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11

MAPPING BIODIVERSITY METRICS REPRESENTING ECOSYSTEM SERVICES AT THE LANDSCAPE SCALE IN THE AMERICAN SOUTHWEST

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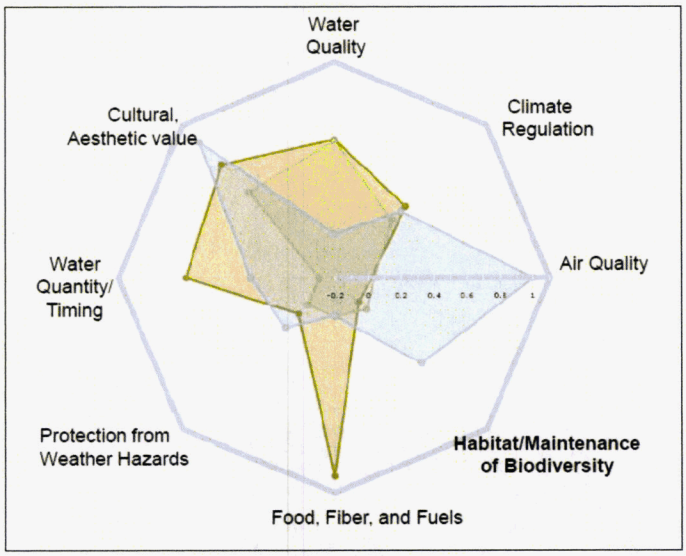
Photo by Adriel Heisey

EPA Atlas Vision/Implementation



- Contain series of clickable background maps
- Select ecosystem services from Table of Contents
- Allow "stacking" of multiple services
- Multiple metrics for each category
- Ancillary data
- Include potential and future scenarios
- Allow user to place their "area" in context of others

Page 3 of the PDF

Evaluation Factors for Selecting Indicators

- **Focus on Clients,**
  - *e.g.* FWS, BLM, USFS, & State departments of environment and natural resources (State & Tribal Wildlife Grants Program- $90M in FY10)
- **Include decision makers**
- include a **suite of indicators** to inform tradeoffs
- **Select scale** best needed to inform the decision
- select & evaluate within the **timeframe** needed to inform decision
- select indicators that can **easily be interpreted by non-scientists**

W. Munns, April 2010

Page 4 of the PDF

Scaling of Services

Objective

Develop and produce maps of an ecosystem service (e.g., habitat provisioning…a surrogate measure of biodiversity) based on current condition and available data for place-based, regional, and national scales of interest.

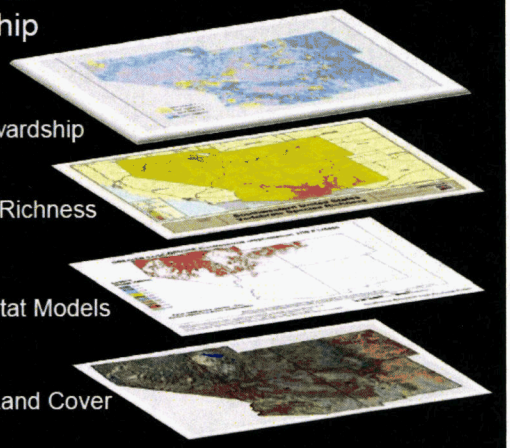
Page 5 of the PDF

Gap Analysis Products and Data Sources

(Southwest Regional Example)

Available Data

- Land cover dataset
- Terrestrial vertebrate models
- Land ownership/stewardship



Page 7 of the PDF

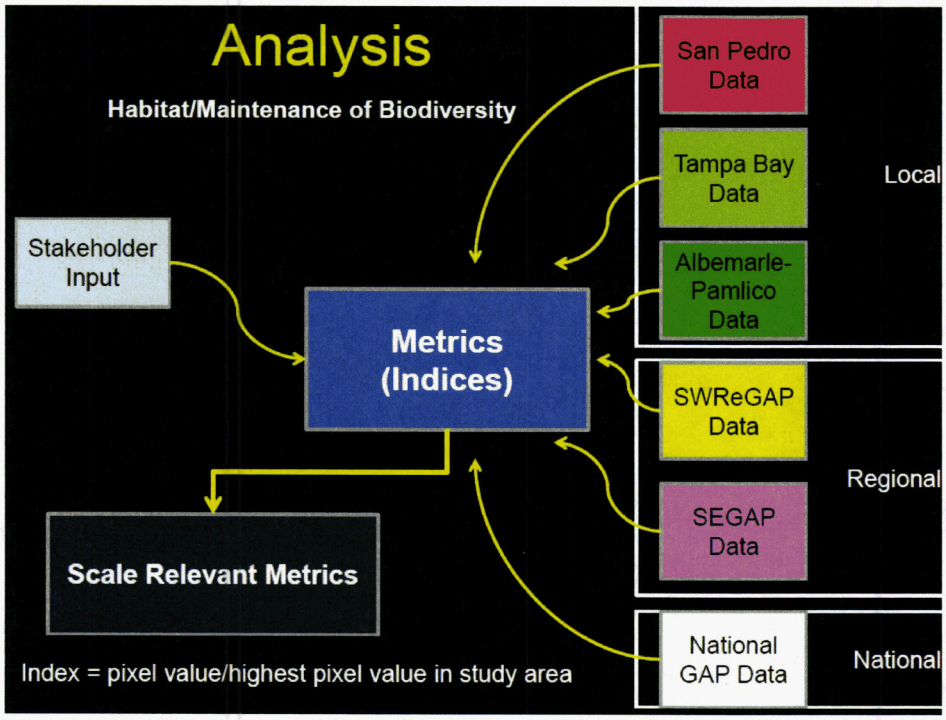
Metrics to Measure Biodiversity

Outcomes of joint EPA/USGS/FWS Workshop on Biodiversity/Habitat Metrics (Oct. 2009, Reston, VA)

Category
Recreational Hunting
Wildlife –cultural, spiritual, intrinsic
Biodiversity for its intrinsic value, ecosystem resilience
Species Composition Intactness
Rarity/scarcity of ecological systems

Terrestrial Vertebrates	Species of Greatest Conservation Need	Harvestable Species	Ecological Systems (Land Cover)
All Species	All Species	Big Game	Richness/Diversity
Amphibians	Amphibians	Upland Game	
Birds	Birds	Furbearers	
Mammals	Mammals	Waterfowl	
Reptiles	Reptiles		
Bats			
T & E Species			

Page 8 of the PDF



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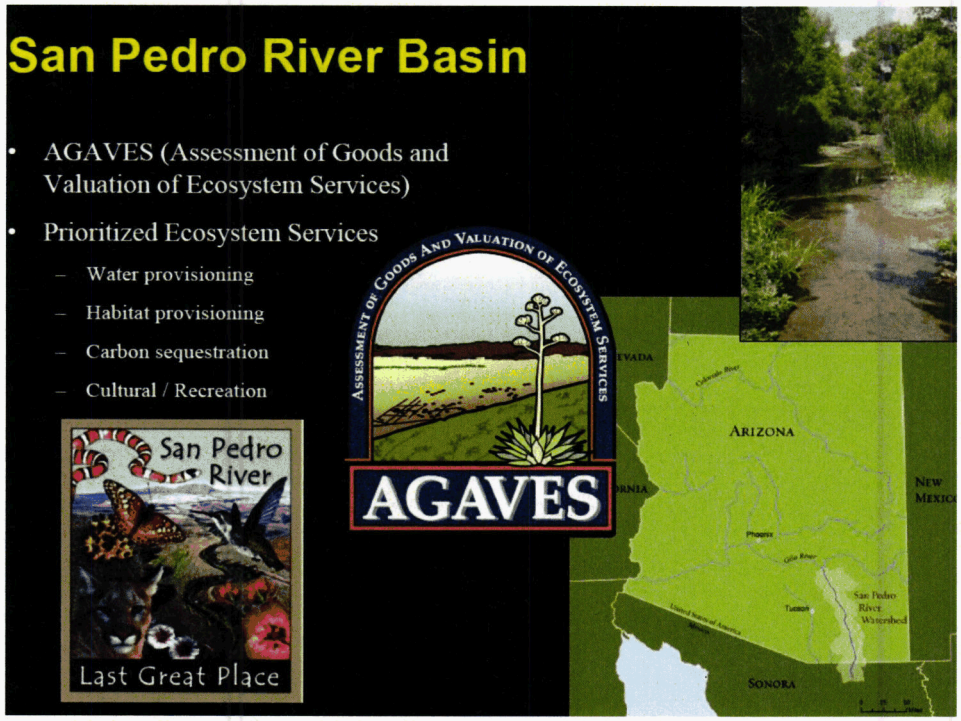

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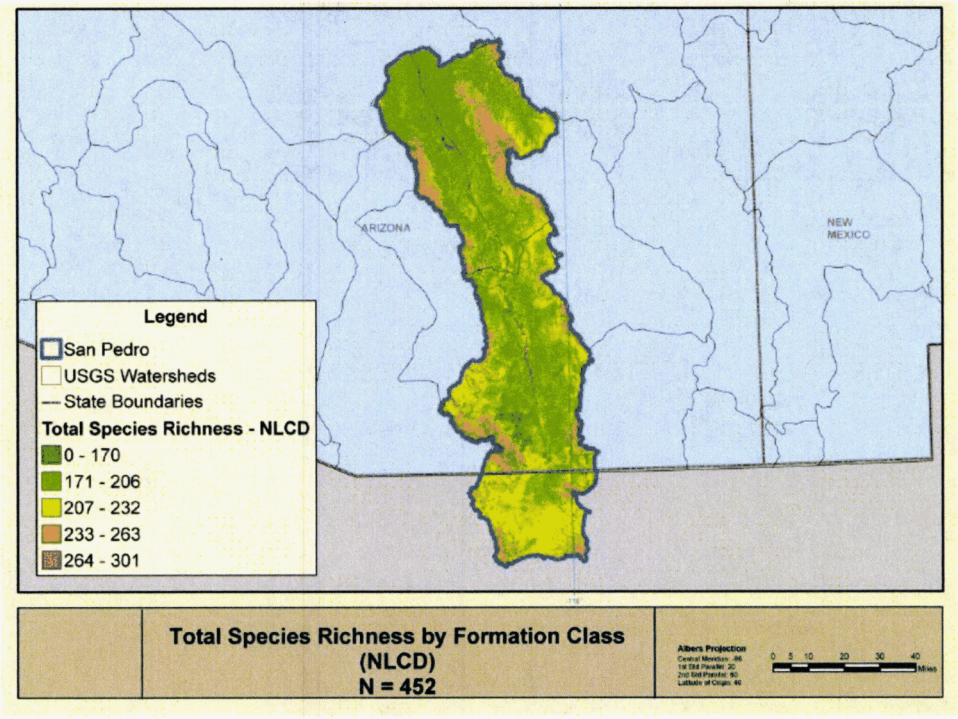

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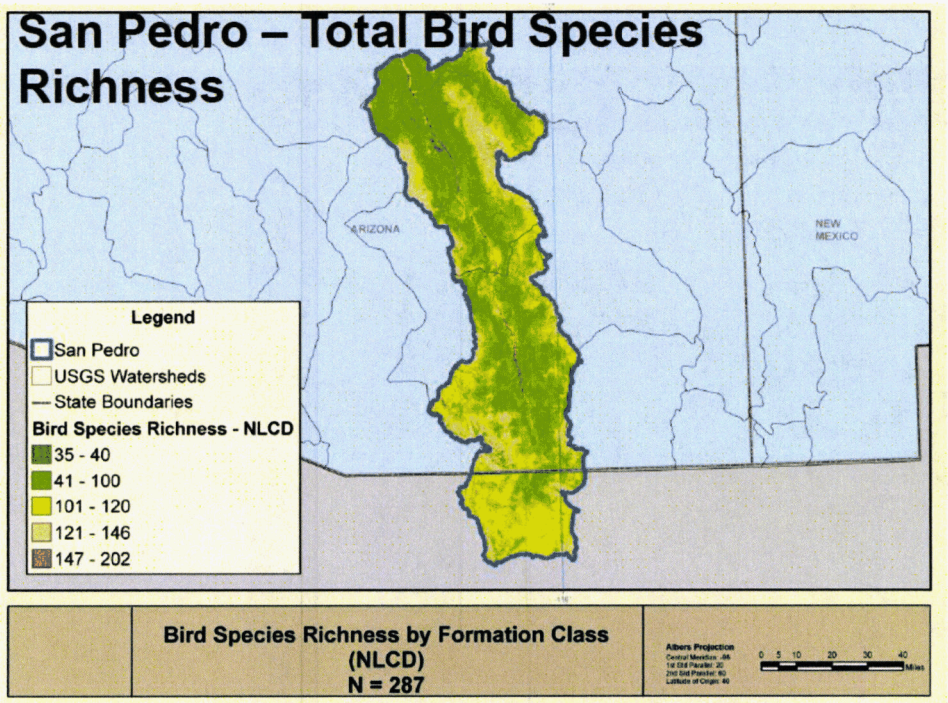
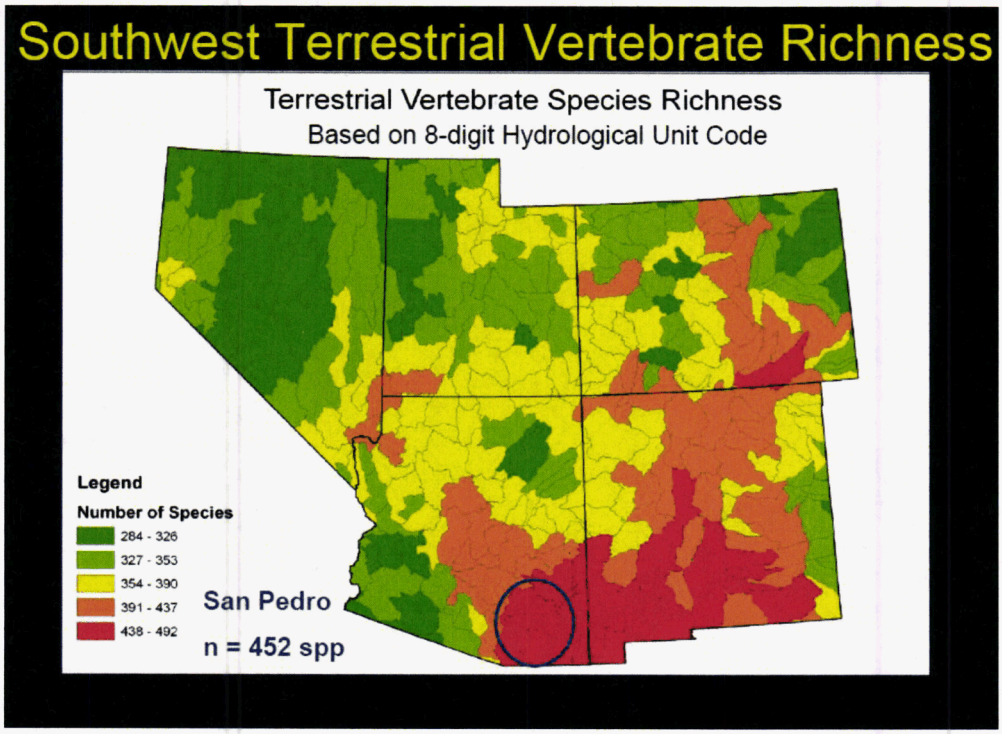


Page 13 of the PDF

	Number of Species					
Formation (NLCD)	Total	Amphibians	Birds	Mammals	Reptiles	Areal Extent
Barren Lands	107	3	35	43	26	
Evergreen Forest	263	3	146	74	40	18.2%
Deciduous Forest	104	0	68	32	4	
Shrub/Scrub	206	6	96	76	45	49.4%
Grassland	232	5	102	80	45	27.8%
Woody Wetland	301	6	202	61	36	1.3%
Emergent Wetland	149	3	108	35	3	
Barren Lands	149	3	108	108	3	
Urban/Agriculture	170	1	131	33	7	
Water	94	2	79	12	1	
Total	452	16	287	88	61	

Page 14 of the PDF



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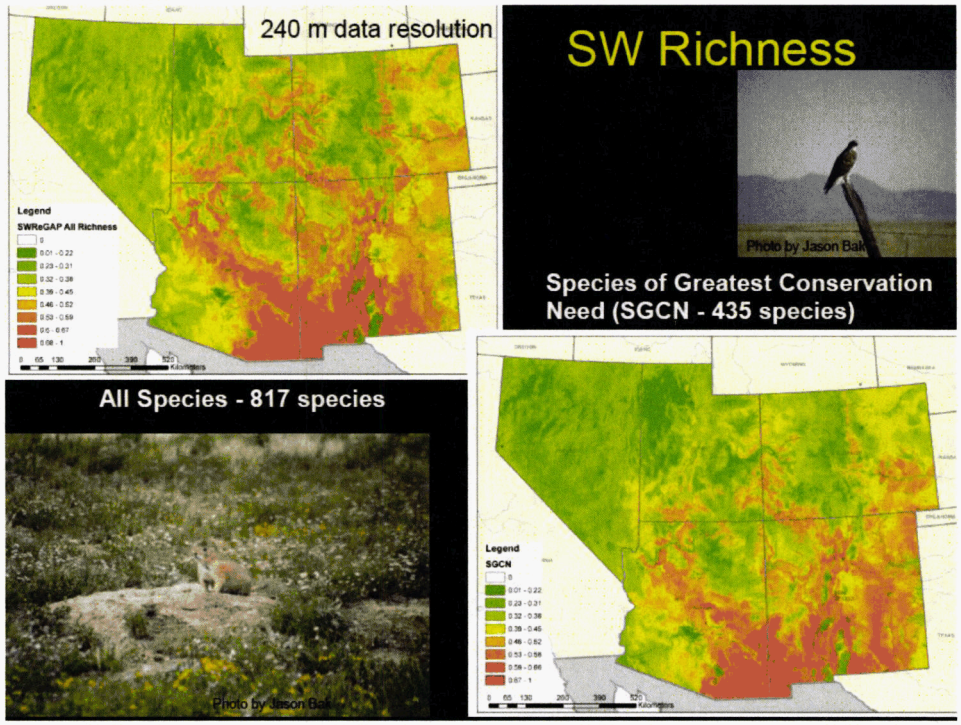
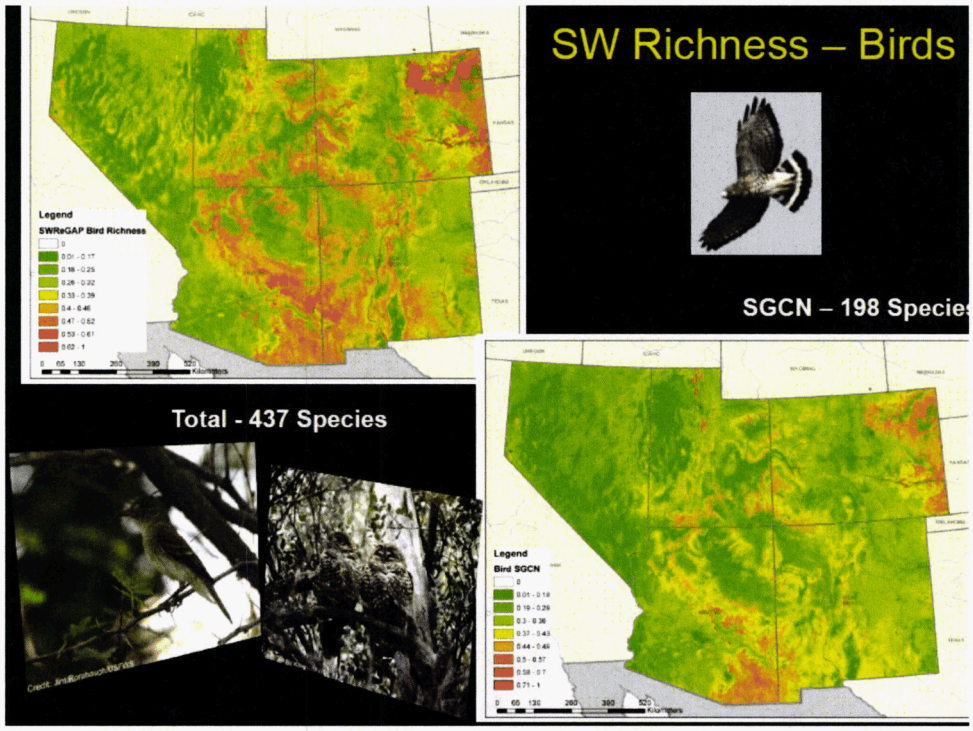
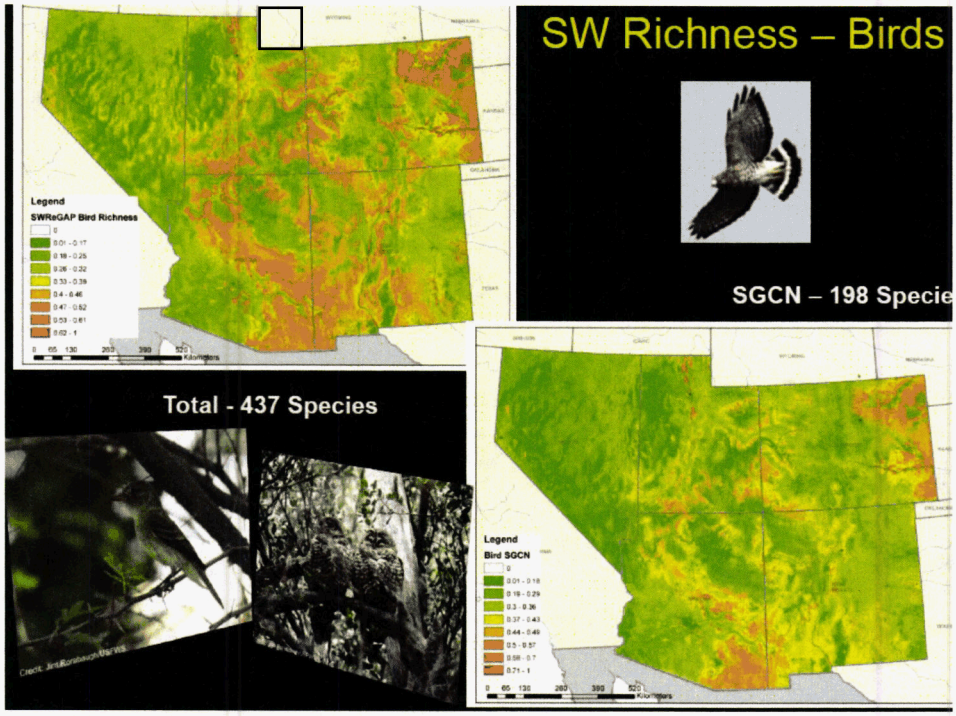
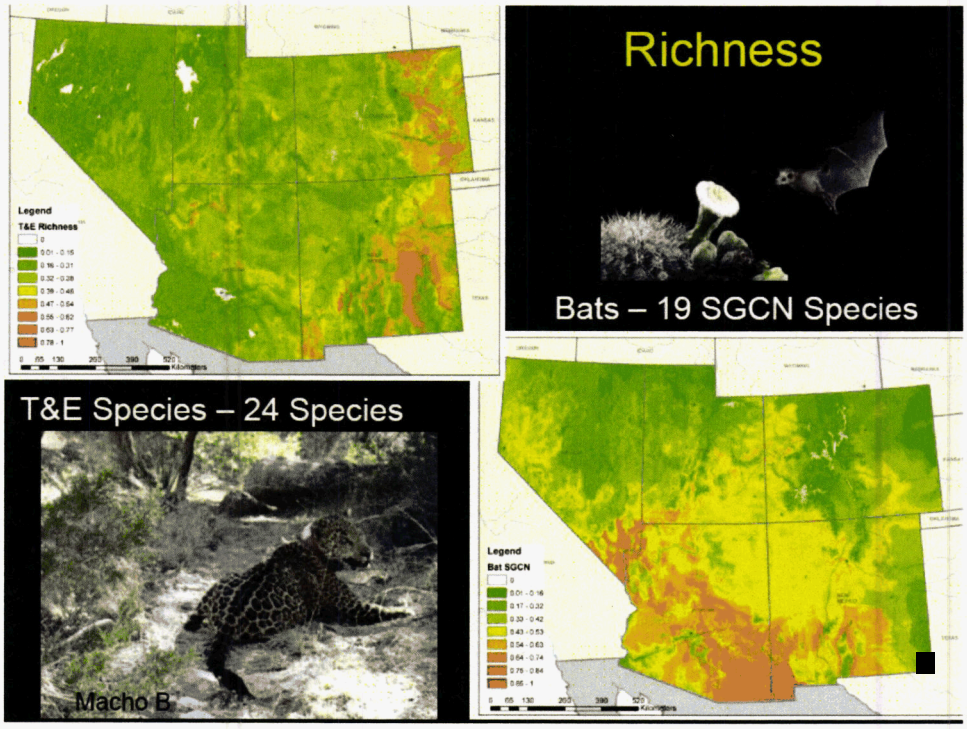




Page 16 of the PDF



Page 17 of the PDF



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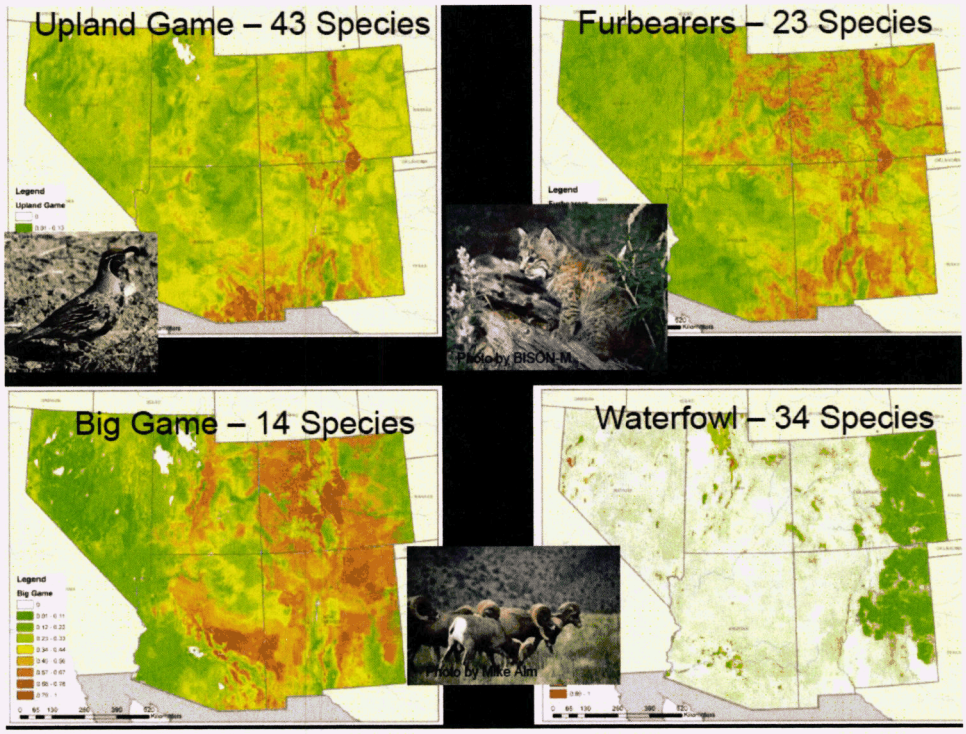
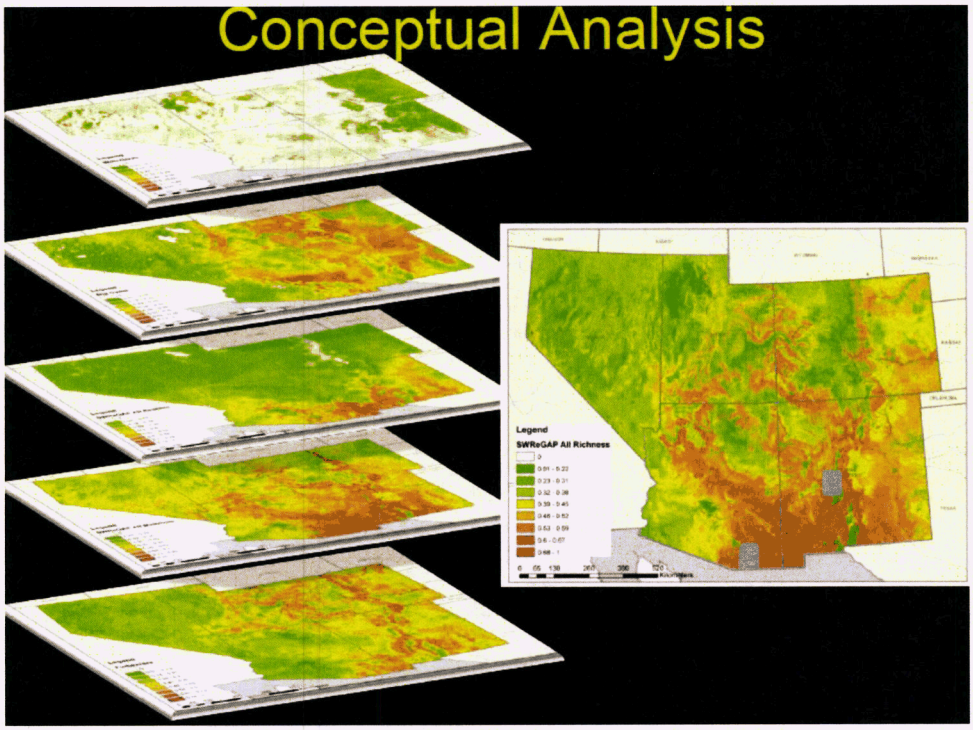
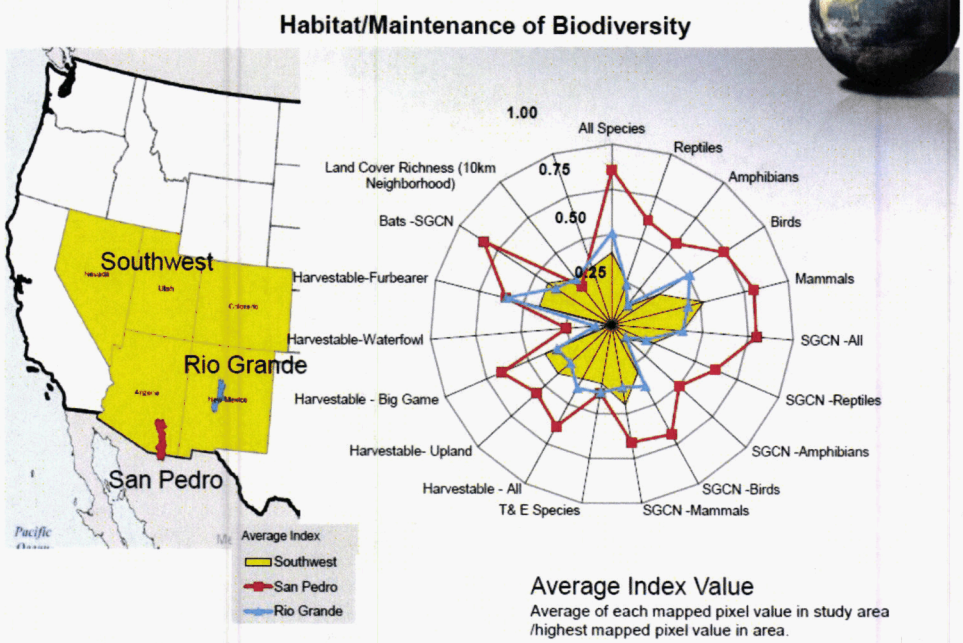


Page 20 of the PDF



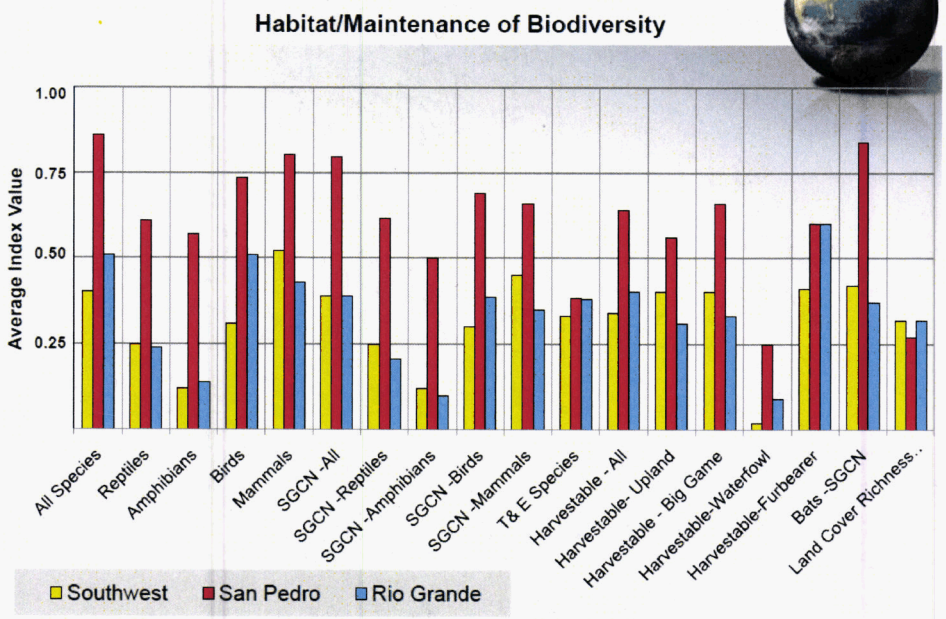
Page 21 of the PDF

Radar Graphs



Page 22 of the PDF

Bar Graph



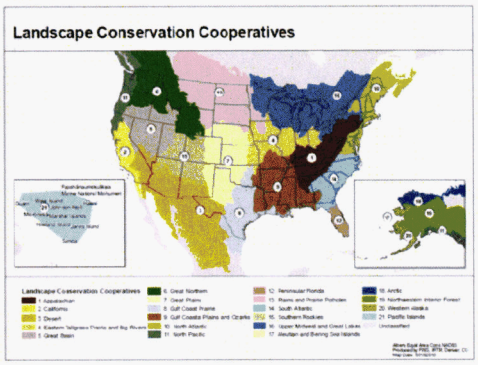
Page 23 of the PDF

Local Efforts

AGAVES

State Wildlife Action Plans

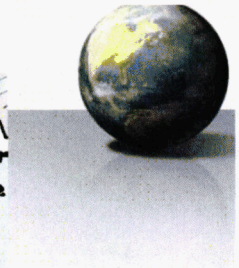
Landscape Conservation Cooperatives



Secretarial Order No. 3289 establishes Landscape Conservation Cooperatives, which are management-science partnerships that inform integrated resource-management actions across landscapes (February 22, 2010).

Page 24 of the PDF

Species Richness by Scale



* Preliminary Data

Taxon	San Pedro	Southwest	Albemarle Pamlico	Tampa Bay *	Southeast	Nation
Amphibians	16	37	40	9	124	310
Birds	287	435	155	192	259	719
Mammals	88	215	52	5	99	555
Reptiles	61	130	57	18	124	509
Total Species	452	817	304	224	606	2094

Page 25 of the PDF

General Conclusions

- Deductive modeling appears promising for mapping and quantifying metrics of habitat provisioning at multiple scales
  - Evaluating metrics (e.g., indices, species groups, keystone species, or guilds)
- First level effort and further work is underway
  - Application at national scale (USGS-GAP)
  - Ability to map wildlife as an Ecosystem Service (EPA)
- Provides reference conditions for alternative future scenarios (e.g. climate change, urbanization)
- Establish common sense *indicators of ES* for end-user and decision maker needs
  - Landscape Conservation Cooperatives
  - State Wildlife Action Plans
  - Local Initiatives (e.g. AGAVES)

Page 26 of the PDF

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http://gapanalysis.nbii.gov
http://fws-nmcfwru.nmsu.edu/swregap/
http://www.epa.gov/nerlesd1/land-sci/gap.htm

12

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MADREAN ARCHIPELAGO RAPID ECOREGIONAL ASSESSMENT

EXECUTIVE SUMMARY

Contents

1 Executive Summary 4
1.1 Rapid Ecoregional Assessments: Purpose and Scope 4
1.2 Organization of the MAR REA Final Report 4
1.2.1 Common Terminology 4
1.3 The Assessment Region 5
1.4 Management Questions 6
1.5 Conservation Elements 7
1.6 Change Agents 8
1.7 REA Products and Results 10
1.7.1 Conservation Elements: Current Status 10
1.7.2 Current Ecological Integrity of the Ecoregion 13
1.7.3 Conservation Elements Future Risk 16
1.7.4 Recent and Future Climate Trends 17
1.7.4.1 Overall Climate Trends and Evaluation of Conservation Elements 19
1.7.4.2 Bioclimatic Envelope Modeling 19
1.8 Limitations and Applications 20
1.8.1 Conservation Element Distributions 21
1.8.2 Change Agent Distributions 21
1.8.2.1 Development, Invasive Species, and Fire 21
1.8.2.2 Climate Change Data 22
1.8.3 Modeling Methods 23
1.8.3.1 Conservation Element Status and Ecological Integrity Assessments 23
1.8.3.2 Climate Change: Bioclimatic Envelope Modeling 23
1.9 Potential Applications and Decision Support 23

Tables

Table 1-1. Ecological system conservation elements (CEs) selected for the Madrean Archipelago REA. 7
Table 1-2. Species conservation elements (CEs) selected for the Madrean Archipelago REA. 8

Figures

Figure 1-1. Map of the Madrean Archipelago REA assessment area. 6
Figure 1-2. Example of a development change agent. 9
Figure 1-3. Example of a KEA indicator scenario. 10
Figure 1-4. Current overall ecological status scores for the nectivorous bat assemblage 12
Figure 1-5. Overall ecological status scores for the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque and Stream CE (left) and graphs of frequency distribution (right). 13
Figure 1-6. Distribution (left) and integrity assessment results (right) of the Terrestrial Desert Scrub life zone in the Madrean Archipelago ecoregional assessment area. 14
Figure 1-7. Historical vs. current area of select terrestrial ecological systems for the entire MAR ecoregion. 15
Figure 1-8. Future ecological status scores for Apacherian-Chihuahuan Semi-Desert Grassland and Steppe. 17
Figure 1-9. Recent monthly trends in precipitation over last 30 years, compared to 20th century baseline. 18
Figure 1-10. Climate Change Exposure Index (CCEI), observed values. 19
Figure 1-11. Summary of modeled expansion, contraction, and stability for the geographic distribution of suitable climate conditions for Madrean Encinal. 20

1 Executive Summary

This executive summary describes the breadth of the entire Madrean Archipelago (MAR) Rapid Ecoregional Assessment (REA) and illustrates examples from all of the products. It does not summarize methods but instead focuses on products, key findings, and limitations. Because of the breadth and number of assessments, this summary is necessarily longer than a typical executive summary and is intended to give a brief but fairly complete picture of the MAR REA results.

1.1 Rapid Ecoregional Assessments: Purpose and Scope

Working with agency partners, the BLM is conducting rapid ecoregional assessments (REAs) covering approximately 800 million acres of public and non-public lands in 14 ecoregions and combinations of ecoregions in the American West. The goal of the REAs is to characterize the status of ecological resources and their potential to change from a landscape viewpoint. REAs are intended to serve BLM's developing Ecoregional Direction that links REAs and the BLM's Resource Management Plans and other on-the-ground decision-making processes. Ecoregional Direction establishes a regional roadmap for reviewing and updating Resource Management Plans; developing multi-year work for identified priority conservation, restoration, and development areas; establishing Best Management Practices for authorized use; designing regional adaptation and mitigation strategies; and developing conservation land acquisitions. While REAs produce information designed to be integrated into specific management processes, they are not decision documents and stop short of integrating the findings into management actions.

1.2 Organization of the MAR REA Final Report

This report for the Madrean Archipelago Rapid Ecoregional Assessment (MAR REA) conveys the objectives, methods, and results of the MAR REA. The report is arranged as the main report and a series of nine appendices:

A. Methods for Selecting and Evaluating Feasibility for Conservation Elements, Change Agents, and Assessments
B. Assessment Methods: Approaches and Rationales
C. Technical Methods: GIS Documentation
D. Terrestrial Ecological Systems: Conceptual Models and Ecological Status
E. Aquatic Ecological Systems: Conceptual Models and Ecological Status
F. Species: Conceptual Models and Ecological Status
G. Ecoregional Conceptual Model and Ecological Integrity Assessment
H. Mesquite Scrub Expansion: Restoration Opportunities
I. Climate Change: Assessment Methodology and Results

1.2.1 Common Terminology

Following are key terms and abbreviations used throughout the report; a complete listing of terms and abbreviations is found in the glossary and acronym list in Appendix E.

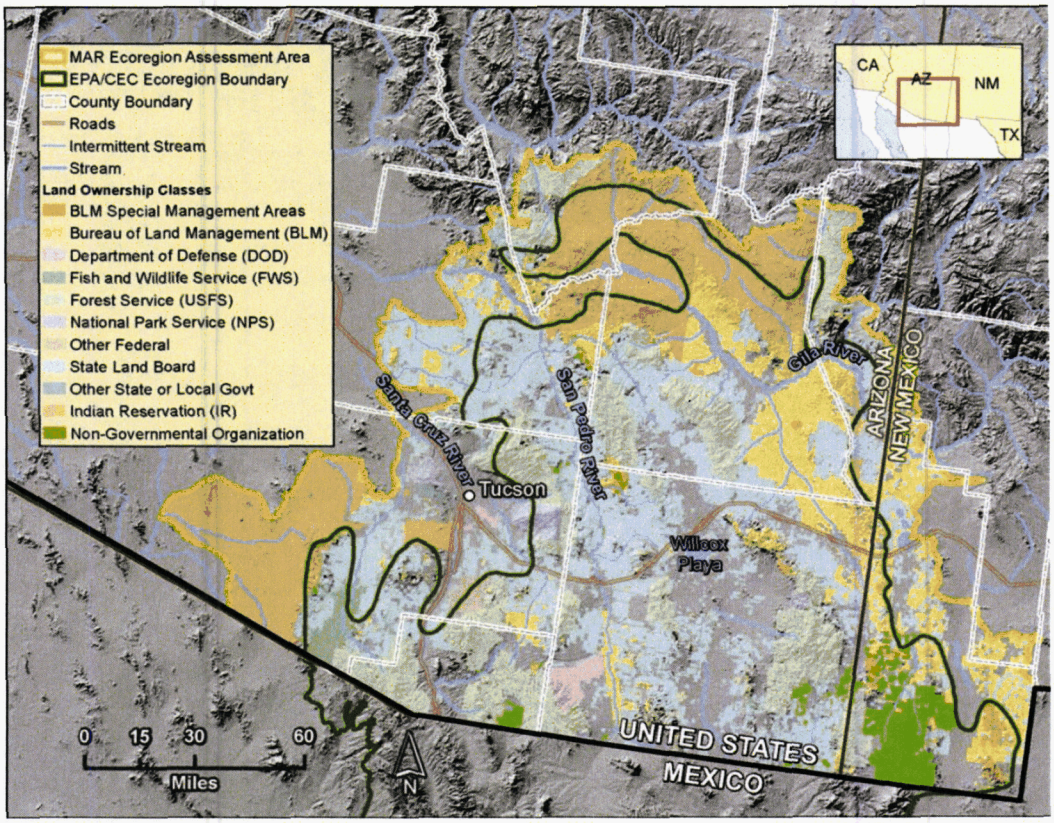
- **AMT**: **Assessment Management Team**. This is the team of BLM staff and participating partners in the region that provided review and guidance for the contractor throughout the REA.

- **CA**: **Change Agent**. These are the features or processes that can negatively impact **conservation elements** (and in some cases can have neutral or beneficial effects on certain CEs). Development, invasive species, fire, and climate change effects are the four primary change agents addressed in this REA.
- **CE**: **Conservation Element**. These are the natural resource features assessed in the REA and include terrestrial and aquatic ecological systems, species, and species assemblages.
- **CE conceptual model**: Conceptual models are the descriptive text and accompanying graphics that characterize the ecology and biology of the CEs, including descriptions of how change agents are expected to affect the **ecological status** or **condition** of CEs.
- **CE response model:** The set of numeric values that characterize the way a CE responds to direct exposure to a **CA** (site intensity value) and (optionally) within a specified distance from the CA.
- **Condition**: used interchangeably with **Status** (see below)
- **Ecological status** (or **Status):** formal term in BLM **REA**s to describe the **condition** or integrity of areas of distribution of a **CE** based on presumed effects of change agents on the CE.
- **EIA**: ecological integrity assessment used to indicate the overall integrity or condition of the ecoregion as a whole.
- **Indicator**: Biophysical attributes that are used either directly or indirectly to measure the status of the **KEA**s, and therefore of the CEs.
- **KEA**: **Key Ecological Attribute**. A KEA is a characteristic of a species' or ecosystem's biology, ecology, or physical environment that is critical to the resource's persistence in the face of both natural and human-caused disturbance. The combined **status** or **condition** of KEAs for a CE together determine the overall **ecological status** of the CE.
- **KEA indicator scenario** (or **Scenario**): The aggregation of **CA** distribution maps used to assess the **indicators** associated with each of the **KEAs** for each of the CEs. The scenarios are input into the **LCM**.
- **Landscape Condition Model** (**LCM**): the geospatial modeling tool used to calculate the **ecological status** of CEs and conduct other related assessments (e.g., ecological integrity of the ecoregion). The **CE response models**, **KEA indicator scenarios**, and **CE** distribution maps are the key inputs that are run through the **LCM**.
- **MAR**: **Madrean Archipelago Ecoregion**, specifically referring to the U.S. portion assessed in this REA.
- **MQ**: **Management Question**. These are questions developed by BLM and gathered during the REA that are important for guiding natural resource management and land use decisions. The **ecological status** assessments of CEs and other assessments conducted in the REA provide information and analysis results to help address the management questions.
- **REA**: **Rapid Ecoregional Assessment**
- **Status:** See **Ecological Status** above.

1.3 The Assessment Region

The U.S. portion of the Madrean Archipelago ecoregion, including its intersecting 5th-level watersheds, was assessed in this REA. The REA assessment area encompasses approximately 6.4 million hectares (15.7 million acres). Within the assessment region, total BLM ownership is 1,009,375 ha (2,494,222 ac) or about 16% of the area and 38,382 ha (94,846 ac) is in BLM special management or 0.6% of the MAR.

Figure 1-1. Map of the Madrean Archipelago REA assessment area. The area assessed for this REA is the U.S. portion of the Madrean Archipelago plus its intersecting 5th-level watersheds, shown in the yellow outline and by the border between the U.S. and Mexico. The Madrean Archipelago ecoregion is shown by the solid green line and extends into Mexico beyond the map extent.



