

# **The Coconino County Wildlife Connectivity Assessment: Report on Stakeholder Input**

March 2011



Photo by G. Andrejko, AGFD

## **Arizona Game and Fish Department**

In partnership with Coconino County and  
the Arizona Wildlife Linkages Workgroup

**Recommended citation:** Arizona Game and Fish Department. 2011. The Coconino County Wildlife Connectivity Assessment: Report on Stakeholder Input.

**Acknowledgments:** This project would not have been possible without the contributions of the individuals and organizations listed below, to whom we extend our sincere appreciation.

**Stakeholders:**

Arizona Department of Emergency and Military Affairs/Camp Navajo, Arizona Department of Transportation, Arizona Game and Fish Department, Arizona Public Service, Arizona State Forestry, AZTEC Engineering, City of Flagstaff, Coconino County - Community Development, Parks and Recreation, and Public Works Departments, Coconino National Forest, Defenders of Wildlife, El Paso Natural Gas, Energy Transfer Company, Flagstaff Regional Plan Citizens' Advisory Committee, Grand Canyon Trust, Grand Canyon Wildlands Council, Habitat Harmony, Hopi Nation, Jenness Enterprises, Kaibab National Forest, National Park Service - Flagstaff Area National Monuments and Grand Canyon National Park, Northern Arizona Audubon Society, Northern Arizona University, Oak Creek Canyon Task Force, The Nature Conservancy, US Department of Transportation/Federal Highway Administration, US Fish and Wildlife Service, US Geological Survey, Verde Valley Land Preservation Institute

**Partners:**

Arizona Wildlife Linkages Workgroup: Arizona Department of Transportation (former members Bruce Eilerts and Siobhan Nordhaugen; current members Mike Traubert, Justin White, and Todd Williams), Arizona Game and Fish Department, AZTEC Engineering (Norris Dodd), Defenders of Wildlife (Matt Clark), Northern Arizona University (Paul Beier), Sky Island Alliance (former member Janice Przybyl, current member Jessica Lamberton), US Bureau of Land Management (Elroy Masters), US Department of Transportation-Federal Highway Administration (former member Steve Thomas, current member Mary Frye), US Fish and Wildlife Service (Debra Bills, Shaula Hedwall, Mike Martinez, Kathy Robertson), USDA Forest Service (Gary Hanna, Fred Wong)

Coconino County: Community Development (John Aber, Tiffany Antol, Sue Pratt, Bill Towler - Director), Parks and Recreation (former Director Todd Graeff, Geoffrey Gross, Jeanne Trupiano)

**Arizona Game and Fish Department:**

Clint Adams, Sue Boe, Todd Buck, Trevor Buhr, Ken Clay, Mike Demlong, Dave Dorum, Rachel Espinosa, Garrett Fabian, Sophia Fong, Vince Frary, Jeff Gagnon, Jessica Gist, David Grandmaison, Chris Hadley, Bill Knowles, Lee Luedeker, Carl Lutch, Susan MacVean, Tom McCall, Julie Mikolajczyk, Mark Ogonowski, Jeff Pebworth, Larry Phoenix, Bob Price, Sarah Reif, Mike Rice, Andi Rogers, Esther Rubin, Ray Schweinsburg, Ron Sieg, Scott Sprague, Janice Stroud, Luke Thompson, Erin Turnpugh, Dana Warnecke, Dannette Weiss, Micah White, John Windes, Kelly Wolff-Krauter

**Technical guidance:**

Wayne Spencer

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## EXECUTIVE SUMMARY

This report and the accompanying geographic information system (GIS) datasets summarize the results of two stakeholder workshops held in Flagstaff in 2009 and 2010. At these workshops, stakeholders representing a broad range of organizations and interests identified and mapped the locations of important wildlife linkages across Coconino County. Participants included biologists, land managers, planners and other professionals from federal, state, tribal, private, and non-governmental organizations. The workshops were supported by a partnership between the Arizona Game and Fish Department, Coconino County, and the Arizona Wildlife Linkages Workgroup known as the Coconino County Wildlife Connectivity Assessment. The goal of this partnership is to encourage biologists and non-biologists alike to incorporate information about wildlife linkages and strategies for their conservation into land use decisions. The workshops provided a forum in which stakeholders shared and discussed their knowledge, outlined the general locations of wildlife linkages on large maps, and provided descriptive information about each linkage on datasheets. Participants also identified the locations of barriers such as highways and railroads that can interfere with wildlife movements. The hand-drawn linkages and barriers were then digitized with GIS software, and later refined after an additional opportunity for stakeholder review.

This report provides background information on the importance and benefits of conserving wildlife linkages for both people and wildlife in Coconino County, and describes the methods used in our stakeholder workshops and in developing our 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. The maps are followed by tables of 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 and barrier. 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 and barriers across Coconino 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 stakeholder input, GIS-based linkage modeling, and research studies of wildlife movement patterns. Maps illustrate approximate locations of wildlife movements on the landscape and should be regarded as the starting point for further consultation with the Arizona Game and Fish Department and other wildlife and land management agencies, preferably in the early stages of project planning. The report and associated GIS data provide a framework for professionals across a range of disciplines to begin to identify opportunities for maintaining and enhancing wildlife connectivity within their project areas in Coconino County. We hope this report stimulates detailed planning and collaborative on-the-ground actions for conserving wildlife linkages through land acquisition and open space conservation, habitat restoration, creation of highway crossing structures for wildlife, and other approaches.

## **LIST OF FIGURES**

Figure 1: Effect of roadways on movement of pronghorn

Figure 2: Arizona State Route 260 wildlife underpass project

Figure 3: Wildlife overpass and underpass examples

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Figure 7: Central Coconino County stakeholder-drawn linkages and barriers to wildlife movement

Figure 8: Flagstaff Area stakeholder-drawn linkages and barriers to wildlife movement

Figure 9: South-central Coconino County stakeholder-drawn linkages and barriers to wildlife movement

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Figure 11: Coconino County stakeholder-drawn barriers to wildlife movement

## DEFINITIONS

*Note: Terms in this list are highlighted in **bold** where they first appear in the text.*

Habitat fragmentation - The process through which previously intact areas of wildlife habitat are divided into smaller disconnected areas by roads, urbanization, or other barriers.

Habitat block – A relatively large and unfragmented area of land capable of sustaining healthy populations of wildlife into the foreseeable future.

Habitat connectivity – The extent to which an area of the landscape facilitates ecological processes such as unrestricted movement of wildlife. Habitat connectivity is reduced by habitat fragmentation.

Wildlife linkage – An area of land used by wildlife to move between or within habitat blocks in order to complete activities necessary for survival and reproduction. Also referred to as a “wildlife movement area” or “wildlife corridor.”

Wildlife corridor – This term is often used interchangeably with “wildlife linkage” as we do in this report. Some biologists define the term “corridor” more narrowly to represent features such as canyons, ridgelines, riparian areas, and other landscape features that constrain or “funnel” wildlife movements in more restricted paths.

Diffuse movement area - A type of wildlife linkage in which animals move *within* a habitat block across a relatively broad area, rather than *between* habitat blocks through a well-defined linkage.

Riparian linkage – A type of wildlife linkage associated with a river or stream and its adjacent plant community. Riparian linkages facilitate movement of both terrestrial and aquatic wildlife species.

Stepping stone corridor – A type of wildlife linkage composed of a series of relatively small and isolated areas of habitat separated by barriers such as housing or roads. Stepping stones serve as linkages for highly mobile species such as birds and bats.

## **BACKGROUND**

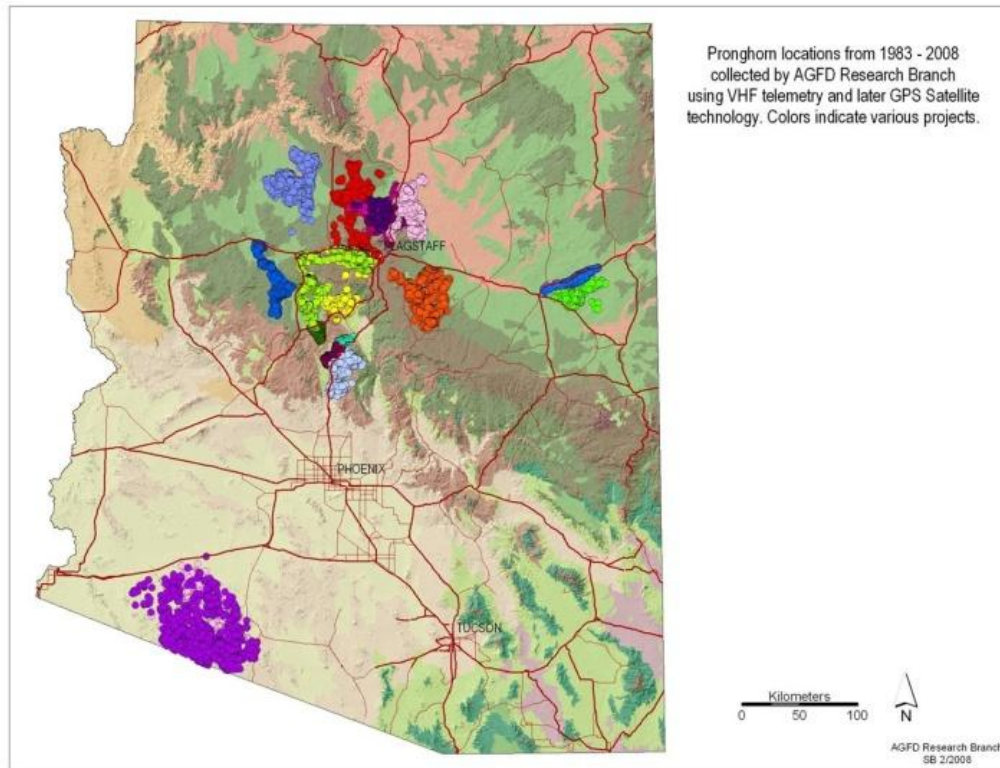
### **Why we need wildlife linkage planning in Coconino County**

Blessed with abundant sunshine and great natural beauty, Arizona annually draws large numbers of new residents and visitors alike. The state has grown rapidly in recent decades and its human population is expected to more than double from almost 6½ million in 2010 to greater than 14 million by 2050 (Arizona Department of Transportation 2010a, US Census Bureau 2011). While much of that growth will likely be concentrated throughout the “Sun Corridor” connecting Tucson, Phoenix, and areas of central Yavapai County, communities in other areas of the state are also expected to grow. The population of Coconino County may increase by more than 50% in this period, especially along State Route 64, Interstate 40 west of Flagstaff, and around Fredonia near the Utah border (Arizona Department of Transportation 2010a). Given the largely rural nature of Coconino County, much of this growth will involve expansion of cities and towns into relatively undeveloped areas, and expand the footprint of roadways such as I-40 and other infrastructure. Future development of wind and solar energy facilities, utility corridors, and other energy-related infrastructure may be considerable given the Renewable Energy Standard and Tariff, established in 2006 by the Arizona Corporation Commission, which includes rules requiring that Arizona’s utility companies must produce 15% of the state’s electricity from renewable sources by 2025 (Arizona Corporation Commission 2006). Growth outside of Coconino County will also influence our regional landscape, as reflected in the projected increase in rail traffic through northern Arizona in coming decades which may include the creation of additional tracks of the BNSF Railroad and significant expansion of the Camp Navajo rail depot (Arizona Department of Transportation 2010b).

The growth of Arizona’s human population and expanding infrastructure has consequences for Coconino County’s wildlife species and the habitats on which they depend. Elevation in the County ranges from 1,350 feet above sea level at the bottom of the Grand Canyon to 12,633 feet above sea level atop the San Francisco Peaks. This elevational gradient combined with the region’s diverse topography creates conditions for a range of ecosystems and vegetation types including arid grasslands, pinyon-juniper woodlands, ponderosa pine forests, spring-fed and ephemeral wetlands, mixed conifer and aspen stands, and alpine tundra. These vegetation communities support a diversity of wildlife, including commonly-occurring species such as black bear, elk, and deer mouse; federally listed species (US Fish and Wildlife Service 2011); and state and federal species of conservation concern (Arizona Game and Fish Department 2011a). While human activities can adversely affect Coconino County’s wildlife by causing direct loss or degradation of habitat, the disruption of wildlife movement patterns is a less obvious but equally important consequence.

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, black bears, and mule deer roam over vast expanses that can encompass thousands of acres, while smaller animals such as tassel-eared squirrels and northern leopard frogs engage in essential movements on a much smaller scale. 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 such as roads, urban areas, and railroads can affect each of these movement patterns and may pose a threat to 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; see Figure 1).





