP and MSCP planning processes, which used vertebrate habitat to help inform the identification of areas of high conservation value (RECON Environmental 2006).

Despite their appeal to the general public, vertebrates can be difficult and expensive to monitor, in part because mobility and other life-history characteristics make them elusive to detect (Yoccoz et al. 2001; Alcock 2005). The number of potential parameters for vertebrates monitoring is large and requires careful consideration so that only the most relevant and efficient parameters are included in the Pima County EEMP. A recent effort to assess monitoring parameters for vertebrates in the Sonoran Desert considered all possible parameters including demographics, health, age structure, diet, etc. and recommended that only population and community parameters (i.e., abundance, presence/absence, and relative abundance) be considered for monitoring because of their efficiency and relevance to management (Mau–Crimmins et al. 2005). Further, it was recommended that field methods that can survey multiple species simultaneously are most efficient, except for threatened and endangered species, which require adherence to single-species protocols. Community parameters, such as species richness and diversity (syntheses of single-species population parameters) are also useful for monitoring trends over large spatial scales, though are less sensitive to change (Philippi et al. 1998).

2.1.6 Categories and Parameters Not Favored for Inclusion in the Pima County EEMP

The range of monitoring parameters currently included in the Pima County EEMP is broad and should provide a comprehensive assessment of ecosystem status and trend. As with all monitoring programs, the Pima County EEMP will have monetary constraints that will limit the number of parameters that can be monitored. The STAT Monitoring Subcommittee determined to exclude some parameter categories such as air quality (ozone, wet and dry deposition, visibility, and particulate matter), soils, invertebrates (except for aquatic macroinvertebrates), and social parameters (e.g., human population statistics, ethnicity, income, etc.) at this time because of their high cost or because other agencies or departments within Pima County are already monitoring them. In addition, it will be determined later in the development of the program if some of the parameters not currently considered can be monitored concurrently while collecting data for the highly favored parameters. For example, basic soils monitoring protocols may be able to be implemented during vegetation monitoring.

2.2 Workshops to Inform Development of the Pima County EEMP

2.2.1 Initial Determinations and Materials

RECON Environmental Inc. and Pima County hosted a series of workshops in fall 2006 to assist the development of the Pima County EEMP. The goals for each workshop were to identify a list of potential parameters for inclusion into the program, and to score and rank those parameters based on criteria established by the STAT Monitoring Subcommittee. Seven workshops were held including six subject-based workshops (landscape pattern, water and riparian resources, vegetation, birds, amphibians and reptiles, and mammals) and one workshop for regional land managers (Figure 2.1). No workshops were held for climate or fish. Climate monitoring, especially precipitation, will be monitored at all or a subset of monitoring sites. Temperature and humidity data are already collected at locations throughout Pima County. Similarly, Pima County determined that fish monitoring would be an assured component of the Pima County EEMP.

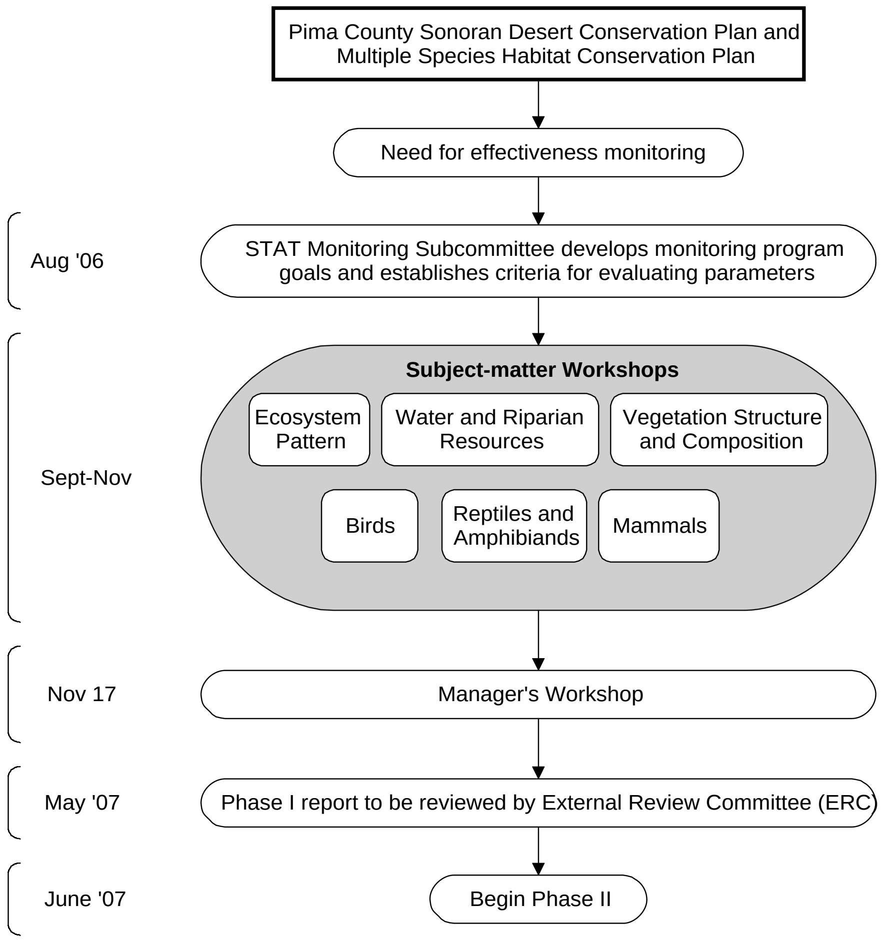

Figure 2.1. Timeline and Process for Initial Pima County EEMP Parameter Selection and Review. Fish and climate were excluded from the workshop process, because they are assured monitoring components. See Chapter 3.0 for more information on Phase II development.

Expert workshops were attended by leading regional scientists with experience in monitoring, data analysis, and natural history of their respective disciplines. Together, the experts represented a diverse range of entities: University of Arizona, state and federal agencies, and non-profit organizations and consultants (see Appendix C for participant list).

2.2.2 Pima County EEMP Expert Workshops: Process and Methods

Expert workshops began by first considering a list of monitoring parameters suggested during workshops hosted by the Sonoran Institute in 2003 (Sonoran Institute 2007). Known as the Sonoran Desert Ecoregional Monitoring Framework (SDEMF), this series of 10 workshops produced a ranked list of parameters that could be adapted by local, state, and federal governments and non-governmental organizations interested in monitoring. The Sonoran Desert Network program of the NPS was the first and only program to date to adopt recommendations from this process; they reviewed the suggested parameters, compared them to park-specific management goals, and chose a subset for further development (Mau-Crimmins et al. 2005).

Participants in each workshop refined the parameter list suggested by the SDEMF by splitting or lumping parameters or by adding new parameters (see Appendices D–G for lists of parameters from the SDEMF). Once participants agreed on a final parameter list, the nominal group technique was employed to allow each participant an opportunity to provide input (Schmoldt and Peterson 2000). In particular, each participant in the landscape, vegetation, and water workshops scored each parameter and provided a brief narrative based on criteria that addressed ecological relevance, response variability, and feasibility of implementation (Table 2.1).

The procedure employed during the three vertebrate workshops followed a slightly different process, because the SDEMF did not specify the most promising parameters for vertebrate monitoring. Therefore, the three vertebrate workshops began the respective meetings by organizing taxa into groups of species that could be surveyed using one or two common and accepted survey methods. For example, participants in the reptile and amphibian workshop chose to evaluate the following groups or species separately: ranid frogs, nocturnal reptiles, diurnal lizards and snakes, toads and spadefoots, Mexican garter snake, box turtle, and desert tortoise (Appendix G). The reptile and amphibian workshop was the only one to separate individual species for monitoring.

After vertebrate workshop participants delineated species groups, they discussed parameters to consider for evaluation. All workshops discussed the range of parameters that could be included in a monitoring program: population size, demographics, diet, home-range size, etc. Each workshop chose only population parameters such as occupancy (presence/absence) and abundance, or community parameters such as species richness and diversity as relevant and feasible for long-term monitoring. In addition to abundance and community parameters, participants in the bird workshop also chose productivity and breeding status as an informative parameter for some species groups. Once each workshop had a list of species groups and parameters, they evaluated each combination using criteria similar to those used by other workshops (see

TABLE 2.1
CRITERIA USED BY WORKSHOP PARTICIPANTS TO EVALUATE MONITORING PARAMETERS FOR THE PIMA COUNTY EEMP

Participants provided both a quantitative score and narrative for each criterion. The criterion for management relevance and utility was evaluated only by participants in the Manager's meeting; managers did not evaluate parameters using other criteria. Vertebrate workshop participants provided additional information on response variability and feasibility (see text and Appendix G).

Criteria Group	Criterion	Description
Ecological Relevance	Changes parallel those of a larger component or system of interest	Parameters are used as indicators of environmental change. As such, there must be a demonstrated link between the parameter and the system which it is meant to represent or respond to. These links should be well accepted and justifiable. Ideally, the resource to which a parameter responds is itself being monitored.
	Changes quickly in response to changes in the larger component or system	Ideal parameters are those that track changes in the resources and are thought to influence them within a reasonable time frame. By contrast, some parameters have long lag times between the events that influence them and the value or status of the parameter, meaning they may provide information on past events that may no longer be relevant. This criterion is important in the Pima County EEMP because of the short time frame of the permit and the need for current trend information. However, it must be recognized that some parameters may not track resources quickly, which is often the case with vertebrate population parameters (e.g.,Wiens 1985).
Response Variability	Low inherent natural variation	Natural variation is the difference in the parameter over time and among sites, irrespective of sampling variation (see next criterion). Parameters with high natural variation, particularly within season and among years, are difficult to monitor, because if a trend is occurring it is often obscured by widely fluctuating counts (Yoccoz et al. 2001; Kurtz et al. 2001). High natural variation makes it difficult to establish thresholds and to have confidence when asserting that a threshold has been exceeded. Increasing sampling frequency or sample size has little effect on temporal variation. Assuming there are enough samples to adequately estimate the parameter of interest, natural variation among sites (spatial variation) can be quantified and is often not consequential to trend estimation, if the same sites are visited over time (Larsen et al. 2004).

TABLE 2.1
CRITERIA USED BY WORKSHOP PARTICIPANTS TO EVALUATE MONITORING PARAMETERS FOR THE PIMA COUNTY EEMP
(CONT.)

Criteria Group	Criterion	Description
Response Variability (cont.)	Low sampling error	The process of collecting and analyzing data generates errors (variability) that can obscure trend detection and influence program cost. Parameters that can be measured or estimated and that account for this type of variation are preferred. Variability introduced by observers is common in all types of ecological sampling. Increasing within-season sampling effort, calibrating instruments, training observers, and ensuring quality-assurance and quality-control procedures can reduce sampling error (Kurtz et al. 2001). Detectability (one component of sampling error) can vary among vertebrate species and is an important consideration. For example, many species are conspicuous (e.g., most birds) and are easily detected, while other species are inconspicuous (e.g., rodents, reptiles) and have low or variable detectability. Some vertebrate parameters, such as occupancy and abundance, can explicitly account detectability during modeling and estimation.
Feasibility of Implementation	Cost efficient	Cost is the most significant limiting factor for monitoring and is influenced by many factors including response variability (i.e., precision), equipment needs, and level of technical skill of field technicians and data analysts. Storing data and samples can also be expensive. Costs can be identified and compared among parameters as cost-per-sample unit.

TABLE 2.1
CRITERIA USED BY WORKSHOP PARTICIPANTS TO EVALUATE MONITORING PARAMETERS FOR THE PIMA COUNTY EEMP
(CONT.)

Criteria Group	Criterion	Description
Feasibility of Implementation (cont.)	Survey and estimation methods are well established	Parameters that have well-established and scientifically accepted field methods and analyses are preferable to those that are in development. If a new and untested method for data collection and estimation is undertaken, considerable resources may be required, and there is no guarantee that the new method will be appropriate.
	Survey protocols capture information on more than one species or parameter	Most of the cost of a monitoring program is to pay skilled observers to travel to and from a site and collect data. Once at a site, the number of samples that can be collected in a single day and the number of parameters that can be measured are important considerations. Overlap between protocols that allow observers to gather data on multiple species and/or parameters (e.g., water-quality parameters) are preferred to those that provide information on only a single species or parameter.
Management Relevance and Utility	Has value for informing county's acquisition and management programs	Ultimately a parameter is most useful if it can provide information to support management decisions (Failing and Gregory 2003). Because the goal of the Pima County EEMP is to provide information on progress toward the SDCP biological goal, a parameter must contribute to that goal. This criterion will assist with focusing on parameters that may be affected by county management actions or by putting those actions into a larger spatial context by monitoring the relative change in the parameter on lands managed by Pima County compared to lands managed by other entities.

*Selected from a suite of potential criteria (from Noon et al. 1999, Hilty and Merenlender 2000, Dale and Beyeler 2001, Tegler et al. 2001).

Table 2.1). Vertebrate workshop participants were also asked more specific questions about sampling efficiency, methods to facilitate comparisons among and within species groups, and conservation value and threat (see Appendix G for a more detailed description of the workshop discussions).

2.2.3 Managers' Workshop

Although subject-matter experts provided a list of possible parameters and input for a variety of criteria, they did not discuss the relevance of each parameter for informing management. To obtain this input, a one-day workshop was held attended primarily by Pima County and other regional land managers. Managers were given the opportunity to rank the top parameters from all expert workshops based on their ability to inform natural resource management in Pima County. Managers were not invited to add parameters for evaluation that were not already considered by expert workshops, but notes were taken during the meeting to capture those discussion points (see Appendix H).

Once the managers reviewed the entire list of parameters from the expert workshops, they each ranked two sets of parameters separately: one each for landscape pattern, vegetation, and water and one for all vertebrates. The separate analysis was deemed important because, early in the workshop discussion, managers regarded vertebrates as less important for monitoring than parameters in the other categories. Workshop participants were asked to rank vertebrates separately because of their importance for the MSCP and SDCP.

2.2.4 Pima County EEMP Expert Workshops: Results

Participants in the six expert workshops identified a total of 45 parameters or groups of parameters for consideration in the Pima County EEMP (Appendices D–G; Table 2.2). Although the structure of the landscape pattern, vegetation, and water workshops were similar, participants were given the opportunity to change the initial list of parameters (suggested from the SDEMF) to better suit the needs of the program. The degree of change from the initial lists varied and was greatest for the landscape workshop; they suggested lumping parameters into broad groupings from which many parameters could be derived. For example, they grouped three parameters related to land cover, roads, and connectivity into a single parameter for land cover (see Appendix D). In contrast, participants in the water workshop largely maintained the list of parameters suggested by the SDEMF but added additional parameters. The vegetation workshop chose to lump all parameters for perennial species and then decided to score the three communities of interest separately (riparian, Sonoran Desert uplands, and semi-desert grasslands). As mentioned previously, participants in the vertebrate workshop grouped species with the number of groupings ranging from three for mammals to seven for both birds and reptiles and amphibians (Appendix G).

TABLE 2.2
PARAMETERS SUGGESTED FOR INCLUSION INTO THE PIMA COUNTY EEMP BY SUBJECT-MATTER EXPERTS AND REGIONAL LAND MANAGERS

Participants in subject-matter workshops (landscape pattern, vegetation, water, birds, reptiles and amphibians, and mammals) scored parameters based on ecological relevance, response variability, and feasibility of implementation; these scores are reflected in the "Workshop Rank" column (see Appendices D-G for additional information). Participants in the Manager's workshop evaluated all parameters suggested by the other workshops using criteria for management significance. The Ranking by Managers column reflects the results of two separate analyses: one for parameters for landscape pattern, vegetation, and water and another for all vertebrate groups combined (including fishes).

				Ranking	
Category 1	**Category 2**	**Parameter(s)**	**Description (if needed)**	**By Workshop Experts**	**By Managers**
Landscape Pattern	Land cover type	Area and distribution of type, roads, connectivity, etc.	Natural, urban, agriculture, mining, roads.	1	1
	Land Use	Area and distribution	Both current and potential future use of land.	1	5
	Upland Vegetation Formation[a]	Area and distribution	Physical structure of vegetation communities.	2	5
	Greenness Index	NDVI, floristics, phenology,	Measure of chlorophyll in plants.	3	
	Fire	Frequency, size, severity		Not scored	
Vegetation	Perennial species: mesoriparian	Community composition, relative abundance, frequency, distribution, recruitment		1	3
	Perennial species: semi-desert grasslands	Community composition, relative abundance, frequency, distribution, recruitment		1	4
	Perennial species: Sonoran Desert uplands	Community composition, relative abundance, frequency, distribution, recruitment		1	

TABLE 2.2
PARAMETERS SUGGESTED FOR INCLUSION INTO THE PIMA COUNTY EEMP BY SUBJECT-MATTER EXPERTS AND REGIONAL LAND MANAGERS
(CONT.)

Category 1	Category 2	Parameter(s)	Description (if needed)	Ranking	
				By Workshop Experts	By Managers
Vegetation (cont.)	Exotic, invasive species	Distribution, area, frequency, relative abundance	May include some species covered under various perennial-species categories.	1	4
	Vegetation Formation[a]	Area and distribution	See Landscape Pattern	2	5
Water	Geomorphology	1) Channel cross section, longitudinal profile, pebble count	Expression of watershed health, floodplain function, surface water availability, and riparian vegetation.	5	
		2) Planform analysis and floodplain change	How a river moves in relation to floodplain.		
	Water Quality	1) Field parameters- (e.g., temperature, turbidity, pH, etc.)	Most basic characteristics of water quality.	1	
		2) Nutrient loading (e.g., ammonia, nitrite, nitrate)	A good indicator of aquatic health.	3	
		3) Priority pollutant metals (e.g., Sb, Cd) and carcinogens.	Toxic metals resulting from human land uses.		
		4) Algal blooms	Indicator of nutrient loading.		
		5) Streamflow extent and/or persistence of flow	Number of km of surface water; especially during dry periods.		5

TABLE 2.2
PARAMETERS SUGGESTED FOR INCLUSION INTO THE PIMA COUNTY EMP BY SUBJECT-MATTER EXPERTS AND REGIONAL LAND MANAGERS
(CONT.)

Category 1	Category 2	Parameter(s)	Description (if needed)	Ranking	
				By Workshop Experts	By Managers
Water (cont.)	Water Quality (cont.)	6) Streamflow discharge-natural streams and springs	Amount of water in streams and springs	4	5
		7) Ephemeral pools-volume and persistence (availability)	Amount and timing of water availability for wildlife and plants.		
	Groundwater	Depth/gradient to shallow groundwater	Gradient is an early warning indicator of changes of depth.	2	2
	Macroinvertebrates	Community structure	Generally defined as insects that can be seen with the naked eye. Community structure is often used as a measure of water quality and overall stream health.		
Other	Disturbance[b]	e.g., insect and pathogen outbreaks, floods, toxic spills, etc.	Distribution and characterization of disturbance events		
Fishes	All Species	Occupancy/abundance	Native and non-native	[c]	1
Amphibians and Reptiles	Frogs	Occupancy/abundance	Leopard frogs, bullfrogs	1	3
	Toads and spadefoots	Occupancy/abundance		3	
	Nocturnal reptiles	Occupancy/abundance	Primarily snakes	2	
	Diurnal lizards and snakes	Occupancy/abundance	Whiptail lizards and common snakes	4	
	Mexican garter snake	Occupancy/abundance		Not scored	

TABLE 2.2
PARAMETERS SUGGESTED FOR INCLUSION INTO THE PIMA COUNTY EEMP BY SUBJECT-MATTER EXPERTS AND REGIONAL LAND MANAGERS
(CONT.)

Category 1	Category 2	Parameter(s)	Description (if needed)	Ranking	
				By Workshop Experts	By Managers
Amphibians and Reptiles (cont.)	Box turtle	Occupancy/abundance		Not scored	
	Desert tortoise	Occupancy/abundance		Not scored	
Mammals	Predators	Occupancy/abundance	Bear, cats, skunks, fox, coyote, raccoon, badger, coati, ringtail	1	2
	Bats	Occupancy/abundance		2	5
	Small mammals	1) Occupancy/abundance	Rodents, squirrels, lagomorphs	3	
		2) Species diversity, evenness, and composition		4	
Birds	Songbirds: breeding season	1) Occupancy/abundance	Including allies like cuckoos	2	4
		2) Productivity	Number of young	2	
	Songbirds: non-breeding season	1) Occupancy/abundance			
	Diurnal raptors: breeding season	1) Occupancy/abundance	Hawks, falcons, golden eagle	5	
		2) Productivity	Number of young	3	
		3) Breeding status	Binary; whether they bred or not	1	
	Diurnal raptors: non-breeding season	Occupancy/abundance			
	Nocturnal raptors and nightjars: breeding season	1) Occupancy/abundance	Most owls and nightjars	4	
		2) Productivity	Number of young		
	Hummingbirds	1) Occupancy/abundance			
	Ducks and waders	1) Occupancy/abundance	Ducks, grebes, shorebirds, etc.		

See Notes on the following page.

TABLE 2.2
PARAMETERS SUGGESTED FOR INCLUSION INTO THE PIMA COUNTY EMP BY SUBJECT-MATTER EXPERTS AND REGIONAL LAND MANAGERS
(CONT.)

NOTES

Ranks: 1 = highest ranking; no rank means it was not in the top five; ties are common.

[a] Vegetation formation was scored by both the landscape pattern and vegetation workshops. The landscape pattern participants chose to focus on upland communities whereas the vegetation group did not make a distinction between upland and riparian. The manager's workshop participants were asked to rank only upland vegetation formation.

[b] Only the manager's workshop was asked to rank disturbance but participants in all meetings expressed interest in collecting this information.

[c] No expert workshop for fishes.

Based on scoring and narrative responses (see Appendices D–G), approximately 28 parameters received high ranks from subject-matter experts, and 15 parameters received high ranks from managers (see Table 2.2; see Appendices D–H for detailed discussion notes and scores). Scores, ranks, narrative responses, and workshop discussion notes will be used to further develop the Pima County EEMP through the next phases of the program. Though high-ranking parameters from the workshop process will be considered monitoring, their inclusion into the monitoring program is not assured and will be further evaluated using the tools outlined in Chapter 3.0.

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3.0 Future Development

The preceding Chapters provided an overview of the rationale for an integrated, multi-parameter monitoring program to determine, if the goals of the SDCP and MSCP are being met. Much work remains before monitoring can begin. Fundamental decisions that must be made include choosing a final list of parameters to monitor; deciding where, when, and how to measure these parameters; and designing a management structure that is integrated into Pima County's existing objectives and monitoring programs. This chapter outlines a process to accomplish these tasks and thereby provides a pathway for creating an effective and efficient monitoring program.

3.1 Phase II: A Comprehensive Approach to Choosing Monitoring Parameters

Monitoring all parameters that were suggested by expert workshop participants (see Table 2.2) is not financially or logistically feasibly and prudent. The first step in Phase II of the Pima County EEMP will be to reduce the number of potential parameters by selecting a subset that has the highest probability of informing the program goal. This task will be accomplished by incorporating information from expert workshops and from conceptual models. Once the full list of potential monitoring parameters is reduced to a subset, the second step in Phase II will be to determine key design elements such as sampling frames, spatial and temporal sampling designs, and measurable objectives. This process will lead to reduced estimates of overall program cost and other potential tools to reduce that cost through collaboration with other entities that are engaged in monitoring. These and other tools, along with appropriate program oversight and integration with existing Pima County activities (e.g. existing groundwater monitoring), will culminate in a ranked list of parameters and initial estimates of cost and breadth of program coverage. Phase II will provide the tools that are necessary to develop and implement protocols that will be used in Phase III (Figure 3.1).

3.1.1 Ranking Parameters

The first steps in developing the Pima County EEMP provided an opportunity to identify a range of potential monitoring parameters. The primary challenge in developing Phase II will be to select those parameters that have the greatest potential to detect ecological change and inform better management of natural resources in Pima County. Reducing the parameter list will be accomplished by gathering information from four sources: (1) suggestions from STAT during creation of the SDCP and MSCP, (2) outcomes from Phase I workshops (Section 2.2), (3) development of conceptual models, and (4) evaluation of existing monitoring efforts. Information from sources 1 and 2 has been

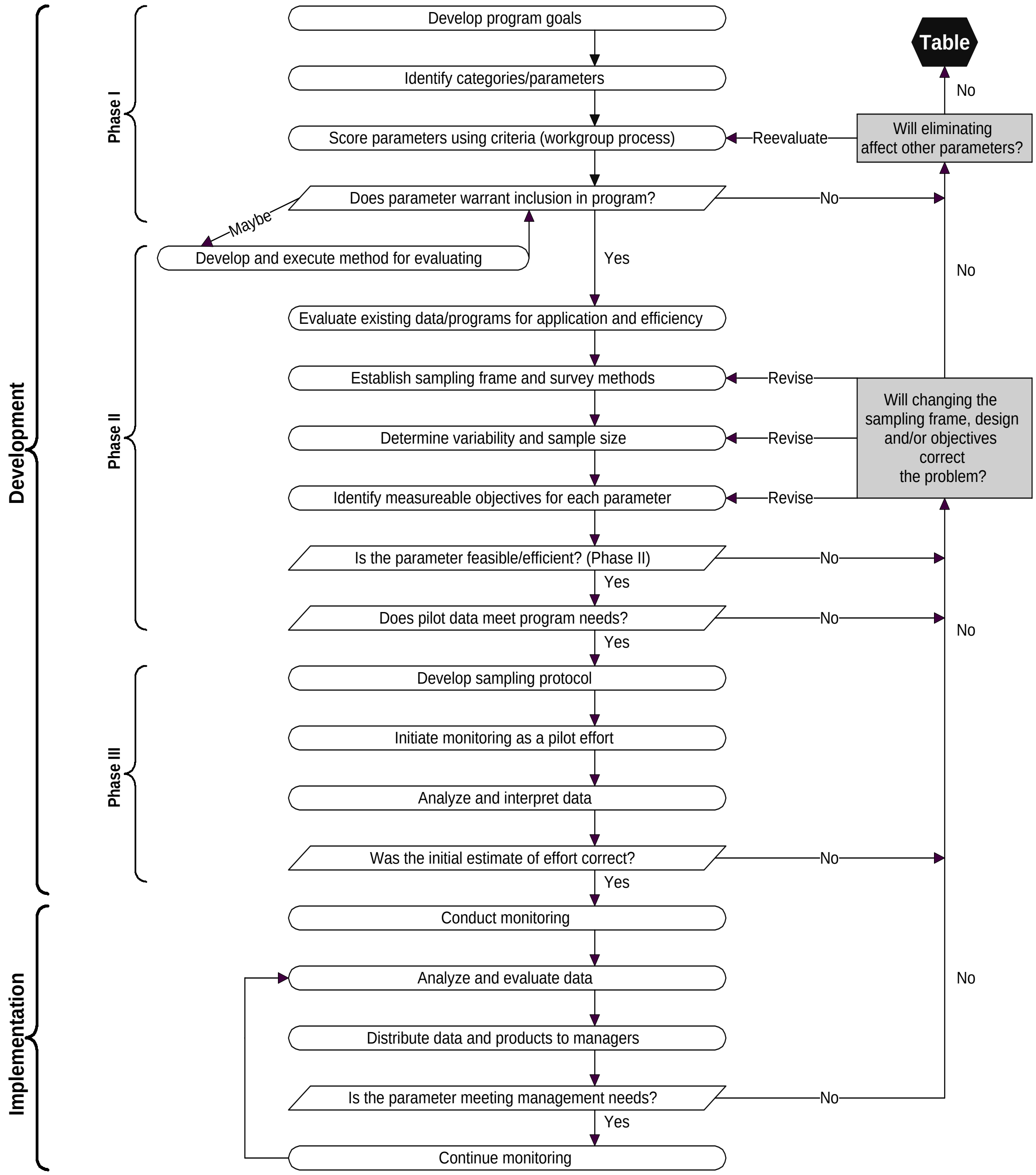

Figure 3.1. Stages of Development and Implementation for the Pima County EEMP. Diagram adapted from Cauglan and Oakley (2001).

gathered and information from sources 3 and 4 will be developed at the beginning of Phase II (see 3.1.1.3 and 3.1.1.4).

After all sources of information have been developed, they will be applied toward generating a final ranked list of parameters. The first step in this process will be to assign a rank to all parameters within each information source. Comparisons can then be made among sources, because the list of parameters for each source will be very similar to the list presented in Table 2.2. To provide a final ranking for each parameter, the four ranks for each parameter will be given equal weight in the ranking process. For example, a parameter might receive ranks of 1^{st}, 4^{th}, 11^{th}, and 6^{th} from each of the four information sources. The final score will be an average of those ranks (in this example the final score is 5.5). After all parameters receive a score, they will then be ranked.

Once all parameters are evaluated using this method, top-ranked parameters will be evaluated in more depth using the design tools outlined in section 3.1.2. It is likely that many parameters will rank high based on all or most information sources, and this evaluation will provide an important record of that process. Parameters that are likely to receive high ranks include land cover, groundwater depth, and water quantity. It is important to note that all parameters in Table 2.2 will be ranked, and no parameter will be excluded from this initial evaluation. Below is a brief introduction to the four sources of information that will be used in this initial evaluation process.

3.1.1.1 STAT Recommendations

Throughout development of the SDCP and MSCP, STAT recommended a number of monitoring parameters including land cover, perennial vegetation (focused on riparian systems), groundwater, landbirds, and aquatic vertebrates and invertebrates (Shaw 2006). Emphasis was also placed on large-scale ecological processes related to conversion of semi-desert grasslands to shrublands and Sonoran Desert uplands to buffelgrass savannahs.

3.1.1.2 Phase I Workshop Rankings

Section 2.2 described the process used during workshops to obtain information from experts and to rank these results. The list of parameters identified during workshops will be used as a baseline to develop conceptual models and to evaluate other monitoring activities (see below). In addition, a number of expert workshop participants will be joining the Monitoring Subcommittee of STAT where they will provide additional input on the parameter rankings.

3.1.1.3 Development of Conceptual Models

Expert workshops provided an important first step for generating and evaluating potential monitoring parameters, because each workshop was restricted to specific subject information that needed to be integrated across disciplines. Conceptual models are a useful tool for this integration process, because these models describe how systems function by identifying relationships among parameters, what stressors and drivers regulate the behavior of a system, and what information gaps are present (Manley et al. 2000, Atkinson et al. 2004; Appendix J provides a brief introduction to and examples of conceptual models that will be useful during Phase II). Conceptual models also promote better communication among managers and stakeholders and provide a record for program review (Atkinson et al. 2004). To make conceptual models relevant for monitoring, particular emphasis will be placed on how systems change as a result of management actions and other anthropogenic changes.

For Phase II, conceptual models provide an efficient means of identifying and selecting monitoring parameters. In riparian systems, for example, perennial vegetation is affected by a wide range of stressors and processes (see Figure J.3). Vegetation, in turn, plays an important role in determining habitat quality for vertebrates. In addition to the riparian systems model, early conceptual models will also focus on the Sonoran Desert upland and semi-desert grassland systems.

After a list of high-ranking parameters has been identified, conceptual models will be created for each parameter. The ultimate goal of these parameter-specific models is to clearly illustrate why each parameter was chosen and what its connection is to other parameters and to a suite of stressors and management actions. Although the initial focus will be on creating qualitative conceptual models (i.e., diagrams), quantitative models may also become important when focusing on individual parameters or species. In particular, sensitivity analysis and population viability analysis may be suitable for modeling populations of endangered or threatened species (Morris et al. 2002).

The two-stage conceptual modeling approach advocated for the Pima County EEMP differs markedly from many other MSCP monitoring efforts that typically start by modeling covered species and expand to cover landscape-level characteristics (e.g., Atkinson et al. 2004). The top–down approach advocated for the Pima County EEMP is consistent with the broad approach to ecosystem monitoring that has been articulated throughout this planning process.

3.1.1.4 Evaluating Existing and Planned Monitoring Efforts

Pima County and other entities are actively engaged in long-term monitoring, and these efforts have direct application to the development and implementation of the Pima County EEMP. Early in Phase II there will be an emphasis on identifying existing programs that can provide information to the Pima County EEMP for little or no cost.

Whether or not to include a parameter that is already being monitored by another entity will be evaluated based on how well the parameter addresses the following questions:

1) Does the parameter rank high on the list of parameters from workshops?

2) Is the parameter being monitored at many or few sites in Pima County?

3) If it is being monitored at only a few sites, how expensive would it be to add additional sites?

4) Is future funding assured or has there been a strong commitment to funding in the past?

5) Is the monitoring entity willing to share data?

6) Are data and associated information well documented and archived?

The answer to these questions will help determine, if it is appropriate to rank those parameters higher than what they would otherwise rank on the priority list based on STAT recommendations, expert workshops, and conceptual models. These issues may be given serious consideration, if there are existing data. Saguaro cactus recruitment and age-structure monitoring would be an excellent example of on-going monitoring that might be appropriate for adoption by the Pima County EEMP. In many cases it is anticipated that acquisition of data from low-ranking parameters may not be worth staff time and effort The importance of these and other challenges to incorporating outside data should not be underestimated; they can take away staff time that could be used elsewhere.