1.4 *Management Questions*

In this REA, natural resources management questions (MQs) and issues were identified by various agencies participating in the REA process. These MQs were iteratively reviewed and distilled into a discrete set of potential assessments and evaluated for appropriatness for an REA and feasibility. Relevant available datasets needed to answer the MQs were identified and evaluated, and proposed analytical steps were summarized for conducting the identified assessments. Based on management needs, data availability and suitability, and technical feasibility of the proposed analyses, the pool of potential assessments was narrowed to the following:

- Ecological Status of CEs (current)
- Ecoregional Ecological Integrity (current)
- Climate Space Trends (recent)
- Climate Space Trends (future)
- CE Distributions Intersected with Future Climate

- Bioclimate Envelope Models
- 2025 Risk Assessment (for three case study CEs)
- Mesquite Scrub Expansion: Restoration Opportunities
- Soil Erosion Potential

1.5 Conservation Elements

Conservation elements (CEs) are one of the core components of the REA. They are the natural resources – ecosystems and species (inclusive of species assemblages) -- that are the focus of the assessment. Ecological system and species CEs were selected through an iterative review process based on the following criteria and considerations:

- Regional significance
  - Relevant to more than one BLM field office or other agency's local management jurisdiction (ecosystems and species)
  - Dominant in the ecoregion (ecosystems)
  - Broadly represent a cross-section of the region's diversity (ecosystems and species)
  - Endemism (ecosystems and species)
- Nexus with identified management issues (ecosystems and species)
- Representation by associated ecological system CE (i.e., species that would add to, rather than being duplicative of, ecosystem CEs)

This resulted in the identification of 18 CEs that were the focus of the assessments in this REA (see Table 1-1 and Table 1-2). In addition, a significant portion of the ecoregion (~19%) is occupied by Apacharian-Chihuahuan Mesquite Upland Scrub, an ecological system that has greatly expanded primarily through mesquite expansion into grassland areas. This system is treated separately from the other 18 conservation elements (via the Mesquite Scrub Expansion assessment listed above) because managers desired information about restoration opportunities rather than a generalized status assessment of this ecosystem type.

Table 1-1. Ecological system conservation elements (CEs) selected for the Madrean Archipelago REA. The ecological systems are organized in this table according to the four major system divisions or groupings (valley upland system, montane upland system, connected stream and wetland, and isolated wetland) from the ecoregion conceptual model. Apacharian-Chihuahuan Mesquite Upland Scrub is a non-natural ecological system that has greatly expanded primarily through mesquite expansion into grassland areas.

Ecological System [illegible]	[illegible]
Valley Upland System Division	**56.0%**
Apacherian-Chihuahuan Mesquite Upland Scrub	19.5%
Chihuahuan Creosotebush Desert Scrub	13.2%
Apacherian-Chihuahuan Semi-Desert Grassland and Steppe	18.2%
Madrean Encinal	5.1%
Montane Upland System Division	**13.4%**
Madrean Pinyon-Juniper Woodland	5.8%
Montane Conifer-Oak Forest and Woodland	2.8%

[illegible]	[illegible]
Mogollon Chaparral	4.8%
Isolated Wetland System Division	**<1%**
North American Warm Desert Playa and Ephemeral Lake	<1%
Connected Stream and Wetland System Division	**4.3%**
North American Warm Desert Riparian Woodland and Shrubland, Mesquite Bosque and Stream	3.3%
North American Arid West Emergent Marsh/Ciénega and Pond	1.0%
North American Warm Desert Lower Montane Riparian Woodland and Shrubland and Stream	<1%

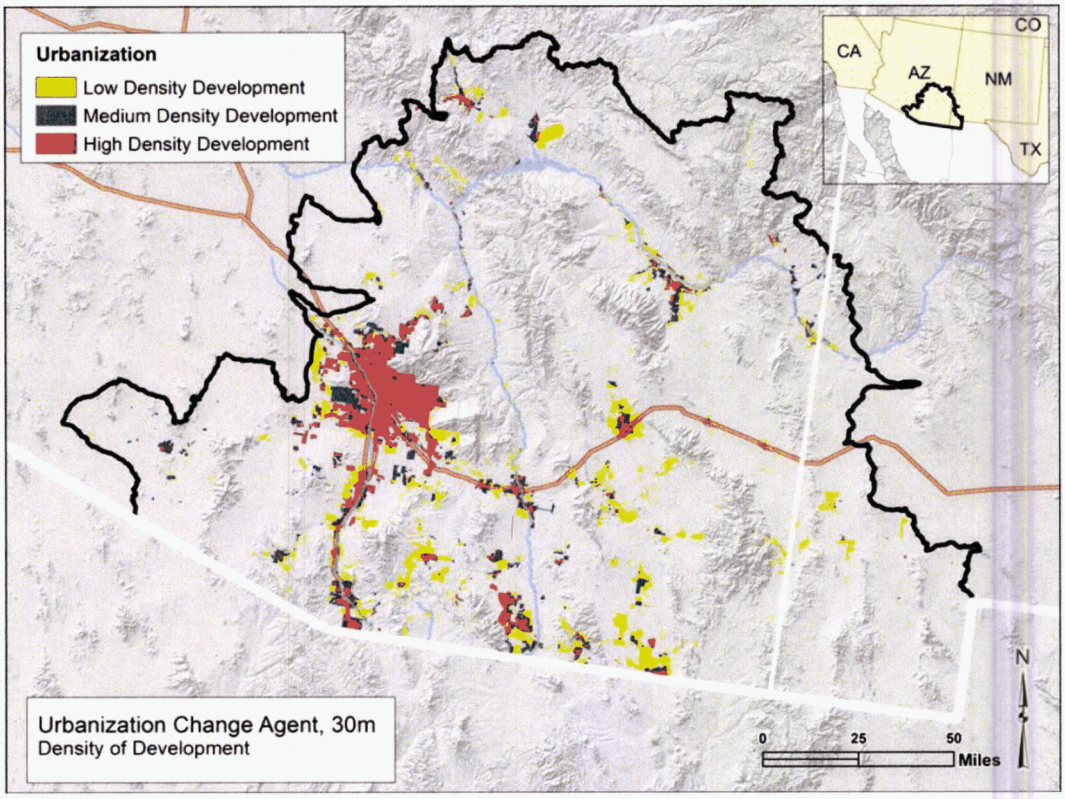
Table 1-2. Species conservation elements (CEs) selected for the Madrean Archipelago REA. Includes current state or federal endangered listing status.

[illegible]	[illegible]	[illegible]
Mammal	Pronghorn (*Antilocapra americana*)	None
Mammal	Coues white-tailed deer (*Odocoileus virginianus couesi*)	None
Mammal	Desert bighorn sheep, all subspecies (*Ovis canadensis*)	None
Mammal	Nectar-feeding bats	See conceptual model
Mammal	Black-tailed prairie dog (*Cynomys ludovicianus*)	None
Bird	Grassland bird assemblage	See conceptual model
Reptile	Ornate box turtle (*Terrapene ornata luteola*)	None
Amphibian	Chiricahua leopard frog (*Lithobates chiricahuensis*)	Federally Threatened, Arizona Threatened

1.6 Change Agents

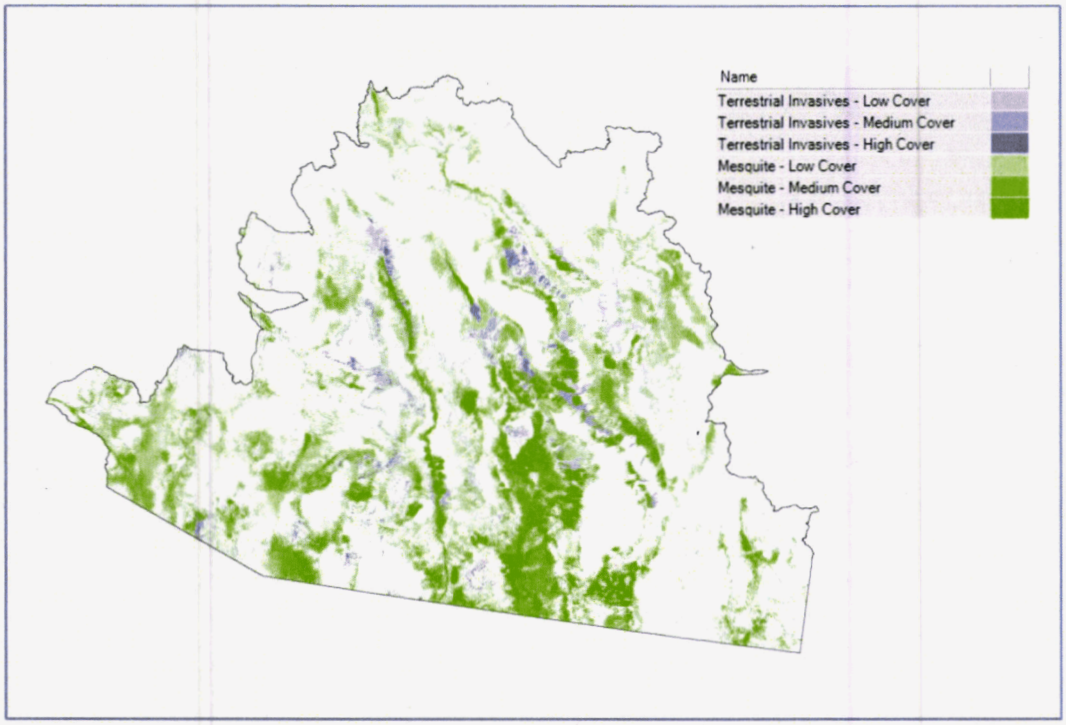
Change agents (CAs) are those anthropogenically-driven or -influenced land uses, activities, or phenomena that can affect the ecological status or condition of conservation elements. They are drawn from the standard REA change agent categories of development, climate change (described in greater detail below), invasive species, and wildland fire (fire). Development is a particularly broad category that includes any direct human use, activity, or infrastructure on the landscape, such as agriculture, border patrol activities, roads, urban development, or energy development, among many others. The invasive species CA includes invasive non-native species, managed non-native species (e.g., sport fish, game animals), and native woody increasers (such as mesquite). Figure 1-2 provides an example of a development CA; all individual CA maps can be viewed on the BLM REA GIS portal.

Figure 1-2. Example of a development change agent. The urbanization change agent comes from a model of urban density ICLUS SERGoM generated by EPA.



There were no direct assessments made of change agents in isolation (i.e., without interactions with CEs, other than climate change trends). Instead, change agents were incorporated into a series of "KEA indicator scenarios" (scenarios) that represent indicators of conservation element Key Ecological Attributes (see example Figure 1-3). These scenarios were used to model the current status of the conservation elements, the 2025 future landscape condition (development-caused) status of three case study conservation elements, and model the current ecological integrity of the ecoregion as a whole (see sections below). Additionally, more speculative modeled urban development for the 2025 timeframe is graphically overlaid on the case study conservation elements and solar potential maps are presented alone to indicate where future risks to conservation elements may occur (see section 1.7.3).

Figure 1-3. Example of a KEA indicator scenario. The invasive species indicator scenario is comprised of invasive species change agents represented at different levels of density that could be associated to different levels of impact to the KEA indicator.



The climate change assessment addresses climate exposure across the MAR by analyzing recent and future climate trends and their estimated influence on conservation elements (CEs). The recent and future climate trend analysis examines spatial and temporal patterns of change in a range of climate variables. Multiple trend detection statistics were employed to quantify the distribution and magnitude of recent climate change, as well as future changes projected by a suite of six global climate models run under the A2 greenhouse gas emissions scenario. Additionally, bioclimatic envelope modeling explores how projected future climate change may affect the distribution of suitable climate conditions for several ecological communities of the MAR. This approach estimates suitable climate conditions for a given CE and projects where those suitable conditions are likely to occur in the mid-century future.

1.7 REA Products and Results

1.7.1 Conservation Elements: Current Status

Current ecological status was assessed for five terrestrial upland CEs, four aquatic CEs, five species and two species assemblage CEs. Each indicator for each key ecological attribute was assessed individually for each CE; the indicators were then combined to calculate the overall ecological status for each CE. The individual indicators and overall ecological status were assessed at 30 m resolution and then the overall status was averaged across reporting units to show broader patterns of overall ecological status

for each CE (see example of both resolution products for the nectivorous bat assemblage CE, Figure 1-4). Additionally, a frequency graph of status by reporting unit is provided for each CE that illustrates the proportion of the CE area in which range of status values (e.g., in Figure 1-5, the bulk of the CE's distribution is in relatively low status).

Generally across the three groups of CEs, similar patterns were observed in the assessment results. First, while development activities can have major, local-scale impacts; most development occurs in, and hence has impacts upon, lower elevation areas including valleys, floodplains, or in the foothill zones. Therefore, it is generally a minor driver of the status results for the CEs found at higher elevations. Effects of development on CE distributions close to heavily populated or developed areas are evident in the ecoregion-wide maps. Effects of the many small roads and highways, which are pervasive throughout the area, are difficult to visually discern in the maps. Their impacts on status locally are evident when zoomed into specific areas and these smaller, pervasive impacts do contribute to ecoregional status results.

Secondly, altered fire regimes are affecting most areas of the ecoregion. All of the terrestrial upland ecosystems have significant portions of their distribution in either moderate or severe departure categories from historical fire regimes. Most of the species also have poor ecological status across much of their distribution due to the fire regime indicator.

Third, invasive species, both in the upland and aquatic realms, are a significant problem at middle to lower elevations of the ecoregion. The data for the invasives indicators was generally of poor to moderate quality, but the patterns are similar across all three groups of CEs. Lower elevations (i.e. not in the mountain ranges) are impacted by invasives, while the higher montane elevations are much less affected. These results are not unanticipated; invasion by mesquite (*Prosopis* spp.), exotic grasses and forbs, tamarisk (*Tamarix* spp.) or Russian olive (*Elaeagnus angustifolia*) and exotic aquatic animal species, is well documented for this ecoregion and known to be a growing issue.

Lastly, water use is one of the greatest stressors affecting aquatic CEs in the Madrean Archipelago ecoregion, especially at lower elevations. While the water use data used in this assessment are spatially coarse, the effects of high water usage can be severe and cause stress to the plants and animals dependent upon aquatic ecosystems and their associated riparian or wetland vegetation. The abbreviation "AMA" designates a basin identified as an "Active Management Area" for groundwater resources under Arizona water law. The areas of high rates of water use are all basins in Arizona with either dense municipal development (Tucson "AMA") or large areas of intensive irrigation (Pinal "AMA," Douglas and Willcox basins). Figure 1-5 illustrates the 30 m overall ecological status for one of the aquatic CEs, as well as its ecological status averaged across the watershed reporting units.

Figure 1-4. Current overall ecological status scores for the nectivorous bat assemblage for each 30m pixel (top) and 4km grid cells (reporting units, bottom). LCM = landscape condition model. Yellow scores (equivalent to 0) indicate high impacts from the CAs and correspondingly lower ecological status, dark blue (equivalent to 1) indicate little to no impact from the CAs and correspondingly higher ecological status. In the second map, the score for each 4km cell is an average of the overall ecological status scores of the 30m pixels within the 4km cell that were were scored for the CE.

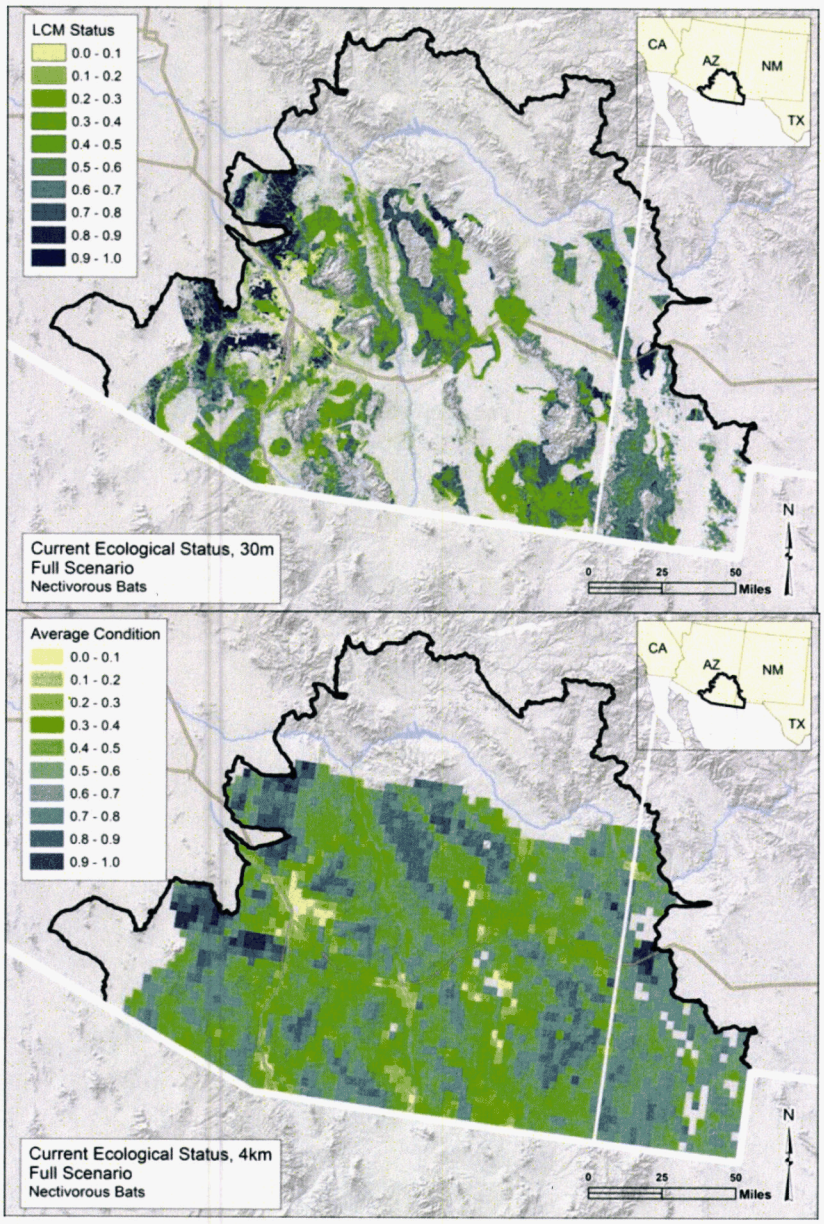
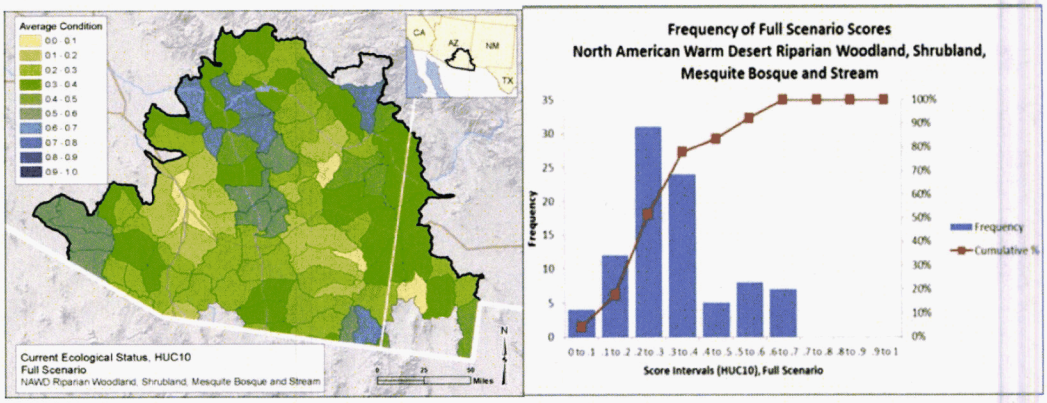


Figure 1-5. Overall ecological status scores for the North American Warm Desert Riparian Woodland, Shrubland, Mesquite Bosque and Stream CE (left) and graphs of frequency distribution (right). Ecological status scores were averaged across 5th-level watersheds for the CE. A companion graph indicates the frequency distribution of ecological status scores for the CE. The x-axis represents the 0.1 increment scoring intervals, while the y-axis shows the number of watersheds in each interval (left) and the cumulative percentage of the grid cells for each interval (right).

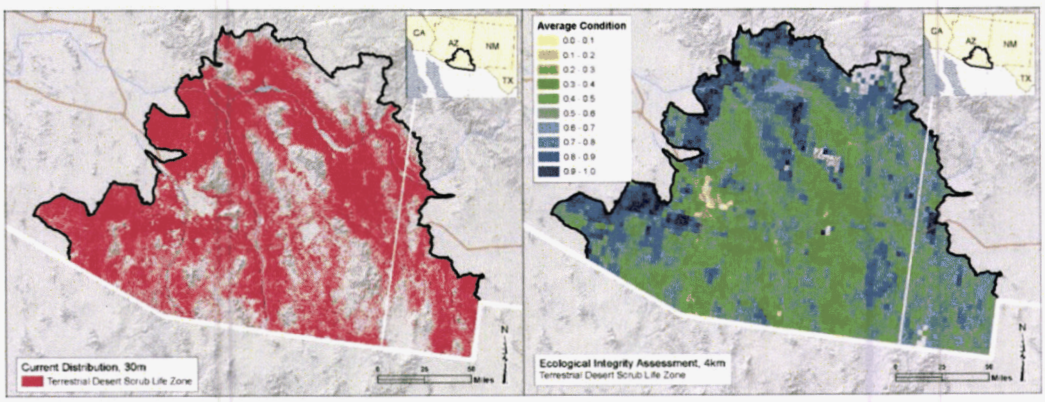


1.7.2 Current Ecological Integrity of the Ecoregion

Ecological integrity assessment characterizes the overall status or condition of the ecoregion. For the MAR, integrity was assessed for five life zones that incorporated the CEs but provided ecoregion-wide coverage: two for the aquatic realm (montane and lowland) and three for the uplands (montane, valley and desert). An additional analysis calculated the change in extent of distribution for upland ecological systems from historical distribution to current.

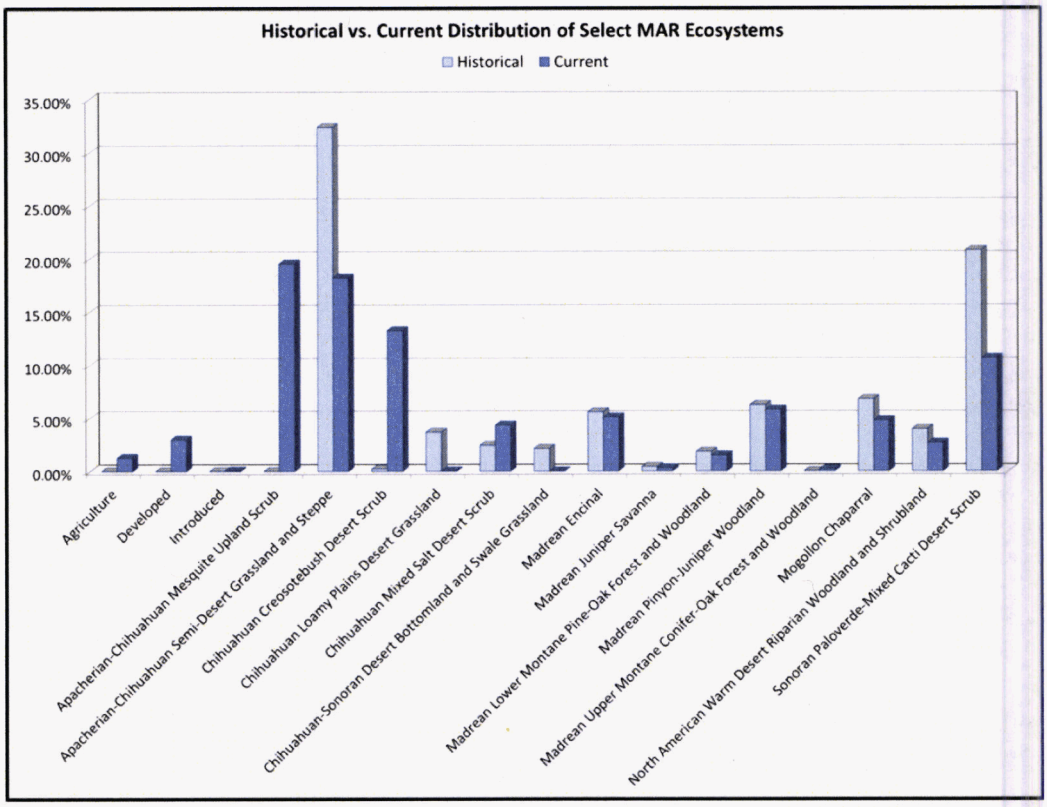
For the five life zones, the results for the ecological integrity assessment of the ecoregion show similar patterns to those for the CEs. In general, the higher elevation regions have better ecological integrity, a result of less development and fewer invasive species, although fire regime departure is significant in all of the upland life zones. The Desert Scrub life zone has poor to moderate ecological integrity for much of its distribution, a result of fire regime alterations and proximity to heavily developed areas (Figure 1-6). In contrast, much of the Montane Forest life zone has moderate to good ecological integrity (less development or invasives species). However, altered fire regimes are a real issue throughout much of the montane zone. The Valley Grassland life zone has low ecological integrity across much of its distribution. This life zone suffers from effects of all three indicators- extensive development impacts, invasive species including mesquite, and moderately to severely altered fire regimes. Only a few areas in the northern portions of the ecoregion have good integrity.

Figure 1-6. Distribution (left) and integrity assessment results (right) of the Terrestrial Desert Scrub life zone in the Madrean Archipelago ecoregional assessment area. The map on the left shows the combined distributions of 13 terrestrial ecological systems which comprise the distribution of this life zone. The map on the right illustrates integrity results for all three indicators: development, fire regime departure, and invasive species, which were combined into a single ecological integrity score for each 4km^2 grid cell. Yellow scores (equivalent to 0) indicate high impacts from the CAs, dark blue (equivalent to 1) indicate little to no impact from the CAs.



The results of the change in extent analysis from historical to current area of terrestrial ecological systems show major compositional changes have occurred that have resulted in type conversion (i.e. from one ecosystem to another) and resultant changes in extent (Figure 1-7). Mesquite Upland Scrub has expanded substantially (0% to 20%), as has Chihuahuan Creosotebush Desert Scrub (0.5% to 13%) with subsequent large declines in all of the grassland ecological systems (Apacherian-Chihuahuan Semi-desert Grassland and Steppe (32% to 18%), Chihuahuan Loamy Plains Desert Grassland (4% to nearly 0%), Chihuahuan Bottomland and Swale Grassland (2% to nearly 0%). In addition there has been a large decline in the extent of Sonoran Paloverde-Mixed Cacti Desert Scrub (21% to 11%), largely due to urban expansion from Tucson and surrounding areas and conversion to other desert scrub systems. There are only modest amounts of conversion from natural vegetation due to increases in post-European settlement (as a proportion of the ecoregion area) such as agriculture (to 1.3%) and development (to 3%).

Figure 1-7. Historical vs. current area of select terrestrial ecological systems for the entire MAR ecoregion. The y-axis presents the percent of the MAR study area of the mapped historical (light shade) or current (dark shade) extent of each ecological system or land cover type. Historical distribution was derived from the Landfire biophysical settings map and current distribution from the NatureServe terrestrial ecological systems map, which is based upon the land cover mapping of SW ReGAP.



The Aquatic Lowland life zone has reduced ecological integrity primarily because of water use and development whereas the Aquatic Montane life zone has much better integrity. For the Lowland life zone, areas surrounding, and waters within, the Gila River downstream from the San Simon River confluence, most of the San Pedro River, and most of the Santa Cruz River south of Tucson show high levels of impact from development, water use, and invasive species. The most altered watersheds are located in the areas of Safford, Willcox, and the Tucson metropolis, AZ. The least altered watersheds occur in the far west-southwestern corner of the ecoregion assessment area west and south of Sells, AZ (in the buffer area of the ecoregion); in the northern third of the lower San Pedro River basin; in the lower San Francisco River basin; and surrounding San Bernardino National Wildlife Refuge. Watersheds in the Aquatic Montane life zone occur in areas that are generally not impacted by significant groundwater withdrawal and surface water diversions, nor are they as heavily exposed to development.

1.7.3 Conservation Elements Future Risk

Inadequate data were available to conduct complete status assessments of the CEs for the 2025 timeframe equivalent to those done for the current (2014) assessments. However, a variety of data representing potential areas of development change agents for near future timeframes were available. Therefore, only the development indicator was assessed for the 2025 timeframe for each of the three case study CEs (see example Figure 1-8) to provide a limited picture of potential ecological status in 2025. In addition, the case study CE distribution maps were overlaid with a "risk map" of potential urban expansion areas to further inform areas and CEs at risk. Solar energy potential maps are provided but not overlaid on the CE distributions because of their broad distribution, but they can be overlaid with any CE via BLM's GIS portal found at http://www.blm.gov/wo/st/en/prog/more/Landscape_Approach/reas/dataportal.html.

Comparing the development indicator scores for the current timeframe to the 2025 development-based ecological status scores, the observable differences are subtle at the ecoregion scale and are primarily driven by urban expansion in the central and southwest portions of the ecoregional assessment area and around Tucson and the SunZia and Southline planned transmission corridors. For the aquatic ecosystem assessed, the impacts from proposed development appear negligible.

The extent of future development currently planned, modeled, or with fairly high potential for action by 2025 is relatively small compared to the ecoregion extent. Therefore, separate assessments would need to be conducted to characterize localized effects of individual projects. The SunZia and Southline electrical transmission corridors bisect the entire ecoregion and numerous occurrences for several CEs. No Solar Emphasis Zones were designated in the BLM Solar PEIS in the Madrean Archipelago Ecoregion, but there is some solar development on non-federal lands. There are extensive areas of federal lands delineated as variance areas where, through careful planning, facilities could be located on certain federal lands.

13

DOCKET NO. L-00000YY-15-0318-00171-MCV_13

Economic Contributions of Wildlife Viewing to the Arizona Economy: A County-Level Analysis

Tucson Audubon Society

TUCSON AUDUBON SOCIETY

conservation education recreation

Economic Contributions of Wildlife Viewing to the Arizona Economy: A County-Level Analysis

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Recommended citation / reference: Tucson Audubon Society: The Economic Contributions of Wildlife Viewing to the Arizona Economy: A County-Level Analysis. 2013. Southwick Associates / Arizona Game & Fish Department.

Analysis and report prepared by Southwick Associates, May 1, 2013

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INTRODUCTION

This report assesses the 2011 economic contributions of watchable wildlife recreation in Arizona, statewide, by county and by specific types of activity. Direct spending by both residents and non-residents for wildlife watching was analyzed, along with the multiplier effects of that spending. Only watchable wildlife activities that occurred within Arizona were considered.

...

Overall, 1.6 million people participated in some form of residential or non-residential watchable wildlife recreation in Arizona in 2011.

EXCERPT PAGE 8 of the PDF

Table 8. Economic Contributions of All Watchable Wildlife Recreation in Arizona, by County where the Activity Occurred in 2011

...

		County Residents	Residents From Other Counties	Non-Residents	TOTAL
Cochise	Retail Sales	$7,357,921	$3,546,665	$3,227,150	$14,190,743
	Total Multiplier Effect	$12,470,790	$6,031,619	$5,528,034	$24,130,389
	Salaries and Wages	$3,830,269	$1,913,801	$1,878,401	$7,651,115
	Full & Part-Time Jobs	127	56	53	234
	State & Local Tax Revenue	$816,778	$359,172	$390,684	$1,570,931
	Federal Tax Revenue	$929,261	$408,610	$425,603	$1,769,276
Graham	Retail Sales	$4,446,570	$1,447,610	$1,440,366	$7,283,288
	Total Multiplier Effect	$7,455,617	$2,457,967	$2,467,315	$12,292,101
	Salaries and Wages	$2,378,423	$781,026	$838,383	$3,977,764
	Full & Part-Time Jobs	61	22	24	105
	State & Local Tax Revenue	$475,759	$159,869	$174,373	$806,268
	Federal Tax Revenue	$541,824	$181,325	$189,958	$908,067

EXCERPT PAGE 10 of the PDF – Table 8 Continued

		County Residents	Residents From Other Counties	Non-Residents	TOTAL
Pima	Retail Sales	$95,440,007	$40,537,825	$42,208,205	$179,459,718
	Total Multiplier Effect	$161,002,669	$68,771,763	$72,301,688	$304,368,133
	Salaries and Wages	$51,012,094	$21,869,589	$24,567,791	$97,947,943
	Full & Part-Time Jobs	1406	614	688	2736
	State & Local Tax Revenue	$10,252,806	$4,411,036	$5,109,794	$19,866,395
	Federal Tax Revenue	$11,666,952	$5,016,001	$5,566,505	$22,374,716
Pinal	Retail Sales	$23,141,009	$13,572,187	$14,677,151	$52,631,795
	Total Multiplier Effect	$39,067,381	$23,007,700	$25,141,624	$89,450,156
	Salaries and Wages	$12,384,663	$7,321,508	$8,543,012	$28,733,395
	Full & Part-Time Jobs	341	203	239	812
	State & Local Tax Revenue	$2,490,479	$1,468,670	$1,776,840	$5,826,399
	Federal Tax Revenue	$2,833,792	$1,670,505	$1,935,653	$6,562,038

[Greenlee County's sample size was too small – data not available]

ECONOMIC SECTORS STIMULATED BY RESIDENT+NONRESIDENT WILDLIFE WATCHING SPENDING

	Total Output (Sales)	Employment	Income
Ag, Forestry, Fish & Hunting	79,221,793	1,402	15,464,831
Mining	38,683,906	324	6,086,188
Utilities	15,826,239	27	3,265,830
Construction	10,375,163	77	4,044,720
Manufacturing	249,473,696	574	38,188,913
Wholesale Trade	118,192,670	719	53,432,251
Retail trade	191,677,954	2,864	90,472,109
Transportation & Warehousing	79,399,937	521	29,874,434
Information	36,494,376	137	7,822,203
Finance & insurance	86,161,603	470	23,901,612
Real estate & rental	141,594,658	581	11,747,431
Professional- scientific & tech svcs	42,773,983	392	23,378,904
Management of companies	12,005,983	78	5,848,491
Administrative & waste services	28,584,852	452	14,902,529
Educational svcs	7,623,480	116	4,435,439
Health & social services	56,391,568	578	31,885,933
Arts- entertainment & recreation	7,434,417	152	3,233,180
Accomodation & food services	148,140,231	2,199	51,483,151
Other services	57,419,015	985	27,147,402
Government & non NAICs	30,722,079	245	16,954,174
TOTAL	**1,438,197,603**	**12,892**	**463,569,725**

14

ELSEVIER

Biological Conservation 86 (1998) 67–76

BIOLOGICAL CONSERVATION

Biological and conservation aspects of bird mortality caused by electricity power lines: a review

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Received 19 July 1997; received in revised form 31 October 1997; accepted 9 November 1997

Abstract

Empirical data and theoretical considerations indicate that species with high wing loading and low aspect run a high risk of colliding with power lines. These birds are characterised by rapid flight, and the combination of heavy body and small wings restricts swift reactions to unexpected obstacles. When the number of reported collision victims is considered relative to the abundance and population size of the species concerned, some Galliformes, Gruiformes, Pelecaniformes and Ciconiiformes species seem to appear in disproportionately high numbers. In contrast, species frequently affected by electrocution particularly seems to involve Ciconiiformes, Falconiformes, Strigiformes and Passeriformes. An alarmingly large number of species with endangered and vulnerable status are identified among the victims, but there are insufficient data at present for judging the significance of mortality caused by power lines at the population level. © 1998 Elsevier Science Ltd. All rights reserved.

Keywords: Bird; Electrocution; Endangered species; Collision; Power line

1. Introduction

Steadily increasing environmental stress has made mortality factors important that were once considered insignificant. Healthy populations can normally compensate for additional mortality deriving from unusual causes but may be seriously affected when these act on a reduced population. Ecologists (e.g. Temple, 1986) have emphasised that the circumstances that ultimately cause a species to perish may be entirely unlike the incidents that first caused the population to become endangered. The annual death of birds world-wide through electrocution and collision with power lines and other types of overhead wires (Braaksma, 1966; Renssen et al., 1975; Gylstorff, 1979; Hoerschelman et al., 1988; Bevanger, 1994a, 1995a) is an example of a poorly understood mortality, although it was observed and commented on for more than one hundred years (Coues, 1876; Emerson, 1904). Reports mainly derive from South Africa, North America and Europe, where they were highlighted because of the economic impact of interruptions in energy supply, and the scientific and conservation concern for endangered, vulnerable and harvestable species (Brown and Lawson, 1989; Bevanger, 1994a,b, 1995a,b; Negro and Ferrer, 1995). Information from the rest of Africa, South America, Asia and Australia is scarce (for a literature review, see Avery et al., 1980; Herbert and Reese, 1995). As a majority of power lines are located in remote areas far away from public awareness of the bird collision or electrocution problems, reported losses must be considered a superficial measure of its occurrence (Thompson, 1978; Longridge, 1986; Faanes, 1987).

Much is known about how topographical, meteorological and technical factors can alter collision or electrocution hazards for birds (Bevanger, 1994a; Alonso et al., 1994; Brown and Drewien, 1995; APLIC, 1996). Less attention was paid to the biological and ecological characteristics of the victims, i.e. behaviour, physiology and morphology. No investigations seem to have been designed to test the influence of, for instance, biomechanics on collisions. A main question addressed in the present paper is whether existing data can reveal qualities of morphology and biomechanics that predict a species' susceptibility to collisions with power lines or electrocution accidents. The implications of this mortality for conservation are discussed in the light of principles of population dynamics.

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PII: S0006-3207(97)00176-6

2. Predicting bird collisions with power lines

The causes of birds colliding with power lines is a complex problem (Bevanger, 1994a,b). Statistical testing of pooled data is inappropriate because the records are biased by several factors: the geographical location of the research, the abundance of the species, their behavioural patterns (e.g. the time different species spend in the air) and their nocturnal and/or crepuscular habits. It is, for instance, impractical to obtain relative figures, i.e. the number of collisions compared to the number of birds crossing overhead wires, for rare species or species with a ground-dwelling life style. Resident and migratory species have frequently been pooled and treated together. Investigations addressing this type of information (e.g. Meyer, 1978; James and Haak, 1979; Willdan Associates, 1982; Faanes, 1987; Hartman et al., 1992) have partly been designed as 'worst case studies' connected with key functional areas for birds and major flyways of migratory species.

Rayner (1988) applied principal component analysis to wing morphology and derived statistically independent measures of size and wing proportions. Of particular interest were the 'loading' and 'aspect' components, and a scatterplot of these for flying birds is informative (Fig. 1). The major bird groups fall into six main categories, determined by differences in aerodynamic performance: 'poor' flyers, water birds, diving birds, marine soarers, aerial predators and thermal soarers.

As Rayner (1988) emphasised, the species in the lower right-hand quadrant (the 'poor' flyers) are interesting as they have probably never experienced strong pressure to enhance their flight efficiency. Most of them belong to Gruiformes, Galliformes and Tinamiformes. It is interesting to relate Rayner's categories to the data derived from the literature on 'collision species' (Table 1).

Indeed, rails, coots and cranes are among the species most commonly and numerously recorded as collision victims in America and Europe (e.g. McKenna and Allard, 1976; Heijnis, 1980; Zerda and Rosselli, 1997). Moreover, 14 species of the Gruidae and Rallidae families world-wide were classified as endangered (Temple, 1986). Most of the 15 crane species are known to have dwindling populations with endangered status (Bylin, 1983) mainly as a result of destruction of wetland habitats.

Several gallinaceous species were known to suffer losses because of flying into overhead wires (Leopold, 1931; Borell, 1939; Paludan, 1963; Krapu, 1974; Rose and Baillie, 1992). Recent research in Norway has revealed that tetraonids are particularly exposed to collision hazards (Bevanger, 1988, 1995a,b), which is all the more striking considering their ground-dwelling behaviour.

The 47 species of Tinamiformes are endemic to the Neotropical Region (del Hoyo et al., 1992). Most of them look like gallinaceous birds, although their morphology reflects convergent evolution. Unfortunately, almost no research addressing the problem of bird collisions with power lines was carried out in Latin America, but these birds are known to 'fly into obstacles—branches, posts, wires and even houses' (del Hoyo et al., 1992, p. 113). If the theoretical considerations about high collision probability for the 'poor' flyer group are correct, Tinamiformes species should be particularly vulnerable to colliding with power lines. Several Tinamiformes species are ranked as vulnerable and endangered (del Hoyo et al., 1992).

'Water birds' and 'diving birds' (Fig. 1) also have high wing loading, and many species of Anseriformes are recorded as frequent collision victims (Table 1). The Charadriformes vary somewhat. Species belonging to the Scolopacidae family are found as collision victims in nearly every investigation related to birds and power lines. This is not surprising considering that most of the species are Neotropical and Palaeotropical migrants crossing vast distances—and many power lines—in huge numbers. The snipe *Gallinago gallinago*, however, figures in the high wing loading group and accounts for 21% (n = 602) among the 2833 Scolopacidae victims recorded (Table 1).

In the 'low loading' group, gulls are frequent collision victims, and are therefore an exception to the prediction based on wing morphology (Table 1). Studies in Washington and Oregon (Meyer, 1978; James and Haak, 1979; Beaulaurier, 1981) showed a significantly higher probability that Anatidae species would collide than Laridae species, ducks being 50–100 times more likely to collide than gulls. However, Laridae species spend much of their time in the air and are numerous; moreover, the investigations incorporated in Tables 1 and 2 mainly derive from wetland and coastal habitats where they are particularly common. It has also been suggested that birds such as gulls, with high aspect ratio and low loading, are susceptible to being blown into wires in strong winds, and also that birds in flocks, like gulls, may be in greater danger of colliding, particularly those that are far behind, as their view is obstructed by the birds in front (Scott et al., 1972; Renssen et al., 1975; Henderson et al., 1996).

As Rayner (1988) emphasised, there are significant variations within some groups (e.g. Anatidae) regarding wing load and aspect ratio, underlining the importance of making accurate analyses among species in the same family to predict the species-specific collision hazard. Moreover, reaction studies (James and Haak, 1979) have revealed significant variations in the reaction of ducks when approaching a power line, indicating differences in perceptional and reactional abilities as well as behaviour (e.g. descending or elevating flight course,

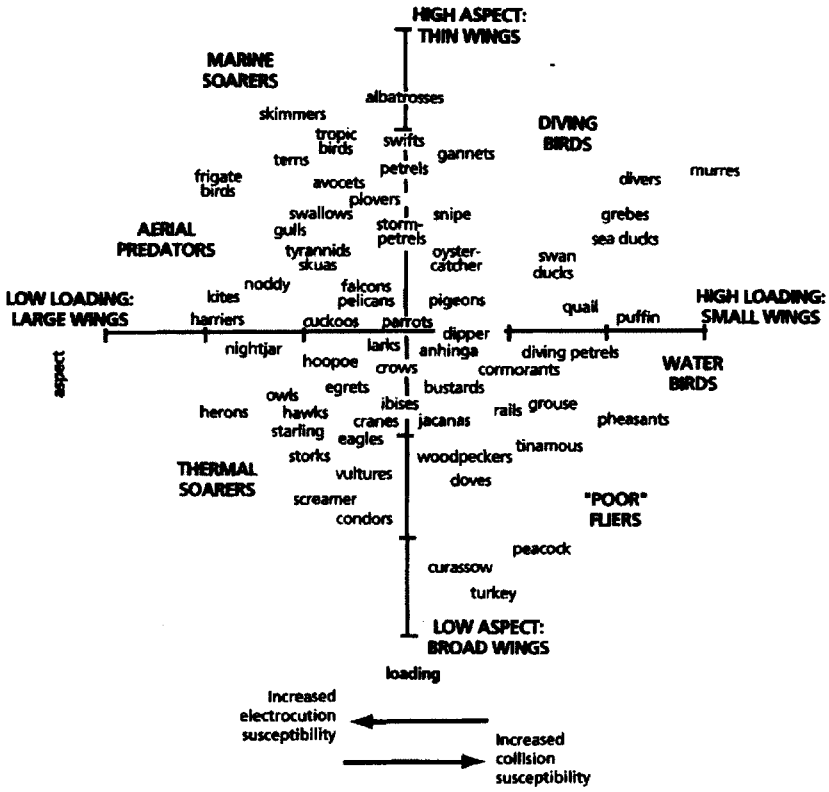

Fig. 1. Major bird groups arranged according to wing morphology expressed in principal-components form where statistically independent measures of size and wing proportions are derived. The figure is based on a scatterplot of the size-independent components of flying birds (after Rayner, 1988).

or flight interruption when attempting to cross the wires).

Aerial hunters like the European swift *Apus apus* and several raptor species possess excellent flying abilities (and binocular vision). However, they spend a major part of their life in the air and the probability of crossing power lines (and colliding) is higher compared to ground-dwelling species, which may explain why aerial predators are regularly recorded as collision victims, although in seemingly small numbers (Bevanger and Overskaug, in press).

It is difficult to predict the danger to 'thermal soarers' (Fig. 1), i.e. birds with large and broad wings and a decreased wing loading. Some species seem to be susceptible both to electrocution and collision. Herons and several other Ciconiiformes species and Gruiformes and Pelecaniformes species, suffer an alarmingly high mortality from power lines, but available data do not allow clear distinctions to be made between electrocution and collision accidents. However, electrocution accidents seem to be increasingly important among these groups, apparently being dependent on body size, hunting, perching or roosting behaviour.

Empirical evidence is amassing that species with high wing loading and low aspect, i.e. the 'poor' flyers, deserve to be classified in a high risk group as regards collisions with power lines. The 'poor' flyers are characterised by rapid flight, and the combination of heavy body and small wings obviously restricts swift reactions to unexpected obstacles.

An interrelationship between biomechanical factors and vision should certainly be considered. Unfortunately, there is a lack of detailed information about the sensory capacities of birds, although research into bird vision has revealed a great variety of adaptations among various groups (Sillman, 1973; Martin, 1985; Schmidt-Morand, 1992).

3. Characteristics of bird electrocution

Electrocution of birds is a simpler problem than collision. It may take place when a bird touches two phase conductors or one conductor and an earthed device simultaneously, especially when the feathers are wet.

Table 1
Birds recorded as victims of collisions with power lines in 16 investigations

Order	Family	Genera	Species	Individuals
Gaviformes	Gavidae (divers)	1	2	3
Podicipediformes	Podicipedidae (grebes)	4	7	303
Procellariiformes	Procellaridiidae (fulmars, petrels, shearwaters)	1	1	4
Pelecaniformes	Pelecanidae (pelicans)	1	2	4
	Sulidae (boobies, gannets)	1	1	1
	Phalacrocoracidae (cormorants, shags)	1	2	62
Ciconiiformes	Ardeidae (bitterns, herons)	4	6	79
	Ciconiidae (storks)	1	1	5
	Threskiornithidae (ibises, spoonbills)	2	3	13
	Phoenicopteridae (flamingoes)	1	1	8
Anseriformes	Anatidae (wildfowl)	14	37	2983
Falconiformes	Accipitridae (hawks, vultures, eagles)	3	4	7
	Falconidae (falcons and allies)	1	4	7
Galliformes	Phasianidae (partridges, quails, pheasants and allies)	7	9	321
Gruiformes	Rallidae/Gruidae (rails, coots, cranes)	6	9	1653
Charadriformes	Haematopodidae (oystercatchers)	1	1	54
	Recurvirostridae (stilts, avocets)	2	3	12
	Burhinidae (stone-curlews, stone-plovers)	1	1	1
	Charadriidae (plovers, lapwings)	3	7	520
	Scolopacidae (snipes, sandpipers and allies)	19	48	2833
	Laridae (gulls)	5	16	1447
Apodiformes	Apodidae (swifts)	1	1	6
Columbiformes	Columbidae (pigeons)	3	7	374
Cuculiformes	Cuculidae (cuckoos)	1	1	2
Strigiformes	Tytonidae (barn owls and allies)	1	1	1
	Strigidae (typical owls)	2	3	4
Passeriformes	Tyrannidae (tyrant flycatchers)	2	2	6
	Alaudidae (larks)	1	1	68
	Hirundinidae (swallows)	1	1	9
	Motacillidae (pipits, wagtails)	2	3	34
	Troglodytidae (wrens)	2	3	3
	Turdidae (chats, thrushes)	6	12	420
	Sylviidae (warblers and allies)	5	12	117
	Muscicapidae (flycatchers)	1	2	3
	Emberizidae (buntings and allies)	7	11	86
	Parulidae (wood-warblers)	3	4	7
	Icteridae (blackbirds, orioles and allies)	3	3	87
	Fringillidae (finches)	2	4	25
	Ploceidae (weavers and allies)	1	1	46
	Sturnidae (starlings)	4	6	590
	Corvidae (crows and allies)	2	2	18

References: Scott et al. (1972); McKenna and Allard (1976); Anderson (1978); Gylstorff (1979); Meyer (1978); Christensen (1980); Grosse et al., (1980); Heijnis (1980); Willdan Associates (1982); Longridge (1986); Rusz et al. (1986); Bevanger (1988); Thingstad (1989); Hartman et al. (1992); Bevanger (1993); Bevanger and Sandaker (1993).