**Figure 1:** Radio and satellite telemetry studies by the Arizona Game and Fish Department's Research Branch reveal that major roadways can act as barriers to pronghorn movement. This barrier effect can effectively isolate populations, potentially reducing genetic diversity and reproductive success over time. Colors indicate groups of animals studied in separate projects.

The process through which previously intact areas of habitat are divided into smaller disconnected areas by roads, urbanization, and other barriers is known as **habitat fragmentation**, which decreases the degree of **habitat connectivity** of the landscape for wildlife. The disruption of animal movement by habitat fragmentation presents problems for Arizona's wildlife ranging from direct mortality on roadways to the genetic isolation of fragmented populations, and negatively impacts human welfare by increasing the risk of vehicle collisions and the frequency of unwanted "close encounters" with wildlife. It is important to note, however, that the effects of habitat fragmentation can often be mitigated by identifying and protecting areas that wildlife use for movement, known as **wildlife linkages** or **wildlife corridors** (Beier and Noss 1998, Haddad et al. 2003, Eggers et al. 2009, Gilbert-Norton 2010). Ridgelines, canyons, **riparian** areas, cliffs, swaths of forest or grassland, and other landscape or vegetation features can serve as wildlife linkages. Animals may also move across a relatively broad area rather than through a well-defined corridor, a type of wildlife linkage we identify as a **diffuse movement area**. Wildlife linkages are most effective when they connect (or are located within) relatively large and unfragmented areas referred to as **habitat blocks**. Habitat blocks are areas large enough to sustain healthy wildlife populations and in which essential biological processes are likely to be maintained in the future (Noss 1983, Noss and Harris 1986, Noss 1987, Noss et al. 1996). Wildlife linkage planning should include conservation of wildlife linkages and the habitat blocks they connect, and can include a range of strategies. Land acquisition, open space conservation, habitat restoration, and installation of roadway mitigation features such as wildlife crossing structures and fencing intended to funnel wildlife to crossing structures (Figures 2a and 2b) can all help to maintain habitat connectivity on the landscape, particularly if considered early in the planning process for transportation and development projects.



**Figures 2a and 2b:** Along Arizona State Route 260 near Payson, a series of highway underpasses effectively increased the permeability of the highway by 60% while ungulate-proof fencing linking those underpasses reduced elk-vehicle collisions by over 95% for an estimated cost savings of \$1 million dollars annually (Photographs: Arizona Game and Fish Department).

### Benefits of wildlife linkage planning

Identifying and conserving habitat connectivity by maintaining wildlife linkages can provide many important benefits for both humans and wildlife.

*Benefits to wildlife.* By facilitating wildlife movement patterns, linkages allow animals to access essential resources such as food and water needed during their daily activities. They also enable longer-range, seasonal migratory movements between summer and winter habitats and facilitate the movement of animals in search of breeding sites. Linkages that connect otherwise isolated populations help prevent small populations from extinction (Laurance 1991, Beier and Loe 1992), help maintain genetic diversity, and reduce the risk of inbreeding (Beier and Loe 1992, Bennett 1999). Habitat connectivity also helps ensure that critical ecological processes such as pollination and seed dispersal, which often depend on animal intermediaries, are maintained. In some cases the linkages themselves may sustain actively reproducing wildlife populations (Perault and Lomolino 2000, Beier et al. 2007). Linkages are also expected to play an important role in helping animal populations adapt to and endure the effects of climate change, by allowing animals to shift their range with latitude or elevation as vegetation communities change their distribution and suitable environmental conditions shift on the landscape (Hannah et al. 2002, Glick et al. 2009).



**Figures 3a and 3b:** (a) Wildlife overpasses, like the one in this artist rendering proposed by the Arizona Department of Transportation and Arizona Game and Fish Department biologists to facilitate pronghorn passage over US Highway 89, and (b) wildlife underpasses can sustain important wildlife linkages while greatly reducing the threat of vehicular collisions. Crossing structures are most effective when they are designed to meet the needs of species known to be using the linkage. (Photograph: Arizona Game and Fish Department).

*Benefits to people.* Measures to conserve wildlife linkages can benefit human communities in important ways as well, perhaps most obviously by improving public safety. Each year more than 200 motorists are killed and approximately 29,000 are injured as a result of wildlife-vehicle collisions in the United States (Bies 2007) with annual costs estimated in the hundreds of millions of dollars. The Federal Highway Administration estimates the total societal cost of an individual elk-vehicle accident at \$18,000 (Huijser et al. 2008). In Arizona more than 300 elk are hit by vehicles per year, costing the state an estimated \$5.5 million. This problem is acute and growing along Coconino County's major highways. For example, from 2007 to 2009 more than 190 collisions involving wildlife occurred on Interstate Highway 40 between Williams and Twin Arrows alone, the majority of these involving elk (Arizona Game and Fish Department 2011b). Identifying important wildlife movement areas that traverse transportation corridors during the construction of new roads or 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; Figures 3a and 3b). Along Arizona State Route 260 a combination of wildlife underpasses and ungulate-proof fencing reduced elk-vehicle collisions by 97% (Gagnon et al. 2010; Figures 2a and 2b). Incorporating knowledge of wildlife movement areas can also play a role in setting priorities for rural and urban open space planning and acquisition and can help avoid potential conflicts between recreationists and wildlife. Maintaining wildlife populations through conservation efforts such as the protection wildlife linkages is also of economic and social value given the significant contribution of wildlife-based recreation to the economies of Coconino County and the state of Arizona (Southwick Associates 2003, American Sportfishing Association 2007). One study found that in 2001 non-consumptive wildlife recreation alone (including activities such as wildlife watching) generated an estimated \$87 million in Coconino County (Southwick Associates 2003). In that same year, fishing and hunting generated over \$124 million, supported 1,860 jobs, provided residents with \$22 million in salary and wages, and generated \$6 million in state tax revenue across the County (Silberman 2003).

### **Regional planning efforts acknowledge the importance of conserving wildlife linkages**

There is a growing appreciation among local governments, land management agencies, transportation departments, conservation organizations, energy and utility companies, and citizens across Coconino County of the importance of conserving wildlife linkages and mitigating the impacts of barriers to wildlife movement. The Resource Management section of the Flagstaff Area Open Spaces and Greenways Plan (1998), the Natural Environment element of the Coconino County Comprehensive Plan (2002), and the Environmental Planning and Conservation element of the revised Flagstaff Area Regional Land Use and Transportation Plan (in preparation) all include preservation of wildlife movement areas among their conservation goals. The Federal Highway Administration and the Arizona Department of Transportation recognize wildlife-vehicle collisions as a serious problem along major northern Arizona roadways, and have supported collaborative research with Arizona Game and Fish Department biologists to identify wildlife movement patterns and design effective mitigation strategies (Dodd et al. 2009, Dodd et al. 2010, Gagnon et al. 2010, Gagnon et al. 2011). The County's National Forests have identified the maintenance of habitat connectivity as an important goal in the revision of their forest plans (USDA 2010a, b), and have begun to integrate wildlife linkage data into their wilderness designation process (Sarah Dechter, Coconino National Forest, pers. com.).

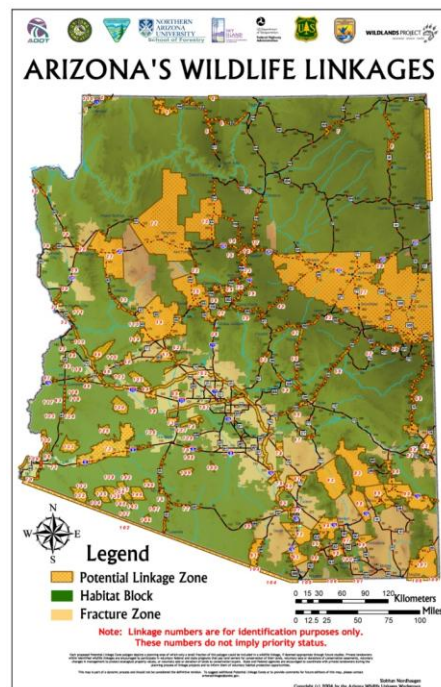
Planning efforts in other areas of Arizona have also begun to incorporate information on wildlife linkages. For example, Pima County's Conservation Lands System (Pima County 2001), an outgrowth of the widely-acclaimed Sonoran Desert Conservation Plan and adopted as policy in the County's Comprehensive 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). This focus on maintaining habitat connectivity for wildlife will only grow as Arizona becomes more developed and populous in coming

decades and the threat of habitat fragmentation increases. Given the relatively undeveloped status of many areas of Coconino County at present, the time is right to integrate knowledge of wildlife linkages and mitigation strategies into land use and transportation planning in our region.

## THE COCONINO COUNTY WILDLIFE CONNECTIVITY ASSESSMENT

To assemble current knowledge of wildlife linkages and barriers to wildlife movement across Coconino County and to help build collaborative partnerships with local jurisdictions for implementation efforts, the Arizona Game and Fish Department (AGFD), the government of Coconino County, and the Arizona Wildlife Linkages Workgroup (AWLW; see “Acknowledgments” for list of member organizations) initiated the Coconino County Wildlife Connectivity Assessment. This project grew out of a prior initiative of the AWLW known as Arizona’s Wildlife Linkages Assessment, which used a similar expert-based approach to create a statewide map of potential linkage areas and barriers at a coarse scale (AWLW 2006; Figure 4). The Coconino County Wildlife Connectivity Assessment represents a continuation of the mission of this prior 2006 statewide effort, and is intended to identify wildlife linkages at a finer scale that may have been overlooked in the 2006 assessment and that will be useful for regional and local planning efforts.

A principal activity of the Coconino County Wildlife Connectivity Assessment was the convening of two stakeholder workshops in 2009 and 2010. In these workshops a diverse range of participants with an interest in maintaining habitat connectivity for wildlife shared their knowledge and outlined the general locations of wildlife linkages and barriers to wildlife movement on large maps. These hand-drawn maps were digitized using geographic information system (GIS) software to produce the maps found in this report. Future project activities will include using the information in this and other county-level reports to support the development of finer-scale, GIS-based wildlife corridor models using established methodology (see [www.corridordesign.org](http://www.corridordesign.org) for details). These models will further refine a subset of the stakeholder-identified linkage areas in this report based on habitat requirements of focal wildlife species that rely on each linkage and will help identify land parcels of highest conservation priority within the stakeholder linkages—both necessary for successful implementation. We anticipate that our selection of sites for fine-scale GIS corridor modeling and collaborative conservation efforts will evolve over time as Arizona’s developed landscape changes and our knowledge of wildlife habitat use and movement patterns grows.



*Figure 4: Statewide map of wildlife linkages and barriers created for Arizona’s Wildlife Linkages Assessment (2006).*



## HOW TO USE THIS REPORT AND ASSOCIATED GIS DATA

### A screening tool for wildlife linkage planning

This report and associated GIS datasets are intended to help planners, developers, land managers, wildlife experts, and others incorporate knowledge of the location of important wildlife linkages and barriers into project planning. The wildlife linkages contained in the shapefile and shown on the maps are not intended to identify finite boundaries. Instead they illustrate the *general* locations of wildlife movements on the landscape, and should be regarded as the starting point for consultation with biologists from the Arizona Game and Fish Department and other wildlife and land management agencies including the US Fish and Wildlife Service (especially when federally-listed species may be involved) and the US Forest Service—ideally in the early stages of project planning. These materials thus comprise a *screening tool* to identify areas where linkage planning goals or concerns for wildlife connectivity may exist. The next step in the consultation process would likely include the development of site-specific plans to address the movement needs of the wildlife in the area.

It is crucial for the users of this report to understand that conservation of the habitat blocks that the identified wildlife linkages are connecting is also essential for the long term health of wildlife populations in Coconino County. While we have not delineated the limits of these habitat blocks on our maps they are named in the descriptions of each linkage (see “Wildlife Linkage Descriptions” below). It is also important to emphasize that the information in this report reflects the views and expertise of workshop participants, and that these participants had diverse expertise and varying degrees of individual familiarity with wildlife linkages and barriers in different areas of Coconino County. Given that there may have been some areas of the County for which fewer expert participants were present at the stakeholder workshops or for which less is known in general about wildlife movement patterns, this report should not be regarded as an exhaustive mapping of all important wildlife linkages and barriers. While we have attempted to provide a comprehensive analysis the information we present will benefit from further refinement through additional stakeholder input, GIS-based linkage modeling, and additional research on wildlife movement patterns.