Evaluation of ongoing monitoring efforts will also be valuable after the initial ranking process. Data from past efforts can be essential in assessing cost and sampling design components (e.g., sample-size estimation using power analysis; see Section 3.1.2.2). Programs that hold the most promise for informing this effort are highlighted in Appendix B. Characteristics of programs that will be of particular value in the design portion of Phase II include:

1) Data were collected consistently and with established protocols;

2) Data were useful for management;

3) There was consistent institutional support for the program;

4) The parameter and the frequency that it is monitored describe ecosystem processes of interest.

In addition to informing cost estimates and program design, evaluating existing monitoring efforts can help determine, if Pima County EEMP should adopt a particular monitoring protocol by providing an opportunity to evaluate the successes and mistakes of these efforts. Using these evaluations combined with a better understanding of the data needs of the Pima County EEMP, Pima County could begin forging monitoring partnerships with entities that are willing to meet or that have met strict adherence to protocols for data collection and management (see Section 3.4). Possibilities for future partnerships exist with City of Tucson and the Town of Marana, both of which are currently developing HCPs with the NPS, BLM, U.S. Forest Service, Arizona Game and Fish Department, the Nature Conservancy of Arizona, and the Sonoran Institute (Figure 3.2; Appendix B). Finally, the University of Arizona has a suite of research scientists and faculty who can provide technical assistance and coordination for the Pima County EEMP to secure outside funding sources (e.g., the National Science Foundation). These entities are likely to become invaluable partners in the development and implementation of monitoring in the Pima County EEMP.

The most valuable partnerships will involve coordination of monitoring both within and outside of the Permit Area. Monitoring outside the Permit Area will place ecological trends and management needs within the Permit Area into a broader spatial context and aid both the biological goal of the SDCP and permit compliance under the MSCP. This approach will also facilitate earlier detection of trends and faster response times to important stressors such as invasive species. These monitoring efforts will even be more powerful when coordinated with national and international programs (National Research Council 2000; The Heinz Center 2002; Pereira and Cooper 2006).

3.1.2 A Design-based Approach to Evaluating Top-Ranked Parameters

The parameter-ranking process (Section 3.1.1) will outline the most valuable parameters and aid establishment of measurable objectives, estimates of cost and spatial application, and ultimately our ability to detect trends (see Figure 3.1). Evaluation will begin with the highest-ranked parameters and move down the list as time and resources allow.

3.1.2.1 Establishing Sampling Frame and Survey Methods

The sampling frame is the entire collection of monitoring sites that is available for inclusion into a monitoring program. Sampling frames will vary by parameter with the most important characteristic being spatial extent. For example, land cover can be measured across all of Pima County, whereas only a small number of pools are available for sampling breeding frogs. Therefore, the first level of evaluation for each top-ranked parameter will be to determine appropriate sampling frames. In many cases, sampling frames are already well known based on data gathered for the SDCP (e.g.,

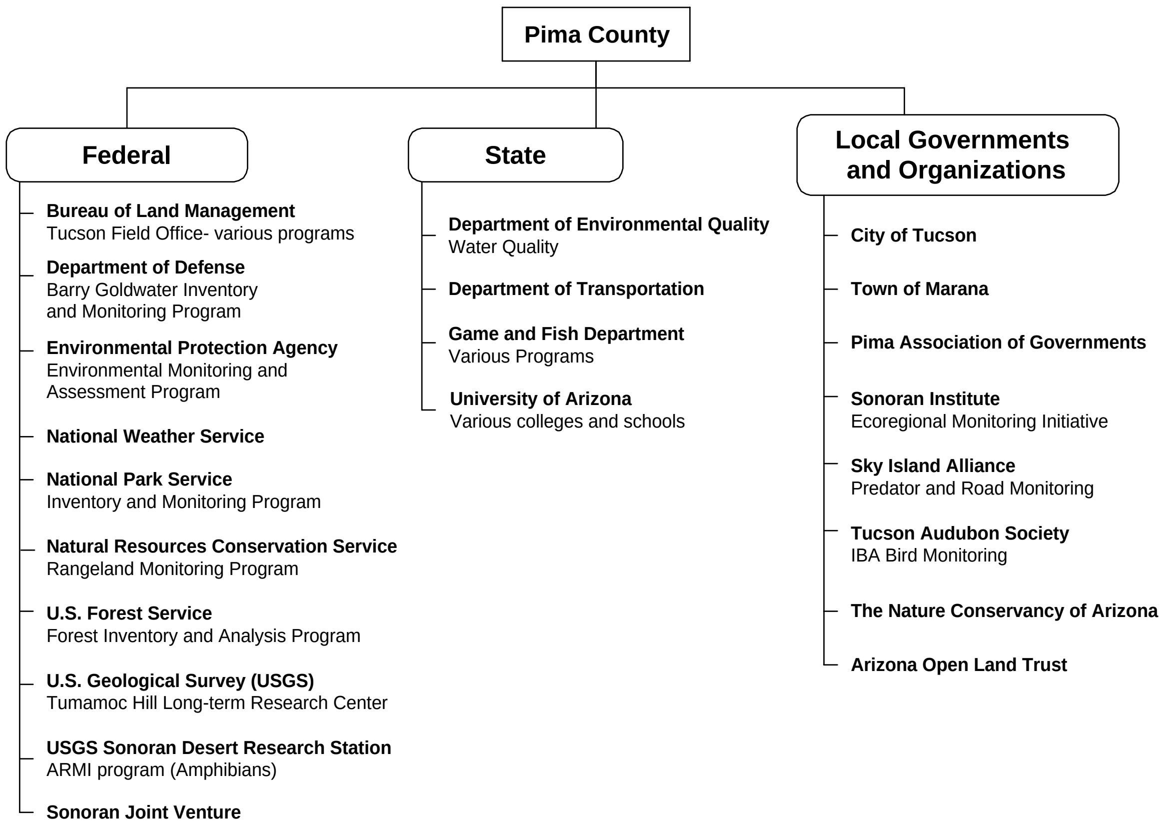

Figure 3.2. Potential Collaborators in the Development and Implementation of the Pima County EEMP.

Harris et al. 2000), but for many parameters sampling frames will need to established using expert opinion. Decisions will also need to be made as to whether to extend a sampling frame beyond the Permit Area or lands outside of Pima County. Legal access to areas potentially included in sampling frames will also be an important consideration.

Once sampling frames have been identified, the most appropriate sampling methods can be assessed. Much of this information was collected during the workshops and it may be necessary to again contact workshop participants or other experts for additional information. Other important types of information for estimating cost include:

- Level of skill required to collect, analyze, and interpret data;
- Equipment costs and other resources for collecting and archiving data;

- Technological challenges to implementation.

These data can then be used to create a cost matrix to estimate the costs per sampling unit across a range of sample sizes over the duration of the permit (see Coachella Valley Planning Commission 2006 for example). This process will provide direct cost comparisons among parameters.

3.1.2.2 Determining Variability and Sample Sizes

The principal design component during Phase II will involve evaluation of parameters based on how they vary spatially and temporally as well as an assessment of sampling (i.e., measurement) error that can occur during data collection and interpretation. These factors are critical to consider when designing a monitoring program (Figure 3.3), because natural variation and sampling error directly affect the cost of monitoring; parameters with high natural variation are more expensive to estimate (Christensen et al. 1996; Urquhart et al. 1998). In addition to estimating sources of variation, this portion of Phase II will focus on appropriate temporal sampling designs to assess their relative costs. For example, a parameter may be too expensive to monitor annually, and in some cases biennial surveys may be sufficient.

Because monitoring vertebrates is especially challenging, this group will be given special consideration during Phase II. During workshops, information was obtained on the length of the survey period and number of observations per sampling unit. These estimates and others for sampling error and temporal variability will be evaluated more thoroughly to produce detailed cost estimates and comparisons among taxa. For example, Powell et al. (2006b) following protocols outlined in Urquhart et al. (1998) used landbird monitoring data from Organ Pipe Cactus National Monument (southwestern Pima County) to investigate alternative sampling designs for landbird monitoring in the region. Investigations like this require data from regional research or monitoring efforts, which may pose challenges if no long-term datasets are available. In these cases it will be necessary to model temporal and spatial variation components.

Among the tools that are valuable for informing the design of the Pima County EEMP, prospective power analysis will play a prominent role. Power analysis is a statistical tool used to assist with balancing tradeoffs among spatial and temporal sampling designs, sample size, the magnitude of trends that can be detected, and the level of certainty that we desire (Steidl and Thomas 2001). These design elements can each be varied to determine a range of appropriate options for meeting desired objectives (see Steidl et al. 1997; Gibbs et al. 1998). Using this approach, alternative sampling designs using probability-based sampling can be assessed (e.g., stratified random or cluster sampling; see Appendix I for overview of spatial and temporal sampling designs). These evaluations can be conducted as a form of optimization given a range of budgetary scenarios. Power analyses will also assist with establishing measurable objectives, because the ability to detect trends is contingent on the spatial variability of a parameter and the desired level of precision and certainty (see Section 3.1.2.3).

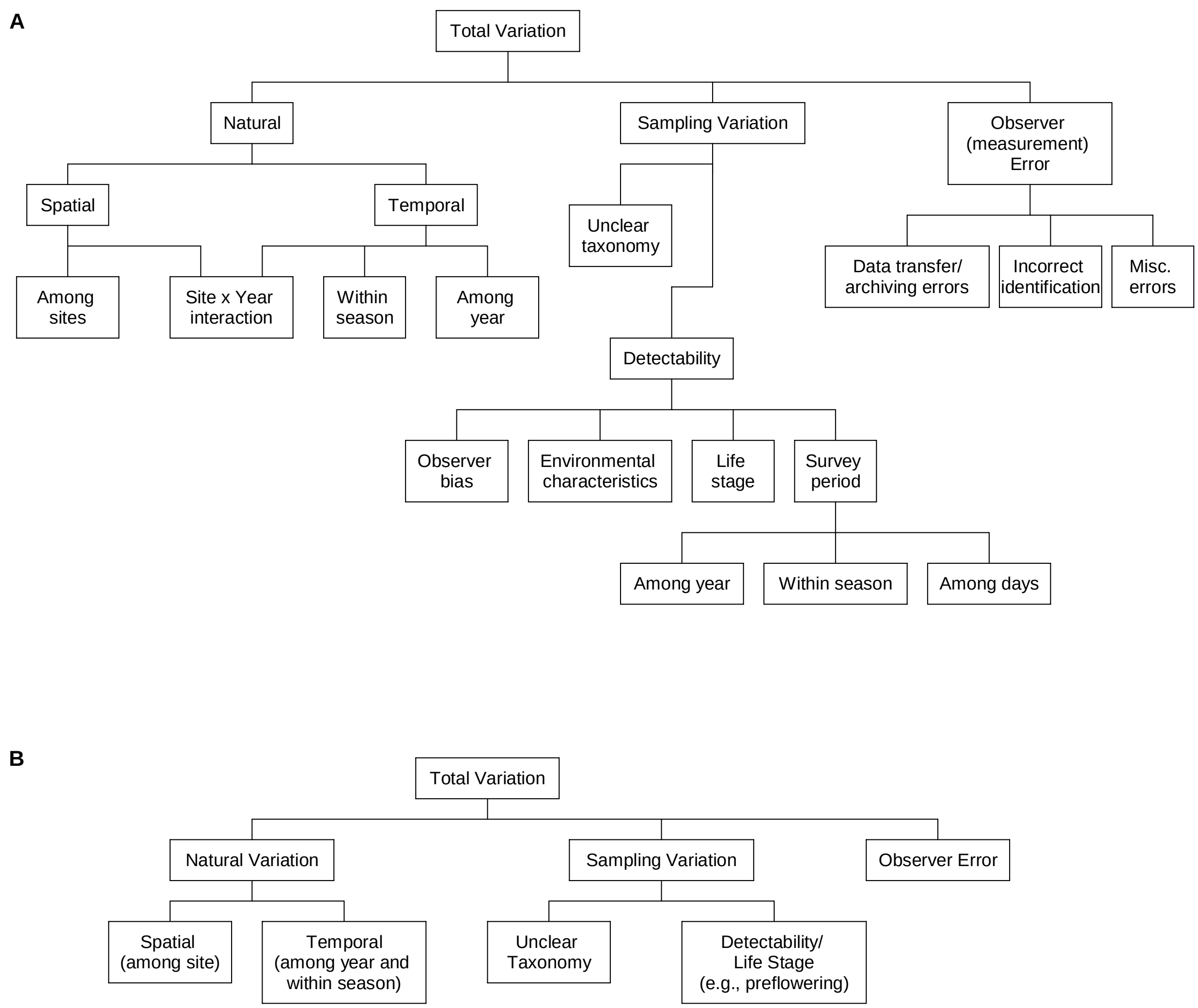

Figure 3.3. Types of Natural Variation and Sampling Error in Monitoring Vertebrates (A) and Vegetation (B). The relative contribution of each source of variation differs by parameter, but all sources influence program cost and the ability to detect trends. These sources of variation will be investigated in Phase II of the Pima County EEMP.

The integrated, multi-category monitoring program proposed for the Pima County EEMP creates an opportunity to collect data on multiple parameters at the same sites (i.e., co-location), so that relationships among changing physical and biological parameters and responses to stressors can be evaluated. In Phase II these efficiencies and advantages will be investigated by relating them directly to sampling design components, most notably where and how often to sample (Scott 1998). In general, considering alternative designs that efficiently capitalize on the shared objectives of multi-parameter monitoring provides a practical approach for decreasing costs and increasing the utility of the data. Riparian systems provide an outstanding opportunity for realizing these efficiencies.

3.1.2.3 Developing Parameter-specific Objectives

Success of the Pima County EEMP will be measured by its ability to meet the program goal (see Section 1.3). Informing this goal will be a set of objectives related to each of the parameters included in the program. Monitoring objectives must be realistic, measurable, specific, and understandable to policy makers. By contrast, vague objectives provide little direction for informing program design and determining whether the goals of the program are being met (Olsen et al. 1999, Ringold et al. 2003). Examples of objectives for vegetation monitoring for the Pima County EEMP might include:

- Determine changes to the distribution of dominant vegetation communities (formations) in eastern Pima County;
- Determine changes to the structural characteristics of key vegetation communities, with particular emphasis on the mesoriparian community;
- Determine changes to the composition of key vegetation communities with an emphasis on early detection of non-native and invasive species.

Linking narrative objectives like these to measurable objectives will be essential. For example, a typical measurable objective would be to detect a 2-percent annual change in the parameter over a 30-year period with an 80-percent probability and a Type I error rate (false-alarm rate) of 10 percent (e.g., Bart et al. 2004). Put another way, the objective would be to be 80 percent certain of detecting a 45-percent change in the parameter over 30 years with a 10-percent chance of declaring that there is change when it fact it has not occurred. The design tools discussed earlier, such as cost and sample-size estimation, have a direct connection to the establishment of measurable objectives. Most importantly, if it is desired to increase our estimates of precision for determining change, additional samples much be taken, which increases program cost. In this early design phase it is crucial to determine, if an ecological relevant change can be detected and what the tradeoffs would be, for example, of relaxing our level of certainty in declaring that there is a change when in fact it did not occur. These and other design tradeoffs are essential in the early planning stages of any program and once again, data from the other monitoring programs, both in the region and outside the region, will be essential for informing the range of responses (i.e., rate and magnitude of trends) and estimates of precision.

Concurrent with identifying measurable objectives, it will be necessary to establish ecologically meaningful thresholds at which to trigger active management. For example, it may be determined that a 50-percent reduction in native fish abundance would trigger management reintroduction or intensive habitat management.

3.1.3 Step 5: Reconciliation with Permit Requirements

The approach to MSCP monitoring that is being advocated by Pima County attempts to address the difficulties that other HCP and MSCP monitoring efforts have had at meeting their goals (see critiques in Harding et al. 2001; Hierl et al. 2005). The approach for Pima County may necessitate that less emphasis is placed on tracking most PVS populations, which can be prohibitively expensive to monitor, and instead place more emphasis on broader measures of ecosystem condition. Because this approach is so different from other MSCPs, it will be imperative to work closely with the USFWS to ensure that the proposed list of parameters meets the monitoring requirements of the permit. Reconciling regulatory requirements of PVS with economic reality of a limited budget for ecological monitoring will be one of the greatest challenges in the design of the Pima County EEMP.

To meet this challenge, USFWS involvement should take place both in their representation on the Monitoring Subcommittee and separately in consultation with the various Pima County agencies in charge of permit implementation. In these forums it will be important to further define the monitoring requirements of individual species. It may be determined, for example, that some PVS may be expensive to monitor throughout the permit area, though monitoring may be more appropriate for a subset of those lands that are owned or that are under direct management control of Pima County. The results of these parallel meetings with the USFWS will inform the direction of the broader effort through refinement of the sampling frame. Finally, upon formal submission of the permit, the USFWS will have another opportunity to review Pima County's proposed monitoring in terms of the covered species and therefore require any necessary adjustments.

3.1.4 Establish Funding Mechanisms and Levels

The greatest challenge to the implementation of the Pima County EEMP will be to ensure adequate and consistent funding throughout the term of the permit. As yet, no mechanism has been identified that will provide the necessary funds for implementation. Among the funding options are revenue-sharing agreements with future business enterprises, similar to recent agreements between Pima County and Marriott and Wal-mart. Unfortunately, funding for effectiveness monitoring cannot be provided for through Pima County bonds or through development impact fees, a typical mechanism for funding MSCP monitoring programs (Conservation Biology Institute 2006). It is worth noting that Pima County and its Regional Flood Control District are currently providing funding for ongoing monitoring programs that would likely become part of the Pima County EEMP (e.g., water monitoring, GIS analysis, and database services).

Resolution to the funding issue must be found early in Phase II so that decisions can be made regarding which and how many parameters can be monitored. To aid in this process, three funding scenarios have been identified with rough approximations of coverage and cost:

- **Optimal**. Full funding for approximately 20 parameters for the life of the permit. Creates most extensive network of parameters, thereby providing comprehensive view of ecological change in Pima County. In addition, provides most expanded spatial coverage due to efficiencies. Full time staff: one coordinator, one ecologist, one data manager, three biological technicians. Approximate initial annual cost is $900,000.

- **Moderate**. Full funding for approximately 12 parameters for the life of the permit. Provides moderate representation for most parameter groups, but some groups may not be covered. In this program, the area of inference more restricted than in the optimal program. Full-time staff: one coordinator, one ecologist, two biological technicians. Approximate annual cost is $600,000.

- **Minimal**. Partial funding for approximately 8 parameters for the life of the permit. Most focus would be on monitoring covered species or their habitats; minimal and spotty coverage for additional ecosystem parameters. Program would provide little information for adaptive management at the broader ecosystem level because spatial coverage would be limited to a subset of Pima County owned and managed lands. Full-time staff: one coordinator, two biological technicians. Approximate annual cost is $300,000.

This approach to estimating program cost for multiple funding levels will be more refined in Phase II; it will feed directly into the parameter ranking and cost estimate processes (see Section 3.1.2). As part of the budget planning process it will be important to develop timeline and budget scenarios for both the development and implementation phases of the program.

3.1.5 Creating Internal Management Structure

On November 27, 2006, the County Administrator's Office identified Pima County Regional Flood Control District as the lead county agency for developing and implementing the Pima County EEMP. The Regional Flood Control District can now begin exploring inter-agency agreements to have other agencies to assist with the many tasks that are necessary to implement a comprehensive monitoring program.

To facilitate the creation of the Pima County EEMP, Pima County Regional Flood Control District will convene an internal advisory group made up of representatives from all Pima County departments responsible for implementing the permit: Development Services, Environmental Quality, Natural Resource, Parks and Recreation, Flood

Control, Technical Services, Transportation, and Wastewater Management. Many of these departments have active monitoring programs for parameters specific to their mission such as: stocking rates of livestock (Parks and Recreation) and land use, zoning, and assessor data (Development Services). Integrating these monitoring activities into the Pima County EEMP will be the most important function of this group. This advisory group will also:

- Ensure that suggested parameters meet the regulatory requirements of the permit;
- Identify and develop existing resources within respective departments to support the Pima County EEMP;
- Develop recommendations for the permanent structure of the program;
- Identify funding from existing county sources and write grants, contracts, and intergovernmental agreements;
- Oversee development of a comprehensive data management plan.

The result of staff's work will be summarized in the MSCP to complete the requirements for the permit application to the USFWS.

3.1.6 Additional Phase II Tasks

Develop Initial Data Management Plan. Proper data collection, storage, and analyses are essential to the success of any long-term monitoring program (Palmer and Mulder 1999). A comprehensive data management plan (e.g., Angell 2006) will be a critical tool that will be fully developed in Phase III. During Phase II, an initial data management plan will be written; it will cover the basic principles of data management (quality, interpretability, security, longevity, and availability) and how these will be addressed in the comprehensive plan. Other data management activities during Phase II include inventorying existing data resources such as Geographic Information System files, databases, and identifying legacy data requiring long-term storage.

Investigate Use of Volunteers. Throughout the development of the program, every effort should be made to use volunteers for data collection where it is technically feasible and administratively prudent. The cost savings of using volunteers for collecting data that requires little training and low observer error can be significant (Fore et al. 2001). Volunteer monitoring projects could include photographic monitoring, off-road vehicle use, wildcat dumping, and compliance-related monitoring activities including fencing and overall site assessment. In addition to saving money, volunteers can generate crucial community involvement and support for the monitoring program. Current monitoring programs in Pima County that effectively use volunteers include the Tucson Bird Count, predator and road monitoring by the Sky Island Alliance, and the Important Bird Areas program of the Tucson Audubon Society (Appendix B).

3.2 Phase III Overview

Phase III will begin the process of implementing the Pima County EEMP through development of detailed protocols using national standards (Oakley et al. 2003). Protocol development for each parameter will involve selecting specific study sites, outlining step-by-step instructions for field sampling and data analysis, and detailing protocols for data management. Operational monitoring should begin only after detailed protocols have been developed and reviewed by subject-matter experts to ensure scientific rigor and feasibility.

The success of any long-term monitoring program is dependant upon the dissemination of information to policy makers, land managers, and the general public (Woodward et al. 1999; Palmer and Mulder 1999; Harwell et al. 1999). Therefore, an important component during Phase III will be to create a communications plan that will highlight key constituents and target materials appropriate to each. Pima County is already taking the lead in this area and is expected to produce its first “State of the Sonoran Desert Conservation Plan” report in the coming year.

3.3 External Program Oversight

Input and support from the public and scientific community was one of the keys to the successful implementation of the SDCP. To date, over 200 scientists and subject-matter experts have contributed to the MSCP and SDCP, and this broad participation continues in the development of the Pima County EEMP. To ensure proper oversight, it is recommended that three advisory groups oversee different facets of the Pima County EEMP to help ensure credibility, feasibility, and efficiency.

The advisory group currently overseeing the development of the monitoring plan is the Monitoring Subcommittee of STAT, which will be expanded to include additional individuals with expertise in monitoring. The Monitoring Subcommittee is expected to perform the following functions for Phase II:

- Oversee development of the Pima County EEMP to ensure representative coverage of species and defensible integration among parameters.
- Provide technical advice on parameter development (e.g., cooperative research projects).
- Provide guidance for integration with other efforts in the region.

Second, Pima County will reconstitute STAT to oversee the monitoring program into Phase III and beyond. This reformulated STAT will have different responsibilities than the existing STAT. (Current STAT members were chosen for the purpose of developing a reserve design and other species-protection measures for the draft MSCP, processes that are now largely complete). The new STAT will interact closely with County staff and USFWS to help reconcile inherent tradeoffs in the financial commitments of Pima County, permit needs of the USFWS, and the monitoring recommendations of the subcommittee. Once the monitoring program is in implementation, this reconstituted STAT group will be responsible for assessing whether it is informing management and meeting the biological goals of the SDCP. If and when monitoring deficiencies are identified, STAT will evaluate potential adjustments.

A third advisory group, the External Review Committee (ERC), would comprise nationally and internationally recognized experts in ecosystem monitoring. Their charge would be to ensure scientific validity of the program at important “milestones,” such at the completion of Phase I, II, and III plans. Suggested membership in the ERC includes:

- Paul Beier-Northern Arizona University;
- Bruce Bingham-NPS Intermountain Regional I&M Coordinator;
- James Gibbs-State University of New York;
- Nancy Grimm-Arizona State University and Central Arizona Phoenix Long-term Ecological Research Center;
- Andrew Hansen-Montana State University;
- Bill Kepner-Environmental Protection Agency;
- James Nichols-USGS Patuxent Wildlife Research Center;
- Barry Noon-Colorado State University;
- John Sauer-USGS Patuxent Wildlife Research Center.

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Julia Fonseca and Neva Connolly of Pima County Regional Flood Control District were instrumental in development of this monitoring plan and for coordinating all workshops. Bill Shaw and Bob Steidl of the School of Natural Resources at the University of Arizona provided outstanding guidance and monitoring design assistance throughout the development of this plan. The cover illustration was prepared by Bill Singleton, Pima County Graphics Design. In addition to the workshop participants (Appendix C) and the aforementioned individuals, project oversight was also provided by:

- Ms. Sherry Barrett, U.S. Fish and Wildlife Service
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5.0 Glossary of Terms and Acronyms

5.1 Terms Used

Adaptive management: Systematic process for continually improving management by learning from management actions.

Adaptive monitoring: The monitoring program itself should be adaptable because new information on the function of the system, new threats, or new field methods may change program objectives or ways of collecting data (Ringold et al. 1996).

Bankfull stage: Point at which the river's flow begins to enter the floodplain (Leopold 1994).

Community: Assemblage of plants and animals living within a specified area, usually described by the presence, abundance, and distribution of all species.

Compliance monitoring: Evaluation of the terms and conditions of the Pima County MSCP by providing compliance information on the status of permit implementation including administrative and financial information.

Driver: Major forces of change (sometimes anthropogenic) that operate on large regional scales, such as climate. See stressor.

Ecosystem: Collections of organisms integrated by flow of matter and energy among each other and the abiotic environment.

Ecosystem health: based on four characteristics of complex systems: sustainability, activity, organization, and resilience: "an ecological system is healthy if it is stable and sustainable – that is, if it is active and maintains its organization and autonomy over time and its resilience to stress" (Haskell et al. (1992).

Effectiveness monitoring: Program to assess the achievement of the biological goals and objectives of the MSCP and to inform management through an adaptive management process.

Formation: A level in the National Vegetation Classification Standard hierarchy below subgroup which represents vegetation types that share a definite physiognomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes (Grossman et al. 1998).

Habitat: A species-specific term referring to the area with a combination of biotic and abiotic features that provides individuals of a species all or some of the resources they need to survive and reproduce (Morrison et al. 1998).

Inventory: A point-in-time effort to determine the status, condition, or location of resources. Can be used as a baseline for monitoring.

Metapopulation: A system of isolated populations that are interconnected by gene flow, extinction, and colonization.

Monitoring: Repeated measurement and analysis of a parameter over time. Determination of a system's status at various times yields information on trends, which is fundamental to the potential for detecting change in a system.

Occupancy: The number of sampling units occupied (i.e., presence or absence) by a species over time and adjusted for imperfect detectability (e.g., patches where animals are present but undetected) during trend estimation (MacKenzie et al. 2006)

Parameter: Attribute of the environment that can be measured or estimated and that provides insight into the system of interest. Often referred to as an indicator (Busch and Trexler 2003).

Parameter category: A collection of parameters that are connected by a common theme (e.g., water resources consist of water quality, quantity, geomorphology, etc.).

Parameter group: Aggregation of parameters evaluated by workshop experts. For example, five parameters associated with perennial vegetation (community composition, relative abundance, frequency, distribution, and recruitment) were evaluated together.

Permit: ESA Section 10(a)(1)(B) permit from the U.S. Fish and Wildlife Service for incidental take of listed species. Permit duration is 30 years.

Permit Area: Unincorporated and Pima County owned lands (607,700 acres) to which the Section 10(a)(1)(B) permit will apply.

Population (sampling): The entire group (universe) from which sampling units are drawn and to which reference is made.

Population demography: The proximate expression of a population's vital rates (immigration, emigration, birth, and death).

Priority Vulnerable Species (PVS): Plant and wildlife species that were used to develop the Conservation Lands System of the SDCP, 36 of which are proposed for coverage by the pending Pima County Section 10(a)(1)(B) permit. See complete list in Appendix A.

Probability Sampling: The selection of samples, each with a known likelihood of being chosen. See overview in Appendix I.

Research: Employing scientific methods to answer questions related the structure or function of the system of interest or elements of a system that change as a result of management actions.

Sampling Unit: The basic unit (plot, transect, point) on which measurements are made. A collection of sampling units is used to describe the population of interest.

Sampling Design: The way in which sampling locations are chosen and the proportions of the sampling frame actually monitored.

Sampling Error: Error introduced in the field, laboratory, or during analysis that is unrelated to natural variation.

Sampling Frame: The complete collection of the possible sampling units from which samples can be drawn. Sampling frame determines the inference of results.

Special Element: Used in the SDCP to denote areas of conservation significance for PVS, but which are not captured by the dominant community types of interest (Sonoran Desert upland, semi-desert grassland, and mesoriparian forest and woodland). Special Elements include talus slopes for snails, and caves, adits, and bridges for bats.

Species of Conservation Concern: Species listed under the ESA as endangered, threatened, or candidates for listing; species identified as Priority Vulnerable Species by the SDCP; and species that have been identified by the State of Arizona as warranting conservation status.

Species Group: Species that can be surveyed using similar field methods, as delineated by the vertebrate workshop participants (see Appendix G).

Scientific and Technical Advisory Team (STAT): Scientific and technical personnel from a variety of entities and appointed by the County Administrator who advise Pima County on technical and ecological issues related to the SDCP and MSCP. Monitoring Subcommittee is a subcommittee of STAT.

Stressor: Physical, chemical, or biological perturbations that cause changes in the ecological structure or function of natural systems, usually at more local scales than drivers. Stressors are often foreign to the system; if they are natural, they are often applied at an excessive or deficient level.

5.2 Acronyms

AGFD	Arizona Game and Fish Department
BLM	Bureau of Land Management
EDW	Effluent Dominated Water
EDS	Effluent Dominated System
EEMP	Ecological Effectiveness Monitoring Program
ERC	External Review Committee
ESA	Endangered Species Act
EVI	Enhanced Vegetation Index
GRTS	Generalized Random-tessellation Stratified
HCP	Habitat Conservation Plan
I&M	Inventory and Monitoring
IMN	Ironwood National Monument
LCNCA	Las Cienegas National Conservation Area
MSCP	Multi-species Conservation Plan
NAWQA	National Water Quality Assessment Program
NDVI	Normalize Difference Vegetation Index
NPS	National Park Service
PVS	Priority Vulnerable Species
SD	standard deviation
SDCP	Sonoran Desert Conservation Plan
SDEMF	Sonoran Desert Ecoregional Monitoring Framework
STAT	Science and Technical Advisory Committee
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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APPENDICES

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APPENDIX A

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List of PVS Likely to be included in Pima County MSCP Permit

Species in bold-faced type are currently listed as threatened or endangered by the U.S. Fish and Wildlife Service.

Species Group	Common name	Scientific name
Plants	**Pima pineapple cactus**	***Coryphantha scheeri var. robustispina***
	Needle-spined pineapple cactus	*Echinomastus erectocentrus var. erectocentrus*
	Huachuca water umbel	***Lilaeopsis schaffneriana recurva***
	Tumamoc globeberry	*Tumamoca macdougalii*
Mammals	Mexican long-tongued bat	*Choeronycteris Mexicana*
	Allen's big-eared bat	*Idionycteris phyllotis*
	Southern yellow bat	*Lasiurus xanthinus*
	Western red bat	*Lasiurus blossevillii*
	Lesser long-nosed bat	***Leptonycteris curasoae yerbabuena***
	California leaf-nosed bat	*Macrotus californicus*
	Pale Townsend's big-eared bat	*Plecotus townsendii pallescens*
	Merriam's mouse	*Peromyscus merriami*
Birds	Burrowing owl	*Athene cunicularia hypugaea*
	Cactus ferruginous pygmy-owl	*Glaucidium brasilianum cactorum*
	Rufous-winged sparrow	*Aimophila carpalis*
	Swainson's hawk	*Buteo swainsoni*
	Western yellow-billed cuckoo	*Coccyzus americanus*
	Southwestern willow flycatcher	***Empidonax traillii extimus***
	Abert's towhee	*Pipilo aberti*
	Bell's vireo	*Vireo bellii*
Fishes	Longfin dace	*Agosia chrysogaster*
	Desert sucker	*Catostomus clarki*
	Sonora sucker	*Catostomus insignis*
	Desert pupfish	***Cyprinodon macularius***
	Gila chub	***Gila intermedia***
	Gila topminnow	***Poeciliopsis occidentalis occidentalis***
Amphibians	**Chiricahua leopard frog**	***Rana chiricahuensis***
	Lowland leopard frog	*Rana yavapaiensis*
Reptiles	Desert box turtle	*Terrapene ornate luteola*
	Sonoran desert tortoise	*Gopherus agassizii*
	Tucson shovel-nosed snake	*Chionactis occipitalis klauberi*
	Mexican garter snake	*Thamnophis eques megalops*
	Giant spotted whiptail	*Aspidoscelis burti stictogramma*
	Red-backed whiptail	*Aspidoscelis burti xanthonotus*
	Ground Snake (valley form)	*Sonora semiannulate*
Invertebrates	Arkenstone Cave pseudoscorpion	*Albiorix anopthalmus*

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APPENDIX B

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Existing Monitoring and Related Research Efforts within Pima County

Many of the partners listed below are interested in assisting with the development and implementation of the Pima County EEMP. Partners or monitoring activities that can inform the development of the program are highlighted.