Hence, body size and behaviour, such as perching and roosting on poles or wires, are the keys to understanding why and how birds become electrocuted.

Birds below the size of a jackdaw *Corvus monedula* have a reduced chance of becoming electrocuted because the conductors and earth wire or earthed devices are generally too far apart. However, irregular and unexpected electrocution accidents do take place because of the huge diversity in electrical installations and equipment (Kroodsma and Van Dyke, 1985; Negro and Ferrer, 1995). In Norway, pole-mounted transformers, pin insulators and a triangular conductor configuration were reported as the most dangerous electrocuting devices by the energy companies as a response to a questionnaire (Bevanger and Thingstad, 1988). Flocks of small birds (house sparrow *Passer domesticus*, starling *Sturnus vulgaris* and thrushes *Turdus* spp.) crossing a high tension power line (and when several roosting birds take off simultaneously) have also been observed to result in short circuits, as the current can pass through several individuals (reported by four energy companies in Norway; cf. Bevanger and Thingstad, 1988).

Species frequently affected by electrocution belong to Ciconiiformes, Falconiformes, Strigiformes and Passeriformes (Tables 2 and 3) (Bevanger, 1994b). Data on electrocution from Germany, Switzerland and Spain (Haas, 1980) show a majority of medium sized raptors

Table 2
Birds recorded as collision or electrocution victims. The data have been separated into studies dealing with: (i) bird collisions with power lines; (ii) bird electrocution; and (iii) ringing recoveries reporting 'killed by electricity'. Category (iii) cannot be separated into collision or electrocution as recoveries of ringed birds are not normally specific regarding collision or electrocution mortality

Order	Number of birds		
	Collision	Electrocution	Ringing recoveries
Gaviformes	3	—	—
Podicipediformes	303	—	2
Procellariiformes	4	—	18
Pelecaniformes	67	—	45
Ciconiiformes	105	14	193
Anseriformes	2983	—	3091
Falconiformes	14	739	648
Galliformes	321	—	17
Gruiformes	1653	—	37
Charadriformes	4867	1	1150
Apodiformes	6	—	74
Columbiformes	374	12	20
Cuculiformes	2	—	3
Strigiformes	5	68	263
Caprimulgiformes	—	—	1
Coraciiformes	—	—	4
Piciformes	—	—	13
Passeriformes	1519	416	1258

References collision data: Scott et al. (1972); McKenna and Allard (1976); Anderson (1978); Meyer (1978); Gylstorff (1979); Christensen (1980); Grosse et al. (1980); Heijnis (1980); Willdan Associates (1982); Longridge (1986); Rusz et al. (1986); Bevanger (1988); Thingstad (1989); Hartman et al. (1992); Bevanger (1993); Bevanger and Sandaker (1993).

References electrocution data: Haas (1980); Ferrer et al. (1991).

References ringing recoveries: Stolt et al. (1986); Bevanger and Thingstad (1988); Rose and Baillie (1992).

and owls (and also corvids) figuring among the casualties. Unfortunately, few reports addressing electrocution mortality have included complete lists of the victim species and the numbers of casualties. Several species among the 'thermal soarers' (e.g. hawks, eagles, vultures, condors) are obviously susceptible to electrocution using utility structures for perching. However, records, even from biologists, frequently fail to distinguish between death caused by collision or electrocution.

Adult white storks *Ciconia ciconia* and eagle owls *Bubo bubo* seem to be surprisingly common among electrocution (and collision) victims of these species (Fiedler and Wissner, 1980; Stolt et al., 1986; Larsen and Stensrud, 1988; Grischtschenko and Gaber, 1990). These data seem to be among the most convincing indication of a population-regulating effect of mortality caused by utility structures. In their analyses of 1185 recoveries of 'Helgoland ringed' white storks, Riegel and Winkel (1971) found that, of 294 birds recovered in Germany with known causes of death, 226 were killed because of 'overhead wires'. Of these, 62.8% were 1-year-old subadults, 2.2% were 2- and 3-year-old birds and 35% were 4-year-old or older adults.

Benson (1980, 1982) concluded that subadult age classes of large raptors suffer higher losses because of electrocution than adults, as a result of inexperience in flight and different hunting methods. Young and juvenile birds are inexperienced flyers less adept at manoeuvring than adults, e.g. when landing and taking off (Nelson and Nelson, 1976, 1977) and may even overbalance while perching on a high-tension wire and become electrocuted (Lesbem, 1985). Several authors have stressed that there is a high percentage of juveniles and subadults among collision victims because subadults normally constitute the majority of a population, particularly in autumn; subadults often have a more gregarious behaviour, and several investigations were carried out in periods when the proportion of young birds in the population is high and exposed. It was claimed that birds learn to avoid air obstacles through experience (Lee, 1978; Thompson, 1978). However, no hard data seem to exist. Birds injured in collisions and electrocution may recover (Benson, 1982), but most individuals only gain experience once, and habituation seems particularly irrelevant in the case of electrocution.

In South Africa, several hundred individuals of the vulnerable, endemic Cape vulture *Gyps coprotheres* were found electrocuted (Markus, 1972; Ledger and Annegarn, 1981; Mundy et al., 1992; Ledger et al., 1993), and numerous Egyptian vultures *Neophron percnopterus*—

Table 3
Birds recorded as electrocution victims (based on Haas, 1980)

Order	Family	No. of genera	No. of species	No. of individuals
Ciconiiformes	Ciconiidae (storks)	1	2	14
Falconiformes	Accipitridae (hawks, vultures, eagles)	9	13	430
	Falconidae (falcons and allies)	1	1	88
Charadriformes	Laridae (gulls)	1	1	1
Columbiformes	Columbidae (pigeons)	1	3	12
Strigiformes	Tytonidae (barn owls and allies)	1	1	14
	Strigidae (typical owls)	3	3	54
Passeriformes	Turdidae (chats, thrushes)	2	4	15
	Sturnidae (starlings)	1	1	18
	Lanidae (shrikes)	1	1	1
	Corvidae (crows and allies)	2	4	382

considered as endangered in South Africa—were found electrocuted in the Sudan (Nikolaus, 1984). During the last few years, numerous reports of electrocuted raptors have come from Spain and other parts of southern Europe, particular concern being expressed for the Spanish imperial eagle *Aquila adalberti* (Ferrer et al., 1991; Negro and Ferrer, 1995). In Norway, most of the owl and raptor species were recorded as either collision or electrocution victims (Bevanger and Overskaug, in press).

It is now hoped to save the California condor *Gymnogyps californianus* from becoming extinct through breeding in captivity (Wallace, 1992; Caughley, 1994). In 1992, three of eight released birds in the former distribution area of the species were found electrocuted (Mestel, 1993). While the initial population decline was supposed to have been caused by habitat loss, shooting, etc., it was stressed that toxic organochlorines were the main factor during the 1970s and 1980s. It is imperative to clearly determine the causes of decline in the population of a critically endangered species to enable appropriate management actions to be implemented. Particular attention should be paid to local populations and areas with a high density of overhead wires.

4. Conservation impacts of collision and electrocution mortality

No investigation was found that was specifically designed to judge effects of power lines on bird mortality at the population level, and the problem has mainly been addressed as one co-objective among empirical questions connected with collision extent, behavioural effects and mitigating measures (Meyer, 1978; Beaulaurier, 1981; Willdan Associates, 1982; Faanes, 1987; Hartman et al., 1992).

The impact of seemingly density-independent mortality factors, like hunting, predation and utility structures, is generally thought to be compensated for among the survivors. Although numerous birds and mammals generally show a type II survivorship curve (e.g. Begon et al., 1996), indicating that few individuals reach their physiological life span and that survival is highly age-dependent, it is well known that heavy hunting may change survivorship curves within a population, for example from a type I survivorship (i.e. mortality is massive towards the end of the greatest life span) towards a type II survivorship curve (Lowe, 1969). If a dwindling population is unable to respond with compensatory actions to the mortality caused by utility structures, this mortality is population regulatory and must be considered a significant problem for nature management authorities.

Species with dwindling populations are listed in Red Data Books (RDB) and it is reasonable that RDB species are a main target of concern regarding anthropogenically-induced mortality factors (e.g. Willard, 1978. There are numerous collision and electrocution victims among bird species recorded as vulnerable and endangered (Appendix A). It is not surprising that there are no good data for most rare species. Even in abundant species, like waders and gulls, observed collisions occur in only between 0.07 and 0.003% of total flights (Meyer, 1978). However, recoveries of rare species, ringed in small numbers, were made. For example only two ringed individuals of both corn crake *Crex crex* and water rail *Rallus aquaticus* were recovered in Norway during the period 1914–1981 (Bevanger and Thingstad, 1988), which constitute 3.3 and 6.1% of the total number of ringed birds, respectively. In both these species, one of the recoveries was a collision victim.

There are contrasting views regarding threat categories for birds and animals (e.g. Collar and Andrew, 1988; Mace and Lande, 1991; Bibby et al., 1992). Species recorded in a world-wide RDB list do not necessarily reflect local or regional (in some instances not national) situations. When the significance of collision and electrocution-induced mortality is being addressed particular attention should be paid to local populations. Unfortunately, some countries are still ignorant about the population status of potentially vulnerable and endangered species, and lack a conservation management action plan.

The indirect effects of utility structures are rarely focused upon. Clear-felled transmission-line corridors in forest areas vary in breadth from 30 m up to 60 m or more depending on the voltage, and may have far-reaching fragmenting and habitat-changing effects that might affect the fauna (e.g. Bevanger and Henriksen, 1996). Habitat fragmentation is identified as a main threat to biodiversity and is a focal point among conservation biologists, especially in tropical and neotropical areas (Bierregaard et al., 1992; Fiedler, 1993). There is no question that many more power lines will be built in the future, particularly in vulnerable, tropical and subtropical areas (Bevanger, 1994a). It was stressed that power-line corridors may be particularly damaging and create barriers to some groups of species (e.g. antbirds (Formicariidae), ovenbirds (Furnariidae), hummingbirds (Trochilidae) and tapaculos (Rhinocryptidae)) that are restricted to the understorey of mature forests (Zerda and Rosselli, 1997). Specialised mammals in the tropics, including primates, bats and rodents, are vulnerable to habitat fragmentation, as are amphibians and reptiles. Several of these creatures are also prone to electrocution (e.g. Quincy, 1993; Lawson and Wyndham, 1993; Zerda and Rosselli, 1997), although few studies have focused on this.

Conservation management authorities should not only focus on the lack of hard data rooted in population dynamics but use available documentation and indices

to carry out an early warning policy, like those deriving from analyses of morphology and biomechanics. Hopefully this can also convince energy companies to seriously consider financially adverse alternative routing, earth cabling and technical solutions for the construction of utility structures to reduce the adverse wildlife effects.

Appendix

Species regarded as rare, vulnerable or endangered (nationally or internationally) reported as collision and/or electrocution victims. The taxonomy follows Howard and Moore (1991)

Order	Family	Genus	Species	Source
Pelecaniformes	Pelecanidae	*Pelecanus*	Dalmatian pelican *P. crispus*	Crivelli et al., 1988
			White pelican *P. erythrorhynchos*	Ryder, 1981
			Brown pelican *P. occidentalis*	McNeil et al., 1985
Ciconiiformes	Ardeidae	*Botaurus*	Eurasian bittern *B. stellaris*	Andersen-Harild and Bloch, 1973; Gylstorff, 1979; Rose and Baillie, 1992
	Ciconiidae	*Ciconia*	White stork *C. ciconia*	Fiedler and Wissner, 1980; Haas, 1980; Oatley and Rammesmayer, 1988
	Phoenicopteridae	*Phoenicopterus*	Lesser flamingo *P. ruber*	Longridge, 1986
			Greater flamingo *P. minor*	Longridge, 1986
Anseriformes	Anatidae	*Cygnus*	Mute swan *C. olor*	Perrins and Sears, 1991; Rose and Baillie, 1992; Mathiasson, 1993
			Whooper swan *C. cygnus*	Folkestad, 1980; Rose and Baillie, 1992; Bevanger, unpubl.
			Tundra swan *C. columbianus bewickii*	Rose and Baillie, 1992
		Anser	Greylag goose *A. anser*	Rose and Baillie, 1992
Falconiformes	Cathartidae	*Gymnogyps*	California condor *G. californianus*	Snyder, 1986; Anon., 1993
	Pandionidae	*Pandion*	Osprey *P. haliaëtus*	Stolt et al., 1986; Bevanger and Thingstad, 1988; Muñoz-Pulido, 1990
	Accipitridae	*Pernis*	Western honey buzzard *P. apivorus*	Stolt et al., 1986
		Milvus	Red kite *M. milvus*	Haas, 1980; Ferrer et al., 1991; Rose and Baillie, 1992
		Haliaëtus	American bald eagle *H. leucocephalus*	Smith and Murphy, 1972; Meyer, 1980; Olendorff and Lehman, 1986
			White-tailed sea eagle *H. albicilla*	Bevanger and Thingstad, 1988
		Aegypius	Cinereous vulture *A. monachus*	Garzon, 1977
		Gyps	Griffon vulture *G. fulvus*	Mundy, 1983; Leshem, 1985; Ferrer et al., 1991
			Cape vulture *G. coprotheres*	Markus, 1972; Ledger, 1984; Ledger and Annegarn, 1981
			African white-backed vulture *G. africanus*	Drake and Mundy, 1981
		Neophron	Egyptian vulture *N. percnopterus*	Nikolaus, 1984
		Gypaetus	Lammergeier *G. barbatus*	Wuethrich, 1993
		Hieraaetus	Martial eagle *H. bellicosus*	Brooke, 1984; Maclean, 1985; Ledger, 1990
		Circus	Hen harrier *C. cyaneus*	Scott et al., 1972; Rose and Baillie, 1992
			Montague's harrier *C. pygargus*	Rose and Baillie, 1992
			Western marsh harrier *C. aeruginosus*	Rose and Baillie, 1992
		Accipiter	Northern goshawk *A. gentilis*	Stolt et al., 1986; Bevanger and Thingstad, 1988; Rose and Baillie, 1992
		Aquila	Spanish imperial eagle *A. heliaca adalberti*	Garzon, 1977; Haas, 1980; Ferrer and Court, 1988; Meyburg, 1989; Ferrer et al., 1991
			Golden eagle *A. chrysaëtos*	Olendorff et al., 1981; Bevanger and Thingstad, 1988; Rose and Baillie, 1992
	Falconidae	*Falco*	Gyr falcon *F. rusticolus*	Gudmundsson and Clausen, 1974
			Peregrine falcon *F. peregrinus*	Olsen and Olsen, 1980; Stolt et al., 1986; Rose and Baillie, 1992
Gruiformes	Gruidae	*Grus*	Common crane *G. grus*	Stolt et al., 1986
			Sandhill crane *G. canadensis*	Walkinshaw, 1956; Drewien, 1973; Brown et al., 1987; Windingstad, 1988
			Manchurian crane *G. japonensis*	Brown et al., 1987
			Whooping crane *G. americana*	Brown et al., 1987; Doughty, 1989; Howe, 1989
		Bugeranus	Wattled crane *B. carunculatus*	Johnson and Sinclair, 1984
	Rallidae	*Rallus*	Water rail *R. aquaticus*	Scott et al., 1972; Grosse et al., 1980; Bevanger and Thingstad, 1988
		Crex	Corn crake *C. crex*	Stolt et al., 1986; Bevanger and Thingstad, 1988
		Porzana	Spotted crake *P. porzana*	Grosse et al., 1980; Heijnis, 1980
	Otidae	*Ardeotis*	Kori bustard *A. kori*	Longridge, 1986
		Otis	Great bustard *O. tarda*	Cramp and Simmons, 1980; Cardoso, 1985
Strigiformes	Tytonidae	*Tyto*	Barn owl *T. alba*	Rose and Baillie, 1992
	Strigidae	*Bubo*	Northern eagle owl *B. bubo*	Glutz and Bauer, 1980; Förstel, 1983; Larsen and Stensrud, 1988
		Strix	Ural owl *S. uralensis*	Stolt et al., 1986
			Great grey owl *S. nebulosa*	Stolt et al., 1986

15

Bird Strikes and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science – Next Steps Toward Mitigation[1]

Albert M. Manville, II[2]

Abstract

Migratory birds suffer considerable human-caused mortality from structures built to provide public services and amenities. Three such entities are increasing nationwide: communication towers, power lines, and wind turbines. Communication towers have been growing at an exponential rate over at least the past 6 years. The U.S. Fish and Wildlife Service is especially concerned about growing impacts to some 836 species of migratory birds currently protected under the Migratory Bird Treaty Act of 1918, as amended. While mortality estimates are often sketchy, and won't be verified until nationwide cumulative impact studies are conducted, current figures are troubling. Communication towers may kill from 4-50 million birds per year. Collisions with power transmission and distribution lines may kill anywhere from hundreds of thousands to 175 million birds annually, and power lines electrocute tens to hundreds of thousands more birds annually, but these utilities are poorly monitored for both strikes and electrocutions. More than 15,000 wind turbines may kill 40,000 or more birds annually nationwide, the majority in California. This paper will address the commonalities of bird impacts among these industries; those bird species that tend to be most affected; and research (completed, current, and proposed) intended to reduce bird collisions and electrocutions nationwide. The issues of structure location (siting), lighting, guy supports, lattice or tubular structures, bird behavior, and habitat modifications are reviewed. In addition, this paper reviews the respective roles and publications of the Avian Power Line Interaction Committee and the Wildlife Workgroup of the National Wind Coordinating Committee, the roles of the Service-chaired Communication Tower Working Group and Wind Turbine Siting Working Group, and the Fish and Wildlife Services' voluntary tower and turbine siting and placement guidelines. An update on recent Communication Tower Working Group research initiatives will also be discussed along with promising research findings and needs.

Key words: APLIC, avian impacts, avian mortality, BGEPA, bird strikes, collisions, communication towers, CTWG, electrocutions, ESA, MBTA, mitigation measures, NWCC, power lines, transmission and distribution lines, wind turbines.

Introduction

Acquiring reliable estimates of avian population mortality is difficult, even under controlled circumstances, and the threats to birds from human development continue to increase in the United States and elsewhere globally. As the U.S. human population grows – now the third largest in the world – human structures and the services needed to meet population demands continue to increase. Unfortunately, the impacts of these structures and services on birds, bats, and other species are generally unaccounted for, unknown, or only roughly estimated. This paper will address three of these structural impacts, those from power lines, communication towers, and wind turbines.

To better understand the impacts of human-caused mortality on landbirds – and recently on bats, attempts have been made not only to estimate these mortality factors, but also to assess the spring and fall populations of breeding landbirds in North America to determine rough mortality percentages. While bird hunting mortality has been documented back to at least Biblical times, mortality caused by structures was first documented in the United States in 1874 at lighthouses and lamps (Forest and Stream 1874) and in 1876 at telegraph wires (Coues 1876). The first U.S. Fish and Wildlife Service (USFWS or Service) attempt to estimate nationwide human-caused annual mortality was published by Banks (1979) where he estimated 196 million bird deaths caused by human activity. This estimate represented 1.9 percent of the then existing estimated bird population in North America. Of the 196 million estimated deaths, 61 percent were from hunting, 32 percent from collisions with structures, and 2 percent from pollution and poisoning. To assess the nationwide status of breeding bird populations, Aldrich et al. (1975) used the 1973 Breeding Bird Survey, which averaged 1,284 birds/km^2 (3,325 birds/mi^2), to

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**

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estimate 9.975 billion breeding landbirds in the United States exclusive of Alaska and Hawaii. They concluded that the autumn landbird population was probably twice that figure – 20 billion. Banks (1979) used the figure of 10 billion breeding birds in the contiguous United States and assumed an average annual mortality of 10 billion birds. J. Trapp (unpubl. data), of the USFWS' Division of Migratory Bird Management, examined Breeding Bird Censuses for 1991 and 1992, extrapolated from these figures, and concluded that it was probably safe to talk about minimum breeding populations on the order of 10 billion birds, and minimum fall populations on the order of 20 billion birds in North America north of Mexico. While there are far more birds than people generally realize, population impacts can be sizable and most human-caused avian mortality factors are not systematically monitored or assessed.

The USFWS is currently responsible for the conservation and management of 836 species of migratory birds in the United States; these birds are killed by myriad non-hunting-related factors. These include collisions with communication towers, power lines, wind turbines, buildings and windows, smokestacks and monuments, automobiles, and aircraft; electrocutions at power lines; predation by domestic cats; poisoning from pesticides, oil and contaminant spills; drowning in oil and wastewater pits; entanglement, strangulation, and drowning in fishing gear; and loss or degradation of habitat.

Of the 836 migratory bird species managed by USFWS, at least 223 are in trouble. These include 92 listed on the Federal Endangered Species Act (ESA; 16 U.S.C. 1531 et seq.: 77 are endangered and 15 are threatened), and 131 on the USFWS's National List of Birds of Conservation Concern 2002 (USFWS 2003). Populations are declining precipitously for some of these species. To add yet another challenge to managing birds, we essentially lack data on the status of fully one-third of all North American bird populations. These challenges make management difficult. Recent extrapolations from various databases indicate that human-caused mortality could account for billions of bird deaths per year (Klem 1990, Corcoran 1999, Erickson et al. 2001, Manville 2001a, Manville 2001b). Based only on estimates of annual mortality from vehicles strikes (60- 80 million), building and window collisions (98- 980 million), smoke stack casualties (tens to hundreds of thousands), power line electrocutions (tens to hundreds of thousands), power line impacts (hundreds of thousands to perhaps 175 million), communication tower accidents (4-5 to 40-50 million), and wind turbine impacts (~ 34,000), Erickson et al. (2001) estimated from 100 million to well over one billion birds killed annually. The extent to which cumulative mortality from all human-caused factors affects bird populations, and measures that can be taken to reduce these events, are matters of considerable interest and concern to the Service and others (Manville 2001b).

Structural Review

The U.S. Power Grid

Since the U.S. power grid was first constructed in the late 1880s, power line expansion has increased tremendously. With a growing U.S. population, industrial expansion, and public demand for more electricity as exemplified by energy challenges in California in 2001, more power lines are being installed. The most recent nationwide estimates indicate that there are more than 804,500 km (500,000 mi) of bulk transmission lines in the U.S. (transmission lines in the U.S. carry ≥115,000 volts/115 kV, with conductors attached to either tall wood, concrete or steel towers; APLIC 1996, Harness 1997, Edison Electric Institute 2000). Much of the problem with bird collisions is associated with transmission lines. Distribution lines (those in the U.S. carrying ≤69,000 v/69kV) are constructed on 11- 15 m (36- 49 ft) wooden, steel, or concrete poles, typically configured with one, two, or three energized (phase) wires and one neutral (grounded) wire. Raptor electrocutions, especially in the western United States, are most frequently associated with distribution lines. Distribution lines have phase-to-phase and phase-to-ground wire clearances which place birds perching on the supporting poles at much greater risk of completing a circuit and suffering electrocution, often resulting in a power outage (Boeker and Nickerson 1975, Harness 1997). Because of rapid expansion, new development, and jurisdictional issues, no good accounting of the total amount of distribution line is available for the United States; it is certainly in the millions of kilometers. Williams (2000) cites the figure of 116,531,289 distribution poles in the United States but lists no figure for wire length.

Power Line Electrocutions

Birds have been subject to electrocutions and collisions in the United States since the first overhead telegraph wires were strung in the late 1860s, initially reported by Coues (1876) in rural Colorado. Electrification of the United States and development of the U.S. power grid began by the late 1880s and has rapidly expanded since. Not surprisingly, by 1922, eagle electrocutions were first reported at transmission lines, followed in 1933 by hawk electrocutions at distribution lines, and in 1940 by power outages on Idaho Power lines which subsequently were retrofitted with a deterrent device intended to discourage eagles from landing (R. Harness, EDM International, pers. comm.). By the early 1970s the electric utility industry had become

acutely aware of bird electrocutions – especially to eagles, hawks, and owls. Reports of significant bird mortality during the winter of 1970-1971 in Colorado and Wyoming drew the attention of state and Federal law enforcement agents and the industry; nearly 1,200 eagle deaths were reported resulting from poisoning (N = 300+), shooting from aircraft (N = 800+) and electrocution or shooting along a power line (N = 300+) (Olendorff et al. 1981; L. Suazo, USFWS, pers. comm.). M.W. Nelson's 1980 film "Silver Wires, Golden Wings" followed, which was one of the first public relations efforts designed to help prevent eagle electrocutions and to encourage use of nesting platforms on power poles (Lehman et al. 1999). Nelson filmed trained Golden Eagles (*Aquila chrysaetos*) during take-offs and landings on un-energized mock-up power poles to determine how electrocutions occurred and how they might be prevented. His and other research led to an update to the Suggested Practices document (Olendorff et al. 1981).

In an attempt to begin addressing both collision (specifically Whooping Cranes [*Grus americana*]) and electrocution problems, an ad hoc committee represented by several investor-owned electric utilities (IOUs), the National Audubon Society (NAS), and the Service was created in 1983. By 1989, a more formal relationship was established with the creation of the Avian Power Line Interaction Committee (APLIC) composed then of nine IOUs and the FWS (Lewis 1997) – with technical advice from staff of NAS, Clemson University, and the University of Idaho. APLIC was housed in the IOU trade association Edison Electric Institute (EEI), Washington, DC (Huckabee 1993). Following research and earlier publications in 1975 and 1981, Suggested Practices for Raptor Protection on Powerlines (APLIC 1996) became the first definitive work on raptor electrocutions. It was reprinted in 2000 in Spanish. That same year the instructional video, Raptors at Risk (North American Falconers' Association et al. 2000) was released to the public, documenting raptor electrocutions and illustrating inexpensive avoidance techniques. Copies can be obtained from R. Harness at EDM International, <rharness@edmlink.com>.

While the efforts of APLIC to reduce bird electrocutions and collisions have been key, many in the electric utility industry may still not be getting the message that human-caused bird deaths are unacceptable (Williams 2000). At present, APLIC is composed of 18 IOUs (out of 186-some IOUs within this country); one IOU trade association (EEI); some 960 cooperatives represented by the National Rural Electric Cooperative Association (NRECA; out of approximately 1,056 cooperatives housed under the U.S. Department of Agriculture [USDA]); one research organization (Electric Power Research Institute); and three Federal agencies (including USFWS, the Bonneville Power Administration, and the Western Area Power Administration) (L. Suazo, USFWS, pers. comm.; R. Loughery, Edison Electric Institute, pers. comm.; www.APLIC.org). To be a more effective arm of the overall industry, APLIC still needs to recruit additional utility membership. However, many of the cooperatives are small companies, and the $5,000 APLIC initiation fee and $2,500 annual dues are viewed by many as better spent on mitigation or for other purposes.

NRECA – somewhat like APLIC – is the not-for-profit national service organization representing most of the USDA cooperatives which provide electricity to more than 30 million consumer-owners primarily in sparsely population rural areas in 46 states. NRECA published a definitive manual for their industry, Animal Caused Outages (Southern Engineering Company 1996), which addresses wire configurations and situations unique to this segment of the industry. APLIC and NRECA are working to integrate guidance in Suggested Practices for Raptor Protection on Power Lines (APLIC 1996) that conforms to both types of utility structures and needs. USDA cooperatives, for example, now must construct distribution lines using non-conducting wooden braces and cross arms, and install ground wires that are raptor safe.

Prior to 1999, only two fines had been levied by law enforcement agents against electric utility companies for electrocuting birds protected under the Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703-712) and the Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668-668C), one in 1993 and the other in 1998. MBTA is a strict liability statute; the killing of any protected migratory bird is not technically allowed under law unless a permit is obtained, and the Service does not issue "incidental or accidental take" permits. The landscape changed in August 1999 with the District Court's decision against the Moon Lake Electric Association in western Colorado and eastern Utah. Beginning in 1997, agents of the Service's Office of Law Enforcement (LE) in the West investigated bird mortalities from electrocutions and strikes, and found to their dismay that the statistics rivaled those from the 1970s. As a result of this investigation, the Department of Justice prevailed in its first criminal prosecution of a utility under BGEPA and MBTA. Moon Lake pleaded guilty and agreed to pay $100,000 in fines and restitution, serve 3 year's probation, sign a memorandum of understanding (MOU) with the Service, implement an avian protection plan, and retrofit poles that were killing raptors. The message was a powerful one, sending shock waves through the electric utility, wind generation, and communication tower industries. In addition to fines as high as $500,000, company officers could be convicted of felonies, lose their right to vote, pay per-

sonal fines as high as $250,000, and be jailed for up to two years (Williams 2000).

Following release of the Moon Lake MOU, LE was inundated with requests for other MOUs. In 2002, an historic MOU was signed with Xcel Energy and the USFWS Denver, Colorado, Regional Office in concurrence with the Department of Justice. The proactive agreement presently covers Colorado and Wyoming. The USFWS is currently finalizing the template for an avian protections plan (APP) with APLIC These voluntary, proactive agreements will call for the development of comprehensive APPs which are intended to reduce electrocutions and bird strikes by participating companies.

Looking specifically at the problem of electrocutions, eagles are the most commonly reported electrocuted birds, Golden Eagles reported 2.3 times more frequently than Bald Eagles (*Haliaeetus leucocephalus*) by Harness (1997) in the West, with juveniles more frequently reported killed than adults. Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (*Bubo virginianus*) were the most commonly reported hawk and owl species by Harness (1997) and Harness and Wilson (2001). Power outages can result in damaged equipment, safety problems, brush and forest fires, and loss of service to customers. Nationwide, animals are the third leading identifiable cause of all power outages, with birds causing more outages than any other animal (Southern Engineering Company 1996). Of 4,300 eagle mortalities investigated by the Department of Interior from the early 1960s to 1995, electrocution was reported as the second greatest cause of mortality to Golden Eagles and the third greatest cause to Bald Eagles (LaRoe et al. 1995). Electrocution is now rated the fourth leading cause of death for Bald Eagles, following accidental trauma, poisoning, and shooting (Lehman 2001).

Where vegetation is low and terrain is flat, power poles are particularly attractive to raptors in the West since they provide structures from which to hunt and roost (Boeker 1972, Benson 1981). Eagles and buteos (soaring hawks) actively seek out poles, especially where prey is abundant and few other perches exist, increasing their range of vision, allowing greater attack speed when hunting, and advertising territorial ownership (Olendorff et al. 1981, Colson and Associates 1995). It was commonly believed in the 1980s that a very small percentage of distribution poles was actually electrocuting raptors. These were designated as "preferred poles," situated in good habitat or near high prey concentrations (Olendorff et al. 1981). Nelson and Nelson (1976) even estimated that 95 percent of electrocutions could be prevented by modifying 2 percent of the poles. Conventional wisdom indicates that these assessments were probably unrealistic due, in part, to lack of a nationwide reporting system and systematic natio wide studies, and observational and data-collectio biases (Lehman 2001).

Twelve North American raptor species are known nes ers on utility structures. In the East, Osprey (*Pandio haliaetus*) is frequently seen nesting on power pol (Blue 1996). Due to lack of staff and funding, very li tle of the U.S. power grid is assessed – if even infr quently – for bird electrocutions. The estimates of te of thousands to hundreds of thousands or more bir killed each year are only very rough approximatio based on very limited data. True mortality could b much higher. Recent information suggests that rapt electrocutions may be under-reported, possibly larg by several orders of magnitude (Lehman 2001).

Mitigation measures can vary in cost, depending o whether or not they are required for new constructio or are retrofitted. Sufficient phase-to-phase and phas to-ground wire spacing is critical for large-winge birds. This can be costly if wires have to be re-strun for wider separation. Three-phase transformers can b especially deadly where bare energized jumper wir connect transformers, protective cutouts, and surge a resters. These can be deadly to small and large rapto (Negro and Ferrer 1995). Jumper wires on all electric equipment should be insulated, including at tap an dead-end locations. Existing transformers can be retr fitted by replacing bare wire with either 600 v insulate jumpers or by sliding insulating material over ba jumpers; new jumpers should contain 600 v insulate jumpers and be insulated with bushing covers (Harne 1997, Harness and Wilson 2001). Specifications a provided by APLIC (1996) and Southern Engineerin Company (1996). With the use of cost-effective new replacement steel distribution poles – steel has bee used on transmission towers for years – we see a ne electrocution challenge. The mitigation measures use on wooden poles are not effective on metal ones. In European study, insulating cross-arm braces on ste distribution poles proved most effective, while perc guards were less effective (Janss and Ferrer 1999 Harness and Wilson (2001) call for more research t attempt to qualify the relationships between rapt electrocutions and different types of electrical pow structures. The Service strongly agrees.

Power Line Collisions

Birds of a much greater variety strike power transmi sion and distribution lines. Coues (1876) was the fir to report over 100 dead birds, mostly Horned Lar (*Eremophila alpestris*), along a 4.8-km (3-mi) sectio of telegraph line, and even witnessed the deaths three birds. Cohen (1896) reported 14 Red Phalarop (*Phalaropus fulicaria*) and a Ruddy Duck (*Oxyu jamaicensis*) verified by necropsies as telegraph wi

kills. Emerson (1904) reported shorebirds and a Black Rail (*Laterallus jamaicensis*) colliding with electrical wires over a salt marsh and evaporation ponds – representing the first reported power line strikes. Large, less maneuverable birds are more vulnerable to collisions with power lines, including Great Blue Herons (*Ardea herodias*), cranes (*Grus* spp.), swans (*Cygnus* spp.), and pelicans (*Pelicanus* spp.; Huckabee 1993). Line collisions resulted in 36 percent of the known mortality to fledged Greater Sandhill Cranes (*G. canadensis tabida*) in the Rocky Mountains (Drewien 1973), 44 percent mortality of fledged Trumpeter Swans (*C. buccinator*) in Wyoming (Lockman 1988), and 40 percent of the know mortality of endangered fledged Whooping Cranes in the Rocky Mountains (Lewis 1993). In a study near wetlands in North Dakota, Faanes (1987) found that waterbirds (based on 46 percent documented mortality), waterfowl (26 percent), shorebirds (8 percent), and passerines (5 percent) were most vulnerable to strikes with transmission lines. In habitats away from wetlands, raptors and passerines appear to be most susceptible to collisions with power lines. Collisions from many other species have also been reported (Erickson et al. 2001).

On Kaua'i, Hawaiian Islands, studies by Podolsky et al. (1998) and Ainley et al. (2001) documented rather unique lighting and power line impacts to Newell's Shearwaters (*Puffinus auricularis newelli*). During the first nocturnal flights of fledglings from nests to the ocean, a high percentage (≥2 to ≥10 percent) of fledglings were reported blinded by man-made lighting, disoriented, and killed while colliding with lights, utility poles, wires, buildings, and automobiles (Ainley et al. 2001). Contrary to recommendations by APLIC, wide spacing of power transmission lines appeared to increase collisions of summer nesting season adults and subadults during their nocturnal and crepuscular flights to and from bird colonies (Podolsky et al. 1998). It was hypothesized that the wide spacing increased the incidence of collisions as birds attempted to avoid hitting one line, only to hit another. In experimental areas, light shielding was shown to reduce attraction by as much as 40 percent while reducing light intensity also lowered deaths significantly (Ainley et al. 2001). Burying power lines was also recommended for particular hot spots.

Estimates of mortality from avian collisions with power lines have varied considerably and have frequently been based on extrapolations. Faanes (1987) estimated 124 avian fatalities/km/yr (200 fatalities/mi/yr) near prairie wetlands and lakes in North Dakota. Koops (1987) examined 4,666 km (2,900 mi) of bulk transmission line in the Netherlands, estimating 0.75 - 1 million birds killed there per year. U.S. mortality could range from hundreds of thousands up to perhaps 175 million birds per year, based on extrapolations by Erickson et al. (2001) and Koops (1987). Very little of the power grid, however, is currently being examined so these estimates are not particularly meaningful.

In an attempt to comprehensively address the collision problem, APLIC (1994) provided voluntary guidance to the industry on avoiding power line strikes. The document will be updated once research being conducted by the Electric Power Research Institute and others at the Audubon National Wildlife Refuge, North Dakota, is completed, and results of tests on a Bird Strike Indicator and Bird Activity Monitor can be published. Other research findings will also likely be included. For example, marker balls, bird diverters, and paint have been shown to reduce collisions, sometimes significantly. Strikes were reduced by 53 percent at a South Carolina transmission line outfitted with yellow marker balls (Savereno et al. 1996). In southwestern Colorado, polyvinyl chloride plastic dampers reduced collisions of cranes and waterfowl by 61 percent while yellow fiberglass square plates reduced mortality to the same species by 63 percent (Brown and Drewien 1995).

Communication Tower Collisions and Related Problems

Communication towers, whether monopole cellular telephone, or tall, lattice structured digital television (DTV) antennas, are an increasingly familiar sight in neighborhoods, near highways, and along ridge tops. For at least the past 6 years, the number of communication towers (including but not necessarily limited to radio, television, cellular, microwave, emergency broadcast, national defense, paging, and related) constructed across the landscape has been growing at an exponential rate. Based on the July 2002 statistics from the Federal Communication Commission's (FCC) Antenna Structure Registry Database (FCC 2002), more than 138,000 towers were listed with the Commission – of which some 106,000 were lighted. Revised published statistics (FCC 2003) may have indicated some double-counting of the 2002 numbers, since nearly 93,000 towers were reported registered in June 2003. Due to an under-reporting to the FCC of up to some 35 percent, the actual number of existing towers is likely higher (Manville 2001b).

While this is positive news for the communications industry, it is decidedly problematic for migrating birds. Towers today pose a likely significant impact on migratory birds, especially some 350 species of passerines. The earliest known report of a bird-tower kill in the United States took place in September 1948 at a 137-m (450-ft) radio tower in Baltimore, Maryland, although no details about the incident were available (Aronoff 1949). The first long-term study of the impact of a television tower on birds was begun in 1955 by the

16

OUTSTANDING ARIZONA WATERS (OAWs)

A.A.C. R18-11-112(G)

1. West Fork of the Little Colorado River, from its headwaters at 33°55'02"/109°33'30" to Government Springs at 33°59'33"/109°27'54" (approximately 9.1 river miles);
2. Oak Creek, from its headwaters at 35°01'30"/111°44'12" to its confluence with the Verde River at 34°40'41"/111°56'30 (approximately 50.3 river miles);
3. West Fork of Oak Creek, from its headwaters at 35°02'44"/111°54'48" to its confluence with Oak Creek at 34°59'14"/111°44'46" (approximately 15.8 river miles);
4. Peeples Canyon Creek, from its headwaters at 34°23'57"/113°19'45" to its confluence with the Santa Maria River at 34°20'36"/113°15'12" (approximately 8.1 river miles);
5. Burro Creek, from its headwaters at 34°52'46.5"/113°05'13.5" to its confluence with Boulder Creek at 34°374.5"/113°18'36" (approximately 29.5 miles);
6. Francis Creek, from its headwaters at 34°54'38"/113°20'30" to its confluence with Burro Creek at 34°44'29"/113°14'37" (approximately 22.9 river miles);
7. Bonita Creek, from its boundary of the San Carlos Indian Reservation at 33°03'08"/109°33'41" to its confluence with the Gila River at 32°53'36"/109°28'43" (approximately 14.7 river miles);
8. Cienega Creek, from its confluence with Gardner Canyon and Spring Water Canyon at 31°47'38.5"/110°35'21.5" to the USGS gaging station at 32°02'09"/110°40'34" (approximately 28.3 river miles);
9. Aravaipa Creek, from its confluence with Stowe Gulch at 32°52'10"/110°22'03" to the downstream boundary of the Aravaipa Canyon Wilderness Area at 32°54'23"/110°33'42" (approximately 15.5 river miles);
10. Cave Creek, from its headwaters at 31°50'30"/109°17'04.5" to the Coronado National Forest boundary at 31°54'38"/109°08'40" (approximately 10.4 river miles);
11. South Fork of Cave Creek, from its headwaters at 31°50'20"/109°16'33" to its confluence with Cave Creek at 31°53'04"/109°10'30" (approximately 8.6 river miles);
12. Buehman Canyon Creek, from its headwaters at 32°52'0.5"/110°39'54.5" to its confluence with unnamed tributary at 32°24'31.5"/110°32'08" (approximately 9.8 river miles);
13. Lee Valley Creek, from its headwaters at 33°55'49"/109°31'34" to its confluence with Lee Valley Reservoir at 33°56'28"/109°30'15.5" (approximately 1.6 river miles);
14. Bear Wallow Creek, from its headwaters at 33°35'54"/109°26'54.5" to the boundary of the San Carlos Indian Reservation at 33°37'52"/109°29'44" (approximately 4.25 river miles);
15. North Fork of Bear Wallow Creek, from its headwaters at 33°34'47.5"/109°21'59.5" to its confluence with Bear Wallow Creek at 33°35'54"/109°26'54.5" (approximately 3.8 river miles);
16. South Fork of Bear Wallow Creek, from its headwaters at 33°34'38.5"/109°23'58" to its confluence with Bear Wallow Creek at 33°35'54"/109°26'54.5" (approximately 3.8 river miles);
17. Snake Creek, from its headwaters at 33°37'21.5"/109°26'11" to its confluence with the Black River at 33°40'31.5"/109°28'58.5" (approximately 6.2 river miles);
18. Hay Creek, from its headwaters at 33°51'00"/109°28'48" to its confluence with the West Fork of the Black River at 33°48'30"/109°25'19" (approximately 5.5 river miles);
19. Stinky Creek, from the White Mountain Apache Indian Reservation boundary at 33°52'36.5"/109°29'45" to its confluence with the West Fork of the Black River at 33°51'21.5"/109°27'09.5" (approximately 3.0 river miles);
20. KP Creek, from its headwaters at 33°34'03"/109°21'19" to its confluence with the Blue River at 33°31'44"/109°12'04.5" (approximately 12.7 river miles);
21. Davidson Canyon, from the unnamed spring at 31°59'00"/110°38'46" to its confluence with Cienega Creek; and
22. Fossil Creek, from its headwaters at the confluence of Sandrock and Calf Pen Canyons above Fossil Springs at 34°26'48.7"/111°32'25" to its confluence with the Verde River at 34°18'21.8"/111°40'31.6" (approximately 17.2 river miles).

