

Arizona CorridorDesigner Toolbox Documentation

corridordesign.org



v 0.001

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Credits

The CorridorDesigner project is funded by a generous grant from the Environmental Research, Development and Education for the New Economy (ERDENE) initiative from Northern Arizona University.

Our approach was initially developed during 2001-2006 for South Coast Missing Linkages, a set of 16 linkage designs in southern California (draft & final designs at scwildlands.org). Kristeen Penrod, Clint Cabañero, Wayne Spencer, and Claudia Luke made enormous contributions to SCML and the procedures in CorridorDesigner.

Our approach was modified for the Arizona Missing Linkages Project, supported by Arizona Game and Fish Department, Arizona Department of Transportation, U.S. Fish and Wildlife Service, U.S. Forest Service, Federal Highway Administration, Bureau of Land Management, Sky Island Alliance, Wildlands Project, and Northern Arizona University.

Over the past 5 years, we discussed these ideas with Andrea Atkinson, Todd Bayless, Clint Cabañero, Liz Chatten, Matt Clark, Kevin Crooks, Kathy Daly, Brett Dickson, Robert Fisher, Emily Garding, Madelyn Glickfeld, Nick Haddad, Steve Loe, Travis Longcore, Claudia Luke, Lisa Lyren, Brad McRae, Scott Morrison, Shawn Newell, Reed Noss, Kristeen Penrod, E.J. Remson, Seth Riley, Esther Rubin, Ray Sauvajot, Dan Silver, Jerre Stallcup, and Mike White. We especially thank the many government agents, conservationists, and funders who conserve linkages and deserve the best possible science.

Photos for species accounts courtesy of Robert Shantz (<http://www.rshantz.com/>) unless otherwise stated.

Terms & Conditions

By downloading or using any of the CorridorDesigner GIS tools, you agree to the following terms and conditions:

These tools are available to assist in identifying general areas of concern only. Results obtained by the tools provided should only be relied upon with corroboration of the methods, assumptions, and results by a qualified independent source.

The user assumes full responsibility for the misinterpretation or manipulation of the data. The user of this information shall indemnify and hold free the Northern Arizona University, the State of Arizona, and the creators of the CorridorDesigner GIS tools from any and all liabilities, damages, lawsuits, and causes of action that result as a consequence of his/her reliance on information provided herein or from any misinterpretation or manipulation of the data.

Using the Arizona CorridorDesigner Toolbox

The Arizona CorridorDesigner toolbox was designed to work in conjunction with the general CorridorDesigner toolbox to streamline the design of wildlife corridors within Arizona. The AZ toolbox includes habitat parameterizations for species throughout Arizona modeled for the Arizona Missing Linkages project, and must be used in conjunction with the land cover and elevation layers downloadable from the corridordesign.org website.

Using the AZ CorridorDesigner toolbox involves several steps:

1. Download the accompanying statewide GIS data from the [corridordesign](http://corridordesign.org) website, and unzip to a location on your computer. If you attended one of the CorridorDesigner workshops, copy the data from the workshop DVD, found under \CorridorDesigner\tutorial\data, to your computer.
2. Download the AZ CorridorDesigner toolbox, unzip to your computer, and add to ArcCatalog or ArcMap. Note: we have had problems with the tools running in ArcMap. At the present time, we recommend running all tools in ArcCatalog. As some tools may take 2-20 minutes to run, running all tools in ArcCatalog will also allow you to use ArcMap for other purposes simultaneously.
3. Create a project folder. This project folder will store all of your input layers for analysis, as well as all output layers created during the modeling process.
4. Determine *wildland blocks* (large blocks for which you are designing a corridor to connect), and create a shapefile of the analysis area. The analysis area should encompass both wildland blocks, and allow a little extra 'room to run' if deemed necessary. Save the analysis area shapefile and wildland blocks in your project folder.
5. Run 1) *Prepare project working directory tool* in AZ toolbox. This tool clips all statewide GIS layers to your analysis area shapefile, creates a topographic position raster, slope raster, and distance-from-roads raster. The tool creates a /basemap folder in your project working directory, and stores all GIS layers there. The tool also creates an /output folder, where all output modeling layers will be saved.
6. Run habitat, patch, and corridor modeling tools. Note that patch modeling tool is dependent on output data from habitat modeling tool, and corridor modeling tool is dependent on output data from patch tool—these tools must be run sequentially. If a tool asks for the *project working directory*, this is the root folder for your project, established in step 3.
 - Within the /output folder, the AZ toolbox automatically creates a folder named after each species when a habitat model is first created. An example directory structure might look like this:

/projectFolder/

/projectFolder/basemap/

/projectFolder/output/

/projectFolder/output/badger

/projectFolder/output/mtnlion

- Habitat suitability models created using the AZ toolbox will automatically be named speciesName_hsm. For example, a badger habitat model will be called badger_hsm.
- Patch models created using the AZ toolbox will automatically be named speciesName_patches.shp. For example, a badger patch model will be called badger_patches.shp, and will automatically be saved in /projectFolder/output/badger/.
- Corridor models created using the AZ toolbox will be named speciesName_cst. This raster layer can be sliced into different width corridor slices using the 2) *Create corridor slices tool* in the general CorridorDesigner toolbox. By default, the corridor tool will create corridor slices in 1% equal area intervals.

Species Accounts

Specific scores for each species are found in Excel table, located in
\CorridorDesignerAZToolbox\documentation\corridorDesigner_speciesScores.xls

In many cases, the original spreadsheets for each species can be found in the
\CorridorDesignerArizonaToolbox\arizonaScripts\species folder. Note: the Arizona Missing Linkages
project parameterized habitat models based on a 1(best) – 10(worst) scale. All values used in the AZ
toolbox have linearly stretched these values to a 0(worst) – 100(best) scale.

Mammals

Antelope Jackrabbit (*Lepus alleni*)



Justification for Selection

Antelope jackrabbits have a geographic distribution limited to the deserts and grasslands of southern Arizona and northern Mexico, and are threatened with habitat alteration from expanding agriculture and development (Best & Henry 1993).

Distribution & Status

Within the United States, the antelope jackrabbit is limited to southern Arizona. The species is also found in the northern portion of the Mexican state Nayarit, and on Tiburón Island in the Gulf of California (Best & Henry 1993).

Habitat Associations

Antelope jackrabbits are primarily associated with grassy slopes on moderate elevations up to 4900 feet (Best & Henry 1993). In southern Arizona, antelope jackrabbits live on dry valley slopes away from water, and do not drink water if it is available (Best & Henry 1993). Brown & Krausman (2003) identified the species 73% of the time within vegetation associations composed of mesquite and creosote, while others have found stomach content comprised of 45% grass, 35% mesquite, and 7.8% cactus (Vorhies & Taylor 1933).

Spatial Patterns

The average home range of antelope jackrabbits has been estimated as 642.8 ha (Swihart 1986), and population density has may range from 0.025 ha to 0.5 ha (Best & Henry 1993). Swihart's (1986) estimate of home range for antelope jackrabbits is much larger than the home range for congeners of the species, such as the black-tailed jackrabbit, which have estimated home ranges ranging from 20 to 140 ha (Best 1993). No information was available on dispersal distances for the species.

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Because Brown & Krausman (2003) censused the species using a roadway survey which identified the species within 100m of the road, we assumed antelope jackrabbits do not show an aversion to roads. However, this non-sensitivity may result in increased roadkill, so we assigned distance from roads a weight of 7%. Vegetation received an importance weight of 70%, while elevation and topography received weights of 10% and 13%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 100 ha, based on Best's (1993) estimate of home range size for black-tailed jackrabbits. Minimum potential habitat core size was defined as 500 ha, or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was

first averaged using a 3x3 neighborhood moving window analysis.

References

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Brown, C.F., Krausman, P.R. 2003. Habitat characteristics of three leporid species in

southeastern Arizona. Journal of Wildlife Management 67: 83-89.

Vohies, C.T., Taylor, W.P. 1933. The life histories and ecology of jack rabbits, *Lepus alleni* and *Lepus californicus* spp., in relation to grazing in Arizona. University of Arizona College Agricultural Technical Bulletin 49: 471-587.

Arizona Gray Squirrel (*Sciurus arizonensis*)



Justification for Selection

Arizona gray squirrels have limited geographic distributions and are habitat specialists with strong dependency on montane forest. They are also sensitive to roads (Brown 1984 in Best & Riedel 1995), and most likely dispersal limited.

Distribution

The Arizona gray squirrel is found in Arizona and New Mexico, and to a limited extent in Sonora, Mexico. In Arizona, they occupy a number of mountain ranges in the southeastern part of the state, as well as the southern and western slopes of the Mogollon Plateau (Best & Riedel 1995).

Habitat Associations

Arizona gray squirrels are primarily associated with dense, mixed broadleaf forests within deciduous riparian forests (Best & Riedel 1995). They may extend along streams into semi-desert and chaparral areas. Ponderosa pine (*Pinus ponderosa*) and Gambel oak (*Quercus gambeli*) are used extensively when found within riparian communities. Key indicators of Arizona gray squirrel include Arizona walnut (*Juglans major*), Arizona oak (*Quercus arizonica*), and Gambel oak, which provide key nesting & foraging sources (Best & Riedel 1995). While individuals of this

species are often killed on roadways, they are not greatly disturbed by dogs and humans. In Arizona, typical elevation range is between 4900 & 6400 feet, although the species can range from approximately 3600 to 8900 feet (Best & Riedel 1995).

Spatial Patterns

No information is known on spatial requirements of the Arizona gray squirrel. Abert's Squirrel (*Sciurus aberti*), a species within the same genus, has been found to have an average home range of 2.5 to 13 ha (6.2-32 acres), with larger home ranges associated with recent timber harvesting (Patton 1977). Average summer home ranges of western gray squirrels in California and Oregon have been found to vary between 2.6 and 4.2 ha (6.4-10.4 acres) (Ryan & Carey 1995). Home ranges of Abert's squirrel have been observed to commonly overlap (Keith 2003), while the home ranges of western gray squirrel displayed little overlap (Vander Haegen et al. 2005) While no dispersal information is available for the Arizona gray squirrel, dispersal distance for tree squirrels is generally not more than several kilometers (NatureServe 2005).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Due to this species' strong vegetation preferences, vegetation received an importance weight of 70%, while elevation, topography, and distance from roads each received a 10% weight. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Based on the range of home ranges for western gray squirrels estimated by Ryan & Carey (1995), we defined minimum patch size for Arizona gray squirrel as 3.4 ha. We assumed the amount of high-quality habitat necessary to support a relatively isolated breeding group of Arizona gray squirrels for approximately 10 years was 17 ha, or five times estimated minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

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Badger (*Taxidea taxus*)



Justification for Selection

Because of their large home ranges, many parks and protected lands would not be large enough to ensure protection of a badger population, or even an individual (NatureServe 2005). Consequently, badgers have suffered declines in recent decades in areas where grasslands have been converted to intensive agricultural areas, and where prey animals such as prairie dogs and ground squirrels have been reduced or eliminated (NatureServe 2005). Badgers are also threatened by collisions with vehicles while attempting to cross highways intersecting their habitat (New Mexico Department of Game and Fish 2004, NatureServe 2005).