Partner Group	Partner	Monitoring-related Activities and Expertise
Federal Government	Agriculture Research Service	Watershed research; Interest in developing stream-channel monitoring protocol; Expertise in developing conceptual ecological models.
	BLM, Tucson Field Office: 1) Las Cienegas National Conservation Area (LCNCA) 2) Ironwood National Monument (IMN)	Monitoring Avian Productivity and Survivorship (bird) monitoring (LCNCA); Southwestern willow flycatcher monitoring (LCNCA); Cactus ferruginous pygmy owl, desert tortoise, and Turk's head cactus monitoring (IMN); Bat roost inventory (INM); **Fish (relative abundance) and aquatic habitat monitoring (LCNCA);** **Ecological site models and upland vegetation monitoring (LCNCA);** Stream gauge monitoring (LCNCA); Recreation impacts (inventory; LCNCA and INM).
	Department of Defense–Barry M. Goldwater Range	Developing land-use and monitoring plans- held scoping session in November 2006 to determine parameters; Endangered species monitoring: lesser long-nosed bat and cactus ferruginous pygmy-owl.
	Environmental Protection Agency (EPA), Environmental Monitoring and Assessment Program	**National program with monitoring assessment for water-quality, fish, and air-quality monitoring, but with no known sites in Pima County;** Protocols are developed and can be adapted.

Partner Group	Partner	Monitoring-related Activities and Expertise
Federal Government (cont.)	**NPS, Sonoran Desert Network**	Implementing long-term protocols for 11 park units in Arizona and w. New Mexico for the following parameters: 1) integrated aquatic monitoring program: channel geomorphology, aquatic macroinvertebrates, fish, water quality, paraphyton, and algae, 2) climate, and 3) birds; Future protocol implementation includes vegetation (including non-native species), air quality, soils, visitor impacts, and adjacent land use; Database development for all monitoring parameters; Communications plan development; Vegetation mapping (to formation level) now underway. Plant and vertebrate inventories of all 11 units completed with coordination with USGS Sonoran Desert Research Station.
	NPS, Organ Pipe Cactus National Monument	**Environmental Monitoring and Assessment Program** began in 1986 and have been monitoring: atmospheric deposition, air quality, climate, water quality, well depth, vegetation bats, lizards, birds, Quitobaquito desert pupfish, and nocturnal rodents. Program currently being reviewed and may include monitoring impacts from illegal immigrants; Endangered species monitoring: Sonoran pronghorn, Quitobaquito desert pupfish, and cactus ferruginous pygmy-owl.
	NPS, Saguaro National Park	**Long-term vegetation plots for saguaros and woody plants**; Cactus ferruginous pygmy-owl and desert tortoise monitoring; **Lowland leopard frog and water-availability monitoring project;** **Fire-effects monitoring plots;** Air quality and climate monitoring stations; Study on vertebrate mortality along roads.
	National Weather Service	Gathers and compiles weather data from sites throughout southern Arizona; Developing models for predicting precipitation.
	Natural Resource Conservation Service	**Developing national vegetation monitoring guidelines for rangelands- 30 test sites in southern Arizona;** Various vegetation and soils monitoring projects on private ranches in Pima County.
	USFWS–Ecological Services	Provides regulation assistance.

Partner Group	Partner	Monitoring-related Activities and Expertise
Federal Government (cont.)	USFWS, Buenos Aires National Wildlife Refuge	Vegetation monitoring plots; Active prescribed wildland fire program; Amphibian Research and Monitoring Initiative (ARMI)-monitoring occupancy of spadefoots and other anurans (in conjunction with Cecil Schwalbe of USGS Sonoran Desert Research Station); Endangered species monitoring: cactus ferruginous pygmy and masked bobwhite;
	USFWS, Cabeza Prieta National Wildlife Refuge	Undocumented immigrant and Border Patrol impacts monitoring; Vegetation monitoring plots, including invasive species; Endangered species monitoring: Sonoran pronghorn and cactus ferruginous pygmy-owl Other monitored species: desert bighorn sheep, mule deer.
	U.S. Forest Service	Fire management and effects monitoring; Water-quality monitoring; Air particulate monitoring; Range condition monitoring and soil assessment for all leased land for grazing; Multiple-species Inventory and Monitoring Program beginning to be developed; Bat exit flight monitoring; Single-species monitoring: fishes, Chiricahua leopard frogs, Mexican spotted owl, peregrine falcon nest sites;
	USGS and University of Arizona–Desert Laboratory	**Historic vegetation monitoring plots**; **Invasive plants research and monitoring**; Coordinates Cooperative Weed Management group.
	USGS–Biological Resources Division	**Developing comprehensive landbird monitoring protocol**; Expertise in vegetation and amphibian monitoring; Beginning National Phenology Network program to include monitoring.
	USGS–Water Resources Division	Maintains gauging stations throughout region; Some water-quality monitoring; National Water Quality Assessment Program (NAWQA)-sampled from Santa Cruz at Cortaro (from 1996 to 1997).
State Government	Arizona Department of Transportation	Roadkill monitoring projects.
	Arizona Department of Water Resources	**Regional groundwater monitoring**; Protocols for aquatic macroinvertebrate and water-quality monitoring.

Partner Group	Partner	Monitoring-related Activities and Expertise
State Government (cont.)	Arizona Game and Fish Department	Monitoring many species in Pima County: Bats, Sonoran pronghorn, bighorn sheep, coyotes, deer, javelina, doves, southwest willow flycatcher, all native fishes; Developing state-wide monitoring protocols for birds (especially landbirds and water birds) and bats. Other taxa groups to be developed in the future; General field-method expertise in personnel.
	University of Arizona–School of Renewable Natural Resources–general	Sampling design expertise; Watershed modeling; Data analysis expertise; Citizen-science bird monitoring (**Tucson Bird Count**) throughout the greater Tucson area since 2000.
	University of Arizona–School of Renewable Natural Resources, Santa Rita Experimental Range	**Long-term vegetation monitoring program**; Photo-plot monitoring.
	University of Arizona–Office of Arid Lands Studies	Remote sensing expertise; **Developing land cover and vegetation formation protocols for NPS, Sonoran Desert Network (SODN)**.
	University of Arizona-Department of Soil, Water, and Environmental Sciences	Water-quality monitoring protocol development; Aquatic-macroinvertebrate monitoring protocol development.
County and Local Governments	Pima County-Department of Environmental Quality	Air-quality monitoring at 18 stations: Air particulates, wind speed and direction, ozone, CO, NO2, SO2.
	Pima County Regional Flood Control District	**Precipitation monitoring at 65 self-reporting sites;** Photo monitoring and channel cross sections for stream-channel change; Stream flow extent; Vegetation change at restoration sites; Groundwater monitoring; Climate monitoring- 4 weather stations; **Streamflow gauges (A.L.E.R.T. system).**

Partner Group	Partner	Monitoring-related Activities and Expertise
County and Local Governments (cont.)	Pima Association of Governments	Regional orthophoto program; Water-quality monitoring; **Stream extent and groundwater level monitoring (monthly) at Cienega Creek Natural Preserve (2001);** Water-quality monitoring at Agua Caliente Spring; Public involvement in monitoring activities.
	City Of Tucson	Land-use regulation; Potential HCP permittee; Interested in regional monitoring partnerships.
	Town of Marana	Land use regulation; Potential HCP permittee; Interested in regional monitoring partnerships.
Non-governmental organizations	Arizona-Sonora Desert Museum	Non-native species monitoring program; Research expertise; Public education and outreach.
	Coalition for Sonoran Desert Protection	Public education and outreach; Regional monitoring advocates.
	Sky Island Alliance	Road-status monitoring; Land restoration; **Wildlife monitoring (large carnivores)**.
	Sonoran Institute	Monitoring protocol development (in cooperation with the NPS); Fostering regional partnerships (especially in Mexico).
	The Nature Conservancy of Arizona	Species and community-level monitoring programs (fish and vegetation in cooperation with the BLM); Land restoration.
	Tucson Audubon Society	Land restoration along Santa Cruz with bird and vegetation monitoring to assess effectiveness of restoration efforts; Citizen-science bird monitoring (Important Bird Area program) at sites throughout Arizona.

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APPENDIX C

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List of Workshop Participants

Participants attended one or more workshops: Birds (BRD), Landscape Pattern (LP), Mammals (MAM), Managers (MGR), Reptiles and Amphibians (R&A), Vegetation (VEG), Water (WTR).

Participant	Workshop(s)	Affiliation
Archer, Steve	LP	University of Arizona, School of Natural Resources
Baldwin, Kerry	MGR	Pima County, Natural Resources Parks and Recreation Department
Barrett, Sherry	MGR	U.S. Fish and Wildlife Service, Ecological Services Office
Birkenfield, Scott	MGR	Bureau of Land Management, Tucson Field Office
Bodner, Gita	VEG	The Nature Conservancy of Arizona
Briggs, Mark	WTR	Private consultant
Canfield, Evan	WTR	Pima County, Regional Flood Control District
Changkakoti, Ben	WTR	Pima County, Development Services
Christelman, Jennifer	MGR	Town of Marana, Planning Department
Cordy, Gail	WTR	U.S. Geological Service, Arizona Water Science Center
Corman, Troy	BRD	Arizona Game and Fish Department, Research Branch
Crawford, Cathy	MGR	Arizona Game and Fish Department, Habitat Branch
de Souza, Locana	MGR	Arizona Game and Fish Department/ Pima County, Natural Resources Parks and Recreation Department
Dickerson, Dennis	WTR	Pima Association of Governments, Environmental Planning Department
Duncan, Doug	MAM	U.S. Fish and Wildlife Service, Ecological Services Office
Flesch, Aaron	BRD	University of Arizona, School of Natural Resources
Fonseca, Julia	WTR	Pima County, Regional Flood Control District
Guertin, Phillip	LP	University of Arizona, School of Natural Resources
Hare, Trevor	A&R, MGR	Coalition for Sonoran Desert Protection
Holm, Peter	A&R, VEG	National Park Service, Organ Pipe Cactus National Monument, Ecological Monitoring Program
Ingraldi, Mike	MGR	Arizona Game and Fish Department, Research Branch
Kennedy, Kathleen	MGR	Town of Marana, Planning Department
Kirkpatrick, Chris	BRD	University of Arizona, School of Natural Resources
Koprowski, John	MAM	University of Arizona, School of Natural Resources
Krausman, Paul	MAM	University of Arizona, School of Natural Resources
Litt, Andrea	MAM	University of Arizona, School of Natural Resources

Participant	Workshop(s)	Affiliation
Lowery, Shawn	MGR	Arizona Game and Fish Department, Research Branch
Mack, Chris	LP	Town of Marana, GIS Department
Mannan, Bill	BRD	University of Arizona, School of Natural Resources
McCaffrey, Rachel	BRD	University of Arizona, School of Natural Resources
McPherson, Guy	VEG	University of Arizona School of Natural Resources
Parra Salazar, Iván	LP	University of Arizona, School of Natural Resources/ Office of Arid Land Studies
Payan, Rafael	MGR	Pima County, Natural Resources Parks and Recreation Department
Phillips, Ann	MGR	City of Tucson, Office of Conservation and Sustainable Development
Povilitas, Tony	MAM, VEG	National Park Service, Organ Pipe Cactus National Monument
Regan, John	LP	Pima County, Public Works Department, GIS Services
Richardson, Scott	MGR	U.S. Fish and Wildlife Service, Ecological Services Office
Rosen, Phil	A&R	University of Arizona, Ecology and Evolutionary Biology Department
Ruther, Sherry	MGR	Pima County, Development Services Department
Ruyle, George	MGR	University of Arizona, School of Natural Resources
Schwalbe, Cecil	A&R	U.S. Geological Service, Sonoran Desert Research Station
Shaw, Bill	MAM	University of Arizona, School of Natural Resources
Sidner, Ronnie	MAM	University of Arizona/Independent contractor
Simms, Jeff	MGR	Bureau of Land Management, Tucson Field Office
Simms, Karen	MGR	Bureau of Land Management, Tucson Field Office
Steidl, Bob	BRD	University of Arizona, School of Natural Resources
Sullivan, John	MGR	Pima County, Natural Resources Parks and Recreation Department
Swann, Don	A&R	National Park Service, Saguaro National Park
Tersey, Darrell	MGR	Bureau of Land Management, Tucson Field Office
Thomas, Kathryn	VEG	U.S. Geological Service, Sonoran Desert Research Station
Turner, Dale	A&R, VEG	The Nature Conservancy of Arizona
van Leeuwen, Wim	LP	University of Arizona, Office of Arid Land Studies
van Pelt, Bill	MAM	Arizona Game and Fish Department, Habitat Branch
Walker, David	WTR	University of Arizona, School of Natural Resources/Department of Soil, Water, and Environmental Quality

Participant	Workshop(s)	Affiliation
Windes, John	MGR	Arizona Game and Fish Department, Research Branch
Wissler, Craig	LP	University of Arizona, School of Natural Resources
Youberg, Ann	WTR	Arizona Geological Survey

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APPENDIX D

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Landscape Monitoring Workshop

D.1 Discussion Summary

The landscape workshop was held on October 25, 2006 to discuss monitoring parameters to be included in the Pima County EEMP. Participants (see Appendix B for list and affiliations) began the workshop by discussing parameters suggested by the Sonoran Desert Ecoregional Monitoring Framework (SDEMF) and adapted by the Sonoran Desert Network Inventory and Monitoring Program of the NPS (Table D.1; see main document for description of this early planning process).

All participants agreed to simplify the list of parameters from the SDEMF, particularly for parameters related to land cover. Participants felt that many land-cover parameters can be derived from a single data set, collected every few years. Derived parameters could include: land-cover type, landscape connectivity and fragmentation, and roads. Given the utility to aggregating land-cover parameters, the group felt that it was unnecessary to score and provide narrative on these separate elements. Similarly, the two land-use parameters suggested by the SDEMF (adjacent to and away from riparian areas) were condensed to a single land use parameter with the option (later) to focus on riparian or other areas of interest. The only parameter added for discussion was greenness index (NDVI [Normalized Difference Vegetation Index] or EVI [Enhanced Vegetation Index]), which measures the amount of chlorophyll at large spatial resolution (typically 250 m^2) across large landscapes such as eastern Pima County. In discussions, all participants who expressed opinions suggested that greenness index was a good monitoring parameter because of its rapid change and ability to integrate of structural and functional ecosystem properties. Relative ease of data processing and historical data were also cited as important for consideration. One parameter that participants asserted did not warrant consideration was the amount of area burned. The group also tabled planform analysis of stream channels. Though they believed it was a good parameter, it did not rank as high as the other parameters evaluated, and it was best left to the water group to evaluate. Finally, when evaluating land cover, vegetation formation, and greenness index for the seven criteria, participants found it helpful to consider the type of satellite imagery used to estimate each.

D.2 Results Summary

The landscape participants identified four parameters for scoring and detailed discussion: land use, land cover, greenness index, and upland vegetation formation. Land cover and land use ranked the highest (mean score = 3.9; Table D.2). Greenness index ranked third (mean score = 3.7), followed by upland vegetation formation (mean score = 3.4). As reflected by standard deviations (SD), land use had the least agreement among participants and greenness index had the most agreement.

Table D.1. Initial list of monitoring parameters presented to the Landscape workshop participants for the Pima County Ecological Monitoring Program. Final list of parameters that came from the workshop differed from this list (see Table D.2).

Parameters:	Why monitor?	Challenges to Implementation
Land cover type (natural, urban, agriculture, mining) 1) area 2) distribution	Monitor losses and increases of habitat; changes in distribution of primary stressors	Cost, access for ground truthing, how to resolve what is developed from natural cover
Roads 1) type 2) extent 3) distribution	Roads are important barriers to animal movement and dispersal corridors for non-native plants	None: data available, may want to add new fields to database for year built
Landscape integrity 1) percent fragmentation 2) patch size 3) connectivity	Measure of landscape function, plays role in animal and plant dispersal.	Cost – selection and interpretation of precise variables of interest.
Plan form analysis of stream channel 1) shape 2) size	Measures of ecosystem pattern that directly affect aquatic and riparian resources and their functions.	
Burned land Total area	Affects ecosystem function and structure, especially in semi-desert grasslands (natural) and upland vegetation communities (unnatural; bufflegrass)	Collecting data from managers. Area is easier, but what about intensity?
Upland vegetation formation 1) area 2) distribution	Fundamental expression of topoedaphic, climatic, and disturbance factors	Cost. Formations not worked out for the SW
Riparian vegetation type 1) area 2) distribution 3) condition	Riparian resources are highest priority for the County. Baseline established in 2000 (Harris et al. 2000).	Cost, time, however because it is related to regulation, this is not just a monitoring cost. Condition not part of original dataset.
Land Use–County wide Percent area: 1) zoned 2) actually developed	Important issue/stressor	Zoned is not equal to developed. Data lacking in less developed areas.
Land use adjacent to important riparian areas 1) Type and density of development 2) Distance from active floodplain	Fundamental determinant of riparian function.	

Table D.2. Evaluation scores (including standard deviation [SD]) from the landscape workshop, Pima County Ecological Monitoring Program, October 25, 2006. See Table D.3 for narrative responses from participants.

		Participant Scores									
Parameter	**Criterion**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Total**	**Mean**	**SD**
Land Cover	Changes reflect system	5	5	4	5	4	5	5	33	4.7	0.49
	Changes quickly	4	5	1	4	3	5	2	24	3.4	1.51
	Low natural variability	5		4	4	3	3	4	23	3.8	0.75
	Low sampling error	3	3	3	4	5	3	3	24	3.4	0.79
	Low cost	3	3.5	2.5	4	5	4	3	25	3.6	0.84
	Methods well established	4	4	4	5	5	4	5	31	4.4	0.53
	Mean score									**3.9**	
Land Use	Changes reflect system	3	5	4	4	5	3	5	29	4.1	0.90
	Changes quickly	3	5	3	5	4	3	5	28	4.0	1.00
	Low natural variability	4		4	3	3	3	1	18	3.0	1.10
	Low sampling error	4	4	4	3	2	5	5	27	3.9	1.07
	Low cost	5	4	3	5	5	5	3	30	4.3	0.95
	Methods well established	4	5	2	4	5	5	5	30	4.3	1.11
	Mean score									**3.9**	
Greenness Index	Changes reflect system	3		5	4	4	4	5	25	4.2	0.75
	Changes quickly	4		5	4	5	4	5	27	4.5	0.55
	Low natural variability	2		1	2	1	3	1	10	1.7	0.82
	Low sampling error	3		4	3	3	3	3	19	3.2	0.41
	Low cost	3		4	5	5	5	5	27	4.5	0.84
	Methods well established	4		5	4	4	4	4	25	4.2	0.41
	Mean score									**3.7**	
Upland Vegetation Formation	Changes reflect system	4	5	4	5		5	5	28	4.7	0.52
	Changes quickly	3	4	1	2	2	4	2	18	2.6	1.13
	Low natural variability	4	3	4	4	3	3	4	25	3.6	0.53
	Low sampling error	3	3		3	3	2	3	17	2.8	0.41
	Low cost	3	4	3	3		2	2	17	2.8	0.75
	Methods well established	3	4	3	4		3	5	22	3.7	0.82
	Mean score									**3.4**	

Table D.3. Synthesis of narrative responses from participants (P) of the landscape workshop, Pima County Ecological Monitoring Program, October 25, 2006. See Table D.2 for scored responses from participants.

Group Parameter	Characteris-tic(s) to which parameter is linked	Criteria: Ecological Relevance: Changes reflect larger system	Criteria: Ecological Relevance: Changes quickly	Criteria: Response Variability: Low Natural Variability	Criteria: Response Variability: Low Sampling Error	Criteria: Feasibility: Low Cost	Criteria: Feasibility: Methods well established	Other Comments
Land Cover- Aster (30 m^2 resolution)	Landscape integrity and connectivity, land use, development, degradation, restoration, water resources, sediment, vertebrates	P3: Very static approach; one snapshot does not reflect trends, but good for course land-cover change. P5: Major cover types are indicative of direct and indirect impacts that can be anticipated/ expected. P1: Major driver at large scale.	P3: No, very static; less suitable for development, but good for riparian areas. P6: Changes with develop-ment. P5: Urban sprawl and other types of development (including mining) can change very quickly. P1: Time lags on some impacts.	P4: Variability in classes not much of a factor. P1: Variability is low because conversion is generally in one direction.	P3, P1: Needs accuracy assessment and cover type thresholds. P7: Classification errors can be high. P6: Depends on level of detail; more detail, more error. P4: Overall sampling error is low. P2: Open to question as to level of error.	P3, P1: Acquisition of data processing, mosaicing, and expertise in ground truthing is expensive. P7: Use field crews for other taxa to accomplish ground truthing. P5: Depends on how much ground truthing is required. P2: Resolution of imagery is concern.	P3, P1: Classification schemes based on ground truth/ supervised classification. P5: Methods very well established. P1: Well established for large change detection at this resolution.	P6: Land cover is the basis for most watershed and landscape analysis. P4: Better Landsat images will be available in the future. This is a key element in evaluation of human impact. P2: Not currently done by the County.
Upland Vegetation Formation Aster- 30 m^2 resolution	Climate, landscape health, watershed condition. P5: Connections depend on resolution of imagery. Aster: formations and growth forms or functional groups in a formation.	P6: Depending on vegetation type. P5: Should do a good job of capturing ecosystem structural variables related to wildlife habitat, energy flow, nutrient cycling and watershed properties (or general assessments of these).	P6: Depending on vegetation type. P5: Rate of change depends- fire and land use can cause dramatically; other rapid “natural” change relatively slower. P4: Relatively slow to change mostly due to climate and disturbance. P2: Seasonal and human-made interference may be reflected.	P6: Depending on level of mapping. P4: Relatively low variability within classes. P2: High level of natural variability.	P6, P4: If we use higher resolution images (IKONOS, Quickbird?), this will lead to higher errors. P2: Best guess based on scientific methodology. P1: Classification errors can occur.	P3: Quickbird may be more appropriate, but is expensive. P4: Classification cost intermediate. P1: Think about storage-require a lot of space.	P3: Different vegetation types require different spatial and temporal resolution. Recommends higher resolution data like IKONOS or Quickbird. P1: Not as well developed at land cover. P4: May need higher resolution imagery for finer look periodically.	P7: Higher resolution images will become available and may change feasibility. P6: Will need a good land cover/land use map for landscape and watershed analysis. P5: Designation of “grassland” will not necessarily allow for monitoring of bufflegrass, lovegrass or other herbaceous vegetation. This is problematic-has high potential to alter ecosystem function to the detriment of native biota. P1: Aster images may inform the acquisition of higher resolution data.

Group Parameter	Characteris-tic(s) to which parameter is linked	Criteria: Ecological Relevance – Changes reflect larger system	Criteria: Ecological Relevance – Changes quickly	Criteria: Response Variability – Low Natural Variability	Criteria: Response Variability – Low Sampling Error	Criteria: Feasibility – Low Cost	Criteria: Feasibility – Methods well established	Other Comments
Greenness Index MODIS or NDVI 250 m resolution, biweekly observations.	Vegetation and land cover, landscape integrity, land use, preci-pitation, invasive species, die off, phenol-logy, bio-mass.	P3: Tracks disturbance and climate. P6: Shows changes in newly deve-loped area when used with land cover. P5: Integrates ecosystem structural properties related to function. P4: Reflects larger system trends; may prove useful for identification of areas of interest for a closer look. P1: Linkages to cover not always clear.	P3, P7: Yes, proxy for vegetation activity-cover, biomass. P5: Need seasonal readings, then integrate these to get annual estimates then used to compare inter-annual variability change through time.	P3, P7, P5, P1: Very variable but this reflects the natural variability, especially precipitation. P5: High variability, but indicators of soils, topo-graphy, land cover, land use, etc. P4: Highly dependant on rainfall events because of course mixed pixels.	P3: QA parameters come with the data. P6: Need to develop methods to analyze data; error is not known. P5, P4: High dependence on cloud cover, point in time collected. P4: Over-influence by rainfall events. P1: At landscape level, error is low, but must consider temporary spatial resolution (?).	P3: Range View data is available and free, though might need adjustment for the County P7: Low processing cost. P5: Flexible. Options to use at various spatial and temporal scales that can be customized for various questions. P1: Consider processing and storage requirements.	P7: Still some discussion about "best" index (EVI vs. NDVI vs, SADVI). P6: How to compute is known, how to use is not known. P5: Existing products of good spatial and temporal coverage, some going back to 1970-80s.	P3: Provides excellent data on phenology and timing of greenness in response to climate and land use change. Landscape integrity data can be derived from NDVI time series metrics. P6: Will show the changes in short term and find the "hot" spots. P5: Many spatial resolutions and spatial scales. P4: Human impacts may be lost in mixed and large pixels; more of a vegetation than landscape parameter. P1: Good for pattern change detection.
Land Use- data from Assessor's office and aerial photos	Connectivity, land cover, conversion, ecosystem, watershed function P5: Connection to land cover is not tight.	P7: Uses affect the entire region. P4: Ties in well with land cover. P2: Reflects human-made changes. May or may not ever be fully developed to zoning capacity. P1: May depend on type of change and location.	P3: The source of information might be fairly quick for subdivision of ranchettes. P7: Human pressure moves quickly in the system. P1: Lag times will be evident.	P1: Low; changes are fairly permanent.	P3: Change depends on land use type. P7: County records are usually good. P1: Should check to see if County records match reality.	P3, P7: Database integration and adding additional fields may be an issue that affects cost. P5: Lots of existing information, but sources may miss wildcat development. Supplemental use of remote sensing would help overcome this but would add to cost.	P5: May need some "standardization" of terminology necessary. Also, may need to add some new land use categories (or refine distinctions among existing categories). P2: Land use maps are commonly produced.	P3: Recreational use not specified. P5, P4: Need to separate actual versus potential use (i.e., zoning). Tax records are more detailed than zoning.

D.3 Workshop Meeting Notes

***Present*:** Chris Mack, John Regan, Aaron Flesch, Wim van Leeuwen, Steve Archer, Neva Connolly, Brian Powell, Iván Parra, Craig Wissler, Colby Henley, Carianne Funicelli, Scott Richardson, Phil Guertin, Julia Fonseca, Lori Woods

The following notes were recorded during workshop discussions.

General Questions and Discussion Points

- Ivan- Regarding cause & effect, cause is usually less expensive to measure than effect; however, this discussion seems to be focused on effect. What about monitoring stressors which are the causes?
- Brian- Monitoring is intended to be open to capture responses to a myriad of stressors, but info on stressors will be captured in different parameters and on specific stressors (e.g. roads, etc.)
- Phil- Will we be developing land use/cover map on regular basis? That will be a static picture unless it is update frequently, which increases costs. The level of detail/resolution will be important in any mapping.
- Brian- Frequency = Cost; input from this group will be sued to help determine to most appropriate frequency for mapping.
- Steve- What are the baseline issues that need to be monitored to be able to calculate or derive the other parameters? (e.g., fragmentation, human use, landscape integrity, etc.)
- Steve- Can monitoring be done to feed existing models so that we have a feedback? Identify models that will be used so that the monitoring data are appropriate.

Parameter Discussions

1. Land Cover Type- Include

- Monitoring method = ASTER, LandSat, Mid-resolution (15 – 60 meters). Other on-the-ground monitoring can help to ground truth the imagery.
- Phil- This is the basis of other parameters, and the keys are frequency and level of detail
    - Is 'Natural' one category or is it broken down further?

- Ivan- A 5 yr frequency is very long, especially since the response will take another 2-3 yrs. What about using existing products (e.g., MODIS) that provide a gross scale of info and then do the higher resolution mapping on the 5-yr frequency?
- Phil- Climate and other factors are causing changes that are slow relative to a 5-year timeframe; need to focus on factors that will show change in that time frame (e.g., development).
- John- Possible to use measure of the major land cover changes – tax assessor records of 4-digit land use code, building permits, roads, parcel splits, development plans. These are updated daily. Wildcat developments show up as lot splits, but are difficult to define. Assessor records can get at different residential densities.
- Ivan- Sometimes the data from PC would be more informative than that that can be gathered via remote sensing (e.g., roads).
- Steve- What about extrapolation between local monitoring to regional areas? Need to use tools that can scale up to regional scale and demonstrate structural change as related to functional change. Distribution of changes is as important to total area change.
- Phil- Monitoring on County-wide scale, but reporting at watershed scale?

2. Greenness Indices (NDVI and EVI)- Include

- Ivan- This info is available from MODIS for free.
- Wim- By using heritage data, you could add a historical perspective (20 years).
- Steve- This would be averaged at the correct regional scale and would avoid issues of anomalous site-specific data.
- Brian- how much work would this be?
- Wim- We do it already-- it would not be a big deal to modify it for this use.
- What does it tell you? Timing and magnitude of human impact and climate variability.
    - vegetation health
    - temporal variability,
    - quick overview of where big disturbances have occurring,

  - If you overlay greenness, land use/cover, you can ID correlation between land use and response,
  - inform land connectivity/linkages,
  - Ivan: could be used to monitor bufflegrass,
  - Steve: ground cover and primary production.
- Steve- This data would allow you to identify problem areas that were not previously known, and conversely, identify unexpected positive changes as well.
- BIG CHALLENGE (for the research community): To know where the County is in relation to ecological thresholds, and how to best invest resources.
- Brian- What time of year would yield the most informative data?
  - Ivan- Best to use monthly to capture natural variability. It is the changes throughout the year that are informative, so one measurement (no matter when it was taken) would not be very informative.
  - Phil- To clarify, this approach would not require an operator to deal with data daily; it could be done by capturing all data and then just analyzing once per year.
  - Wim- Vegetation responses can be very sudden and event-driven in the desert.
- Best if land use can be tied to the responses observed in remote sensing.
- MODIS provides some inexpensive data, can provide some historical data.

3. Upland Vegetation Formation- Include

- Monitoring method = ASTER vs. Quickbird ASTER vs. Quickbird
  - Quickbird can be very expensive and take up lots of computer space and manhour intensive for interpretation.
  - Maybe worth it if it is done once over 5-10 years, perhaps using ASTER at shorter intervals.
  - Quickbird has higher resolution and may be necessary for formation edges etc.

- Brian- Should land cover type and vegetation be considered together or separately?
    - Ivan- During implementation, it would make sense to include both together to cut expenses.
- Brian- upland at one scale, riparian at more detailed scale; this requires two different scales of resolution.
    - Upland = Formation Level (shrub, forest, grassland, etc.).
    - Riparian = include floristic information (Alliance).
    - Phil- for watershed scale, formation is ok.
    - Steve- for ecosystem function, formation is ok.
- Steve- overlay this with the greenness index for lots of info regarding things such as mesquite invasion and land clearing.
- Phil- using a watershed-scale approach would link this to other resources.
    - Brian- This approach was also favored by the water resources workshop participants.
    - Phil- There is a national effort to focus on watershed scale, for example making areas of imperviousness to assess health of aquatic ecosystems.
- What is the scope of the question? Habitat for a specific species, or general changes in physiognomy?
    - Brian- There is not a list of species for detailed monitoring.
- Ivan- To consistent with the biological goal of protecting the “full spectrum” of species, is it appropriate to bias the monitoring to riparian (i.e., that is considered at a finer scale)?
    - Julia- This goal guides many other aspects of the SDCP, not just the monitoring plan (e.g., land acquisitions). This monitoring effort is envisioned to be at a broad scale to detect changes.
- Brian- Are there instances when it makes sense to go below formation to include floristic info? Bufflegrass?

4. Land use- Include

- Monitoring method = Tax Assessor records:
    - Commercial, residential, industrial, agricultural;
    - May have minimal tie to higher ecological goals;
    - Land Cover should have higher weight than Land Use.
- John- Important to keep in mind that actual land use and zoning are not the same thing.
- Steve- Metrics that are very dynamic need to be measured with greater frequency.
- Brian- Uni-directional data (e.g., development) can be separated.