17

DOCKET NO. L-00000YY-15-0318-00171-MCV_17

ARIZONA MISSING LINKAGES

Galiuro – Pinaleño – Dos Cabezas Linkage Design

Paul Beier, Emily Garding, Daniel Majka
2008

NORTHERN ARIZONA UNIVERSITY

Table of Contents

TABLE OF CONTENTS 1

LIST OF TABLES & FIGURES 2

TERMINOLOGY 4

EXECUTIVE SUMMARY 5

INTRODUCTION 9

NATURE NEEDS ROOM TO MOVE 9
A STATEWIDE VISION 9
ECOLOGICAL SIGNIFICANCE OF THE GALIURO-PINALEÑO-DOS CABEZAS LINKAGE 10
THREATS TO CONNECTIVITY 11

LINKAGE DESIGN & RECOMMENDATIONS 14

TWO LINKAGES PROVIDE CONNECTIVITY ACROSS A DIVERSE LANDSCAPE 14
LAND OWNERSHIP, LAND COVER, AND TOPOGRAPHIC PATTERNS WITHIN THE LINKAGE DESIGN 15
REMOVING AND MITIGATING BARRIERS TO MOVEMENT 15
IMPACTS OF ROADS ON WILDLIFE 20
Mitigation for Roads 20
Existing Roads in the Linkage Design Area 24
Existing Crossing Structures in the Linkage Design 25
Recommendations for Highway Crossing Structures 26
Figure 13: Existing crossing structures in the Linkage Design Additional Road Crossing Structures Needed to Avoid Isolation of Reptile and Amphibian Populations Not Served by the Two Linkages 29
Additional Road Crossing Structures Needed to Avoid Isolation of Reptile and Amphibian Populations Not Served by the Two Linkages 30
Mitigation for Urban Barriers 32

APPENDIX A: LINKAGE DESIGN METHODS 34

FOCAL SPECIES SELECTION 34
HABITAT SUITABILITY MODELS 35
IDENTIFYING POTENTIAL BREEDING PATCHES & POTENTIAL POPULATION CORES 36
IDENTIFYING BIOLOGICALLY BEST CORRIDORS 37
PATCH CONFIGURATION ANALYSIS 38
MINIMUM LINKAGE WIDTH 39
FIELD INVESTIGATIONS 40

APPENDIX B: INDIVIDUAL SPECIES ANALYSES 41

BADGER (*TAXIDEA TAXUS*) 43

BLACK BEAR (*URSUS AMERICANUS*) 47

BOBCAT (*LYNX RUFUS*) 51

JAGUAR (*PANTHERA ONCA*) 55

JAVELINA (*TAYASSU TAJACU*) 59

KIT FOX (*VULPES MACROTIS*) 63

MEXICAN GRAY WOLF (*CANIS LUPUS BAILEYI*) 67

MOUNTAIN LION (*PUMA CONCOLOR*) 71

MULE DEER (*ODOCOILEUS HEMIONUS*) 75

PRONGHORN (*ANTILOCAPRA AMERICANA*) 79
APPENDIX C: FOCAL SPECIES NOT MODELED 83
APPENDIX D: CREATION OF LINKAGE DESIGN 85
APPENDIX E: DESCRIPTION OF LAND COVER CLASSES 86
APPENDIX F: LITERATURE CITED 89
APPENDIX G: DATABASE OF FIELD INVESTIGATIONS 96

List of Tables & Figures

List of Tables

TABLE 1: FOCAL SPECIES SELECTED FOR GALIURO - PINALEÑOS - DOS CABEZAS LINKAGE 6
TABLE 2: APPROXIMATE LAND COVER IN LINKAGE DESIGN. SEE TEXT FOR LAND COVER IN EACH OF THE FIVE STRANDS OF THE LINKAGE DESIGN 15
TABLE 3. CHARACTERISTICS WHICH MAKE SPECIES VULNERABLE TO THE THREE MAJOR DIRECT EFFECTS OF ROADS (FROM FORMAN ET AL. 2003). 20
TABLE 4: ROADS IN THE LINKAGE DESIGN 25
TABLE 5: HABITAT SUITABILITY SCORES AND FACTOR WEIGHTS FOR EACH SPECIES. SCORES RANGE FROM 1 (BEST) TO 10 (WORST), WITH 1-3 INDICATING OPTIMAL HABITAT, 4-5 SUBOPTIMAL BUT USABLE HABITAT, 6-7 OCCASIONALLY USED BUT NOT BREEDING HABITAT, AND 8-10 AVOIDED 41

List of Figures

FIGURE 1: THE GALIURO-PINALEÑO LINKAGE DESIGN CONTAINS TWO MAIN STRANDS, AND THE PINALEÑO-DOS CABEZAS LINKAGE DESIGN CONTAINS THREE MAIN STRANDS. MULTIPLE STRANDS SERVE SPECIES WITH DIVERSE HABITAT NEEDS. THE LINKAGE DESIGN ALSO CALLS FOR SMALL CULVERTS ON ROADS IN SULPHUR SPRINGS VALLEY (FIGURE 2) 7
FIGURE 2. THE LINKAGE DESIGN CALLS FOR SMALL CULVERTS EVERY 150 M ALONG GRAY-GREEN ROAD SEGMENTS (US-191, SR-186, SR-181) IN SULPHUR SPRINGS VALLEY TO PREVENT ISOLATION AND MINIMIZE MORTALITY TO REPTILE AND AMPHIBIAN POPULATIONS THERE. 8
FIGURE 3: LAND COVER IN THE LINKAGE PLANNING AREA 12
FIGURE 4: EXISTING CONSERVATION INVESTMENTS WITHIN THE LINKAGE PLANNING AREA 13
FIGURE 5: PROPERTY OWNERSHIP AND FIELD INVESTIGATION WAYPOINTS WITHIN LINKAGE DESIGN, THE ACCOMPANYING CD-ROM INCLUDES PHOTOGRAPHS TAKEN AT MOST WAYPOINTS 17
FIGURE 6: LAND COVER IN THE LINKAGE DESIGN. 18
FIGURE 7: TOPOGRAPHIC DIVERSITY ENCOMPASSED BY THE LINKAGE DESIGN: A) TOPOGRAPHIC POSITION, B) SLOPE, C) ASPECT 19
FIGURE 8: POTENTIAL ROAD MITIGATIONS (FROM TOP TO BOTTOM) INCLUDE: HIGHWAY OVERPASSES, BRIDGES, CULVERTS, AND DRAINAGE PIPES. FENCING (LOWER RIGHT) SHOULD BE USED TO GUIDE ANIMALS INTO CROSSING STRUCTURES. 22
FIGURE 9: AN 8X10' BOX CULVERT UNDER I-10 AT MILEPOST 351, WAYPOINT 59 26
FIGURE 10: A 3-BOX CULVERT UNDER US 191 AT MILEPOST 95, WAYPOINT 63 27
FIGURE 11: A 4-BOX CULVERT UNDER US 191 AT MILEPOST 96, WAYPOINT 64 27
FIGURE 12: A LARGE BRIDGE ALONG SR 266 NEAR THE JUNCTION WITH KLONDIKE RD, WAYPOINT 66 28
FIGURE 13: EXISTING CROSSING STRUCTURES IN THE LINKAGE DESIGN 29
FIGURE 14: PERCENT NATURAL VEGETATION DECLINES RAPIDLY AT HOUSING DENSITIES GREATER THAN 1 DWELLING UNIT PER 40 ACRES. 31
FIGURE 15: FOUR HABITAT FACTORS USED TO CREATE HABITAT SUITABILITY MODELS. INPUTS INCLUDED VEGETATION, ELEVATION, TOPOGRAPHIC POSITION, AND DISTANCE FROM ROADS 36
FIGURE 16: EXAMPLE MOVING WINDOW ANALYSIS WHICH CALCULATES THE AVERAGE HABITAT SUITABILITY SURROUNDING A PIXEL. A) ORIGINAL HABITAT SUITABILITY MODEL, B) 3X3-PIXEL MOVING WINDOW, C) 200M RADIUS MOVING WINDOW 37

FIGURE 17: TO GIVE OUR CORRIDORS MODELS "ROOM TO RUN," FOR THE PURPOSES OF BBC ANALYSES, WE MODIFIED THE WILDLAND BLOCKS USED IN OUR ANALYSES, SO THAT THE FACING EDGES WERE PARALLEL LINES ABOUT 15 KM APART. THIS FORCES THE MODELS TO IDENTIFY CORRIDORS WITH THE BEST HABITAT; WITHOUT THIS MODIFICATION, THE MODELS TEND TO IDENTIFY THE SHORTEST CORRIDORS REGARDLESS OF HABITAT QUALITY. 38
FIGURE 18: A) LANDSCAPE PERMEABILITY LAYER FOR ENTIRE LANDSCAPE. B) BIOLOGICALLY BEST CORRIDOR COMPOSED OF MOST PERMEABLE 10% OF LANDSCAPE 39
FIGURE 19: POTENTIAL HABITAT PATCHES AND CORES FOR BADGER IN THE GALIURO-PINALEÑO AREA....44
FIGURE 20: MODELED HABITAT SUITABILITY OF BADGER IN THE GALIURO-PINALEÑO AREA 45
FIGURE 21: POTENTIAL HABITAT PATCHES AND CORES FOR BADGER IN THE PINALEÑO-DOS CABEZAS AREA....45
FIGURE 22: MODELED HABITAT SUITABILITY FOR BADGER IN THE PINALEÑO-DOS CABEZAS AREA 46
FIGURE 23: POTENTIAL HABITAT PATCHES AND CORES FOR BLACK BEAR IN THE GALIURO-PINALEÑO AREA....48
FIGURE 24: MODELED HABITAT SUITABILITY OF BLACK BEAR IN THE GALIURO-PINALEÑO AREA 49
FIGURE 25: POTENTIAL HABITAT PATCHES AND CORES FOR BLACK BEAR IN THE PINALEÑO-DOS CABEZAS AREA....49
FIGURE 26: MODELED HABITAT SUITABILITY FOR BLACK BEAR IN THE PINALEÑO-DOS CABEZAS AREA 50
FIGURE 27: POTENTIAL HABITAT PATCHES AND CORES FOR BOBCAT IN THE GALIURO-PINALEÑO AREA....53
FIGURE 28: MODELED HABITAT SUITABILITY FOR BOBCAT IN THE GALIURO-PINALEÑO AREA 53
FIGURE 29: POTENTIAL HABITAT PATCHES AND CORES FOR BOBCAT IN THE PINALEÑO-DOS CABEZAS AREA....53
FIGURE 30: MODELED HABITAT SUITABILITY FOR BOBCAT IN THE PINALEÑO-DOS CABEZAS AREA....54
FIGURE 31: POTENTIAL HABITAT PATCHES AND CORES FOR JAGUAR IN THE GALIURO-PINALEÑO AREA 56
FIGURE 32: MODELED HABITAT SUITABILITY FOR JAGUAR IN THE GALIURO-PINALEÑO AREA....57
FIGURE 33: POTENTIAL HABITAT PATCHES AND CORES FOR JAGUAR IN THE PINALEÑO-DOS CABEZAS AREA 57
FIGURE 34: MODELED HABITAT SUITABILITY FOR JAGUAR IN THE PINALEÑO-DOS CABEZAS AREA....58
FIGURE 35: POTENTIAL HABITAT PATCHES AND CORES FOR JAVELINA IN THE GALIURO-PINALEÑO AREA 60
FIGURE 36: MODELED HABITAT SUITABILITY FOR JAVELINA IN THE GALIURO-PINALEÑO AREA....61
FIGURE 37: POTENTIAL HABITAT PATCHES AND CORES FOR JAVELINA IN THE PINALEÑO-DOS CABEZAS AREA 61
FIGURE 38: MODELED HABITAT SUITABILITY FOR JAVELINA IN THE PINALEÑO-DOS CABEZAS AREA 62
FIGURE 39: POTENTIAL HABITAT PATCHES AND CORES FOR KIT FOX IN THE GALIURO-PINALEÑO AREA 64
FIGURE 40: MODELED HABITAT SUITABILITY OF KIT FOX IN THE GALIURO-PINALEÑO AREA....65
FIGURE 41: POTENTIAL HABITAT PATCHES AND CORES FOR KIT FOX IN THE PINALEÑO-DOS CABEZAS AREA 65
FIGURE 42: MODELED HABITAT SUITABILITY FOR KIT FOX IN THE PINALEÑO-DOS CABEZAS AREA 66
FIGURE 43: POTENTIAL HABITAT PATCHES AND CORES FOR MEXICAN GRAY WOLF IN THE GALIURO-PINALEÑO AREA68
FIGURE 44: MODELED HABITAT SUITABILITY FOR MEXICAN GRAY WOLF IN THE GALIURO-PINALEÑO AREA 69
FIGURE 45: POTENTIAL HABITAT PATCHES AND CORES FOR MEXICAN GRAY WOLF IN THE PINALEÑO-DOS CABEZAS AREA 69
FIGURE 46: MODELED HABITAT SUITABILITY FOR MEXICAN GRAY WOLF IN THE PINALEÑO-DOS CABEZAS AREA 70
FIGURE 47: POTENTIAL HABITAT PATCHES AND CORES FOR MOUNTAIN LION IN THE GALIURO-PINALEÑO AREA 72
FIGURE 48: MODELED HABITAT SUITABILITY FOR MOUNTAIN LION IN THE GALIURO-PINALEÑO AREA....73
FIGURE 49: POTENTIAL HABITAT PATCHES AND CORES FOR MOUNTAIN LION IN THE PINALEÑO-DOS CABEZAS AREA .73
FIGURE 50: MODELED HABITAT SUITABILITY FOR MOUNTAIN LION IN THE PINALEÑO-DOS CABEZAS AREA 74
FIGURE 51: POTENTIAL HABITAT PATCHES AND CORES FOR MULE DEER IN THE GALIURO-PINALEÑO AREA....76
FIGURE 52: MODELED HABITAT SUITABILITY FOR MULE DEER IN THE GALIURO-PINALEÑO AREA 77
FIGURE 53: POTENTIAL HABITAT PATCHES AND CORES FOR MULE DEER IN THE PINALEÑO-DOS CABEZAS AREA....77
FIGURE 54: MODELED HABITAT SUITABILITY FOR MULE DEER IN THE PINALEÑO-DOS CABEZAS AREA 78
FIGURE 55: POTENTIAL HABITAT PATCHES AND CORES FOR PRONGHORN IN THE GALIURO-PINALEÑO AREA....80
FIGURE 56: MODELED HABITAT SUITABILITY FOR PRONGHORN IN THE GALIURO-PINALEÑO AREA....81
FIGURE 57: POTENTIAL HABITAT PATCHES AND CORES FOR PRONGHORN IN THE PINALEÑO-DOS CABEZAS AREA....81
FIGURE 58: MODELED HABITAT SUITABILITY FOR PRONGHORN IN THE PINALEÑO-DOS CABEZAS AREA....82
FIGURE 59: ADJUSTMENTS TO UNION OF BIOLOGICALLY BEST CORRIDORS TO CREATE THE LINKAGE DESIGN....85

Executive Summary

Habitat loss and fragmentation are the leading threats to biodiversity, both globally and in Arizona. These threats can be mitigated by conserving well-connected networks of large wildland areas where natural ecological and evolutionary processes operate over large spatial and temporal scales. Large wildland blocks connected by corridors can maintain top-down regulation by large predators, natural patterns of gene flow, pollination, dispersal, energy flow, nutrient cycling, inter-specific competition, and mutualism. Corridors allow ecosystems to recover from natural disturbances such as fire or flood, and to respond to human-caused disturbance such as climate change and invasions by exotic species.

Arizona is fortunate to have vast conserved wildlands that are fundamentally one interconnected ecological system. In this report, we use a scientific approach to design a corridor (Linkage Design) that will conserve and enhance wildlife movement between three large wildland administered by the U.S. Forest Service and the Bureau of Land Management in southeastern Arizona. Interstate 10, other highways, urban development, and agriculture threaten to impede animal movement between the Galiuro and Pinaleño Mountains, and between the Pinaleño Mountains and the Dos Cabezas-Chiricahua Mountains. These wildlands represent a large public investment in biological diversity, and this Linkage Design is a reasonable science-based approach to maintain the value of that investment.

To begin the process of designing this linkage, we asked academic scientists, agency biologists, and conservation organizations to identify species sensitive to habitat loss and fragmentation. They identified 18 focal species, including 2 amphibians, 2 reptiles, 2 birds, and 12 mammals (Table 1). These focal species cover a broad range of habitat and movement requirements. Some require huge tracts of land to support viable populations (e.g. mountain lion, jaguar). Some species are habitat specialists (e.g. pronghorn), and others are reluctant or unable to cross barriers such as freeways (e.g. mule deer). Some species are rare and/or endangered while others like javelina are common but still need gene flow among populations. All the focal species are part of the natural heritage of this mosaic of Apache Highlands and Sonoran Desert. Together, these 18 species cover a wide array of habitats and movement needs in the region, so that the linkage design should cover connectivity needs for other species as well.

To identify potential routes between existing protected areas we used GIS methods to identify a biologically best corridor for each focal species to move between these wildland blocks. We also analyzed the size and configuration of suitable habitat patches to verify that the final Linkage Design (Figure 1, Figure 2) provides live-in or move-through habitat for each focal species. The resulting Linkage Design (Figure 1) is composed of two main linkages: the **Pinaleños-Galiuro Linkage** has two strands running 30-50 km, and the **Pinaleños-Dos Cabezas Linkage** has three strands 35-55 km in length. The 5 strands together provide habitat for movement and reproduction of wildlife between the Pinaleño Mountains and the Galiuros Mountains to the east and the Chiricahua Mountains to the south. The Linkage Design also includes recommendations to minimize the risk that publicly owned roads isolate reptile and amphibian populations conserved on private lands in Sulphur Springs Valley (Figure 2). We visited priority areas in the field to identify and evaluate barriers to wildlife movement, and we provide detailed mitigations for barriers to animal movement in the section titled *Linkage Design and Recommendations*.

This region provides significant ecological, educational, recreational, and spiritual values of protected wildlands. Our Linkage Design represents an opportunity to protect a functional landscape-level connection. The cost of implementing this vision will be substantial—but reasonable in relation to the benefits and the existing public investments in protected wild habitat. If implemented, our plan would not only permit movement of individuals and genes between the Galiuro, Pinaleño, and Dos Cabezas wildland blocks, but should also conserve large-scale ecosystem processes that are essential to the

continued integrity of existing conservation investments by the US Forest Service, Arizona State Parks, Bureau of Land Management, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and other conservancy lands.

Next Steps: This Linkage Design Plan is a science-based starting point for conservation actions. The plan can be used as a resource for regional land managers to understand their critical role in sustaining biodiversity and ecosystem processes. Relevant aspects of this plan can be folded into management plans of agencies managing public lands. Transportation agencies can use the plan to design new projects and find opportunities to upgrade existing structures. Regulatory agencies can use this information to help inform decisions regarding impacts on streams and other habitats. This report can also help motivate and inform construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, and land acquisition. Implementing this plan will take decades, and collaboration among county planners, land management agencies, resource management agencies, land conservancies, and private landowners.

Public education and outreach is vital to the success of this effort – both to change land use activities that threaten wildlife movement and to generate appreciation for the importance of the corridor. Public education can encourage residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function. The biological information, maps, figures, tables, and photographs in this plan are ready materials for interpretive programs.

Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. We hope this linkage conservation plan will be used to protect an interconnected system of natural space where our native biodiversity can thrive, at minimal cost to other human endeavors.

Table 1: Focal species selected for Galiuro - Pinaleños - Dos Cabezas Linkage

MAMMALS	AMPHIBIANS & REPTILES	BIRDS
Bats	Ornate Box Turtle	Western Burrowing Owl
*Badger	Plains Leopard Frog	Sandhill Crane
*Black Bear	Texas Horned Lizard	
Black-tailed Prairie Dog	Chiricahua Leopard Frog	
*Bobcat		
*Jaguar		
*Javelina		
*Kit Fox		
*Mountain Lion		
*Mule Deer		
*Pronghorn		
*Wolf		

* Species modeled in this report. The other species were not modeled because there were insufficient data to quantify habitat use in terms of available GIS data (e.g., species that select small rocks), because the species does not occur in both wildland blocks, or because the species probably can travel (e.g., by flying) across unsuitable habitat. Although we did not develop corridor models for ornate box turtleor plains leopard frog, we made special recommendations for roads in Sulphur Springs Valley to promote connectivity for these species.

Page 9 of the PDF Map Figure 1

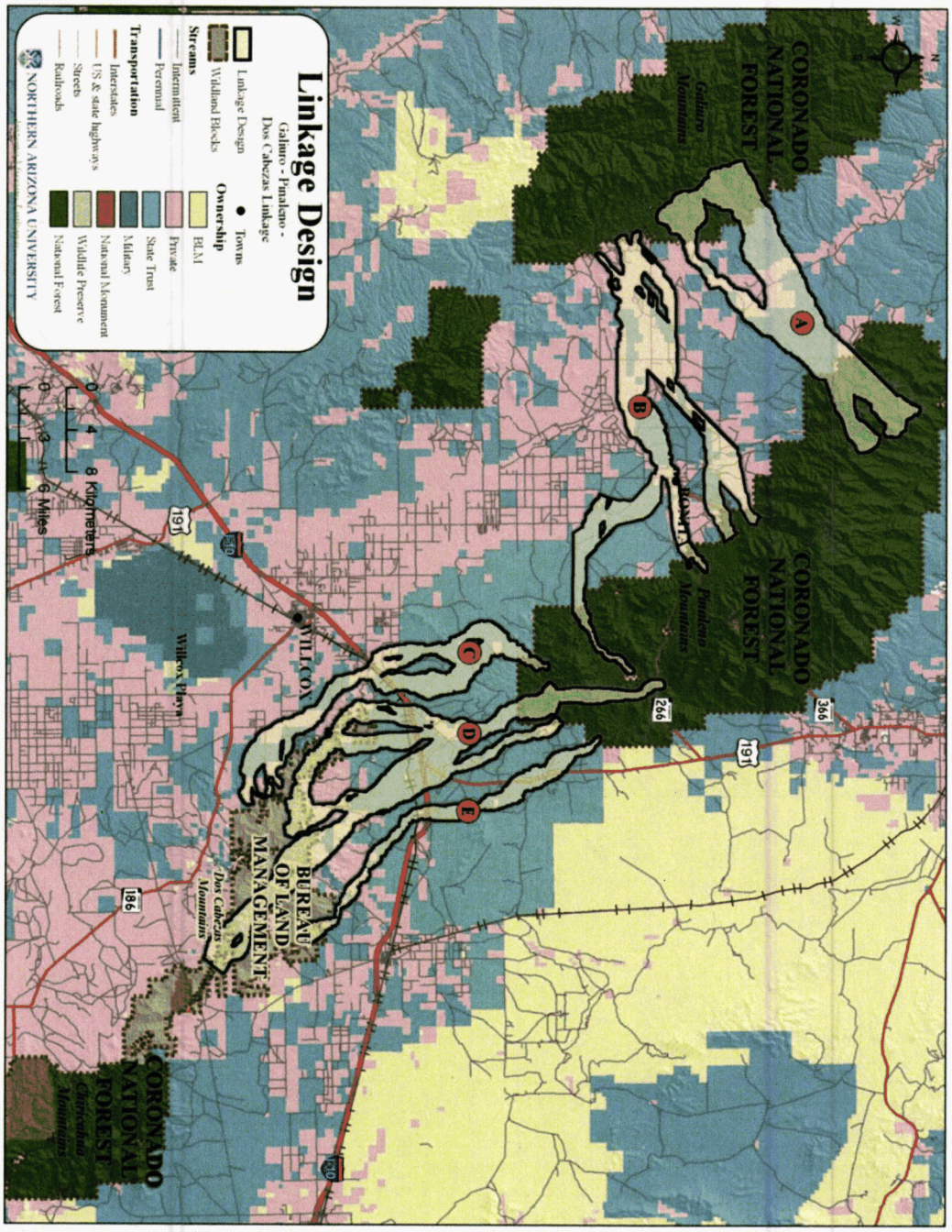


Figure 1: The Galiuro-Pinaleño Linkage Design contains two main strands, and the Pinaleño-Dos Cabezas Linkage Design contains three main strands. Multiple strands serve species with diverse habitat needs. The Linkage Design also calls for small culverts on roads in Sulphur Springs Valley (Figure 2).

Ecological Significance of the Galiuro-Pinaleño-Dos Cabezas Linkage

The Galiuro-Pinaleño-Dos Cabezas linkage planning area lies within Madrean Archipelago of southeastern Arizona. This ecoregion is a unique ecological zone lying south of the Rocky Mountains and north of the Sierra Madre Occidental. Natural communities here range from desert grasslands in the lowlands to coniferous forests in the higher elevations. The isolated mountain ranges separated by valleys are known as "sky islands." The linkage planning area includes three of these sky islands, separated by valleys, farmlands, highways, Interstate 10, and the town of Willcox.

The **Galiuro wildland block** consists of 152,778 protected acres of steep, rugged terrain administered mostly by the Coronado National Forest, with significant holdings by The Nature Conservancy and BLM in the southern Galiuro Mountains. This wildland block includes the Winchester Mountains, also managed by Coronado National Forest. Two wilderness areas (Figure 4) occur here: the 73,317-acre Galiuro Wilderness area in the Coronado National Forest, which reaches over 7,600 feet at Bassett Peak, and the contiguous 6,600-acre Redfield Canyon Wilderness managed by the Bureau of Land Management.

The **Pinaleño wildland block** consists of 198,144 protected acres of steep rocky slopes and rugged canyons. With elevations up to 10,700 feet on Mt Graham, this land supports coniferous forests and the endangered Mt Graham Red Squirrel, as well as oak and pine-oak forests and woodlands, and semi-desert grasslands.

The **Dos Cabezas wildland block** includes 245,900 acres in the BLM-administered Dos Cabezas Mountains and the adjacent Chiricahua Mountains which mostly within the Coronado National Forest. This block contains two wilderness areas, the 11,700-acre Dos Cabezas Mountains Wilderness, a rugged area with peaks above 7,000 feet, and the 87,700-acre Chiricahua Wilderness with 9,000-ft peaks and an extensive trail system. The Fort Bowie National Historic Site, managed by the National Park Service, protects Apache Pass, which links the Dos Cabezas Mountains in the north from the Chiricahua Mountains to the south. Another National Park unit is the Chiricahua National Monument, 12,000 acres of desert grassland and fantastic rock formations. This area is a unique ecological zone where the Sonoran Desert transitions to Chihuahuan Desert and the southern Rocky Mountains give way to the northern Sierra Madres. It contains several springs and streams important for wildlife.

The linkage planning area is dominated by semi-desert grasslands and desert scrub, with Sonoran desert and thornscrub vegetation to the west and Chihuahuan desert to the east. There are isolated patches of pine-oak woodlands. The broad grasslands of Sulphur Springs Valley separate the Gailuro Mountains from the Pinaleño Mountains and the Dos Cabezas. The Willcox Playa, a closed lake basin, lies in the south-central portion of the valley. The Willcox Playa Wildlife Area protects roughly 595 acres including 120 acres of deeded land, 320 acres of land patented from the Bureau of Land Management, a 115-acre perpetual right-of-way from the Arizona State Land Department, and a 40-acre donation from a private land owner. This playa is important wildlife habitat, especially for waterfowl and migratory birds. It attracts over 500 species of birds, including tens of thousands of Sandhill Cranes, and a similar number of tourists for an annual birding festival.

The Linkage Design incorporates and connects important habitat for threatened or endangered species such as jaguar and Mexican grey wolf. The linkage planning area is also home to far-ranging mammals such as mule deer, badger, and mountain lion. These animals move long distances to gain access to suitable foraging or breeding sites, and would benefit significantly from corridors that link large areas of habitat (Turner et al. 1995). Less-mobile species such as javelina also need corridors to maintain genetic diversity, allow populations to shift their range in response to climate change, and promote recolonization after fire or epidemics.

Threats to Connectivity

Major potential barriers in the linkage area include Interstate 10, habitat degradation, and urban and agricultural development. Willcox serves as the major trade and service center for agriculture and tourism within Cochise County. It is also an important cattle center. Human activities including grazing, water diversion, mining, and fire suppression have altered the natural landscape. These barriers could inhibit wildlife movement between the Galiuro, Pinaleño, and Dos Cabezas wildland blocks.

Providing connectivity is paramount in sustaining this unique area's diverse natural heritage. Recent and future human activities could sever natural connections and alter the functional integrity of this natural system. Creating linkages that overcome barriers to movement will ensure that wildlife in all wildland blocks and the potential linkage area will thrive there for generations to come.

Page 15 of the PDF Figure

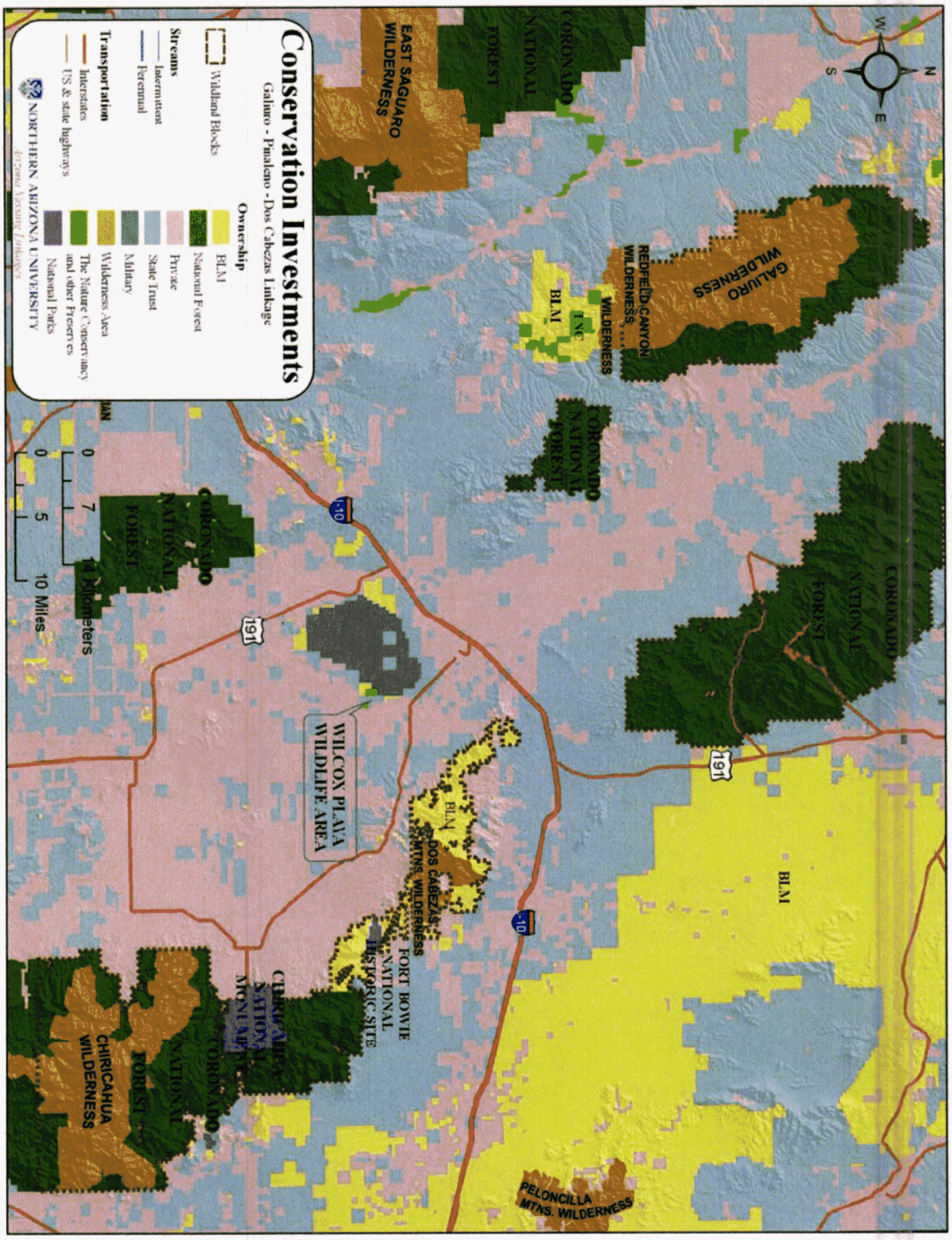


Figure 4: Existing conservation investments within the linkage planning area

Linkage Design & Recommendations

The Linkage Design[1] (Figure 1) is composed of two linkages, and a set of recommendations to minimize roadkill impacts on reptiles and amphibians conserved on private lands in Sulphur Springs Valley. In this section, we describe the linkage design, and recommend mitigations for barriers to animal movement. Methods for developing the Linkage Design are described in Appendix A.

Two Linkages Provide Connectivity Across a Diverse Landscape

The linkage design consists of two linkages, one connecting the Galiuro Mountains to the Pinaleño Mountains, and the other connecting the Pinaleños to the Dos Cabezas Mountains.

LINKAGE DESIGN GOALS

- Provide move-through habitat for diverse group of species
- Provide live-in habitat for species with dispersal distances too short to traverse linkage in one lifetime
- Provide adequate area for a metapopulation of corridor-dwelling species to move through the landscape over multiple generations
- Provide a buffer protecting aquatic habitats from pollutants
- Buffer against edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species
- Allow animals and plants to move in response to climate change

The **Pinaleños-Galiuro Linkage** has two strands. Strand A is made up of the best biological corridors for black bear, bobcat, jaguar, wolf, and mountain lion. About 31 km long, it encompasses much of the Black Hills and spans upper Aravaipa Canyon. The landcover in this strand is a mixture of Scrub-Shrub (42%), Evergreen Forest (42%), and Grassland-Herbaceous (13.5%). The rugged terrain has an average slope of 26% (Range: 0-85%, SD: 7.9). While 48% of the land was identified as steep slopes, almost 30% is composed of flat to gentle slopes.

Strand B provides habitat for badger, javelina, kit fox, mule deer, and pronghorn. It runs from the Galiuro Mountains across the Ash Creek Black Hills. East of there, it forks into 4 branches, each of which is important to different species. The longest branch stretches approximately 49 km. It is dominated by Grassland-Herbaceous vegetation (73%) and Scrub-Shrub (23%). Terrain is mostly gentle with an average slope of 3% (Range: 0-76%, SD: 5.1) and 96% of the strand is classified as flat to gentle slopes.

The **Pinaleños-Dos Cabezas Linkage** has three strands. About 36 km long, strand C provides habitat for badger and pronghorn. Its landcover is dominated by Grassland-Herbaceous (54%), and Scrub-Shrub (43%) vegetation. Average slope is 6% (Range: 0-79%, SD: 7.3) and 88% of the strand is classified as flat to gentle slopes, while 10% was classified as steep slopes.

Strand D provides habitat for black bear, bobcat, jaguar, javelina, wolf, mountain lion, and mule deer. This strand is made up of many branches, each of which provides habitat for different species. The longest branch stretches approximately 53 km. The dominant landcover types are Evergreen Forest (40%), Grassland-Herbaceous (23%), and Scrub-Shrub (36%). The variable topography has an average slope of 22% (Range: 0-98%, SD: 19.2). It has roughly as much flat to gentle slopes (41%) as steep slopes (40%).

[1] The reader will note that the strands of the linkage design extend well into each wildland block. As explained in Appendix A, for modeling purposes we had to redefine the wildland blocks such that the facing edges were parallel lines about 15 km apart.

The 35-km Strand E provides habitat for kit fox and is dominated by Scrub-Shrub (78%) and Grassland-Herbaceous (19%) vegetation. This strand has an average slope of 6% (Range: 0-85%, SD: 7.9) and 87% of the strand has a slope of less than or equal to 6%.

Special consideration for reptiles and amphibians in Sulphur Valley. Some of the reptiles and amphibians proposed as focal species find most of their habitat in the private and ASLD land in Sulphur Valley, rather than in the publicly-owned wildland blocks. This distribution precluded corridor modeling (which requires a clearly defined terminus at each end). However, to reduce the impact of roads on these species, we recommend regularly-spaced, soft-bottom culverts on paved roads throughout Sulphur Springs Valley (Figure 2).

Land Ownership, Land Cover, and Topographic Patterns within the Linkage Design

The Linkage Design encompasses 165,391acres (66,931 ha), of which 47% is state trust land, 28% privately owned, 17% in Coronado National Forest, and 8% managed by the Bureau of Land Management (Figure 5).The linkage design supports six natural vegetation communities (Figure 6), with developed land accounting for less than 1% of the linkage design. Natural vegetation is dominated by desert Scrub-Shrub associations and Grassland-Herbaceous vegetation.

The Linkage Design captured a range of topographic diversity, providing for the present ecological needs of species, as well as creating a buffer against a potential shift in ecological communities due to future climate change. Within the Linkage Design, 62% of the land is classified as gentle slopes, 26.5% is classified as steep slopes, with nearly equal parts canyon bottom (6%)or ridgetop (6%)(Figure 7). More land in the linkage had southern aspects than northern aspects (Figure 7).

Table 2: Approximate land cover in Linkage Design. See text for land cover in each of the five strands of the Linkage Design.

LAND COVER CATEGORY	ACRES	HECTARES	% OF TOTAL AREA
Evergreen Forest (< 0.1%)			
Pinyon-Juniper Woodland	44	18	< 0.1%
Scrub-Shrub (98%)			
Creosotebush-White Bursage Desert Scrub	12326	4988	13.7%
Desert Scrub (misc)	4739	1918	5.3%
Mesquite Upland Scrub	958	388	1.1%
Paloverde-Mixed Cacti Desert Scrub	69891	28284	77.9%
Woody Wetland (0.9%)			
Riparian Mesquite Bosque	540	219	0.6%
Riparian Woodland and Shrubland	288	116	0.3%
Barren Lands (0.1%)			
Non-specific Barren Lands	131	53	0.1%
Developed and Agriculture (0.9%)			
Open Space-Low Intensity Developed	662	268	0.7%
Medium-High Intensity Developed	152	61	0.2%

Removing and Mitigating Barriers to Movement

Although roads, rail lines, canals, agriculture, and urban areas occupy only a small fraction of the Linkage Design, their impacts threaten to block animal movement between the wildland blocks. In this section, we review the potential impacts of these features on ecological processes, identify specific barriers in the Linkage Design, and suggest appropriate mitigations. The complete database of our field investigations, including UTM coordinates and photographs, is provided in Appendix G and the Microsoft Access database on the CD-ROM accompanying this report.

While roads, canals, and fences impede animal movement, and the crossing structures we recommend are important, we remind the reader that crossing structures are only part of the overall linkage design. To restore and maintain connectivity between these wildland blocks, it is essential to consider the *entire* linkage design, including conserving the land in the linkage. Indeed, investment in a crossing structure would be futile if habitat between the crossing structure and either protected block is lost.

Page 20 of the PDF Figure 6

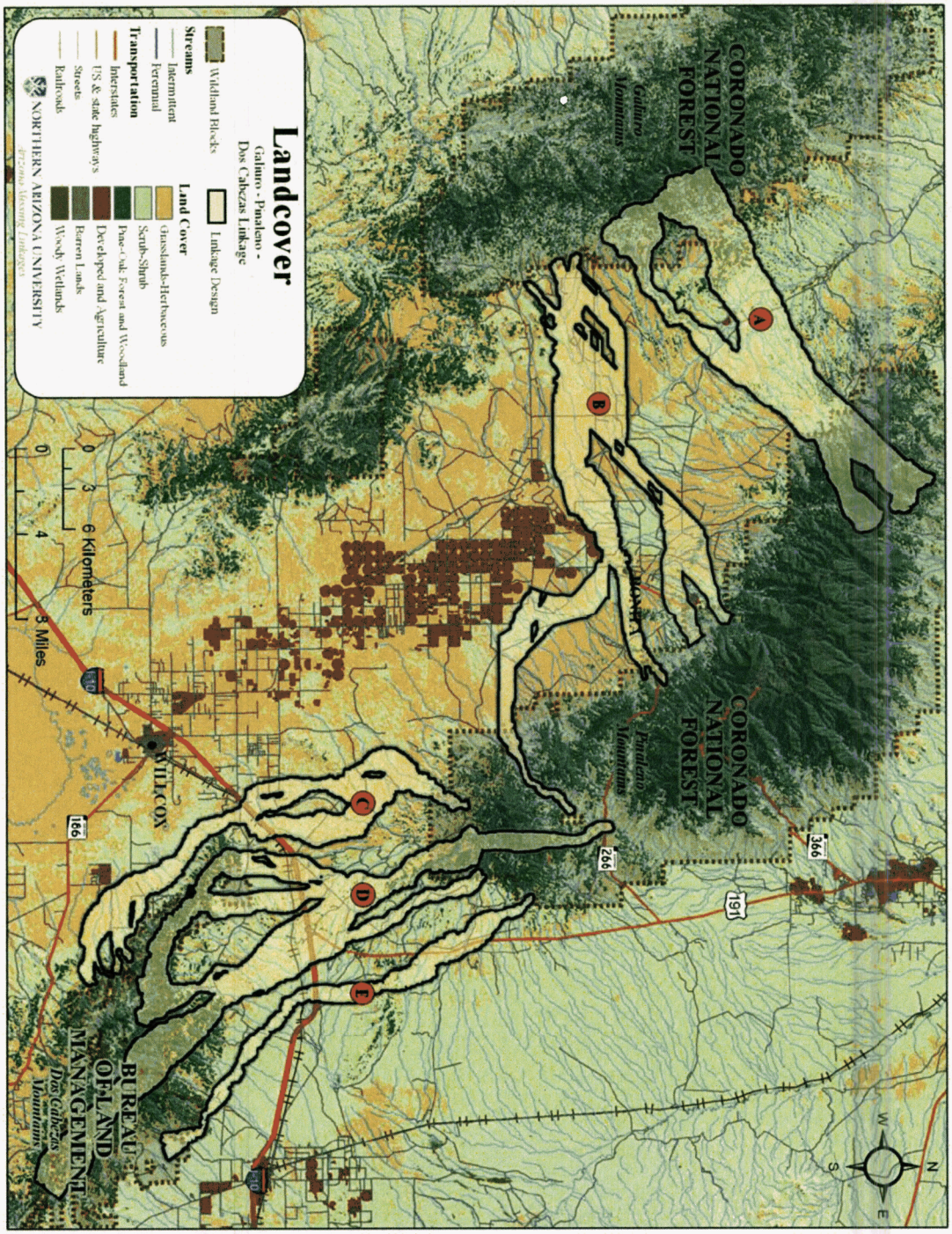


Figure 6: Land cover in the Linkage Design.

18

DOCKET NO. L-00000YY-15-0318-00171-MCV_18

Pinal County Open Space and Trails Master Plan

LOGAN SIMPSON DESIGN INC.

OCTOBER 2007

Pinal County Open Space and Trails Master Plan

TABLE OF CONTENTS

1.0 Project Overview **1**
1.1 Background and Purpose 1
1.2 Planning Process Overview 1

2.0 Inventory and Analysis **3**
2.1 Introduction 3
2.2 Data Collection 3
2.3 Existing Studies and Plans Overview 3
2.4 Adjacent Community Connections 6
2.5 Biological Resources Overview 6
2.6 Cultural Resources Overview 12
2.7 Slope Analysis 15
2.8 Existing Land Ownership, Development Patterns, and Infrastructure 15
2.9 Existing and Planned Parks, Open Space Areas, and Trails 17

3.0 Public Participation **22**
3.1 Introduction 22
3.2 Public Meetings – Values, Issues, and Needs 22
3.3 Public Meetings – Preliminary Master Plan 24
3.4 Stakeholder Taskforce Meetings 26

4.0 Conceptual Master Plan Alternatives **28**
4.1 Introduction 28
4.2 Conceptual Master Plan Alternatives 28
4.3 Preferred Conceptual Master Plan Alternative 32

5.0 Preliminary Master Plan **35**
5.1 Introduction 35
5.2 Open Space Categories 35
5.3 Preliminary Master Plan 37

6.0 Final Master Plan **39**
6.1 Introduction 39
6.2 Vision, Goals, and Objectives 39
6.3 Open Space and Trails Master Plan Elements 41
6.4 Land Ownership Considerations 45
6.5 Designation of Private, State Trust, and Bureau of Land Management Lands 46

7.0 Open Space and Trails Implementation Program **47**
7.1 Introduction 47
7.2 Open Space and Trails Implementation Techniques 47
7.3 Open Space and Trails Implementation Program 51

LIST OF FIGURES

Figure 1. Base Data Map 4
Figure 2. Regional Context Map 7
Figure 3. Biological Resources 10

Figure 4. Cultural Resources 14
Figure 5. Slope Analysis 16
Figure 6. Land Ownership 18
Figure 7. Utilities 19
Figure 8. Open Space and Trails Master Plan Concept A 29
Figure 9. Open Space and Trails Master Plan Concept B 30
Figure 10. Open Space and Trails Master Plan Concept C 31
Figure 11. Preferred Conceptual Master Plan Alternative 33
Figure 12. Preliminary Master Plan 36
Figure 13. Final Master Plan Map 42
Figure 14. Proposed Open Space and Regional Park Implementation 52
Figure 15. Proposed Trail Implementation 53
Figure A1. 2005 Pinal County Trails Plan 67
Figure A2. Bird Species Density 68
Figure A3. Mammal Species Density 69
Figure A4. Reptile Species Density 70
Figure A5. Desert Tortoise Habitat 71
Figure A6. Native Grassland Assessment 72
Figure A7. Nature Conservancy Conservation Areas 73
Figure A8. Springs and Riparian Areas 74
Figure A9. ADOT Corridor Studies 75
Figure A10. Central Arizona Association of Governments PAD Map 76

LIST OF TABLES

Table 1. Land Ownership 17
Table 2. Recreation Areas Within Pinal County 20
Table 3. Existing Pinal County Parks 20
Table 4. Pinal County Open Space and Trails Master Plan Implementation Program 2007-2032 54
Table A1. USFWS threatened, endangered, and candidate species potentially occurring in Pinal County 65
Table B1. NRHP Districts 78
Table D1. Stakeholder Taskforce List 98

LIST OF APPENDIXES

Appendix A – Biological and Environmental Resources Information 64
Appendix B – Cultural Resources Information 77
Appendix C – Public Involvement Information 79
Appendix D – Stakeholder Involvement Information 97
Appendix E – Data Collection Log 136

PAGE 16 of the PDF EXCERPT

The goal of this cultural resources overview is to use existing archaeological survey and site data in conjunction with a basic predictive model to evaluate potential impacts on NRHP-eligible resources for the proposed Pinal County trail system and open space design. Site and survey data from the AZSITE database, which is the repository for all archaeological survey and site data on state public lands were reviewed. In addition, the NRHP database was checked to identify historic districts and NRHP-listed sites within Pinal County. In general, agencies consider all known sites to be NRHP-eligible for planning purposes until their actual NRHP eligibility has been determined; therefore, all known sites were included

PAGE 17 of the PDF EXCERPT

in this analysis. Survey data analyzed for the County includes the total area of previous survey coverage, the number of known sites, and the available descriptive information on the type of sites present. Prehistoric and historic sites are not the only cultural resources that should be taken into consideration. Traditional cultural properties (TCPs) are places that have important cultural significance to Native American groups and other communities. Information on TCPs is often scarce, but the importance of these places should not be overlooked and should be taken into consideration whenever possible. An evaluation of TCPs should be undertaken by initiating consultation regarding sacred places with all interested Native American tribes.

PAGE 18 of the PDF EXCERPT of MAP illustrating Cultural Resources

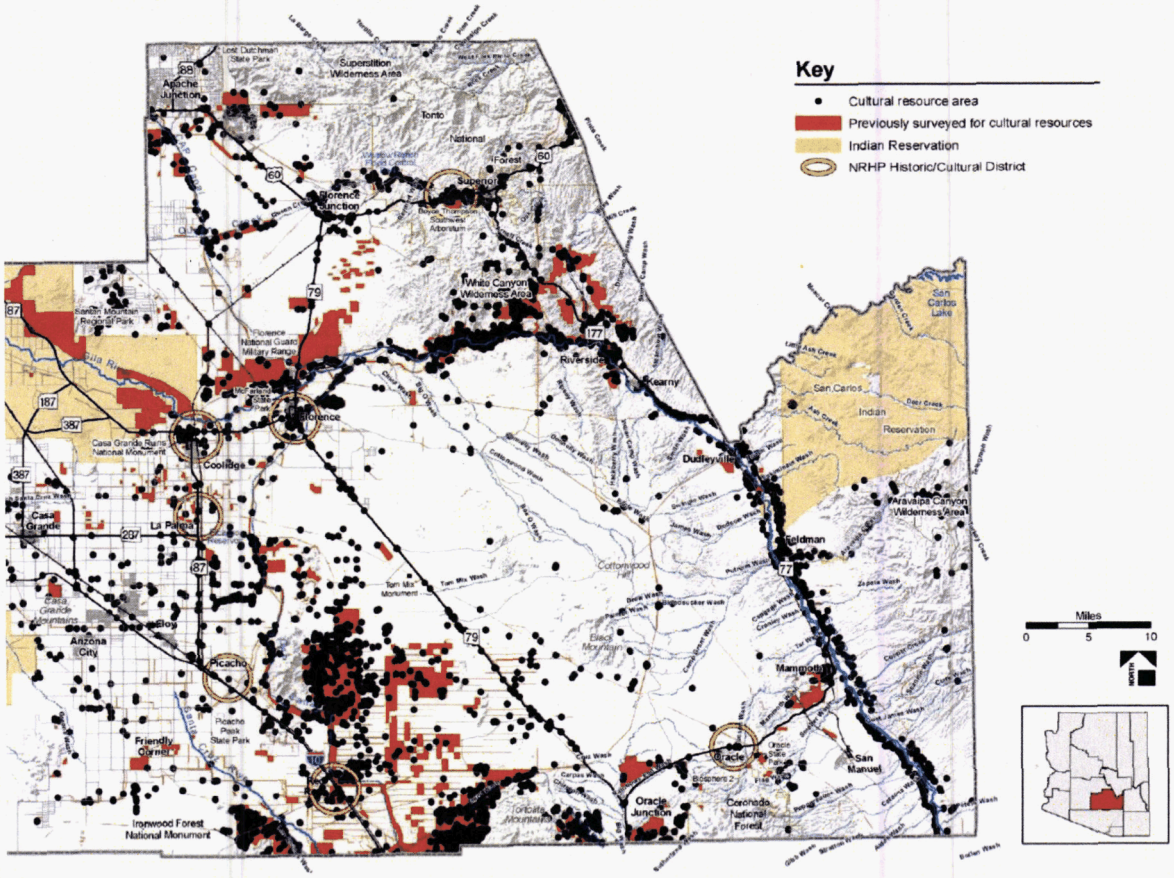


Figure 4. Cultural Resources

PAGE 19 of the PDF EXCERPT

also known as Snaketown, is located on the Gila River Indian Reservation. Both the Los Robles Archaeological District and the McClellan Wash Archaeological District are representative of Classic-period Hohokam settlements and continue to contribute significantly to the understanding of the prehistory of the area.