Distribution

Badgers are found throughout the western United States, extending as far east as Illinois, Wisconsin, and Indiana (Long 1973). They are found in open habitats throughout Arizona.

Habitat Associations

Badgers are primarily associated with open habitats such as grasslands, prairies, and shrublands, and avoid densely wooded areas (NMGF 2004). They may also inhabit mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper and sagebrush habitats

(Long & Killingley 1983). They prefer flat to gentle slopes at lower elevations, and avoid rugged terrain (Apps et al. 2002).

Spatial Patterns

Overall yearly home range of badgers has been estimated as 8.5 km² (Long 1973). Goodrich and Buskirk (1998) found an average home range of 12.3 km² for males and 3.4 km² for females, found male home ranges to overlap more than female ranges (male overlap = 0.20, female = 0.08), and estimated density as 0.8 effective breeders per km². Messick and Hornocker (1981) found an average home range of 2.4 km² for adult males and 1.6 km² for adult females, and found a 20% overlap between a male and female home range. Nearly all badger young disperse from their natal area, and natal dispersal distances have been recorded up to 110 km (Messick & Hornocker 1981).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Badgers prefer grasslands and other open habitats on flat terrain at lower elevations. They do not show an aversion to roads (Apps et al. 2002), which makes them sensitive to high road mortality. Vegetation received an importance weight of 65%, while elevation, topography, and distance from roads received weights of 7%, 15%, and 13%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 2 km², which is an

average of the home range found for both sexes by Messick and Hornocker (1981), and equal to the female home range estimated by Goodrich and Buskirk (1998), minus 1 standard deviation. Minimum potential habitat core size was defined as 10 km², approximately enough area to support 10 effective breeders, allowing for a slightly larger male home range size and 20% overlap of home ranges (Messick & Hornocker 1981).

References

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Desert Bighorn Sheep (*Ovis Canadensis nelsoni*)



Justification for Selection

Bighorn sheep populations have suffered massive declines in the last century, including local extinctions. Human activities such as alteration of bighorn sheep habitat, urbanization, and grazing by domestic sheep have been largely responsible for population declines (Johnson and Swift 2000) (Krausman 2000). These declines, along with barriers to movement such as roads and range fences, have created small, isolated groups of bighorn sheep with a highly fragmented distribution (Singer et al. 2000) (Bleich et al. 1990). Isolated bighorn populations are more susceptible to extirpation than large, contiguous populations due to climate change, fire, or disease, especially introduced diseases from domestic sheep (Epps et al. 2004) (Gross et al. 2000) (Singer et al. 2000) (Singer, Papouchis, and Symonds 2000). Bighorn sheep are listed as USFS Sensitive in New Mexico and Arizona (New Mexico Department of Game and Fish 2004).

Distribution

Bighorn sheep are found throughout western North America from the high elevation alpine meadows of the Rocky Mountains to low elevation desert mountain ranges of the southwestern United States and northern Mexico (Shackleton 1985). Specifically, their

range extends from the mountains and river breaks of southwestern Canada south through the Rocky Mountains and Sierra Nevada, and into the desert mountains of the southwest U.S. and the northwestern mainland of Mexico (NatureServe 2005). In Arizona, bighorns can be found from Kanab Creek and the Grand Canyon west to Grand Wash, as well as in westernmost Arizona eastward to the Santa Catalina Mountains (Hoffmeister 1986).

Habitat Associations

Bighorn sheep habitat includes mesic to xeric grasslands found within mountains, foothills, and major river canyons (Shackleton 1985). These grasslands must also include precipitous, rocky slopes with rugged cliffs and crags for use as escape terrain (Shackleton 1985; Alvarez-Cardenas et al. 2001; Rubin et al. 2002; New Mexico Department of Game and Fish 2004). Slopes >80% are preferred by bighorn sheep, and slopes <40% are avoided (Alvarez-Cardenas et al. 2001). Dense forests and chaparral that restrict vision are also avoided (NatureServe 2005). In Arizona, the desert bighorn subspecies (*O. Canadensis nelsoni*) is associated with feeding grounds that include mesquite, ironwood, palo verde, catclaw, coffeeberry, bush muhly, jojoba, brittlebrush, calliandra, and galleta (Hoffmeister 1986). Water is an important and limiting resource for desert bighorn sheep (Rubin et al. 2002). Where possible, desert bighorn will seek both water and food from such plants as cholla, prickly pear, agave, and especially saguaro fruits (Hoffmeister 1986). Bighorn sheep will also occasionally graze on shrubs such as sagebrush, mountain mahogany, cliffrose, and blackbrush (New Mexico Department of Game and Fish 2004).

Elevation range for bighorn sheep varies across their range from 0 – 3660 m (New Mexico Department of Game and Fish 2004), but in Arizona the desert bighorn subspecies is found from 100 – 1000m elevation, with the best habitat found from 900 – 1000 m in the jojoba communities (Hoffmeister 1986; Alvarez-Cardenas et al. 2001).

Spatial Patterns

Home ranges for bighorn sheep vary depending upon population size, availability and connectivity of suitable habitat, and availability of water resources (Singer et al. 2001). Home ranges have been reported as small as 6.1 km to as large as 54.7 km (Singer et al. 2001). One desert bighorn sheep study in Arizona reports an average home range of $16.9 \pm 3.38 \text{ km}^2$ for ewes, and home ranges for males that increased with age from 11.7 km^2 for a one year old to 37.3 km^2 for a 6 year old (Shackleton 1985). Bighorn sheep that live in higher elevations are known to migrate between an alpine summer range to a lower elevation winter range in response to seasonal vegetation availability and snow accumulation in the higher elevations (NatureServe 2005) (Shackleton 1985). Maximum distances for these seasonal movements are about 48 km (Shackleton 1985). Desert bighorns on low desert ranges do not have separate seasonal ranges (Shackleton 1985). Bighorns live in groups, but for most of the year males over 3 years of age live separate from maternal groups consisting of females and young (Shackleton 1985).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Due to this species' strong topographic preferences, topographic position received an importance

weight of 50%, while vegetation, elevation, and distance from roads received weights of 30%, 10%, and 10%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 16.9 km^2 (Shackleton 1985), and minimum potential habitat core size was defined as 84.5 km^2 , or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

References

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Black Bear (*Ursus americanus*)



Justification for Selection

Black bears require a variety of habitats to meet seasonal foraging demands and have naturally low population densities, making them especially vulnerable to habitat fragmentation (Larivière 2001).

Distribution

Black bears are widely distributed throughout North America, ranging from Alaska and Canada to the Sierra Madre Occidental and Sierra Madre Oriental of Mexico (Larivière 2001). In Arizona, they are found primarily in forested areas from the South Rim of the Grand Canyon to mountain ranges in the southeastern part of the state (Hoffmeister 1986).

Habitat Associations

Black bears are primarily associated with mountainous ranges throughout Arizona. Within these areas they use a variety of vegetation types, ranging from semidesert grasslands to encinal woodlands and montane conifer forests (Hoffmeister 1986). Encinal woodlands and conifer-oak woodlands are optimal habitat, providing food such as acorns (LeCount 1982; LeCount et al. 1984; Cunningham 2004). In autumn, black bears use grass and shrub mast as well as prickly pear found in desert scrub (S. Cunningham, personal comm.). In many locations

throughout Arizona, black bears are found in riparian communities (Hoffmeister 1986), and prefer to bed in locations with 20-60% slopes (S. Cunningham, personal comm.).

Spatial Patterns

Individual black bears do not have territorial interactions, and home ranges of both sexes commonly overlap. Home ranges are generally larger in locations or years of low food abundance, and smaller when food is plentiful and have been observed to range from 2 - 170 km² (Larivière 2001). Daily foraging movements are also dependent on food supply, and have been observed to range from 1.4 – 7 km (Larivière 2001). Males have larger dispersal distances than females, as females stay close to their natal range, and males must migrate to avoid larger males as their mother comes back into estrus (Schwartz & Franzmann 1992). Depending on vegetation, females may disperse up to 20 km, while males often move 20-150 km (S. Cunningham, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Cover is the most important factor for black bears, so vegetation was assigned an importance weight of 75%. Elevation and topography each received a weight of 10%, and distance from roads received a weight of 5%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 10 km², since this is the minimum amount of optimum habitat

necessary to support a female and cub (Bunnell & Tait 1981; S. Cunningham, pers. comm.). Minimum potential habitat core size was defined as 50km², or five times the minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Black-tailed Jackrabbit (*Lepus californicus*)



Justification for Selection

Black-tailed jackrabbits are important seed dispersers (Best 1996) and are frequently killed by roads (Adams & Adams 1959). They also serve as prey for predators such as hawks, eagles, owls, coyotes, badgers, foxes and bobcats (Hoffmeister 1986; Best 1996).

Distribution

Black-tailed jackrabbits are common through western North America. They range from western Arkansas and Missouri to the Pacific Coast, and from Mexico northward to Washington and Idaho (Best 1996). They are found throughout the lower elevations of Arizona (Lowe 1978).

Habitat Associations

This species primarily prefers open country, and will typically avoid areas of tall grass or forest where visibility is low (Best 1996). In Arizona, black-tailed jackrabbits prefer mesquite, sagebrush, pinyon juniper, and desert scrub (Hoffmeister 1986). They are also found in sycamore, cottonwood, and rabbitbrush habitats (New Mexico Department of Fish and Game 2004). Dense grass and/or shrub cover is necessary for resting (New Mexico Department of Fish and Game 2004).

Spatial Patterns

Home range size varies considerably for black-tailed jackrabbits depending upon distances between feeding and resting areas. Home ranges have been reported from less than 1 sq km to 3 sq km in northern Utah (NatureServe 2005); however, daily movements of several miles to find suitable forage may be common in southern Arizona, with round trips of up to 10 miles each day possible (Hoffmeister 1986). Black-tailed jackrabbits are also known to avoid entering water, making large rivers possible population barriers (Best 1996).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Due to this species' strong vegetation preferences, vegetation received an importance weight of 70%, while elevation, topography, and distance from roads each received weights of 10%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 100 hectares (Best 1993), and minimum potential habitat core size as 500 ha, or five times the minimum patch size. To estimate potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 (90x90m²) neighborhood moving window analysis.