5. Roads—DISMISSED

- Can be derived from other parameters.

6. Landscape Integrity—DISMISSED

- Can be derived from other parameters.

7. Plan Form Analysis of Streambed Channel—ABLED

- Phil: good index of landscape integrity:
    - Mapping over landscape or just sampling sites;
    - Air photos would give width but not depth;
    - Monitor sites over time?
- Brian and Julia: This sounds like a lower priority parameter, and maybe better suited for a different set of experts.

8. Burned areas—DISMISSED

- Wim: easy data source for larger fires (NASA / Goddard satellites), but this is coarse and would not capture grassland fires. AZ Fire Map (Gov. Napolitano's council, Arid Land Studies) might be any easy data source, however it is not clear if this will be continually updated.
- Phil: Ask land managers for their fire covers?

- ALL: Difficult to get reliable information from private lands.
- Ivan: Biased toward federal lands, could be already identified from the greenness index data, maybe not worth the effort.
    - Mapping over landscape or just sampling sites.

9. Land Use Adjacent to IRAs—DISMISSED

- This would be included in general land use (watershed level).

10. GAP Analysis—DISMISSED

- Derived property, not to be included here.

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APPENDIX E

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Vegetation Monitoring Workshop

E.1 Discussion Summary

The vegetation workshop was held on September 27, 2006 to discuss monitoring parameters to be included in the Pima County EEMP. Participants (see Appendix B for list and affiliations) began the workshop by discussing parameters suggested by the Sonoran Desert Ecoregional Monitoring Framework (SDEMF) and as adapted by the Sonoran Desert Network Inventory and Monitoring Program of the NPS (Table E.1; see main document for description of this early planning process).

Participants modified the parameter list considerably for application to the Pima County EEMP, most notable for perennial vegetation (see Section E.3, below, for discussion summary) for which they split this category into the three dominant plant communities of interest: riparian, semi-desert grassland, and Sonoran Desert upland. Further, they recommended that three parameters from the SDEMF associated with perennial vegetation (sensitive, keystone, and umbrella species; recruitment of dominant species; and nurse plants) be combined to the appropriate community types. In some cases participants suggested that special emphasis can be placed on these parameters (e.g., recruitment of cottonwood and willow trees, two keystone species). Participants determined that three parameters suggested by the SDEMF were not appropriate for the Pima County EEMP: phenology because of lack of local control and the recent creation of a new national program; annual species because of variability and cost; and net primary productivity because of cost. For ease of evaluation, participants evaluated multiple parameters within each parameter group. For example, each of three perennial species communities (parameter groups for this effort) had five associated parameters: community composition, relative abundance, frequency, distribution, and recruitment.

E.2 Results Summary

Participant scoring of each combination of parameter group/criterion produced little separation among parameters (Table E.2). Perennial species in the Sonoran Desert Community had the highest score (mean = 4.0), though it was marginally separated from three other parameter groups (exotic species [mean = 3.9] and semi-desert grasslands [mean = 3.9], and mesoriparian [mean = 3.8] perennial communities). Vegetation formation scored the lowest among the parameter groups (mean = 3.5). The general lack of differentiation among parameters was likely a result of the emphasis on perennial species (even exotic, invasive species) and the fact that participants were not asked to comment on management relevance, which might have put mesoriparian vegetation higher on the list of important parameters. The workshop resulted in extensive written notes for each combination of parameter group/criterion (Table E.3) and items for discussion (Section E.3, below).

Table E.1. List of vegetation monitoring parameters from a previous monitoring effort (Mau-Crimmins et al. 2005) and which were presented to Pima County Ecological Monitoring Program workshop participants as a starting point for discussion.

Parameter(s)	Why monitor ?	Challenges to Implementation
Distribution of vegetation formations	Fundamental expression of topoedaphic, climatic, and disturbance factors	Cost, objective pixel level lifeform classification still in development
Community composition, relative abundance of perennial species	Base measure of structural and functional components of ecosystems	Advanced level of skill and time req'd; cost and time during field season.
Exotic plants – distribution and abundance	A leading resource management issue	Cost, time; protocols have not been fully tested as of 2003
Phenology – leaf out/drop, flowering by guild	Key integrator of seasonal climate and vegetation condition patterns	Plot level observations require limited biological window to capture within season changes
Presence/absence of annual species. – mid and low elevations	Annuals are important contributors to seasonal productivity (biomass), forage for wildlife	Advanced level of taxonomic skill required, cost, time
Distribution and reproduction of sensitive species: saguaro & organ pipe cacti, ironwood	Dominant, wide-ranging species that are very sensitive to perturbation and climate	Concerted effort with partners is critical; linking cause and effect may be tenuous
Recruitment of dominant species	Key "leading indicator" of vegetation change	Cost and time required
Net Primary Production (NPP) – landscape scale	Measure of ecosystem productivity, nutrient and energy flow	Height can be difficult to estimate from shadows and LIDAR is very costly; NPP estimate may be to coarse for effective monitoring
Nurse plants – distribution, relative abundance and reproduction.	Nurse plant relationships are critical in SD ecosystems	Value of data likely does not justify cost & complexity.

Table E.2. Evaluation scores (including standard deviation [SD]) from the vegetation workshop, Pima County Ecological Monitoring Program; September 27, 2006. See Table E.3 for narrative responses.

		Participant Scores							
Parameter Group	**Criterion**	**1**	**2**	**3**	**4**	**5**	**Total**	**Mean**	**SD**
Vegetation Formation	Changes reflect system	5	4	5	5	5	24	4.8	0.45
	Changes quickly	4	3	3	3	2	15	3.0	0.71
	Low natural variability	3	5	4	3.5	5	20.5	4.1	0.89
	Low error	4	3	4	2	2	15	3.0	1.00
	Low cost	3	2	3	2	3	13	2.6	0.55
	Methods well established	5	3	3	2	4	17	3.4	1.14
	Mean score							**3.5**	
Exotic Invasive species	Changes reflect system	1	5	4	5	4	19	3.8	1.64
	Changes quickly	5	5	5	5	5	25	5.0	0.00
	Low natural variability	5	3	3	4	3	18	3.6	0.89
	Low error	3	3	4	4	5	19	3.8	0.84
	Low cost	1		3	4	3	11	2.8	1.26
	Methods well established	4	4	5	5	4	22	4.4	0.55
	Mean score							**3.9**	
Mesoriparian perennial species	Changes reflect system	5	3	4	5	5	22	4.4	0.89
	Changes quickly	4	4	4	5	5	22	4.4	0.55
	Low natural variability	3	4	4	3	2	16	3.2	0.84
	Low error	2	3	4	3	5	17	3.4	1.14
	Low cost	1	3	4	3	3	14	2.8	1.10
	Methods well established	5	5	5	3	5	23	4.6	0.89
	Mean score							**3.8**	
Semi-desert grassland perennial species	Changes reflect system	5	3	4	5	5	22	4.4	0.89
	Changes quickly	3	4	3	4	4	18	3.6	0.55
	Low natural variability	5	4	4	3	3	19	3.8	0.84
	Low error	2	3	5	3	3	16	3.2	1.10
	Low cost	1	3	5	3	4	16	3.2	1.48
	Methods well established	5	5	5	5	5	25	5.0	0.00
	Mean score							**3.9**	
SD Upland perennial species	Changes reflect system	4	3	4	5	5	21	4.2	0.84
	Changes quickly	3	4	3		4	14	3.5	0.58
	Low natural variability	5	4	4	3	5	21	4.2	0.84
	Low error	5	3	5	3	5	21	4.2	1.10
	Low cost	1	3	5	3	4	16	3.2	1.48
	Methods well established	5	5	5	4	5	24	4.8	0.45
	Mean score							**4.0**	

Table E.3. Synthesis of written comments from participants (P) of the vegetation workshop, Pima County Ecological Monitoring Program, September 27, 2006. See Table E.2 for scored responses from participants.

Parameter Group Parameter	Characteris-tic(s) to which parameter is linked	Criteria						Challenges to Implementation	Other Comments
		Ecological Relevance		Response Variability		Feasibility			
		Changes reflect larger system	Changes quickly	Low Natural Variability	Low Sampling Error	Low Cost	Methods well established		
Vegetation Formation 1) Distribution 2) Area	Climate, disturbance, geology. P1: soils, fire, urbanization.	P4, P1, P5: Integrates vegetation response to many factors. P1: Topoedaphic constraints are important and reflected well by formation.	All: Depends on the formation and disturbance- faster in some than in others, but most noticeable in conversions from natural to housing, ag, and mining. P2: Extensive disturbance captured quickly, but natural veg change (no visible disturbance) would not. P5: Directly monitor changes from natural to urban rather than monitor using remote sensing.	P4: Lots of spatial variation but not much temporal. P1: Temporal variability is controlled by many things such as climate, weather, fire, etc.	P4: Some categories are easier to distinguish than others (e.g., riparian forest) but if we get down to floristics, error increases. P2, P3: High variability if protocols are not tested for repeatability. Availability and consistency of imagery can influence error. P1: Error is in interpretation. P5: Accuracy is difficult without extensive ground truthing.	P4, P3: Analysis costs may be high, especially for formations that have similar structure. P2: Can be high cost: look for data sharing, clear protocols, and use of citizen scientists to reduce cost. P1: Lowest cost for riparian in particular because of area and contrast with uplands. P5: Expensive, but still cheap per unit area.	P4: Not for teasing apart some veg characteristics that are structurally similar. P3: methods will get better in the future.	P2: methods exist for vegetation mapping but issues of scale, resolution, repeatability, and detectability need to be resolved. P5: sensitive to drought and seasonal influences on imagery.	P4: Look for categories that have low sampling error. For some categories that are hard to distinguish today, realize that image processing in the future may be possible (though ground-truthing will not be possible). All: Explore partnerships. P5: May be most useful for mesoriparian- easiest to extract from surrounding matrix.

Parameter Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance: Changes reflect larger system	Criteria: Ecological Relevance: Changes quickly	Criteria: Response Variability: Low Natural Variability	Criteria: Response Variability: Low Sampling Error	Criteria: Feasibility: Low Cost	Criteria: Feasibility: Methods well established	Challenges to Implementation	Other Comments
Exotic, Invasive Species 1) Distribution, 2) Area, 3) Frequency, 4) Relative abundance		P2, P3: Invasive species can degrade ecosystems quickly, can alter conditions to favor unnatural disturbance such as fire. P1: Scored very low because stochasticity if very high and important, controlled by climate, soils, etc P5: Depends on spp.; some have more impact than others.	P4, P3: Rapidly spreading species should respond very quickly. P2: Insect infestations can move very rapidly. P1: rapid change can happen with small increase in some non-native spp.	P4: Once problem species get established, then tend not to contract in range. P2: High yearly variation in response to rainfall and disturbance (Brian note- for cover but perhaps not presence or distribution- note annuals?). P1: When invasions occur, variability is low initially, then high, then low again. P5, P3: Response is species-specific.	P2, P5: Targeted list of species has lower error because of observer skill. P1: Requires excellent botanical skill.	P2: Use of citizen scientists for common and conspicuous species. P1: Very expensive P5: Mapping expensive, presence cheap. P3: requires many sites to capture invasions at landscape level.	P2: see protocols by NAWMA.		P4: Prioritize mapping to species that are known to be biggest problem (e.g., buffelgrass). The need for early detection will vary by system and species (e.g., tamarisk needs to be caught early) but some species we have to admit defeat and not concentrate on (e.g., Lehmann's lovegrass). Therefore it may make more sense to monitor more frequently for new invasions and less frequently for long-standing invasions. P2: Partnerships are key (noted Travis Bean-Pima/Santa Cruz Coop Weed Management Area), ASDM, Arizona State Invasive Council. P3: Invasive spp. component should be a part of the perennial species protocol for efficiency.
Perennial species: Semi-desert grasslands 1) Community composition, 2) Relative abundance, 3) Frequency, 4) Distribution, 5) Recruitment	P4: Perennial grass basal cover affects soil erosion, responds to fire, shrubs. P3: Fire, land use, climate	P1: Soils and climate explain most variation in species. P3: Does not reflect ground water	P4: Perennial grasses respond to climate, disturbance fairly quickly. Shrub cover can change a lot within 10 years. P1: In Lehmann's dominated systems it dampens response to other changes.	P4: Grass basal cover is much less variable than grass canopy cover. P1: Variability is low, especially on sites dominated by Lehmann's P5: Community composition can change with drought. P3: Think about phenology	All: Identification problems greatest in this perennial community, need a lot of training; high error because of skill level required.	P1: Expensive P3: More expensive than other communities.	P4: Range folks have suite of well-established methods. All: methods well established.		P4: Observer skill required is higher than for other communities.

Parameter Group Parameter	Characteris-tic(s) to which parameter is linked	Criteria: Ecological Relevance — Changes reflect larger system	Criteria: Ecological Relevance — Changes quickly	Criteria: Response Variability — Low Natural Variability	Criteria: Response Variability — Low Sampling Error	Criteria: Feasibility — Low Cost	Criteria: Feasibility — Methods well established	Challenges to Implementation	Other Comments
Perennial species: Mesoriparian 1) Community composition, 2) Relative abundance, 3) Frequency, 4) Distribution 5) Recruitment		P1: Soils and climate explain most variation in species. P5: Is key habitat for many other species.	P4: Young age classes can change very quickly. Systems can recover much faster than uplands. P1: Invasive spp. respond to changes very quickly, esp. changes in soil, water, and land use P5: Die-off can be rapid with reduced water.	P4, P3: Temporal variability can be high for tree seedlings, less so for samplings and adults. P2: Community structure is fairly constant. P1: Temporal variability is high in understory. P5: Flooding causes natural variation on unpredictable basis	P4: Concentrating on only a subset of species that we really care about would reduce error. P1: Variability is high because plants move in wind (Brian comment- I assume participant refers to cover estimates).	P4: By concentrating on only a few species could reduce costs. P5: Restricted area mean relatively rapid sampling.	P4: Suggests looking at work by Stromberg. All: methods pretty well established.	P2: Use skilled observers and calibrated cover estimates.	P4: Lumping some species in guilds can decrease required observer skill. Co-locate groundwater monitoring with riparian veg. Separating age/size classes would not require much extra work and would speak to demography. P2: Recommends phenology monitoring for all communities P1, P5: Stresses partnerships to get work done (for all communities). All: keystone species such as cottonwood/willow should be monitored
Perennial species: SD Upland 1) Community composition, 2) Relative abundance, 3) Frequency, 4) Distribution, 5) Recruitment	Climate, soils	P1: Fire is starting to drive this system. P3: Probably does not reflect changes in ground water.	P1, P5: Changes vary from rapid (e.g., fire by buffelgrass) to slow (warming during the winters). P3: Response to grazing may be slow.	P5: Most are long-lived and drought tolerant.	P1, P3: Sampling error is lowest for this system than any other.				P2: Monitor *Cactoblastis* moth should be added to protocol. All: Agreed that nurse plants and keystone species (saguaro and ironwood) were important but added to this category because they did not warrant separate consideration. However, there was agreement that delineating a nurse plant is subjective and therefore subject to error.

E.3 Workshop Meeting Notes

Present: Brian Powell, Kathryn Thomas, Peter Holm, Dale Turner, John Regan, Rafael Payan, Guy McPherson, Sherry Ruther, Julia Fonseca, Gita Bodner, Neva Connolly, Tony Pavolitas, Bill Shaw, Carianne Funicelli

The following notes were recorded during workshop discussions.

General Notes Regarding the Process

- Nine vegetation monitoring parameters that are our starting point are from the Sonoran Desert Eco-regional Monitoring framework.
- Not concerned with specific sampling methodologies, but we are focusing on the parameters at a coarser level.
- Spatial variability will be addressed in the overall design (randomization, stratification, efficiency, etc.).
- There will be separate monitoring for endangered species.
- 3 main criteria for evaluating parameters:
  - Ecological relevance,
  - Variability,
  - Feasibility.
- Differences between vegetation communities may necessitate separate consideration of parameters; we will make note of special circumstances as they apply.
- Bill Shaw extended his thanks to everyone on behalf of STAT for taking the time to be involved in this process, and reminded the group that this is a task that has not been accomplished by other HCP monitoring efforts.
- Brian- the challenge is parsing out what is part of this overarching monitoring, versus the individual monitoring goals that are specific to particular pieces of land.

Ecological Relevance

- Peter- Often what is sensitive is rare – not the predominant vegetation community (doesn't necessarily contribute a huge ecological role).
- Rare elements can change more quickly.
- Need meaningful results in 10 year periods (term of permit = 30 years).
- Brian- Program is to be designed not to be specific to threats/stressors.
- Also not a single-species approach; community level; although "keystone" species may be considered within the monitoring.
- Tony- Communities = assemblages of different species each comprised of individuals responding to the environment differently.
- Special Elements:
    - Kathryn asked about saltbush in Pima County; for the Sonoran ecoregion, saltbush emerged as the most impacted (by loss) vegetation community,
    - Julia- this is a special element in SDCP; these have not been identified for specific monitoring, but their status as special elements drives acquisition decisions,
    - Dale- perhaps this relates more to restoration goals?

Response Variability: the noise that happens about the mean line,

- Natural variability versus sampling error,
- Spatial- will be incorporated into the design.

Feasibility

- COST- linked to variability and sampling area; we are thinking at a programmatic level.
- METHODS- need to be well-established.
- SURVEY PROTOCOLS- what other parameters can be captured simultaneously with little extra effort? Opportunities for partnerships…

Parameter Evaluation Discussion

Vegetation formation

- Kathryn- fear that every five years make a map? Costs a lot of money; careful not to suck up so much money; can we use existing resources? Or use very broad definitions but then problem of it not being refined enough to detect the changes that you want to see.

- What is the appropriate level of resolution? Kathryn - 1:6000 aerials are not able to map to vegetation association; Pima County GAP mapping needs to be accuracy assessed because the broad methodology covered 5 states; maybe not right scale to detect gross changes. This method would not, for example, detect Lehmann's lovegrass invasion in semi-desert grassland.

- Dale- How long would this take for an area the size of Pima County? Kathryn -- 2-3 year effort; cost could be reduced by using citizen scientists, etc.

- Tony- aerial photography is ok for detecting structural change; photopoints not helpful for invasive grass id.

- Peter- Different levels of precision would be needed to answer different questions; how can we combine parameters to be most informative "nested scale."

- Kathryn- boundaries between vegetation communities would be where you would expect change to be happening most rapidly.

- Dale- Remote sensing analysis would be valuable in riparian areas; small subset in terms of area, conceivable to use that approach for mesoriparian, maybe not for the entire permit area effective in cost and time.

- Kathryn- fire would be converting vast areas; would be useful to link fire boundaries to vegetation mapping.

- Brian- landscape changes will be another monitoring element; if there is enough different plots, these broad effects should be evident.

Parameter Evaluation

- Changes reflect larger system: climate, land use, soils.

- Peter- high score depends on assumption of low sampling error.

- Gita- soils and climate constrain vegetation very tightly.

- Remote sensing is done by research agencies / universities; needs to be operational for monitoring, not the forte of agencies and universities; they want to do the method formulation, research.

- Brian- Land cover and vegetation formation are linked; land cover would address land clearing, loss of vegetation; lots of overlap between these focus areas.

<u>Sensitive, Keystone, and Umbrella Species</u>

- Examples: saguaro, ironwood, cottonwood, Organ Pipe Cactus juniper, Coahila juniper, Sacaton.

- Kathryn- distribution (not reproduction) could be gotten at remotely.

- Dale- adequate to make note of these in the plots?

- Peter- program might need to designed in order to get enough data to say anything.

- Tony- sensitive species more likely to be responsive to environment, especially species at the edge of their ranges; should take saguaros in account.

- These are long-lived species, will be learn anything in the short 30-year permit time?

- Carianne- yes, in the case of saguaros, there are decades of data preceding this permit application; now is the best time to focus on saguaro populations, as we are just beginning to amass enough information to be able to say anything about long-term population dynamics; these data will be critical in tracking responses to environmental changes. In addition, this aspect would only have to occur relatively infrequently (decadal); would be prudent to coordinate with demographic studies at Saguaro NP (next occurring in 2009 – 2010).

- Kathryn- On the Colorado Plateau, no one worried about piñon until they started dying in large numbers; early indicators could be very helpful.

- Cottonwood-willow: if there is going to be a focus on that community, these trees will clearly already be caught.

- Ironwood- consensus to not include.

- Kathryn- caution- these changes are very unexpected (e.g., pines in northern Arizona).

- Peter- larger nested plot to capture large columnar cacti and trees at larger level; smaller nested plots to capture other parameters.

- Tony- what about climate change?
- Brian- if climate change is the driver, we'll see those changes in partner monitoring.
- Tony- in Pima County, driver would be urbanization; vegetation communities should be chosen with this in mind
- Kathryn- 30 years from now is a new generation of land managers; drastic changes are possible from the current scene; do not exclude a design that would help to inform them.

Other parameters not expressly discussed, but participants made detailed notes in the parameter evaluation tables.

Elimination Round (parameters below top 5)

<u>Phenology</u>: Tabled. But if data can be collected easily, then it could be shared with the National Phenology Monitoring effort that is to be based out of the UA.

- May be sensitive to broad changes.
- Kathryn- does not dismiss as easily; lots of natural variability, harder to get a pattern in a short period of time; because there will be a larger effort, why not add a small component that can help inform their effort?
- Dale- not relevant to short term management.
- Peter- this has been useful at Organ Pipe Cactus NM re: columnar cactus fruit failure and lesser long-nosed bats.
- Does the county need this info to detect if phenology is driving things? Probably not.

<u>Annual Species: Dismissed.</u>

- Annual invasives would be a part of the invasives parameter.
- Dale- rainfall is highly variable temporally and spatially; Pima County Regional Flood Control District ALERT effort not adequate to track; could this network be augmented?
- Peter- there is no good baseline on how exactly rainfall influences annuals.
- Brian- rainfall gauges will be part of the monitoring program.

Recruitment of Dominant Species: Added as a component to Perennial Species

- Gita- Young cohorts will give a quicker signal than mature individuals, better short-term information; consider age classes under perennial species?

Net-Primary Productivity: Dismissed

Nurse Plants: Dismissed

- Ecologically important, but tend to be mature specimens of a limited number of species
- Only in SD Upland community
- Change in abundance will tend to be slow
- Would be captured by other parameters
- Kathryn- could just attribute if there are plants in plot that are acting as nurse plants.
- Dale- difficult to measure, doesn't seem like something to monitor at a landscape scale
- Peter- linked with other things; pulse of perennial seedlings with good rain event; important function of ecosystem, perhaps getting into the causality again…
- Gita- land use and perennial will really cover this

Other parameters discussed

Soil- seedbank

- George Ruyle (not present) offered the importance of soil mapping; soil mapping to class 3.
- Julia- is the Natural Resources Conservation Service data layers good enough?
- Brian- monitoring of soil crusts has been generally dismissed as too expensive.

Vegetation use by livestock

Fire

- Guy- Fire is the single best integrative indicator of grassland management / health; we can count on fire maps on federal lands (maybe fuels maps)

- Brian- fire layer should always be included.
- GIS analysis, historical component (problem with inconsistent reporting); is now the baseline?
- Guy- we do know the historical fire regime (not necessarily site specific, but enough certainly for this application).
- Kathryn- imagery could be used to track fire.

<u>Damage, disease, pest infestation</u>

- Brian- would this fall under disturbance monitoring? Perhaps include on field sheet

<u>Sharing of information</u>

- Julia- no MOU with NPS yet developed that is specific to sharing of monitoring data.
- Gita- NRCS has off-the-shelf protocols and may be interested in sharing data.

Other thoughts

- Tony- Philosophical difficulty – individual versus community, not possible to monitor everything; how does this impact managers? It's a little like fishing…hopefully your method of tossing the line will get you the fish.
- Dale- need threats monitoring; if not a component, then we may be missing something until its impacts are too well established; perhaps periodic analysis of human footprint, water, etc (this is part of the landscape monitoring). Suggest monitoring disease, groundwater draw down, invasives, fire in AZ uplands, lack of fire in the semidesert grassland.
- Good reason to bias sampling toward urban fringe.
- Peter's list of 3 monitoring efforts:
    - Threats;
    - Ecosystem indicators;
    - Vulnerable species.

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APPENDIX F

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Water and Riparian Resources Monitoring Workshop

F.1 Discussion Summary

The water and riparian resources workshop was held on October 12, 2006 to discuss monitoring parameters to be included in the Pima County EEMP. Participants (see Appendix A for list and affiliations) began the workshop by discussing parameters suggested by the Sonoran Desert Ecoregional Monitoring Framework (SDEMF) and adapted by the Sonoran Desert Network program of the National Park Service (Table F.1; see main document for description of this planning process).

At the beginning of the discussion, participants split riparian systems into perennial, ephemeral, and effluent dominated systems (EDS). This discussion process mirrored the splitting of perennial vegetation by the vegetation workshop into upland, semi-desert grassland, and riparian communities (see Appendix E). Many water workshop participants took special exception to the program's emphasis on choosing parameters with low natural variation. Rather, the group suggested embracing the variability in riparian systems because systems that are more variable are also most natural. The group also suggested development of conceptual models would help put these parameters in context.

Participants made few changes to the original list of parameters from Table F.1. A notable exception was the geomorphology parameter group. First, participants further refined channel morphology to include three parameters of interest to them (channel cross section, longitudinal profile, and pebble counts). Participants scored and provided narrative on all parameters together, but many noted in discussions that each of these three parameters did not fulfill criteria in the same way. For example, pebble counts are more variable than channel cross section. Next, participants suggested adding planform analysis and riparian buffer because they believed it was particularly sensitive to urban encroachment in the watershed.

The group decided that 11 parameters did not warrant detailed scoring and narrative: pumping volume, metals, carcinogends/toxics (though chlorine was moved to field parameters), endocrine disrupters, acid-base equilibrium, *Giardia*, algae blooms, oxygen demand/*E. coli*, suspended sediment, channel classification, and bankfull. The reasons given for excluding these parameters from discussion varied from too costly to not applicable to management (see reasons given in Section F.3).

F.2 Results Summary

Participants provided input on 9 parameters (Tables F.2, F.3). Based on scoring, field water-quality parameters received the highest score (mean = 4.1) and water quantity in pools and tanks received the lowest score (mean = 3.1). Other parameters that received high scores were depth to groundwater (mean = 4.0), nutrients (mean = 3.9), discharge/flow of streams and springs (mean = 3.8), and stream-channel morphology (mean = 3.7). Unfortunately, only two or three participants scored water-quality (field parameters and nutrients) and aquatic macroinvertebrates parameters. This was due, in part, to the lack of expertise in the group for these parameters and because there were so many parameters to score (i.e., participants were fatigued).

Table F.1. List of water-related monitoring parameters which were presented to Pima County Ecological Monitoring Program workshop participants as a starting point for discussion.

Parameter Group	Parameter	Why monitor?	Challenges to Implementation
Groundwater Hydrology	1) Depth to groundwater	Primary water supply for some ecosystems	Limited pool/distribution of existing wells. New wells are expensive to drill
	1) Hydrologic (groundwater) gradient	Early warning of change; precursor to changes in groundwater depth	
Water Quality	Field water-quality parameters: 1) Temperature, 2) DO, 3) Conductivity, 4) pH, 5) Flow, 6) Turbidity	Basic measures of physical/ chemical state of water body	Timing concerns using portable vs. *in situ* systems
	Concentration of EPA priority pollutant metals: 1)Sb, 2)As, 3)Be, 4) Cd, 5)Cr, 6)Cu, 7)Pb, 8)Hg, 9)Ni, 10)Se, 11)Ag, 12)Ti, 13)Zn	Toxic metals resulting from human land uses	Cost, sample storage/transport
	Nutrient loading (concentration): 1) ammonia, 2) nitrite 3) nitrate 4) total P	Human and wildlife health issue; eutrophication; algal blooms; riparian health	Cost, sample storage/transport
	1) Suspended sediment	Primary contaminant in SW	Textural/chemical determinations costly; turbidity may be a cheap proxy
	Concentrations of carcinogens & toxins: 1) Free chlorine 2)Trihalomethane 3) Cyanide	Human and wildlife health issue	Costly, limited application
	Acid-base equilibrium: 1) alkalinity 2) major catio-ion balance 3) bicarbonate	Affects DO, dissolved solids	Costly, limited application
	1) Distribution of *Giardia* spp.	Common disease in western N. America	Costly ($500/sample), limited application
	Algal blooms 1)Distribution 2) Extent	Indicator of nutrient loading; may affect DO, eutrophication	Complex, not generally a problem in SW
	1) Biological oxygen demand 2) *E. coli*)	Human and wildlife health issue	Cost, sample storage/transport, subjectivity of qualitative assessment
Water Quantity	1) Amount of water in ponds, tanks, and wetlands	Critical surface water source during dry seasons	Capturing inflow/outflow events
	1) Streamflow extent	Provide extent for groundwater models, habitat modeling for vegetation and vertebrates	

Parameter Group	Parameter	Why monitor?	Challenges to Implementation
Water Quantity cont.	1) Streamflow discharge	With volume, provides discharge measure; crucial for interpreting water quality data	Difficult to time sampling with flow variability
	1) Groundwater pumping volume	Major stressor and leading indicator or change	Must be estimated from registered wells outside the AMA; not as directly linked to riparian health as groundwater
Geomorphology	1) Channel morphology	Important factor in channel stability assessments, flow and sedimentation estimates	
	1) Channel Classification	Good qualitative measure of channel condition, channels can be placed in broader context	Determining causes of changes to classifications is difficult , as is recommendations for managers
	1) Bankfull	Indicator of peak discharge	Often difficult to estimate in field
Biological Condition	Invertebrate community parameters: 1) Species richness 2) Diversity	Community structure indicates health of riparian system	Identification of specimens expensive and requiring high skill

Table F.2. Evaluation scores (including standard deviation [SD]) from the vegetation workshop, Pima County Ecological Monitoring Program, September 27, 2006. See Table F.3 for narrative responses from participants.

		Participant								
Parameter Group	Criterion	1	2	3	4	5	6	Total	Mean	SD
Stream channel morphology- Cross section, pebble count, longitudinal profile	Changes reflect system	5	4	4	4	5	4	26	4.3	0.5
	Changes quickly	4	5	5	4	4	4	26	4.3	0.5
	Low natural variability	3	3	1	3	2	2	14	2.3	0.8
	Low error	4	3	4	3.5	4	3	21.5	3.6	0.5
	Low cost	4	4	3	3.5	4	4	22.5	3.8	0.4
	Methods well established	4	5	4	3.5	4	4	24.5	4.1	0.5
	Mean score								3.7	
Channel morphology- plan form analysis, riparian buffer	Changes reflect system	5	3		4	4	5	21	4.2	0.8
	Changes quickly	3	3		1	4	3	14	2.8	1.1
	Low natural variability	5	4		5	3	3	20	4.0	1.0
	Low error	4	4		2	5	4	19	3.8	1.1
	Low cost	5	3		3	2	2.5	15.5	3.1	1.1
	Methods well established	3	4		2.5	3	4	16.5	3.3	0.7
	Mean score								3.5	
Groundwater depth/gradient	Changes reflect system	5	5	3	4	5	5	27	4.5	0.8
	Changes quickly	4	3	3.5	3	4	2	19.5	3.3	0.8
	Low natural variability	5	3	4	3	3	3	21	3.5	0.8
	Low error	5	5	5	5	4	4	28	4.7	0.5
	Low cost	3	5	3	3	4	2	20	3.3	1.0
	Methods well established	5	5	5	4	5	5	29	4.8	0.4
	Mean score								4.0	
Water quantity: Pool, tank, spring water persistence	Changes reflect system	5	3	1	3	2	3	17	2.8	1.3
	Changes quickly	5	3	5	5	5	2	25	4.2	1.3
	Low natural variability	4	2	1	1.5	1	3	12.5	2.1	1.2
	Low error	5	3		4		3	15	3.8	1.0
	Low cost	5	2	3	4	2	4	20	3.3	1.2
	Methods well established	4	2	2	2		3	13	2.6	0.9
	Mean score								3.1	
Water quantity: Streamflow/surface water extent	Changes reflect system	5	5	3	4	5	4	26	4.3	0.8
	Changes quickly	4	4	3	4	5	2	22	3.7	1.0
	Low natural variability	3	4	2	2.5	2	3	16.5	2.8	0.8
	Low error	5	5	2	3	3	3	21	3.5	1.2
	Low cost	3	3	3	3	2	4	18	3.0	0.6
	Methods well established	5	3	1	3		3	15	3.0	1.4
	Mean score								3.4	
Water quantity- Stream flow discharge- natural streams and springs	Changes reflect system	5	5	3	5	2	20	4.0	1.4	
	Changes quickly		4	4	4	5	5	22	4.4	0.5
	Low natural variability		4	3	1	1	2	11	2.2	1.3
	Low error		4	3	3	4	4	18	3.6	0.5
	Low cost		3	4	3	5	2	17	3.4	1.1
	Methods well established		5	5	5	5	5	25	5.0	0.0
	Mean score								3.8	
Water quality- field parameters	Changes reflect system		3				5	8	4.0	1.4
	Changes quickly		5				5	10	5.0	0.0
	Low natural variability		4				1	5	2.5	2.1
	Low error		5			4	4	13	4.3	0.6

		Participant								
Parameter Group	Criterion	1	2	3	4	5	6	Total	Mean	SD
Water quality- field parameters (cont.)	Low cost		5			3	3	11	3.7	1.2
	Methods well established		5			5	5	15	5.0	0.0
	Mean score								4.1	
Water quality- nutrients	Changes reflect system			5			5	10	5.0	0.0
	Changes quickly			4			5	9	4.5	0.7
	Low natural variability			3			1	4	2.0	1.4
	Low error			4		4	4	12	4.0	0.0
	Low cost			4		3	2	9	3.0	1.0
	Methods well established			5		5	5	15	5.0	0.0
	Mean score								3.9	
Macroinvertebrates	Changes reflect system			5			3	8	4.0	1.4
	Changes quickly			3			5	8	4.0	1.4
	Low natural variability			3			2	5	2.5	0.7
	Low error			4			3	7	3.5	0.7
	Low cost			2			3	5	2.5	0.7
	Methods well established			5			4	9	4.5	0.7
	Mean score								3.5	

Table F.3. Synthesis of written comments from participants (P) of the water and riparian resources monitoring workshop, Pima County Ecological Monitoring Program, October 12, 2006. See Table F.2 for scoring responses from participants.