When considering prehistoric and historic archaeological sites in the planning process, avoidance is generally considered the prudent approach. Future projects may require a Class III cultural survey to determine the presence of NRHP-eligible sites and properties.

PAGE 21 of the PDF EXCERPT

Utilities and Infrastructure

Existing, certified, and proposed utility alignments were identified within the county for 500kv, 345kv, 230kv, 115kv transmission lines; gas pipelines; and the Arizona Corporation Commission (ACC) approved alignment of 500kv and 230kv transmission lines (see Figure 7, *Utilities*). Utility right-of-ways were not used as trail corridors, unless they occurred along a preestablished trail corridor within the *Pinal County 2005 Trails Plan* or other approved planning documents due to homeland security concerns. Future planning efforts should not exclude the use of utility corridors for trails where possible.

PAGE 23 of the PDF EXCERPT of Map illustrating existent Transmission Lines

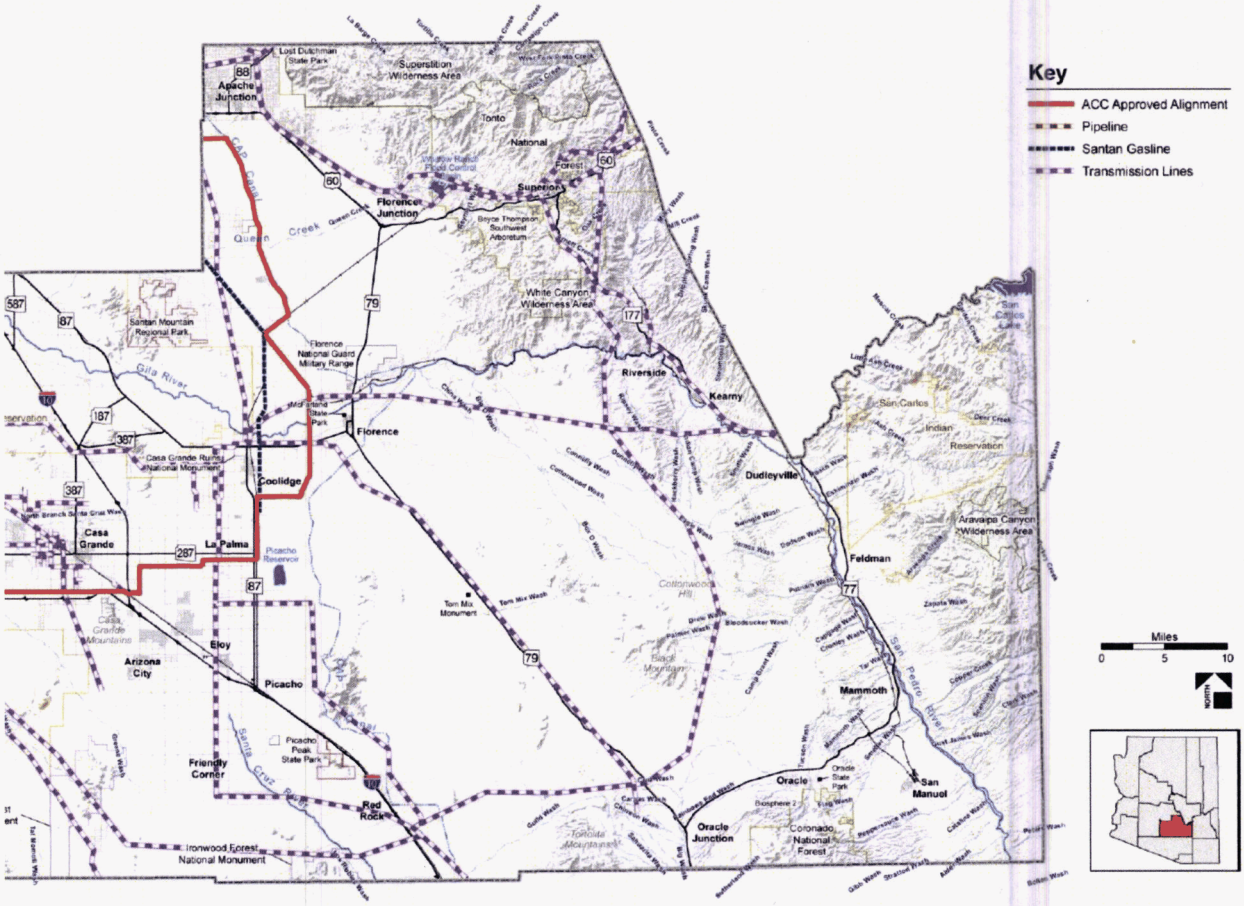


Figure 7. Utilities

PAGE 25 of the PDF EXCERPT

Regional Trail Connections

As identified in the *Pinal County Trails Plan, 2005* (see Figure A1, in Appendix A *2005 Pinal County Trails Plan)* three primary regional trail corridors were identified. These three corridors, the Arizona Trail, the Central Arizona Project (CAP) canal corridor, and the Juan Bautista De Anza National Historic Trail, are described below. In addition, one multi-modal corridor was identified—the Great Western Trail (GWT).

PAGE 26 of the PDF EXCERPT

3.0 PUBLIC PARTICIPATION

An open solicitation of values, issues, and needs for county residents in reference to open space and trails was conducted. The values were based on the premise, if you were to move away from Pinal County for five years, what elements or aspects of the county would you like to stay the same? Likewise, issues and needs were solicited under the same premise, except residents were asked, what would you change? The following is a summary of the publics' values, issues, and needs.

Values

- Dark at night
- Value mountain views and open areas
- Foreground views (non-cluttered)
- Preserve viewsheds
- Wildlife corridors
- Habitat to sustain wildlife
- Riparian corridors preservation
- Undisturbed natural areas (no golf courses)
- Wilderness character of existing open space
- Natural wash corridors
- Geological resources
- Proximity to existing open space areas
- Historic areas
- National historic sites
- Open space corridors along roadways
- Abundant and easy access to trails
- Hiking and equestrian trails
- Close proximity to local equestrian trails

PAGE 32 of the PDF EXCERPT

4.0 Conceptual Master Plan Alternatives

4.1 Introduction

Three *Conceptual Master Plan Alternatives* were developed for the Plan and were based on two general premises: (1) conservation of critical resources including cultural and biological resources, viewsheds, physical characteristic of the land, and major riparian and river corridors and (2) overall connectivity including open space area and trail connectivity. Each conceptual alternative represented varying degrees of conservation and connectivity, with an overall relevancy to land ownership. The conceptual alternatives were developed to present variable scenarios, ideas, and pros and cons for the stakeholders

PAGE 36 of the PDF EXCERPT

4.3 Preferred Conceptual Master Plan Alternative

The majority of Stakeholder Taskforce Meeting attendees preferred Alternative C or a combination of Alternatives B and C. The *Preferred Conceptual Master Plan Alternative* (Figure 11, *Preferred Conceptual Master Plan Alternative*) was developed from the input and comments from the County and stakeholder taskforce members received during Stakeholder Taskforce Meetings No. 2 and No. 3 (see Appendix D for ...

Planning issues and concerns that needed to be addressed in development of the *Preferred Conceptual Master Plan Alternative* included the following: ...

- Remove of all trail alignments from the transmission line corridors due to increasing protection of these facilities based on homeland security concerns. ...

During the Stakeholder Taskforce Meeting No. 3, the following proposed Open Space System definition as presented with the *Preferred Conceptual Master Plan Alternative* for stakeholder comment.

> An open space system is a connected system of open space areas that maintain, as its primary purpose, the ecological health of the region/landscape and has as its natural consequence, the outcome of promoting human and biological health by allowing for passive and active recreational activities, solitude, natural landscapes, and wildlife movement. An open space system conserves elements of existing resources such as natural scenic beauty, view corridors, wildlife habitat, agricultural resources, and cultural heritage for the benefit of present and future generations.

PAGE 39 of the PDF EXCERPT

These categories were presented at the public meetings and reflect the communities' vision, goals, and objectives:

Developed Open Space Areas consist of developed areas that are designated for passive and active park and recreational activities. Developed open space areas should conserve the natural drainage patterns and maintain downstream flows. Drainageways provide natural stormwater management, areas for groundwater recharge, and natural biological movement corridors and can provide valuable natural linkages to adjacent areas. These developed areas can include parks, traditional park and recreational programming, and trails. Although developed open space areas could incorporate stormwater storage areas, these areas will not be substituted for traditional park development.

Transitional Open Space Areas consist of areas that abut or are adjacent to currently protected or planned open space areas such as state and national parks, national monuments, wilderness areas, and national forests, and areas identified within the Plan. Preserving the edge of these dedicated state and national lands will ensure equitable access to all. Every effort shall be made to extend the natural environment of the protected lands, and to provide a natural integration to surrounding protected landscapes. Facilities such as parks and stormwater storage areas within transitional open space areas allow for public access and the preservation of view corridors.

Continued on Page 40 of the PDF

PAGE 41 of the PDF EXCERPT

Heritage Open Space Areas are areas that have significant cultural value. They include working landscapes such as agricultural and ranching heritage, as well as cultural resources such as historic and prehistoric archaeological sites. Heritage areas can also be places of traditional cultural activities such as festivals or ceremonial/religious activities. It is important to recognize heritage areas as areas of diverse human activities that if irresponsibly disrupted could negatively impact social and environmental conditions. Careful consideration should be given to identifying heritage areas, as well as a development of prudent management approaches. The American Farmland Trust has identified areas within Pinal County as strategic prime ranchland at risk, which could be identified as heritage open space areas. Other examples could include prehistoric or historic archaeological sites or districts such as the Los Robles Archaeological District.

Conservation Open Space Areas are areas that have a demonstrated and important ecological function. Areas that have a high to medium habitat value, which includes substantial vegetation, important natural or geologic features, and biological movement corridors, should be preserved in an effort to maintain the ecological health of the region. Examples of high-quality habitat include areas designated as critical habitat, and large undisturbed expanses of land, such as mountain ranges, river corridors, perennial streams, and open desert areas. Medium-quality habitat may include washes nearer to developed areas, where land may be more fragmented but where water and food may be available.

PAGE 43 of the PDF EXCERPT

6.0 Final Master Plan

6.2 Vision, Goals, and Objectives

Vision

Pinal County's Open Space and Trails Master Plan promotes the quality of life of the region by providing areas of passive and active recreational opportunities, while conserving existing resources, such as natural scenic beauty, view corridors, wildlife habitat, agricultural resources designated at risk, and cultural heritage for the benefit of present and future generations. This Plan will encourage appropriate long-range growth planning opportunities, provide for a wide range of recreational activities for residents and visitors, preserve the county's rural and natural open space character, and contribute to the well-being of its communities.

6.3 Open Space and Trails Master Plan Elements

The *Final Master Plan* (see Figure 13, *Final Master Plan Map)* is based on the county's resource opportunities and constraints as identified in Section 2.0, *Inventory and Analysis*, and public, stakeholder, and County staff input identified in Section 3.0, *Public Participation*. The siting of specific proposed open space areas and trail corridors were identified based on the suitability of activities, surrounding land use, ecological factors, topography, viewsheds, and cultural resources.

PAGE 45 of the PDF EXCERPT

The proposed open space areas are based on protection and connectivity of the following items identified during the in-depth analysis of the county's natural and cultural resources discussed in Section 2.0, *Inventory and Analysis*.

Riparian and Mountainous Areas – Habitat fragmentation throughout Pinal County is a particular obstacle to threatened and endangered wildlife and a threat to overall biodiversity. To reduce the threat caused by habitat fragmentation, it is desirable to connect large contiguous areas of open space and allow for species mobility through wildlife movement corridors. As identified in Section 2.0, *Inventory and Analysis*, the highest levels of biodiversity, and the highest quality habitats are found within the riparian and mountainous areas of the county. Riparian corridors provide additional water availability and vegetative cover for wildlife, and protection of these corridors is of critical concern to overall species mobility. Riparian corridors also indicate the greatest concentrations of cultural resources. The Gila, San Pedro, and Santa Cruz Rivers were identified as the three most important riparian corridors throughout the County, and they deserve the highest priority for preservation. In addition, the mountainous areas that dominate the eastern portion of the county such as the Pinal, Superstition, Black, Dripping Springs, and Tortilla Mountains indicate a high level of biodiversity and high habitat values. Other mountainous areas such as the Tortolita and Picacho Mountains were also identified as having a high habitat value and a high level of biodiversity.

PAGE 46 of the PDF MAP – Final Master Plan Map Figure 13

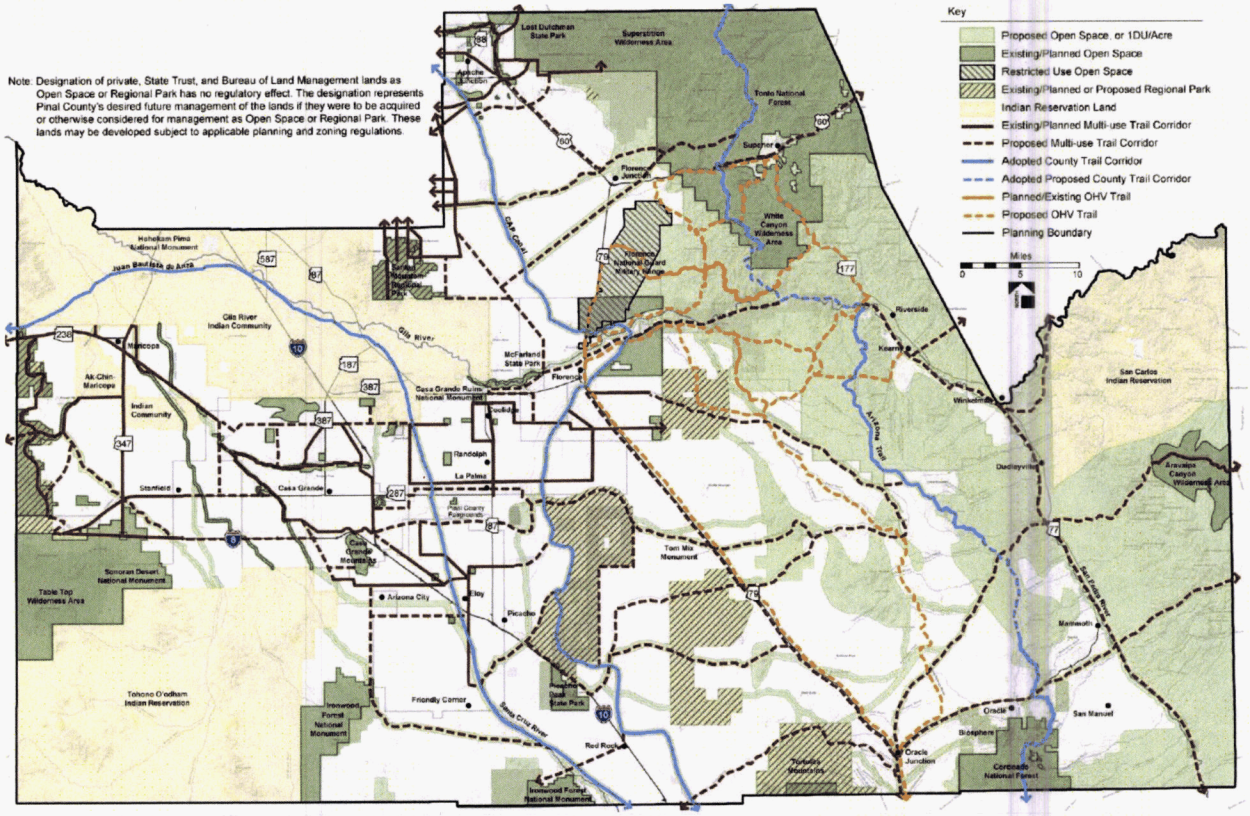


Figure 13.

PAGE 48 of the PDF EXCERPT

Proposed Trail Corridors

Providing equitable access to the county's resources through an interconnected multi-modal trail network ensures a variety of passive and active recreation opportunities. The foundation of the trail system shown on the Final Master Plan Map relies on a skeletal framework of three regional trail corridors. The Juan Bautista de Anza National Historic Trail, the CAP Canal, and the Arizona Trail, which all provide regional connectivity throughout Pinal County from Pima County to the south to Maricopa County to the north and...

The following describes the five proposed regional parks, as shown on Figure 13, *Final Master Plan Map*.

- The regional park proposed along the east side of the city of Florence planning boundary may provide passive and active recreational opportunities that would help to support the growing needs of the users located within the surrounding municipalities.

PAGE 49 of the PDF EXCERPT

- The regional park proposed to the north of Picacho Peak State Park may provide more passive-oriented recreational opportunities that would conserve the natural resources located within this area while allowing users to experience the natural environment.
- The regional park located west of Highway 79 and east of the proposed regional park near Picacho Peak State Park may provide active and passive recreational opportunities to support the future needs of development that may occur in this area of the county.
- The regional park proposed on the western edge of the county was identified in the City of Maricopa's General Plan, and represents the desired future conditions for the city. The Plan identified additional areas surrounding the proposed regional park, and provided additional connectivity to the Table Top Wilderness area. This area may develop through cooperation with the City of Maricopa.
- The regional park located north of Florence Junction may provide passive and active recreational opportunities that would help to support the growing needs of the users located in the surrounding communities and municipalities.

The following describes the two existing/planned regional parks, as shown in Figure 13, *Final Master Plan Map*. These areas may continue to develop through cooperation with Maricopa and Pima Counties.

- The planned Tortolita Mountain Park located along the southern edge of the county may provide more passive-oriented recreational opportunities that would conserve existing natural resources.
- The existing San Tan Mountain Regional Park provides passive-oriented recreational opportunities, to support the growing needs of the expanding urban fringes of the Phoenix Metropolitan Area and the anticipated growth of the surrounding communities and municipalities.

PAGE 53 of the PDF Excerpt

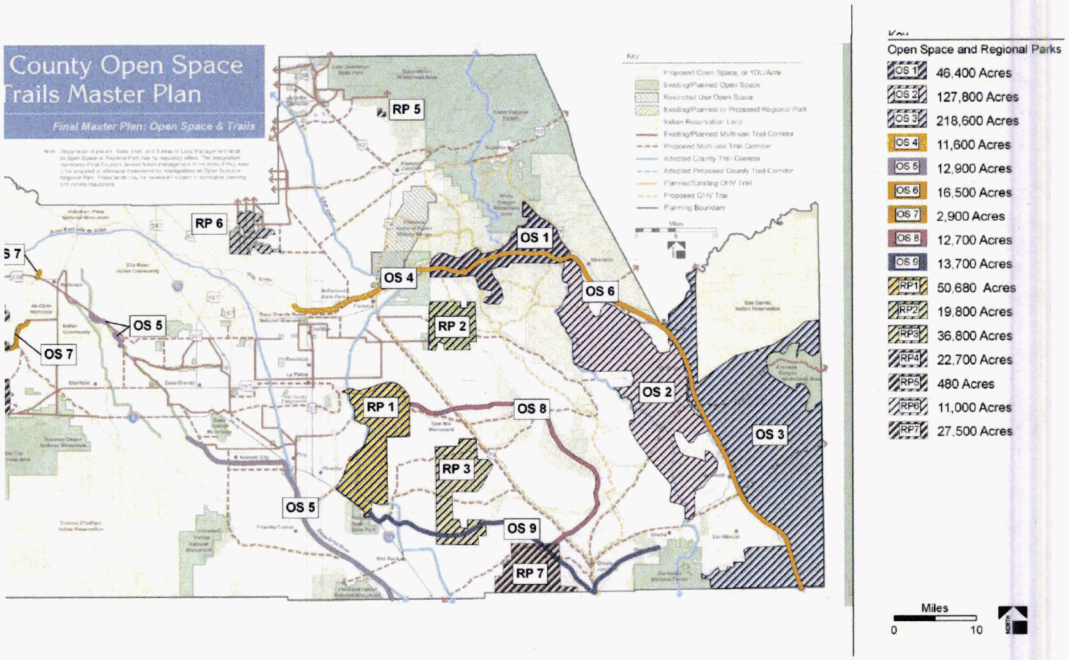
Influencing Land Management Decisions

While local governments do not have regulatory control over state and federal land management agencies, federal land management agencies protect open space on BLM and USFS lands through congressional designations of lands, through designations by the Secretaries of Interior (BLM) and Agriculture (USFS) and the heads of the agencies, and through approved land management plans completed using extensive public involvement processes. It is through these approved land management plans that the local governments can have considerable influence over landowners and managers that are not subject to local government regulation. For example, the Federal Land Management and Policy Act that governs the BLM's management of public land, provides for a significant role for local governments to influence federal land management policies. In a similar manner, Arizona cities and counties may have some input for land management decisions made by the Arizona State Land Department as it relates to the desired future land development patterns of their communities. As federal and state land management plans are undertaken, local governments should express their preferences so that they may be incorporated into the plans.

PAGE 55 of the PDF EXCERPT

The success of the implementation program strategy is dependent on the cooperation and coordinated efforts of the County, municipalities within the county, and affected state and federal agencies in order to secure the vision of a connected open space system that conserves the natural and cultural resources of the county. Each of the items indicated in Table 4 will require support and specialized expertise from county, municipal, state, and federal agency departments for which key responsibilities have been identified.

PAGE 56 of the PDF EXCERPT MAP Figure 14 Proposed Open Space and Regional Park Implementation



PAGE 57 of the PDF EXCERPT Map Figure 15 Multi-Use Trails

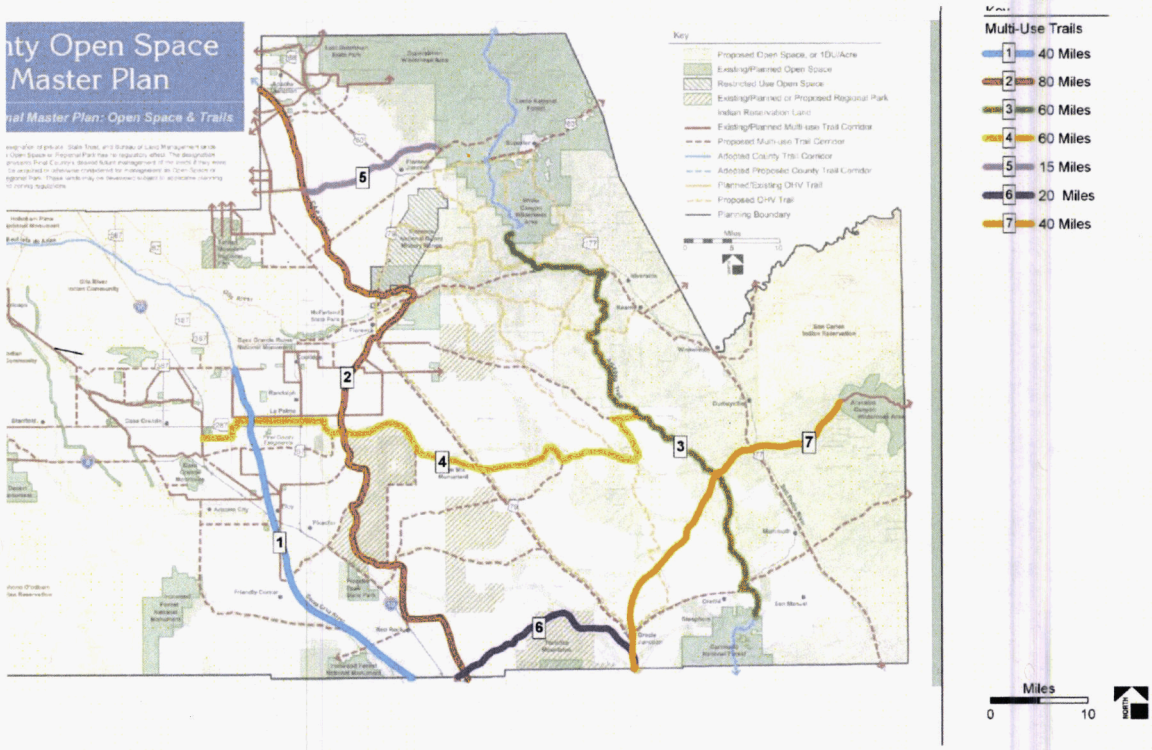


Figure 15. Proposed Trail Implementation

19

DOCKET NO. L-00000YY-15-0318-00171-MCV_19

ARIZONA MISSING LINKAGES

Ironwood–Picacho Linkage Design

Paul Beier, Daniel Majka, Todd Bayless

submitted June 2006
last revised May 24, 2007

NORTHERN ARIZONA UNIVERSITY

Table of Contents

TABLE OF CONTENTS I

LIST OF TABLES & FIGURES III

TERMINOLOGY V

EXECUTIVE SUMMARY VI

INTRODUCTION 1

- NATURE NEEDS ROOM TO MOVE 1
- A STATEWIDE VISION 1
- ECOLOGICAL SIGNIFICANCE OF THE IRONWOOD-PICACHO LINKAGE 2
- EXISTING CONSERVATION INVESTMENTS 3
- THREATS TO CONNECTIVITY 4

LINKAGE DESIGN & RECOMMENDATIONS 6

- TWO ROUTES PROVIDE CONNECTIVITY ACROSS A DIVERSE LANDSCAPE 6
- LAND OWNERSHIP, LAND COVER, AND TOPOGRAPHIC PATTERNS WITHIN THE LINKAGE DESIGN 6
- REMOVING AND MITIGATING BARRIERS TO MOVEMENT 11
- IMPACTS OF ROADS ON WILDLIFE 11
  - *Mitigation for Roads* *11*
  - *Existing Roads and Rail Lines in the Linkage Design Area* *15*
  - *Existing Crossing Structures on I-10* *16*
  - *Recommendations for Interstate 10* *19*
- IMPACTS OF CANALS ON WILDLIFE 21
  - *Canals in the Linkage Design Area* *21*
  - *Mitigation for Canals* *21*
- RECREATIONAL OFF-HIGHWAY VEHICLE USE AS A BARRIER TO MOVEMENT 24
  - *Mitigation for OHV Use* *24*
- URBAN DEVELOPMENT AS BARRIERS TO MOVEMENT 26
  - *Urban Barriers in the Linkage Design Area* *26*
  - *Mitigation for Urban Barriers* *27*

APPENDIX A: LINKAGE DESIGN METHODS 28

- FOCAL SPECIES SELECTION 28
- HABITAT SUITABILITY MODELS 28
- IDENTIFYING POTENTIAL BREEDING PATCHES & POTENTIAL POPULATION CORES 30
- IDENTIFYING BIOLOGICALLY BEST CORRIDORS 31
- PATCH CONFIGURATION ANALYSIS 32
- MINIMUM LINKAGE WIDTH 33
- FIELD INVESTIGATIONS 34

APPENDIX B: INDIVIDUAL SPECIES ANALYSES 35

- BADGER (*TAXIDEA TAXUS*) 39
- BLACK-TAILED JACKRABBIT (*LEPUS CALIFORNICUS*) 42
- DESERT BIGHORN SHEEP (*OVIS CANADENSIS NELSONI*) 45
- JAVELINA (*TAYASSU TAJACU*) 49
- MULE DEER (*ODOCOILEUS HEMIONUS*) 52
- BLACK-TAILED RATTLESNAKE (*CROTALUS MOLOSSUS*) 55
- DESERT TORTOISE (*GOPHERUS AGASSIZII*) 58
- SONORAN DESERT TOAD (*BUFO ALVARIUS*) 62
- SONORAN WHIPSNAKE (*MASTICOPHIS BILINEATUS*) 65
- TUCSON SHOVEL-NOSED SNAKE (*CHIONACTIS OCCIPITALIS KLAUBERI*) 68

CACTUS FERRUGINOUS PYGMY-OWL (*GLAUCIDIUM BRASILIANUM CACTORUM*) 71
APPENDIX C: FOCAL SPECIES NOT MODELED **73**
APPENDIX D: CREATION OF LINKAGE DESIGN **75**
APPENDIX E: DESCRIPTION OF LAND COVER CLASSES **76**
APPENDIX F: LITERATURE CITED **80**
APPENDIX G: DATABASE OF FIELD INVESTIGATIONS **85**

List of Tables & Figures

List of Tables

TABLE 1: FOCAL SPECIES SELECTED FOR THE IRONWOOD-PICACHO LINKAGE. VII
TABLE 2: APPROXIMATE LAND COVER FOUND WITHIN LINKAGE DESIGN. 7
TABLE 3: MAJOR TRANSPORTATION ROUTES IN THE LINKAGE DESIGN. 15
TABLE 4: HABITAT SUITABILITY SCORES AND FACTOR WEIGHTS FOR EACH SPECIES. SCORES RANGE FROM 1 (BEST) TO 10 (WORST), WITH 1-3 INDICATING OPTIMAL HABITAT, 4-5 SUBOPTIMAL BUT USABLE HABITAT, 6-7 OCCASIONALLY USED BUT NOT BREEDING HABITAT, AND 8-10 AVOIDED. 36

List of Figures

FIGURE 1: THE LINKAGE DESIGN HAS 2 STRANDS: ONE CONNECTING THE IRONWOOD NATIONAL MONUMENT TO THE PICACHO MOUNTAINS, AND ONE CONNECTING IRONWOOD NATIONAL MONUMENT TO THE BLM LAND LABELED DURHAM-CORONADO PLAINS. VIII
FIGURE 2: LAND OWNERSHIP WITHIN THE LINKAGE PLANNING AREA. 4
FIGURE 3: LAND COVER WITHIN THE LINKAGE PLANNING AREA. 5
FIGURE 4: PROPERTY OWNERSHIP AND FIELD INVESTIGATION WAYPOINTS WITHIN LINKAGE DESIGN. THE ACCOMPANYING CD-ROM INCLUDES PHOTOGRAPHS TAKEN AT MOST WAYPOINTS (INDICATED BY STARS). 8
FIGURE 5: LAND COVER WITHIN LINKAGE DESIGN. 9
FIGURE 6: TOPOGRAPHIC DIVERSITY ENCOMPASSED BY LINKAGE DESIGN: A) TOPOGRAPHIC POSITION, B) SLOPE, C) ASPECT. 10
FIGURE 7: CHARACTERISTICS WHICH MAKE SPECIES VULNERABLE TO THE THREE MAJOR DIRECT EFFECTS OF ROADS (FROM FORMAN ET AL. 2003). 12
FIGURE 8: POTENTIAL ROAD MITIGATIONS (FROM TOP TO BOTTOM) INCLUDE: HIGHWAY OVERPASSES, BRIDGES, CULVERTS, AND DRAINAGE PIPES. FENCING (LOWER RIGHT) SHOULD BE USED TO GUIDE ANIMALS INTO CROSSING STRUCTURES. 13
FIGURE 9: FOUR 3 X 10 FT BOX CULVERTS UNDER I-10 (PHOTO AZIMUTH 280) AND A WOODEN RAILROAD CROSSING (PHOTO AZIMUTH 174) AT WAYPOINT 72. 17
FIGURE 10: A SMALL TWIN-SPAN CEMENT CULVERT (AZIMUTH: 280) AND A WOODEN RAILROAD CROSSING (AZIMUTH: 174) OCCUR AT WAYPOINT 73. 17
FIGURE 11: THREE SMALL CEMENT CULVERTS (AZIMUTH: 268) AND A WOODEN RAILROAD CROSSING (AZIMUTH: 54) OCCUR AT WAYPOINT 74, NEAR MILE POST 227. 17
FIGURE 12: TWO EXAMPLES OF TWIN-SPAN 4 X 6 FT CULVERTS FOUND IN THE IRONWOOD – PICACHO STRAND OF THE LINKAGE DESIGN (LEFT: WAYPOINT 88, RIGHT: WAYPOINT 89. AZIMUTH ON BOTH PHOTOS: 220). 18
FIGURE 13: THE ENTRANCE OF THIS SMALL BOX CULVERT NORTH OF PICACHO PEAK STATE PARK HAS BEEN BLOCKED WITH VEGETATION (WAYPOINT 90, AZIMUTH 24). 18
FIGURE 14: A SMALL TWIN-SPAN CEMENT CULVERT (AZIMUTH: 220) AND A WOODEN RAILROAD CROSSING (AZIMUTH: 22) OCCUR AT WAYPOINT 91. 19
FIGURE 15: A SMALL 4 X 6 FT CEMENT CULVERT FILLED WITH TUMBLEWEEDS (AZIMUTH: 228) OCCURS AT WAYPOINT 92. 19
FIGURE 16: CANALS IN THE LINKAGE DESIGN AREA. THE 4 BLACK LINES INDICATE BURIED SECTIONS OF THE CENTRAL ARIZONA PROJECT CANAL: A 1.3-KM STRETCH ON THE NORTHWEST SIDE OF THE PICACHO MOUNTAINS, A 70-M STRETCH AT MCCLELLAN WASH, A 2.5-KM STRETCH IN THE EASTERN STRAND OF THE LINKAGE DESIGN, AND A 2.5 KM STRETCH UNDER INTERSTATE 10. 22
FIGURE 17: AN IRRIGATION CANAL CONNECTED TO THE CAP CANAL INTERSECTS ALL PORTIONS OF THE IRONWOOD - PICACHO MTNS LINKAGE (WAYPOINT 98, AZIMUTH: 96). 23
FIGURE 18: THE ONLY LOCATIONS WHERE AN ANIMAL CAN SAFELY CROSS THE IRRIGATION CANAL ARE WHERE ROADS PASS OVER THE CANAL (WAYPOINT 99, AZIMUTH: 286). 23
FIGURE 19: AN OHV AREA ON STATE TRUST LAND NEAR PINAL AIR PARK AFFECTS CONNECTIVITY BETWEEN IRONWOOD FOREST NATIONAL MONUMENT AND THE DESERT BLM BLOCK TO THTE NORTHWEST. 24
FIGURE 20: OHV USE HAS ALTERED VEGETATION AND THREATENS CONNECTIVITY (WAYPOINT 102, AZIMUTH: 122). SEE FIGURE 19 TO LOCATE THIS SCENE WITHIN THE LINKAGE DESIGN. 25

FIGURE 21: THE SAGUARO POWER PLANT BORDERS THE SOUTHERN END OF THE IRONWOOD - PICACHO LINKAGE ADJACENT TO I-10 (WAYPOINT 72; AZIMUTH: 38) 26
FIGURE 22: THE PINAL AIR PARK BORDERS THE SOUTHERN END OF THE IRONWOOD - PICACHO LINKAGE 4 KM NORTHWEST OF IRONWOOD FOREST NATIONAL MONUMENT. ATV USE IN FOREGROUND (WAYPOINT 103; AZIMUTH: 178). 27
FIGURE 23: FOUR HABITAT FACTORS USED TO CREATE HABITAT SUITABILITY MODELS. INPUTS INCLUDED VEGETATION, ELEVATION, TOPOGRAPHIC POSITION, AND DISTANCE FROM ROADS. 29
FIGURE 24: EXAMPLE MOVING WINDOW ANALYSIS WHICH CALCULATES THE AVERAGE HABITAT SUITABILITY SURROUNDING A PIXEL. A) ORIGINAL HABITAT SUITABILITY MODEL, B) 3X3-PIXEL MOVING WINDOW, C) 200M RADIUS MOVING WINDOW. 31
FIGURE 25: A) LANDSCAPE PERMEABILITY LAYER FOR ENTIRE LANDSCAPE, B) BIOLOGICALLY BEST CORRIDOR COMPOSED OF MOST PERMEABLE 10% OF LANDSCAPE. 33
FIGURE 26: MODELED HABITAT SUITABILITY OF BADGER. 40
FIGURE 27: POTENTIAL HABITAT PATCHES AND CORES FOR BADGER. 41
FIGURE 28: MODELED HABITAT SUITABILITY OF BLACK-TAILED JACKRABBIT. 43
FIGURE 29: POTENTIAL HABITAT PATCHES AND CORES FOR BLACK-TAILED JACKRABBIT. 44
FIGURE 30: MODELED HABITAT SUITABILITY OF DESERT BIGHORN SHEEP. 47
FIGURE 31: POTENTIAL HABITAT PATCHES AND CORES FOR DESERT BIGHORN SHEEP. 48
FIGURE 32: MODELED HABITAT SUITABILITY OF JAVELINA. 50
FIGURE 33: POTENTIAL HABITAT PATCHES AND CORES FOR JAVELINA. 51
FIGURE 34: MODELED HABITAT SUITABILITY OF MULE DEER. 53
FIGURE 35: POTENTIAL HABITAT PATCHES AND CORES FOR MULE DEER. 54
FIGURE 36: MODELED HABITAT SUITABILITY OF BLACK-TAILED RATTLESNAKE. 56
FIGURE 37: POTENTIAL HABITAT PATCHES AND CORES FOR BLACK-TAILED RATTLESNAKE. 57
FIGURE 38: MODELED HABITAT SUITABILITY OF DESERT TORTOISE. 60
FIGURE 39: POTENTIAL HABITAT PATCHES AND CORES FOR DESERT TORTOISE. 61
FIGURE 40: MODELED HABITAT SUITABILITY OF SONORAN DESERT TOAD. 63
FIGURE 41: POTENTIAL HABITAT PATCHES AND CORES FOR SONORAN DESERT TOAD. 64
FIGURE 42: MODELED HABITAT SUITABILITY OF SONORAN WHIPSNAKE. 66
FIGURE 43: POTENTIAL HABITAT PATCHES AND CORES FOR SONORAN WHIPSNAKE. 67
FIGURE 44: MODELED HABITAT SUITABILITY OF TUCSON SHOVEL-NOSED SNAKE. 69
FIGURE 45: POTENTIAL HABITAT PATCHES AND CORES FOR TUCSSON SHOVEL-NOSED SNAKE. 70
FIGURE 46: PROPOSED CRITICAL HABITAT FOR CACTUS FERRUGINOUS PYGMY-OWL. 72
FIGURE 47: FIELD INVESTIGATION WAYPOINTS. 85

The Ironwood-Picacho region provides significant ecological, educational, recreational, and spiritual values of protected wildlands. Our Linkage Design represents an opportunity to protect a functional landscape-level connection. The cost of implementing this vision will be substantial—but reasonable in relation to the benefits and the existing public investments in protected wild habitat. If implemented, our plan would not only permit movement of individuals and genes between the Ironwood National Monument, Picacho Mountains, and desert BLM wildland blocks, but should also conserve large-scale ecosystem processes that are essential to the continued integrity of existing conservation investments by the US Forest Service, Arizona State Parks, Bureau of Land Management, Arizona Game and Fish Department, U.S. Fish and Wildlife Service, and other conservancy lands.

Next Steps: This Linkage Design Plan is a science-based starting point for conservation actions. The plan can be used as a resource for regional land managers to understand their critical role in sustaining biodiversity and ecosystem processes. Relevant aspects of this plan can be folded into management plans of agencies managing public lands. Transportation agencies can use the plan to design new projects and find opportunities to upgrade existing structures. Regulatory agencies can use this information to help inform decisions regarding impacts on streams and other habitats. This report can also help motivate and inform construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, and land acquisition. Implementing this plan will take decades, and collaboration among county planners, land management agencies, resource management agencies, land conservancies, and private landowners.

Public education and outreach is vital to the success of this effort – both to change land use activities that threaten wildlife movement and to generate appreciation for the importance of the corridor. Public education can encourage residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function. The biological information, maps, figures, tables, and photographs in this plan are ready materials for interpretive programs.

Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. We hope this linkage conservation plan will be used to protect an interconnected system of natural space where our native biodiversity can thrive, at minimal cost to other human endeavors.

Table 1: Focal species selected for the Ironwood-Picacho Linkage.

MAMMALS	AMPHIBIANS & REPTILES	BIRDS
*Badger *Bighorn Sheep *Black-tailed Jackrabbit *Javelina[1] *Mule Deer	*Sonoran Desert Toad *Black-tailed Rattlesnake Chuckwalla Desert Iguana *Desert Tortoise Lyre Snake *Sonoran Whipsnake Tiger Rattlesnake *Tucson Shovel-nosed Snake	Cactus Ferruginous Pygmy-Owl Roadrunner **PLANTS** Ironwood Tree Palo Verde **INSECTS** Bee species Hawkmoth

* Species modeled in this report. The other species were not modeled because there were insufficient data to quantify habitat use in terms of available GIS data (e.g., some snakes that select small rocks), or because the species probably can travel (e.g., by flying) across unsuitable habitat.

[1] During field work, we found a dead javelina (apparently road-killed) near the entrance to a culvert under I-10 in the potential linkage area.

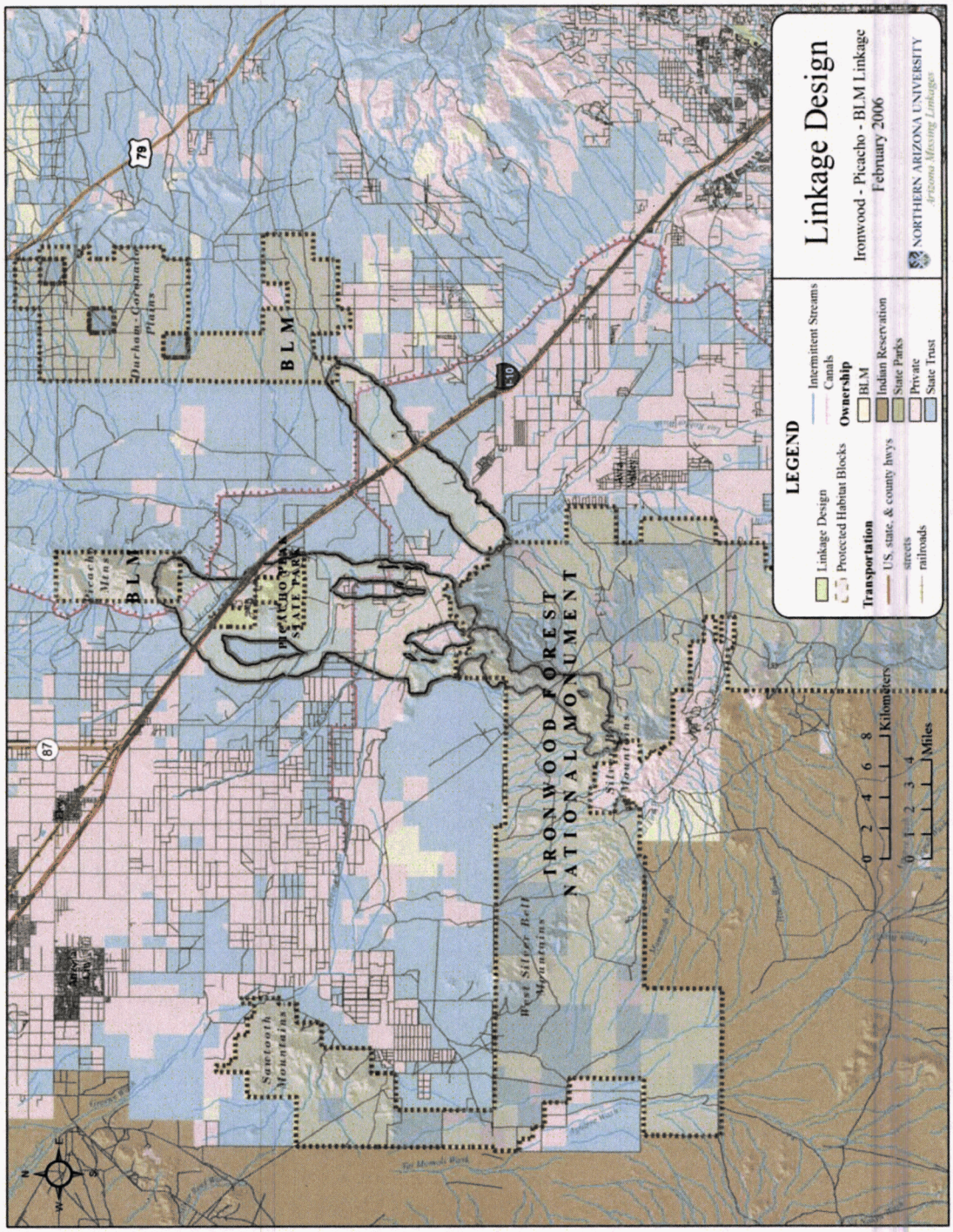


Figure 1: The Linkage Design has 2 strands: one connecting the Ironwood National Monument to the Picacho Mountains, and one connecting Ironwood National Monument to the BLM land labeled Durham-Coronado Plains.

Ecological Significance of the Ironwood-Picacho Linkage

The Ironwood-Picacho-BLM Linkage Planning area lies within the 55-million acre Sonoran Desert Ecoregion of southern Arizona, southeastern California, and northwestern Sonora, Mexico. This ecoregion is the most tropical of North America's warm deserts (Marshall et al. 2000). Bajadas sloping down from the mountains support forests of ancient saguaro cacti, paloverde, and ironwood; creosotebush and bursage desert shrub dominate the lower desert (The Nature Conservancy 2006). The Sonoran Desert Ecoregion is home to more than 200 threatened species, and its uniqueness lends to a high proportion of endemic plants, fish, and reptiles (Marshall et al. 2000; The Nature Conservancy 2006). More than 500 species of birds migrate through, breed, or permanently reside in the ecoregion, which are nearly two-thirds of all species that occur from northern Mexico to Canada (Marshall et al. 2000). The Sonoran Desert Ecoregion's rich biological diversity prompted Olson and Dinerstein (1998) to designate it as one of 233 of the earth's most biologically valuable ecoregions, whose conservation is critical for maintaining the earth's biodiversity.

Within the Sonoran Desert Ecoregion, the Linkage Planning Area includes three wildland blocks: Ironwood National Monument, the Picacho Mountains, and a block of Sonoran desert we call Durham-Coronado Plains[2]. All 3 areas are administered by the Bureau of Land Management (Figure 2).

The Ironwood Forest National Monument, the southern habitat block, encompasses several desert mountain ranges including the Silver Bell, Waterman and Sawtooth Mountains, which extend for 42 km (26 mi) (Bureau of Land Management 2005). These mountains support drainage systems such as Los Robles Wash, Blanco Wash, Cocio Wash, and the Santa Cruz River. Elevation ranges from 1,800 to 4,261 feet, providing a geologic and topographic variability that contributes to high biological diversity (Bureau of Land Management 2005).

The BLM land in the Picacho Mountains is one of the northern wildland blocks in the Ironwood-Picacho Linkage Planning Area. The Picacho Mountains extend for 20 km (12.5 mi) and range in elevation from 1,725 ft to 4,508 ft at Newman Peak. This mountain range supports the Brady and McClellan Washes, and provides important wildlife habitat. Mountain lions have been documented traveling between the Picacho Mountains and the Catalina Mountains (K. Nicholson & P. Krausman, University of Arizona, personal communication).

The Durham-Coronado Plain[2] is a 20 km (12.5 mi) stretch of protected Paloverde-mixed cacti desert communities. The Durham and Coronado Washes run through this habitat block, which ranges from 2000-2500 ft elevation. This area provides protected Sonoran desert for wildlife and plant species in the region.