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Coues' White-tailed Deer (*Odocoileus virginianus couesi*)



Justification for Selection

Coues' white-tailed are sensitive to human disturbance (Galindo et al. 1993; Ockenfels et al. 1991) and are prey for mountain lions, jaguars, coyotes, bobcats, black bears, and eagles (Knipe 1977; Leopold 1959; Ligon 1927; Ockenfels et al. 1991). They are also an important game species. Local populations of these deer have become extinct (apparently due to natural causes) in some small Arizona mountain ranges and connectivity is necessary for natural recolonization to occur.

Distribution

White-tailed deer range throughout most of the conterminous United States, into southern Canada (Smith 1991). As a small-sized, long-eared subspecies of white-tailed deer, Coues' white-tailed deer are found primarily in the mountain ranges of southeastern Arizona, southwestern New Mexico, and northern Mexico (Knipe 1977).

Habitat Associations

The chief habitat association of Coues' white-tailed deer is oak or oak-pinyon-juniper woodlands (Hoffmeister 1986; Knipe 1977). They also use chaparral, desert scrub, and mesquite habitats, and forage primarily on shrubs and trees (Gallina et al. 1981). Cacti and grasses are generally not used, and are of

little importance to foraging (Gallina et al. 1981; Henry & Sowls 1980; Ockenfels et al. 1991). Coues' white-tailed deer favor canyons and moderately steep slopes, and are usually found within several kilometers of water (Evans 1984; Ligon 1951; Ockenfels et al. 1991). Elevation does not appear to constrain the species; however, vegetation associated with elevation does. Coues' white-tailed deer are susceptible to human disturbance – particularly hunting, dogs, cattle grazing, and roads (Galindo et al. 1993; Ockenfels et al. 1993).

Spatial Patterns

White-tailed deer are not territorial, and may have large overlap of home ranges (Smith 1991). Female home ranges in the Santa Rita Mountains were found to average 5.18 km², while male home ranges averaged 10.57 km² (Ockenfels et al. 1991). Knipe (1977) speculated that Coues' white-tailed deer have a home range from 5-16 km². Galindo-Leal (1992) estimated the density of Coues' white-tailed deer to range from 0.82-14.21 deer/km² in the Michilia Biosphere Reserve of Mexico, while Leopold (1959) estimated a density of 12-15 deer/km² in an undisturbed area of the Sierra Madre Occidental mountain area of Mexico. While this species does not migrate, it does shift habitat use seasonally, eating fruits (nuts, beans, berries) in summer, forbs and browse in fall, and evergreen browse in winter (McCulloch 1973; Welch 1960). Dispersal distance for young males at two areas in southern Texas established new areas of use 4.4±1.0 km and 8.2±4.3 km, respectively, from the center of their autumn home range (McCoy et al. 2005).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Due to this species' strong preferences for woodlands and shrubs, vegetation received an importance weight of 65%, while elevation, topography, and distance from roads received a weight of 5%, 15%, and 15%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum patch size for Coues' white-tailed deer as 5.2 km², the average home range for females in the Santa Rita Mountains (Ockenfels 1991). While this species exhibits high home range overlap, we defined minimum core size as 26 km², or five times minimum patch size, to ensure potential cores could account for seasonal movements and use of different habitats. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Elk (*Cervus elaphus*)



Justification for Selection

Elk are seasonal migrants that require large tracts of land to support viable populations. They serve as prey for large carnivores such as mountain lions, and are susceptible to human disturbance and busy roads.

Distribution & Status

By the late 1800's, native elk (*Cervus elaphus merriami*) were believed to be extinct in Arizona. Re-introduction efforts in the early 1900's established stable populations of non-indigenous Rocky Mountain elk (*Cervus elaphus nelsoni*) in virtually all historic elk habitat in the state (Britt and Theobald 1982). Populations were also established in the Hualapai Mountains south of Kingman and on the San Carlos Reservation near Cutter, Arizona. Both areas were believed to be previously uninhabited by elk (Severson and Medina 1983). Arizona elk populations have expanded to an estimated total of 35,000 animals (Arizona Game and Fish Department 2006). Elk are most commonly found in woodlands and forests of northern Arizona extending from the Kaibab Plateau south and eastward along the Mogollon Rim to the White Mountains and into western New Mexico (Severson and Medina 1983).

Habitat Associations

Elk are "intermediate feeders" capable of utilizing a mix of grasses, herbs, shrubs, and trees depending on the season and availability. Although capable of living in a range of habitats from desert chaparral and sagebrush steppe to tundra, elk are most commonly associated with forest parkland ecotones that offer a mix of forage and cover (Thomas et al. 1988; O'Gara and Dundes 2002). Elk are negatively impacted by roads, and have shown avoidance behavior up to 400 m (Ward et al. 1980), 800 m (Lyon 1979) and 2.2 km (Brown et al. 1980; Rowland et al. 2004) from roads.

Spatial Patterns

In Arizona, elk move annually between high elevation summer range (7000 to 10000 ft) and lower elevation winter range (5500 to 6500 ft) (Arizona Game and Fish Department 2006). Elk may move as far as 100 km to lower elevations where there is less snow in the winter (Boyce 1991). Elk avoid human activity unless in an area secure from predation in which they are tolerant of human proximity (Morgantini and Hudson 1979, Lyon and Christensen 2002, Geist 2002).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 75%, while distance from roads received a weights of 25%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Home ranges are highly variable

for elk (O’Gara and Dundes 2002). In Montana, one herd had an average summer home range of 15 km² (Brown et al. 1980), while a herd in northwestern Wyoming had a winter range of 455 km² and a summer range of 4740 km² (Boyce 1991). Minimum patch size for elk was defined as 60 km² and minimum core size as 300 km². To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species’ large spatial requirements.

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Jaguar (*Panthera onca*)



Justification for Selection

Jaguars are listed both as a federally endangered species without critical habitat, and as Wildlife Special Concern species by the state of Arizona. They have suffered from a loss of habitat and hunting by ranchers, and persistence in Arizona is contingent on habitat corridors which allow movement from source populations in Mexico (AZGFD 2004).

Distribution

Jaguars have a limited range in Mexico, Guatemala, and Argentina, and are rare in the United States, Bolivia, Panama, Costa Rica, and Honduras, Peru, Colombia, and Venezuela (Seymour 1989). The largest known populations of jaguars exist in the Amazonian rainforest of Brazil. Within Arizona, they historically occurred in the southeastern part of the state, with several recorded sightings in central Arizona and as far north as the south rim of the Grand Canyon (Hoffmeister 1986).

Habitat Associations

Jaguars are adaptable to a variety of conditions, and are most often found in areas with sufficient prey, cover, and water supply (Seymour 1989). Within Arizona, habitat preferences are not clear; however, the species appears to prefer scrub and grasslands,

evergreen forest, and conifer forest & woodlands (Hatten et al. 2003). It has been suggested that their apparent preference for grasslands may reflect movement corridors from the Sierra Madres of Mexico into southeast Arizona, rather than a preference for this habitat type (Hatten et al. 2003). Jaguars have a strong preference for water, and are often found within several kilometers of a water source such as perennial rivers or cienegas (Hatten et al. 2003; AZGFD 2004). They also appear to prefer intermediate to rugged terrain, and seem to be especially sensitive to human disturbance (Hatten et al. 2003; Menke & Hayes 2003).

Spatial Patterns

The home range of jaguars may vary from 10 to 170 km², with smaller home ranges in rain forests, and larger home ranges recorded in open habitats (AZGFD 2004). In Brazil, the average density of jaguars was approximately one animal per 25 km², with one female ranging up to 38 km², and one male ranging more than 90 km² (Schaller & Crawshaw 1980).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 60%, while elevation, topography, and distance from roads received weights of 5%, 15%, and 20%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum patch size for jaguar was defined as 41 km² and minimum core size

as 205 km². To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Javelina (*Tayassu tajacu*)



Justification for Selection

Young javelina are probably prey items for predators such as coyotes, bobcats, foxes (Hoffmeister 1986), and jaguars (Seymour 1989). Although they habituate well to human development, their herds require contiguous patches of dense vegetation for foraging and bed sites (Hoffmeister 1986; Ticer et al. 2001; NatureServe 2005). Roads are dangerous for urban dwelling javelina (Ticer et al. 1998). Javelina are an economically important game species (Ticer et al. 2001).

Distribution

Javelina are found from Northern Argentina and northwestern Peru to north-central Texas, northwestern New Mexico, and into central Arizona (NatureServe 2005). Specifically in Arizona, they occur mostly south of the Mogollon Rim and west to Organ Pipe National Monument (Hoffmeister 1986).

Habitat Associations

Javelina have adapted to a variety of plant communities, varied topography, and diverse climatic conditions (Ticer et al. 2001). However, javelina confine themselves to habitats with dense vegetation (Ticer et al. 2001; Hoffmeister 1986; NatureServe 2005), and rarely are found above the oak forests on

mountain ranges (Hoffmeister 1986). Javelina prefer habitat types such as areas of open woodland overstory with shrubland understory, desert scrub, and thickets along creeks and old stream beds (Ticer et al. 1998; Hoffmeister 1986). They also will forage in chaparral (Neal 1959; Johnson and Johnson 1964). Prickly pear cactus provides shelter, food, and water (Ticer et al. 2001, Hoffmeister 1986). Other plants in javelina habitat include palo verde, jojob, ocotillo, catclaw, and mesquite (Hoffmeister 1986). Javelina habituate well to human development, as long as dense vegetation is available (Ticer et al. 2001). Their elevation range is from 2000 to 6500 feet (New Mexico Department of Fish and Game 2004).

Spatial Patterns

Javelinas live in stable herds, though occasionally some individuals may move out of the herd to join another or establish their own (Hoffmeister 1986). Home ranges for herds have been reported as 4.7 km² in the Tortolita Mountains (Bigler 1974), 4.93 km² near Prescott (Ticer et al. 1998), and between 1.9 and 5.5 ha in the Tonto Basin (Ockenfels and Day 1990). Dispersal of javelinas has not been adequately studied, but they are known to be capable of extensive movements of up to several kilometers (NatureServe 2005).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation as it relates to both forage and cover requirements is very important for javelina. Sows (1997) lists climate, vegetation, and topography as important factors in javelina habitat use. For this species', vegetation received an importance weight of

50%, while elevation and topography received weights of 30% and 20%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum habitat patch size for javelina was defined as 44 ha, based on an estimate for a single breeding season for one "herd" of one breeding pair. The estimate for minimum habitat core size is 222 ha, based on an estimate of 10 breeding seasons for 1 herd of mean size 9 to 12 animals (Chasa O'Brien, personal comm.). The calculation of area is based upon 3 different estimates of density of animals/ha in south-central and southern Arizona. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

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Kit Fox (*Vulpes macrotis*)



Justification for Selection

Kit fox are susceptible to habitat conversion and fragmentation due to agricultural, urban, and industrial development.