		Criteria						
		Ecological Relevance		Response Variability		Feasibility		
Group Parameter	Characteristic(s) to which parameter is linked	Changes reflect larger system	Changes quickly	Low Natural Variability	Low Sampling Error	Low Cost	Methods well established	Other Comments
Geomorph-ology 1) channel cross section 2) longitudinal profile 3) pebble count	Land use, climate, vegetation, bedload	P2: Most useful at the watershed scale; local events may not be important- sediment waves may not indicated larger channel issues. P5: Well established parameters to monitor changes. P4: Affects water availability and vegetation along the stream channel. P1: Important for water availability, channel stability, aggradation and degradation trends.	P2: Especially sediment/influx. P5, P3, P1: Mostly slow change, but can be quick with large disturbance events. P4, P1: Profiles have slower systematic change, but local change is rapid.	P2: Depends on disturbance and rainfall. P5: Trends are generally in one direction (cross section increases with increasing contributing area). P1: Can be significant high natural variability (spatial?).	P5: Training is imperative to reduce errors. P3: Methods are well established and this will reduce errors and allow for ease of implementation. P1: Use of a total station using trained personnel is critical.	P2: Use on a limited number of streams and on “event” basis, not annually. P5, P1: Field personnel can sample quickly if well trained. P3: Expensive because of labor. P4: Pebble counts, in particular, are time consuming,	P2, P5: Yes, except for pebble counts. P3: See USGS NAWQA program, also USEPA EMAP program. P4: Frequency of sampling may not be well established. P1: Survey methods well established, but analysis methods, detecting when morphologic change is significant and why it is occurring is not well established.	P2: Function of watershed scale and relevance depends on spatial sampling; suggest beginning sampling at small watersheds-no larger than 1km^2. P5: At each site must do at least 3 cross sections and get an average. Cross sections provide width and depth ratios and area which can be used to monitor aggredation/ degradation. Once baseline is established, re-do after 5 yrs or after disturbance. P3: High variability means sampling required often. Include photo monitoring. P4: Affects flood damage risk to social environment, so the expense may not be borne entirely by the Pima County EEMP.

Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance — Changes reflect larger system	Changes quickly	Response Variability — Low Natural Variability	Low Sampling Error	Feasibility — Low Cost	Methods well established	Other Comments
Geomorph-ology 1) Planform analysis and floodplain change 2) Riparian buffer	Land use at watershed scale, encroachment of development.	P2: Can indicate channel entrenchment. P4: Yes, especially to human use.	P2: May be gradual change. P5, P1: Rate of land-use change will drive floodplain change.	P2: Will reflect large scale (events?). P5: High spatial variation. P1: Temporal variation is minimal but directly tied to human use, so change is unidirectional.	P4: Interpretation is more subjective than for cross section, profile, pebbles. P1: Probably low if measured off of photographs.	P2: Could do automated GIS. P5, P4, P1: GIS can be time consuming; geomorphic analysis and GIS work require high skill. P1: Once protocol is established, cost would go down significantly. P5: Cost can be high.	P5: GIS analysis is relatively new but accepted. P1: Methods are probably not well established. However, these types of protocols can be established relatively easily, providing a useful measure of human impact on floodplain surfaces.	P2: Could be done with each new Pima Association of Government air photo. P5: GIS analysis every 5 years; can provide good information on system integrity. P4: Socially relevant and easy to communicate. P1: Must consider viable buffer zones along our stream systems to protect a viable bottomland system.
Water Quality Field Parameters	Land use, land cover, climate, and vegetation along streams, stream discharge.	P3: Yes, excellent indicator.	P3: Yes, under certain circumstances (not indicated which). P6: Can change very rapidly depending on land use; event driven.	P3: Yes, but only during base flow.	P5, P3: Methods, protocols, and instruments well established so errors should be minimal.	P2: Easy to sample using portable systems. P5: Training is important because people need to know how to calibrate instruments. P3: More cost for deployment of hydrolab. P6: Cost = personnel	All: Yes, well established.	P2: For perennial and intermittent suggest using baseflow sampling 1-2/year, also after disturbance. For EDS, may be able to get information from the wastewater plants. P5: Collect field parameters and nutrient sampling at the same time- easy to do this. P3, P6: Probably some of the best long-term indicators of stream health (i.e., highest priority for water monitoring). P6: Does not address biology of system directly (but may be used as proxy?).
Water Quality Nutrient loading		P3: Yes, excellent indicator.	P3: Yes, under certain circumstances.	P3: Nutrient loads increase during major runoff events.	P3: Methods and protocols well established; errors should be minimal.	P3: Can be expensive (staff time) and/or remote sampler could be expensive.	P3: see USGS, EPA manuals.	P3: Probably some of the best long-term indicators of stream health.

Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance — Changes reflect larger system	Changes quickly	Response Variability — Low Natural Variability	Low Sampling Error	Feasibility — Low Cost	Methods well established	Other Comments
Water Quantity Stream flow extent (intermittent, perennial), persistence of flow (Intermittent/ perennial, EDW)	Climate, groundwater, land use, geomorphology	P5, P3, P1: Extent and persistence will reflect hydrologic changes within the basin. P1: Water availability, changes in stream flow (e.g., changes in classes—from perennial to intermittent or from intermittent to ephemeral), and changes in spring output could be related to regional groundwater decline or stream flow.	P2, P3: Reflects long-term trends. P5: Very quick response to hydrology.	P5: Depends on climate. P3: Highly variable; requires frequent visits.	P5: Some subjective interpretation by mappers, but can be monitored using aerial photos.	P2, P5: Low tech-walking reaches, but is time consuming. P3: Yes, if paying, but not if using volunteers.		P2: Valuable if use consistent approach. Do once at dry season. Doesn't like it for EDS because Schmutzdeck complicates issue. P5: Good information for long-term trends.

Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance – Changes reflect larger system	Ecological Relevance – Changes quickly	Response Variability – Low Natural Variability	Response Variability – Low Sampling Error	Feasibility – Low Cost	Feasibility – Methods well established	Other Comments
Water Quantity Stream flow discharge-natural streams and springs	Land use, land cover, climate, pumping volume, ET	P2, P5: Peak flow reflects underlying watershed integrity (P5) to storm flow. P5, P3: Base flow reflects long-term hydrology of basin. P4: Also reflects well to social systems (land use?).	P5, P3, P4: Changes quickly to precipitation.- trends related to land use and are best related to base flows.	P2 and P5: Highly variable- this is ok and to be expected. P3: Make distinction between base and peak flows; base much less variable.	P5: Gauges needs to be calibrated periodically. P3: Depends on stream reach; sandy bottoms that meander have more error in measurement. P4: Low flows are really hard to sample, may need to change equipment as flow diminishes.	P2, P1: High cost (14-15K/year). P5: Good method (gauging stations) available, but can never have enough. P3: Cost and be subsidized by USGS and other cooperators. P4: Installation and maintenance of new equip is high.	All: ALERT and USGS gauges are very well established. P1: Interpretation of data is the challenge.	P3: Really important parameter to determine health of perennial and intermittent streams. P4: Supplement existing USGS gauge system for select high-priority streams and springs, if possible. P1: Nothing is as important as monitoring streamflow. It is one of those foundational bottomland parameters that requires monitoring because so many other parameters are dependant on it. Changes in streamflow can also be directly related to ecological thresholds, providing important information regarding not only how conditions are changing, but why. Long-term records are often available (at least from similar drainages) that allow detailed evaluation of past and present streamflow conditions.
Water Quantity Ephemeral pools- volume and persistence (availability)		P5, P3: Reflect more local area.	P2: Seasonality issues affect interpretation of data. P5, P3: Very rapid temporal change. P1: Persistence of bottomland pools can change over time due to changes in streamflow conditions.	P2, P5: Highly variable seasonally and across land-use gradient. P3, P1: Highly variable depending on climate, streamflow, depth of pool. P1: Bottomland pools may also completely fill in with sediment during following significant discharge events.	P1: Sampling could be as simple as measuring depth. A measurement staff could be installed at the deepest part of the pool, requiring only a brief visit by personnel.	P2: To do well, need to determine max extent and check persistence. P5, P3: High variability of events and conditions make it expensive to monitor. P1: Monitoring water persistence is relatively easy and cheap.		P2: Important but high level of effort will make it costly. P5: Consider monitoring presence/absence of pools. Bedrock pools would be worth monitoring; they are persistent and can be surveyed less frequently. P3: Ecological value is questionable. P1: Monitor the number of pools along a designated reach. Monitoring pools (as well as other isolated water features) maybe most effective during the dry season with particular emphasis on intermittent and ephemeral systems where the presence of small bottomland pools may be affect many bottomland riparian species.

Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance — Changes reflect larger system	Changes quickly	Response Variability — Low Natural Variability	Low Sampling Error	Feasibility — Low Cost	Methods well established	Other Comments
Groundwater Depth/gradient (shallow groundwater, riparian water table)	Land use, pumping volume, ET, climate,	P2, P5, P4, P1: Long-term, large scale indicator- ties directly to vegetation communities. Indirectly to aquatic. P4: Drives the change in extent of base flow. P1: Water availability, can be directly linked (with some additional monitoring) to human disturbances such as pumping.	P5: Very rapid response in parameter, but affects on other ecosystem components will take longer (lag time). P3, P1: Yes, to local pumping.	P2: Should reflect local condition in absence of pumping. P5: High seasonal variability. P3: Variability is low. P4: Change is less variable than stream flow quantity and extent. P1: Depth to shallow groundwater for perennial systems typically does not vary as much as that for ephemeral systems.	P5: Often monitored by dataloggers, which need calibration. P3, P4: Few errors because of standard methods.	P2, P5, P1: Once established, cost is low if only monitoring depth and shallow groundwater. P4: High cost except for dirvepoints, which are susceptible to loss by fire and flood. Low training needs and analytical costs.	P3: Yes. P4: Location and design need a lot of attention (common design problem).	P2: Cheaper without gradient. Ephemeral systems will be more expensive (deeper well rigs) are important for plant response. P5: This is a key parameter for ecosystem health- will be reflected throughout system. (P4) Gradient will be good early warning of impending change. P3: Changes may be very limited in extent. Must have a good understanding of local hydrogeology. Also, methods are straightforward, but interpretation of trends and the affect of trends or conditions on bottomland ecology will require establishing ecologic thresholds that could also vary from one drainage to the next. P1: If fiscally feasible, recommend installing dedicated piezometers – three in a row perpendicular to stream channel – in areas where change in shallow ground water is expected to occur (e.g., downstream end of perennial reaches near areas affected by pumping). Depending on natural streamflow conditions (ephemeral, intermittent, perennial), depth to shallow groundwater and its fluctuation throughout the year can be significant or relatively insignificant (in a system that is not being affected by such human activities as pumping).

Group Parameter	Characteristic(s) to which parameter is linked	Criteria: Ecological Relevance – Changes reflect larger system	Criteria: Ecological Relevance – Changes quickly	Criteria: Response Variability – Low Natural Variability	Criteria: Response Variability – Low Sampling Error	Criteria: Feasibility – Low Cost	Criteria: Feasibility – Methods well established	Other Comments
Macroinverte-brates	Water quality and quantity, precipitation, channel morphology	P3: Good indicator of system. P6: Reflects local conditions but should be course enough spatially to apply to the region.	P3: Responds quickly to changes in water quality (temp, conductivity) over relatively short time periods. P6: Best trophic level to monitor rapid changes	P3: Low variability if water quality parameters are relatively stable; community is predictable. (P6) Higher variability (spatial or temporal?) is desirable. P4: Highly variable.	P3, P4: High variability in observers. P6: Error can be minimized but identification can cause error.	P3: Depends on labor (grad students are cheap) and level of taxa analysis. P6: Compared with benefits, cost is relatively low.	P3: Yes, methods by USGS and EPA are established. P6: Both sampling and interpretation are fairly well established.	P3, P4: Use other parameters for correlation: temp, flow, etc. P4: Given above, we need to question whether to do this if you can get proxy variables. Depends on understanding of other variables.

F.3 Workshop Meeting Notes

Present: Julia Fonseca, Lori Woods, Brian Powell, David Walker, Mark Briggs, Ann Youberg, Dennis Dickerson, Evan Canfield, Ben Changkakoti, Gail Cordy, Neva Connolly, Colby Henley

The following notes were recorded during workshop discussions.

Introductory Statements

- Dave- Question about detecting change, are current conditions ground zero?
- Julia- Numerous studies looked at previous/historic conditions.
- Brian- Restoration will be a separate module w/in the MSCP and will be monitored.
- Gail- Question: Clarification of SDCP vs. MSCP Section 10 permit?
- Julia/Lori – SDCP being implemented regardless of MSCP, looks at landscape scale and goals.
- Dave- Something to think about is what changes happen due to human impacts vs. natural variability.

General Discussion on Parameters and Criteria

- Dave- Natural variation, many systems are driven by variation and parameter shouldn’t be excluded and instead be captured in the monitoring program. Similar to fire in vegetation systems, absence of disturbance events can be monitored, e.g. especially for streamflow, high variability is inherent and important reflection of disturbance regime and changes in geomorphology.
- Mark- Suggests removing high variability as an evaluation criteria.
- Brian- Want to be able to detect trends/change over long term.
- Evan- Maybe looking at smaller scale will provide more information; consider both temporal and spatial scale.
- Evan- Question: will monitoring be done in direct response to stressor events/threats?
- Julia/Brian- Not designed that way but that approach may have some value.
- Dave- Monitoring using thresholds or relative goals?

- Brian- Monitoring objectives will mostly be distributional, but maybe some thresholds.
- Dave- Question: Criteria #2, quick response, is this relative?
- Brian- Yes, most water functions respond quickly, except for geomorphology, which may take decades. Something to consider and keep in mind is 30-year time period.
- If parameter has low variability over 30 years, then maybe it isn't an important parameter in this context.

Parameter discussion, based on 3 systems (Table F.4):

1. Natural Perennial/Intermittent Streams,
2. Effluent Dominated Water (EDW),
3. Ephemeral streams.

Table F.4. Water and Riparian Resources participants considered the following parameters for three water types.

Recommended Parameter	Natural Perennial - Intermittent	Effluent-Dominated Water (EDW)	Ephemeral
Depth to Shallow Groundwater/Gradient	☑	☑	☑
Field Water Quality	☑	☑	☑
Nutrient Loading	☑	☑	
Amount of Water in Pools			☑
Streamflow Extent/Persistence	☑	☑	☑ Persistence in pools
Streamflow Discharge	☑		
Channel Morphology	☑		
Biology/Invertebrates	☑ (pools)		☑ (pools)

Parameters Eliminated from Evaluation

1) <u>Pumping Volume</u>

- Already tracked by all water companies, might be estimated for exempt (or # of private wells) if close to stream. Julia – this was evaluated by PAG, and is being updated.

2) Metals: discard, but do baseline

- Initial baseline and then look at it again after major land-use change?

3) Suspended Sediment

- Ann: Is it more important to measure stream bed sediments vs. suspended? Not critical for ephemeral.
- Mark- time intensive, may be better monitored thru geomorphology. Does measuring instantaneous suspended solids tell us anything?
- Gail- most helpful with perennial systems in small watersheds.

4) Carcinogens/Toxic

- Chlorine residuals moved up to nutrients.

5) Acid/Base equilibrium

- Not important.

6) Giardia

- Human health concern only.

7) Algae blooms

- Some disagreement on whether schmutzdecke is serious problem, especially in EDW. Green filamentous algae is natural and is important for inverts and fish cover.
- Large blooms of cyanobacteria are not good.
- Blooms are very sporadic and probably not worth monitoring.
- Could be noted during monitoring for other parameters.

8) Oxygen demand/E Coli

- Not important (DO is good proxy).

9) Endocrine disrupters

- Not feasible/too expensive.

10) Channel Classification

- Table for landscape group to investigate.

11) Bankfull- not disused

Parameters Preserved and Evaluated

1) Depth to Groundwater/Gradient

- Ties directly to riparian vegetation,
- Useful for hydrologic models,
- Can be influenced by local pumping,
- Must be careful in interpretation based on local hydrogeology – may not extrapolate to broader scale,
- Cost is variable,
- Low sampling error,
- Less variable than discharge,
- Plant evapotranspiration measurement? Ask vegetation workshop,
- Important in all 3 systems.

2) Field Water Quality Measures/Nutrients

(note: Chlorine residuals included in this category)

- Water quality is equal in importance as channel morphology,
- Can have high variability,
- Field measurements not expensive,
- Base flow variability low (target for sampling, especially for nutrients in EDW), flood flows high variability,
- EDW- dual variation, additional monitoring effort,
- Ephemeral - Measure in pools only,
- Lab fees can be expensive, but very consistent standards/data,

- Very important for all three systems, should capture variation of dissolved oxygen during summer in EDW systems,
- Nutrients most important in EDW, this can be incorporated into NPDES monitoring requirements,
- Nutrients can drive field water-quality parameters. Nutrient loading is indicator of development,
- Not important for ephemeral systems, except in ponds, tanks.

3) <u>Amount of surface water in ponds, tanks, wetlands</u>

- Most important in ephemeral systems,
- Volume is most important, less tied to groundwater,
- Duration/persistence of pools during dry season (i.e., is there a refugium to carry through to next rain event?),
- Do these pools reflect the larger system or is it just a character of only localized condition? Is it more important to local managers?
- Refugia for certain species, variability due to disturbance (fire/sediments),
- Mark/Dave- critical as dispersal, refugia, probably most important in ephemeral, persistence of surface water between flows (dry season).

4) <u>Streamflow extent, persistence of flow</u>

- EDW more socially linked and can change quickly,
- Extent more tied to groundwater (i.e. baseflows during dry season),
- Highly variable dependent upon climate, season = manpower intensive, but can be coordinated to reduce time requirement, provides social input and feedback opportunities (San Pedro example),
- Persistence in both perennial/intermittent systems.

5) <u>Streamflow discharge</u>

- Need all components of water balance (rainfall, discharge, groundwater etc),
- With existing discharge and rain gauges, you can evaluate flashiness of storm flows and interpret watershed conditions,

- Need to capture rain/storm intensity?
- Methods are well established,
- Stream flow gauges can be expensive – $14k – $15k per year, may be subsidized by USGS/Cooperators,
- Sandy-bottom streams difficult to calibrate, channel meandering etc.,
- Crest-stage gauge may be all that's needed in ephemeral systems,
- Expensive, but important data for flood flows, base flows, provides good long-term data and can be a quick indicator of watershed conditions.

6) <u>Channel Morphology</u>

- Pebble counts (quick indicator), channel cross sections, longitudinal profiles,
- High variability, so these may need lots of regular monitoring to characterize and still detect trends/changes,
- May be helpful to tie monitoring times to predetermined discharge levels,
- Longitudinal and cross-sections can be done less often and still capture useful data, interpretation important – seeing cross-section trends as you go downstream,
- More important to monitor more sites along watercourse than doing it more frequently (i.e. spatial placement more important than timing of monitoring),
- All 3 parameters can be captured during one monitoring effort,
- Repeat photo-monitoring points useful supplemental material –protocol development,
- Morphology may be best indicator of physical system changes over long term,
- (Planfrom Anaylsis/Buffer) Move to Landscape group?
- Good baseline analysis, can be done with GIS, can be done with each new photo set, flood event, can be time intensive. Socially relevant, easy to communicate.

7) <u>Invertebrates</u>

- Good indicators, can look at diversity, productivity, pollution tolerance, expensive? If goal is biological then important to measure,

- High variability, but best trophic level to capture changes,
- More sessile than fish and most likely indicate 'true habitat',
- Good indicators of pollution,
- Can be indicators of long-term trends,
- Sampling errors comes into play with identification (suggest only identification of specimens to genus),
- How do you sample consistently considering timing of pool duration, season/ water temp, flow events etc., sampling protocol may need to be specific to certain stream reaches – interplay with other parameters,
- Question: Does invertebrate productivity/diversity relate to vertebrate community outside of stream. Invertebrates will be a measure of the 'aquatic/riparian', and may not translate outside the stream.

Miscellaneous Discussion Points

- Dennis- need for buffers, discussion for landscape workshop?
- Mark/Ann- Review of historic aerial photos showing channel/floodplains and changes in land development over time.
- Ann- use of isotopes/chemical constituents as proxy for Gradient.
- Dave/Gail- usually used to determine flow time or flow source. (Research Question?)
- Ann- use of isotopes/chemical constituents as proxy for Gradient. This would give an indication of water movement and source over time (e.g., is a spring of EDS feeding groundwater?).

APPENDIX G

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Vertebrate Workshops Results

G.1 Introduction

The three vertebrate workshops (amphibian and reptile; mammal; and bird) were held on three dates: November 2 and November 5, 2006. The amphibian and reptile and mammal workshops were held simultaneously on November 2. The two groups met for an introduction session, then separated for discussions and evaluations.

All three workshops followed the same format. First, participants were presented with groups of species that were organized based on life-history characteristics and common survey methods (Table G.1). Participants then discussed and changed this list based on their knowledge of the species and survey methods. Once all participants were comfortable with the species groupings, they were then invited to suggest monitoring parameters for those groups. Parameters discussed covered the entire spectrum of possible parameters: population (abundance, presence/absence), productivity, diet, demographics, disease, etc. All workshops except birds chose only population parameters and/or species diversity (a community parameter that combines population parameters from multiple species). The bird workshop participants chose population parameters but also included a number productivity parameters (productivity and breeding status). In general, participants avoided lengthy discussions of which population parameter (abundance vs. occupancy) was most appropriate; rather they were urged to view population monitoring in general terms so that differences among parameters could be investigated in the next phase (see Chapter 3).

Table G.1. Initial list of species groups for consideration by the Pima County EEMP parameter evaluation process. This list was then modified based on the discussions by the respective workshop participants.

Amphibians and Reptiles	Mammals	Birds
Frogs, tiger salamander, and aquatic reptiles	Bats	Songbirds
Toads	Small mammals (rodents and squirrels)	Hummingbirds
Snakes	Meso-predators and omnivores (skunks, fox, coyote, raccoon, bobcat, and badger)	Nightjars
Lizards and skinks (excluding most whiptails)	Large herbivores (deer and pronghorn)	Diurnal raptors
Most whiptail lizards	Large carnivores (black bear, mountain lion)	Nocturnal raptors
Desert tortoise		Ducks and waders

Once the group decided on the final list of species groups and parameters, they were then asked to provide scoring and narrative responses in a format that was similar to the other workshops (see Chapter 2 of the main document for overview). In addition to providing information on the ecological relevance of the proposed parameters, participants were asked additional questions regarding sampling methods, efficiency, and species of interest. The following information was asked for each parameter:

<u>Survey Methods and Efficiency</u>

1. Accepted survey method. There are many survey methods available for each species group and parameter, but usually only one or two are accepted by the scientific community. Name the method of choice for the species or group.

2. Observer error. Are species in this group sometimes misidentified even by experienced observers or are identifications subject to debate?

3. Efficiency I: Number of detections. How many individuals and data points would you expect to record per hour of surveys?

4. Efficiency II: Number of species. How many species would you expect to record per hour of surveys?

5. Efficiency III: Consistency. How similar are data from repeated visits to the same site a day later .

6. Survey window, 24-hour. With few exceptions, animals are most observable (detectable) only during a certain period of time during which we focus our surveys. How many hours during a 24-hour cycle are surveys very efficient? How variable is this period each day?

7. Survey window, annual. How many weeks a year are surveys efficient? How variable is this period annually?

8. Predictability and Adjustment. If the survey window varies, list characteristics that it varies with.

<u>Conservation Value and Threats</u>

9. Species of interest. Rank species of conservation value in order of their priority in this group. These species should reflect our focus on low- to mid-elevation areas in eastern Pima County.

10. Threat. List the two primary threats for each of these species.

G.2 Discussion Summaries and Results

See Section G.3 for detailed discuss notes for each of the three workshops.

G.2.1 Mammals

The mammal workshop began the meeting by considering the species groupings in Table G.1. They suggested excluding large herbivores from consideration because the Arizona Game and Fish Department already conducts annual surveys for species of interest. Participants then suggested combining all meso-predators, omnivores, and large carnivores into one category ("predators"). Therefore, participants decided on three species groups: bats, carnivores, and small mammals (rodents, squirrels, and lagomorphs). One participant felt the lagomorphs should be treated separately. The final list of parameters for each of the species groups consisted of population parameters (abundance and occupancy) and diversity (Table G.2). Because of limited time, participants provided detailed scoring and narrative for three parameters related to occupancy/abundance (Tables G.2, G.5).

Based on the scoring responses from participants, the highest-ranking mammal parameters were both small mammal and predator occupancy/abundance (mean scores = 2.9) and bat occupancy/abundance scored the lowest (mean = 2.6) (Table G.2). Integer responses were not being used to discriminate among parameters at this time.

G.2.2 Amphibians and Reptiles

The amphibian and reptile workshop evaluated the list of parameters in Table G.1 and changed the list to four groups (Ranid frogs, nocturnal reptiles, diurnal lizards and snakes, summer amphibians [principally toads]) and three species that did not fit the groups (Mexican garter snake, desert tortoise, and box turtle). The amphibian and reptile workshop was the only one to identify individual species. There was considerable discussion among participants about the tradeoffs between occupancy and abundance monitoring. In the end, the group was fine with grouping the two parameters together for this level of analysis. Chytrid fungus was also discussed by participants and, though it was not recommended for monitoring, it was suggested to conduct a base-line survey during surveys for Ranid frogs.

The amphibian and reptile workshop provided detailed input on four parameters (Tables G.3, G.6). The three separate species (Mexican garter snake, desert tortoise, and box turtle) were not scored nor did participants provide narrative responses because participants felt they were less deserving of attention than the other groups. Among the groups that did receive scoring, Ranid frog occupancy/abundance was the clear favorite (mean score = 4.0) and the other three had similar, but much lower scores (nocturnal reptiles = 3.4; summer amphibians = 3.3; diurnal lizards and snakes = 3.3).

G.2.3 Birds

Participants made few changes to the proposed list of species in Table G.1, but suggested moving two species of hummingbirds (Costa's and broad-billed) to the songbird group, because they can be easily detected during songbird counts. Participants also added nightjars to the nocturnal raptor group. This left five groups: songbirds (plus the two hummingbirds), diurnal raptors, nocturnal raptors and nightjars, ducks and waders, and other hummingbirds. Participants excluded ducks and waders and other hummingbirds from serious consideration; they felt that ducks and waders are entirely dependant on human-constructed wetlands in Pima County and therefore have limited ability to inform to management outside of those areas, and the "other" hummingbirds are expensive to monitor on their own, have such variable movement, and are already being monitored by an existing program (Hummingbird Monitoring Network). Participants all readily agreed that occupancy and abundance were worthwhile for monitoring. Most also felt that some measures of productivity (number of young fledged) are valuable and sensitive parameters that can be inexpensive to monitor. Participants suggested including productivity for songbirds, diurnal raptors, and nocturnal raptors and nightjars; and breeding status (whether or not they nested) for diurnal raptors. The bird group provided narrative and scoring for nine parameters (Tables G.4, G.7).

Based on the scoring responses by participants, there was little separation among most parameters. Diurnal raptor productivity received the highest score (mean = 3.5), but four other parameters were very close to being top-ranked as well: songbird occupancy/abundance in the breeding season (mean = 3.4), songbird productivity (mean = 3.4), nocturnal raptor productivity (mean = 3.3), and diurnal raptor breeding status (mean = 3.3).

Table G.2. Evaluation scores from the mammal workshop, Pima County Ecological Monitoring Program, November 2, 2006. Small mammal diversity was suggested for inclusion in the program but were not scored. See Table G.5 for narrative responses.

		Participant									Response Means		
Parameter	Criterion/Factor	1	2	3	4	5	6	7	Totals	SD	Integer	Score	Rank
Small	Changes quickly	4	3	4	3.5	4	3	3	24.5	0.50		3.5	
Mammals-	Accepted Survey Method	4	4	4	4	4	4	5	29	0.38		4.1	
Occupancy/	Observer Error	3	2	3	3	5	2	4	22	1.07		3.1	
abundance	Number of detections per night per trap	0.4	0.6	0.4	0.3		0.2	1	2.8	0.32	0.5		
	Number of Spp./hour	0.5	1	0.4	0.1	1.3	0.4	0.5	3.6	0.35	0.5		
	Consistency	4	2	3	4	4	4	4	25	0.79		3.6	
	Survey Window- 24 hour- hours	10	8	12	12	12	12	8	74	1.90	12.3		
	Survey Window- 24 hour- variation	2	1	2	1	1	1	1	9	0.49		1.3	
	Survey Window- annual-weeks	18		40	26		52	26	162	19.28	32.4		
	Survey Window- annual-variability	2		3	2	1	1	1	10	0.98		1.7	
	Mean score										11.4	2.9	1
Bats-	Changes quickly	3			3			1	7	1.41		2.3	
Occupancy/	Accepted Survey Method	4.5			4.5			3	12	2.20		4.0	
abundance	Observer Error	3			3			4	10	1.81		3.3	
	Number of detections	35			30			8.5	73.5	15.41	24.5		
	Number of Spp./hour	0.7			1.3			4	5.9	1.47	2.0		
	Consistency	4			3			2	9	1.70		3.0	
	Survey Window- 24 hour- hours	10			12			8	30	5.47	10.0		
	Survey Window- 24 hour- variation	2			1			2	5	0.95		1.7	
	Survey Window- annual-weeks	12			26			8	46	9.85	15.3		
	Survey Window- annual-variability	2.5			1			1	4.5	0.94		1.5	
	Mean score										13.0	2.6	2
Predators-	Changes quickly		2		3	3	5	1	14	1.83		2.8	
Occupancy/	Accepted Survey Method		4		5	3	5	2	19	2.14		3.8	
abundance	Observer Error		3		4	4	3	3	17	1.72		3.4	
	Number of detections		2		10	5	0.25	0.8	18.1	1.94	3.6		
	Number of Spp./hour		0.5		5	1	4	0.5	11	1.52	2.2		
	Consistency		4		4	3	4	1	16	1.90		3.2	
	Survey Window- 24 hour- hours		8		12	10	24	24	78	9.92	15.6		
	Survey Window- 24 hour- variation		1		2	2	5	2	12	1.70		2.4	
	Survey Window- annual-weeks				26	10	52	12	100	19.13	25.0		
	Survey Window- annual-variability				2	2	3	1	8	1.21		2.0	
	Mean value										11.6	2.9	1

Table G.3. Evaluation scores from the amphibian and reptile workshop, Pima County Ecological Monitoring Program, November 2, 2006. Box turtle, desert tortoise, and Mexican garter snake were suggested for inclusion in the program but were not scored. See Table G.6 for narrative responses.