The Linkage Planning Area ranges from 1700 feet elevation at the Santa Cruz River valley to 4,508 feet at Newman Peak in the Picacho Mountains. Paloverde-mixed cacti desert scrub, semi-desert grassland and steppe, and creosotebush-white bursage desert scrub communities dominate the landscape, with large areas of agricultural lands along the I-10 transportation corridor (Figure 3). Riparian areas in the Linkage Planning Area include the Santa Cruz River, and McClellan, Blanco, and Cocio Washes.

The varied habitat types in the Linkage Planning Area support many animal species. Species listed as threatened or endangered by the U.S. Fish and Wildlife Service include the desert tortoise, bighorn sheep, and the cactus ferruginous pygmy-owl (USFWS 2005). The Corridor Design incorporates and connects critical habitat needed for these species to achieve viable populations. The Ironwood-Picacho Linkage Planning Area is also home to far-ranging mammals such as mule deer, mountain lion, and badger. These

[2] This block of BLM land has no formal designation on most maps. We named it after Durham Wash and Coronado Wash, which are the 2 main drainages in the area

animals move long distances to gain access to suitable foraging or breeding sites, and would benefit significantly from corridors that link large areas of habitat (Turner et al. 1995). Less-mobile species and habitat specialists such as black-tailed jackrabbits, tiger rattlesnakes, and Sonoran desert toads also need corridors to maintain genetic diversity, allow populations to shift their range in response to climate change, and promote recolonization after fire or epidemics.

Existing Conservation Investments

The three wildland blocks are comprised of land federally protected by the Bureau of Land Management. The **southern habitat block** consists of Ironwood Forest National Monument, 129,000 protected acres of ancient legume and cactus forests (Bureau of Land Management 2005). This monument provides an outstanding example of the plant and animal diversity of the Sonoran desert (Bureau of Land Management 2005). The monument's Silver Bell Mountains alone claims more than 674 species, including 64 mammals and 57 birds (Bureau of Land Management 2005). The Ironwood Forest National Monument hosts one of the richest stands of ironwood trees in the Sonoran desert, and is home to many federally listed species, including the Nichols turk's head cactus, the lesser long-nosed bat, and the desert bighorn sheep (Bureau of Land Management 2005; Sierra Club 2006).

Adjacent to the southern habitat block's Ironwood Forest National Monument is a proposed conservation reserve that would protect 6,485 acres of State Trust land in the Sonoran desert (Sonoran Institute 2005). This reserve would help to link the Ironwood Forest National Monument with the Sawtooth Mountains to the north. Another proposed conservation reserve known as Sawtooth would add 3,395 acres of protected land in the southern habitat block's vicinity and encompass a stand of mature ironwood trees not protected within the monument's borders (Sonoran Institute 2005). Both of these proposed reserves would buffer the habitat block from urban development in the Marana and Tucson areas (Sonoran Institute 2005). The Tohono O'odham Nation also abuts the Monument. Although tribal sovereignty includes the right to develop reservation land, conserving this linkage gives the tribe the opportunity to maintain a wildlife corridor to the northeast of the reservation, which is now largely in a natural condition.

The **northwestern habitat block** consists of the Picacho Mountains, 6,400 protected acres owned by the Bureau of Land Management. This habitat block would be expanded by 18,705 acres through a proposed conservation reserve protecting surrounding State Trust Lands in the Picachos (Figure 2; Sonoran Institute 2005).

The Durham-Coronado Plain is 33,200 acres of BLM-protected Sonoran desert that comprise the **northeastern habitat block** in the Linkage Planning Area. This undeveloped tract of Sonoran desert provides desert species refuge from encroaching development in the area.

Picacho Peak State Park, a protected area in the Linkage Planning Area separate from the three wildland blocks, would both contribute to and benefit from a wildlife corridor in this area. This Arizona state park consists of 3,500 acres of Sonoran desert, including the iconic landmark of Picacho Peak, rising to 3,382 feet (Arizona State Parks 2005). The park attracts 60,000 visitors per year, bringing money into the local economy (Arizona Office of Tourism 2003). Adjacent to this state park is the proposed Picacho Peak State Park conservation reserve, which would protect 3,995 acres of additional lands. This conservation reserve would convert State Trust lands for conservation and connectivity between protected lands and buffer Picacho Peak State Park from urban development (Figure 2; Sonoran Institute 2005).

Connectivity between these three valuable and wildland blocks would help to provide the contiguous habitat necessary to sustain viable populations of sensitive and far ranging species in the Sonoran Desert of southern Arizona.

Linkage Design & Recommendations

The Linkage Design (Figure 4 & Figure 5) is composed of two strands which together provide habitat for movement and reproduction of wildlife between the Ironwood, Picacho, and desert BLM protected wildland blocks. In this section, we describe the land cover and ownership patterns in the linkage design, and recommend mitigations for barriers to animal movement. The methods used to develop the linkage design are detailed in Appendixes A through E.

Two Routes Provide Connectivity Across a Diverse Landscape

The linkage design consists of two distinct strands which connect Ironwood Forest National Monument to the Picacho Mountains and the Durham-Coronado Plain.

The western strand connects Ironwood Forest National Monument and the Picacho Mountain wildland blocks. It is approximately 18 km (11 miles) long, and varies in width from approximately 1.5 to 8 km (0.9 – 5 miles). This strand is primarily composed of paloverde-mixed cacti desert scrub and creosotebush-white bursage desert scrub, but also includes riparian woodland, shrubland, and agriculture. This linkage provides live-in and pass-through habitat for species dependent on desert vegetation and/or rugged topography, such as desert tortoise, black-tailed rattlesnake, desert bighorn sheep, javelina, black-tailed jackrabbit, mule deer, and Sonoran whipsnake. Important riparian areas encompassed by this linkage include portions of the Santa Cruz River and Los Robles Wash north of Ironwood Forest National Monument, and McClellan Wash north of Picacho Peak State Park. The Central Arizona Project canal and a smaller irrigation canal both pass through this linkage.

LINKAGE DESIGN GOALS

- Provide move-through habitat for diverse group of species
- Provide live-in habitat for species with dispersal distances too short to traverse linkage in one lifetime
- Provide adequate area for a metapopulation of corridor-dwelling species to move through the landscape over multiple generations
- Provide a buffer protecting aquatic habitats from pollutants
- Buffer against edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species
- Allow animals and plants to move in response to climate change

The eastern strand between Ironwood Forest National Monument and the BLM-administered Durham-Coronado Plain is approximately 15 km (9 miles) long and 2 km (1¼ miles) wide. This corridor crosses the Santa Cruz River and Los Robles Wash northeast or Ironwood, passes north of Pinal Air Park and Saguaro Power plant, and joins the BLM desert block near Desert Peak. This route is primarily composed of creosotebush-white bursage desert scrub and paloverde-mixed cacti desert scrub, but also includes riparian woodland and shrubland. This linkage provides live-in and pass-through habitat for species dependent on desert vegetation and/or flatter topography, such as Tucson shovel-nosed, badger, black-tailed jackrabbit, javelina, and Sonoran desert toad. The entire corridor is also within proposed critical habitat for the Cactus-Ferruginous Pygmy-Owl.

Land Ownership, Land Cover, and Topographic Patterns within the Linkage Design

The Linkage Design encompasses 43,400 acres (17,570 ha) of land, and is composed of 57% state trust land, 22% private land, 12% BLM land, 8% state parks land, and 1% Bureau of Reclamation land (Figure 4). Seven natural vegetation communities account for 95% of the land cover, barren lands account for 0.6%, and developed land accounts for approximately 4% of the land in the Linkage Design (Figure 5, Table 2). Natural vegetation is dominated by desert scrub-shrub associations, and has a similar

Impacts of Canals on Wildlife

Canals can have both positive and negative impacts on desert wildlife. Some species may use canals as a water source, but the steep banks make it impossible or dangerous for most animals to do so. Desert mule deer, bighorn sheep, and Sonoran pronghorn have drowned in canals (Rautenstrauch & Krausman 1989). Canals serve as significant barriers to movement by preventing species from moving to viable habitat on the other side of the canal, drowning species, and rerouting natural movement patterns.

Canals in the Linkage Design Area

Two main canals act as barriers to connectivity in the linkage zone (Figure 16). The Central Arizona Project's (CAP) Tucson Canal crosses through both strands of the linkage design. The CAP canal is approximately 12 meters (39 ft) wide, and is lined with eight-foot fences on both sides to keep large animals out. A smaller irrigation canal connects to the CAP canal, extending westward through the strand of the linkage design connecting Ironwood Forest National Monument to the Picacho Mountains (Figure 17). This canal parallels Baumgartner Rd. for 9 km (5.6 mi), and is approximately 5 meters (16 ft) wide.

There is only one location where wildlife can safely cross the CAP canal in the linkage design. About 1.4 km of a buried stretch of the CAP canal (out of the total 2.5 km length of the buried section) lies in the eastern strand of the linkage design (Figure 16). There are no crossing structures for animals in the western strand of the linkage design.

The only opportunities to cross the smaller irrigation canal are where the canal crosses under dirt roads (Figure 18).

Mitigation for Canals

To conserve connectivity, we have the following recommendations for all existing and future canals in this linkage zone:

1) **Ensure opportunities for wildlife to cross every canal in the linkage area**. This can be accomplished by several methods. The most permeable, yet most expensive method is to bury any canal within the linkage design below ground. The eastern strand contains a buried section of canal that effectively mitigates the effect of the canal in this strand. In the western strand, a significant section of the CAP canal should be buried, or crossing structures should be installed. For *wide canals*, such as the CAP, vegetated overpasses should be installed. While no studies have examined optimal crossing structures for canals, information can be gleaned from the literature on the determinants of success for road mitigation structures. For example, Van Wieren & Worm (2001) recommend wildlife overpasses over roads be at least 40-50 m wide for optimal wildlife usage. For *narrow canals*, such as the irrigation canal in the western strand of the linkage design, an affordable solution would be to cover the canal with metal plates, and cover these plates with an earthen substrate. The existing crossings at dirt roads (Figure 18) are helpful, but lack vegetation needed for some wildlife species to find them attractive. To ensure usability by an array of species, the grade of the entrance and exit to these crossing structures should provide a gentle approach to the canal.

2) **Install fencing on all areas of the canal which do not have crossing structures.** This fencing must completely seal the canal in order for it to effectively restrict wildlife use (Rautenstrauch & Krausman 1989), and be sufficiently high to prevent deer from jumping the fence (Peris & Morales 2004).

3) **Provide alternative water sources adjacent to crossing structures** (Rautenstrauch & Krausman 1989). To discourage use of the canals as a water supply by deer and other species, a small amount of water should be diverted to water catchments to allow wildlife to drink without risk of drowning.

EXCERPT Page 34 of the PDF Figure 16 The remainder of the page is related to deer escape structures.

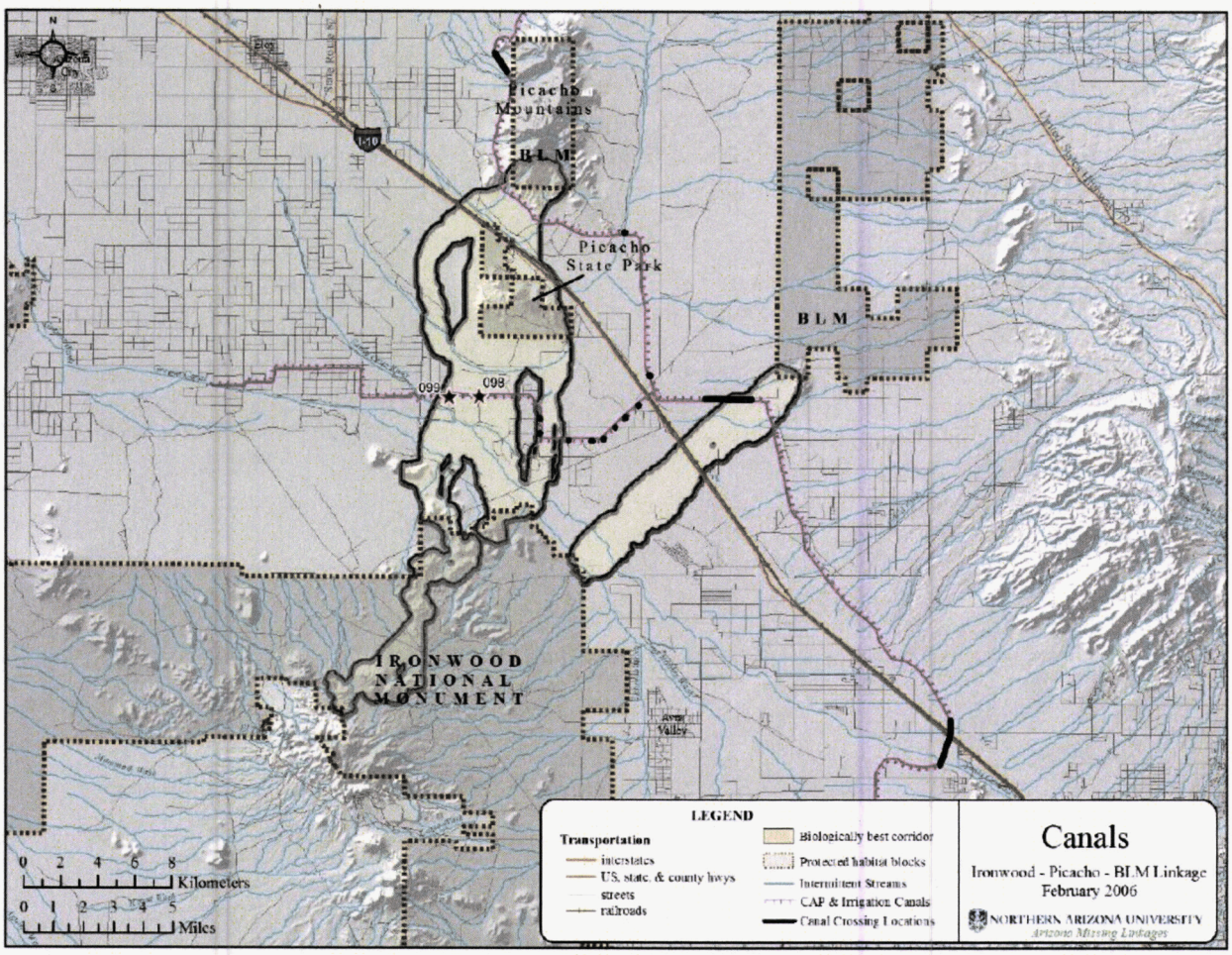


Figure 16: Canals in the Linkage Design area. The 4 black lines indicate buried sections of the Central Arizona Project canal: a 1.3-km stretch on the northwest side of the Picacho Mountains, a 70-m stretch at McClellan Wash, a 2.5-km stretch in the eastern strand of the linkage design, and a 2.5 km stretch under Interstate 10.

Urban Development as Barriers to Movement

While not a current major threat in the linkage area, urban and industrial development may become a greater threat in the future. Urban and industrial development, unlike roads, creates barriers to movement which cannot easily be removed, restored, or otherwise mitigated. Most large carnivores, small mammals, and reptiles cannot occupy these areas for a significant period of time, although several species of lizards or small mammals may occasionally occupy residential areas. While mapped urban areas only accounted for a marginal amount of the land cover in the linkage design, residential development may increase rapidly in the linkage area in the future.

Urban Barriers in the Linkage Design Area

While there are no current residential developments within the Linkage Design, there are several industrial developments. South of the Ironwood – desert BLM strand of the linkage, adjacent to I-10, is the Saguaro Power Plant (Figure 21). Several large tanks from the power plant are 200 m inside the border of this linkage.

Figure 21: The Saguaro Power Plant borders the southern end of the Ironwood - Picacho linkage adjacent to I-10 (waypoint 72; azimuth: 38).

The Pinal Air Park borders the southern end of the Ironwood – desert BLM linkage, approximately 4 km northwest of the Ironwood Forest National Monument boundary (Figure 22). In addition to storing aircraft, there is also a 1.2 mile racecourse for sports cars at the Air Park.

EXCERPT Page 39 of the PDF Complete Text. The rest of the page is a photo of Pinal Air Park Figure 22

Mitigation for Urban Barriers

To conserve connectivity, we have the following recommendations for all future urban, residential, and industrial developments in this linkage zone:

1) Encourage conservation easements and land acquisition with willing land owners in the Linkage Design to protect important habitat.
2) Develop a public education campaign to inform those living and working within the linkage area about the local wildlife and the importance of maintaining ecological connectivity.
3) Encourage homeowners to focus outside lighting on their houses only, and never out into the linkage area.
4) Ensure that all domestic pets are kept indoors or in fenced areas outdoors.
5) Reduce vehicle traffic speeds in sensitive locations.
6) Discourage the conversion of natural areas within the Linkage Design into residential areas. Where development is permitted, encourage small building footprints on large (> 10-acre) parcels.
7) Encourage the use of wildlife-friendly fencing.
8) Discourage the killing of 'threat' species such as rattlesnakes.

The next page is Appendix A: Linkage Design Methods

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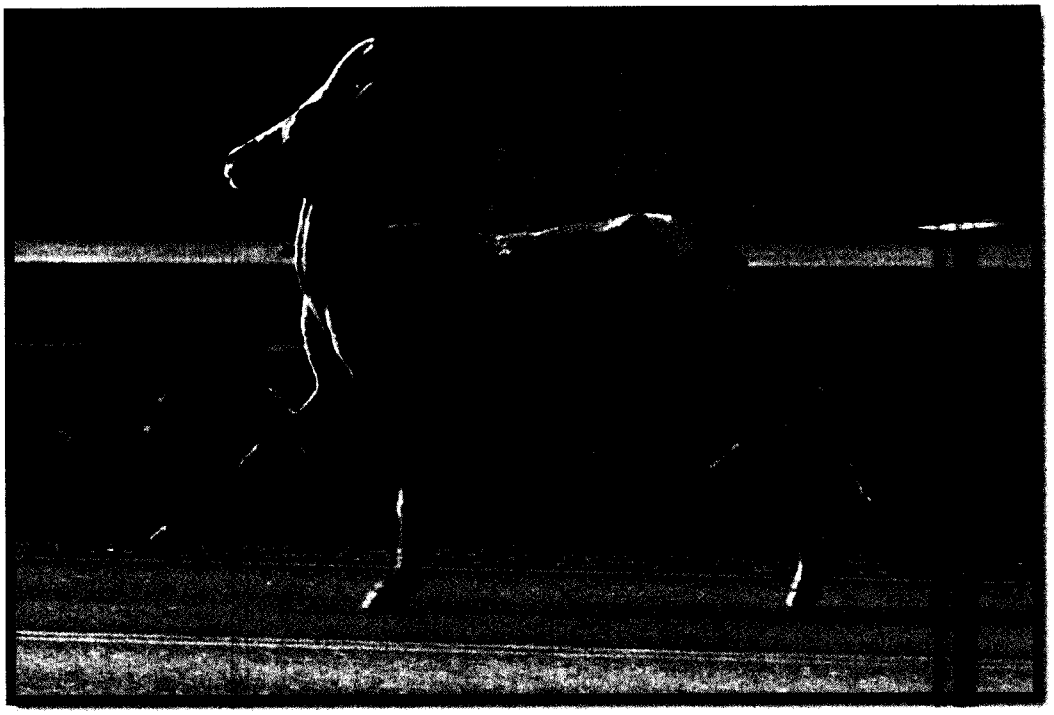
The Pinal County Wildlife Connectivity Assessment: Report on Stakeholder Input

April 2013



Bighorn sheep on highway in Arizona, photo by George Andrejko

Arizona Game and Fish Department

In partnership with the Arizona Wildlife Linkages Workgroup

TABLE OF CONTENTS

LIST OF FIGURES ii
RECOMMENDED CITATION iii
ACKNOWLEDGMENTS iii
DEFINITIONS iv
EXECUTIVE SUMMARY 1
BACKGROUND 2
METHODS 14
MAPS 19
PINAL COUNTY WILDLIFE LINKAGE DESCRIPTIONS 24
REFERENCES 35
APPENDIX I – TRANSPORTATION PLANNING STUDIES IN PINAL COUNTY 40
APPENDIX II – SAMPLE DATASHEET USED IN STAKEHOLDER WORKSHOPS 43

LIST OF FIGURES

Figure 1: ADWR check your water supply

Figure 2: Land ownership in Pinal County

Figure 3a/b: Satellite telemetry studies

Figure 4: Pinal County Multimodal Plan

Figures 5a/b: White-tailed deer movements along SR 260 and underpass near Kohl's Ranch

Figures 6a/b/c/d: Wildlife overpasses, underpasses, U.S. Highway ungulate-proof fencing and overpass allowing desert bighorn sheep to safely move

Figure 7: Pinal County Open Space and Trails Master Plan

Figures 8a/b: Statewide map of wildlife linkages and barriers and Ironwood-Picacho Linkage Design

Figure 9: Pinal County stakeholder-identified linkages – Overview

Figure 10: Pinal County stakeholder-identified linkages – Northern

Figure 11: Pinal County stakeholder-identified linkages – Eastern

Figure 12: Pinal County stakeholder-identified linkages – Southern

Figure 13: Pinal County stakeholder-identified linkages – Western

Stakeholder identified species:
Sonoran desert tortoise
Photo by A. Owens
Arizona Game and Fish Department

Stakeholder identified species:
Bighorn sheep
Photo by Geof Moss and Tim Downs
Arizona Game and Fish Department

Stakeholder identified species:
Cactus ferruginous pygmy-owl
Photo by G. Andrejko
Arizona Game and Fish Department

EXECUTIVE SUMMARY

This report and the accompanying Geographic Information System (GIS) datasets summarize the results of the workshop held in Florence, Arizona in 2010. At this workshop, stakeholders representing a broad range of organizations and interests identified and mapped the locations of important wildlife linkages across Pinal County. Participants included biologists, land managers, planners, and other professionals from federal, state, tribal, private, and non-governmental organizations. The workshop was supported by partnerships between the Arizona Game and Fish Department (AGFD) and the Arizona Wildlife Linkages Workgroup. This multi-agency, multi-disciplinary effort was undertaken to encourage biologists and non-biologists alike to incorporate information about wildlife linkages and strategies for their conservation into transportation corridor and project planning as well as other community projects including land-use decisions. The workshops provided a forum for stakeholders to learn more about wildlife connectivity, outline the general locations of wildlife linkages on large maps, and provide descriptive information about each linkage on datasheets. Participants also identified the locations of barriers such as highways and railroads that may interfere with wildlife movement. The hand-drawn linkages were then digitized with GIS software and refined following an additional opportunity for stakeholder review. The linkages were then further refined to eliminate redundancy for this report.

This report provides background information on the importance and benefits of conserving wildlife linkages for both people and wildlife in Pinal County and describes the methods used during stakeholder workshops and in developing the accompanying GIS products. It includes a series of maps generated from the digitized stakeholder data that depict the general locations of wildlife linkages and potential barriers to wildlife movement within Pinal County. The maps are followed by tables with descriptive information about the habitat areas each linkage connects, the species each linkage serves, and known threats and potential conservation opportunities associated with each linkage. *The information in this report reflects the views and expertise of workshop participants and likely does not represent an exhaustive mapping of all important wildlife linkages across Pinal County.* It should instead be considered an initial assessment of wildlife movement patterns to be supplemented in the future by further analysis and refinement that includes additional expert input, GIS-based linkage modeling, and research studies of wildlife movement patterns.

The maps and GIS data in this report illustrate approximate locations of wildlife movements on the landscape and should be regarded as the starting point for further consultation with AGFD and other wildlife and land management agencies, preferably during the early stages of project planning. While the impetus for this report originated from the community's interest in promoting environmentally-sensitive transportation projects, this report and associated GIS data provide a framework for professionals across a range of disciplines to identify and incorporate opportunities for maintaining and enhancing **wildlife connectivity** within project areas in Pinal County. *We hope this report stimulates detailed planning and collaborative on-the-ground actions for conserving wildlife linkages.*

BACKGROUND

The abundant sunshine and great natural beauty of Arizona draws large numbers of visitors and new residents each year. The state has grown rapidly in recent decades with its human population expected to double from almost 6½ million in 2010 to approximately 13 million by 2050 (Arizona Department of Administration 2006, U.S. Census Bureau 2011). Much of that growth will likely be concentrated throughout the "Sun Corridor" connecting Tucson, Phoenix, and areas of central Yavapai County, including Pinal County. From 1980 to 2006, 83% of Arizona's population growth occurred in Maricopa, Pinal, and Pima counties (Arizona Department of Transportation 2010a). Pinal County is currently home to a population of nearly 400,000 people, which is 109.1% more than in 2000, making it the third largest county in Arizona and the second fastest-growing county in the US during this period (U.S. Census Bureau 2011).

Pinal County is located in central Arizona and much of it is within the Arizona Upland Sonoran Desertscrub Subdivision and Lower Colorado River Valley Subdivision; to a lesser extent within the Semidesert Grassland, Interior Chaparral, Madrean Evergreen Woodland and Great Basin Conifer Woodland (Brown and Lowe 1982). The Nature Conservancy's Ecoregional Assessment (TNC 1995) included Pinal County in the Sonoran Desert and Apache Highlands Ecoregions and identified several conservation areas within the county. The Sonoran desert is the wettest of all North American deserts with a bimodal rainfall pattern, and when combined with the local basin and range physiography and close proximity to higher elevation biomes, it's not surprising that the Sonoran desert supports high biodiversity and is considered one of the Earth's most biologically-valuable, and most vulnerable, ecoregions on a global scale (Olson and Dinerstein 1998). Within Pinal County, a broad array of vegetation communities supports a high diversity of wildlife species--from that commonly occur to species of conservation concern and those listed as threatened or endangered under the federal Endangered Species Act.

In Arizona, surface waters and their extensive system of connected washes play an important role for wildlife—both by providing habitat, shelter, food, and water, and by facilitating movements on a daily or seasonal basis. Overall, the diversity of wildlife associated with Sonoran desert biotic communities and riparian habitats in Arizona are some of the highest in the United States (Hoffmeister 1986; Marshall et al. 2000). All of the surface waters in Pinal County are considered to be ephemeral—including those categorized as significant such as the Gila River, Santa Cruz River, San Pedro River, and Queen Creek (Pinal 2001). This is due to none of the streams exhibiting perennial flow. The Gila River flows west across the north central area of the county and is considered the north eastern boundary. The Gila River is ephemeral through the county and only flows in response to flooding or releasing of water from the dams. Queen Creek is a large tributary that flows into the Gila River and is also considered ephemeral. The Santa Cruz River flows north from Pima County and joins the Gila River near the north western corner of the county and flows only during significant flood events. The San Pedro River flows northwest throughout the eastern portion of the county into the Gila River exhibiting surface flows only during flooding but does contain subsurface flows that are considered perennial. There are two large groundwater sub basins in the county with 5 portions of other sub basins (*Figure 1*). In and of themselves, these rivers and washes provide crucial habitat and movement corridors for a large variety of desert wildlife including desert mule deer, javelina, bobcats,

mountain lion, as well as many small mammals, birds, reptiles, fish, and amphibians. Riparian habitats associated with these rivers and washes also support species such as the bald eagle and Yuma clapper rail that are designated as threatened, endangered, or otherwise sensitive.

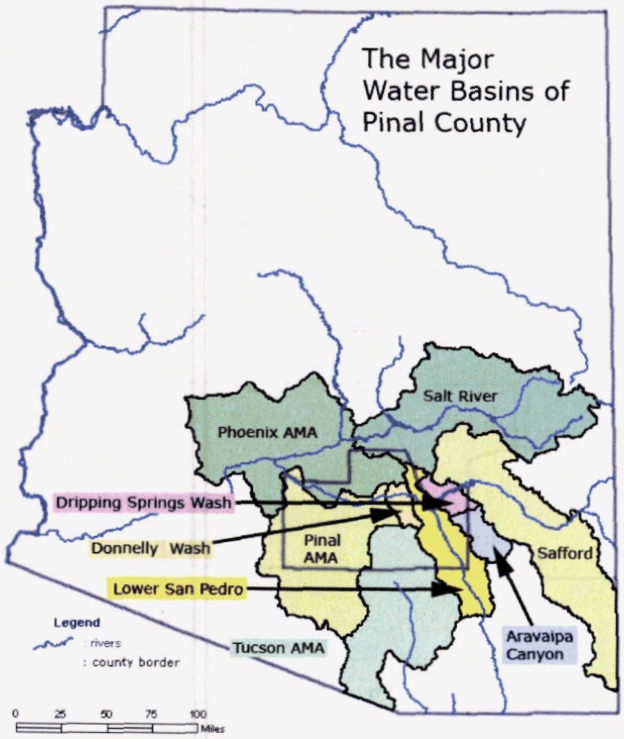


Figure 1: *ADWR check your water supply*

The combination of spectacular scenery and a comfortable climate in Pinal County create the conditions most desired for urban development. As a result, the characteristics of some of the region's most beautiful and ecologically productive landscapes are being dramatically altered by human development and infrastructure.

WHY WE NEED WILDLIFE LINKAGE PLANNING IN PINAL COUNTY

POPULATION GROWTH

Arizona's growing human population and expanding infrastructure has consequences for the wildlife species in Pinal County and for the habitats on which they depend. While human development and disturbance can adversely affect wildlife by causing direct loss or degradation of habitat, the disruption of wildlife movement patterns is a less obvious, but equally important, consequence. Most of the available lands in the county are either private (26%) or state trust (35%) lands with federal (18%) and reservation (20%) ownership making up the rest (Pinal 2007) (*Figure 2*). Areas of State Trust Lands reside under the state charter as the State Land Department has the responsibility on behalf of beneficiaries to assure the highest and best use of trust lands. Fair market value must be obtained under the federal act and state mandate, for all transactions that include sales and commercial leasing. These revenues benefit public education.

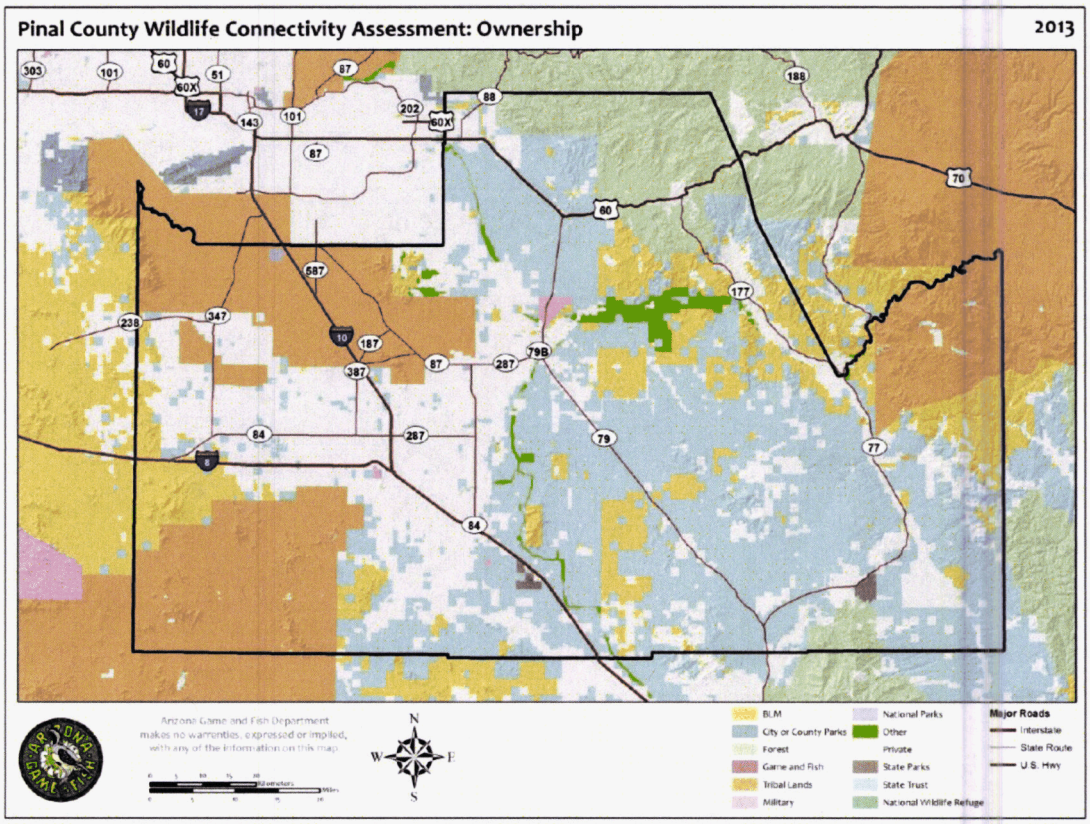


Figure 2 : *Land ownership in Pinal County*

An example where a vision has been adopted in the county through the Comprehensive Plan (2009, amended 2011 to include conceptual land use) as a long term build out, includes Superstition Vistas: 275 square miles between Apache Junction and Florence within undisturbed desert habitat. The planning area is equal to Gilbert, Mesa, Chandler and Tempe combined and would include a wide range of diverse development from very high to very low densities. This would also include activity centers of high intensity mixed uses (employment, shopping, medical, educational, etc.). Most of the developments being proposed and/or planned are between the Gila River community and the Tohono O' Odham and west of State Route 87. These are centered on the incorporated areas of Maricopa, Casa Grande, Eloy, Coolidge and Florence clustering near access to high capacity transportation corridors (existing and planned).

All animals move across the landscape to varying extents in order to acquire the resources necessary for survival: food, water, protective cover, and mates. Mountain lions, bighorn sheep, Arizona gray fox, coyote, javelina and mule deer roam over vast expanses that can encompass thousands of acres, while smaller animals such as the Sonoran desert tortoise, burrowing owl, and Tucson shovel-nosed snakes engage in essential movements in a much smaller area. There is also variation in the temporal patterns of animal movement: some animal movements occur on a daily basis, while seasonal migrations may occur annually, and the dispersal of young from their

natal sites to secure new breeding territories happens only once in an individual's lifetime. Man-made barriers have been shown to have an impact on wildlife movement patterns (*Figure 3*), some to the degree that their presence may affect the long-term persistence of wildlife populations (Noss 1983, Wilcox and Murphy 1985, Noss 1987, Bennett 1999, Henle et al. 2004, Noss and Daly 2006).

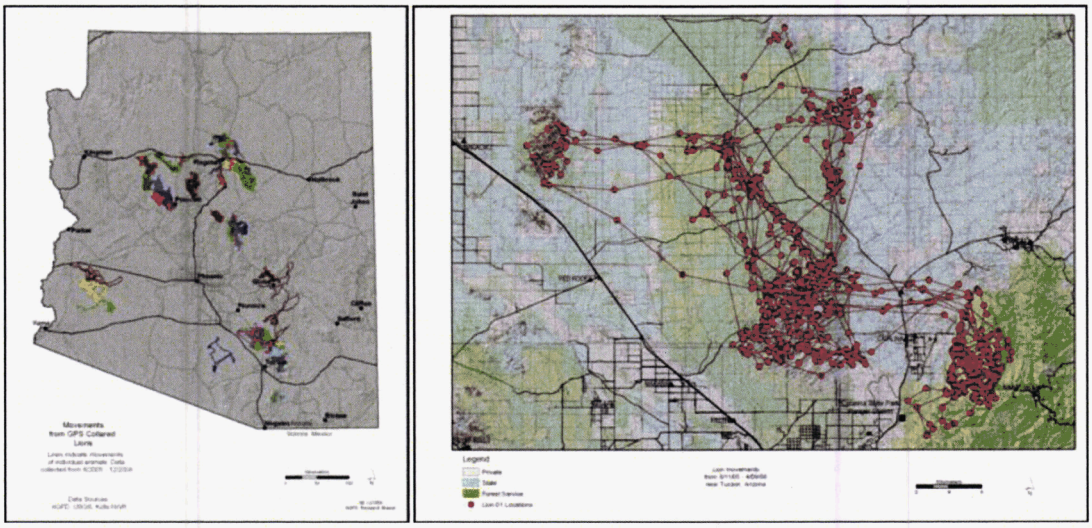


Figure 3a and b: a. *A series of satellite telemetry studies conducted by the Arizona Game and Fish Department, the United States Geological Survey, the United States Fish and Wildlife Service, and the University of Arizona shows that highways act as barriers to lion movements across Arizona. Each color track represents the movements of a different lion. This barrier effect can isolate populations, potentially reducing genetic diversity and reproductive success over time.* ***b:*** *This lion, collared in the Catalina Mountains north of Tucson, crossed State Routes 77 and 79 on multiple occasions and approached but did not cross Interstate-10. Movement data from this project was used in the design of the Tucson-Tortolita-Santa Catalina Mountains Linkage. Construction of crossing structures along SR 77 to accommodate this linkage is expected to begin in 2014.*

The following touches on other barriers that, in combination with urban development, have the potential to specifically interfere with wildlife movement and interrupt wildlife connectivity within Pinal County.

TRANSPORTATION INFRASTRUCTURE

County transportation plans have ramped up to improve existing transportation corridors and to construct other aspects of the transportation network that will support increased traffic and public transportation demand due to the anticipated population growth in Arizona. Many existing transportation corridors such as Interstate 10, AZ Loop 202 San Tan, US 60 and State Route 79 are being evaluated for improvements. Each new road built or existing road improved increases traffic volume, thereby increasing the potential for wildlife-vehicle collisions and other **habitat fragmentation** effects. However, as each new or existing road project goes through the planning process, the opportunity to accommodate the needs of wildlife also increase. Provided here are some examples of the planning processes currently underway within and around Pinal County. Additional details for many of the plans are available in Appendix I.

Many government officials and the public have recognized two related transportation system challenges in Pinal County: 1.) how to meet travel demand on major routes that cross the county,

and 2.) how to meet travel demand from growth within the county. Studies of population growth, travel volume demand, and road capacity are underway at a variety of scales to determine where road improvements or new road infrastructure construction should begin.

Cross-county travel demand has come from the growth of communities like Gilbert, Queen Creek, and San Tan, the expansion of the William's Gateway Airport, and the development of new communities such as Superstition Vistas. The Arizona Department of Transportation (ADOT) and US Department of Transportation's Federal Highways Administration (FHWA) have begun studies for potential new transportation routes such as the North-South Corridor study for travel between US 60 in Apache Junction and I-10 near Eloy (ADOT 2011), State Route 24 for travel between the loop 202 east to SR79 and the I-11& Intermountain West to Las Vegas. Another important component of this planning comes from the ADOT Passenger Rail Corridor Study, which is a study of a high capacity travel option and associated corridor between Tucson and Phoenix. While these new routes are mostly within nearby counties, they would inevitably increase traffic into and within Pinal County.

To address increased travel demand from within Pinal County, short range and long range regional transportation plans continue being developed that will guide the investment of regional transportation resources in local roadway, bus, pedestrian, bicycle, aviation, freight, and rail facilities to stimulate growth. The Pinal County Comprehensive Plan shows areas of high traffic flow (*Figure 4*), in terms of roads, railways, and aviation. Refer to Appendix I for list of various transportation studies, plans, projects within Pinal County (note this list is not exhaustive).

UTILITY INFRASTRUCTURE

The growing population in Arizona will also bring increased energy demands. The development of wind and solar energy facilities, utility corridors, and other energy-related infrastructure may be considerable over the next several decades. In 2012, the Bureau of Land Management and Department of Energy completed a new policy framework for utility-scale (>20 megawatt) solar energy development on BLM lands, which governs and guides the future of this rapidly growing form of energy development across millions of acres of land in the sun-rich state of Arizona. Concurrently, the Arizona BLM's Restoration Design Energy Project delineatedlow-conflict zones across multiple land ownerships where utility and sub-utility solar and wind development will be incentivized. A recently published review paper by the United States Geological Survey (Lovich and Ennen 2011) concluded, "...it appears that insufficient evidence is available to determine whether solar energy development, as it is envisioned for the desert Southwest, is compatible with wildlife conservation". While this study reveals a void of scientific studies quantifying the effects of this relatively new form of energy development on wildlife, some of the known primary impacts of this form of development (i.e. habitat conversion, fragmentation, and disturbance) have been studied extensively elsewhere and have been shown to affect habitat quantity, quality, and connectivity. The expansion of renewable energy development in the West would also spur new development and retrofit of energy transmission infrastructure.

species may require specific landscape features (i.e. ridgelines, stream corridors, etc.), vegetation composition and structure, crossing structure designs (i.e. specific length or "openness"), and certain thresholds of human disturbance/activity in order to be functional (*Figure 6*). Planning for effective wildlife crossings must also consider what is going to happen on those lands in the immediate proximity of the crossing, which may also influence priorities for rural and urban open space planning and acquisition. Allowing development to occur near crossing structures and placing structures in locations that do not provide suitable habitat for the target species generally affects their use by wildlife (Beier and Loe 1992).

BENEFITS TO PEOPLE

Maintaining an interconnected network of wildland blocks will provide benefits to the local human communities as well, perhaps most obviously by improving public safety. It has been estimated that approximately 20% of the land area in the United States is ecologically affected by the country's road network (Forman et al. 2003). The implications of this widespread impact include threats to connectivity and hazards to motorists (Forman and Alexander 1998). One study estimated that each year more than 200 motorists are killed and approximately 29,000 are injured as a result of deer-vehicle collisions in the United States (Conover 1995). Such collisions can cost $2 billion annually (Danielson and Hubbard 1998). Identifying important wildlife movement areas that traverse transportation corridors prior to the construction of new roads or road improvements allows for the informed siting of wildlife-friendly over- and underpasses that can greatly reduce the likelihood of collisions (Clevenger et al. 2001, Forman et al. 2003, Dodd et al 2007; *Figure 6*). Along Arizona State Route 260, for example, a combination of wildlife underpasses and ungulate-proof fencing reduced elk-vehicle collisions by 80% (Dodd et al. 2007; *Figure 6*). A study by Lowery and Blackman (2007) detected direct road kill or evidence of the presence of 55 unique species along Twin Peaks Road in Pima County.

As the optimal objective of providing wildlife linkages is to maintain the connectivity between wildland blocks, there are circumstances where it is important to accommodate a linkage that, either partially or in its entirety, crosses through urban and suburban environments where open spaces invite (intended or not) passive recreation activities. In such situations, the linkage may also serve as a buffer between developed areas and wildland blocks and can help protect the wildland network from potentially damaging external influences. Incorporating and designing rural and urban greenways and/or open spaces that support wildlife movement into municipal planning efforts also helps retain the natural vistas and aesthetic attributes that Arizona residents and visitors value. Since evidence suggests that some species are sensitive to the presence of humans (Clevenger and Waltho 2000, Taylor and Knight 2003), multi-use buffer zones should be made wide enough to maintain separation between human recreation activities and the needs of the wildlife species using the corridor.

Maintaining linkages that facilitate the ecological health of wildland blocks can also be a significant investment in contributing to the diversity and vitality of an area's economy and the American economy. The Outdoor Industry Association developed a report in 2012 on "The Outdoor Recreation Economy". The report recognized outdoor recreation as being critical to the economy through direct spending, manufacturing, finance, retail, tourism, travel and generates jobs. Also emphasized in the report, "Not only is access to quality places to play outside critical to our businesses, it is fundamental to recruiting employers and at the heart of healthy and

productive communities. Open spaces and recreation areas are magnets that draw after-work activity and tourists alike". The economic value associated with fish and wildlife-related recreation is significant for Pinal County and contributes greatly to Arizona's economy. A national survey of fishing, hunting, and wildlife-associated recreation has been conducted about every five years since 1955 to evaluate national trends. The survey provides information on the number of participants in fishing, hunting, and wildlife watching (observing, photographing, and feeding wildlife), and the amount of time and money spent on these activities. In the most recent survey, it was reported that in 2011, state resident and nonresidents spent $2.4 billion on fishing, hunting, and watchable wildlife related recreation in Arizona (U.S. Department of the Interior 2012). In 2001, a county-level analysis of the national survey data revealed that in Pinal County watchable wildlife activities generated a total economic effect of $96 million, supporting 950 jobs, providing residents with $27 million in salary and wages, and generating $2.9 million in state tax revenue (*Table 1*, Southwick Associates 2003). Fishing and hunting recreation generated a total economic effect of $22.9 million for the County, supporting 296 jobs, providing residents with $3.8 million in salary and wages and generating $933,000 in state tax revenue (Silberman 2003). These economic benefits illustrate that conserving our wildlife populations, through efforts such as maintaining or restoring habitat connectivity is also good for business in the County.

Pinal County	Economic Effect	Number of Jobs Supported	Amount in Salary and Wages	Amount in State Tax Revenue
Watchable Wildlife	$96,000,000	950	$27,000,000	$2,900,000
Fishing and Hunting	$22,900,000	296	$3,800,000	$933,000

***Table 1**: Economic benefits of fishing, hunting, and watchable wildlife activities by county. Summarized from Southwick Associates 2003 and Silberman 2003.*

Overview of Regional Planning Efforts That Acknowledge the Importance of Conserving Wildlife Linkages

There is a long-standing appreciation among local governments, land management agencies, transportation departments, conservation organizations, energy and utility companies, and citizens across Pinal County of the importance of conserving wildlife linkages and mitigating the impacts of barriers on wildlife movement. The Federal Highway Administration and the Arizona Department of Transportation (ADOT) recognize wildlife-vehicle collisions (WVCs) as a serious problem along major northern Arizona roadways, and have supported collaborative research with Department biologists to identify wildlife movement patterns and to design effective mitigation strategies (Dodd et al. 2007, Dodd et al. 2009, Dodd et al. 2010, Gagnon et al. 2010, Gagnon et al. 2011).

Planning efforts in other areas of Arizona have also begun to incorporate information on wildlife linkages. For example, Pima County's Conservation Lands System (Pima County 2001), an outgrowth of the widely-acclaimed Sonoran Desert Conservation Plan and adopted as policy in

the County's Comprehensive Plan, includes protection and restoration of wildlife linkages as a key objective in the evaluation of Plan amendments and all land uses requiring rezoning. The Town of Oro Valley incorporated the conservation of an important wildlife linkage in the Arroyo Grande planning area as an amendment to its General Plan (Town of Oro Valley 2008). Most recently, the City of Surprise incorporated the conservation of an important wildlife corridor as an amendment to the General Plan 2030, near the White Tank Mountains (City of Surprise 2011). The need to maintain habitat connectivity for wildlife will only grow as Arizona becomes more developed and populous in coming decades and the likelihood of habitat fragmentation increases. Given the relatively undeveloped status of the several regions in Pinal County at present, it is good timing to integrate knowledge of wildlife linkages and mitigation strategies into land use and transportation planning.

Open space planning efforts substantively began in Pinal County in 2005 with the data gathering and development of the *Pinal County Open Space and Trails Master Plan* (Plan) as the foundation of the Open Space and Recreation Element of the *Pinal County Comprehensive Plan* (amended 2007 to include the Plan), and it identifies 399,300 acres of existing or planned open space, 802,400 acres of proposed open space, 25,900 acres of restricted use open space, and 168,700 acres of regional parks (*Figure 7*). The Plan reflects the vision of county residents and identifies goals and objectives for the attainments of open space, trails, and regional parks. The Plan includes an implementation program offering a variety of techniques from regulatory, acquisition, influencing land management decisions to land acquisition funding techniques. To aid the implementation of the Pinal Open Space Plan (adopted 2007), a committee was appointed by the Pinal County Board of Supervisors as the Pinal Partnership Parks, Trails, Open Space and Public Lands Committee. This committee has interest in incorporating wildlife linkages into the planning and implementation efforts within the county.