Distribution & Status

Kit fox are found throughout arid regions of several states in the western U.S., including Arizona, New Mexico, Texas, Utah, Nevada, California, Colorado, Idaho, and Oregon (Natureserve 2006). They historically ranged throughout all major desert regions of North America, including the Sonora, Chihuahuan, and Mohave Deserts, as well as the Painted Desert and much of the Great Basin Desert (McGrew 1979). Within Arizona, Kit fox are found in desert grasslands and desert scrub throughout much of southern and western parts of the state.

Habitat Associations

Kit fox are mostly associated with desert grasslands and desert scrub, where they prefer sandy soils for digging their dens (Hoffmeister 1986). Most dens are found in easily diggable clay soils, sand dunes, or other soft alluvial soils (McGrew 1979; Hoffmeister 1986).

Spatial Patterns

Spatial use is highly variable for kit fox, depending on prey base, habitat quality, and

precipitation (Zoellick and Smith 1992; Arjo et al. 2003). One study in western Utah found a density of 2 adults per 259 ha in optimum habitat, while an expanded study in Utah found density to range from 1 adult per 471 ha to 1 adult per 1,036 ha (McGrew 1979). Arjo et al. (2003) reported home range size from 1,151-4,308 ha. In Arizona, one study found an average home range size of 980 ha for females, and 1,230 ha for males; however, home ranges the authors also reported 75% overlap of paired males and females (Zoellick and Smith 1992).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –

Vegetation received an importance weight of 75%, while topography and distance from roads received weights of 15% and 10%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – In our analyses, we defined minimum patch size for kit fox as 259 ha and minimum core size as 1,295 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Mountain Lion (*Puma concolor*)



Justification for selection

The mountain lion, which occurs in low densities across their range, requires a large area of connected landscapes to support even minimum self sustaining populations (Beier 1993) (Logan and Sweanor 2001). Connectivity is important for hunting, seeking mates, avoiding other pumas or predators, and dispersal of juveniles (Logan and Sweanor 2001). The Yuma mountain lion is listed as a State Endangered species in Arizona uplands (Arizona Game and Fish Department 2002). Protection of riparian communities within their range is necessary for their persistence (Arizona Game and Fish Department 2002).

Distribution & Status

Historically, mountain lions ranged from northern British Columbia to southern Chile and Argentina, and from coast to coast in North America (Currier 1983). Presently, the mountain lion's range in the United States has been restricted, due to hunting and development, to mountainous and relatively unpopulated areas from the Rocky Mountains west to the Pacific coast, although isolated populations may still exist elsewhere (Currier 1983). In Arizona, mountain lions are found throughout the state in rocky or mountainous areas (Hoffmeister 1986). One subspecies found in Arizona, the Yuma

mountain lion (*Puma concolor browni*), is limited to areas of southwestern Arizona including Mohave County along the Colorado River and east to Organ Pipe Cactus National Monument, and south to the Tohono O'Odham Indian Reservation (Arizona Game and Fish Department 2002).

Habitat Associations

Mountain lions are associated with mountainous areas with rocky cliffs and bluffs (Hoffmeister 1986) (New Mexico Game and Fish Department 2004). They use a diverse range of habitats, including conifer, hardwood, and mixed forests, and shrubland, chaparral, and desert environments (NatureServe 2005). They are also found in pinon/juniper on benches and mesa tops (New Mexico Game and Fish Department 2004). Mountain lions are found at elevations ranging from 0 to 4000 m (Currier 1983). The Yuma mountain lion subspecies is more associated with riparian bottomlands, including areas of cottonwood-willow forests, mesquite bosques, dense vegetation along rivers and creeks, and adjacent desert foothills, canyons, and rocky uplands (Arizona Game and Fish Department 2002). The elevation range of this subspecies is from 1000-3500 feet (Arizona Game and Fish Department 2002).

Spatial Patterns

Home range sizes of mountain lions vary depending on sex, age, and the distribution of prey. One study in New Mexico reported annual home range size averaged 193.4 km² for males and 69.9 km² for females (Logan and Sweanor 2001). This study also reported daily movements averaging 4.1 km for males and 1.5 km for females (Logan and Sweanor 2001). Dispersal rates for juvenile mountain

lions also vary between males and females. Logan and Sweanor's study found males dispersed an average of 102.6 km from their natal sites, and females dispersed an average of 34.6 km. A mountain lion population requires 1000 - 2200 km² of available habitat in order to persist for 100 years (Beier 1993). These minimum areas would support about 15-20 adult cougars (Beier 1993).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – While mountain lions can be considered habitat generalists, vegetation is still the most important factor accounting for habitat suitability, so it received an importance weight of 70%, while topography received a weight of 10%, and distance from roads received a weight of 20%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum patch size for mountain lions was defined as 79 km², based on an average home range estimate for a female in excellent habitat (Logan & Sweanor 2001; Dickson & Beier 2002). Minimum core size was defined as 395 km², or five times minimum patch size. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Mule Deer (*Odocoileus hemionus*)



Justification for Selection

Mule deer are widespread throughout Arizona, and are an important prey species for carnivores such as mountain lion, jaguar, bobcat, and black bear (Anderson & Wallmo 1984). Road systems may affect the distribution and welfare of mule deer (Sullivan and Messmer 2003).

Distribution

Mule deer are found throughout most of western North America, extending as far east as Nebraska, Kansas, and western Texas. In Arizona, mule deer are found throughout the state, except for the Sonoran desert in the southwestern part of the state (Anderson & Wallmo 1984).

Habitat Associations

Mule deer in Arizona are categorized into two groups based on the habitat they occupy. In northern Arizona mule deer inhabit yellow pine, spruce-fir, buckbrush, snowberry, and aspen habitats (Hoffmeister 1986). The mule deer found in the yellow pine and spruce-fir live there from April to the beginning of winter, when they move down to the pinyon-juniper zone (Hoffmeister 1986). Elsewhere in the state, mule deer live in desert shrub, chaparral or even more xeric habitats, which include scrub oak, mountain mahogany,

sumac, skunk bush, buckthorn, and manzanita (Wallmo 1981; Hoffmeister 1986).

Spatial Patterns

The home ranges of mule deer vary depending upon the availability of food and cover (Hoffmeister 1986). Home ranges of mule deer in Arizona Chaparral habitat vary from 2.6 to 5.8 km², with bucks' home ranges averaging 5.2 km² and does slightly smaller (Swank 1958, as reported by Hoffmeister 1986). Average home ranges for desert mule deer are larger. Deer that require seasonal migration movements use approximately the same winter and summer home ranges in consecutive years (Anderson & Wallmo 1984). Dispersal distances for male mule deer have been recorded from 97 to 217 km, and females have moved 180 km (Anderson & Wallmo 1984). Two desert mule deer yearlings were found to disperse 18.8 and 44.4 km (Scarborough & Krausman 1988).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation has the greatest role in determining deer distributions in desert systems, followed by topography (Jason Marshal, personal comm.). For this reason, vegetation received an importance weight of 80%, while topography and distance from roads received weights of 15% and 5%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum patch size for mule deer was defined as 9 km² and minimum core

size as 45 km². To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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Porcupine (*Erethizon dorsatum*)



Justification for Selection

The porcupine's range has been reduced in some areas due to changes in human distribution and land use (Woods 1973). Porcupines are frequently killed by automobiles while crossing roads (Woods 1973).

Distribution

Porcupines are widespread in much of North America, from Alaska and northern Canada to parts of northern Mexico (Woods 1973). The porcupine's range includes most of Arizona in forested, mountainous regions of the state as well as riparian areas in lower elevations; they are considered absent or rare in desert areas (Hoffmeister 1986).

Habitat Associations

Porcupines inhabit montane and subalpine forests that include ponderosa pine, spruce-fir, aspen, pinyon, juniper, and oak in higher elevations. They also live in cottonwood-willow forests of riparian areas and mesquite thickets of semidesert shrublands (New Mexico Department of Game and Fish 2004). In Arizona, they also occur in grassland, chaparral or desert scrub (Hoffmeister 1986). Porcupines consume bark from trees in these areas, as well as mistletoe, pine needles, oak leaves, acorns, fungi, buckbrush, and the fruit

of prickly pear cactus (New Mexico Department of Game and Fish 2004). Porcupines seek out rock piles, rocky slopes, mine shafts, and caves for shelter (Hoffmeister 1986).

Spatial Patterns

Home ranges of porcupines are restricted, with summer range larger than winter range (Woods 1973). Average summer home range is 14 hectares (Marshall et al. 1962), while winter home range is up to 5 hectares (Smith 1979). Average yearly home range has been estimated as 70 ha (Roze 1989). They will occupy the same dens for many years and even generations (Hoffmeister 1986). Individuals move an average of 1.5 kilometers to and from their winter den (Woods 1973).

Dispersal among porcupines is female-biased, with juvenile female porcupines dispersing an average of 3.7km while juvenile males generally remain within their natal ranges (Sweitzer and Berger 1998).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 87%, while topography and distance from roads received weights of 3% and 10%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum patch size for mule deer was defined as 70 ha and minimum core size as 250 ha. To determine potential habitat patches and cores, the habitat suitability

model for this species was first averaged using a 3x3 neighborhood moving window analysis.

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Pronghorn (*Antilocapra americana*)



Justification for Selection

Pronghorn are known to be susceptible to habitat degradation and human development (AZGFD 2002a). One example of harmful development is right of way fences for highways and railroads, which are the major factor affecting pronghorn movements across their range (Ockenfels et al. 1997). Existence of migration corridors is critical to pronghorn survival for allowing movement to lower elevation winter ranges away from high snowfall amounts (Ockenfels et al. 2002). The Sonoran pronghorn subspecies, which requires large tracts of land to obtain adequate forage, has only 25 individuals remaining due to loss of habitat and drought (AZGFD 2002b).

Distribution

Pronghorn range through much of the western United States, and are found throughout the grasslands of Arizona, except in the southeastern part of the state (Hoffmeister 1986). The Sonoran pronghorn subspecies is found in northwest Sonora, Mexico and southwestern Arizona including on the Cabeza Prieta National Wildlife Refuge, the Organ Pipe Cactus National Monument, the Barry M. Goldwater Gunnery Range (AZGFD 2002b).