Parameter	Criterion	Participant 1	2	3	4	5	6	Totals	SD	Response Means Integer	Response Means Score	Rank
Ranid Frogs-Occupancy/abundance	Changes quickly	2	5	5	5	5	5	27	1.22		4.5	
	Accepted Survey Method	5	5	5	5	5	5	30	0.00		5.0	
	Observer Error	4	3	3	4	4	4	22	0.52		3.7	
	Number of detections	5	250	250	250	50	20	825	124.09	137.5		
	Number of Spp/hour	0.3	2	1.5	3	1.5	1.5	9.75	0.89	1.6		
	Consistency	5	4	4	4	4	4	25	0.41		4.2	
	Survey Window- 24 hour- hours	24	12	18	24	8	12	98	6.74	16.3		
	Survey Window- 24 hour- variation	3	3	3	5	4	4	22	0.82		3.7	
	Survey Window- annual-weeks	21	11	2	3	10	10	57	6.83	9.5		
	Survey Window- annual-variability	1	1	4	5	4	2	17	1.72		2.8	
	Mean score									41.2	4.0	1
Nocturnal Reptiles-Occupancy/abundance	Changes quickly	2.5	2	2	4	3	2	15.5	0.80		2.6	
	Accepted Survey Method	3	4	4	5	5	5	26	0.82		4.3	
	Observer Error	3	2	2	5	5	3	20	1.37		3.3	
	Number of detections	5	25	4	5	3	1.5	43.5	8.80	7.3		
	Number of Spp/hour	1.5	2.5	2.5	5	3	1	15.5	1.39	2.6		
	Consistency	3.5	5	4	4	3	3	22.5	0.76		3.8	
	Survey Window- 24 hour- hours	5.5	4	3	6	8	5	31.5	1.72	5.3		
	Survey Window- 24 hour- variation	1	3	5	4	5	1	19	1.83		3.2	
	Survey Window- annual-weeks	26	13	15	4	26	30	114	9.96	19.0		
	Survey Window- annual-variability	4	3	2	4	5	1	19	1.47		3.2	
	Mean score									8.5	3.4	2
Diurnal Lizards and snakes-Occupancy/abundance	Changes quickly	2.5	2	2.5	5	4	4	20	1.17		3.3	
	Accepted Survey Method	4	4	4	3	4	5	24	0.63		4.0	
	Observer Error	3	2	2	3	3	4	17	0.75		2.8	
	Number of detections	25	25	11.5		10	12.5	84	7.54	16.8		
	Number of Spp/hour	5	3.5	2.5		5	2.5	18.5	1.25	3.7		
	Consistency	5	3	3		3	4	18	0.89		3.6	
	Survey Window- 24 hour- hours	4	6	4	4	5	6	29	0.98	4.8		
	Survey Window- 24 hour- variation	2	3	2	3	4	2	16	0.82		2.7	
	Survey Window- annual-weeks	30	26	10	17	52	24	159	14.36	26.5		
	Survey Window- annual-variability	1	3	2	3	5	2	16	1.37		2.7	
	Mean score									13.0	3.2	4

Parameter	Criterion	Participant 1	2	3	4	5	6	Totals	SD	Response Means Integer	Score	Rank
Summer Amphibians-Occupancy/abundance	Changes quickly	1	4.5		3	4	5	17.5	2.01		3.5	
	Accepted Survey Method	3	4	2	4	4	3	20	0.82		3.3	
	Observer Error	4.5	1.5	4	3	4	4	21	1.10		3.5	
	Number of detections	200	5000	100	550	100	60	6010	1967.03	1001.7		
	Number of Spp/hour	2	3.5	2.5	8	5	3	24	2.21	4.0		
	Consistency	1	4	1	3	4	1	14	1.51		2.3	
	Survey Window- 24 hour- hours	7	6	8	10	8	10	49	1.60	8.2		
	Survey Window- 24 hour- variation	1	4	5	5	5	3	23	1.60		3.8	
	Survey Window- annual-weeks	6.5	5.5	6	4	1	4	27	2.00	4.5		
	Survey Window- annual-variability	3	2	1	5	3	4	18	1.41		3.0	
	Mean score									254.6	3.3	3

Table G.4. Evaluation scores from the bird workshop, Pima County Ecological Monitoring Program, November 5, 2006. See Table G.7 for narrative responses.

Parameter	Criterion/Factor	Participant 1	2	3	4	5	6	7	Totals	SD	Response Means Integer	Scores	Rank
Songbirds: breeding; occupancy/abundance	Changes quickly	5	3	3	3	4	3.5	4	25.5	0.75		3.6	
	Accepted survey method	5	5	5	5	5	4	5	34	0.38		4.9	
	Observer error	4	3	3	3	3	4.5	3	23.5	0.63		3.4	
	Number of detections	150	350	200	150	150	200	63	1263	87.64	180.4		
	Number of species/hour	30	50	50	25	25	20	30	230	12.20	32.9		
	Consistency	5	4	4	4	4	4	4	29	0.38		4.1	
	Survey window- 24 hour- hours	4.5	4	5	4	3	3.5	5	29	0.75	4.1		
	Survey window- 24 hour- variation	1	2	5	3	1	1	2	15	1.46		2.1	
	Survey window- annual-weeks	14	12	12	9	12	12	11	82	1.50	11.7		
	Survey window- annual-variability	1	2	5	3	1	1	1	14	1.53		2.0	
	Mean value										57.3	3.4	2
Songbirds: non-breeding; occupancy/abundance	Changes quickly	4	3	5	3	4	3.5	5	27.5	0.84		3.9	
	Accepted survey method	5	4	3	5	5	3	2	27	1.21		3.9	
	Observer error	3	3	2	3	3	4	2	20	0.69		2.9	
	Number of detections	68	500	200	100	75	50	40	1033	164.27	147.6		
	Number of species/hour	13.5	15	50	15	19	15	18	145	13.04	20.7		
	Consistency	4	2	1	2	4	1.5	2	16.5	1.18		2.4	

Parameter	Criterion/Factor	Participant							Totals	SD	Response Means		Rank
		1	2	3	4	5	6	7			Integer	Scores	
Songbirds: non-breeding; occupancy/ abundance (cont.)	Survey window- 24 hour- hours	8	10	5	9	3	4	5	44	2.69	6.3		
	Survey window- 24 hour- variation	1	3	5	4	1	1	5	20	1.86		2.9	
	Survey window- annual-weeks	30	16	16	15	12	12	11	112	6.51	16.0		
	Survey window- annual-variability	1	3	5	2	1	1	1	14	1.53		2.0	
	Mean value										190.6	3.0	6
Diurnal Raptors: breeding; Occupancy/ abundance	Changes quickly	4		2	4	4	3.5	1	18.5	1.65		3.1	
	Accepted survey method	4		4	4	5	4.5	2	23.5	1.75		3.9	
	Observer error	5		5	3	3	4.5	4	24.5	1.76		4.1	
	Number of detections	5		20	5	10	9	3	52	6.50	8.7		
	Number of species/hour	4		4	3	5	4	1.5	21.5	1.74	3.6		
	Consistency	4		2	4	4	4.5	4	22.5	1.63		3.8	
	Survey window- 24 hour- hours	5		8	6	3	12	5.5	39.5	3.77	6.6		
	Survey window- 24 hour- variation	1		5	2	1	1	1	11	1.62		1.8	
	Survey window- annual-weeks	18		12	20	12	14	22	98	7.30	16.3		
	Survey window- annual-variability	1		5	2	1	1	1	11	1.62		1.8	
	Mean value										35.2	3.1	5
Diurnal Raptors: non-breeding; Occupancy/ abundance	Changes quickly	4			4	4	3	3	18	1.81		3.6	
	Accepted survey method	3			3	5	4	2	17	1.90		3.4	
	Observer error	3			3	3	4	3	16	1.60		3.2	
	Number of detections	17.5			25	5	9	16	72.5	9.51	14.5		
	Number of species/hour	4			5	3	3	7	22	2.54	4.4		
	Consistency	2			2	4	1.5	3	12.5	1.47		2.5	
	Survey window- 24 hour- hours	8			11	8	12	6.5	45.5	4.82	9.1		
	Survey window- 24 hour- variation	1			2	1	1	1	6	0.69		1.2	
	Survey window- annual-weeks	30			20	12	16	22	100	11.22	20.0		
	Survey window- annual-variability	1			2	1	1	1	6	0.69		1.2	
	Mean value										48.0	2.5	7
Nocturnal Raptors: breeding; Occupancy/ abundance	Changes quickly	3	3		4	4	3.5	4	21.5	1.43		3.6	
	Accepted survey method	5	4		4	5	5	3	26	1.80		4.3	
	Observer error	5	4		4	3	4	3	23	1.60		3.8	
	Number of detections	3	10		10	.	15	2.5	40.5	5.86	8.1		
	Number of species/hour	3	5		3.5	.	4	1.5	17	1.97	3.4		
	Consistency	4	2		3	3	4	2	18	1.40		2.6	
	Survey window- 24 hour- hours	6	25		5	6	8	3	53	8.10	8.8		
	Survey window- 24 hour- variation	4	3		2	1	2		12	1.50		2.4	
	Survey window- annual-weeks	10	6		12	12	12	22	74	6.70	12.3		
	Survey window- annual-variability	3	3		3	1	1		11	1.40		2.2	
	Mean value										32.7	3.2	4

Parameter	Criterion/Factor	Participant							Totals	SD	Response Means		Rank
		1	2	3	4	5	6	7			Integer	Scores	
Songbirds: Productivity	Changes quickly	3	4	5	4	5	1		22	1.95		3.7	
	Accepted survey method	5	5	5	4	5	5		29	1.86		4.8	
	Observer error	4	4	5	4	3	4		24	1.62		4.0	
	Number of detections	5	8	5	2.5	.	4		24.5	2.90	4.9		
	Number of species/hour	3	4	3	3.5	.	3		16.5	1.65	3.3		
	Consistency	5	2	3	5	3	2		20	1.77		3.3	
	Survey window- 24 hour- hours	12	12	10	5	12	4		55	4.85	9.2		
	Survey window- 24 hour- variation	1	2	5	2	1	1		12	1.60		2.0	
	Survey window- annual-weeks	12	12	10	12	8	9		63	4.28	10.5		
	Survey window- annual-variability	1	2	5	3	2	1		14	1.63		2.3	
	Mean value										27.9	3.4	2
Nocturnal Raptors: Productivity	Changes quickly	4			4	4			12	2.14		4.0	
	Accepted survey method	5			4				9	2.21		4.5	
	Observer error	5			4				9	2.21		4.5	
	Number of detections	1			2.5				3.5	0.96	1.8		
	Number of species/hour	2							2	0.76	2.0		
	Consistency	5							5	1.89		5.0	
	Survey window- 24 hour- hours	12							12	4.54	12.0		
	Survey window- 24 hour- variation	1							1	0.38		1.0	
	Survey window- annual-weeks	18							18	6.80	18.0		
	Survey window- annual-variability	1							1	0.38		1.0	
	Mean value										33.8	3.3	3
Diurnal Raptors: Productivity	Changes quickly	4	3.5	3	4	5	3.5		23	1.58		3.8	
	Accepted survey method	5	5	5	4	5	5		29	1.86		4.8	
	Observer error	5	5	5	4	3	4.5		26.5	1.82		4.4	
	Number of detections	3	2.5	2	2.5		2		12	1.22	2.4		
	Number of species/hour	3	2.5	1	3.5		1.5		11.5	1.41	2.3		
	Consistency	5	4	3	5	4	2		23	1.80		3.8	
	Survey window- 24 hour- hours	12	12	10	5	12	12		63	4.73	10.5		
	Survey window- 24 hour- variation	1	1	5	2	1	1		11	1.62		1.8	
	Survey window- annual-weeks	16	12	10	20	8	8		74	6.40	12.3		
	Survey window- annual-variability	1	2	5	2	2	2		14	1.53		2.3	
	Mean value										27.5	3.5	1
Diurnal Raptors: Breeding status	Changes quickly	4	3.5			5	3.5		16	2.20		4.0	
	Accepted survey method	5	5			4	3		17	2.37		4.3	
	Observer error	5	5			4	3		17	2.37		4.3	
	Number of detections	10	12				2		24	5.26	8.0		
	Number of species/hour	3	2.5				2		7.5	1.37	2.5		

Parameter	Criterion/Factor	Participant 1	2	3	4	5	6	7	Totals	SD	Response Means Integer	Scores	Rank
Diurnal Raptors: Breeding status (cont.)	Consistency	5	4				1		10	2.15		3.3	
	Survey window- 24 hour- hours	12	12			12	12		48	6.41	12.0		
	Survey window- 24 hour- variation	1	1			1	3		6	1.07		1.5	
	Survey window- annual-weeks	16	12			8	5		41	6.44	10.3		
	Survey window- annual-variability	1	2			4	2		9	1.50		2.3	
	Mean value										32.8	3.3	3

Table G.5. Synthesis of written comments from participants (P) of the mammal workshop, Pima County Ecological Monitoring Program, November 2, 2006. See Table G.2 for scored responses.

Parameter	Criterion/Factor	Narrative Responses
Small Mammals-Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1, P4-P7: Vegetation structure and composition. P2: Vegetation structure and composition, moisture, soils. P3: Vegetation structure.
	Changes quickly	P1: Lag times variable among species. P2: Depends on seed production, insects, and species considered. P3: May respond quickly depending on species. P4: Fast response to food, seeds. P6: Lag times not common. P7: Rodents quick changes larger species slower.
	Accepted survey method	P1, P5, P7: Trap grids or distance sampling for some species. P2: Live trapping. P3. Trap grids with mark recapture and distance sampling for squirrels and lagomorphs. P4: Trapping grids, distance sampling. P6: Mark-recapture, and cone use for squirrels.
	Observer error	P1: Rodents difficult to ID. P2: Need expert. P3-4: Difficult for some species. P5: Low for most except *Peromyscus*. P6, P7: Need knowledge.
	Consistency	P1: Trap shyness. P2: Small home ranges so repeatable. P3: Variable seasonally and annually and highly dependent on effort. P4: Small territories frequent recapture. P5: Variable. P6: Fairly consistent but depends on species, season, wind, rain, moon. P7: Trapability varies among species.
	Variation in survey window- 24 hour	P1: Temperature. P2: Seasonal. P3: Nights varies with weather. P6: Only reliable at night but day possible.
	Variation in survey window- annual	P1, P4: Monsoon onset. P2: Same time each year. P3: Moon phase and rainfall. P5: Late Apr to early July before rain. P6: Warm season before monsoon. P5: Highly variable. P6: Seasonally variable. P7: Moon phase.
	Species ranked by interest	P1: *P. merriami, D. spectabilis, O. torridus, S. arizonae, L. alleni.* P2: Endemics like mesquite mouse. P4: Antelope jackrabbit, mesquite and pygmy mouse, yellow-nosed cottonrat. P5, P7: Mesquite mouse. P6, P7: Allen's jackrabbit.
	Threats ranked by importance	P1: Changes in vegetation structure and composition. P2: Habitat loss of key components. P3: Exotic species, disturbance to vegetation structure. P4: Loss of grass and mesquite woodland. P5: Land cover change. P6: Lack of knowledge, habitat fragmentation. P7: Loss of mesquite.
	Comments	E 2: Stratify sampling to include species most threatened. P4: Trap shyness and multiple types of traps should be addressed.
Bats-Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Water, vegetation structure and composition, roosts. P4: Vegetation structure and composition. P7: Loosely with vegetation community
	Changes quickly	P1: Moderate P4: Unknown.

Parameter	Criterion/Factor	Narrative Responses
Bats-Occupancy/ abundance (cont.)	Accepted survey method	P1: Netting or recording sonar such as Anabat with Zcaim recorder. P4: Anabat, netting, roost counts. P7: Nests or audio.
	Observer error	P1: Visual errors possible, sonar errors more serious and depend on season and complexity of site. P4: Some genera hard to ID. P7: Need experience.
Bats-Occupancy/ abundance (cont.)	Consistency	P1: Varies seasonally. P4: Roost surveys yes netting no.
	Variation in survey window- 24 hour	
	Variation in survey window- annual	P1: Depends on season. P4: Many species migratory so seasonal surveys.
	Species ranked by interest	P1: Lepto, Cho. mex, Cor. townsendii, Las. bloss., Las. xanthinus, Mac. calif. P4: Many species in Arizona. P7: All bats on PVS list.
	Threats ranked by importance	P1: Lose of refuges and roosts due to humans, loss of agaves due to development of grasslands, loss of riparian vegetation and broadleaf species. P4, P7: Loss of roosts and nests.
	Comments	P1: Use of netting to estimate occupancy and abundance has little error if done by experts but it covers very small space and takes lots of effort; use of sonar is more efficient but there is error, see notes
Predators-Occupancy/ abundance	Characteristic(s) to which parameter is linked	P2: Vegetation structure and composition, topography. P4: Vegetation structure, prey, and geophysical features. P5: Larger species fragmentation, for small species changes in land cover. P6: Prey base, vegetation structure and composition. P7: Prey and disease.
	Changes quickly	P1: Lag times significant. P2: Changes slowly with vegetation. P5: One year lag times common. P6: Pray base decreases and predators have to prey switch or numbers will decrease. P7: Lag times varies with life span.
	Accepted survey method	P2: Bait stations. P4: Track surveys, scent stations, camera traps. P5: Scent traps, photo traps. P6: Scent stations, camera traps, hair snares. P7: Camera trap, scent station.
	Observer error	P2: Based on traps yes pictures no. P4, P5, P7: Skunks hard to ID. P6: Careful observer with resources.
	Consistency	P2: Highly variable especially with large species. P4: Large territories. P5: Low as territories large. P6: Fairly consistent but varies with temperature, rainfall, and habitat.
	Variation in survey window- 24 hour	P2: Depends on season. P5: Low variation but low detectability.
	Variation in survey window- annual	P2: Stable weather conditions and same time of year. P5: Low variation but low detectability. P6: All year round.
	Species ranked by interest	P2: Skunks, kit fox, coati, ringtail. P4: Hog-nosed skunk, T and E spp., Mexican opossum, spotted skunk. P5:Mt Lion, hooded and hognose skunks. P6: Skunks, kitfox, badger, ringtail, bear, loin, coyotes, bobcat. P7: Skunks, kit fox, coati, Lion.
	Threats ranked by importance	P2: Habitat loss of key components. P4: Loss and fragmentation of habitat. P4: Land conversion, exotics. P5: Habitat loss, dogs, cats. P6: Lack of information. P7: Fragmentation and connectivity.
	Comments	P5: Large predators already being monitored by others but mesopredators need study. P6: Much of these data collected by AZGF and Sky Island Alliance. P7: Sky Island Alliance and NPS collecting data.

Table G.6. Synthesis of written comments from participants (P) of the amphibian and reptile workshop, Pima County Ecological Monitoring Program, November 2, 2006. See Table G.3 for scored responses.

Parameter	Criterion/Factor	Narrative Responses
Ranid Frogs: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1-6: Water availability or quantity.
	Changes quickly	P1: Lag times in dry years. P2, P5, P6: Quick response if water gone.
	Accepted survey method	P1-3, E 6: Visual encounter surveys. P5: Plop counts.
	Observer error	P1: Qualified observers only. P2, P4, P6: Leopard and bull frogs can be difficult to distinguish. P3, P5: Some potential for confusion between species.
	Consistency	P2: Frogs stay in suitable habitat. P3: Consistent within season. P5: Depends on time since disturbance.
	Variation in survey window- 24 hour	P1: Best evening and night but day surveys OK. P2: dark best but day possible. P3: Early AM best but 24hr OK. P4-5: Day and night but detectability varies in day. P6: Only reliable at night but day possible.
	Variation in survey window- annual	P1: Apr-Jun, Sept-Oct. P2: May-Jun when least water. P3: May vary in day survey when least water. P4: Dry summers. P5: Late Apr to early July before rain. P6: Warm season before monsoon.
	Species ranked by interest	P1: Lowland leopard frog (LLF), Chiricahua leopard frog (CLF), Bullfrog (Bull), Canyon treefrog. P2: CLF, LLF, Bull. P3: LLF, CLF, Bull. P4: Bull, LLF, CLF. P5: LLF, Bull. P6: LLF, CLF.
	Threats ranked by importance	P1: Exotic species, disease. P2: Water loss, exotic species, disease. P3: Exotic species, water loss, disease. P4: Exotic species, chytrid, water loss. P5: Water loss, exotic species. P6: Disease, water loss, sediment, exotic species.
	Comments	P1: Restoration is happening and is relevant to study design.
Nocturnal Reptiles: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Vegetation structure, soil, substrate. P2: Soil, vegetation, food. P3: Prey availability, soil. P4 Vegetation, soil. P5: Soil, vegetation structure, rodents, lizards, climate. P6: Human disturbance, rodents, insects, soil.
	Changes quickly	P1: Slow to natural stressors. P2: Slow response to vegetation changes. P3: Varies. P5: Lags 1 year. P6: Lags 1-3 years behind prey abundance, declines fast if urban development.
	Accepted survey method	P1-4, P6: Road cruising and drift fences with funnel traps. P5: Road cruising, traps, and visual encounter surveys.
	Observer error	P1: Visual errors along roads possible. P2: Some snakes move before ID. P3: More experienced observers find more but not with trapping. P5: No error for recaptures when trapping. P6: Some species hard to ID.
	Consistency	P1: Varies seasonally and with daily weather. P2: Highly variable. P3: Varies for unknown reasons. P5: Humidity. P6: Many species are rare so varies.
	Variation in survey window- 24 hour	P1: Low within season. P2: 4 hrs after sunset, longer if warm. P3: Highly variable but can trap for 24 hrs. P5: Dark nights with no moon.
	Variation in survey window- annual	P1: Cool dry spring, monsoon, and early fall. P2: Best July to Aug. P3: Dusk and night only. P4: Humidity and day temperature must be high. P5: Warmest months yet peak in activity highest July to Sept.
	Species ranked by interest	P1: Ground and shovel-nosed snakes. P2: All snakes. P3: All species. P4-6: Shovel-nosed snake.
	Threats ranked by importance	P1: Road density, development, climate change. P2: People, roads. P3: Habitat loss due to development. P4: Exotic predators. P5: Habitat loss and fragmentation.
	Comments	P2-3: Trap mortality can be an issue.

Parameter	Criterion/Factor	Narrative Responses
Diurnal Lizards and snakes: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Vegetation structure, hydrology. P2, P5: Soil and vegetation. P3: Vegetation, soil, rock. P4: Vegetation, predators, soil. P6: Vegetation community composition.
	Changes quickly	P1: 1-3 year lag times and may persist and decline slowly for long time. P2: Changes slowly with vegetation. P3: Abundance changes rapidly, occupancy slowly. P5: One year lag times common.
	Accepted survey method	P1, P4: Visual encounter surveys distance or time-area constrained. P2, P5, P6: Visual encounter surveys time-area constrained. P3: Visual encounter surveys OK for relative abundance.
	Observer error	P1: Errors in ID common unless dedicated observer. P2: Easy except whiptails. P3: Easy to confuse species. P4, P5: Move fast hard to ID.
	Consistency	P1: Highly repeatable. P2: Varies by temperature. P3: Varies with wind, clouds, temperature. P4: Temperature and precipitation. P5: Better for more common species not for rare ones.
	Variation in survey window- 24 hour	P1: Warm sunny days very consistent. P2, P3, P5: Survey time varies by species due to temp
	Variation in survey window- annual	P1: Variable but if low temperature adjustment needed. P2: Varies between seasons. P3: Spring different than summer. P5: Depends on air and surface temperature.
	Species ranked by interest	P1: Giant-spotted whiptail and 7 others species. P2: Diurnal lizards. P3: Giant-spotted whiptail. P4: All. P5: Chuckwalla, desert iguana, collared and leopard lizards, giant-spotted whiptail. P6: Desert iguana, *Uta*, giant-spotted whiptail, desert horned lizard, leopard lizard.
	Threats ranked by importance	P1: Urbanization, change in predator community. P2: Loss of riparian vegetation and climate change. P3: Development and loss and fragmentation of habitat. P4: Land conversion, exotics. P5: Habitat loss, dogs, cats. P6: Road mortality, cats, habitat loss.
	Comments	P1: Study of this group can yield lots of data. P6: Whole suite of species lost in Arva Valley.
Summer Amphibians: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Floodplain hydrology and vegetation. P2: Ephemeral breeding sites. P3: Water availability. P4: Hydrology, geomorphology, vegetation, soil, predators. P5: Climate. P6: Temporary pools.
	Changes quickly	P1: Lag times as lives underground and persists after habitat gone. P2: Slow. P4: Changes fast. P5: Depends on availability of breeding sites. P6: Timed response to monsoon rains.
	Accepted survey method	P1, P2: Calling surveys. P3: Calling and road surveys. P5: Acoustic monitoring. P6: Survey of calling sites.
	Observer error	P1, P5: Only trained observer. P2, P6: Some confusion between species possible. P3: Not too hard.
	Consistency	P1: Highly consistent. P2: Reliable with timely summer rains. P3: Usually just nights. P5: Good after the first few nights of rain. P6. First large monsoon night key.
	Variation in survey window- 24 hour	P1-5: Low variation, always after rain. P6: Dark to early morn afternoon rains.
	Variation in survey window- annual	P1: High variation some years. P2: With summer rains very variable but predictable. P3, P4: Precipitation. P5, P6: Depends on onset of rains.
	Species ranked by interest	P1: Mexican spadefoot, narrow-mouthed toad, 5-6 others. P2: Couches spadefoot, Bufo alvarius, B. cognatus, B. puncatus, Gastrophyne. P3: Sonoarn gr. toads? P4: All. P5: Bufo retif, Pternohyla, Gastrophyne. Bufo alvarius, Couches spadefoot, Spea multipl., Gastrophryne.
	Threats ranked by importance	P1: Loss of habitat connectivity. P2: Land conversion and roads. P3: Habitat loss and target practice. P4-6: Development.
	Comments	P1: Feasible esp for urban areas. P2-4, P6: Need to map all occupied sites in County in next 5-10 years to account for varying rains for use in monitoring. P5:Involve TO Nation in sampling. P6: Need better rainfall data.

Table G.7. Synthesis of written comments from participants (P) of the bird workshop, Pima County Ecological Monitoring Program, November 5, 2006. See Table G.4 for scored responses.

Parameter	Criterion/Factor	Narrative Responses
Songbird-breeding: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Vegetation structure, insect availability, nectar. P2, 3: Vegetation structure. P4: Vegetation structure and composition. P5: Vegetation structure, water and food availability. P6: Vegetation cover and structure. P7: Drought and temperature.
	Changes quickly	P1: High linkage. P2: Lag times long for slow vegetation changes, short for major disturbance. P3: Lags. P4: Lags 1-2 years possible but uncommon. P5: Lag times and reproductive differences. P7: Lags 1-2 years.
	Accepted survey method	P1-2, P5, P7: Variable circular plots with distance sampling. P3: Point counts. P4, P6: Distance sampling.
	Observer error	P1, P2, P7: Qualified observers only. P2: Big problem for some species. , P4: Misidentification, double counting, variation in observer ability. P5: Differences in ability is an issue.
	Consistency and predictability	P1: Fairly high as small territories, varies with wind and rain. P3: Very, food resources. P4: Little change unless vegetation disturbed, survey window varies with season and species. P5: Monsoon. P7: Variation based on temperature, wind, humidity, species, nest timing, habitat.
	Species ranked by interest	P1: YBCu, YeWa, BeVi, AbTo, SoSp, ScQu, BoSp, GrSp. P2: YBCu, BeVi, BoSp, WiFl. P3: YBCu, SoSp, YeWa, BeVi, CaSp. P5: RWSp, YBCu, AbTo. P7: YbCu, YeWa, BoSp, CaSp, AbTo, BeVi, RwSp.
	Threats ranked by importance	P1: Groundwater pumping, loss of riparian vegetation, overgrazing. P2: Groundwater pumping, changes in land cover, exotic species,. P3: Habitat loss. P4: Loss of riparian vegetation, shrub encroachment, urbanization. P5: Urbanization, loss of riparian habitat. P6: Urbanization, non-native plants.
	Comments	P1: Point counts will capture broad suites of species. P3: Best parameter in summer for birds.
Songbird-non-breeding: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1: Vegetation, insects, seeds. P2, P3: Vegetation structure. P4: Vegetation structure and composition. P5-6: As above.
	Changes quickly	P1: Lags sometimes. P2: Lag times long for slow vegetation changes, short for major disturbance. P3: Fast for food.
	Accepted survey method	P1-2: Line transects with distance sampling or mist nets. P3: Netting, flush counts. P4: Distance sampling, mist netting. P6: Mist netting. P7: Area search
	Observer error	P1: More difficult than in summer as only visual cues. P3: Sparrow difficult to see and ID. P4: Low efficiency due to misidentification. P7: Winter calls more difficult to ID than songs in summer.
	Consistency and predictability	P1: Larger home ranges in winter and less territoriality and therefore less consistent. P2: Large winter flocks impose higher variation. P3: Winter severity. P4: Some nomadic increases variation. P6: Many species are rare so varies. P7: Winter birds flock and move around more and call less so less predictability.
	Species ranked by interest	P1: BaSp, GrSp. P2: GrSp, BaSp.
	Threats ranked by importance	P1: Groundwater pumping, loss of riparian vegetation, overgrazing. P2: Shrub encroachment, changes in fire frequency, grazing. P3: Habitat loss due to development. P5: as above.
	Comments	P3: Best parameter overall but for summer not in winter when variation very high.
Diurnal Raptors-breeding:	Characteristic(s) to which parameter is linked	P1: Nest substrate, prey. P3: Prey. P4: Nesting structures, vegetation structure, prey base. P5: Vegetation, food availability, water availability. P6: Vegetation structure and community composition, land cover. P7: Prey.

Parameter	Criterion/Factor	Narrative Responses
Occupancy/ abundance	Changes quickly	P1: Lag times for prey, loss of nest structure immediate effects. P4: Loss of nesting structure causes immediate response. P5: Nest trees. P7: 3-5 year lag times.
	Accepted survey method	P1: Broadcast surveys, nest surveys. P3: Scanning, scoping. P4: Location of nests. P5: Driving transects, nest searches, point counts. P6: Playback surveys, site surveys at historical and new sites. P7: Nest searches, road survey transects.
	Observer error	P1: Vocalizations easy to tell apart and audible. P3: Few species very conspicuous. P4: Missing nests low efficiency. P5: Some morphs hard to ID at long distances. P7: Little error
	Consistency and predictability	P1: Highly consistent due to territoriality and fixed nesting locations, varies with short-term weather and to some extent with different phases of the nesting cycle. P3: Larger home ranges makes for more variation. P4: Some variability with weather. P5: Highly repeatable when spatially overlap. P6: Varies little. P7: Dependent on species window varies between resident and migrant populations.
	Species ranked by interest	P1: FePO, SwHa, GrHa, PeFa, GoEa. P3: GoEa, SwHa, PeFa. P4: GrHa, SwHa, FePO, PrFa, PeFa, GoEa. P5: GrHa, HaHa, FePO. P7: FePO, HaHa, BuOw, GoEa, SwHa.
	Threats ranked by importance	P1: Nest-site and woodland loss. P3: Pesticides, habitat loss. P4: Loss of riparian vegetation, urbanization. P5: Electrocution, disease, loss of riparian habitat.
	Comments	P1: May be able to fly to survey in open country like grasslands were nests are visible.
Diurnal Raptors-non-breeding: Occupancy/ abundance	Characteristic(s) to which parameter is linked	P1, P4: Perches, prey base. P5: Vegetation, prey. P6: Vegetation structure and community composition, land cover. P7: Prey.
	Changes quickly	P1: Lag times for prey, loss of nest structure immediate effects. P5: Moderately. P6: Timed response to monsoon rains. P7: Varies with prey availability.
	Accepted survey method	P1, P4, P6: Line or road transects with distance sampling in open country. P5, P7: Driving transects.
	Observer error	P1: All visual cues so error possible. P5: More than in summer. P7: Accipiters and juvis hard to ID.
	Consistency and predictability	P1: Less consistent than breeding season due to larger territories and lower detectability. P4: Variability with factors that dictate migration.
	Species ranked by interest	P1: FeHa, FePO, GoEa, PeFa. P4: GoEa, PrFa, PeFa. P5: SsHa? P7: BuOw, FeHa, HaHa
	Threats ranked by importance	P1: Loss of grasslands and ag, fields esp. hedgerows and large trees. P5: Electrocution, disease, loss of riparian habitat.
Nocturnal Raptors, Nightjars-breeding:	Characteristic(s) to which parameter is linked	P1: Prey availability, nest trees or cacti, fire suppression and changes in forest structure. P2: Vegetation structure, food. P4: Vegetation structure, nest sites. P5: Vegetation, food, water. P6: Vegetation structure, land cover. P7: Vegetation structure.
	Changes quickly	P1: Moderately quick. P2: Depends on level of disturbance. P5: Within certain range. P7” Loss of saguaros and riparian vegetation causes dramatic changes.
	Accepted survey method	P1, P4: Call response surveys along transects. P2: Call broadcast or point-count surveys. P5, P7: Call surveys. P6: Playback surveys with or without distance sampling.
	Observer error	P1-2: Little, few species unique voices. P4: Call identifiable, few exceptions. P6: Varies with species. P7: Later season calls similar among species.