To best integrate knowledge of wildlife linkages and barriers to wildlife movement into planning efforts we recommend a collaborative approach involving project proponents, municipal planners, transportation, wildlife, and land management agency specialists, citizen groups, and others with an interest in conserving habitat connectivity for wildlife in a manner compatible with regional development goals. This effort should develop conservation goals for both wildlife linkage areas and the habitat blocks they connect.

### Geospatial (GIS) dataset

The geospatial dataset associated with this report should be used with GIS software to allow users to incorporate information of wildlife linkages into land use planning, development, or project level spatial decision-making processes. To obtain a copy of the GIS dataset for use in your local planning efforts please contact Mark Ogonowski with the Habitat Program at the Arizona Game and Fish Department’s Flagstaff office (928-214-1252 or [mogonowski@azgfd.gov](mailto:mogonowski@azgfd.gov)) or the Department’s GIS Program ([gis@azgfd.gov](mailto:gis@azgfd.gov)).

### Other resources

Additional tools are available from the Arizona Game and Fish Department to help planners identify wildlife resources in a project planning area. These tools include the Species and Habitat Conservation Guide, a model depicting areas of wildlife conservation potential; and the Geospatial Planning Tool, an online geospatial data viewing platform that serves as a data exploration tool for AGFD’s wildlife

datasets. Site-specific reports on wildlife species of concern and federally-listed threatened and endangered species are available through the Online Environmental Review Tool. In addition to these resources, guidelines documents and other information is available on the Arizona Game and Fish Department's "Planning for Wildlife" web page at <http://www.azgfd.gov/WildlifePlanning>.

For a description of GIS wildlife corridor modeling approaches and to download ArcGIS modeling tools developed by scientists at Northern Arizona University please see the CorridorDesign website at <http://corridordesign.org>. Here you will also find a number of completed wildlife linkage designs produced by the CorridorDesign team through funding provided by the Arizona Game and Fish Department's Heritage Fund.

## **METHODS**

### **Initial stakeholder workshop**

In spring of 2009, Coconino County and the Arizona Game and Fish Department, in partnership with the Arizona Wildlife Linkages Workgroup, hosted a full-day workshop for stakeholders and experts in the fields of wildlife management and land use planning. Attendees included private citizens and representatives from federal agencies, state agencies, non-profit organizations, and tribal and local governments. Following a brief series of presentations on wildlife connectivity principles and the goals of the Coconino County Wildlife Connectivity Assessment, stakeholders were instructed to visit one or more of six work stations where a portion of the county was displayed on a paper map. These maps displayed hillshade to show topography, locations of major roads, and labels designating cities, mountains, watercourses, and other prominent features. Participants mapped important wildlife linkages and areas of known wildlife movement, including diffuse movement areas within habitat blocks and locations where wildlife cross (or should previously have crossed) barrier features between habitat blocks. Participants were encouraged to use additional mylar overlays depicting vegetation type, conservation status, and land ownership as needed for reference. Some AGFD wildlife management personnel did not attend the workshop and contributed their input individually from remote work locations. These participants were given base maps with added game distribution information when hand-drawing species movements. The linkages they illustrated were then integrated with the information provided by other stakeholders during the workshop. For each wildlife linkage drawn or barrier feature noted, participants were also asked to fill out a datasheet describing wildlife movement patterns and existing or future land uses that may affect the wildlife in the area (Appendix 1).

A consequence of this voluntary, expert-based approach is that not all geographic areas were equally represented by knowledgeable stakeholders and the information we were able to collect about wildlife linkages and barriers was more comprehensive in some areas than in others. There may thus be important wildlife linkages in areas of Coconino County where none appear on our maps, so this absence should be interpreted with caution pending further study. Also, the type and amount of evidence on which each linkage was based varied from isolated personal observations to long-term empirical data from telemetry studies. This variation in the amount of stakeholder input available and sources of evidence for each linkage and barrier is reflected in the level of detail we were able to provide in the “Wildlife Linkage Descriptions” below. Thus a relative lack of detail for a given linkage or barrier, in terms of species using the linkage, current or potential threats, or additional “Notes” (see below), should not lead to the conclusion that this linkage is not important. Further information collected in the future will hopefully expand these descriptions, as well as pointing out locations of additional linkages and barriers across the County.

### **GIS digitizing and editing methods**

Stakeholder linkages from this first workshop were digitized in ArcGIS and their associated datasheets entered into an Access database. Project staff used the following guidelines when digitizing stakeholder drawings in ArcGIS:

- Trace contour lines to digitize canyons or hills when a drawing or description indicates a topographic feature is being used.
- When a linkage polygon is drawn across a road but information from the datasheet indicates that stakeholder meant to identify a barrier only and not specify a linkage, define the stretch of road as a barrier.
- Where linkages overlap or fall inside larger linkages, keep only those shapes that provide unique information or show movement in contrasting directions. Otherwise merge the shapes and



combine the information from each datasheet (e.g. species using linkage) into attributes for the single merged shape.

- Do not include linkages for which the data provided are insufficient. Follow up with stakeholders whenever possible to obtain needed information about the linkage.

### **Follow-up workshop and GIS refinement**

A second stakeholder workshop was convened in spring of 2010 to allow participants to review the digitized linkage polygons for accuracy, omissions, and redundancy. Participants were also encouraged to provide additional information about the linkages including the species served, habitat blocks connected, and threats to connectivity that may have been overlooked the first time around. Input from the second stakeholder workshop was also incorporated following the decision rules described above and linkage and barrier polygons were re-digitized when necessary. This report contains the final version of the information provided through the stakeholder workshop process.

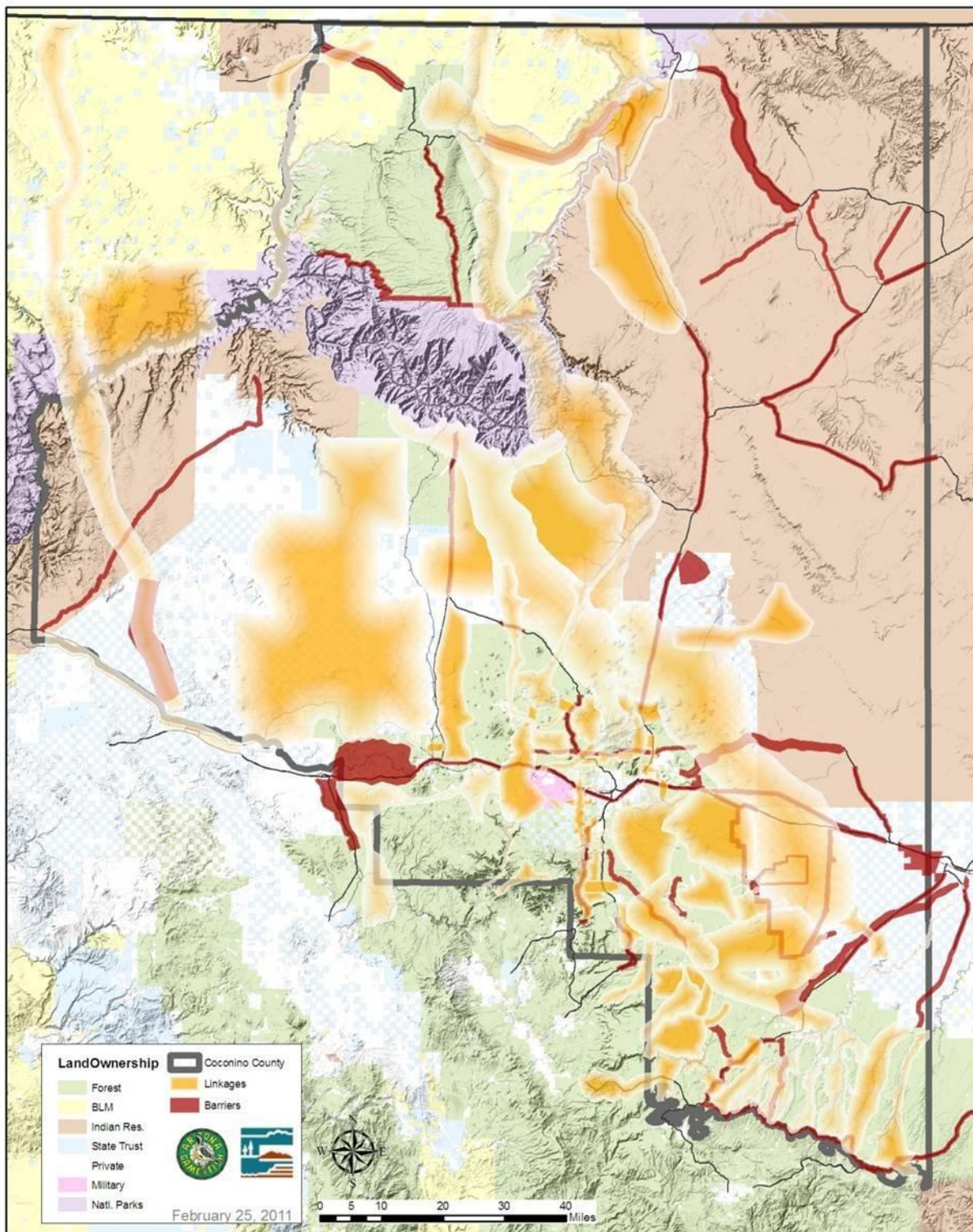
## MASTER LIST OF WILDLIFE LINKAGES

- Hurricane Rim – Aubrey Cliffs
- North Grand Canyon National Park – South Rim
- Kaibab Plateau – Paunsaugunt Plateau, Utah
- Buckskin Mountains – Antelope Valley
- House Rock Valley – Utah
- Utah – San Francisco Peaks
- Vermillion Cliffs – Echo Cliffs – White Plateau Area
- Marble Canyon
- Echo Cliffs – Eminence Break
- Espee-Cataract – Kaibab National Forest
- Aubrey Valley/Aubrey Cliffs – South of Hwy 66
- South Rim – San Francisco Peaks – Woody Ridge/Bellemont Area
- Grassland north and east of San Francisco Peaks – east of Anderson Mesa
- Grasslands south of Valle – I-40
- Wupatki National Monument – Navajo Reservation
- Garland Prairie – Wagon Tire Flat
- Coconino Plateau
- Fues Hill – Threemile Lake
- Dog Knobs – Ebert Mountain – Government Prairie
- Mesa Butte - Kendrick
- Garland Prairie – Government Prairie/Government Hills
- Walnut Canyon – Anderson Mesa – Antelope Park/Mormon Mountain
- Youngs and Mormon/Padre Canyons
- GMU 6B block of Barney Pasture – Turkey Butte – Casner Mountain – Sycamore Pass
- Schoolhouse Draw – Pumphouse Wash and Fry Canyon
- Mormon Mountain – Hutch Mountain
- Ashurst/Kinnikinick – Mormon Lake
- Kendrick – Spring Valley Knolls/Government Hill/Government Prairie
- East of Kendrick – Government Hills
- Kendrick – Hochderffer Hills
- San Francisco Peaks – North of the Peaks
- San Francisco Peaks – Mount Elden/Timberline
- San Francisco Peaks – Sunset Crater and O’Leary Peak
- San Francisco Peaks – Observatory Mesa - Bellemont
- Elden Springs Road – Cinder Lake Landfill
- Highway 180 Meadows
- San Francisco Peaks – Woody Ridge
- Elden Foothills
- Turkey Hills – Picture Canyon (Rio de Flag) – Elden Pueblo
- Rio de Flag
- Woody Ridge
- Rogers Lake – Volunteer Canyon
- Dry Lake – Rogers Lake
- Bow and Arrow
- Hoffman Tank Area
- Peaceful Valley – Campbell Mesa
- Rio de Flag – Walnut Canyon
- Sycamore Canyon
- Black Pass
- Sinclair Wash
- Oak Creek Canyon
- Mexican Pocket/Pumphouse Wash – Village of Oak Creek
- Newman Park – Willard Springs

- Pumphouse Wash – Munds Canyon
- Anderson Mesa Summer – Winter Range
- Robber’s Roost/Dutch Tank Area – Mormon Lake Area
- White Mesa – North of Rocky Park – Rattlesnake Quiet Area
- Stoneman Lake Area – Happy Jack/Jacks Canyon
- Hutch/Pine/Turkey Mountains – Jacks Canyon/Chavez Mountain/Grapevine Canyon
- East Sunset – West Sunset
- Clear Creek Canyon
- Diversion Park – Cedar Flats
- Bargaman Park – Buck Mountain Area
- Willow Valley – Buck Mountain
- Turkey Draw – Mahan Park/Buck Mountain/Buck Butte
- Blue Ridge
- Long Lake Area – East Clear Creek
- Blue Ridge Reservoir/Clear Creek – Mogollon Rim
- West Clear Creek – Fossil Springs Wilderness
- West Clear Creek – Dirtyneck Canyon
- East Clear Creek – Potato Lake
- Mogollon Rim – Mogollon Plateau
- Chevelon Canyon
- Ward Terrace
- Hopi Lands – Navajo/Hopi Joint-use Lands
- Moenkopi Plateau