Habitat Associations

Pronghorn are found in areas of grasses and scattered shrubs with rolling hills or mesas (New Mexico Department of Fish and Game 2004) (Ticer and Ockenfels 2001). They inhabit shortgrass plains as well as riparian areas of sycamore and rabbitbrush, and oak savannas (New Mexico Department of Fish and Game 2004). In winter, pronghorn rely on browse, especially sagebrush (O’Gara 1978). Pronghorn prefer gentle terrain, and avoid rugged areas (Ockenfels et al. 1997). Woodland and coniferous forests are also generally avoided, especially when high tree density obstructs vision (Ockenfels et al. 2002). Also for visibility, pronghorn prefer slopes that are less than 30% (Yoakum et al. 1996). Sonoran pronghorn habitat is described as broad alluvial valleys separated by block-faulted mountains (AZGFD 2002b). Elevations for this subspecies vary from 400 to 1600 feet (AZGFD 2002b). Sonoran pronghorn are found in vegetation types that include creosote bush, bursage/palo verde-mixed cacti, and saguaro (deVos and Miller 2005).

Spatial Patterns

In northern populations, home range has been estimated to range from 0.2 to 5.2 km², depending on season, terrain, and available resources (O’Gara 1978). However, large variation in sizes of home and seasonal ranges due to habitat quality and weather conditions make it difficult to apply data from other studies (O’Gara 1978). Other studies report home ranges that average 88 km² (Ockenfels et al. 1994) and 170 km² in central Arizona (Bright & Van Riper III 2000), and in the 75 – 125 km² range (n=37) in northern Arizona (Ockenfels et al. 1997). The Sonoran

pronghorn subspecies is known to require even larger tracts of land to obtain adequate forage (AZGFD 2002b). One study of collared Sonoran pronghorn found the home range of 4 males to range from 64 km² – 1214 km² (avg. 800 km²), while females ranged from 41 km² -1144 km² (avg. 465.7 km²) (AZGFD 2002b). Another study of Sonoran pronghorn found home range to range from 43 to 2,873 km², with mean home range size of 511 + 665 SD km² (n=22), which is much larger than other pronghorn subspecies (Hervert et al. 2005). One key element in pronghorn movement is distance to water. One study found that 84% of locations were less than 6 km from water sources (Bright & Van Riper III 2000), and another reports collared pronghorn locations from 1.5-6.5 km of a water source (Yoakum et al. 1996). Habitats within 1 km of water appear to be key fawn bedsite areas for neonate fawns (Ockenfels et al. 1992).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 45%, while topography and distance from roads received weights of 37% and 13%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum patch size for pronghorn was defined as 50 km² and minimum core size as 250 km². To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 200m radius moving window analysis due to the species' large spatial requirements.

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White-nosed Coati (*Nasua narica*)



Justification for Selection

White-nosed coatis are primarily forest species, and may serve as prey for top carnivores such as mountain lion (NMDGF 2004). They also appear to be dispersal-limited.

Distribution

White-nosed coatis are found in southern Arizona and New Mexico, and Texas, and throughout Mexico and Central America (Gompper 1995). In Arizona, coatis are found as far north as the Gila River, and throughout southeastern Arizonan forests.

Habitat Associations

Coatis are primarily a forest species, preferring shrubby and woodland habitats with good horizontal cover (Gompper 1995; C. Hass, personal comm.). While they do not have strong topographic preferences, they are generally found within several miles of water, and prefer riparian habitats if available (Gompper 1995). In Arizona, elevation places no constraints on habitat use, as this species are found from sea level to mountains exceeding 10,000 feet. While they are not a desert species, coatis will move through desert scrub and shrublands when moving between forested areas (Hoffmeister 1986).

Spatial Patterns

Female coatis and their yearlings (both sexes) live in groups of up to 25 individuals, while males are solitary most of the year (Hoffmeister 1986). In southeastern Arizona, average home range of coati troops was calculated as 13.57 km² (Hass 2002). Home ranges of males overlapped other males up to 61% and overlapped troops up to 67%, while home ranges of troops overlapped each other up to 80% (Hass 2002). Virtually nothing is known about dispersal distance in coatis, and radioed animals have not dispersed more than a few kilometers (C. Hass, personal comm.). Females are philopatric, but males have been observed at large distances from known coati habitat, and tend to get hit by cars. While successful dispersal of any distance is unknown, it is thought that males may disperse up to 5 km (C. Hass, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Due to this species' strong vegetation preferences, vegetation received an importance weight of 95%, while distance from roads received a weight of 5%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – We defined minimum potential habitat patch size as 25 km², which is slightly larger than their observed average home range in southeastern Arizona, because the home range boundaries of coati shift yearly, and the species appears to be dispersal-limited (C.

Hass, personal comm.). Minimum potential habitat core size was defined as 40 km².

References

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Amphibians & Reptiles

Note: Models created for most amphibians and reptiles may overstate potential habitat for the species. In our experience, it is very difficult to create adequate habitat and corridor models for most herpetofauna, because major factors related to their habitat preferences – such as rocky outcrops, riparian areas, or sandy substrates – are not adequately encompassed in existing GIS factors.

We caution the user of these models for amphibians and reptiles that they may not adequately reflect habitat needs of amphibians and reptiles, and recommend consulting a biologist knowledgeable of your study area to ensure that habitat requirements for all species are addressed.

Black-tailed Rattlesnake (*Crotalus molossus*)



Justification for Selection

Ecologically, the black-tailed rattlesnake is a generalist, able to live in a variety of habitats, making this species an important part of many ecosystems throughout Arizona. This rattlesnake requires various habitat types during different times of the year (Beck 1995), and relies on connectivity of these habitat types during its life cycle.

Distribution

This rattlesnake is found from central and west-central Texas northwest through the southern two-thirds of New Mexico to northern and extreme western Arizona, and southward to the southern edge of the Mexican Plateau and Mesa del Sur, Oaxaca (Degenhardt et. al 1996).

Habitat Associations

Black-tailed rattlesnakes are known as ecological generalists, occurring in a wide variety of habitats including montane coniferous forests, talus slopes, rocky stream beds in riparian areas, and lava flows on flat deserts (Degenhardt et. al 1996). In a radiotelemetry study conducted by Beck (1995), these snakes frequented rocky areas, but used arroyos and creosotebush flats during late summer and fall. Pine-oak forests, boreal forests, mesquite-grasslands, chaparral, tropical deciduous forests, and thorn forests

are also included as habitats for this species (New Mexico Department of Game and Fish 2004). In New Mexico, black-tailed rattlesnakes occur between 1000 and 3150 meters in elevation (New Mexico Department of Game and Fish 2004).

Spatial Patterns

The home range size for black-tailed rattlesnakes has been reported as 3.5 hectares, in a study within the Sonoran desert of Arizona (Beck 1995). These snakes traveled a mean distance of 15 km throughout the year, and moved an average of 42.9 meters per day (Beck 1995). No data is available on dispersal distance for this species, but a similar species, Tiger rattlesnake (*Crotalus tigris*), has been found to disperse up to 2 km (Matt Goode & Phil Rosen, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – While this species is a vegetation generalist, it is strongly associated with rocks and outcrops on mountain slopes, and rarely seen at any distance from these environments (Matt Goode & Phil Rosen, personal comm.). Because of this strong topographic association, topography received an importance weight of 90%, while distance from roads received a weight of 10%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Beck (1995) found home ranges from 3-4 ha in size; however, it is thought that home ranges for most black-tailed rattlesnakes are slightly larger (Phil Rosen,

personal comm.), so minimum patch size was defined as 10 ha. Minimum core size was defined as 100 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

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Chiricahua Leopard Frog (*Rana chiricahuensis*)



Justification for Selection

The Chiricahua leopard frog's population is declining in Arizona, and has been extirpated from about 75 percent of its historic range in Arizona and New Mexico (U.S. Fish and Wildlife Service 2002). Reasons for decline include habitat fragmentation, major water manipulations, water pollution, and heavy grazing (Arizona Game and Fish Department 2001). The Chiricahua leopard frog has been listed as a threatened species by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2002), and is also Forest Service Sensitive and a Species of Special Concern in Arizona (Arizona Game and Fish Department 2001). This frog has a metapopulation structure and requires dispersal corridors to include a buffer and riparian and stream corridors (Pima Co., Arizona 2001). Human activities have eliminated natural dispersal corridors in Arizona (Pima Co., Arizona 2001).

Distribution

The range of the Chiricahua leopard frog includes the montane regions of central and southern Arizona, southwestern New Mexico south into the Sierra Madre Occidental to western Jalisco, Mexico (Pima Co., Arizona 2001). Within Arizona, this species' range is divided into two portions: one extending from montane central Arizona east and south along

the Mogollon Rim to montane parts of southwestern New Mexico; the other extends through the southeastern montane sector of Arizona and into Sonora, Mexico (Degenhardt 1996; Arizona Game and Fish Department 2001).

Habitat Associations

The Chiricahua leopard frog's primary habitat is oak, mixed oak, and pine woodlands, but also is found in areas of chaparral, grassland, and even desert (Arizona Game and Fish Department 2001). Within these habitats, this frog is an aquatic species that uses a variety of water sources including thermal springs and seeps, stock tanks, wells, intermittent rocky creeks, and main-stream river reaches (Degenhardt 1996). Other aquatic systems include deep rock-bound pools and beaver ponds (Arizona Game and Fish Department 2001). The elevation range for this species is 1000 – 2600m (New Mexico Department of Game and Fish 2004).

Spatial Patterns

Home range requirements of Chiricahua leopard frogs are not known. Available information on movements of Chiricahua leopard frogs indicates that most individuals stay within a few kilometers of their breeding sites, though occasionally individuals will move distances of several kilometers (NatureServe 2005). Chiricahua leopard frogs have been observed dispersing up to 1.5 miles from their home ponds (Pima Co., Arizona 2001).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –
Vegetation received an importance weight of 55%, while elevation, topography, and

distance from roads received weights of 25%, 10%, and 10%, respectively. This species is an aquatic obligate, so we restricted its habitat suitability model to only those riparian areas likely to be important for this species.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum patch size was defined as 0.05 ha, while minimum core size was defined as 0.1 ha (Phil Rosen, personal comm.). Because distinctions between these two habitat thresholds cannot be made using the GIS data layers available to us, we did not map potential habitat patches.

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Desert Box Turtle (*Terrapene ornate luteola*)

Justification for Selection

The desert grassland box turtle is uncommon in Arizona, and its habitat continues to be limited by recent residential developments (Pima Co., Arizona 2001). Habitat alterations from agriculture also may be eliminating populations in some areas of its range (New Mexico Department of Game and Fish 2004). This turtle is sensitive to highway traffic, and automobiles are considered a significant cause of mortality (Pima Co., Arizona 2001).

Distribution

The desert box turtle's range encompasses south-central New Mexico south to central Chihuahua and Sonora, Mexico, and from west Texas across southern New Mexico to the eastern base of the Baboquivari Mountains (Pima Co., Arizona 2001). In Arizona, the desert box turtle occurs in Pima and Santa Cruz counties (New Mexico Department of Game and Fish 2004). This species has historically occurred in the Santa Cruz Valley, but may have been extirpated (Phil Rosen, personal comm.).