Parameter	Criterion/Factor	Narrative Responses
Nocturnal Raptors, Nightjars-breeding: Occupancy/ abundance (cont.)	Consistency and predictability	P1: Varies with moon phase, small changes in weather and wind and esp. with species. P2: Moon phase and individual effects, varies by species. P4: Dependent on weather, varies with phases of nesting cycle. P5: High for territorial birds, depends on species breeding season and behavior, some species more vocal. P6: Best during tails of day for most species, high predictability annual and seasonal. P7: Wind speed and moon phase, varies among resident and migrant species.
	Species ranked by interest	P1: MSOw, FlOw, BCNi, WhSOw. P2: ElOwl, FePO. P4: Pygmy-owls, ElOw. P5: BCNi, GHOw. P7: ElOw, BCNi
	Threats ranked by importance	P1: Fire and logging, loss of saguaros and large trees in lowlands. P2: Land cover conversion. P4: Urbanization. P5: Habitat loss. P7: Desert fires fill saguaros and large trees, ground water and loss of riparian habitat.
	Comments	P2: Comments for owls not nightjars. P6: Survey period spans much of the year depending on species.
Songbird-breeding: Productivity	Characteristic(s) to which parameter is linked	P1: Food availability, vegetation structure, risk of predation. P2: Food, predators, cowbirds. P3: Climate. P4: Weather, food. P5: Vegetation, food, water, winter conditions. P6: Vegetation structure, prey, predators, weather.
	Changes quickly	P1: Lag effects but predation risk unpredictable often times. P3: Rapid annual changes to climate. P4: Responds rapidly to changes in resources. P6: Not linked well.
	Accepted survey method	P1-2, P4-5: Nest searching and monitoring. P3, P6: Mist netting, nest searching.
	Observer error	P1: Expert observer necessary. P2: Rarely a problem. P3-4: Very low. P5: Depends on species
	Consistency and predictability	P1: Very variable among vegetation communities, forget it in grasslands. Age at which nest found poses big potential bias. P2: Varies with observer skill and rains. P3: Very variable by species, depends on stage of nesting. P4: Easiest during nestling stage. P5: Depends on species. P6: Consistent windows and times.
	Species ranked by interest	P1: BeVi, AbTo, T&E sp., P2: BeVi, SuTa, AbTo, YWar, YBCu, BoSp, CaSp, LuWa, RWSp. P3: All riparian species. P5: AbTo, BeVi, RWSp, GrRo, YBCu.
	Threats ranked by importance	P1: Loss of key nest substrates, edge effects, urbanization, cowbirds. P2: Cowbirds, competition for cavities with exotic species like EuSt. P3: Drought. P5: Habitat loss, exotic species, predation.
	Comments	P1: This parameter valuable but only worth the cost for species of extreme conservation concern or those that can be monitored incidentally to abundance estimation. P2: Some species of interest are simply not amenable to nest monitoring because of cost. P3: Cavity nesters easy to do, Validity of data in question; what is it really telling us without very broad spatial coverage. P5: Only for species of conservation concern.
Nocturnal Raptors-breeding: Productivity	Characteristic(s) to which parameter is linked	P1: Food, vegetation structure. P4: Prey base. P5: Vegetation, food, water, winter conditions. P6: Pesticides, food, predators.
	Changes quickly	P1: Short lags. P4: Responds rapidly to changes in resources.
	Accepted survey method	P1, P4: Nest searching and monitoring, playback surveys. P6: Site visits.
	Observer error	P1, P4: Consistent.
	Consistency and predictability	P1: High variability, some species do not nest every year but window consistent. P4: Varies among species. P6: Varies by species but consistent within a species.
	Species ranked by interest	P1: MSOw.
	Threats ranked by importance	P1: Logging and forest structure, saguaro and large tree abundance.

Parameter	Criterion/Factor	Narrative Responses
Nocturnal Raptors-breeding: Productivity (cont.)	Comments	P1: This parameter valuable but only worth the cost for species of extreme conservation concern or those that can be monitored incidentally to abundance estimation.
Diurnal Raptors-breeding: Productivity/ breeding status	Characteristic(s) to which parameter is linked	P1: Food, vegetation structure. P2: Vegetation structure, food. P3: Climate. P4: Food, toxins. P5: Vegetation, food, water, winter conditions. P6: Pesticides, food, predators.
	Changes quickly	P1: Lag times for food. P3: Long lags for food, seasonal climate effects changes fast. P4: Responds rapidly to changes in resources. P6: Linked well to some elements of change.
	Accepted survey method	P1: Nest searching and monitoring, playback surveys, or large search area methods. P2-5: Nest searching and monitoring. P6: Site visits.
	Observer error	P1: Low error. P2: Easy to ID. P3: Need qualified observer. P4: Few nests misidentified. P6: Low but always perfect.
	Consistency and predictability	P1: Little adjustment needed, wind is an issue during surveys. P2: Consistent. P3: Varies with home range size. P4: Consistent year to year. P5: Varies with species. P6: Consistent
	Species ranked by interest	P1: FePO, SwHa. P2: GrHa, CBHa, ZTHa, CoHa. P3: SwHa, PeFa, CBHa. P5: FePO, HaHa, CoHa.
	Threats ranked by importance	P1: Loss of saguaros and nest substrates, shrub invasion in grasslands. P2: Toxins, disease, electrocution. P3: Habitat loss. P5: Disease, habitat loss.
	Comments	P1: This parameter valuable but only worth the cost for species of extreme conservation concern or those that can be monitored incidentally to abundance estimation. P3: May be better than abundance but expensive.

G.3 Meeting Notes from Workshops

Mammal and Herpetofauna Meeting: November 2, 2006

Present: Julia Fonseca, Neva Connolly, Lori Woods, Aaron Flesch, Brian Powell, Colby Henley, Scott Richardson, Paul Krausman, Cecil Schwalbe, Phil Rosen, Tony Povilitis, Doug Duncan, Dale Turner, Ronnie Sidner, Don Swann, Peter Holm, Trevor Hare, Andrea Litt, John Koprowski, Bill Shaw, Bill Van Pelt

General Questions and Discussion Points

Question: Will 'Data Sharing' between agencies be specifically stipulated in the monitoring plan?

- A possible need for Inter-Governmental Agreements to ensure free flow of data, but agencies are currently agreeable to open data exchange.
- Important to capture all info from various monitoring programs going on around county – crucial to create formal data exchange structure to ensure that info is accessible even as staff and players change over time.
- Review of existing monitoring/data sources may help point out monitoring gaps/incompleteness. Can guide County with overall design of what to monitor and if changes in monitoring efforts are needed as Land Management agencies develop or modify their monitoring programs.
- Participants emphasized the use of existing data (UA/AGFD) as baseline and to guide future efforts. Important to make sure that assumptions about other agencies monitoring of species or are valid and remain so during life of monitoring plan.

Question: Why wasn't this process done by reviewing literature and going with established methods?

Response: County felt it was importance to get local perspective and expertise and to validate the process with more open/inclusive participation rather than limited number of people reviewing literature. County wants to get input from wide variety of perspectives. Established methods in the literature will be reviewed in later stages during protocol development.

<u>Question</u>: How was team put together?

<u>Response</u>: Peer input, local contacts, cost considerations.

- Suggestion to coordinate with AGFD Permit Administrator (Melissa Swain) to see who has Scientific Collection Permits – open process to broader group of experts.

- Several participants expressed interest in reviewing and providing feedback on Draft Monitoring Plan once it is developed.

- Ronnie Sidner suggested that Allen's big-eared bat be removed as surveys show it likely doesn't exist in Pima Co.

<u>Question</u>: Is focus just the County Reserves or broader landscape?

- Generally eastern 1/3 of Pima County to formulate parameters; where monitoring will eventually occur is uncertain, but will be refined in later stages.

Discussion about elevation limits for monitoring plan.

- Most higher-elevation lands are under USFS, NPS Management, but most Pima County lands are 4,000 ft and lower.

- However, many Priority Vulnerable Species have important distribution above 4,000 ft.

Reminder to focus on holistic approach, refinements will be done later in the process. Goal is to optimize monitoring effort to get the most data covering the most species

Discussion of funding for monitoring – what is the expected amount?

- No real answer, but parameter selection should be driven by what is needed to detect changes in species/groups, not what we think will get funded.

<u>Mammal Subgroup Discussion</u>

Suggested species groupings (prior to workshop):

1. Bats

2. Small mammals

3. Meso predators

4. Large herbivores

5. Large carnivores

- Remove large herbivore game species, as AGFD/other agencies will be tracking, more efficiently than PC can do.
- Large carnivores – also may be able to use AGFD data or collect large carnivore data in mesopredator monitoring techniques (camera, scent stations, jaguar camera stations etc). Habitat fragmentation is important to monitor for these species. Conclusion=Lump into mesopredator group.
- What about ringtail, coati, kit fox, other small mammals [add mesquite mouse & lagomorphs to small mammals] – are any of these in danger of being extirpated and in need of additional monitoring?
    - Hognose, hooded skunk, kit fox, badger, Allen's jackrabbit – little data on these species exists.
    - Because of this lack of data, maybe give these a higher priority.
    - Important to document the concern for these species, but they will likely be tracked with other methods.
    - Less detectability for skunks than Allen's jackrabbit.
- Another approach is to look at which members of groups could have something happen to them without us detecting a change.
- Small mammals (rodents), bats are quick indicators of change (sensitive).
- Two most useful/important foundations – Vegetation and land use
    - Vegetation – important to capture both composition and structural components to be useful in monitoring vertebrate population.
    - Also important to capture invasive/non-natives.
    - NDVI won't be helpful at the species group level for the most part, not enough detail.
- Most efficient approach would be if monitoring for species groups will also capture changes in MSCP Permit species.

Suggested species grouping (from discussion):

- Predators:
    - Black bear, mountain lion, skunks, fox, coyote, raccoon, bobcat, badger, coati, ringtail.

- Small mammals:
  - Rodent, squirrels, lagomorphs.
- Bats.

<u>Possible Parameters</u>

- Occupancy – relatively easy.
- Abundance – more cost prohibitive.
- Disease issues:
  - Rabies'? – possible issues w/ bats & skunks, but is this just a human concern?
  - Transfer of disease from domestic stock (sheep) to ungulates– will AGFD track this?
  - Canine Distemper – maybe a concern in mesopredator group.
- Diversity – which species are present, as opposed to just number of species, especially important to small mammals and bats.
  - This can be derived from occupancy/abundance in most cases.
- Illegal immigrant disturbance (border related impacts, illegals, law enforcement etc.)
  - Maybe put under Landscape group, as part of land-use tracking.
  - Focus on heavy traffic areas – riparian areas.
- Demographic data - expensive to collect, so maybe just collect one component.
  - Productivity? – possibly gathered while doing simultaneously with occupancy/abundance.
  - Recruitment would better reflect population.
  - Applicability to groups will depend on survey methods, i.e. small mammal trapping – have them in hand, vs. camera/scent station/sonic surveys.
  - Maybe only if needed for special issues and incidental to collecting other data.

- Climate - tie sampling times to climate variations (monsoon, drought).

Miscellaneous Discussion Notes

- Redundancy with existing data sources.
- Data gaps/needs for different species.
- Particularly difficult species identification issues or training requirements.

Final Species Groups and Parameters

- Small Mammals:
  - Occupancy,
  - Abundance,
  - Diversity.
- Predators:
  - Occupancy,
  - Abundance.
- Bats:
  - Occupancy,
  - Abundance,
  - Diversity.

Herpetofauna Subgroup Discussion

Parameter Discussion

Discuss occupancy and abundance as much as possible, but are there any other parameters?

- Leopard frog monitoring to date - size class of herps, toads? Time of year? Try to have a more accurate count before they start moving with the rain.
- Suggestion to combine time and abundance.
- Comprehensive inventory of chrytrid fungus.

- Identify habitat to start with…maybe at another meeting. County start with stream stretches and look for detection of leopard frogs.
- Suggestion to look at Disease as a parameter. Threats for a specific thing such a chrytrid.
- Discussion regarding randomization and sampling.
- What are the things we need to know: interactions with introduced species, disease? How are these two processes functioning? Then you take the larger program and set it up according to what you know. Start with a sophisticated notion of what we want to start with.
- Herp surveying is a lot of wandering around, taking notes on what is observed.
- Lizards: can go out and pick up diurnal lizards in a couple of hours. Occupancy models still have to think about detectability.
- What are other parameters besides abundance and occupancy? Stand on their own parameters. For example, in birds, monitoring programs are built on nest success.

Discussion of occupancy and abundance

- Species richness and abundance use the same capture/recapture models.
- Occupancy doesn't work will with all species. Abundance you can get a trend from it. Can't get a trend from presence/absence. Problem with presence/absence data when the abundance data is thrown out.
- If you're doing landscape monitoring, and you sample for abundance for a lot of species, you would miss information for more rare species. Also a distributional trade-off. Monitoring program will have to determine how many places, how many sites. If you go out, you will get abundance information of abundant species, just can't ignore.
- Monitoring demographics? Record size structure, etc. Want to know about the demographics of a site. Eggs, tadpoles, juveniles, adults? Modify existing protocol to include demographics.

Species Groups

- Box turtle is stand alone.
- What about breaking things down into habitat groups or in terms of sampling group.

- Nocturnal, diurnal, aquatic. Sampling based strategy.
- Or by ways of sampling things. Snake and lizard sampling is different. Separate protocols.

<u>Final Species Groups</u>

- Ranid frogs (mud turtles)
    - Can get information on mud turtles, tree frogs at the same time.
- Nocturnal reptiles
    - Ranking data--not a data set that we have. And could provide some valuable information. Can show the biggest change from now. Mostly snakes, geckos, occasional Gila monster.
    - Two methods are common: trapping gets diurnal and nocturnal. Depends on locations. Trapping is good in protected area like Organ Pipe Cactus National Monument, in open area like Avra Valley it's dangerous and not effective. Trap mortality. Road cruising also has its problems too (can't do it on major highways, etc). Can get good key data by road cruising, but trapping can get new information, plus you get lizards, mammals, arthropods, and etc.
- Diurnal lizards (snakes)
    - Can get good data because they are so accessible. And there are special status lizards that can be included in this category.
    - Transects, lines, time constraint search. Doesn't matter since both methods have the same limitations.
- Toads, spadefoots
    - Monitoring protocol for toads-calling surveys is expensive. Tadpole ID, lots of error, difficult to do.
- Mexican garter snake other riparian herps.
- Desert tortoise .
- Box turtle (non-nocturnal snakes): nobody is looking at box turtles.

Last three are equal to each other. With some of these you can record certain mammals, predatory birds, ancillary species groups.

Bird Meeting; November 5, 2006

Present: Bob Steidl, Aaron Flesch, Brian Powell, Bill Mannan, Troy Corman, Chris Kirkpatrick, Rachel McCaffrey, Carianne Funicelli

Species Groupings (Proposed):

- Songbirds
- Hummingbirds
- Nightjars
- Diurnal Raptors
- Nocturnal Raptors
- Ducks and waders

Species Groupings after discussion:

- Songbirds (+ Costa's and broad-billed hummingbirds)
- Diurnal Raptors
- Nocturnal Raptors (+ nightjars)
- Ducks and waders
- Other Hummingbirds

General Discussion on Species Groups

- Rachel- The original groupings make sense from a monitoring perspective, but not necessarily from an importance standpoint; how about a community perspective?
- Brian- County has always used 3 general vegetation communities to filter their world according to upland, riparian, semi-desert grassland.
- Troy, Bob- breeding season groupings?
- Bob- Sonoran Desert is important on a larger scale for migratory birds – Pima County plays a larger role than on just resident birds.
- Rachel-urban avoiders versus urban affiliates.

- Brian- ratio of natives versus non-natives is one of the fastest changing.

Nocturnal Raptors and Nightjars

- Troy- nocturnal raptors why not survey for nightjars at the same time, can they be combined?
- Bob- makes sense if the point is survey convenience is the primary organizing force.

Ducks and Waders

- Brian- Are ducks and waders high priority because it is a limited resource or low priority because it is a limited resource?
- Bob- Are there any PC duck/wader species of importance, ie., worth tradeoffs to other species groups?
- Bill- limited resource, but not too vulnerable since they do well in developed areas…golf courses are going to continue.
- Troy- Black bellied whistling duck – private ponds are saving grace from hunters.
- Rachel- most wet areas are already managed and protected for waterfowl.
- Troy- Black necked stilt and avocet might be of interest.
- Brian- Perhaps an informal program to record observations of these really conspicuous and easy to see birds? Also, incidental observations while surveying for other species groups?
- Bill- This group seems to be the group of lowest importance.
- Aaron- Eliminate it entirely? Except to overlap, when it is easy to get incidental observations.

Hummingbirds

- Aaron- to eliminate these too?
- Aaron, Chris- The hummingbirds were separated from the other groups based on differing sampling methods.
- Bob- Perhaps enough data can be gotten with incidental observations; hummingbirds are regionally emblematic.

- Troy- Costas and broadbilled – most important to county; would have to be done early in the season; more broadbilled here than anywhere else in the country.
- Brian- How to maximize information realizing that some data will be missed because of timing?
- Brian- lump with songbirds?
- Bob- split hummers into 1) the 2 species of interest (add to songbird sampling) and 2) the rest.

<u>Discussion on Monitoring Parameters</u>

Abundance and occupancy are the commonly used monitoring parameters for population monitoring (general agreement)

- Bill- abundance is only meaningful if you have info on productivity and survival; presence versus breeding is not the same.
- Chris- some subset might be really easy to get this info on highly conspicuous birds.
- Bob- Occupancy versus abundance difference is whether distance sampling is used (songbirds not diurnal raptors).
- Bill- level 1 = documentation of nesting, next level = productivity.
- Chris- point counts in morning, then time to search for nests, then productivity is next level.
- Troy- desert nesters are sometimes easier to find.
- Rachel- survivorship and reproductive efforts should be concentrated on the 7 species that are already identified.
- Bob- raptors are easier; strong historic precedent for nesting monitoring; songbirds are harder.
- Aaron- go with occupancy and abundance; behavioral cues associated with breeding (save more in depth demographic parameters for more sensitive species).
- Bob- productivity for diurnal raptors.
- Bill- more doable to monitor productivity for diurnal raptors, but no more or less important that the songbirds.

- Bob- just threw it out as a possibility.
- Bob and Bill- set priorities first, then decide what to drop based on it being done elsewhere (AGFD).
- Brian- cliff nesting raptors are not very abundant in eastern PC.
- Subset of raptors that we'd like to get productivity info for (another discussion).
- Brian- Not talking survivorship, just productivity.

<u>Species richness – DISMISS</u>

- gotten incidentally from other methods; needed to think about as its own? You get it for songbirds, but what about the others?
- Diurnal raptors – so few species, not applicable; some survey effort for all species; not useful as a parameter by itself.
- Bill- doesn't have much meaning if you are replacing native species with non-native species (or if you are losing riparian species).

<u>Parameters considered and scored:</u>

1) Abundance:

- Songbirds (+ 2 hummingbirds):
  - Breeding,
  - Non-breeding.
- Diurnal Raptors:
  - Breeding,
  - Non-breeding.
- Nocturnal Raptors & Nightjars (breeding).

2) Productivity:

- Songbirds (+ 2 hummingbirds),
- Diurnal Raptors,
- Nocturnal Raptors & Nightjars.

3) Breeding Status: Diurnal Raptors

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APPENDIX H

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Managers' Workshop Results

H.1 Discussion Overview

The managers' workshop was held on November 17, 2006, approximately two weeks after the completion of the expert workshops. The goal of the managers' workshop was very different from that of the other workshops. Specifically, input was sought from managers about how valuable monitoring data for each parameter would be if the managers were in charge of managing on a landscape scale in Pima County. To inform this process, each participant was first asked to present the group with their most important land-management issues and monitoring needs as they pertained to their own management experience. The round-robin session provided a wealth of information and perspectives on ecosystem management and monitoring in Pima County (See section H.3 for discussion notes).

The participants were then presented the entire list of parameters that were suggested for inclusion into the program by the seven expert workshops. After all participants understood what each parameter represented, they were each encouraged to pretend as though they were managers of all of Pima County. From this perspective they were asked to choose the ten monitoring parameters that would be most informative to them. Based on the previous round-robin discussion of land management issues and monitoring needs, it was apparent that vertebrate monitoring was a lower priority than monitoring for other parameters such as water and vegetation. Because of the importance of including some species-level monitoring into the program (i.e., to comply with the legal requirements of the permit, participants were asked to rank and provide narrative for two groups of parameters (ranking groups). The first ranking group represented all parameters from the landscape, water, and vegetation categories (Table H.1). The other ranking group represented all vertebrate parameters. Each participant ranked and gave narrative on parameters separately from other participants, and no attempt was made to encourage participants to share their choices with others.

Once all participants provided narrative responses and ranks, they were each given 10 stickers, which they then placed next to their highest ranking parameters that were listed on a wall of the meeting room. This provided participants the opportunity to interact with each other and see the results of their collective rankings.

H.2 Results Summary

Forty-one parameters were presented to the workshop participants (Table H.1). Of those, six parameters received $\geq$10 total ranks, and nine parameters did not receive any ranks. Among the top-ranked parameters in the first ranking group (landscape pattern, water, and vegetation), depth to shallow groundwater received the most ranks (*n* = 13), followed by land cover (*n* = 10), and mesoriparian vegetation (*n* = 9). In the second ranking group (vertebrates), abundance and occupancy of fishes received the most ranks (*n* = 11), followed by abundance and occupancy of songbirds, predators, and ranid frogs, which each received 10 ranks. It is interesting to note that while the total number of ranks was similar among vertebrate parameters, fishes and predators each received five #1 rankings (i.e., a total of five participants each considered fishes and predators to the most important vertebrate monitoring parameter), while songbirds and frogs each received only two #1 rankings. Similarly, land cover received three fewer total ranks compared to depth to shallow groundwater, but land cover received six #1 rankings and three #2 rankings. These rankings and narrative responses will further inform the next phase of the program's development (see Chapter 3).

Table H.1. Narrative and ranking results from the Manager's workshop, Pima County Ecological Monitoring Program, November 17, 2006. Workshop participants (P) ranked the most important parameters that were provided by subject-matter workshops. Managers ranked the five most important parameters for landscape, vegetation, and water (Ranking Group 1) separately from the five most important parameters for vertebrates (Ranking Group 2). Climate parameters were excluded from ranking because this information will be an assured component of the monitoring program.

Ranking Group	Subject Group	Parameter or species group	Narrative Responses	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Total number of ranks
1	Landscape	Land-cover	P1: Gives best snapshot of regional landscape-level habitat changes. Can trigger broad policy/ordinance management planning. Can impact multiple species. P2, P9: Informs conditions of land and determines where management should occur. P5, P12, P3: Fragmentation issues are important and increase with roads. P10, P9: Informs acquisitions and permit compliance. All land management agencies could use the information. P7: Affects viewshed. P15: Can be linked as causative factor in changes to other elements. P3: Good example of importance of linkages is in the Town of Marana between the Tucson and Tortolitas Mountains.	6	3			1	10
		Upland Vegetation Formation	P4: Permeability of wildlife movements can be assessed. P10: Informs acquisitions and permit compliance. P9: Conversions are important for managers, but analysis, particularly edge definition, has been problematic to define in past efforts.	2			1	1	4
		Greenness Index	P4: Very difficult to get in desert systems and difficult to compare NDVI between different images.			1	1		2
		Land Use	P2: Informs where management should be focused and where development will occur. P5: Maintaining open space should be priority. Can be used by managers to limit impacts by providing for corridors. P15, P13: Information leads to good tools for regulation. P9, P13: Good leading indicators of expected future impacts. Best done at regional level with other land managers.	1	1	2		1	5
		Fire	P15: Only useful if linked to upland vegetation formation. Affects aquatic health.						0
	Vegetation	Perennial species: mesoriparian	P1: General indicator of water-quality issues. Important to broadest list of species. P4: Important to many desert fauna for breeding/cover/movement corridors. P12: Must focus on communities that are limited and provide habitat for so many species.		1	5	2	1	9
		Perennial species: semi-desert grasslands	P7: All perennial communities: establishes health of system. P11: Important for grazing- an important concern for the County. P12: Grasslands seem more sensitive to change than S.D. uplands			3	2	1	6
		Perennial species: Sonoran Desert uplands				2	1		3
		Exotic, invasive species	P5: Change in community dynamics will affect vertebrate populations. P15: Think about non-native invertebrates as well. P3, P9: Good parameter for management action (removal) before major infestations happen.	1	1		1	3	6

Ranking Group	Subject Group	Parameter or species group	Narrative Responses	Rank 1	2	3	4	5	Total number of ranks
1 (cont.)	Water- Geomorphology	Channel cross section, etc.	P15: If sampled extensively enough, can locate offending portion of drainage system.			1		3	4
		Planform analysis	P15: Analysis will pinpoint source(s) of watershed stressors. P13: Leading indicator of impacts from humans due to bank protection. Potential for restoration.				1	1	2
	Water Quality	Field parameters	P4: These parameters fluctuate daily (i.e., they are problematic).						0
		Nutrient loading	P15: Only useful where there is a potential for input of excessive nutrients.						0
		Pollutant metals							0
		Algal blooms	P15: Too ephemeral to monitor.						0
	Water Quantity	Streamflow extent and/or persistence of flow	P2, P11: Directly relates to aquatic/riparian habitat availability. P15: Can help locate core habitat areas- highest priority for conservation. P8: Development impacts may be revealed in this parameter. P3: Link to water rights. P9: Great use of citizen volunteers. Great parameter for assessing a wide range of stressors. Important to tie to groundwater.		3	1			4
		Streamflow discharge- natural streams and springs	P10: Informs acquisition of water rights. P15: Essential for filing for surface water rights and for showing harm from adjacent pumping.		3			2	5
		Ephemeral pools- volume and persistence	P11: When, how much, and the amount affects ecosystem more than other parameters.	1					1
	Water- misc.	Depth to shallow groundwater	P1, P2, P3, P13: Influences a wide range of plants/animals/land uses. P5, P10: Good for informing management- for developing thresholds and triggers. P10: Informs acquisition or defense of water rights. P14: Should inform management, but few examples of this type of adaptive management exist in region. P15: Should be done jointly with streamflow extent. P12: All future development and conservation efforts rely on this necessary component for life. P9: This is the parameter that “binds” many other parameter together (i.e., critical linkage).	4	4	1	4		13
		Macroinvertebrates	P1: Easy to do, good trigger, gives general water quality. P4, P5: indicates water quality. P15: May not be sensitive to changes in warm-water ecosystems.			1	1	2	4
	Other	Disturbance	P7: Very informative for rapid response to threats.		1				1
2	Fishes- abundance	All fishes	P3, P8, P13: Linked to many parameters in water, vegetation. P6, P9: Changes easily figured and implicate changes in water parameters. P10, P13: Covers numerous species, most of which are threatened. Will inform the need for restoration.	5	3	2		1	11
	Amphibians- abundance	Frogs	P1, P3, P5, P10, P13: Represent species that are sensitive- indicators of changes to aquatic systems. P9, P13: Abundance and occupancy of exotics is critically important to natives. P10: Good group for restoration efforts and reintroductions. P14: Coordinate with existing Game and Fish monitoring.	2	6			2	10

Ranking Group	Subject Group	Parameter or species group	Narrative Responses	Rank 1	2	3	4	5	Total number of ranks
2 (cont.)		Toads and spadefoots		1					1
	Reptiles-abundance	Nocturnal Reptiles	P8: Catches unique habitat types such as soil types, but not as closely tied to vegetation components.			1			1
		Diurnal lizards and snakes						1	1
		Mexican garter snake							0
		Box turtle							0
		Desert tortoise	P9: Very important for the BLM. P13: Declining because of habitat loss. P14: Long-lived species that are affected by fragmentation. Game and Fish does some monitoring in the County- should coordinate efforts.			1	1	3	5
	Mammals-abundance	Predators	P3, P8, P9, P10: Good indicator on system level; need large areas. Expensive to monitor? P5: Mesopredators- indicate prey base. P6: Iconic species susceptible to lots of impacts. Umbrella species. P8: Especially useful indicator along urban/rural fringe. P13: Public appeal, even if they are less significant than other species.	5	1	1	1	2	10
		Bats	P1: Good indicators, sensitive to habitat changes- triggers. P9: Bat roosts (caves and mines) are very important management issue. P10: Covers many Priority Vulnerable Species. P13: Important for insect control. P14: Game and Fish has working group to develop monitoring plan.		2	1	3		6
		Small mammals-Occupancy/abundance					1		1
	Birds-abundance	Songbirds	P1: Suggest separating species to guilds. P4, P5: Residents only or (P7) at least separate out neotropical migrants and residents. P6: Gives information on larger landscape. P9: Good group for restoration efforts due to responsiveness (especially residents spp.). P10: Good indicator of vegetation/habitat health. Lends itself to citizen science efforts (P14). Species composition informs of relative impacts along urban/rural gradient.	2		5	3		10
		Diurnal raptors	P8: Mortality related to development, also disease from contact with urban birds.			1	1	2	4
		Nocturnal raptors and nightjars			2				2
		Hummingbirds							0
		Ducks and waders	P14: Arizona Game and Fish developing monitoring plan.				1		1
2 (cont.)	Birds-reproductive success	Songbirds					2		2

Ranking Group	Subject Group	Parameter or species group	Narrative Responses	Rank 1	2	3	4	5	Total number of ranks
		Diurnal raptors				1	1		2
		Nocturnal raptors and nightjars							0
	Small Mammals	Diversity, evenness, community composition						1	1

H.3 Workshop Meeting Notes

Present: Julia Fonseca, Neva Connolly, Brian Powell, Aaron Flesch, Bill Shaw, George Ruyle, Trevor Hare, Mike Ingraldi, John Windes, Cathy Crawford, Shawn Lowery, Sherry Ruther, Kerry Baldwin, John Sullivan, Locana de Souza, Rafael Payan, Jennifer Christelman, Kathleen Kennedy, Scott Birkenfield, Karen Simms, Jeff Simms, Darrell Tersey, Ann Phillips, Sherry Barrett, Scott Richardson, Colby Henley. See Appendix C for affiliations.

H3.1 Agency Roundtable: Management issues and stressors; current monitoring efforts.

- Trevor Hare/Coalition for Sonoran Desert Protection:
    - Motorized recreation,
    - Aquatic invasives,
    - Monitoring= mapping of closure of roads.
- Mike Ingraldi & John Windes/Arizona Game and Fish Department:
    - Linkages between open space (bighorn sheep, etc),
    - Off-highway vehicles,
    - Grazing that affects game/nongame (State lands),
    - Development pressures (Elimination & Fragmentation of habitat),
    - Riparian restoration (coordination between agencies – stop reinventing wheel, learn from each other),
    - Comprehensive Wildlife Conservation Strategy:
        - State wildlife grants,
        - Wildlife Action Plan – Wildlife 2012 =Monitoring goals with Fed funds/grants,
    - Introduced idea of triggering mechanism to implement some management response and avoid endless monitoring/collection of data.

- Jeff Simms/Bureau of Land Management:
    - Monitoring – mostly using up/down or trend methods (Gila topminnow [catch per unit effort-trend/not looking for subtle changes because it is a r-selected species-looking for order of magnitude changes] quick, affordable method. No time to tighten up method – need to balance limited time/resources for both monitoring and management,
    - Example = Fish threshold – Arivaipa creek – 2 T/E fish species impacted by several nonnative species –What would the threshold be to trigger management action? No consensus because concern that cure could be as bad as disease. Got stuck in just tracking but no step toward management response,
    - Comment on graphic in introduction suggesting a feedback loop from Vertebrates to Water/riparian resources (e.g. cattle grazing/beaver impacts to riparian areas [Cienega Creek]),
    - Aquatic Invasive/Nonnatives:
        - Introductions from adjacent developed area (bullfrogs, aquatic disease),
    - Unsustainable water extraction (problem of common property resource),
        - Surface water won't last except in topographically undevelopable areas,
        - May require legal action to maintain surface water for T&E species.
- Karen Simms/Bureau of Land Management:
    - Working with TNC to tweak current system to better detect changes and inform management (15-20 yr datasets),
    - Upland – change data collection to inform shrub reduction program,
    - Upland – change range transect intensity to better detect changes with minimal increase in effort,
    - Upland/Las Cienegas – inform stocking rate changes each yr (influx of annuals),
    - Riparian/aquatic – no livestock on creek 95-98 = even age stand of riparian trees, high density/shading (once some trees out compete, will

change to fewer taller trees with more incidental light. Leaf litter reducing oxygen – drop in Gila topminnow, now looking at management to counter tree density – beaver?

- Monitoring Weaknesses/Gaps:
  - Not much groundwater monitoring (only on SPRNCA),
  - Recreation impacts,
  - UDA/Border impacts-no standardized monitoring,
  - Bullfrog and upland vegetation changes – need to coordination with surrounding land owners/agencies,
  - Sharing/partnering with other agencies:
    - Using trained citizens for monitoring,
    - Photopoints,
    - Wet/dry monitoring,
    - Invasive species inventory,
    - More trained volunteers for upland vegetation monitoring.