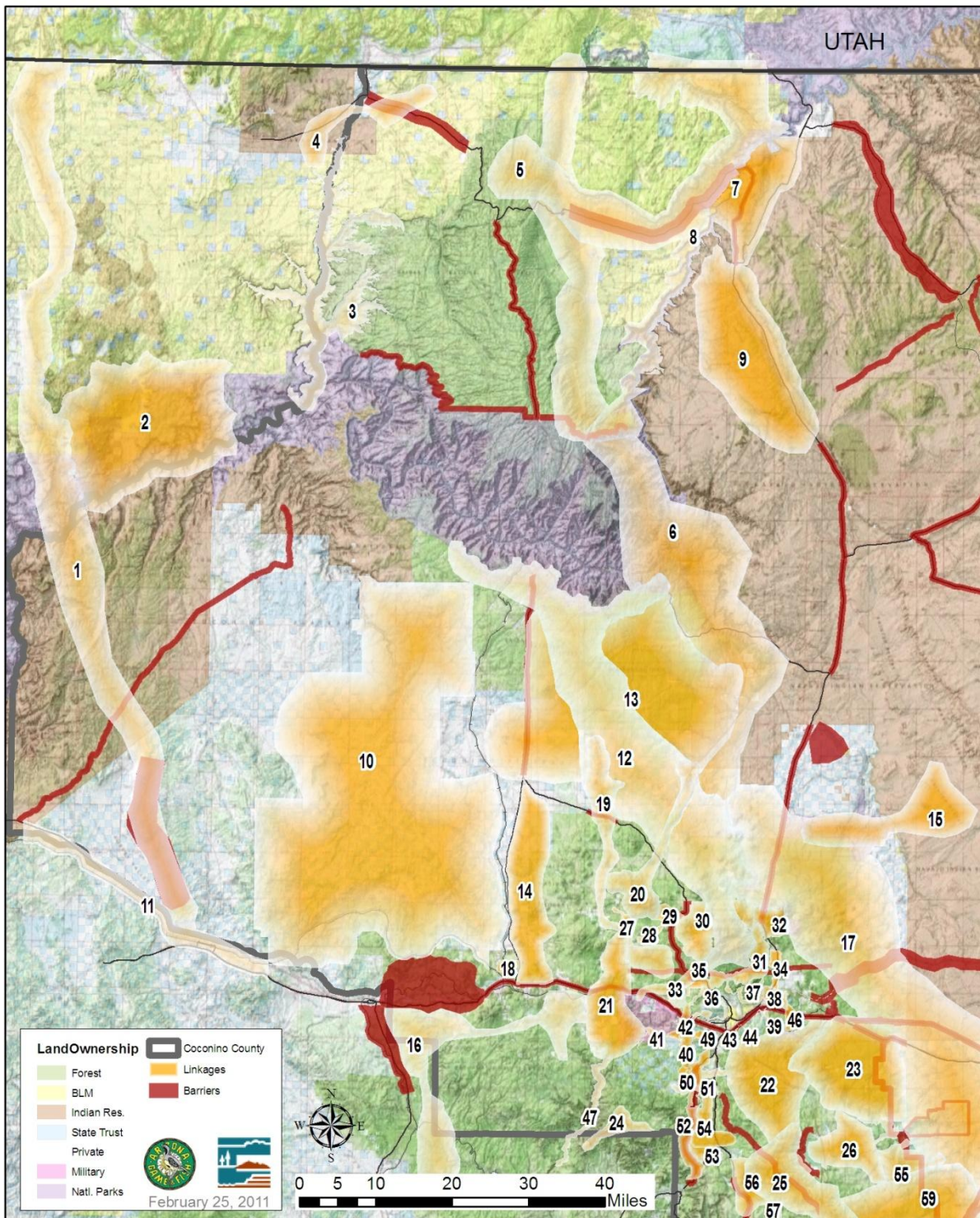
## REFERENCE MAPS

The following maps display linkage polygons and barriers to wildlife movement that were identified by stakeholders in the 2009 and 2010 workshops. We provide six linkage maps, zoomed to varying extents, to aid the user in visualizing both larger landscape-scale and smaller, more localized wildlife linkages described by workshop participants. The first linkage map (Figure 5) is a County-wide map showing all stakeholder-drawn wildlife linkages and barriers to wildlife movement, while Figures 6 through 10 are larger-scale maps that provide greater detail for selected areas of Coconino County. The seventh and final map (Figure 11) displays only the identified barriers to wildlife movement for the entire County. Further inspection or analysis of the data should be conducted using GIS software. **The linkage polygons are intentionally symbolized with a gradient fill: the exact extent of each polygon and the shape of its edges are not intended to be sharply defined, but should in all cases be regarded as “fuzzy” (please see “How to use this report and associated GIS data” for further explanation).** Numeric labels for each linkage polygon or barrier correspond to numbered narrative descriptions that follow the maps, the source of which are the datasheets filled out by workshop participants for each linkage. Linkage descriptions include a name associated with the geographic location, the habitat types or features connected by the linkage, a list of species known or expected to use the linkage, threats to functional habitat connectivity in the linkage, and additional notes. Barrier descriptions include a name and additional notes focusing on current and future threats to connectivity and/or opportunities for conservation actions to improve connectivity in the area.



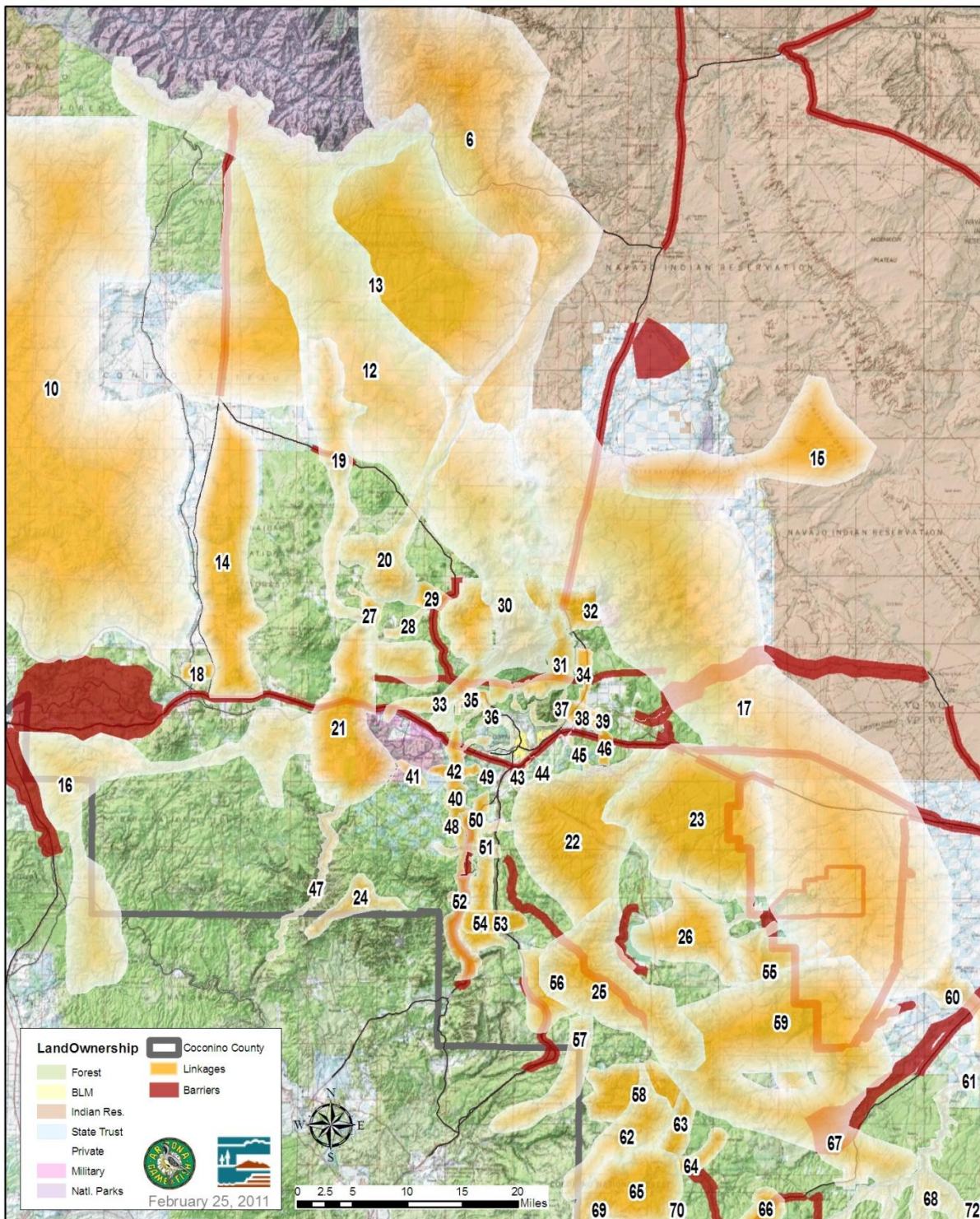
**Figure 5.** Coconino County stakeholder-drawn linkages and barriers to wildlife movement





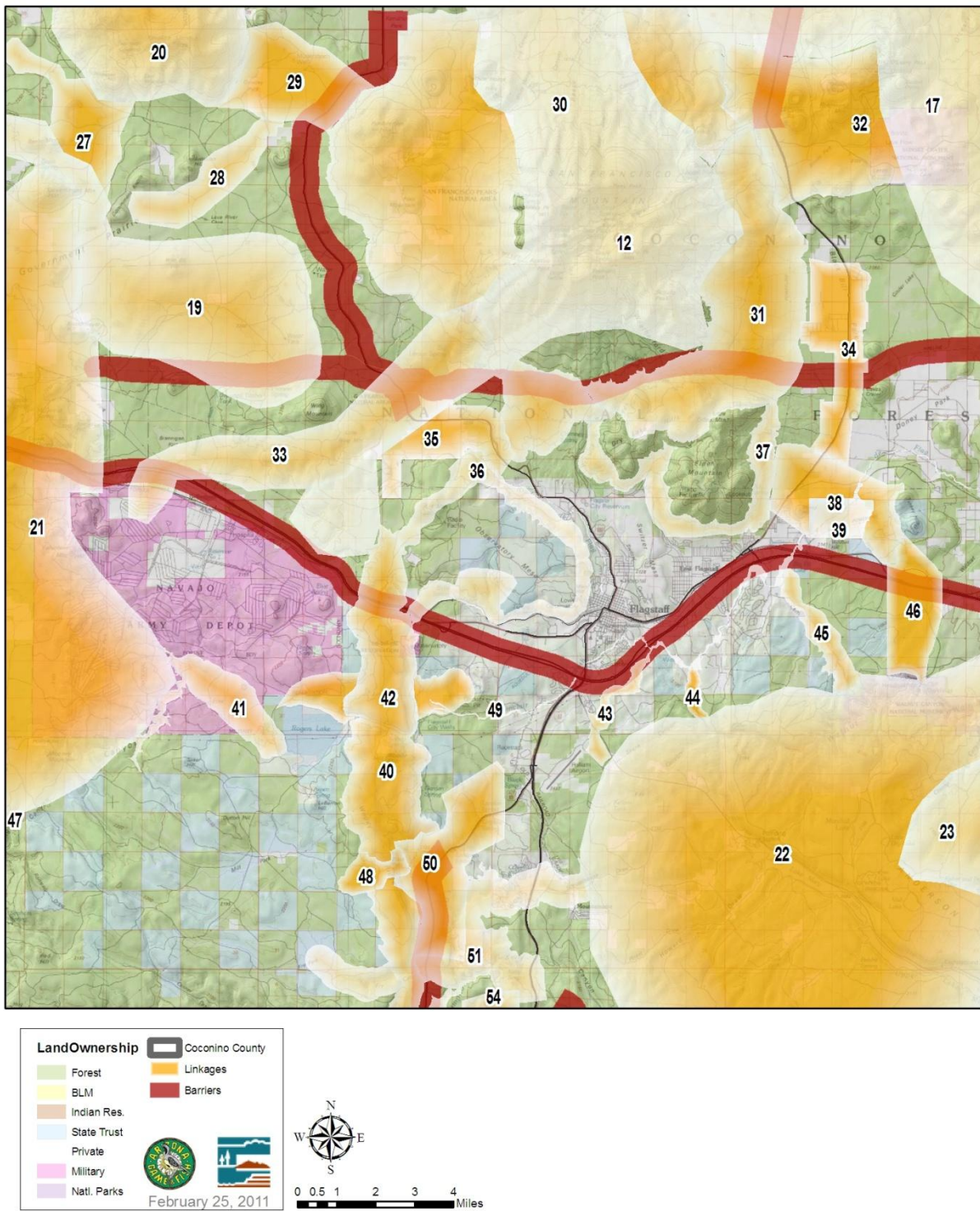
**Figure 6.** Northern Coconino County stakeholder-drawn linkages and barriers to wildlife movement