Habitat Associations

This species is associated with arid and semiarid regions, and is found in grasslands, plains, and pastures (New Mexico Department of Game and Fish 2004). It prefers open prairies with herbaceous vegetation and sandy soil (New Mexico Department of Game and Fish 2004). This turtle also occurs in rolling grass and shrub land, as well as open woodlands with herbaceous understory (Pima Co., Arizona 2001). Specifically, it is common to mesquite-dominated bajada and abundant in bajada grasslands, grassland flats, and mesquite-dominated flats, but uncommon in rocky

slopes and bajada desert scrub (New Mexico Department of Game and Fish 2004). This turtle has been observed taking refuge in subterranean mammal burrows, especially those of the kangaroo rat (Plummer 2004). Elevation range for this species is 0 to 2000 meters, but elevations of 1200 to 1600 meters are most suitable (Pima Co., Arizona 2001). In arid regions, this species is dependent on inhabitable sections of riparian bottoms (Phil Rosen, personal comm.)

Spatial Patterns

Due to extended periods of unfavorable weather conditions within its range, the desert box turtle is active only a few weeks out of the year (Plummer 2004). During activity, it requires up to 12 ha for its home range, including land with moist soil that is not compacted (Pima Co., Arizona 2001). One study in Cochise County, Arizona reported average home ranges of 1.1 ha in a dry year and 2.5 ha in a wet year (Pima Co., Arizona 2001). Another study at Fort Huachuca found home ranges that varied from 1.6 ha to 12.4 ha, with an average of 8.5 ha (Pima Co., Arizona 2001). Daily movements include early morning and late afternoon excursions to flat water sites, including cattle tanks (New Mexico Department of Game and Fish 2004; Plummer 2004).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 40%, while elevation, topography, and distance from roads received weights of 15%, 20%, and 25%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the

included Excel spreadsheet,
corridorDesigner_speciesScores.xls.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 5 ha, and minimum potential core size was defined as 50 ha (Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

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Sonoran Desert Tortoise (*Gopherus agassizii*)



Justification for Selection

While the Mojave population of desert tortoise is listed as Threatened by the Fish & Wildlife Service, the Sonoran population is not currently listed. However, all desert tortoise populations are susceptible to habitat fragmentation, and need connectivity to maintain genetic diversity. Their ability to survive as an individual or population near roads is limited because of the potential for roadkill (Edwards et al. 2004).

Distribution

Desert tortoises are found deserts throughout California, southeastern Nevada, southwestern Utah, and Arizona. Desert tortoises are divided into two populations: the Mojave Desert population occurs north and west of the Colorado River, while the Sonoran Desert population occurs south and east of the Colorado River. Desert tortoises are found within Ironwood Forest National Monument with greatest frequency in the Sawtooth, West Silverbell, and Silverbell Mountains.

Habitat Associations

Tortoises are dependent on soil type and rock formations for shelter. Typical tortoise habitat in the Sonoran Desert is rocky outcrops (Bailey et al. 1995) where they make their burrows on south facing slopes. Exceptions to

this rule usually involve some other topographical feature (such as caliche caves) that act similarly as shelter (Taylor Edwards, personal comm.). Desert Tortoises are obligate herbivores (Ofstedal 2002) so vegetation is an important part of their habitat. However, desert tortoises also occur over a wide range of vegetation (Sinaloan thornscrub - Mojave Desert), so vegetation is therefore a variable resource. Desert tortoises eat both annuals and perennials, but not generally the desert plants that characterize a vegetation type (saguaro cactus, palo verde, etc.). Optimal habitat usually lies in Arizona Upland, between 2,200 and 3000 ft, although some low desert populations occur at ~1500 ft (Eagletail Mtns) and others breed at elevations up to ~4500ft (Chimineia Canyon) (Aslan et al. 2003; T. Edwards, personal comm.).

Spatial Patterns

Mean home range estimates (minimum convex polygon) from 5 different studies at 6 different sites across the Sonoran Desert are between 7 and 23 ha (Averill-Murray et al. 2002). The Sonoran desert tortoise: natural history, biology, and conservation. Density of tortoise populations range from 20 - upwards of 150 individuals per square mile (from 23 Sonoran Desert populations; Averill-Murray et al. 2002). Tortoises have overlapping home ranges, so the estimated space needed for roughly 20 adults is approximately 50 hectares, which is the size of the Tumamoc Hill population near Tucson (Edwards et al. 2003). Desert tortoises are a long-lived species (well exceeding 40 years; Germano 1992) with a long generation time (estimated at 25 years; USFWS 1994). A 5-10 year time frame for a desert tortoise population is relatively insignificant, such that 20 adult individuals might maintain for 30+ years without ever

successfully producing viable offspring. Also, tortoises have likely maintained long-term, small effective population sizes throughout their evolutionary history (see Edwards et al. 2004 for more insight into genetic diversity; Germano 1992; USFWS 1994). While long-distance movements of desert tortoises appear uncommon, they do occur and are likely *very* important for the long-term maintenance of populations (Edwards et al. 2004). Desert tortoises may move more than 30 km during long-distance movements (T. Edwards, personal comm.)

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 30%, while elevation, topography, and distance from roads received weights of 25%, 40%, and 5%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum potential habitat patch size was defined as 15 ha, and minimum potential core size was defined as 50 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

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Rosen, P.C. and K. Mauz. 2001. Biological values of the West Branch of the Santa Cruz River, with a Preliminary Flora. Document (independently contracted) for the Sonoran Desert Conservation Plan, Pima County Board of Supervisors, Pima

Co., Arizona.

[http://www.co.pima.az.us/cmo/sdcp/sdcp2/
reports/WB/WestB.htm](http://www.co.pima.az.us/cmo/sdcp/sdcp2/reports/WB/WestB.htm)

U.S. Fish and Wildlife Service. 1994. Desert
Tortoise (Mojave Population) Recovery
Plan. U.S. Fish and Wildlife Service,
Portland, Oregon, USA. 73pp.

Giant Spotted Whiptail (*Aspidoscelis burti stictogrammus*)



Justification for Selection

The giant spotted whiptail is thought to be stable; however, little is known of its population trends (Arizona Game and Fish Department 2001). This species has a limited distribution, and is listed as Forest Service Sensitive (1999) and Bureau of Land Management Sensitive (2000; Arizona Game and Fish Department 2001). Although the giant spotted whiptail is not considered to be migratory, corridors are needed to connect disjunct populations (Pima Co., Arizona 2001). They are adversely impacted by habitat alteration due to overgrazing of riparian vegetation (Pima Co., Arizona 2001).

Distribution

This lizard's range is limited to southeastern Arizona including the Santa Catalina, Santa Rita, Pajarito, and Baboquivari Mountains. It is also known to exist in the vicinity of Oracle, Pinal County, and Mineral Hot Springs, Cochise County. Outside of Arizona, the giant spotted whiptail is found in Guadalupe Canyon in extreme southwest New Mexico and northern Sonora, Mexico (Arizona Game and Fish Department 2001).

Habitat Associations

Giant spotted whiptails are found in the riparian areas of lower Sonoran life zones, as well as mountain canyons, arroyos, and mesas

in arid and semi-arid regions (Pima Co., Arizona 2001). These lizards inhabit dense shrubby vegetation, often among rocks near permanent and intermittent streams, as well as open areas of bunch grass within these riparian habitats (Arizona Game and Fish Department 2001). They are able to access lowland desert along stream courses (Pima Co., Arizona 2001). Elevation ranges of suitable habitat are from 2,200 to 5,000 feet (670 to 1,500m) (Pima Co., Arizona 2001).

Spatial Patterns

Giant spotted whiptails require only 2-4 ha for their home range (Rosen et al. 2002). Within this area, they rely on a mosaic of open spaces and cover of dense thickets of thorny scrub while foraging (Pima Co., Arizona 2001). These lizards are not migratory, and hibernate in winter.

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 70%, while elevation received a weight of 30%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, corridorDesigner_speciesScores.xls.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum patch size was defined as 4 ha, while minimum core size was defined as 25 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

Arizona Game and Fish Department. 2001.
Aspidoscelis burti stictogrammus.

Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

Pima County, Arizona. 2001. Priority Vulnerable Species: Analysis and Review of Species Proposed for Coverage by the Multiple-Species Conservation Plan. Sonoran Desert Conservation Plan Public Review Draft. Obtained from <http://www.co.pima.az.us/cmo/sdcp/sdcp2/>

pvs/pdfs/ (accessed 8 November 2005). 421 pp.

Rosen, P. C., R. B. Duncan, P. A. Holm, T. B. Persons, S. S. Sartorius, and C. R. Schwalbe. 2002. Status and ecology of the Giant Spotted Whiptail (*Cnemidophorus burti stictogrammus*) in Arizona. Final Report to Arizona Game & Fish Department, Heritage Grant (IIPAM program) I99018. 128 pp.

Gila Monster (*Heloderma suspectum*)



Justification for Selection

Gila monsters do are state-listed in every state in which they occur, and are listed as Threatened in Mexico (New Mexico Department of Game and Fish 2004). Gila monsters are susceptible to road kills and fragmentation, and their habitat has been greatly affected by commercial and private reptile collectors (AZGFD 2002; NMDGF 2004).

Distribution

Gila monsters range from southeastern California, southern Nevada, and southwestern Utah down throughout much of Arizona and New Mexico.

Habitat Associations

Gila monsters live on mountain slopes and washes where water is occasionally present. They prefer rocky outcrops and boulders, where they dig burrows for shelter (NFDGF 2004). Individuals are reasonably abundant in mid-bajada flats during wet periods, but after some years of drought conditions, these populations may disappear (Phil Rosen & Matt Goode, personal comm.). The optimal elevation for this species is between 1700 and 4000 ft.

Spatial Patterns

Home ranges from 13 to 70 ha have been recorded (Beck 2005). Home ranges 3-4 km long have been recorded. Gila Monsters are widely foraging, and capable of long bouts of exercise, so it is assumed that they can disperse up to 8 km or more (Rose & Goode, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –

Vegetation received an importance weight of 10%, while elevation, topography, and distance from roads received weights of 35%, 45%, and 10%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, corridorDesigner_speciesScores.xls.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 100 ha, and minimum potential core size was defined as 300 ha (Rosen & Goode, personal comm.; Beck 2005). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

- Arizona Game and Fish Department. 2002. *Heloderma suspectum cinctum*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.

Beck, D. E. 2005. Biology of Gila Monsters and Beaded Lizards. University of California Press, Berkeley.