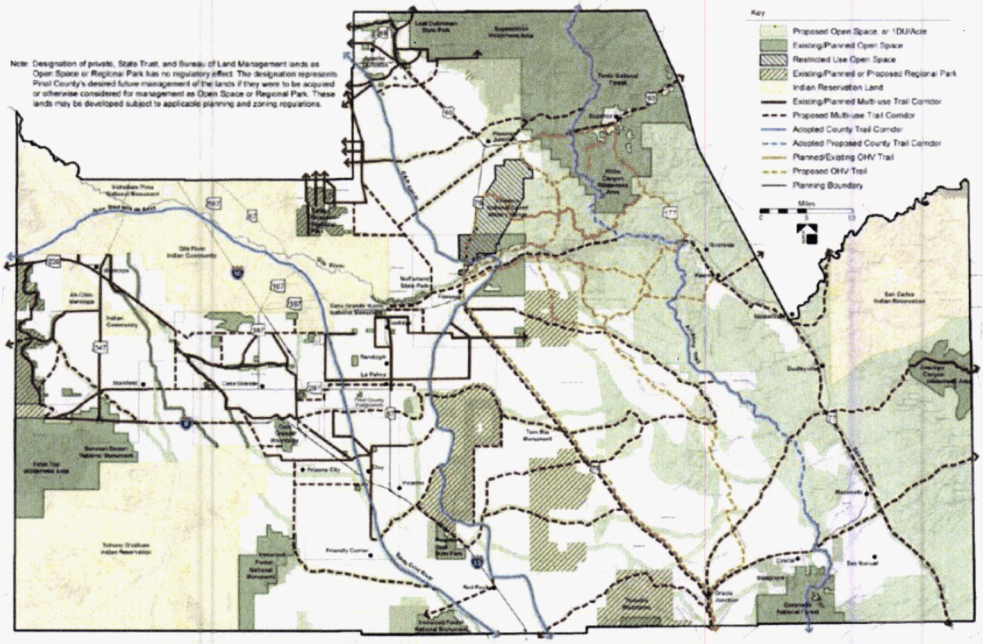


***Figure** 7: Pinal County Open Space and Trails Master Plan*

Page 18 of the PDF & Figures 8a & 8b

THE PINAL COUNTY WILDLIFE CONNECTIVITY ASSESSMENT

To assemble current knowledge of wildlife linkages and barriers to wildlife movement across Pinal County and to help build collaborative partnerships with local jurisdictions for eventual implementation efforts, AGFD joined with partner organizations (please see Acknowledgments for a list) to initiate the Pinal County Wildlife Connectivity Assessment. This project grew out of prior initiatives including the statewide Arizona Wildlife Linkages Workgroup (AWLW) known as Arizona's Wildlife Linkages Assessment, or AWLA. The AWLA used an expert-based approach to create a statewide map of potential linkage areas and barriers at a coarse scale (Arizona Wildlife Linkages Workgroup 2006; *Figure 8a*). This Pinal County Wildlife Connectivity Assessment represents a continuation of these previous efforts and is intended to identify wildlife linkages at a finer scale that may have been overlooked in the earlier assessment, as well as those that will be useful for regional and local transportation or land-use planning efforts.

a.

b.

***Figures 8a and b**: (a) Statewide map of wildlife linkages and barriers created for Arizona's Wildlife Linkages Assessment (2006). (b) Certain high priority linkage areas identified in the Arizona's Wildlife Linkages Assessment, such as the Ironwood-Picacho Linkage Design shown here were further refined as represented in the Arizona Missing Linkages and in detailed linkage modeling efforts by the Arizona Game and Fish Department. High priority wildlife linkages defined in this assessment will be modeled using similar methods on a per project basis*

Page 24 of the PDF & Figure 9

MAPS

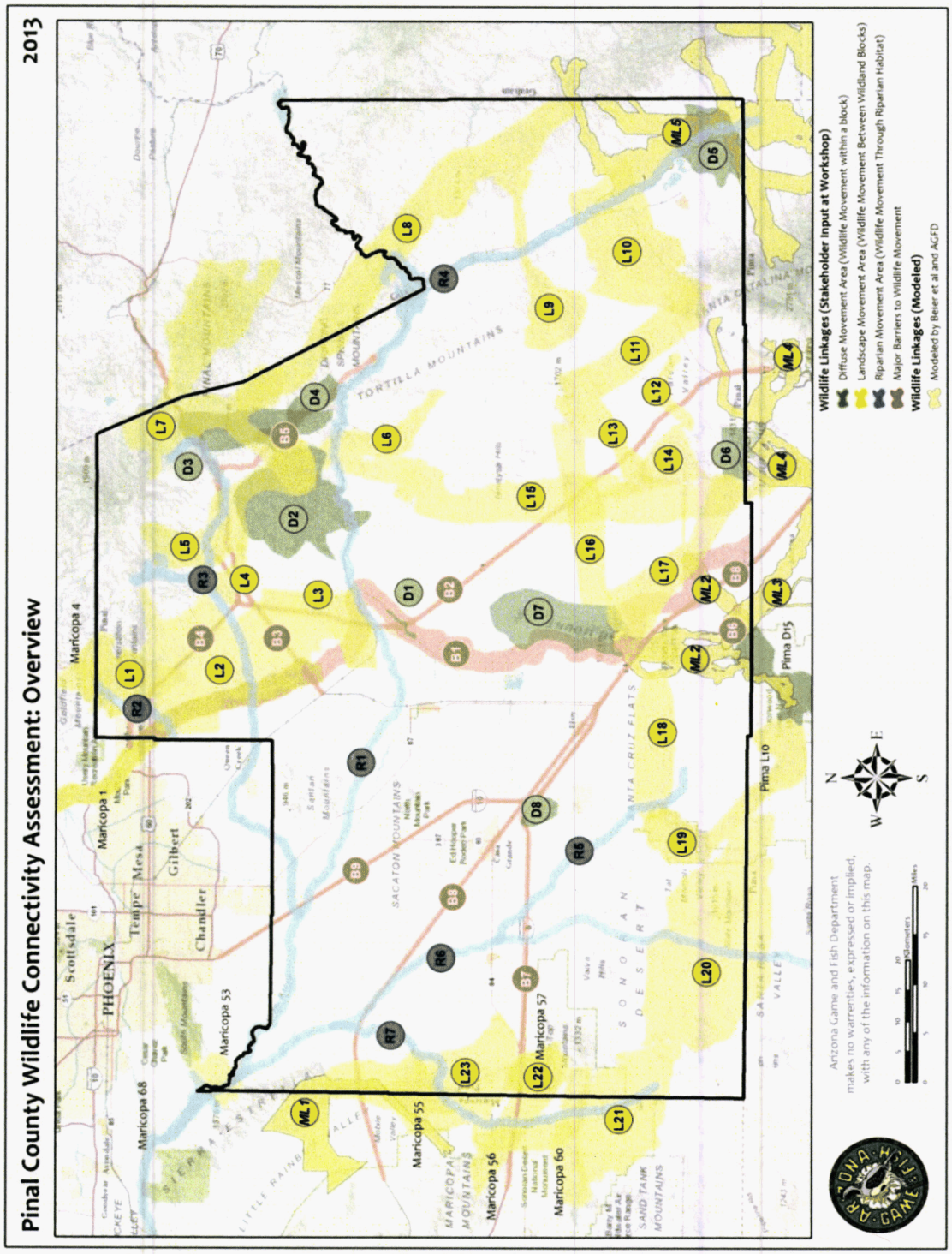


Figure 9: Pinal County stakeholder-identified linkages – County overview

Page 27 of the PDF & Figure 12

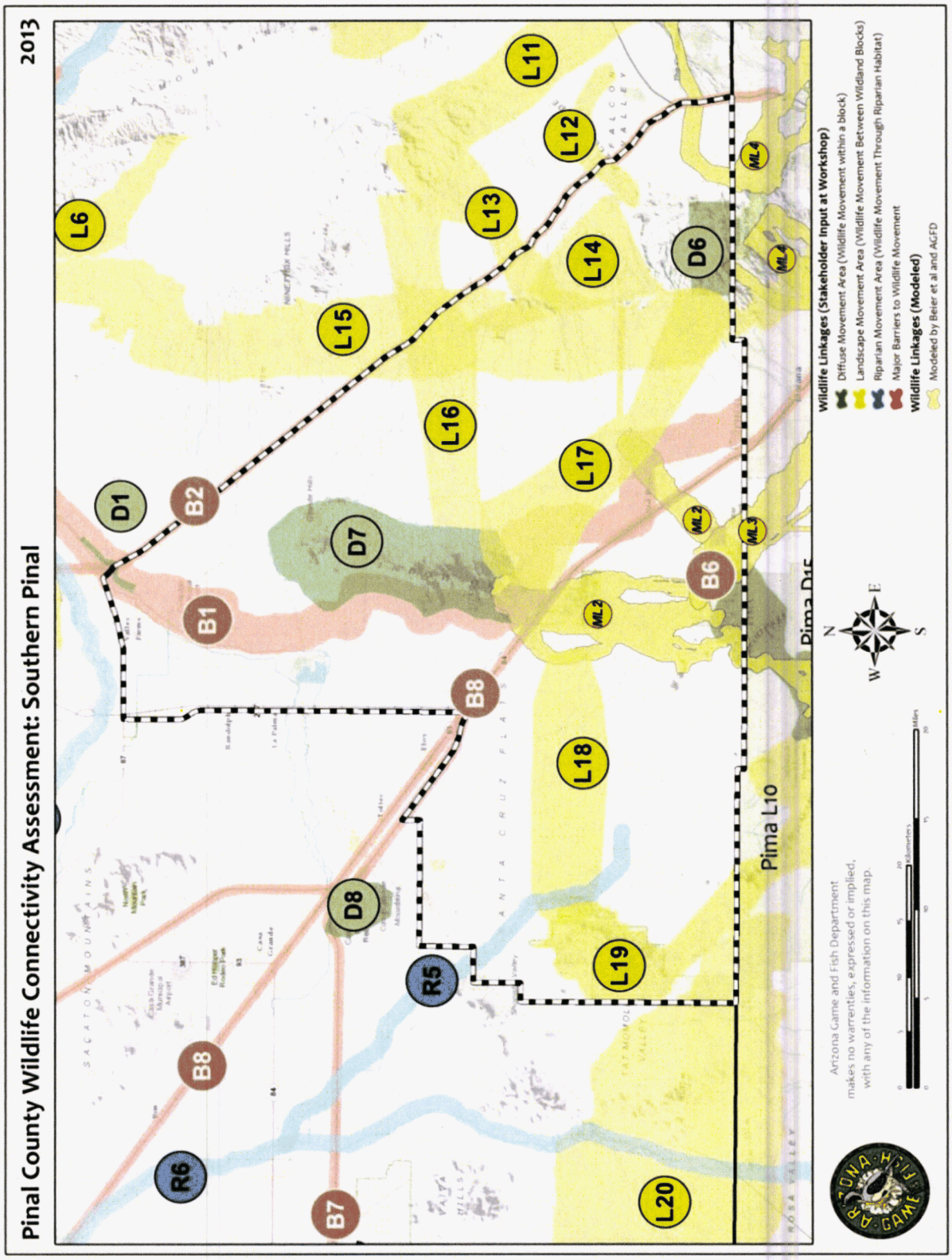


Figure 12: Pinal County stakeholder-identified linkages –Southern

Page 28 of the PDF & Figure 13

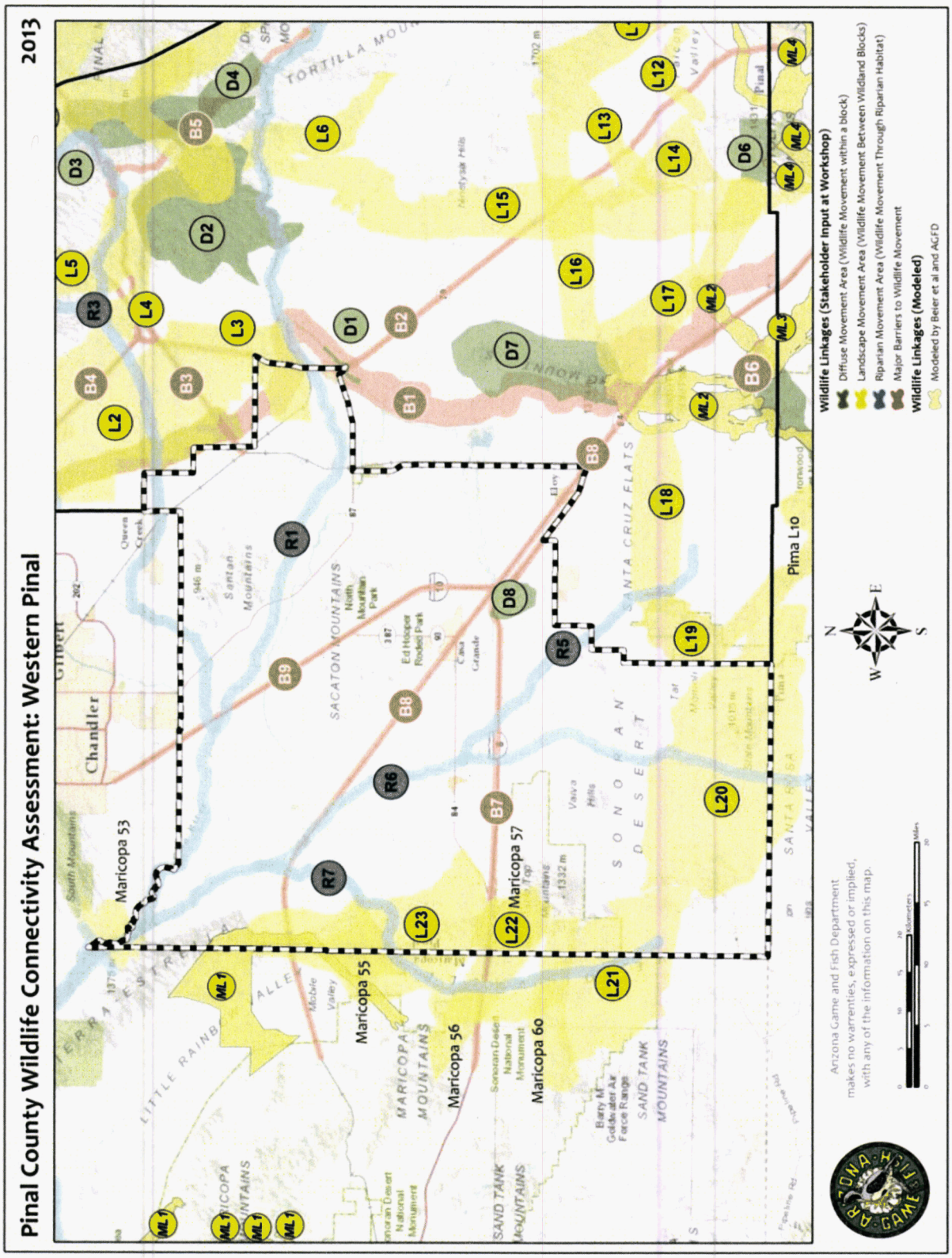


Figure 13: Pinal County stakeholder-identified linkages –Western

PINAL COUNTY WILDLIFE LINKAGE DESCRIPTIONS

PINAL COUNTY DIFFUSE MOVEMENT AREAS: D1-D8

(WILDLIFE MOVEMENT WITHIN A WILDLAND BLOCK)

D1. Southeast of Florence

Species Identified:	Coati, Coyote, Herpetofauna, Rabbit
Current Threats/Barriers:	• Canal • Roads: SR 79
Future Threats/Opportunities:	None identified at workshop
Notes:	Small animal movement along canal through agricultural and residential/commercial area of Florence

D2. Mineral Mountains

Species Identified:	Bighorn sheep, Desert tortoise, Mule deer, Tucson shovel-nosed snake
Current Threats/Barriers:	• Agriculture • Canal • Invasive species • Military activity • Mining • OHV activity • Pipeline • Powerline • Railroad • Roads: SR 79, SR 802, gravel and paved roads
Future Threats/Opportunities:	Widening of SR 79 and SR 802 and development of military reservation
Notes:	Includes movements as indicated by telemetry data for bighorn sheep

D3. Devil's Canyon

Species Identified:	Mexican spotted owl, Peregrine falcon
Current Threats/Barriers:	• Mining
Future Threats/Opportunities:	None identified at workshop
Notes:	

D4. Ray Copper Mine

Species Identified:	Gila monster, Herpetofauna
Current Threats/Barriers:	• Mining • Roads: Hwy 177, Ray Mine Rd
Future Threats/Opportunities:	None identified at workshop
Notes:	

D5. Valley Between Santa Catalina Mountains and Galiuro Mountains

Species Identified:	Black bear, Bobcat, Javelina, Mountain lion, Mule deer, White-tailed deer
Current Threats/Barriers:	• Mining • OHV activity • Residential development (high and low density) • Roads
Future Threats/Opportunities:	None identified at workshop
Notes:	Drainages and washes concentrate movement across mountain ranges

D6. Tortolita Mountains

Species Identified:	Desert tortoise, Javelina, Mountain lion, Mule deer
Current Threats/Barriers:	• OHV activity • Roads (Moore Road, Tangerine Road)
Future Threats/Opportunities:	Road widenings
Notes:	Conservation efforts underway via the Sonora Desert Conservation Plan (Tortolita – Carpenter Ranch, Tortolita Mountain Park)

D7. Picacho Mountains

Species Identified:	From Ironwood Missing Linkage Design (Badger, Bighorn sheep, Black-tailed jackrabbit, Black-tailed rattlesnake, Cactus ferruginous pygmy owl, Desert tortoise, Javelina, Mule deer, Sonoran desert toad, Sonoran whipsnake, Tucson shovel-nosed snake)
Current Threats/Barriers:	• Agriculture • Railroads • Roads (I-10, others)
Future Threats/Opportunities:	High and low density residential developments planned
Notes:	Includes water catchments around Newman Peak; adds habitat block of Picacho Mountains onto north end of Ironwood Missing Linkage Design (Beier et al., 2006b).

D8. Casa Grande Mountains

Species Identified:	None identified at workshop
Current Threats/Barriers:	• None identified at workshop
Future Threats/Opportunities:	Trails are planned for area
Notes:	May become isolated from nearby development

PINAL COUNTY DIFFUSE MOVEMENT AREAS: L1-L16
(WILDLIFE MOVEMENT BETWEEN WILDLAND BLOCKS)

L1. Superstition Mountains to Goldfield Mountains and Weekes Wash

Species Identified:	Coyote, Mule deer
Current Threats/Barriers:	• Roads: Hwy 88
Future Threats/Opportunities:	None identified at workshop
Notes:	N/A

L2. Valley north and east of the San Tan Mountains

Species Identified:	Desert tortoise, Mule deer
Current Threats/Barriers:	• Residential development (Superstition Vistas and Lost Dutchman Heights) • Roads: US 60, Hwy 79
Future Threats/Opportunities:	High and low density residential and commercial development planned
Notes:	Diffuse movement; more concentrated movement along washes

L3. Florence Military Reservation

Species Identified:	Desert tortoise, Tucson shovel-nosed snake
Current Threats/Barriers:	• Military activity • OHV activity • Residential development (low density) • Roads (Hwy 79)
Future Threats/Opportunities:	High density residential development in future, potential widening of Hwy 79
Notes:	

L4. Queen Valley – Middle Gila/Mineral Mountains

Species Identified:	Javelina, Mule deer
Current Threats/Barriers:	• Agriculture • Alternative energy development potential (wind and solar) • Canal • Invasive species • Mining • OHV activity • Pipeline • Powerline • Railroad • Residential development (low density) • Roads: US60, high traffic gravel road
Future Threats/Opportunities:	High and low density residential and commercial development planned in future
Notes:	

L5. Tonto Forest West of Superior through Gonzales Pass

Species Identified:	Bighorn sheep, Desert Tortoise, Hedgehog cactus, Javelina, Mule deer, White-tailed deer
Current Threats/Barriers:	• Agriculture • Mining • OHV activity • Railroad (north of US 60) • Residential development (low density) • Roads (US 60)
Future Threats/Opportunities:	High density residential development planned in future, Expansion of US 60
Notes:	North-south big game movement corridor

L6. Tortilla Mountains – Ripsey Wash – Donally Wash

Species Identified:	Desert tortoise
Current Threats/Barriers:	• Mining • OHV activity • Powerline • Roads (Hwy 79)
Future Threats/Opportunities:	None identified at workshop
Notes:	

L7. Canyon Passes between Superior and Globe

Species Identified:	None identified at workshop
Current Threats/Barriers:	• Mining • Roads (Hwy 60)
Future Threats/Opportunities:	None identified at workshop
Notes:	Major north/south movement corridor, especially along canyon passes

L8. El Capitan – Aravaipa Canyon

Species Identified:	Bighorn sheep
Current Threats/Barriers:	• Mining • OHV activity • Power lines
Future Threats/Opportunities:	Road proposed (I-10 bypass), potential Sunzia powerline route
Notes:	Bighorn sheep movement north/south

L9. Galiuro Mountains – Tortilla Mountains

Species Identified:	Coati, White-tailed deer
Current Threats/Barriers:	• Agriculture • Roads (Hwy 77)
Future Threats/Opportunities:	Potential Sunzia powerline route
Notes:	East-west movement through San Pedro corridor along Aravaipa Canyon – Putnam – Camp Grant Wash

L10. Galiuro Mountains – Santa Catalina Mountains

Species Identified:	Bighorn sheep, Black bear, Bobcat, Desert tortoise, Javelina, Mountain lion, Mule deer, White-tailed deer
Current Threats/Barriers:	• Mining • OHV activity • Powerline Residential development (High and low density) • Roads (Hwy 77, annexation of land along Hwy 77, high traffic gravel road)
Future Threats/Opportunities:	Future low and high density residential developments
Notes:	General east/west movement of large mammals and desert tortoise

L11. Black Mountain – Santa Catalina Mountains

Species Identified:	Mountain lion, Mule deer
Current Threats/Barriers:	• Residential development (High density) • Roads (Hwy 77, high traffic gravel road)
Future Threats/Opportunities:	None identified
Notes:	

L12. Santa Catalina Mountains – Tortolita Mountains (north)

Species Identified:	Mountain lion, Mule deer
Current Threats/Barriers:	• Roads (Hwy 77, Hwy 79)
Future Threats/Opportunities:	None identified
Notes:	Large mammal movement through Falcon Valley

L13. Durham Hills – Black Mountains

Species Identified:	Gila monster, Mountain lion, Mule deer
Current Threats/Barriers:	• Agriculture • Invasive species • Mining • OHV activity • Pipeline • Powerline • Residential development (high and low density) • Roads (SR 79)
Future Threats/Opportunities:	None identified at workshop
Notes:	Mountain lion telemetry movement and habitat

L14. Tortolita Mountains – Suizo Mountains – Durham Hills

Species Identified:	Cactus ferruginous pygmy owl, Desert tortoise, Mountain Lion, Mule deer
Current Threats/Barriers:	• OHV activity • Power line • Residential development (low density) • Roads
Future Threats/Opportunities:	High density residential development planned
Notes:	Mountain lion and cactus ferruginous pygmy owl telemetry movement data

L15. Tortolita Mountains – Tortilla Mountains

Species Identified:	Cactus ferruginous pygmy owl, other avian species
Current Threats/Barriers:	• Agriculture • Mining • Railroad • Residential development (high density) • Roads (Hwy 79)
Future Threats/Opportunities:	None identified
Notes:	Potential migratory route for cactus ferruginous pygmy owl and other species, primarily along elevation corridor or 2,400 feet and 2,800 feet with meso-vegetation

L16. Black Mountain – Picacho Mountains

Species Identified:	Bobcat, Cactus ferruginous pygmy owl, Coyote, Deer, Desert tortoise, Fox, Javelina, Mountain lion, Mule deer
Current Threats/Barriers:	• Invasive species • Landfill • Recreation • Residential development (low density) • Roads (SR 79)
Future Threats/Opportunities:	High and low density residential developments planned
Notes:	Mountain lion and large mammal movements

L17. Tortolita Mountains – Picacho Peak

Species Identified:	Desert tortoise, Mountain lion
Current Threats/Barriers:	• Recreational activity • Roads (High traffic gravel road, paved road)
Future Threats/Opportunities:	Residential development (low and high density) planned
Notes:	

L18/L19. Picacho Peak – Silver Bell Mountains – Sawtooth Mountains

Species Identified:	Bighorn sheep, California leaf-nosed bat, Cave myotis, Desert tortoise
Current Threats/Barriers:	• Agriculture • Mining • OHV activity • Residential development (low density) • Roads (high traffic gravel road)
Future Threats/Opportunities:	High density residential development planned
Notes:	Bat movement and roosting habitats; Continues through L19 which was also identified at Pima County Workshop (Pima L10)

L20. Ironwood National Monument – Vekol Mountains

Species Identified:	Bats
Current Threats/Barriers:	• None identified at workshop
Future Threats/Opportunities:	Potential high and low residential development planned
Notes:	

PINAL COUNTY RIPARIAN MOVEMENT AREAS: R1-R16
(WILDLIFE MOVEMENT THROUGH RIPARIAN HABITAT)

R1. Gila River

Species Identified:	Beaver, Bighorn sheep, Bobcat, Burrowing owl, Coyote, Gray fox, Javelina, Migratory birds, Mississippi kite, Mule deer, Muskrat, Osprey, Raccoon, Skunk, Southwest Willow Flycatcher, Various amphibians, Various reptiles, Various small mammals, Waterfowl, Yellow-billed cuckoo, Yuma clapper rail
Current Threats/Barriers:	• Agriculture • Canals • OHV activity • Urbanization
Future Threats/Opportunities:	Increased OHV activity, Proposed roads (Hwy 303, Hwy 801, I-10 Bypass, etc.)
Notes:	Continuation of as Maricopa County Report Linkage number 68, species and threats listed here were identified in the Maricopa County report and at the Pinal County Stakeholder Workshop; Cultural resource areas with proposed expansion of Casa Grande National Ruins

R2. Weekes Wash

Species Identified:	Coyote, Mule deer
Current Threats/Barriers:	• Residential development • Roads (Hwy 88)
Future Threats/Opportunities:	High density residential development planned
Notes:	Superstition Mountains to Goldfield Mountains

R3. Queen Creek – Gila River Indian Community

Species Identified:	Coyote, Hawk, Javelina, Mule deer
Current Threats/Barriers:	• Agriculture • Canal (CAP, Eastern canal) • Railroad (Union Pacific) • Recreation (golf courses) • Roads (Hwy 60, I-10) • Sand and gravel operations • Urbanization
Future Threats/Opportunities:	Expansion of existing roadways and future freeways planned
Notes:	Queen Creek from dam to Gila River Indian Communities; includes Queen Creek tributaries; Same as Maricopa County Report Linkage number 24; Species and threats listed here were identified in the Maricopa County report

R4. Gila River – San Pedro River

Species Identified:	Various aquatic species, Various avian species, Various riparian species
Current Threats/Barriers:	• Agriculture • Mining • OHV activity • Railroad • Residential (low and high density) • Roads (Hwy 177, various high traffic gravel roads)
Future Threats/Opportunities:	Proposed Sunzia powerline
Notes:	Connects to Pima County Linkage Report R19

R5. Greene Wash and Reservoir

Species Identified:	None identified at workshop
Current Threats/Barriers:	• Agriculture • Illegal trafficking • OHV activity • Residential development
Future Threats/Opportunities:	None identified at workshop
Notes:	Tribal lands; Critical water supply

R6. Gila River to Lake St. Claire

Species Identified:	Coyote, Mountain lion
Current Threats/Barriers:	• Agriculture • Illegal trafficking • OHV activity • Railroad (Union Pacific) • Roads (Maricopa-Casa Grande Hwy 238 with high traffic)
Future Threats/Opportunities:	Increase in OHV activity; Numerous high density residential developments planned
Notes:	Tribal lands

R7. Vekol Wash

Species Identified:	Arizona mud turtle, Badger, Bighorn sheep, Bobcat, Casque-headed toad, Couch's spadefoot toad, Desert iguana, Desert kangaroo rat, Desert tortoise, Gray fox, Great Plains Narrow-mouthed toad, Great Plains toad, Sonoran desert toad, Javelina, Kit fox, Mountain lion, Mule deer, Red-spotted toad, Sidewinder, Shovel-nosed snake, Sonoran green toad, Various small mammals
Current Threats/Barriers:	• Illegal trafficking • Residential development (low and high density) • Roads (I-8, Hwy 303, I-10, Hwy 238, Rainbow Valley Road)
Future Threats/Opportunities:	Proposed Sonoran Valley Parkway
Notes:	Same as Maricopa County Report Linkage number 70, species and threats listed here were identified in the Maricopa County report

ARIZONA MODELED WILDLIFE LINKAGES: ML1-ML5 (DETAILED/MODELED WILDLIFE LINKAGE DESIGNS)

ML1. Gila Bend –Sonoran Desert National Monument – Sierra Estrella Mountains (Beier et al. 2008)

See Missing Linkage report at http://corridordesign.org/dl/linkages/reports/GilaBendMtns-SonoranDesertNM-SierraEstrella_LinkageDesign.pdf for complete list of modeled species, current and future threats and barriers, and additional recommendations on providing connectivity between these wildland blocks. Note that this linkage design was modified after the publication of the report to avoid private land after careful evaluation of values on different linkage alternatives.

ML2. Ironwood – Picacho Mountains (Beier et al. 2006a)

See Missing Linkage report at http://corridordesign.org/dl/linkages/reports/Ironwood-Picacho_LinkageDesign.pdf for complete list of modeled species, current and future threats and barriers, and additional recommendations on providing connectivity between these wildland blocks.

ML3. Coyote – Ironwood – Tucson Mountains (AGFD 2012b)

See Detailed Linkage report at http://www.azgfd.gov/w_c/documents/CoyoteIronwoodTucson_LinkageDesign_lowres.pdf for complete list of modeled species, current and future threats and barriers, and additional recommendations on providing connectivity between these mountain ranges.

ML4. Tucson – Tortolita – Santa Catalina Mountains (Beier et al. 2006b)

See Missing Linkage report at http://corridordesign.org/dl/linkages/reports/Tucson-Tortolita-SantaCatalina_LinkageDesign.pdf for complete list of modeled species, current and future threats and barriers, and additional recommendations on providing connectivity between these wildland blocks.

ML5. Santa Catalina/Rincons – Galiuros Mountains (AGFD 2012c)

See Detailed Linkage report at http://www.azgfd.gov/w_c/documents/SantaCatalinaRinconGaliuro_LinkageDesign_lowres.pdf for complete list of modeled species, current and future threats and barriers, and additional recommendations on providing connectivity between these mountain ranges.

21

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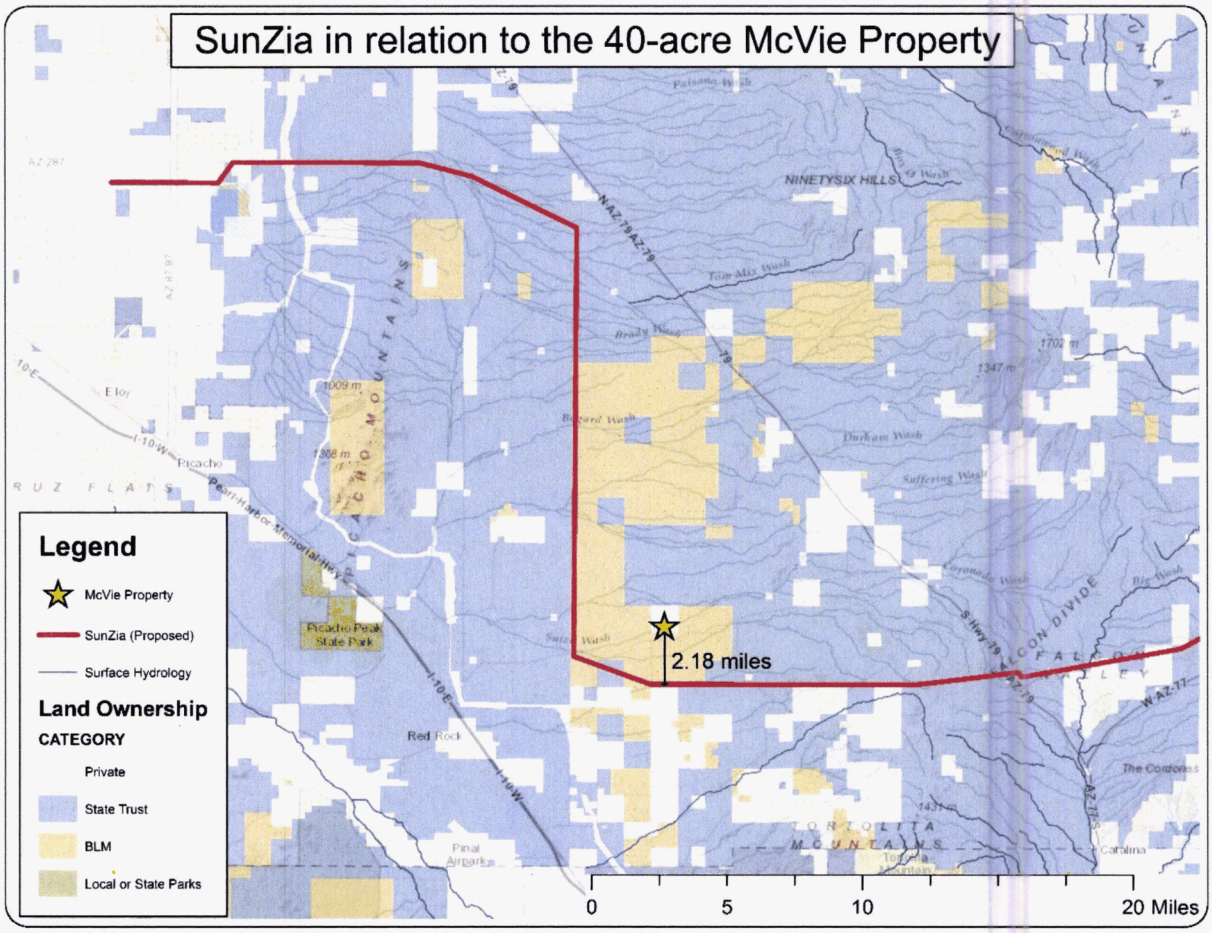
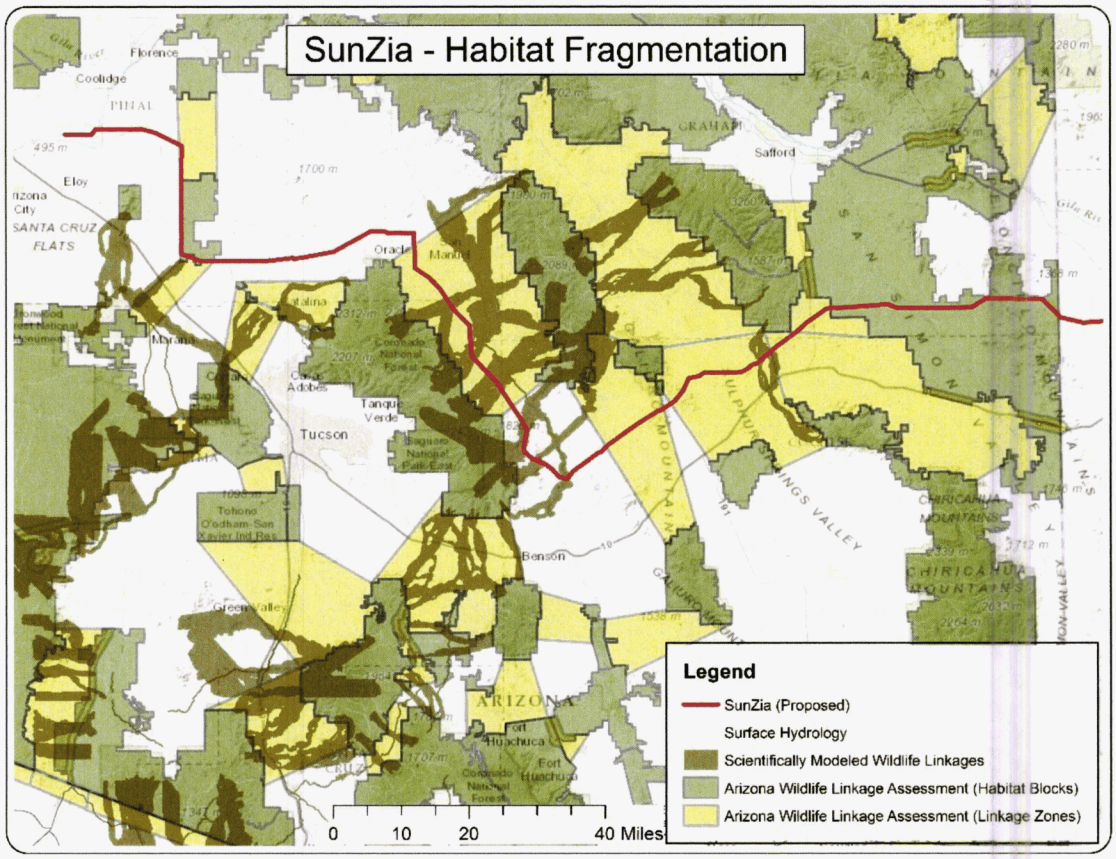


22

DOCKET NO. L-00000YY-15-0318-00171-MCV_22_Map of ~~McVie Property~~ Habitat Fragmentation



23

Arizona Wildlife Linkages Assessment Report, Arizona Department of Transportation Website:

http://www.azdot.gov/business/environmental-planning/programs/wildlife-linkages
(Accessed on 10/14/15)

From the webpage

"Biologists, engineers, planners and land managers from nine public agencies have worked together since 2004 to identify large blocks of protected habitat, the potential wildlife movement corridors through and between them, the factors that could possibly disrupt these linkage zones and opportunities for conservation.

Recognizing that habitat connectivity is a landscape issue involving multiple land jurisdictions, this workgroup has engaged in unprecedented cooperation and facilitated discussions and partnerships to help ensure a unified approach to wildlife linkage conservation and management.

This reinforces the commitment to and efficiency of wildlife connectivity measures undertaken by all stakeholders, using research and adaptive management in ongoing evaluations of those measures.

The assessment document (below) and map are the initial efforts to identify potential linkage zones that are important to Arizona's wildlife and natural ecosystems. This is only the first step in a continuing process of defining critical habitat connectivity areas.

This nonbinding document and map serve as an informational resource to planners and engineers, providing suggestions for the incorporation of these linkage zones into their management planning to address wildlife connectivity at an early stage of the process. If considerations for wildlife connectivity can be integrated into regional planning and projects early in the process, the linkage areas (or some portion of them) have the potential to be maintained or conserved during this time of growth and development."

Arizona's Wildlife Linkages Assessment Document

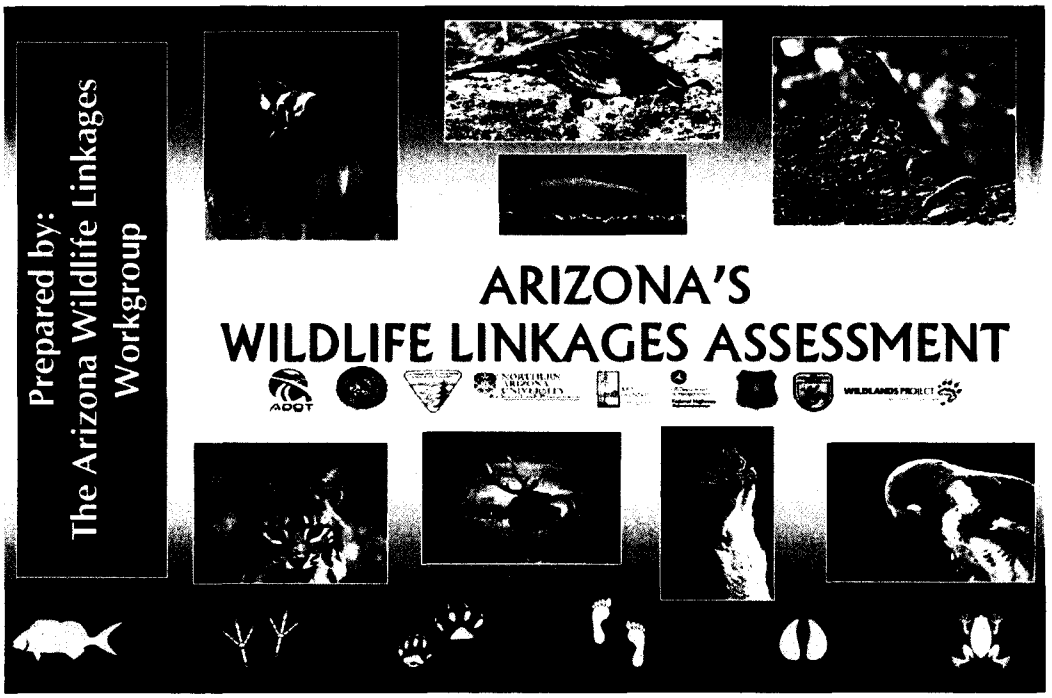
Due to the large file size of this study, it is divided up into the separate Adobe PDF segment.

- **Arizona Wildlife Linkages Assessment (15435 KB)**
- **Section I Introduction (970 KB)**
- **Section II Arizona Wildlife Linkages Workgroup (223 KB)**
- **Section III Arizona Missing Linkages Workshop (14086 KB)**
- **Section IV Arizona Wildlife Linkages Mapping (103 KB)**

- Section V Arizona Wildlife Linkages Prioritization (923 KB)
- Section VI Arizonas Wildlife Linkages (200975 KB)
    - Figure 6 1 Arizona Wildlife Linkages (10162 KB)
    - Figure 6 2 Arizona Wildlife Linkages Across Habitat Blocks (9819 KB)
    - Figure 6 3 Arizona Fracture Zones (9499 KB)
    - Figure 6 4 Arizona Biotic Communities (10879 KB)
    - Figure 6 5 Landownership (11387 KB)
    - Figure 6 6 Tribal Nations (10814 KB)
    - Figure 6 7 USDA Forest Service (10851 KB)
    - Figure 6 8 Department of Defense (10756 KB)
    - Figure 6 9 Arizona Highway System with County Boundaries (10720 KB)
    - Figure 6 10 ADOT Engineering Districts (10582 KB)
    - Figure 6 11 ADOT Maintenance Districts (10947 KB)
    - Figure 6 12 ADOT Natural Resources Management Group (10363 KB)
    - Figure 6 13 Arizona Game and Fish Department (10651 KB)
    - Figure 6 14 Bureau of Land Management Districts (10518 KB)
    - Figure 6 15 Bureau of Land Management Field Offices (10514 KB)
    - Figure 6 16 Congressional Districts, 10690 KB
    - Figure 6 17 Council of Governments, 10632 KB
    - Figure 6 18 Federal Highway Administration Engineering Districts, 10472 KB
    - Figure 6 19 Legislative Districts, 10670 KB
- Section VII Potential Linkage Zones (9367 KB)
- Section VIII Riparian Habitat Linkage Zones (81776 KB)
    - Figure 8 2 Riparian Habitat Linkage Zones (11310 KB)

- Figure 8 3 Perennial Waters (12027 KB)
- Figure 8 6 Surface Water Basins (10823 KB)
- Figure 8 7 Unique Waters (9898 KB)
- Figure 8 8 Wild and Scenic Rivers (10760 KB)
- Figure 8 9 Impaired Waters (10506 KB)

- Section IX Future Directions (526 KB)
- Section X Connectivity Related Projects (1368 KB)
- Section XI Contributor Connectivity Efforts (213 KB)
- Section XII Sources for Connectivity Resolution (1424 KB)
- Appendix A Linkage Data Sheet (446 KB)
- Appendix B Workshop Participants (246 KB)
- References (521 KB)"



Page 11 of the PDF

EXECUTIVE SUMMARY

The phenomenal growth of Arizona's human population, economy, and infrastructure present challenges to maintaining natural ecosystems and wildlife populations that constitute an important part of Arizona's wealth. In particular, roads, urbanization, canals, railways, energy corridors and activities of illegal migrants and border security operations not only destroy habitat, but create barriers that isolate wildlife populations and disrupt ecological functions such as gene flow, predator-prey interactions, and migration. Addressing each of these potential barriers one-at-a-time is expensive and inefficient. In each landscape, we must address all these factors concurrently to successfully maintain or restore linkages between habitats and conserve the wildlife and natural ecosystems that Arizona's residents and visitors rely on and benefit from.

Conspicuous evidence of habitat fragmentation is wildlife road kill - a far too common sight along many Arizona roadways. These often fatal encounters have far-reaching effects. Wildlife-vehicle collisions can result in human deaths and injuries, millions of dollars in property damage, loss of game and non-game animals, and sometimes expose the State to liability. Working together, federal, state, county and private stakeholders can minimize these social costs while enhancing opportunities for movement of wildlife between Arizona's habitat areas.

The Arizona Wildlife Linkages Workgroup (AWLW) has taken the first step in that process. The AWLW is a collaborative effort between public and private sector organizations formed to address habitat fragmentation through a comprehensive, systematic approach. Through this partnership and commitment, a statewide assessment was conducted to identify large blocks of protected habitat, the potential wildlife movement corridors between as well as through them, and the factors threatening to disrupt these linkage zones. After four successful workshops and many hours spent coordinating, meeting, mapping and writing, we present our initial findings, methodology and recommendations – a product that is intended to evolve and ultimately be used as a planning instrument.

The *Arizona's Missing Linkages Workshop* held in April 2004 and the *follow-up workshops that ensued are the basis for this report and* mapping tool. Attendance at the workshops was well represented with biologists, engineers, planners and land managers from state and federal agencies, universities, consulting firms and private sector conservation organizations. Individuals were divided into *groups to address specific geographic regions. They used map* transparencies and tailored questionnaires to assist in the identification of habitats, wildlife species, wildlife behavior and needs, *potential linkage zones* (see *Table 4-1*) as well as present and future threats or opportunities for conservation. One of the many products resulting from this process was a computerized geographic information system (GIS) projection graphically displaying the compiled information. There are over 150 potential linkage zones included in the Arizona's Wildlife Linkages Map.

The potential linkage zones represent areas that are important to Arizona's wildlife and natural ecosystems. If integrated into regional planning frameworks, these areas have the potential to be maintained or preserved during this time of prosperity, growth and development. As such, for each potential linkage zone, the AWLW built on information collected from the workshops to further define existing conditions, recording biotic communities, listing species that depend on particular linkages, identifying land ownership within those linkages, and detailing known and anticipated threats.

For further refinement, potential linkage zones were prioritized based on biological importance, threats - existing and anticipated - and opportunities for preservation and/or restoration purposes. Biological importance scores depended on the size and habitat quality of the *habitat blocks* (see *Table 4-1*) and on the ability of the potential linkage zones to support special status species, aquatic ecosystems, or seasonal migrations. Threat scores reflect the barrier effect of canals, roads, urbanization and railroads. Opportunity scores indicate ongoing and proposed conservation efforts in the areas, and whether impending major road projects provide an opportunity to increase the permeability of roads. As road construction programs are updated and development in the State progresses, this evaluation and resulting prioritization will need revision.