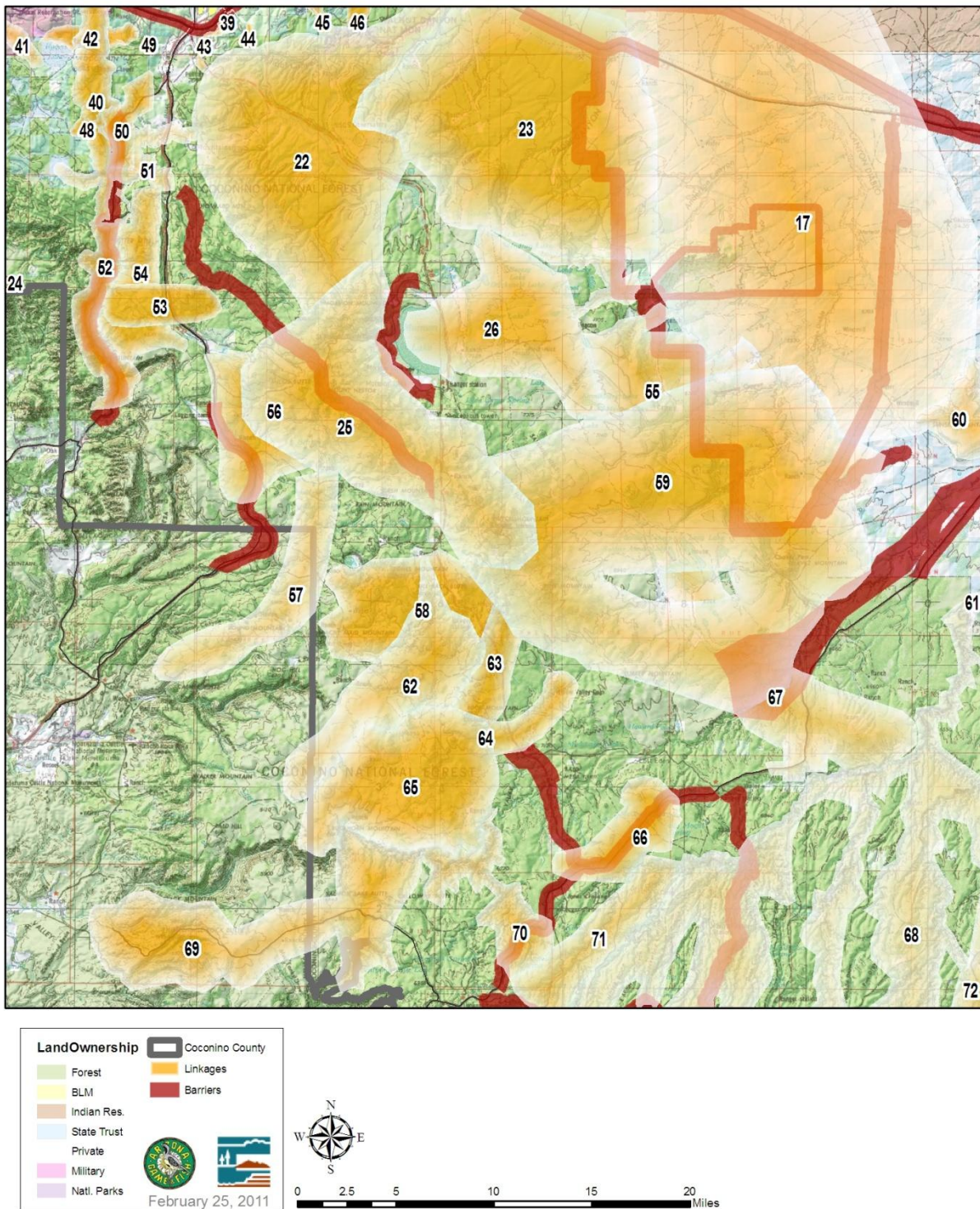
**Figure 7.** Central Coconino County stakeholder-drawn linkages and barriers to wildlife movement





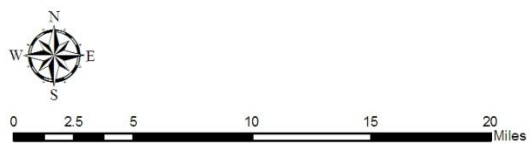
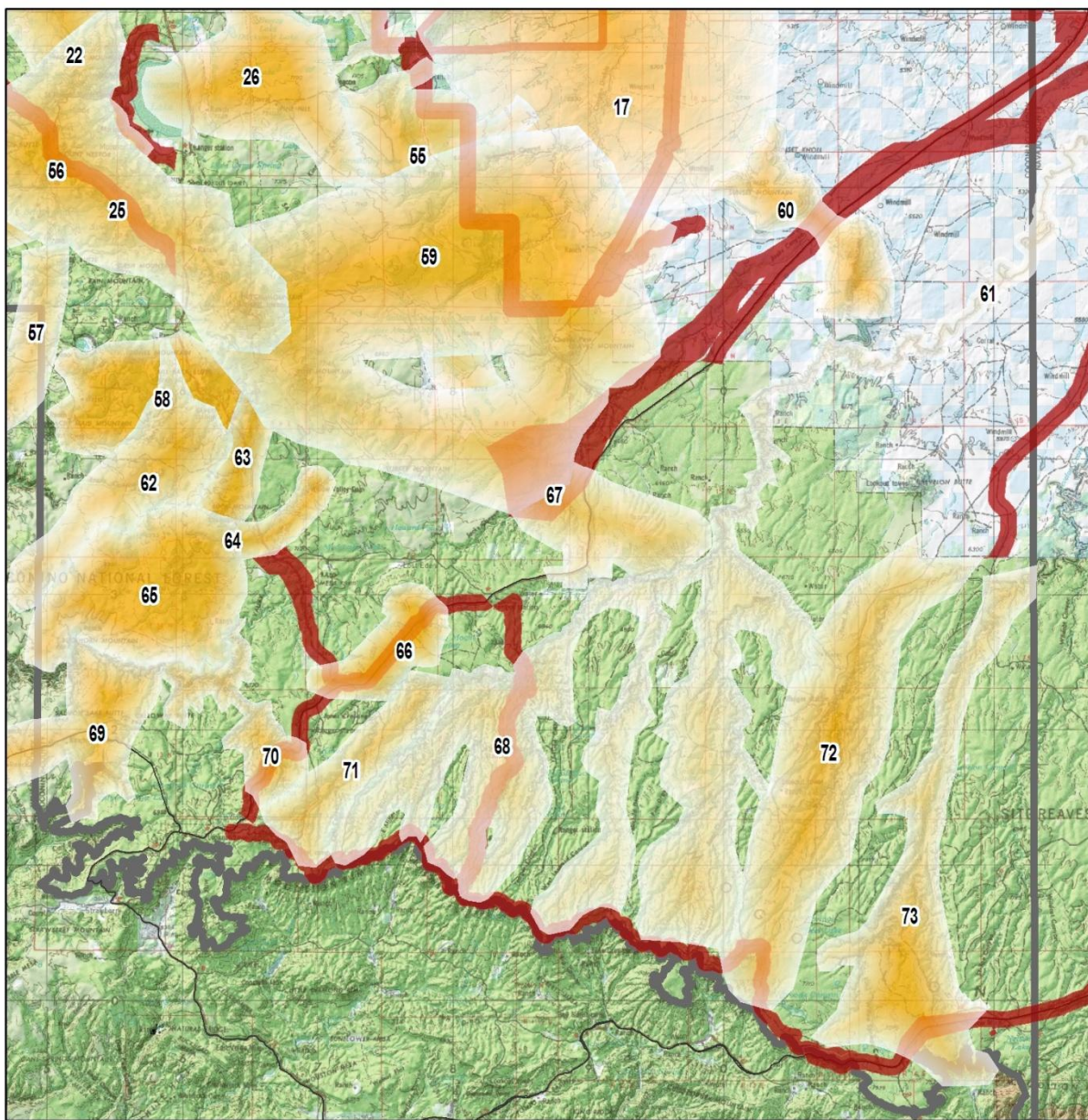
**Figure 8.** Flagstaff area stakeholder-drawn linkages and barriers to wildlife movement





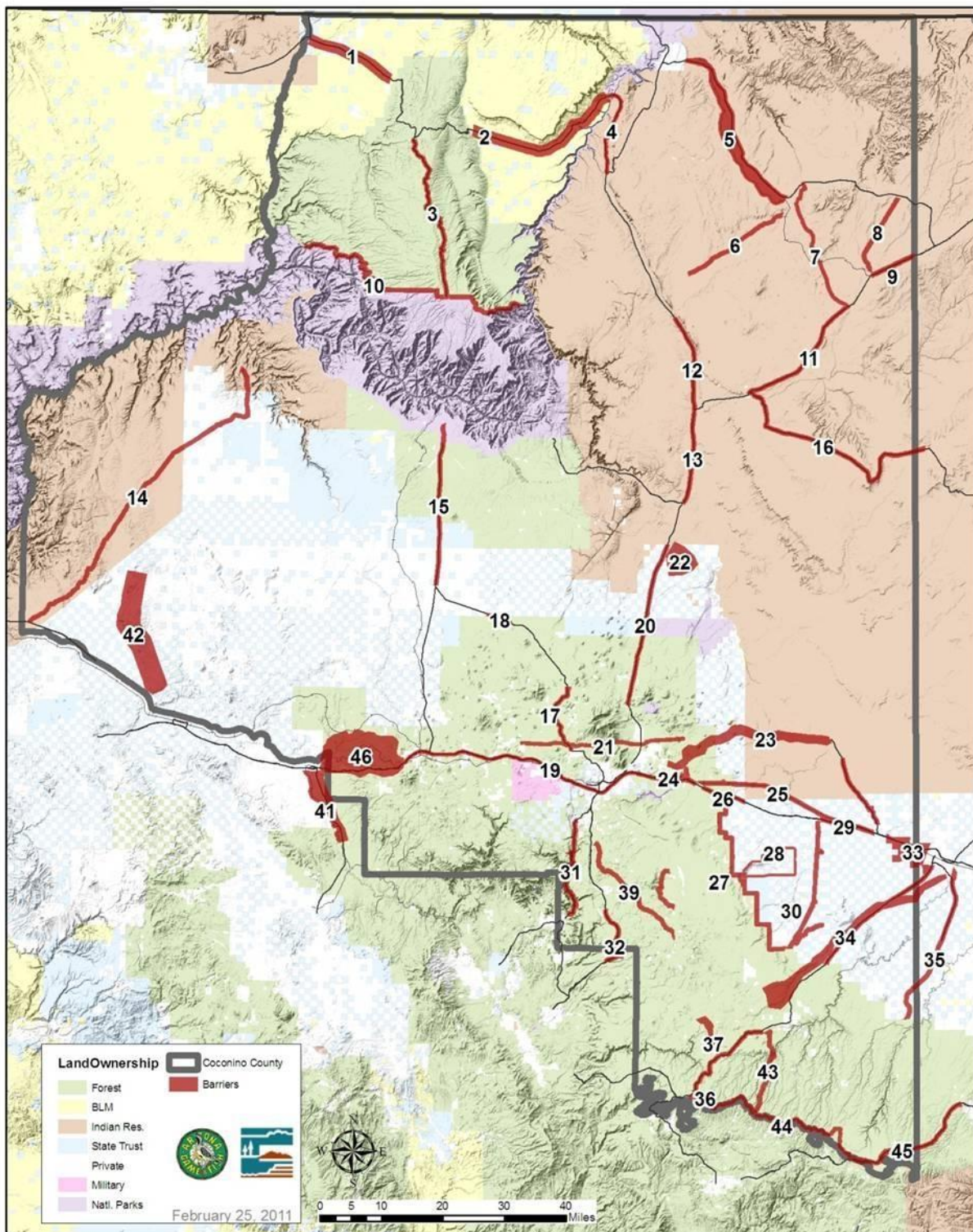
**Figure 9.** South-central Coconino County stakeholder-drawn linkages and barriers to wildlife movement





**Figure 10.** Southern Coconino County stakeholder-drawn linkages and barriers to wildlife movement





**Figure 11.** Coconino County stakeholder-drawn barriers to wildlife movement

## WILDLIFE LINKAGE DESCRIPTIONS

### Northern Coconino County wildlife linkages (See Figure 6)

#### 1. Hurricane Rim - Aubrey Cliffs

Habitat Blocks Connected: Piñon-juniper/short-grass prairie
Species Identified: Mule deer, raptors, migratory birds, bats
Current Threats/Barriers: Invasive species, uranium exploration, off-highway vehicle use, St. George Pipeline, existing powerline, county roads, future wind development
Notes: Functions as a north-south migratory path connecting Utah to Aubrey Cliffs for raptors, birds, bats. Some east-west pronghorn movement between game units 13A&B. Proposed bighorn sheep habitat area on extreme north end near Cottonwood and Rock Canyons.