New Mexico Department of Game & Fish. 2004. Biota Information System of New

Mexico. New Mexico Department of Game & Fish electronic database, BISON, Version 1/2004, Santa Fe, New Mexico. <http://nmnhp.unm.edu/bisonm/bisonquery.php>. Accessed 9 September 2005.

Lowland Leopard Frog (*Rana yavapaiensis*)



Justification for Selection

This species has a limited distribution and is susceptible to road mortality. They have lost much of their habitat due to development, fragmentation, and water manipulation, and have been negatively impacted by bullfrogs, crayfish and chytrid fungus (Arizona Game and Fish Department 2001).

Distribution

The lowland leopard frog historically ranged throughout low elevation sites in the lower Colorado River and its tributaries in Arizona, New Mexico, California, Nevada, and northern Mexico. Within Arizona, the species is found in the Colorado River near Yuma, and south of the Mogollon Rim (AZGFD 2001).

Habitat Associations

This species is 100% dependent on aquatic habitat. They can occur in aquatic systems ranging from desert grasslands to pinyon-juniper. Generally, effective corridors would tend to be in stream bottoms (like Cienega Creek, where it still occurs) and connecting to stock ponds and mountain springs or tinajas via major washes, especially those with intermittent, rather than ephemeral flow (Phil Rosen, personal comm.). Optimal elevation for this species is from 900 to 4000 ft,

although it can be found at higher elevations (Lannoo 2005; P. Rosen, personal comm.)

Spatial Patterns

Very small but suitable sites as small as 0.05 ha, such as stock tanks, exceptional springs, or maintained frog pools, can sustain populations of leopard frogs (Fernandez 1996; P. Rosen, personal comm.). The longest recorded movement from a known population of leopard frogs is 5km, although the species could potentially disperse up to 16 km from a huge, burgeoning population (Platz 1990; Rosen & Schwalbe 1997, 1998).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –

Vegetation received an importance weight of 60%, while elevation and distance from roads received weights of 30% and 10%, respectively. This species is an aquatic obligate, so we restricted its habitat suitability model to only those riparian areas likely to be important for this species.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum patch size was defined as 0.05 ha, while minimum core size was defined as 0.1 ha (Phil Rosen, personal comm.). Because distinctions between these two habitat thresholds cannot be made using the GIS data layers available to us, we did not map potential habitat patches.

References

Arizona Game and Fish Department. 2001. *Rana yavapaiensis*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 6 pp.

- Fernandez, P.J. 1996. A facility for captive propagation of Chiricahua Leopard Frogs, *Rana chiricahuensis*. *Advances in Herpetoculture* 1: 7-12.
- Lanoo, M. (editor). 2005. *Amphibian Declines: The Conservation Status of United States Species*. University of California Press, Berkeley.
- Platz, J.E., R.W. Clarkson, J.C. Rorabaugh, and D.M. Hillis. 1990. *Rana berlandieri*: recently introduced populations in Arizona and southeastern California. *Copeia* 1990: 324-333.
- Rosen, P.C. and C.R. Schwalbe. 1997. Bullfrog impacts on sensitive wetland herpetofauna, and Herpetology of the San Bernardino National Wildlife Refuge. Final Report to Arizona Game & Fish Dept. Heritage Program, and USFWS. 30 pp.
- Rosen, P.C. and C.R. Schwalbe. 1998. Status of native and introduced species of herpetofauna at San Bernardino National Wildlife Refuge. Final Report for Project 196056 to Arizona Game & Fish Dept. Heritage Program, and USFWS. 52 pp.

Lyre Snake (*Trimorphodon biscutatus*)

Justification for Selection

Lyre Snakes are susceptible to habitat fragmentation

Distribution

This species ranges from southern Nevada and Utah through western Mexico.

Habitat Associations

This species lives on mountain slopes in virtually all vegetation types up to about 7400' in Arizona, and occurs in riparian zones as well. It is strongly associated with rocks and outcrops, but is infrequently but regularly seen in creosote flats at distances of several miles from the usual rock slope habitats (Phil Rosen & Matt Goode, personal comm.)

Spatial Patterns

There is no published data on spatial patterns for the Lyre Snake. Based on limited telemetry data, Matt Goode has estimated home range to range from 2 to 4 ha, and movements to be limited to approximately 500 m. Phil Rosen (unpublished) found that in wet years at

Organ Pipe Cactus NM, individuals moved 2-3 mi from the rock slopes to which they were restricted in normal and dry years.

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Because this species is found on mountain slopes in virtually all vegetation types, topography received a weight of 80%, while elevation and distance-from-roads received weights of 10%. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 4 ha, and minimum potential core size was defined as 20 ha (Matt Goode, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

Mexican Garter Snake (*Thamnophis eques megalops*)

Justification for Selection

The Mexican Garter Snake is designated a Species of Concern by the U.S. Fish and Wildlife Service, and a Species of Special Concern by the Arizona Game and Fish Department (Pima Co., Arizona 2001). This species is vulnerable to urbanization and lowered water tables, habitat destruction, overgrazing, and predation by introduced bullfrogs and predatory fishes (Arizona Game and Fish Department 2001).

Distribution

The Mexican Garter Snake's current range extends from southeastern Arizona and extreme southwestern New Mexico southward to Oaxaca, Mexico (Arizona Game and Fish Department 2001). Specifically within Arizona, this snake is found from the Santa Cruz Valley east and south of the Gila River. Recent sightings have been recorded in the San Rafael and Sonoita grasslands, Arivaca, the Aqua Fria, Verde, and Salt/Black River, and Oak Creek (Arizona Game and Fish Department 2001).

Habitat Associations

This snake species requires intact riparian vegetation communities along permanent water that is free of bullfrogs (Pima Co., Arizona 2001). In Arizona, it is associated with densely vegetated habitat surrounding cinegas, cinega streams, and stock tanks, and also in or near water along streams in valley floors and open areas of elevations up to 8500 feet, but not in steep mountain canyon stream habitats (Arizona Game and Fish Department 2001).

Spatial Patterns

The Mexican Garter Snake requires a home range of slightly more than 2 acres (Pima Co., Arizona 2001). This species requires large habitat areas of dense vegetation habitat and interconnected areas of ponds, springs, and streams to assure survival (Pima Co., Arizona 2001).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –

Vegetation received an importance weight of 40%, while elevation, topography, and distance from roads received weights of 15%, 40%, and 5%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum patch size for Mexican garter snake was defined as 0.5 ha and minimum core size as 1 ha (Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

- Arizona Game and Fish Department. 2001. *Thamnophis eques megalops*. Unpublished abstract compiled and edited by the Heritage Data Management System, Arizona Game and Fish Department, Phoenix, AZ. 5 pp.
- Pima County, Arizona. 2001. Priority Vulnerable Species: Analysis and Review of Species Proposed for Coverage by the

Multiple-Species Conservation Plan.
Sonoran Desert Conservation Plan Public
Review Draft. Obtained from

<http://www.co.pima.az.us/cmo/sdcp/sdcp2/pvs/pdfs/> (accessed 8 November 2005). 421 pp.

Sonoran Desert Toad (*Bufo alvarius*)



Justification for Selection

This species is thought to be potentially susceptible to extirpation or demographic impact from road mortality due to its large size, conspicuous activity, numerous observations of road-killed adults, presumed long natural lifespan, and apparent declines in road-rich urban zones. However, in at least one place, a population is thriving in central Tucson (Rosen and Mauz (2001).

Distribution

Sonoran desert toads range from southeastern California to southwestern New Mexico (New Mexico Department of Game & Fish 2004).

Habitat Associations

Breeding is naturally concentrated in canyons and upper bajada intermittent streams, and on valley floors in major pools, but not naturally frequent on intervening bajadas. With stock ponds, breeding can occur anywhere on the landscape, but valley centers and canyons likely remain as the core areas (Phil Rosen, personal comm.).

Spatial Patterns

Little is known about spatial patterns for this species. Rosen (personal comm.) estimates the smallest area of suitable habitat necessary to support a breeding group for 1 breeding

season to be 25 ha, based on limited knowledge of movements and smallest occupied patches in Tucson. Based on unpublished data by Cornejo, adults appear to be highly mobile, and long distance movements (5 km to be conservative) seem likely (P. Rosen, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Sonoran desert toads appear capable of occupying any vegetation type, from urbanized park to their maximum elevation. Roads can have a massive mortality impact and presumed population impact, but some populations live near roads that may be peripheral or marginal to the core habitat (Phil Rosen, personal comm.).

Vegetation received an importance weight of 5%, while elevation, topography, and distance from roads received weights of 50%, 25%, and 20%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 100 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

New Mexico Department of Game & Fish.
2004. Biota Information System of New Mexico. New Mexico Department of Game & Fish electronic database, BISON,

Version 1/2004, Santa Fe, New Mexico.
<http://nrmhp.unm.edu/bisonm/bisonquery.php>. Accessed 9 September 2005.

Rosen, P.C. and K. Mauz. 2001. Biological values of the West Branch of the Santa Cruz River, with a Preliminary Flora.

Document (independently contracted) for the Sonoran Desert Conservation Plan, Pima County Board of Supervisors, Pima Co., Arizona.
<http://www.co.pima.az.us/cmo/sdcp/sdcp2/reports/WB/WestB.htm>

Sonoran Whipsnake (*Masticophis bilineatus*)



Justification for Selection

Wide-ranging, active, diurnal snakes including whipsnakes and racers are usually observed to disappear when urban road networks become dense, and the assumption is that road mortality plays a large roll. However, coachwhips are still found on the Tucson Foothills bajada, suggesting a small tolerance for roads (Phil Rosen, personal comm.).

Distribution

The Sonoran whipsnake is mainly found in the Sonoran desert of Mexico, but also occurs within southern Arizona and New Mexico.

Habitat Associations

This species tends to prefer areas with rugged topography, and will also use mid-to-high elevation riparian flats. This species is mobile, may occur along or move along desert and grassland washes, and thus might occasionally traverse areas of flat non-habitat between mountains, like some other larger reptiles. Preferred land cover types include Encinal, Pine-Oak Forest, Pinyon-Juniper Woodland, Chaparral, Creosotebush - Mixed Desert and Thorn Scrub, and Paloverde-Mixed-Cacti Desert Scrub.

Spatial Patterns

Home range has been estimated as 50 ha for this species (Parizek et al. 1995). Little is know about dispersal distance, but a telemetry study found one large male to move up to 1 km per day (Parizek et al. 1995). Based on observations of other whipsnakes, movement events of up to 4.5 km may be feasible (Phil Rosen, personal comm.)