Our intention in this report is to provide a starting point for detailed consultation and coordination among the organizations and agencies that have a major role to play in maintaining habitat connectivity. To offer flexibility in the use of this report, all the maps within this document have been created at the same scale so that the transparency of the Arizona's Wildlife Linkages Map included in the front of this document may be used as an overlay. Furthermore, the *report was drafted in a manner to allow each individual chapter to be* used as a stand-alone tool. For that reason, terminology common throughout the entire document is defined in each section. All technical terms are also collectively defined in the glossary.

Important to taking the next step in preserving or restoring habitat connectivity is the physical design and construction of linkages. To help facilitate these applications, this report outlines the methodology used to create specific linkage designs within potential linkage zones. In the coming years, the AWLW intends to develop linkage designs for each potential linkage zone through a combination of GIS analysis and fieldwork. This analysis coupled with a feasibility study on linkage protection will further define the present potential linkage zones into smaller, more site-specific delineations and is intended to aid in conservation and planning efforts. Linkages ranking highest in our prioritization will be addressed first. Future assessments will identify additional potential linkage zones.

This report represents the results of the first statewide wildlife linkages assessment. We hope to elevate the current level of awareness of wildlife connectivity areas and issues in Arizona. The tools in this report will allow land managers to incorporate the identified wildlife linkage zones into their management planning processes to address habitat fragmentation due to highways and other human development. We expect to facilitate the integration of the potential linkage zones presented in this report and those identified in the future into early project planning efforts. We acknowledge that this is only the first step in a continuing process of defining critical habitat connectivity areas.

Now more than ever, decision makers have a responsibility to protect and maintain wildlife linkages to sustain Arizona's diverse wildlife species and wild landscapes. We firmly believe that government agencies and citizens working together with a comprehensive landscape-scale approach can achieve these conservation goals while accommodating the growth of Arizona's population, an expanding economy, and associated infrastructure.

- The Arizona Wildlife Linkages Workgroup

Page 13 of the PDF

TABLE OF CONTENTS

EXECUTIVE SUMMARY i
DISCLAIMER ii
TABLE OF CONTENTS iii
LIST OF FIGURES vii
LIST OF TABLES viii
LIST OF ACRONYMS ix
GLOSSARY x
ACKNOWLEDGEMENTS xi
SECTION I INTRODUCTION 1
The Challenge 1
Legal Environment 3
Providing Solutions 4
SECTION II ARIZONA'S WILDLIFE LINKAGES WORKGROUP 5
Forming Partnerships 5
AWLW Mission Statement 5
Primary Goals 5
Founding Individuals 6
SECTION III ARIZONA'S MISSING LINKAGES WORKSHOP 7
Breakout Sessions 7
Follow-up Workshops (November 2004) 9
Arizona's Missing Linkages Workshop Agenda (April 13 – 14, 2004) 10
SECTION IV ARIZONA'S WILDLIFE LINKAGES MAPPING 15
Layers 15
Mapping Generalities 16
Habitat Block Mapping Decision Rules 16
Potential Linkage Zone Mapping Decision Rules 16
SECTION V ARIZONA'S WILDLIFE LINKAGES PRIORITIZATION 17
Biological Value 17
Biological Value Weighting 19
Threat and Opportunity Value 19
Threat and Opportunity Value Weighting 20
Top Priority Linkages 20
SECTION VI ARIZONA'S WILDLIFE LINKAGES 21
Potential Linkage Zone Information 21
SECTION VII POTENTIAL LINKAGE ZONES 41
Linkage 1 Beaver Dam Slope – Virgin Sloce 41
Linkage 2 Beaver Dam – Virgin Mountains 41
Linkage 3 Cedar Rim/Fredonia Pronghorn Crossing 42
Linkage 4 Kaibab – Paunsaugunt Plateau 43
Linkage 5 Kaibab Plateau – North Rim 43
Linkage 6 Paria Plateau – Kaibab Plateau 44
Linkage 7 Skeleton Mesa – Black Mesa 44
Linkage 8 Chinle Valley – Chuska Mountains 45
Linkage 9 Chuska Mountains – New Mexico 45
Linkage 10 Mount Tipton – Mount Perkins 46
Linkage 11 Grand Canyon – Prescott National Forest 47
Linkage 12 Coconino Plateau – Kaibab National Forest 47
Linkage 13 South Rim Grand Canyon 48
Linkage 14 Valle – Bellemont 49
Linkage 15 Garland – Arizona Divide 49
Linkage 16 Flagstaff 50
Linkage 17 Deadman Mesa – Gray Mountain 51
Linkage 18 Black Mountains – Cerbat Mountains 51
Linkage 19 Mount Perkins – Warm Springs 52
Linkage 20 Hualapai Mountains – Cerbat Mountains 53
Linkage 21 I-40 and US 93 – Kingman 53
Linkage 22 Big Black Mesa – Nell Canyon 54
Linkage 23 Oak Creek Canyon – Munds Park 55
Linkage 24 Cottonwood – Sedona 56
Linkage 25 State Route 179 56
Linkage 26 Northern I-17 Corridor 57
Linkage 27 Mogollon Rim – Navajo Nation 58
Linkage 28 North – South Petrified Forest 59
Linkage 29 Warm Springs – Hualapai Mountains 60
Linkage 30 Warm Springs – Aubrey Peak 60
Linkage 31 The Needles – Mohave Mountains 61
Linkage 32 Bill Williams – Aubrey Hills 62
Linkage 33 Hualapai Mountains – Bagdad 62

Page 14 of the PDF

Linkage 34 Tres Alamos Wilderness – Prescott National Forest 63
Linkage 35 East – West Prescott National Forest 64
Linkage 36 Yeager Canyon – Camp Verde 65
Linkage 37 North – South Black Hills 66
Linkage 38 Bradshaw Mountains – Agua Fria National Monument 67
Linkage 39 SR 260 West from I-17 to SR 87 67
Linkage 40 East – West Mogollon Plateau 68
Linkage 41 SR 260 Payson – Heber 69
Linkage 42 Arizona – Cibecue 69
Linkage 43 Parker Valley – Cactus Plain 70
Linkage 44 Cactus Plain – Plomosa Mountains 71
Linkage 45 La Posa Plain 71
Linkage 46 Buckskin Mountains – Harcuvar Mountains 72
Linkage 47 Dome Rock Mountains 73
Linkage 48 Ranegras Plain 73
Linkage 49 Granite Wash – Little Harquahala Mountains 74
Linkage 50 Harcuvar Mountains – Harquahala Mountains 75
Linkage 51 Wickenburg 75
Linkage 52 Hassayampa River – Rez Picacho 76
Linkage 53 North – South Mazatzal Mountains 77
Linkage 54 Sierra Ancha – Superstition Mountains 78
Linkage 55 East – West Sierra Ancha SR 288 78
Linkage 56 Sevenmile – Sevenmile East US 60 79
Linkage 57 Faught Ridge – Baldy SR 73 80
Linkage 58 State Route 260 East 81
Linkage 59 Corrieo Crossing – Clifton US 191 81
Linkage 60 Black Hills – Tollgate Canyon 83
Linkage 61 Black Hills – Peloncillo Mountains 83
Linkage 62 State Route 75 83
Linkage 63 Trigo Mountains – Kofa Mountains 84
Linkage 64 Bighorn Belmont – Saddle Mountain 85
Linkage 65 White Tanks – Hassayampa River 85
Linkage 66 Superior – Miami US 60 86
Linkage 67 Gila River – El Capitan 87
Linkage 68 Saddle Mountain – Gila Bend Mountains 87
Linkage 69 Laguna Mountains – Muggins Mountains 88
Linkage 70 Arizona Service Highway (ASH) 89
Linkage 71 North – South Gila Mountains 89
Linkage 72 Sentinel Plain 90
Linkage 73 Gila Bend Mountains – North Maricopa Mountains 91
Linkage 74 North Maricopa Mountains – Sierra Estrella Mountains 92
Linkage 75 State Route 85 92
Linkage 76 South Maricopa Mountains – Sane Tanks 93
Linkage 77 Quijotoa Valley 94
Linkage 78 State Route 79 95
Linkage 79 Ironwood – Tortolita 95
Linkage 80 Saguaro – Tortolita 96
Linkage 81 Santa Catalina – Tortolita 97
Linkage 82 Santa Catalina – Galliuro 97
Linkage 83 Galliuro – Pinaleno 98
Linkage 84 Pinaleno – San Simon Valley 99
Linkage 85 Avra Valley 100
Linkage 86 Kitt Peak 100
Linkage 87 Tucson Mountains – San Xavier/San Robles Pass 101
Linkage 88 Galliuro – Winchester – Dragoon 102
Linkage 89 Wilcox Playa – Winchester – Pinaleno – Dos Cabezas 102
Linkage 90 Pinaleno – Dos Cabezas – San Simon Valley 103
Linkage 91 Baboquivari – San Luis Mountains 104
Linkage 92 San Xavier – Sierrita – Santa Rita 104
Linkage 93 Tumacacori – Santa Rita 105
Linkage 94 Rincons – Whetstone – Santa Rita 106
Linkage 95 Santa Rita – Empire Complex 106
Linkage 96 Patagonia – Santa Rita 107
Linkage 97 Whetstone – San Pedro River 108
Linkage 98 Las Cienegas – Huachuca 108
Linkage 99 Dragoon – San Pedro River 109
Linkage 100 Fort Huachuca – San Pedro River 110
Linkage 101 Chiricahuas– Peloncillos 110
Linkage 102 Western International Border 111
Linkage 103 Altar Valley – Mexico 112
Linkage 104 Tumacacori – Mexico 112
Linkage 105 Santa Cruz – Mexico 113
Linkage 106 Patagonia/Huachuca – Mexico 114
Linkage 107 San Pedro River – Mexico 114
Linkage 108 San Bernadino – Mexico 115
Linkage 109 Peloncillo – Mexico 116
Linkage 110 Beaver Dam Slope East – West 116
Linkage 111 Monave Mountains – Castaneda Hills 117
Linkage 112 Gibraltar Mountain – Cactus Plain 118
Linkage 113 Poachie Range – Black Mountains 118
Linkage 114 Harcuvar Mountains – Black Mountains 119
Linkage 115 Cunningham Pass 120
Linkage 116 North – South Plumosa Mountains 120
Linkage 117 South Trigo Peaks – Trigo Mountains 121
Linkage 118 Indian Well – Livingston Hills 122
Linkage 119 Livingston Hills – Kofa Mountains 122
Linkage 120 Eagletail Mountains – Clanton Hills – Little Horn Mountains 123
Linkage 121 Harquahala Mountains – Little Harquahala Mountains 124
Linkage 122 Harquahala Mountains – Belmont Mountains – Big Horn Mountains 124
Linkage 123 Mohave Peak – Chocolate Mountains 125
Linkage 124 Kofa Mountains – Castle Dome 126
Linkage 125 Tank Mountains – Palomas Mountains 126
Linkage 126 Bunyan Peak – Painted Rock Mountains 127

Page 15 of the PDF

Linkage 127 Margies Peak – Sheep Mountain 128
Linkage 128 North Maricopa – South Maricopa Mountains 128
Linkage 129 Southern Colorado River 129
Linkage 130 Chocolate Mountains – Trigo Mountains – Laguna Mountains 130
Linkage 131 Castle Dome Mountains – Red Bluff Mountains – Muggins Mountains 131
Linkage 132 Tinajas Altas Mountains – Cabeza Prieta Mountains 131
Linkage 133 Copper Mountains – Cabeza Prieta Mountains 132
Linkage 134 Cabeza Prieta Mountains – Tule Mountains 133
Linkage 135 Sierra Pinta – Cabeza Prieta Mountains 133
Linkage 136 Mohawk Mountains/Bryan Mountains – North Sierra Pinta 134
Linkage 137 South Sierra Pinta – Papago Well 135
Linkage 138 Northern Mohawk Mountains 135
Linkage 139 Mohawk Mountains – Bryan Mountains 136
Linkage 140 Bryan Mountains – Antelope Hills 137
Linkage 141 Granite Mountains – Mohawk Mountains/Bryan Mountains 137
Linkage 142 Granite Mountains – Antelope Hills 138
Linkage 143 Aguila Mountains – Granite Mountains 139
Linkage 144 Crowler Mountains – Granite Mountains 139
Linkage 145 Bates Mountains/Cipriano Hills – Agua Dulce Mountains/Quitobaquito Hills 140
Linkage 146 Childs Mountains – Crowler Mountains 141
Linkage 147 Crowler Mountains – Bates Mountains 141
Linkage 148 Round Butte – Javelina Mountain 142
Linkage 149 Sand Tank Mountains – Sauceda Mountains 143
Linkage 150 Little Table Top – Vekol Mountains 143
Linkage 151 Gila/Salt River Corridor Granite Reef Dam – Gillespie Dam 144
Linkage 152 Central Arizona Project Canal 145

SECTION VIII RIPARIAN HABITAT/LINKAGE ZONES 147
Arizona Riparian Areas 147
Arizona Hydrological Classifications 150
Unique Waters 152
Wild and Scenic Rivers 152
Impaired Waters 162
Potential Impacts 162
Overview of Spatial and Temporal Impacts of Road or Other Construction Projects 162
Phase Descriptions 164
Ecological Components Consideration 164
General Recommendations 165

Section IX FUTURE DIRECTIONS 167
Additional Potential Linkage Zone Identification 167
Linkage Designs 167
Interactive Linkage Map Tool 168
Integrated Planning and Interagency Coordination 169
Outreach 169

Section X CONNECTIVITY RELATED PROJECTS 171
Wildlife Research 171
Road Kill Database 174

SECTION XI CONTRIBUTOR'S CONNECTIVITY EFFORTS 175
Arizona Department of Transportation 175
Arizona Game and Fish Department 175
Bureau of Land Management 176
Comprehensive Wildlife Conservation Strategy 176
The Federal Highway Administration 176
The Nature Conservancy 177
Northern Arizona University 177
The Sky Island Alliance 177
USDA Forest Service 177
The Wildlands Project 178

SECTION XII SOURCES FOR CONNECTIVITY RESOLUTION 179
Acres for America 179
Arizona Game and Fish Commission Heritage Fund 179
Arizona Growing Smarter Grant Program 180
Arizona Wildlife Conservation Fund 181
Arizona Partners in Amphibian and Reptile Conservation 181
Arizona Water Protection Fund 181
Bring Back the Natives 181
Candidate Conservation Agreements with Assurances 182
Conservation Innovation Grants 182
Conservation Reserve Program 182
Conservation Banking 182
Conservation Security Program 183
Cooperative Endangered Species Conservation Fund 183
Doris Duke Charitable Foundation 184
Environmental Quality Incentives Program 184
Farm and Ranch Land Protection Program 184
FishAmerica Foundation 184
Fish and Wildlife Habitat Improvement Grants 185
Five-Star Restoration Matching Grants Program 185
Grassland Reserve Program 185
Healthy Forests Reserve Program 186
Land and Water Conservation Fund 186
Landowner Incentive Program 186
Leonardo DiCaprio Foundation 186
Local, Regional and State Parks Heritage Fund 187
More Fish Partnership Fund 187
Multistate Conservation Grants Program 187
National Fish Passage Program 188
National Fish and Wildlife Foundation General Matching Grants Program 188
National Fish and Wildlife Foundation in Partnership with the NRCS 188
National Scenic Byways Grants Program 189
Native Plant Conservation Initiative 189
Neotropical Migratory Bird Conservation Act Grants Program 189

Page 16 of the PDF

North American Wetlands Conservation Act Grants Program ---189
North American Bat Conservation Fund ---189
Partners for Fish and Wildlife Program ---189
Private Stewardship Grant ---190
Pulling Together Initiative ---190
Resource Conservation and Development Program ---190
Riparian Trust Fund ---190
Rockefeller Brothers Fund ---191
Safe Harbor Agreements ---191
State Comprehensive Wildlife Conservation Support Program ---191
State Lake Improvement Fund Grant Program ---192
Sustina Foundation ---192
Transportation Enhancement Grants ---192
Tribal Landowner Incentive Program ---192
Tribal Wildlife Grants ---192
United States Golf Association Wildlife Links ---192
Wetlands Reserve Program ---193
Wilburforce Foundation ---193
Wildlife Habitat Incentives Program ---193
Wildlife Action Opportunities Fund ---193
Wildlife Habitat Policy Research Program ---193
Excerpts from the Highway Transportation Bill SAFETEA-LU ---194

APPENDIX A LINKAGE DATA SHEET ---197

APPENDIX B WORKSHOP PARTICIPANTS ---199

REFERENCES ---203

Page 17 of the PDF

LIST OF FIGURES

Figure 3-1. Arizona's Ecoregions ---8
Figure 3-2. Workshop Resource Maps ---7
Figure 3-3. Flowchart of Project Development ---9
Figure 3-4. Priority Conservation Areas Identified by The Nature Conservancy through Ecoregional Assessments ---12
Figure 4-1. Diagram of Refinement Progression ---16
Figure 5-1. Prioritization Graph ---17
Figure 5-2. Upper Right Quadrant of Prioritization ---20
Figure 6-1. Arizona's Wildlife Linkages ---22
Figure 6-2. Arizona's Wildlife Linkages Across Habitat Blocks ---23
Figure 6-3. Fracture Zones ---24
Figure 6-4. Arizona's Biotic Communities ---25
Figure 6-5. Landownership ---26
Figure 6-6. Tribal Nations ---27
Figure 6-7. USDA Forest Service ---28
Figure 6-8. Department of Defense ---29
Figure 6-9. Arizona Highway System ---30
Figure 6-10. ADOT Engineering Districts ---31
Figure 6-11. ADOT Maintenance Boundaries ---32
Figure 6-12. ADOT Natural Resources Management Section ---33
Figure 6-13. Arizona Game and Fish Department Regions ---34
Figure 6-14. Bureau of Land Management Districts ---35
Figure 6-15. Bureau of Land Management Field Offices ---36
Figure 6-16. Congressional Districts ---37
Figure 6-17. Council of Governments ---38
Figure 6-18. Federal Highway Administration Engineering Districts ---39
Figure 6-19. Legislative Districts ---40
Figure 8-1. Classification of Rivers and Streams ---147
Figure 8-2. Riparian Habitat/Linkage Zones ---148
Figure 8-3. Perennial Rivers, Stream and Selected Washes ---149
Figure 8-4. Major Pathways of Exchanges of Materials, Energy and Organisms in the Longitudinal, Lateral and Vertical Dimensions of a Riverine System (From Ward and Wiens 2001 and Wiens 2002) ---147
Figure 8-5. Hierarchical Classification of Stream Habitats (Wiens 2002) ---150
Figure 8-6. Arizona Department of Water Resources Surface Water Basins ---151
Figure 8-7. Unique Waters ---153
Figure 8-8. Wild and Scenic Rivers ---154
Figure 8-10. Impaired Waters ---163
Figure 8-11. Temporal and Spatial Extent of Ecological Impacts on Riparian Areas Due to Three Phases of Road Development (Angermeier et al. 2004) ---163

Page 18 of the PDF

LIST OF TABLES

Table 4-1. Important Terms ---- 16
Table 5-1. HB1 Size of Habitat Blocks ---- 17
Table 5-2. HB2 Habitat Quality of the Smaller Block ---- 18
Table 5-3. HB3 Presence of Linkage Dependent Species ---- 18
Table 5-4. L1 Facilitates Seasonal Migration ---- 18
Table 5-5. L2 Riparian Area ---- 18
Table 5-6. L3 Conservation Ownership ---- 18
Table 5-7. L4 Special Status Species WITHIN the Linkage Zone ---- 19
Table 5-8. L5 Other Linkages Depend on This One ---- 19
Table 5-9. Weighting for Biological Values ---- 19
Table 5-10. T1 – T5 Development Threats ---- 19
Table 5-11. O1 Linkage to Other State or Mexico ---- 19
Table 5-12. O2A ADOT 5-Year Plan ---- 19
Table 5-13. O2B ADOT Long Range (20-Year) Plan ---- 19
Table 5-14. O3 Active Conservation Efforts ---- 20
Table 5-15. Weighting for Threats and Opportunities ---- 20
Table 8-1. Arizona's Designated Unique Waters ---- 152
Table 8-2. Arizona Waters Potential Candidates for Wild and Scenic Designations ---- 155

Page 11 of the PDF Excerpt

This report represents the results of the first statewide wildlife linkages assessment. We hope to elevate the current level of awareness of wildlife connectivity areas and issues in Arizona. The tools in this report will allow land managers to incorporate the identified wildlife linkage zones into their management planning processes to address habitat fragmentation due to highways and other human development. We expect to facilitate the integration of the potential linkage zones presented in this report and those identified in the future into early project planning efforts. We acknowledge that this is only the first step in a continuing process of defining critical habitat connectivity areas.

Now more than ever, decision makers have a responsibility to protect and maintain wildlife linkages to sustain Arizona's diverse wildlife species and wild landscapes. We firmly believe that government agencies and citizens working together with a comprehensive, landscape-scale approach can achieve these conservation goals while accommodating the growth of Arizona's population, an expanding economy, and associated infrastructure.

- The Arizona Wildlife Linkages Workgroup

SECTION 1 AWLA Introduction

SECTION 1 INTRODUCTION

Why do people come to Arizona? Hiking in the desert? Birding in the southeast riparian galleries? The majesty of the Grand Canyon? The modern wonder of Hoover Dam? Is it the skiing in the high mountains? Rafting the Colorado River? Sunshine in all of those places?

Scenic vistas and wide, open spaces are a part of Arizona's allure.

The varied landscapes and climates that draw people from all over the world to Arizona are also responsible for the tremendous abundance of plant and animal diversity in this state. Ranking third in the nation for overall biodiversity, Arizona has 4,759 plant, invertebrate and vertebrate species of which 135 are endemic to this state (NatureServe 2002). All species that reside in and migrate through the state have habitat needs that include the basics for survival; food, shelter and water. Arizona supports nearly 900 vertebrate wildlife species in habitats of low oeserts to alpine biotic communities ranging in elevation from only 70 feet to more than 12,500-feet above sea level (Swartz 2005). These spectacular wildlife resources help fuel our state's economy through tourism, hunting and fishing, as well as enhancing the quality of our own lives.

To protect the safe movement of people and plan for a future that includes wildlife, a blueprint is needed for Arizona's remaining wildlife habitats promoting the conservation or restoration of linkages in areas important for wildlife movement. This report is a preliminary statewide linkage assessment identifying important wildlife habitat connectivity areas, or linkage zones, as well as the associated threats. It is anticipated that this document will serve as a planning tool for all types and levels of planning including development, transportation, wildlife management and conservation.

To ensure the survival and persistence of Arizona's wildlife, minimization of further fragmentation is required. Maintaining landscape connectivity can lessen the detrimental consequences caused by the built environment. The effects of economic growth do not have to be mutually exclusive from the preservation of our state's ecological resources. A comprehensive approach is needed to efficiently, effectively protect and maintain Arizona's natural areas. Cooperation of all those involved (federal, state and county agencies, special interest groups and private landowners) must be facilitated with early involvement.

The Challenge

As Arizona seeks economic growth, there is a pressing need to protect and enhance the environment. The Arizona Department of Economic Security projects that the state's population will increase by 54% from 4.7 million in 1998 to 7.4 million in 2020. The sixth largest state in land area, Arizona is rapidly losing its status as a state of wide-open spaces and low human impact. The unique natural areas that attract these new residents as well as visitors are being impacted and diminished at an unprecedented pace.

The most significant threats to Arizona's wildlife populations are habitat alteration, fragmentation, and loss. Some of the leading causes of these threats are development, transportation corridors and land conversion. Worldwide, 85% of endangered species are imperiled by habitat fragmentation (Shaffer et al. 2000).

On a local level, remnant populations of pronghorn antelope, bighorn sheep, desert tortoise, badger, and other species will be lost if habitat fragmentation continues unchecked. As connectivity between key habitat elements is lost, isolation deprives species of their daily, seasonal and lifetime needs. Loss of connectivity deprives animals of resources, prevents some animals from finding mates, reduces gene flow, prevents animals from re-colonizing areas where extirpations have occurred, and ultimately prevents animals from contributing to ecosystem functions such as pollination, seed dispersal, control of prey numbers, and resistance to invasive species. Maintaining biodiversity and ecosystem functions requires habitat connectivity (CERI 2001).

As a leading threat to habitat connectivity, transportation corridors cut through many large tracts of wildlife habitat, destroying and fragmenting their integrity. Upgrading the state's rural highways to support rapid growth and increased traffic creates new challenges. As two-lane roads are expanded to four-lane divided highways, heavily used wildlife corridors are further fragmented and highways become a serious impediment to wildlife movement. In some cases, wildlife alter their behavior to use culverts and bridge underpasses to reach portions of their habitats. For those species that cover smaller home ranges, including reptiles, access to previously utilized habitat is destroyed or cut off in perpetuity. These corridors can become either impassable to wildlife, or passable only at great risk to the traveling public and the wildlife crossing the highway.

Arizona's expanding human population requires land and infrastructure. Sprawl consumes substantial amounts of acreage leading to further fragmentation and elimination of habitat. Roads can provide access to previously undisturbed areas, making these regions more vulnerable to commercial and residential development.

SECTION 1 AWLA Introduction Page 1 of the PDF Excerpt

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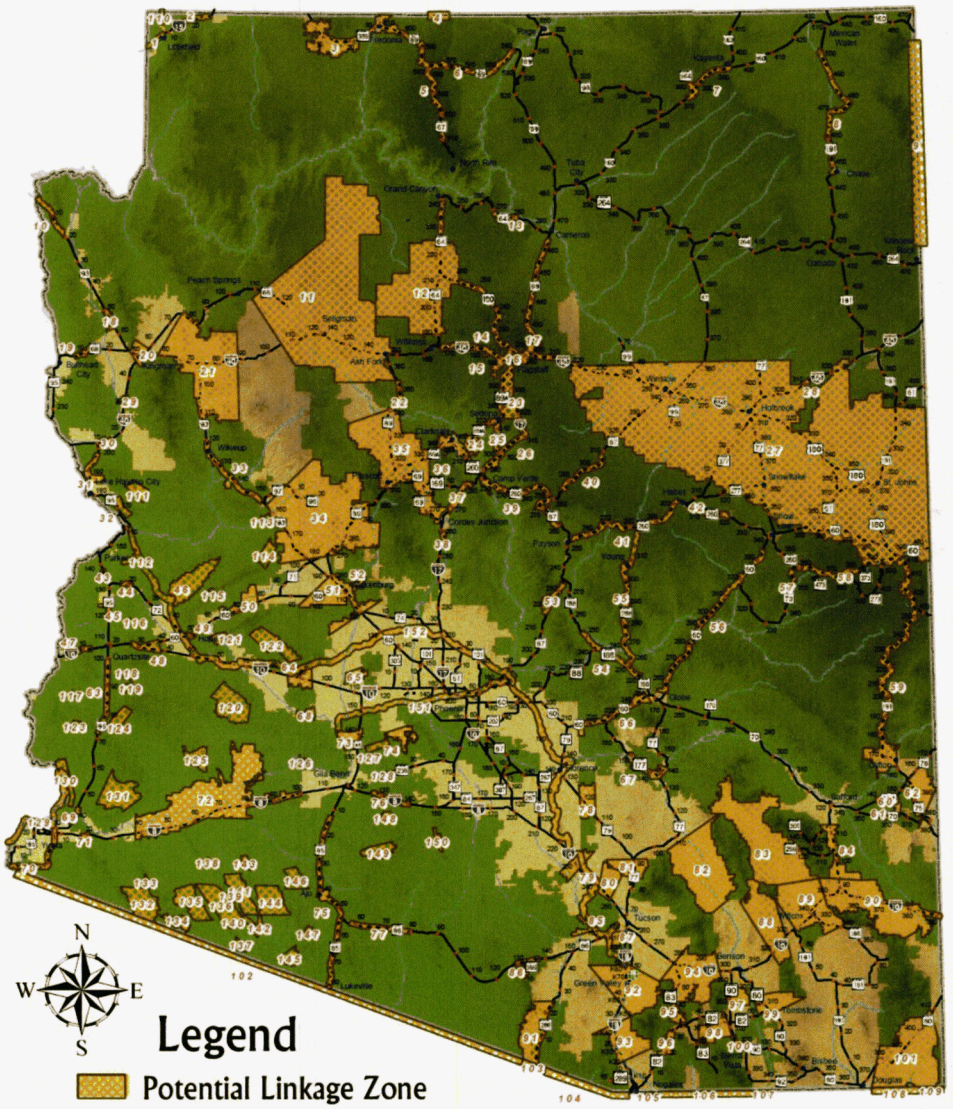
Page 2 of the AWLA Introduction PDF Excerpt

(Cerulean 2002). Likewise, urban expansion demands the ancillary structures of transmission lines, roads, canals and reservoirs. Along the international border, security measures pose additional barriers. Off road vehicle travel and the creation of wildcat roads also impact wildlife and habitat.

It is becoming increasingly obvious that manmade barriers such as highways and urban development are causing huge ecological problems with their concomitant costs. Increased pollution from roadsides into watersheds is an indirect result of proliferating roadways. The introduction and spread of non-native and invasive species is another associated concern. Disturbance and noise related to barriers including highways, border security and urbanization cause some species to abandon areas. And, of course, there is the direct mortality of wildlife on roadways, the size of which is unknown in aggregate, but estimated to be in the billions of vertebrates annually. Wildlife-vehicle collisions are a serious human safety concern. Nationally, it is estimated that over 200 human fatalities and nearly 30,000 injuries occur annually from these accidents with more than one billion dollars in related property damage (Meyer 2004).

Figure 6.1

ARIZONA'S WILDLIFE LINKAGES



Note: Linkage numbers are for identification purposes only. These numbers do not imply priority status.

Each proposed Potential Linkage Zone polygon depicts a planning area of which only a small fraction of this polygon could be included in a wildlife linkage, if deemed appropriate through future studies. Private landowners within identified wildlife linkages are encouraged to participate in voluntary federal and state programs that pay land owners for conservation of their lands, voluntary sale or donations of conservation easements, voluntary changes in management to protect ecological property values, or voluntary sale or donation of lands to conservation buyers. State and Federal agencies are encouraged to coordinate with private landowners during the planning process of linkage projects and to inform them of voluntary habitat protection opportunities.

This map is part of a dynamic process and should not be considered the definitive revision. To suggest additional Potential Linkage Zones or to provide comments for future editions of this map, please contact arizonalinkage@azdot.gov.

Siobhan Nordhaugen

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Enlargement Wildlife Linkages

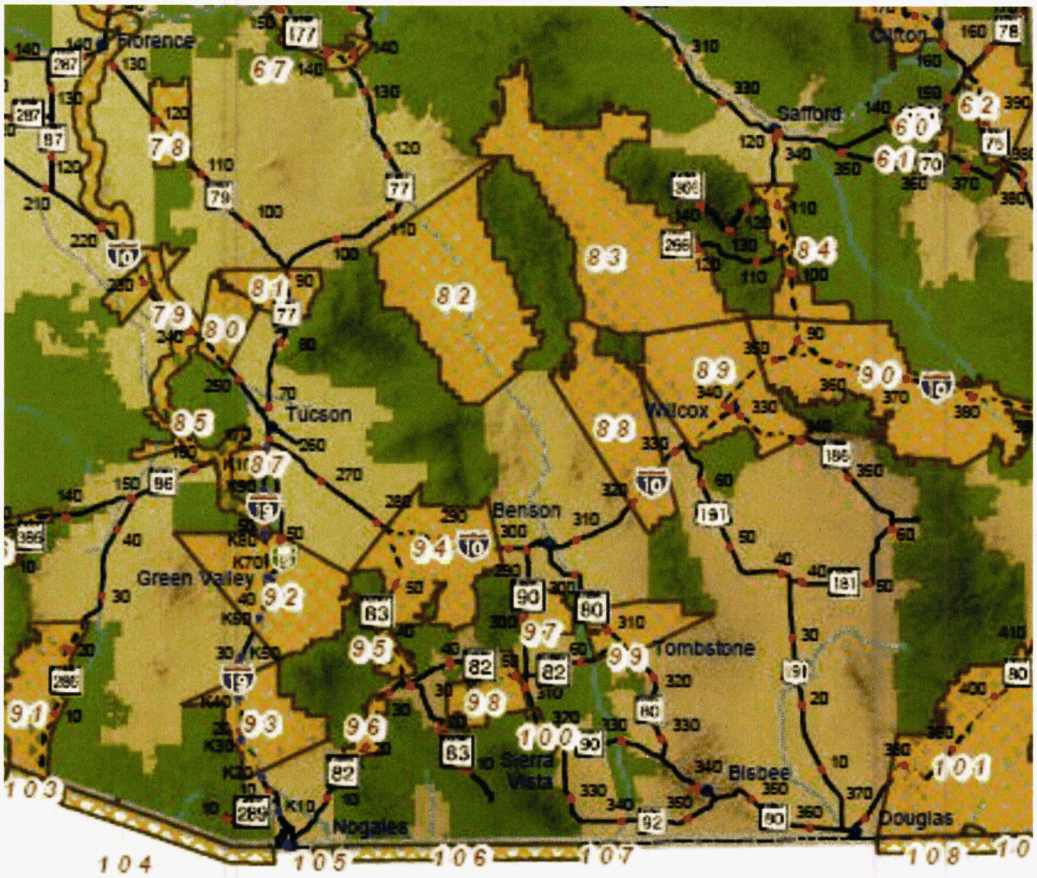
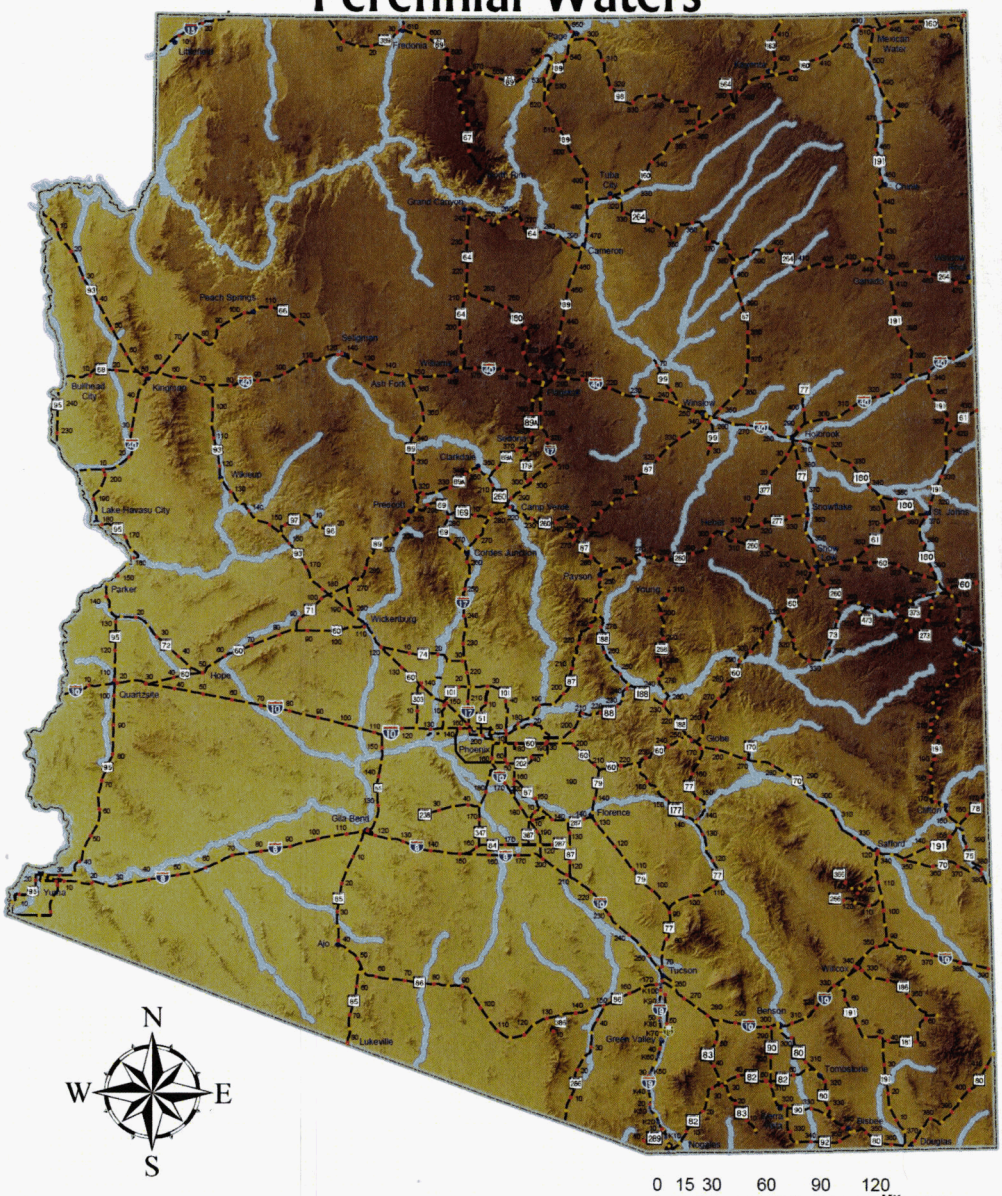


Figure 8.2

RIPARIAN HABITAT/LINKAGE ZONES

Perennial Waters



0 15 30 60 90 120 Kilometers

0 12.5 25 50 75 100 Miles

Legend

Riparian Habitat/Linkage Zone

Figure 8-2. Riparian Habitat/Linkage Zones

Siobhan Nordhaugen 2006
ADOT Statewide Natural Resources Management Group

Enlargement Riparian Linkages

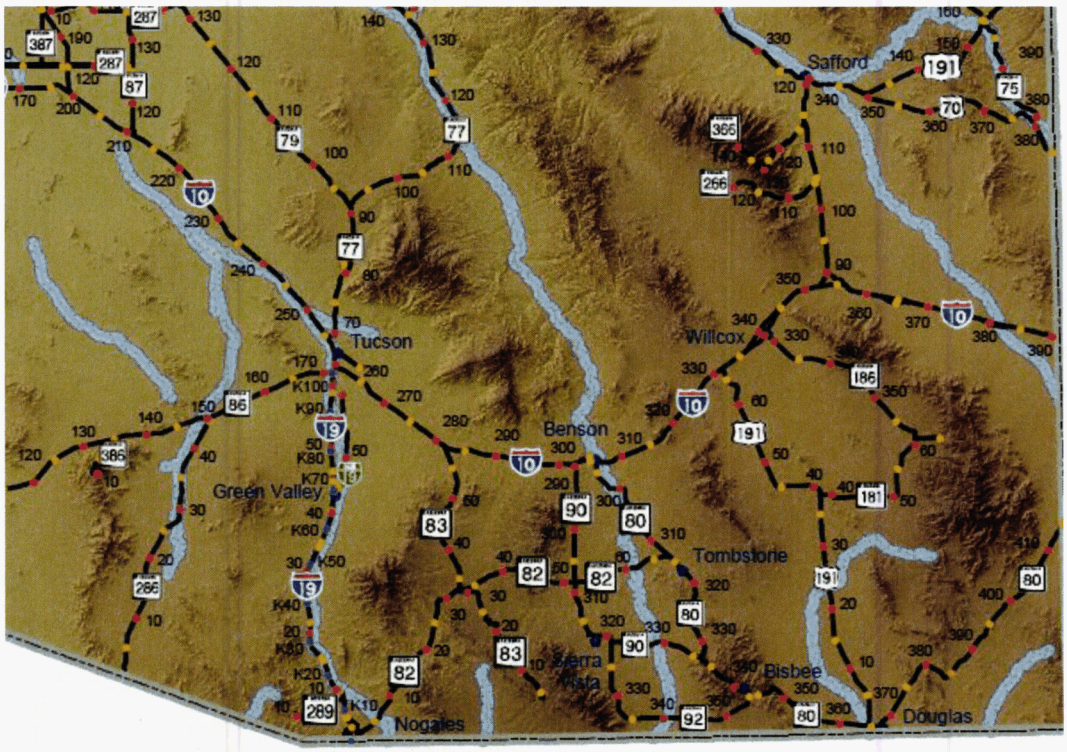
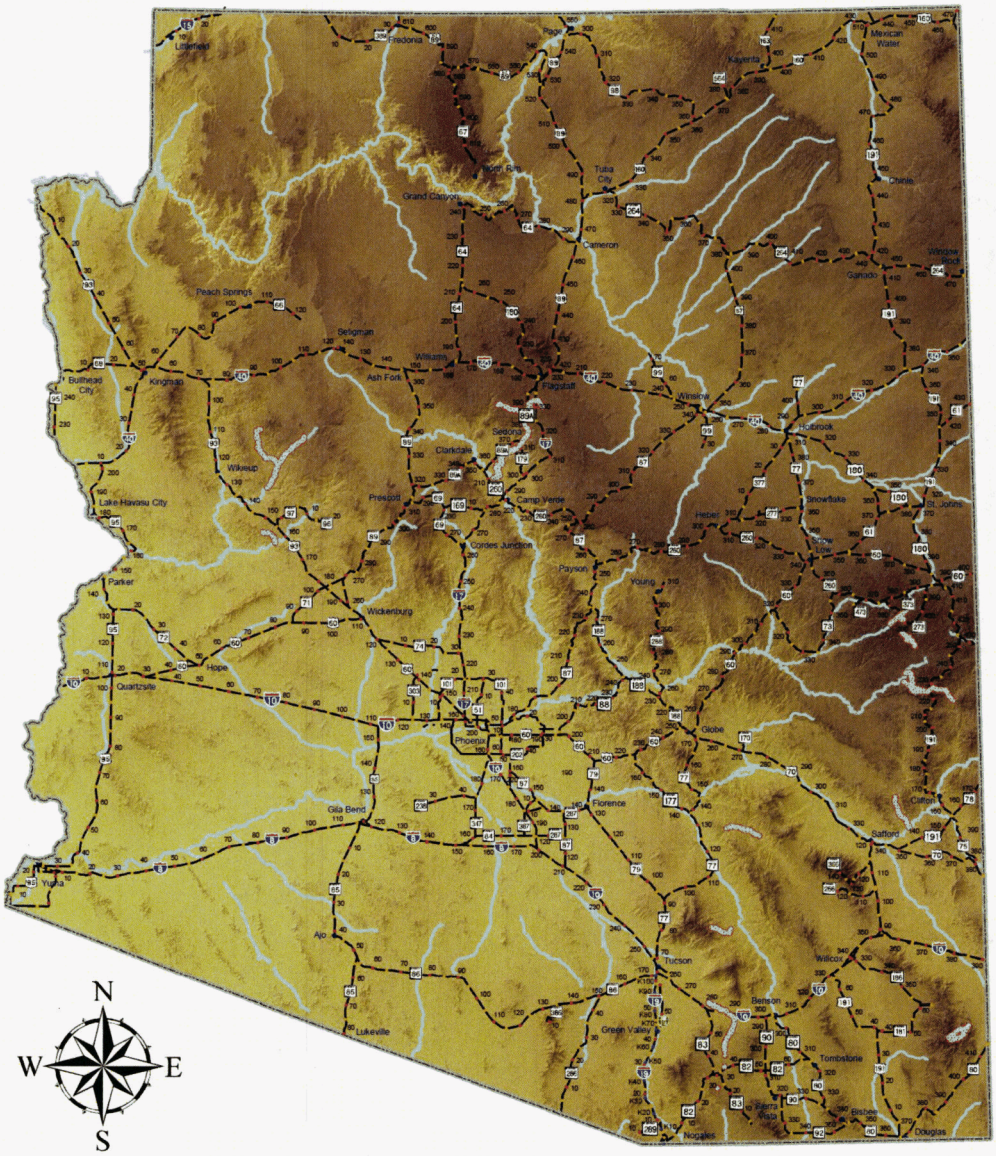


Figure 8.7

UNIQUE WATERS



N
W E
S

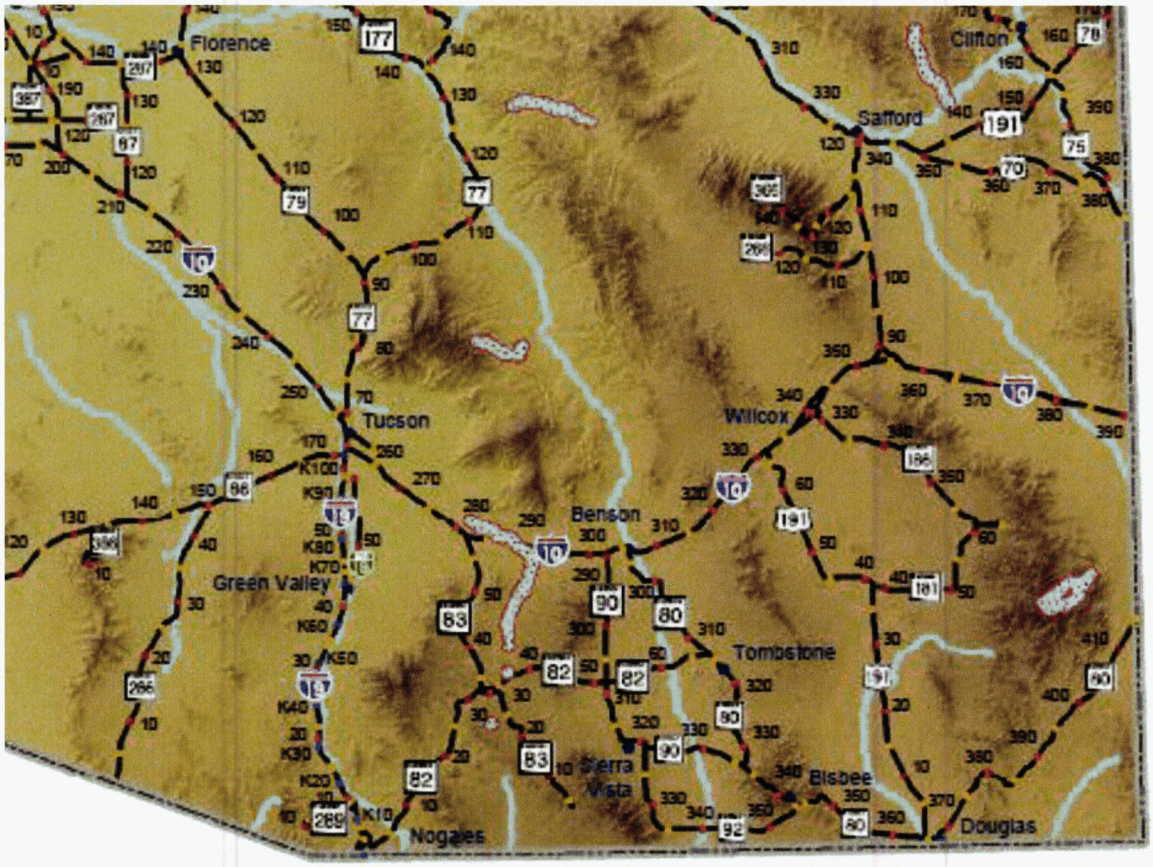
Legend

Unique Waters

0 15 30 60 90 120 Kilometers

0 12.5 25 50 75 100 Miles

Figure 8-7. Unique Waters

Siobhan Nordhaugen 2006
ADOT Statewide Natural Resources Management Group

Enlargement Unique Waters outlined in red (ADEQs Outstanding Waters of Arizona)