#### 2. North Grand Canyon National Park – South Rim

Habitat Blocks Connected: Desert scrub/piñon-juniper on BLM, NPS, and tribal lands through side canyons
Species Identified: Mule deer, raptors, migratory birds, bats
Current Threats/Barriers: Invasive species, uranium exploration and mining, off-highway vehicle use, county roads, future wind development
Notes: Functions as a seasonal migration corridor, connecting mule deer winter range to the northeast with summer range to the southwest. These canyons and cliffs are large geographic features, funneling migration of raptors, birds, and bats north to south.

#### 3. Kaibab Plateau – Paunsaugunt Plateau, Utah

Habitat Blocks Connected: North Kaibab piñon-juniper/grassland
Species Identified: Mule deer, pronghorn, Siler pincushion cactus, golden eagle, bald eagle, California condor
Current Threats/Barriers: Lake Powell Pipeline, Highway 89A, off-highway vehicle use, potential wind development, potential mining, exotic species (cheatgrass, Russian thistle), shrub/tree encroachment
Notes: Paunsaugunt mule deer seasonal migration corridor - Utah summer range to Buckskin/Northern Kaibab Winter Range. Mule deer and pronghorn cross 89; Austin identified important Siler pincushion cactus area along 89.

#### 4. Buckskin Mountains – Antelope Valley

Habitat Blocks Connected: Sagebrush flats
Species Identified: Pronghorn
Current Threats/Barriers: Ryan Road, potential dam development
Notes: Johnson Wash herd moves from 13A to 12B across Highway 89A.

## **5. House Rock Valley - Utah**

Habitat Blocks Connected: House Rock Valley sagebrush
Species Identified: Pronghorn, Sentry milk vetch
Current Threats/Barriers: Highway 89, water development
Notes: Functions as a seasonal migration corridor. Pronghorn only cross via the Hwy 89 underpass. Culvert upgrades could benefit herpetofauna and small mammals.

## **6. Utah – San Francisco Peaks**

Habitat Blocks Connected: Piñon-juniper, sagebrush, desert, grassland along valleys, canyons, edges of cliffs/plateaus
Species Identified: Raptors, bats
Current Threats/Barriers: Powerlines, increasing off-highway vehicle use, proposed wind and solar developments, exotic species (cheatgrass, Russian thistle, snakeweed)
Notes: Functions as a migratory flyway for avian species.

## **7. Vermillion Cliffs – Echo Cliffs – White Plateau Area**

Habitat Blocks Connected: Mountain cliffs
Species Identified: Bighorn sheep, California condor
Current Threats/Barriers: Highway 89, road widening
Notes: Bighorn sheep use Soap Creek, Badger Creek, Cathedral Wash and cross all three stretches of 89. Culvert construction during highway improvements could benefit herpetofauna and small mammals.

## **8. Marble Canyon**

Habitat Blocks Connected: Grand Canyon National Park to Vermillion Cliffs
Species Identified: Bighorn sheep, California condor
Current Threats/Barriers: Tamarisk
Notes: Tamarisk congestion in waterways especially affects bighorn sheep.

## **9. Echo Cliffs – Eminence Break**

Habitat Blocks Connected: Rocky cliffs and elevational transitions
Species Identified: Bighorn sheep, California condor
Current Threats/Barriers: Highway 89 expansion, fencing
Notes: Provides for movement through elevational transitions

#### 10. Espee-Cataract - Kaibab National Forest

Habitat Blocks Connected: Grasslands
Species Identified: Pronghorn
Current Threats/Barriers: Urban development, proposed wind development
Notes: Functions as a seasonal migration corridor. GPS data are available for north-south pronghorn movement, planned restoration and fence improvements.

#### 11. Aubrey Valley/Aubrey Cliffs – South of Hwy 66

Habitat Blocks Connected: Grasslands and piñon-juniper woodland
Species Identified: Elk, deer, mountain lion, black bear, Gunnison's prairie dog
Current Threats/Barriers: Potential wind development, Railroad, Hwy 66, I-40 and associated double fencing, urban development, potential solar development, cement/lime plant construction
Notes: Roadkills recorded for mountain lion and bear; telemetry data exist for elk.

#### 12. South Rim – San Francisco Peaks – Woody Ridge/Bellemont Area

Habitat Blocks Connected: Canyons and conifer forest to grasslands
Species Identified: Sentry milkvetch, mule deer, elk, Gunnison's prairie dog
Current Threats/Barriers: Hwy 64, development in foothills on north side of the Peaks along FR 418, I-40
Notes: Functions as a seasonal migration corridor. GPS data show important highway crossing areas (see Dodd et al. 2010). Prairie dog dog movement especially between Peaks and Camp Navajo.

#### 13. Coconino Plateau

Habitat Blocks Connected: Grasslands, conifer woodlands, and conifer forest
Species Identified: Elk, mule deer, pronghorn
Current Threats/Barriers: Hwy 64
Notes: GPS data describe at least three pathways for pronghorn and important highway crossing areas.

#### 14. Grasslands south of Valle – I-40

Habitat Blocks Connected: Private/State grasslands
Species Identified: Pronghorn
Current Threats/Barriers: Development, fencing, roads
Notes: Functions as a seasonal migration corridor. Based on pronghorn telemetry data (see Dodd et al. 2010).

### **15. Wupatki National Monument – Navajo Reservation**

Habitat Blocks Connected: Piñon-juniper woodland, grasslands, desert scrub across Little Colorado River
Species Identified: Pronghorn, small mammals, herpetofauna
Current Threats/Barriers: Little Colorado River (for some species)
Notes: Black Falls Dam currently has good riparian habitat. See Dodd et al. 2009 for pronghorn movement data.

## Central Coconino County wildlife linkages (See Figure 7)

### 16. Garland Prairie – Wagon Tire Flat

Habitat Blocks Connected: Grassland, ponderosa pine, riparian
Species Identified: Pronghorn, golden eagle, mule deer, mountain lion
Current Threats/Barriers: Fencing along FR 73 between Dogtown and Bill Williams Mountain
Notes: Functions as a seasonal migration corridor. Telemetry-based. Muldoon and MC Canyons are important riparian segments within the corridor.

### 17. Grassland north and east of San Francisco Peaks - east of Anderson Mesa

Habitat Blocks Connected: Grasslands
Species Identified: Pronghorn, Gunnison's prairie dog, jackrabbit, golden eagle, milksnakes, birds, bats
Current Threats/Barriers: Hwy 89A, Leupp Rd, Meteor Crater Rd, FR 69, grazing and shrub encroachment, planned Red Gap pipeline, Grapevine wind development, BSNF Railroad, State Lands
Notes: Currently little or no connectivity for pronghorn across I-40 or Hwy 89

### 18. Fues Hill – Threemile Lake

Habitat Blocks Connected: Conifer forest to intermittent wetland
Species Identified: Pronghorn, mule deer, elk
Current Threats/Barriers: Grand Canyon Railroad
Notes: None.

### 19. Dog Knobs - Ebert Mountain - Government Prairie

Habitat Blocks Connected: Piñon-juniper woodland, ponderosa pine forest, grassland
Species Identified: Pronghorn, mule deer, black bear, mountain lion
Current Threats/Barriers: Hwy 180, fencing
Notes: Specific pronghorn movement areas identified within the linkage, Hwy 180 mountain lion crossings verified



## **20. Mesa Butte – Kendrick**

Habitat Blocks Connected: Ponderosa pine forest to grasslands
Species Identified: Mountain lion, elk, pronghorn
Current Threats/Barriers: Highway 180
Notes: Confirmed mountain lion movements across Hwy 180; mule deer and pronghorn movement areas identified within linkage.

## **21. Garland Prairie – Government Prairie/Government Hills**

Habitat Blocks Connected: Grassland, ponderosa pine
Species Identified: Pronghorn, mule deer, black bear, turkey, elk
Current Threats/Barriers: Roads, railroad, urban development, I-40
Notes: Inner fence at Camp Navajo shunts black bear movement around base. Elk migrate seasonally both east-west and north-south. Seasonal movements for many species through Sycamore Canyon.

## **22. Walnut Canyon – Anderson Mesa – Antelope Park/Mormon Mountain**

Habitat Blocks Connected: Riparian washes and canyons, surrounding uplands, mesa wetlands
Species Identified: Mountain lion, elk, mule deer, black bear, northern goshawk, Mexican spotted owl, neotropical migratory birds, turkey, northern leopard frog, bats, bald eagle, peregrine falcon, tarantula, gray fox, raccoon, coyote, small mammals, bull snakes
Current Threats/Barriers: Lake Mary Rd, recreation, crayfish invasion
Notes: Cherry Canyon to northeast of Marshall Lake is an important corridor within, as is all of Walnut Canyon. GPS movement data available for pronghorn. Ungulates also move daily to water.

## **23. Youngs and Mormon/Padre Canyons Area**

Habitat Blocks Connected: Summer to winter range for ungulates
Species Identified: Pronghorn, elk, mule deer, white-tailed deer
Current Threats/Barriers: Recreation
Notes: Ungulates move broadly through this whole area; deer primarily use canyon features.

## **24. GMU6B block of Barney Pasture - Turkey Butte - Casner Mountain - Sycamore Pass**

Habitat Blocks Connected: Ponderosa pine/oak habitat (Turkey Butte), chaparral, chaparral-savanna, and juniper-piñon/savanna habitats (Sycamore Pass)
Species Identified: Mule deer, white-tailed deer, elk, black bear, pronghorn
Current Threats/Barriers: OHV use and other recreation
Notes: Functions as a seasonal migration corridor. North-south movement for ungulates. Black bear and pronghorn use documented with telemetry data.

## **25. Mormon Mountain – Hutch Mountain**

Habitat Blocks Connected: Bar-M Watershed ponderosa pine/oak forest
Species Identified: Mexican spotted owl, forest bats, wintering bald eagle, northern leopard frog, other amphibians
Current Threats/Barriers: High-severity landscape-level fire, forest restoration treatments, Lake Mary Rd
Notes: None.

## **26. Ashurst/Kinnikinick – Mormon Lake**

Habitat Blocks Connected: Permanent and ephemeral lakes and wetlands
Species Identified: Tiger salamander, northern leopard frog, other amphibians
Current Threats/Barriers: OHV use, Lake Mary Rd
Notes: Mass migration of over 1,000 tiger salamanders in late summer

## **27. Kendrick – Spring Valley Knolls/Government Hill/Government Prairie**

Habitat Blocks Connected: Ponderosa pine and relic grasslands
Species Identified: Pronghorn, black bear
Current Threats/Barriers: Forest roads
Notes: None.

## **28. East of Kendrick – Government Hills**

Habitat Blocks Connected: Ponderosa pine, grasslands
Species Identified: Pronghorn
Current Threats/Barriers: Roads, development, recreation
Notes: None.

## **29. Kendrick – Hochderffer Hills**

Habitat Blocks Connected: Ponderosa pine forest and subalpine forest
Species Identified: Black bear, elk, Mexican spotted owl
Current Threats/Barriers: Highway 180
Notes: None.

### 30. San Francisco Peaks – North of the Peaks

Habitat Blocks Connected: Peaks to grasslands north of the Peaks
Species Identified: Mountain lion, pronghorn, elk, mule deer, black bear, badger, northern goshawk, Mexican spotted owl, Gunnison's prairie dog, turkey, northern leopard frog, Mexican vole, bats, neotropical migratory birds
Current Threats/Barriers: FR 418, OHV use of illegal trails, traffic on FR 151, recreation
Notes: Provides for movement through elevational transitions

### 31. San Francisco Peaks – Mount Elden/Timberline

Habitat Blocks Connected: Subalpine forest, ponderosa pine/mixed conifer forest
Species Identified: Mountain lion, deer, bear, northern goshawk, Mexican spotted owl, Gunnison's prairie dog, turkey, bats, neotropical migratory birds
Current Threats/Barriers: Illegal OHV trails, traffic on Schultz Pass Rd, recreation
Notes: Provides for movement through elevational transitions

### 32. San Francisco Peaks – Sunset Crater and O'Leary Peak

Habitat Blocks Connected: Subalpine meadows and forest with low-elevation woodlands, forest, and meadows
Species Identified: Elk, northern goshawk, mountain lion
Current Threats/Barriers: Mining, off-highway vehicle use, urban development, Sunset National Monument entrance road, Hwy 89
Notes: Mountain lion telemetry data available.