- Scott Birkenfield/Bureau of Land Management:
  - Development/urban interface (unknown what predicted visitation will be),
  - Access to critical areas (OHV),
  - Many resources are being taken up by illegal immigrant control,
  - Disease/Invasives (Big horn loss to disease),
  - ID Potential Acquisitions,
  - Education of users in partnering to take action,
  - Need to protect funding/priority of monitoring over the long-term as personnel and agency priorities change.
- Kerry Baldwin/Pima County Natural Resources, Parks & Recreation:

    - o Lack of data on newly acquired lands (30,000 acres fee/100,000 acres of grazing lands in last couple months),
    - o Water use/surface water sustainability (use of natural spring water for grazing. Acquisition to protect water drainages. Balancing all users needs,
    - o Vegetation – conversion of grasslands to shrub/woodlands, plant diversity changes at smaller scale, invasive species,
    - o Public uses – social issue, undocumented migrants, off-highway vehicles.
    - o Agency Cooperation/Relationships – Social measures -how well the various players work together/cooperate. (Suggestion to Brian-this effort needs to be integrated with social monitoring because it does impact environment),
    - o Monitoring:
        - ▪ Some data exists on ranches, but not being used, also need to bring historic owners up to speed on monitoring approach/value.
        - ▪ Just getting baseline data:
            - Long-term plant transect data,
            - Ocular evaluations by long-term managers,
            - Not ideal but need to address initial issues.

- Rafael Payan/Pima County Natural Resources, Parks & Recreation:
    - o Successional plans for acquisitions – prioritize both site and regional monitoring approach,
    - o Development & Edge effects – pets/lighting etc,
    - o Viewshed protection,
    - o Undocumented migrants (roads/trails are good indicator),
        - ▪ Example at Organ Pipe Cactus National Monument – wildlife movement (walls/barriers), cooperation with law enforcement, off-road pursuits,

- Ann Phillips/City of Tucson, Office of Conservation and Sustainable Development:

  - Challenge of changing something that is incredibly degraded and trying to bring it back,
  - Learned a lot by using what was available and going with the potential of the site, what the land responds to (does it provide wildlife habitat, prevent spread of invasives, stabilize soils). Work with what the land allows; don't get hung up on trying to return to ideal historical condition,
  - Ecosystems are dynamic; don't try to freeze something in museum. OK even if Simpson Farm is totally different 20 yrs from now,
  - Pick your battles with non-natives – which one can you affect with the resources you have? – must consider upstream seed sources,
  - KEY = Site Stewards who have intimate knowledge of conditions, increased perception of changes that periodic monitors may not detect,
  - Water harvesting – lack of supplemental irrigation (requires trade-offs of disturbance) – focuses water and seed pockets,
  - Timing of monitoring/restoration-how do we know when we have enough data to refocus our efforts,
  - Monitoring is important in tracking invasives and rate of spread, possibly using just photo points,
    - Impact of effluent system – unnatural miracle grow with spike of tree growth, then urban flood spikes = increase woody debris and affects to downstream (piling up on bridges).
- Kathleen Kennedy/Town of Marana:
  - Development, open space is mostly on private land, outside control of Town of Marana,
  - How does Marana exert control to maintain wildlife linkages?
  - Wildcat dumping (Tortolita fan),
  - Rate of development – Marana hasn't been able to keep pace with ordinances, policies (no tools for enforcement),
  - Habitat Conservation Plan – keep moving forward,
  - Lack of data,

  - Large part of Town is State Land – brings uncertainty for future.

- George Ruyle/University of Arizona:
  - Livestock impacts,
  - Off-highway vehicles,
  - Drought,
  - We don't know as much as we need to know in vegetation dynamics – especially in relation to drought,
  - Linking long-term data sets to management is harder than it sounds,
  - Linking people with land – education process,
    - Need connection to land, ongoing observations.

- Sherry Barrett/U.S. Fish and Wildlife Service:
  - Invasives – Lehmann's – is it naturalized, worth fighting?
  - Border issues, closing part of refuges to public access,
  - Climate change,
  - Erosion – Brawley Wash,
    - Grants to install 'induced meandering,'
  - Fire Management – invasives, shrub invasions,
    - Need to consider secondary impacts (Pima pineapple cactus, riparian areas, pygmy-owl habitat).

PARAMETER REVIEW/DISCUSSION (Landscape, Vegetation, Water, Disturbance)

<u>Question and Answer, Comments</u>

- MSCP – list of unforeseen/unknown issues – needs to feedback to Pima County EEMP
- Discussion of stressors and influence in parameter selection:
    - Does this parameter inform/trigger/change mgt on the ground – feedback loop?
    - Does the parameter inform me about more than one system/function?
    - Ann- Cost Effectiveness – how frequently does it need to be done, is it one-time or ongoing, can volunteers do the work?
    - Sherry- parameters that detect change and then guide further research to determine causation.
    - Condition = deviation from optimal – but first need to know what that is (baseline), example – mule deer browse, is there enough – what do we need?
    - Define Upland vegetation formation? – forest, woodland, shrubland, grassland, desert = broad structural formation.
    - Why only upland and not riparian? Response: Because in riparian systems, need to know more composition/species info
        - Next step down included floristics.
    - Land cover type vs. Land Use.
        - Cover type is current use, land use from zoning is potential future use.
- Difficult to choose rank without knowing cost/feasibility,
    - Don't emphasize cost too much, choose based on ecological relevance etc.
- Potential or desired future site conditions? Not something you measure, instead it is a goal. Probably applied more at a site-specific level. Not necessarily

something that is applied or determined at a landscape level. Need to set the goal so that we know (through monitoring) when we've succeeded.

- Water:
  - Geomorphology/channel morphology (done in the field) – down cutting, erosion = watershed erosion, flooding peaks etc.
  - Planform analysis (done with aerial photo) – channel meander = encroachment
  - Was geomorphology of springs considered?– Looked at if they are working properly (flowing), water quality, persistence of flow (but not currently listing impacts to springs [naturalness vs. boxing]).

Review of Evaluation Criteria

1. Value of parameter in detecting/tracking changes or trends,
2. Broad application to multiple ecosystem functions or systems,
3. Does parameter trigger initial management action,
4. Does parameter influence change in current management actions?

Chosen Parameters: 5-dot exercise (See Table H.1 for Results).

- Land Cover:
  - Sherry- inform land acquisition and permit compliance,
  - Rafael- Some satellite data may already exist and may establish baseline for existing conditions,
  - Karen- info that all the agencies could use.
- Depth to Groundwater:
  - Karen- without it, not much else would be here,
  - Sherry- Would inform acquisition of and defense of water rights,
  - Jeff- Has a lot more strength/validity when tied to discharge and streamflow persistence:
    - Water rights, legal protection.

- Mesoriparian Vegetation:
    - Karen- many species in MSCP are dependent upon riparian systems.
- Uplands-Perennial Vegetation:
    - Combine Sonoran Desert and Grassland (due to invasives, Sonoran Desert almost as endangered as grassland).
- Macroinvertebrates:
    - Kerry- easy parameter to collect and quick indicator of change – high value, could include use of citizen science – also can be coupled with other data collection efforts,
    - Can also point to other things, air etc.,
    - Alternative to monitoring nutrient loading/metals etc.,
- Streamflow extent:
    - Ann- both decrease (from development use) and increase (from ‘development discharge’).

VERTEBRATE PARAMETERS

Question and Answer, Comments

- Mike Ingraldi- Why diurnal raptor productivity? – adult female survivorship is more meaningful:
    - Response: bird group thought that would be too expensive.
- Trevor - Does this list include T/E species surveys?
    - Response: No, those will be done separately.
- Sherry- if PC can show that listed species are adequately monitored in overall monitoring, no need for individual species protocol surveys.
- Need to show tie/validation between landscape level monitoring and species level for MSCP species to make sure it has value.

5-dot exercise (See Table 2 for Results)

- Fish:

  - Assumed.
- Frogs:
  - Trevor- natives in trouble; bullfrogs.
- Mexican Garter Snake:
  - In more trouble than frogs, but probably not as many votes as frogs because it's a single species.
- Desert Tortoise:
  - Long-lived, susceptible to disturbance – good indicator species.
  - Iconic of Sonoran Desert.
  - Broadly distributed.
- Predators:
  - Karen- important to guide connections/linkages, acquisition.
  - Rafael- high public value.
  - Brian- Low-tech monitoring methods, citizen science.
- Bats:
  - Sherry -Covers many of the MSCP species, can't capture this in the other parameters (lack of info on roosts etc),
  - Karen- high priority for BLM because they have many abandoned mineshafts/roosts,
  - Kerry- proposed to have Species-Specific management plan under MSCP.
- Songbirds:
  - Karen- get info on a lot of different scales, and can get info on many species at once.
- Riparian Raptors:
  - Trevor- Can these be broken out? – grey hawks, black hawks.

- Diurnal Raptors:
    - Darrel – Citizen science, easy to monitor, some species urban adapted and some open adapted – can inform about urban encroachment.
- Ducks & Waders:
    - Brian- low priority because not many natural environments in PC.
- Diurnal lizards/snakes:
    - Trevor – lizards/snakes as indicators,
    - Kerry – what do they trigger or tell us?
    - Jeff – large variety-can tell us many different things.

Upcoming Monitoring Initiatives/Activities/Meetings (FYI)

- Trevor- State Park NAPAC
    - San Rafael State Natural Area – Conservation Area Monitoring.
- Ann- Photo monitoring points.
- Karen- Regional Monitoring program – Sonoran Institute/National Parks – Las Cienegas focus:
    - Cienega Watershed workshop – broader focus beyond just BLM lands,
    - Atlas of information/studies & monitoring efforts & results =Jan-Feb 2007?
- Scott/BLM- Dec 5-6 – discussion of land acquisition, conservation easements, habitat conservation, reviewing what other agencies are doing to protect habitat etc.
- Trevor- TNC Land Trust- Habitat Protection Priorities – southern Arizona.
- Cathy/Brian- AGFD Coordinated bird monitoring:
    - Common methodologies, database.
- Kerry- Upland, Riparian, & Bats = overarching management for PC lands under MSCP:

- AGFD LLNB coordinated roost survey,
- See what's being done and complement that effort,
- Cooperation from all agencies providing one person to contribute to a team effort.

- Sherry- As process develops, continue to brief agency leads on this program to get their buy-in:
    - Kerry- Develop Comprehensive Resource Monitoring Plan to compliment CRMP.

APPENDIX I

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Sampling Design Primer

I.1 Sampling Design Basics

The general goal of monitoring is to determine the status and trend of resource conditions over time, yet it is rarely possible to survey all resources of interest due to financial or logistical limitations. To increase the efficiency of monitoring, efforts must employ *sampling,* which is the process of selecting units from a larger population so as to draw inferences to it. The method of selecting where and how often to sample is referred to as *sampling design*; these choices ultimately determine the power and precision, spatial and temporal inference, and overall cost of a monitoring program.

This appendix provides a brief overview of sampling design considerations for the Pima County EEMP. Specifics about where to sample each parameter are essential components of a good monitoring protocol (see Oakley et al. 2003), which will be developed in Phase III (see Chapter 3). More detailed discussions of sampling design strategies and issues are available elsewhere (see Thompson and Seber [1996], Lohr [1999], Morrison et al. [2001], Thompson [2002], listed in the *6.0 Literature Cited* section of this report).

I.2 Sampling Design Considerations: Precision, Bias, and Inference

To determine status and trends in resources over time, there are a number of critical elements of sampling design that must be met. First, a collection of *sampling units,* on which measurements are made, must be drawn from a larger population of interest and each unit must have a known likelihood of being included in the sample. This is known as *probability-based sampling* and it employs a component of randomization in selecting sampling units to ensure that the true value of a parameter of interest is estimated accurately and with a known level of precision. Precision of an estimate, based on these samples, will increase with the number of samples taken and will approach, and eventually converge with, the actual value of the parameter as more samples are taken.

Random sampling allows inference to a larger population from which samples are drawn and estimates the true value of a parameter. Unbiased and precise measurements of a parameter over space and time is critical to estimating trend. While precision is largely a function of variation in a parameter, bias is determined by the spatial sampling design and can only be controlled by using a probability-based design. Another important feature of probability sampling is the ability to draw inference to areas that were not sampled.

Probability-based sampling contrasts with a variety of non-probability based approaches that are often used in ecological monitoring and research because of budgetary constraints or ignorance (Olsen et al. 1999). Subjective approaches include judgment sampling (investigator knows best where sites should be placed), haphazard sampling (any site will be sufficient), and search sampling (historical information narrows range of sites) (Morrison et al. 2001). At best these approaches provide limited information and at worst can lead to erroneous conclusions (Yoccoz et al. 2001). For example, if fish sampling takes place solely in areas that were occupied during previous time periods or that contained a particular habitat feature, no inference can be drawn to areas outside those areas sampled. Perhaps more importantly, any observed changes in the distribution or abundance of the fish may misrepresent those of the population at large.

I.3 Types of Spatial Sampling Designs

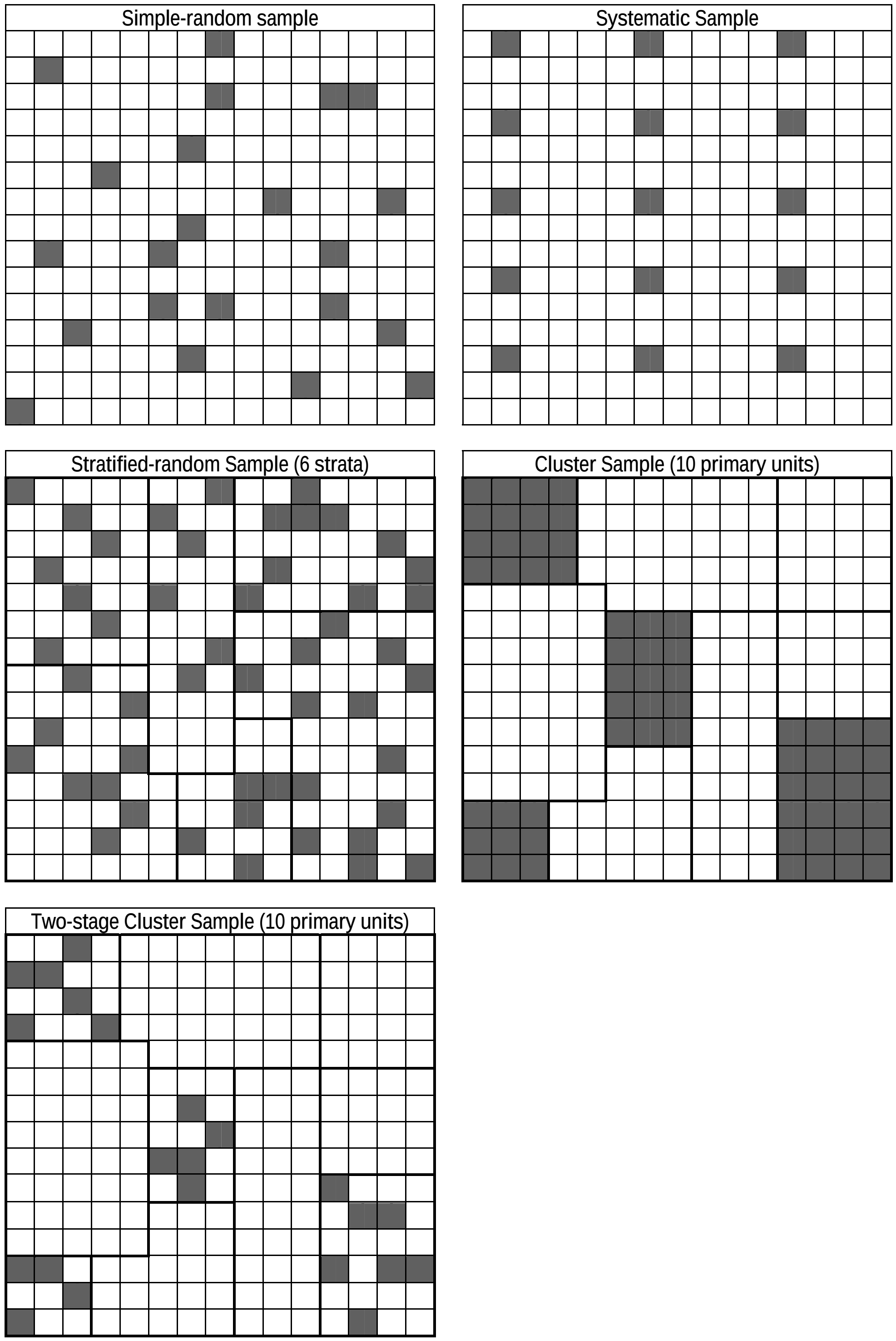
As a result of these considerations, probability sampling will be employed for the Pima County EEMP unless it feasible to sample an entire population. There are many types of designs for probability sampling and the advantages and disadvantages of each are only evident after comparisons among parameters of interest are made. A brief overview of the most common types of spatial sampling designs for monitoring follows (see Figure D.1 for diagram).

Simple random sampling results in each possible sampling unit having an equal probability of being drawn from the population and is the most common probability sampling design. Analyses are simple and there is no need for prior knowledge about the population. Disadvantages are that this design can be inefficient and inaccurate if the population of interest is rare or its distribution is variable (e.g. clumped or restricted).

Systematic sampling is the process whereby one sample unit is selected randomly and additional sample units are selected in a systematic pattern based on the original unit. For example, after a random starting point is determined, every 10th unit could be selected. Systematic sampling has many of the advantages of simple random sampling but with better spatial dispersion. Disadvantages include the same inefficiencies as for simple random sampling and biased estimates if characteristics of interest are aligned or have distributions that are far from random. Systematic sampling may also be imprecise in some situations.

Stratified random sampling invokes a sampling frame that is separated into mutually exclusive subpopulations (strata) that are based on properties thought to drive the distribution of the characteristic of interest. This approach is more complex and requires prior knowledge of the distribution of the unit of interest. Elevation, vegetation community, and soil type are examples of properties often used as strata in ecological monitoring programs. Stratified random designs are used primarily to increase precision and efficiency in estimation yet if strata are incorrectly subdivided these advantages may not be realized. Data analyses are more complicated than simple or systematic sampling.

Figure I.1. Diagram illustrating five of the most common types of probability-based spatial sampling designs. See text for description of each.



Cluster sampling is employed when a resource is rare or spatially aggregated, as is often the case for many plant and terrestrial vertebrate populations. Primary units are chosen randomly and estimated and associated secondary units are sampled thereafter. The primary advantage of cluster sampling is that secondary units are easily accessible and can be surveyed efficiently without the costs incurred during travel. Disadvantages are that analyses are significantly more complicated because the probability that a sampling unit is selected is more difficult to estimate. Further, precision can be lower because fewer primary units may be sampled than in a simple random design. Adaptive cluster sampling can increase these efficiencies because selection of secondary samples are dependent on whether a resource of interest is encountered initially (see Noon et al. 2006 for example).

Multi-stage cluster sampling is similar to cluster sampling in that it involves selection of a subset of secondary (two-stage sampling) or tertiary units (three-stage sampling). It is differs from cluster sampling because secondary or tertiary units are selected at random from within the primary unit. In two-stage cluster sampling for example, the sampling frame in Figure I.1 is divided into 9 primary units, of which four are chosen for sampling. With each primary unit, sampling takes place at between four and seven secondary units. Multi-stage designs have many of the advantages and disadvantages of cluster sampling except the random component for the secondary units allows for greater efficiency.

Generalized Random-tessellation Stratified (GRTS) is a new sampling method that uses a hierarchical randomization process to acquire spatial balance across the sampling frame (Stevens and Olsen 2004, Theobald et al. *in press*). Advantages of GRTS are that sampling units can be added after the initial sample is drawn and spatial autocorrelation can be limited when neighboring samples have similar properties. Key challenges to using GRTS are that it is less intuitive to understand and requires use of sophisticated software.

I.4 Temporal Sampling Designs

Spatial design of a monitoring program provides the framework for which samples are selected and where they are located, whereas temporal design determines when they are sampled. Traditionally, all monitoring sites are surveyed at the same intervals, such as once per year. However, there are advantages to using alternative temporal designs, known as *panel designs* (McDonald 2003). The *panel* refers to a collection of sample units that are sampled during the same occasion, typically a season (Figure I.2). A complete revisit design results in one measurement on the panel each year and an alternative could be a split panel design that results in sampling both the same panel and a new panel each year (Figure I.2). In general, designs that involve multiple panels have advantages over a complete revisit design because they have greater spatial coverage and are more accurate for estimating trends. Careful temporal design can remedy problems associated with an initially poor spatial sampling design (Urquhart and Kincaid 1999). Primary disadvantages are that they are considerably more complex and analyses are still being developed.

Figure I.2. Diagram of the Four Most Common Types of Panel Designs and Revisit Schedules

In these examples, sampling occasions are a single sampling season, so that 20 sites are visited each sampling occasion. Note that the Never Revisit design has an unlimited number of panels whereas in other designs, the number of panels are fixed at 1 (Complete Revisit) or 10 (Repeating Panel and Split Panel). Other variations are possible (see Larsen et al. 1995, Larsen et al. 2001, Kincaid et al. 2004).

Complete Revisit										
	Sampling Occasion									
Panel	1	2	3	4	5	6	7	8	9	10
1	20	20	20	20	20	20	20	20	20	20
2										
3										
4										
5										
6										
7										
8										
9										
10										

Repeating Panel										
	Sampling Occasion									
Panel	1	2	3	4	5	6	7	8	9	10
1	10					10				
2		10					10			
3			10					10		
4				10					10	
5					10					10
6	10					10				
7		10					10			
8			10					10		
9				10					10	
10					10					10

Never Revisit										
	Sampling Occasion									
Panel	1	2	3	4	5	6	7	8	9	10
1	20									
2		20								
3			20							
4				20						
5					20					
6						20				
7							20			
8								20		
9									20	
10...										20

Split Panel										
	Sampling Occasion									
Panel	1	2	3	4	5	6	7	8	9	10
1	10	10	10	10	10	10	10	10	10	10
2	5					5				
3		5					5			
4			5					5		
5				5					5	
6					5					5
7	5					5				
8		5					5			
9			5					5		
10				5					5	

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APPENDIX J

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Examples of Conceptual Models

The majority of effort in Phase II will be in estimating cost and optimizing sampling design choices. Complementing this process will be assessment of relationships among parameters and their application for determining trends and triggering management action. Conceptual models can integrate existing knowledge, establish relationships among system parts, and identify uncertainties. Three main types of conceptual models should be developed in Phase II. First, a *control model* details current understanding of how ecosystems operate and illustrates key processes, interactions, and feedbacks (Gross 2003; see example in Figure J.1). These models typically lack an element of time and therefore do not convey how the same ecosystem can have multiple "states." Rather, *State and transition models* are used to convey these processes; they are simple box and arrow diagrams that show known or likely system assemblages and responses to changes over time (see example in Figure J.2). State and transition models will be particularly useful in conveying processes of interest to the STAT, such as conversion of Sonoran Desert uplands to exotic "Savannah" grassland; shrub

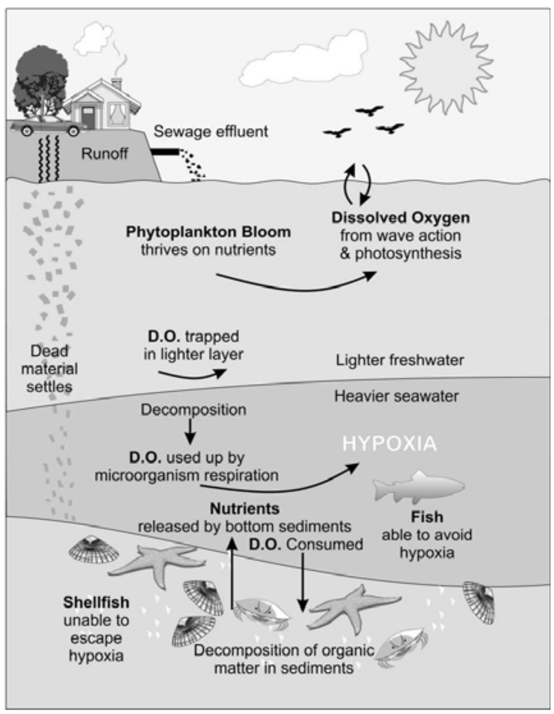

Figure J.1. Example of a control model showing effects of dissolved oxygen (DO) in estuarine ecosystems (from Kurtz et al. 2001). This model highlights the role that management can play in affecting trends—in this case by controlling the amount of effluent that influences DO. These models are also excellent communication tools to inform the general public and policy makers.

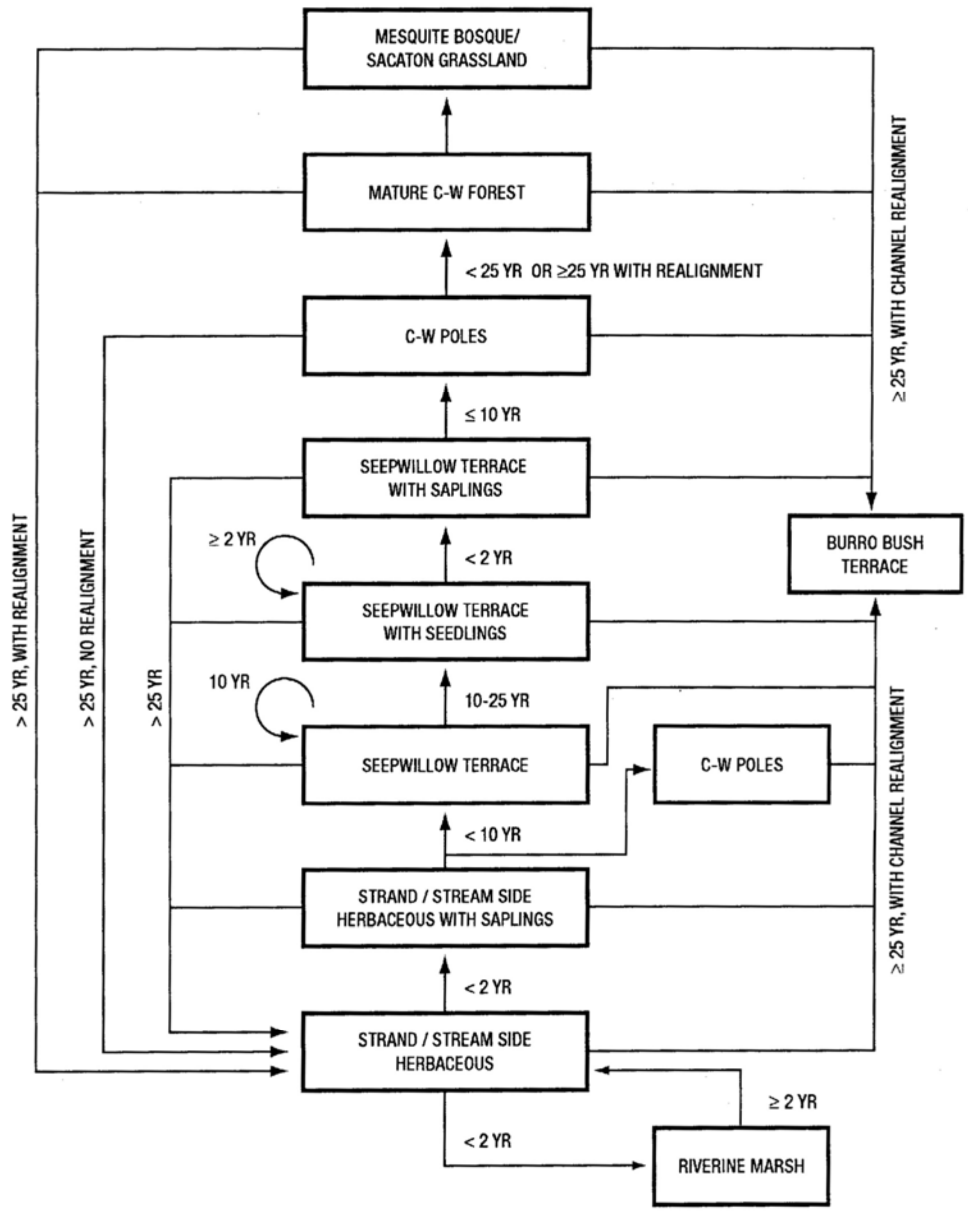

Figure J.2. Example of a state and transition model for riparian systems of southern Arizona (from Gori 1996). State and transition models are useful for predicting future conditions and therefore are especially useful in planning restoration efforts.

encroachment on semi-desert grasslands, and groundwater decline and riparian ecosystems, etc. Finally, a *stressor model* identifies known sources of stress or management actions and the parameters likely to respond to them (see example in Figure J.3). Pima County has already developed some conceptual models and synthesized current knowledge. An example of this is a study on the water quantity requirements of mature riparian forests (Pima Association of Governments 2001).

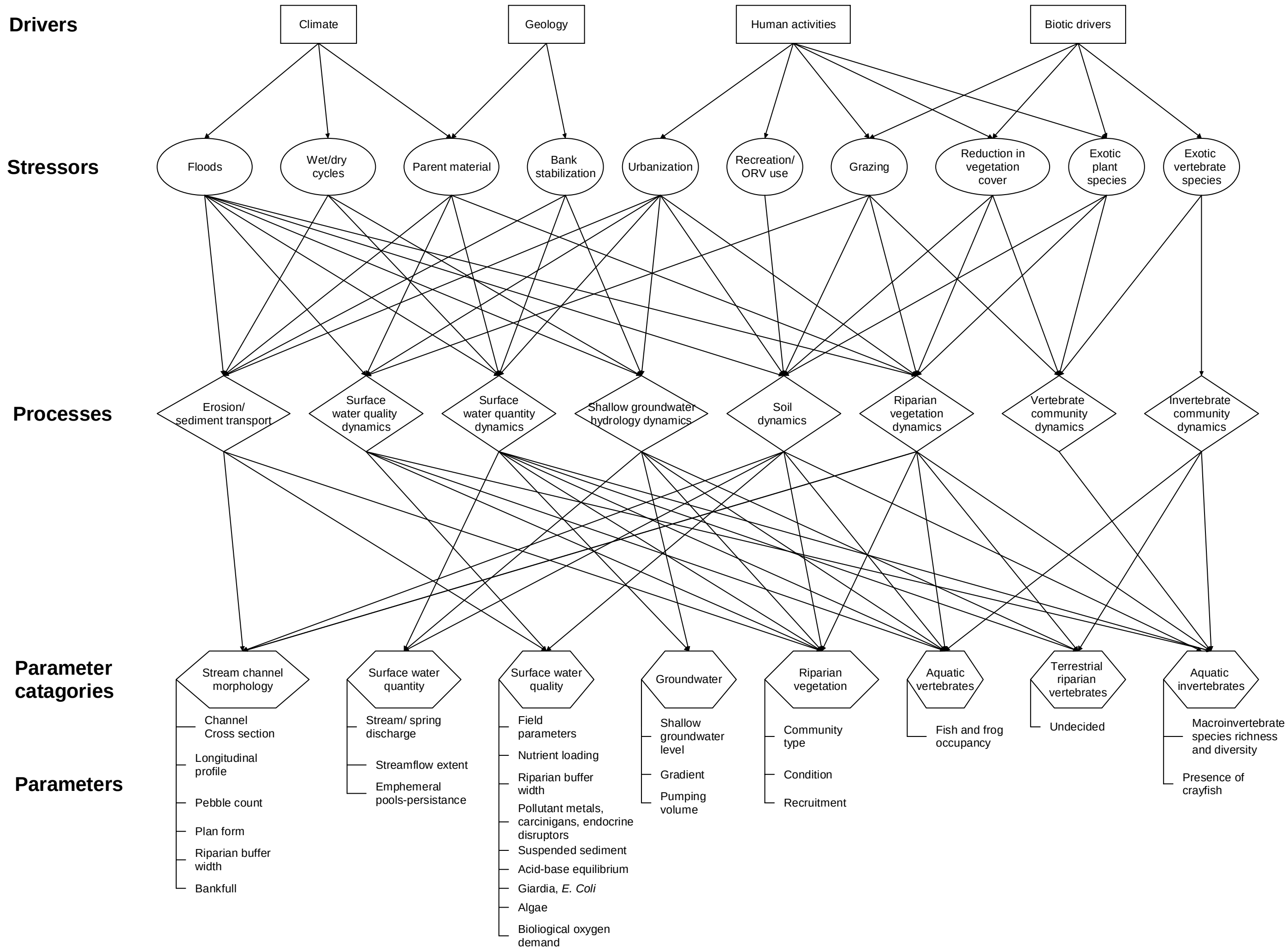

Figure J.3. Example of a stressor-based conceptual model of riparian ecosystems in Pima County. Models such as this are useful for identifying the most promising parameters for monitoring. This model will link to an upland ecosystem model that will include land use, upland vegetation, disturbance events, and social parameters.

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