### 33. San Francisco Peaks - Observatory Mesa - Bellemont

Habitat Blocks Connected: Conifer forest to meadows around Bellemont
Species Identified: Elk, mountain lion, mule deer, badger, Gunnison's prairie dog
Current Threats/Barriers: I-40, urban and suburban development
Notes: Functions as a seasonal migration corridor. Existing highway culverts are currently poorly functioning for wildlife connectivity

### 34. Elden Springs Road – Cinder Lake Landfill

Habitat Blocks Connected: Ponderosa pine forest through grasslands
Species Identified: Mule deer, mountain lion, striped skunk, raccoon, gray fox, coyote
Current Threats/Barriers: Hwy 89 current use and future widening, OHV use, Timberline development, Timberline Trail development and trailhead at Elden Springs Rd
Notes: None.

## Flagstaff Area wildlife linkages (See Figure 8)

### 35. Hwy 180 Meadows

Habitat Blocks Connected: Open meadows north and south of Hwy 180 on state-private checkerboard
Species Identified: Gunnison's prairie dog, ferruginous hawks, burrowing owls, other meadow species
Current Threats/Barriers: Hwy 180, development
Notes: Connectivity is important for metapopulation colony dynamics

### 36. San Francisco Peaks – Woody Ridge

Habitat Blocks Connected: Peaks to the Mogollon Rim
Species Identified: Pronghorn, mountain lion, elk, mule deer, black bear, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican vole, bats, raptors
Current Threats/Barriers: Hwy 180, I-40, urban and suburban development, recreation
Notes: None.

### 37. Elden Foothills

Habitat Blocks Connected: Mt. Elden ponderosa pine to lower elevation foothills
Species Identified: Mountain lion, mule deer, bats
Current Threats/Barriers: Urban and suburban development, recreation, illegal mountain bike trail use
Notes: Provides for movement through elevational transitions

### 38. Turkey Hills - Picture Canyon (Rio de Flag) - Elden Pueblo

Habitat Blocks Connected: Ponderosa pine forest and riparian habitat
Species Identified: Elk, mule deer, turkey, bald eagle, peregrine falcon, neotropical migratory birds, porcupine, bats, Gunnison's prairie dog, bats
Current Threats/Barriers: Rural development, OHV recreation
Notes: All species use Picture Canyon – Turkey Hills. Elden Pueblo to Turkey Hills particularly serves mule deer.

### 39. Rio de Flag

Habitat Blocks Connected: Patchy riparian habitats in the Rio de Flag throughout Flagstaff (Museum of Northern Arizona, Francis Short Pond, I-40 Wetlands, Picture Canyon, etc)
Species Identified: Neotropical migratory birds, waterfowl, bald eagle, bats
Current Threats/Barriers: Hwy 89 current use and future widening, OHV use, Timberline development, Timberline Trail development and trailhead at Elden Springs Rd
Notes: Functions as a riparian stepping stone (non-contiguous) corridor.

#### 40. Woody Ridge

Habitat Blocks Connected: San Francisco Peaks foothills and Woody Ridge to the Mogollon Rim
Species Identified: Pronghorn, mountain lion, black bear, elk, mule deer, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican voles, bats
Current Threats/Barriers: Highway I-40, traffic and recreation along Woody Mountain Rd (FR 231), some fuels reduction treatments
Notes: I-40 telemetry data should inform this linkage.

#### 41. Rogers Lake – Volunteer Canyon

Habitat Blocks Connected: Seasonal lake and meadows to Camp Navajo ponderosa pine and mixed conifer forest
Species Identified: Elk, pronghorn, deer, turkey, black bear, mountain lion, northern leopard frog, bald eagle, bats, Gunnison's prairie dog
Current Threats/Barriers: Recreation, military training
Notes: Coconino County acquired Rogers Lake as open space in 2010.

#### 42. Dry Lake – Rogers Lake

Habitat Blocks Connected: Ephemeral lake and wetland habitats
Species Identified: Pronghorn, elk, mule deer, black bear, turkey, Mexican spotted owl, bald eagle, Gunnison's prairie dog, northern goshawk, northern leopard frog, Mexican vole, neotropical migratory birds, bats
Current Threats/Barriers: Suburban development, recreation, traffic on Woody Mountain Road
Notes: Coconino County acquired Rogers Lake as open space in 2010.

#### 43. Bow and Arrow

Habitat Blocks Connected: Patches of habitat in Bow and Arrow Wash
Species Identified: Neotropical migratory birds, bats, striped skunk
Current Threats/Barriers: Urban and suburban development, Lake Mary Rd, Lone Tree Rd, invasive plants
Notes: Functions as a stepping stone (non-contiguous) corridor

#### 44. Hoffman Tank Area

Habitat Blocks Connected: Rio de Flag to Walnut Canyon
Species Identified: Neotropical migratory birds, Gunnison's prairie dog, bats, elk
Current Threats/Barriers: Suburban and rural development, invasive plants
Notes: None.

#### 45. Peaceful Valley – Campbell Mesa

Habitat Blocks Connected: Rio de Flag to Walnut Canyon
Species Identified: Bald eagle, neotropical migratory birds, Gunnison's prairie dog, elk, mule deer, porcupine, bats
Current Threats/Barriers: Suburban development, recreation
Notes: None.

#### **46. Rio de Flag – Walnut Canyon**

Habitat Blocks Connected: Picture Canyon area to Walnut Canyon
Species Identified: Mountain lion, bald eagle, northern goshawk, neotropical migratory birds
Current Threats/Barriers: I-40 expansion
Notes: None.

#### **47. Sycamore Canyon**

Habitat Blocks Connected: Ponderosa pine and mixed conifer forest, chaparral
Species Identified: Elk, mule deer, white-tailed deer, javelina, black bear, mountain lion, Mexican spotted owl, peregrine falcon, Rocky Mountain bighorn sheep
Current Threats/Barriers: Recreation
Notes: As a wilderness area, Sycamore Canyon is relatively protected. However, habitat improvement that includes browse restoration could improve habitat.

#### **48. Black Pass**

Habitat Blocks Connected: Woody Ridge to Mogollon Rim
Species Identified: Pronghorn, mountain lion, elk, mule deer, black bear, badger, northern goshawk, Gunnison's prairie dog, Mexican spotted owl, neotropical migratory birds, turkey, leopard frog, Mexican vole, bats
Current Threats/Barriers: State Route 89A, recreation, some fuels reduction treatments
Notes: None.

#### **49. Sinclair Wash**

Habitat Blocks Connected: Riparian patches
Species Identified: Neotropical migratory birds, bats
Current Threats/Barriers: Urban/suburban/commercial development, Milton Avenue, Beulah Road, Interstate 40, invasive plants, trash, stormwater
Notes: Functions as a riparian stepping stone (non-contiguous) corridor

#### **50. Oak Creek Canyon**

Habitat Blocks Connected: Sycamore Canyon to Pumphouse Wash through riparian/canyon habitat, ponderosa pine/chaparral/mixed conifer
Species Identified: White-tailed deer, black bear, javelina, elk
Current Threats/Barriers: Highway 89A, recreation
Notes: Forest Highlands elk herd crosses 89A (east-west daily and north-south seasonally). Specific crossing locations have been identified.

#### **51. Schoolhouse Draw - Pumphouse Wash and Fry Canyon**

Habitat Blocks Connected: Coconino National Forest lands north of Mountaineer to Pumphouse Wash
Species Identified: Mountain lion, elk, deer, black bear, hawks, Gunnison's prairie dog, Mexican spotted owl, waterfowl, bald eagle, neotropical migratory birds, turkey, leopard frog, bats
Current Threats/Barriers: I-17 and Hwy 89, suburban/rural development, OHV use on illegal trails, recreation and traffic along FR 237
Notes: Black bear normally move E-W through Fry Canyon. See Gagnon et al. 2011 for elk movement data.

#### **52. Mexican Pocket/Pumphouse Wash – Village of Oak Creek**

Habitat Blocks Connected: Ponderosa pine and pine-oak forest
Species Identified: Turkey, black bear, elk, mule deer, mountain lion, Abert's squirrel, Mexican spotted owl
Current Threats/Barriers: Summer dispersed camping, off-highway vehicle use, State Route 89A, forest thinning
Notes: Corridor is primarily riparian/canyon habitat.

#### **53. Newman Park – Willard Springs**

Habitat Blocks Connected: Open meadows
Species Identified: Arizona black rattlesnake, elk, reptiles
Current Threats/Barriers: I-17, shooting range
Notes: Snake populations near Willard Springs are a particular concern. See Gagnon et al. 2011 for elk movement data.

#### **54. Pumphouse Wash – Munds Canyon**

Habitat Blocks Connected: Interior chaparral through ponderosa pine forest
Species Identified: Elk, mule deer, turkey
Current Threats/Barriers: Off-highway vehicle use
Notes: North-South movement is diffuse throughout the linkage. See Gagnon et al. 2011 for elk movement data.

## South-central Coconino County wildlife linkages (See Figure 9)

### 55. Anderson Mesa Summer – Winter Range

Habitat Blocks Connected: Anderson Mesa to lower elevation grassland habitat off the Mesa
Species Identified: Pronghorn, elk
Current Threats/Barriers: Fencing, proposed wind development, conifer encroachment
Notes: Functions as a seasonal migration corridor. Pronghorn telemetry data used. Elk primarily travel through canyons.

### 56. Robber's Roost/Dutch Tank Area – Mormon Lake Area

Habitat Blocks Connected: Transitional oak habitat
Species Identified: Turkey, elk, javelina
Current Threats/Barriers: I-17
Notes: Functions as a seasonal migration corridor. Turkey do not commonly cross the highway.

### 57. White Mesa – North of Rocky Park – Rattlesnake Quiet Area

Habitat Blocks Connected: Ponderosa pine/mixed conifer, transitional oak habitat
Species Identified: Mule deer, elk, turkey, pronghorn, frogs, snakes
Current Threats/Barriers: FR 213
Notes: Known turkey travel-ways identified within corridor.

### 58. Stoneman Lake Area – Happy Jack/Jacks Canyon

Habitat Blocks Connected: Wetlands and piñon-juniper woodlands to ponderosa pine forest
Species Identified: Mule deer, elk, turkey, pronghorn, frogs, snakes, tiger salamander
Current Threats/Barriers: FR 213, crayfish and non-native fishes, off-highway vehicle use, Lake Mary Rd
Notes: Mass migration for tiger salamanders from Stoneman Lake occurs in late summer. This is an important area for elk-vehicle collisions.

### 59. Hutch/Pine/Turkey Mountains – Jacks Canyon/Chavez Mountain/Grapevine Canyon

Habitat Blocks Connected: Summer to winter range for turkey and pronghorn
Species Identified: Turkey, pronghorn, elk, bald eagle, mountain lion, bobcat, fox, javelina, mule deer
Current Threats/Barriers: Roads, fencing
Notes: Functions as a seasonal migration corridor. Telemetry data describes specific pronghorn movement on Anderson Mesa.



## **Southern Coconino County wildlife linkages (See Figure 10)**

### **60. East Sunset – West Sunset**

Habitat Blocks Connected: Piñon-juniper grasslands
Species Identified: Elk, mule deer
Current Threats/Barriers: Hwy 87
Notes: None.

### **61. Clear Creek Canyon**

Subtype: Canyon/riparian corridor
Habitat Blocks Connected: Piñon-juniper grasslands, washes and canyons
Species Identified: Pronghorn
Current Threats/Barriers: Development, the canyon is a barrier for some species
Notes: Pronghorn cross especially at Sheep's Crossing (T16R13S13) and development on either side of Sheep's Crossing is a major concern.

### **62. Diversion Park – Cedar Flats**

Habitat Blocks Connected: Summer to winter range for pronghorn
Species Identified: Pronghorn
Current Threats/Barriers: Roads, fencing
Notes: Functions as a seasonal migration corridor.

### **63. Bargaman Park – Buck Mountain Area**

Habitat Blocks Connected: Summer to winter range for pronghorn
Species Identified: Arizona black rattlesnake, elk, deer, pronghorn
Current Threats/Barriers: Lake Mary Rd, off-highway vehicle use, powerline
Notes: Functions as a seasonal migration corridor. Important area for rattlesnake roadkill and ungulate-vehicle collisions.

### **64. Willow Valley – Buck Mountain**

Habitat Blocks Connected: Ponderosa pine forest
Species Identified: Mule deer, elk, Mexican spotted owl, bats
Current Threats/Barriers: Invasive species (crayfish, toadflax), off-highway vehicle use
Notes: None.

**65. Turkey Draw – Mahan Park/Buck Mountain/Buck Butte**

Habitat Blocks Connected: Summer to winter range for turkey
Species Identified: Turkey
Current Threats/Barriers: None identified
Notes: Functions as a seasonal migration corridor.

**66. Blue Ridge**

Habitat Blocks Connected: Mixed conifer, ponderosa pine
Species Identified: Black bear, turkey, elk
Current Threats/Barriers: Hwy 87
Notes: Black bear move across the highway primarily through Little Spring Canyon. Based on roadkill data.

**67. Long Lake Area – East Clear Creek**

Habitat Blocks Connected: Long Lake/Soldier Lake to the Mogollon Rim
Species Identified: Elk, eagles, deer, turkey
Current Threats/Barriers: Crayfish, small gravel mining operation, off-highway vehicle use, kV power line to Winslow, potential wind energy development, urban development by Starlight Pines, Hwy 87
Notes: None.

**68. Blue Ridge Reservoir/Clear Creek – Mogollon Rim**

Habitat Blocks Connected: Mogollon Rim riparian vegetation
Species Identified: Mexican spotted owl, black bear, bats, neotropical migratory birds
Current Threats/Barriers: Crayfish, SRP pipeline to Payson, power development, Lake Mary Rd
Notes: Primarily a riparian/canyon corridor

**69. West Clear Creek – Fossil Springs Wilderness**

Habitat Blocks Connected: Riparian/canyon habitats and conifer forest
Species Identified: White-tailed deer, mule deer, elk, black bear, javelina, turkey, mountain lion
Current Threats/Barriers: Hwy 260
Notes: North-south movement for many species; roadkills documented along Hwy 260.

#### **70. West Clear Creek – Dirtyneck Canyon**

Habitat Blocks Connected: Riparian habitat and ponderosa pine forest canyons
Species Identified: Mule deer, elk, black bear, neotropical migratory birds, raptors, bats
Current Threats/Barriers: Hwy 87
Notes: Mule deer move east-west, while elk and black bear follow Clover and Dirtyneck Canyons.

#### **71. East Clear Creek – Potato Lake**

Habitat Blocks Connected: Ponderosa pine canyons and ridgelines
Species Identified: Mexican spotted owl, black bear, bats, neotropical migratory birds
Current Threats/Barriers: Crayfish, SRP pipeline to Payson, power development, Forest Service roads
Notes: None.

#### **72. Mogollon Rim – Mogollon Plateau**

Habitat Blocks Connected: West Chevelon Canyon and Aspen Creek from the Rim through National Forest lands
Species Identified: Mexican spotted owl, black bear, bats, neotropical migratory birds, elk, spinedace, native suckers
Current Threats/Barriers: Invasive species, rural development, climate/drought and water levels
Notes: Riparian/canyon corridor

#### **73. Chevelon Canyon**

Habitat Blocks Connected: Mogollon Rim to Mogollon Plateau through Chevelon Canyon
Species Identified: Black bear, elk, deer, Mexican spotted owl
Current Threats/Barriers: Hwy 260, road development associated with Forest Lakes
Notes: Canyon/riparian corridor

## IDENTIFIED BARRIERS TO WILDLIFE MOVEMENT

### 1. US Highway 89: Fredonia – Kaibab National Forest

Important area for Siler pincushion cactus. Scenic roadways being developed; culvert upgrades could benefit herpetofauna and small mammals (e.g. kangaroo rat).

### 2. US Highway 89A: House Rock – Marble Canyon

Highway crosses Colorado River, Navajo Bridge on East to foot of Kaibab Plateau

### 3. State Highway 67: Jacob Lake – North Rim Entrance, Grand Canyon National Park

ADOT and USFS are in discussions over highway fencing, which would impede mule deer movement. ADOT staff have observed turkey in Le Fevre Fire/outlook treatment area (South of Le Fevre ~5 miles).

### 4. US Highway 89: Marble Canyon - Bitter Springs

Highway culvert upgrades and maintenance are opportunities to improve connectivity for herpetofauna and small mammals.

### 5. State Highway 98 & Peabody Railroad: Navajo Reservation boundary – Kaibito

### 6. N-21 Road: BIA Highway 20 - Peabody Railroad

This is currently partially paved, but is to be fully paved in the future.

### 7. BIA Road 21: Tonalea - Kaibito

This is currently a dirt road, but is to be paved in the future.

### 8. N-16 Road: BIA Highway 98 – Railroad at Cow Springs

### 9. Railroad Segment northeast of Tonalea

Highway 160 will be expanded to four lanes.

### 10. Grand Canyon National Park – North Kaibab National Forest fence boundary

Mule deer move north across the barrier near Bright Angel Creek and north-west across 107 near Shinumo Creek.

### 11. US Highway 160: Red Lake - Tuba City

Highway 160 will be expanded to four lanes.

**12. US Highway 89: BIA 20 Road - Highway 160**

Highway 89 may be expanded to four lanes. See Dodd et al. 2009 for pronghorn movement data.

**13. Highway 89: Highway 160 - State Route 64**

Mule deer move north across the barrier near Bright Angel Creek and north-west across 107 near Shinumo Creek.

**14. Hualapai Hilltop Highway: Route 66 – Hualapai Hilltop**

Currently not a substantial barrier, however any upgrades or fencing could cause future problems.

**15. State Highway 64: Grand Canyon - Valle**

ADOT is funding a study of elk, mule deer, and pronghorn in this area and have committed to incorporating passage structure during the impending rebuild. Pronghorn and badger cross between MP 218 and MP 220; mule deer and pronghorn cross between MP 222 and MP 227; elk and mule deer cross between MP 231 and MP 233. See Dodd et al. 2010 for further information.

**16. State Highway 264: Moenkopi – Mile Post 362**

**17. US Highway 180: Flagstaff – Deadman Flat Rd**

Important for ungulate movement

**18. US Highway 180: MP 251 – MP 256**

Barrier to pronghorn movement.

**19. Interstate 40: Williams – Townsend Winona Rd**

Barrier to numerous species. Potential for highway upgrades and urban development. Movement data is being collected for big game species.

**20. US Highway 89A: MP 430 – MP 457**

Barrier to multiple species including pronghorn, Gunnison's prairie dog, and jackrabbit. Highway 89A is a proposed travel corridor to Utah and surrounding State Trust lands could be developed. There is a ten-year plan to widen the highway from Cameron to the existing four-lane segment.

**21. El Paso Pipeline**

Only a portion of the pipeline is shown on the map. It is 100' wide, buried, and graded. Revegetation has only been in the last 40-50 years and trees will not be allowed to establish there. The pipeline is currently not fenced

**22. Gray Mountain Wind Farm (proposed)**

Potential development on Navajo lands.

**23. Leupp Road**

Fragments pinon-juniper woodlands on Coconino National Forest for elk, pronghorn, mule deer, and bats.

**24. Interstate 40 and Railroad intersection**

Fragments habitat for elk, pronghorn, and mule deer. Surrounding private property could be developed and/or highway improvements could occur.

**25. Canyon Diablo Railroad**

Existing permeability across I-40 is good, but could be improved.

**26. Interstate 40 across Padre Canyon**

Barrier to pronghorn, bald eagle, jackrabbit, bobcat, mountain lion. Potential for further development around Twin Arrows.

**27. Forest Service boundary fence**

Barrier to species using Forest and adjacent private/state lands.

**28. Raymond Ranch Fence**

Buffalo fencing is a pronghorn barrier.

**29. Interstate 40: Meteor Crater Rd – Leupp Rd**

I-40 to be expanded.

**30. Meteor Crater Road and Chavez Pass Road**

Upgrades to Meteor Crater Rd would likely impact milksnake populations.

**31. State Highway 89A: I-17 – Oak Creek Canyon**

The highway and the creek itself are barriers to movement by a number of species. Highway improvements could increase permeability. Narrow-headed gartersnakes occur here. Recreation and sedimentation are further threats to wildlife connectivity.

**32. Interstate 17: MP 307 – MP319**

ADOT is funding an elk movement study to determine best areas for crossings. The highway crosses a migratory route for elk and mule deer (see Gagnon et al. 2011 for movement data). Bald eagle are found here in high numbers and are susceptible to roadkill.

**33. Interstate 40 and Tucker Flat**

Potential for further development of both the highway and the community.

**34. State Highway 87: Winslow – Jacks Canyon**

High volume collision area for elk. Pronghorn very rarely cross.

**35. State Highway 99: Winslow – Mormon Crossing**

Potential for expansion or fencing.

**36. State Highway 87: Clint's Well – MP 282**

Species include Mexican spotted owl, elk, and bats.

**37. State Highway 87: MP 299 – Clint’s Well**

Important wildlife crossing. Black bear are killed yearly; turkey and elk cross at Spring Hill just North of Blue Ridge Reservoir turn off.

**38. Mormon Lake Road**

This is probably not a major barrier for large animals, however tiger salamanders and frogs need to disperse from Mormon Lake. Road improvements could enhance connectivity for amphibians.

**39. Forest Service 700 Road**

Barrier to movement for tiger salamanders and other amphibians, elk,

**40. Lake Mary Road: Willow Valley – Clint’s Well**

Important wildlife crossing for mule deer, elk (large herds), Mexican spotted owl, bats. Potential for development around Clint’s Well area.

**41. US Highway 89 and Railroad: Ashfork – MP 351**

Highway expansion could occur as population grows in the area.

**42. Aubrey Valley: Potential Wind Development**

Wind development has been proposed for the Aubrey Valley area.

**43. Forest Highways 95 & 139: Highway 87 – Mogollon Rim**

Barrier for Mexican spotted owl, bats, neotropical migratory birds, and other riparian/canyon species.

**44. Rim Road (Forest Road 300)**

The Apache-Sitgreaves National Forest has discussed paving the Rim Road, which would likely increase the traffic volume.

**45. State Highway 260: Rim Road – Heber**

Important crossing area for black bear, elk, and deer. Highway expansion proposed.

**46. Interstate 40 and Route 66: Ashfork – Williams**

Telemetry data has been collected for elk; roadkill information available for mountain lion, black bear.

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## APPENDIX 1 – SAMPLE DATASHEET USED IN STAKEHOLDER WORKSHOPS

# COCONINO COUNTY LINKAGE DATASHEET NORTH (100)

Your name(s) \_\_\_\_\_

Linkage number: \_\_\_\_\_

Linkage description (Please try to describe the areas being connected as much detail as possible):

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**What are the main threats to the linkage?** Use a separate line for each major paved road crossing the linkage.

**\*\* 1 is least severe and 5 is most severe\*\***

Threat	Severity (1-5)**	Details (Describe the type of threat, area impacted, etc.)
Agriculture (grazing, farming)		
Exotic species invasion		
Canals (with names)		
Mining		
OHV Use		
Pipeline		
Powerline		
Wind energy development		
Solar energy development		
Uranium mining		
Railroad		
High Density Residential Dev.		
Low Density Residential Dev.		
Industrial/Commercial Dev.		
Paved road (with name)		
Paved road (with name)		
High Traffic Gravel Road (with name)		

**Describe federal, state, or local support for conserving the linkage** (willing land sellers, agencies interested in acquisition, formal conservation planning for the linkage, etc.)

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If you have information you would prefer not appear in print but that you are willing to discuss, provide your name and contact information.

Provide details on FUTURE or PROPOSED road or development projects.

Name of Project	Road/Hwy Description (e.g., realign 20 mile of existing road, 2 lanes each way) Development description (e.g., 20,000 new homes, plus commercial and industrial areas)	Entitled or Platted?	Funded?	Est. start date	Env. review completed?	Contact person, affiliation (e.g., "John Doe, ADOT PHX")
		Yes/No	Yes/No		Yes/No	
		Yes/No	Yes/No		Yes/No	
		Yes/No	Yes/No		Yes/No	

Provide any other helpful information (e.g., location, number, and size of key parcels in the linkage, ongoing restoration projects in the linkage, etc.).


Key contacts for this linkage: Please provide the names of one or more persons we can contact for additional information and future planning efforts.

Name	Affiliation	Phone	Email