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL –

Vegetation received an importance weight of 30%, while elevation, topography, and distance from roads received weights of 10%, 45%, and 15%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 50 ha, and minimum potential core size was defined as 250 ha (Parizek et al. 1995; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

- Parizek, D.A., P.C. Rosen, and C.R. Schwalbe. 1995. Ecology of the Mexican rosy boa and Ajo Mountain Whipsnake in a desert rockpile snake assemblage. Final Report to Arizona Heritage Program, Arizona Game and Fish Dept., Phoenix. 65 pp.

Tiger Rattlesnake (*Crotalus tigris*)

Justification for Selection

Tiger rattlesnakes are a rare species in Arizona, and rely on the ability to move across varied habitats and elevations for migration. Radio telemetry research suggests avoidance of busy roads (M. Goode, pers. comm.), possibly impeding their movement requirements.

Distribution

The tiger rattlesnake has a limited distribution, encompassing south-central Arizona to the New Mexico border and south into Sonora, Mexico (Lowe 1978; Degenhardt et al. 1996).

Habitat Associations

Tiger rattlesnakes are most common in Arizona Upland habitats of saguaro, palo verde and mixed cactus, but also can be found in lower elevations of oak grassland and creosote flats on the lower bajada if rocky washes are present (M. Goode, pers. comm.). They have a known elevational range in Arizona of 300-1700 m, and are never found far from rock outcrops (M. Goode, pers. comm.).

Spatial Patterns

There is considerable variation in movement patterns of tiger rattlesnakes among individuals, sexes, age classes, seasons, and years (M. Goode, pers. comm.). Male home ranges vary from 5 to 25 hectares, depending on landscape patterns and year. Occasionally, rogue males may have home ranges as large as 125 hectares (M. Goode, pers. comm.). Female home ranges are generally smaller, averaging from 1 to 5 hectares (M. Goode, pers. comm.). In general, tiger rattlesnakes move from rocky slopes in spring to xeroriparian washes in summer and back to

slopes in fall, demonstrating elevational migration (M. Goode, pers. comm.).

Preliminary genetic data (microsatellite markers) indicate that tiger rattlesnakes moved between mountain ranges, but radiotelemetry data suggest that this no longer happens (M. Goode, pers. comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Tiger rattlesnakes have a known elevational range in Arizona (300-1700 m), and they are never found far from rock outcrops. Although mostly in Arizona Upland (saguaro/palo verde/mixed cactus), they can be found at the lower elevations of oak grassland and out into creosote flats on the lower bajada if rocky washes are present (Matt Goode, personal comm.). Vegetation received an importance weight of 20%, while elevation, topography, and distance from roads received weights of 30%, 40%, and 10%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, *corridorDesigner_speciesScores.xls*.

PATCH SIZE & CONFIGURATION

ANALYSIS – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 100 ha. To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

Degenhardt, W.G., Painter, C.W., and A.H. Price. 1996. Amphibians and Reptiles of New Mexico. UNM Press, Albuquerque, NM. 431 pp.

Lowe, Charles H. 1978. The Vertebrates of
Arizona. University of Arizona Press,
Tucson, Arizona. 270 pp.

Tucson Shovel-nosed Snake (*Chionactis occipitalis klauberi*)



Justification for Selection

Tucson shovel-nosed snakes have a very limited distribution, and are only known to exist in two counties of Arizona. They are susceptible to habitat loss, and are dependent on flat valley floors which are rapidly being converted to agriculture and residential development. A petition has recently been filed to protect the species under the Endangered Species Act.

Distribution

Tucson shovel-nosed snakes are a subspecies of the western shovel-nosed snake, which ranges from southern Arizona to southern California. This subspecies is found only within the deserts of Pima and Pinal county within Arizona, and has apparently disappeared from a large part of its range in Avra Valley, possibly due to habitat fragmentation. Populations are known to exist near Picacho Peak State Park, and probably also within Ironwood Forest National Monument (Phil Rosen, personal comm.)

Habitat Associations

This species is dependent on flat (< 1%), sandy valley floors, and may also use washes. They occur mainly in vegetation associations consisting of creosotebush and desert grasses.

Spatial Patterns

Estimation of home range based on tracks in sandy places indicate this species may move less than many other snake species, needing only 25 ha to sustain a home range. While nothing is known about juvenile dispersal, most snakes are not known to have a dispersal phase. This species is likely to settle into a home range within 1-2 home ranges of their natal area, giving an estimated dispersal distance ranging from 0.25-2 km (P. Rosen, personal comm.).

Conceptual Basis for Model Development

HABITAT SUITABILITY MODEL – Vegetation received an importance weight of 20%, while elevation, topography, and distance from roads received weights of 20%, 45%, and 15%, respectively. For specific scores of classes within each of these factors used for the modeling process, see the included Excel spreadsheet, corridorDesigner_speciesScores.xls.

PATCH SIZE & CONFIGURATION ANALYSIS – Minimum potential habitat patch size was defined as 25 ha, and minimum potential core size was defined as 250 ha (Rosen & Mauz 2001; Phil Rosen, personal comm.). To determine potential habitat patches and cores, the habitat suitability model for this species was first averaged using a 3x3 neighborhood moving window analysis.

References

Rosen, P.C., and K. Mauz. 2001. Biological values of the West Branch of the Santa Cruz River, with a Preliminary Flora. Document (independently contracted) for the Sonoran Desert Conservation Plan,

Pima County Board of Supervisors, Pima
Co., Arizona.

[http://www.co.pima.az.us/cmo/sdcp/sdcp2/
reports/WB/WestB.htm](http://www.co.pima.az.us/cmo/sdcp/sdcp2/reports/WB/WestB.htm)

Description of Land Cover Classes

Vegetation classes were derived from the Southwest Regional GAP analysis (ReGAP) land cover layer. To simplify the layer from 77 to 46 classes, we grouped similar vegetation classes into slightly broader classes by removing geographic and environmental modifiers (e.g. Chihuahuan Mixed Salt Desert Scrub and Inter-Mountain Basins Mixed Salt Desert Scrub got lumped into “Desert Scrub”; Subalpine Dry-Mesic Spruce-Fir Forest and Woodland was simplified to Spruce-Fir Forest and Woodland). What follows is a description of each class, taken largely from the document, Landcover Descriptions for the Southwest Regional GAP Analysis Project (Available from <http://earth.gis.usu.edu/swgap>)

Evergreen Forest (7 classes)

Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species maintain their leaves all year. Canopy is never without green foliage.

Conifer-Oak Forest and Woodland – This system occurs at the upper elevations in the Sierra Madre Occidentale and Sierra Madre Orientale. In the U.S., it is restricted to north and east aspects at high elevations (1980-2440 m) in the Sky Islands (Chiricahua, Huachuca, Pinaleno, Santa Catalina, and Santa Rita mountains) and along the Nantanes Rim. The vegetation is characterized by large- and small-patch forests and woodlands dominated by *Pseudotsuga menziesii*, *Abies coahuilensis*, or *Abies concolor* and Madrean oaks such as *Quercus hypoleucoides* and *Quercus rugosa*. It is similar to Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland

Encinal (Oak Woodland) – Madrean Encinal occurs on foothills, canyons, bajadas and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north into Trans-Pecos Texas, southern New Mexico and sub-Mogollon Arizona. These woodlands are dominated by Madrean evergreen oaks along a low-slope transition below Madrean Pine-Oak Forest and Woodland and Madrean Pinyon-Juniper Woodland. Lower elevation stands are typically open woodlands or savannas where they transition into desert grasslands, chaparral or in some case desert scrub.

Mixed Conifer Forest and Woodland – Comprised of *Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Montane Mesic Mixed Conifer Forest and Woodland* classes. These are mixed-conifer forests occurring on all aspects at elevations ranging from 1200 to 3300 m. The composition and structure of overstory is dependent upon the temperature and moisture relationships of the site, and the successional status of the occurrence.

Pine-Oak Forest and Woodland – This system occurs on mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, Trans-Pecos Texas, southern New Mexico and southern and central Arizona, from the the Mogollon Rim southeastward to the Sky Islands. These forests and woodlands are composed of Madrean

pinus (*Pinus arizonica*, *Pinus engelmannii*, *Pinus leiophylla* or *Pinus strobiformis*) and evergreen oaks (*Quercus arizonica*, *Quercus emoryi*, or *Quercus grisea*) intermingled with patchy shrublands on most mid-elevation slopes (1500-2300 m elevation). Other tree species include *Cupressus arizonica*, *Juniperus deppeana*.

Pinyon-Juniper Woodland – These woodlands occur on warm, dry sites on mountain slopes, mesas, plateaus, and ridges. Severe climatic events occurring during the growing season, such as frosts and drought, are thought to limit the distribution of pinyon-juniper woodlands to relatively narrow altitudinal belts on mountainsides. In the southern portion of the Colorado Plateau in northern Arizona and northwestern New Mexico, *Juniperus monosperma* and hybrids of *Juniperus* spp may dominate or codominate tree canopy. *Juniperus scopulorum* may codominate or replace *Juniperus osteosperma* at higher elevations. In transitional areas along the Mogollon Rim and in northern New Mexico, *Juniperus deppeana* becomes common. In the Great Basin, Woodlands dominated by a mix of *Pinus monophylla* and *Juniperus osteosperma*, pure or nearly pure occurrences of *Pinus monophylla*, or woodlands dominated solely by *Juniperus osteosperma* comprise this system.

Ponderosa Pine Woodland – These woodlands occur at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests typically in warm, dry, exposed sites. Elevations range from less than 500 m in British Columbia to 2800 m in the New Mexico mountains. Occurrences are found on all slopes and aspects, however, moderately steep to very steep slopes or ridgetops are most common. *Pinus ponderosa* is the predominant conifer; *Pseudotsuga menziesii*, *Pinus edulis*, and *Juniperus* spp. may be present in the tree canopy.

Spruce-Fir Forest and Woodland – Engelmann spruce and subalpine fir forests comprise a substantial part of the subalpine forests of the Cascades and Rocky Mountains from southern British Columbia east into Alberta, south into New Mexico and the Intermountain region. They are the matrix forests of the subalpine zone, with elevations ranging from 1525 to 3355 m (5000-11,000 feet). Sites within this system are cold year-round, and precipitation is predominantly in the form of snow, which may persist until late summer. Despite their wide distribution, the tree canopy characteristics are remarkably similar, with *Picea engelmannii* and *Abies lasiocarpa* dominating either mixed or alone. *Pinus contorta* is common in many occurrences and patches of pure *Pinus contorta* are not uncommon, as well as mixed conifer/*Populus tremuloides* stands. Xeric species may include *Juniperus communis*, *Linnaea borealis*, *Mahonia repens*, or *Vaccinium scoparium*.

Deciduous Forest (1 class)

Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75 percent of the tree species shed foliage simultaneously in response to seasonal change.

Aspen Forest and Woodland – Elevations generally range from 1525 to 3050 m (5000-10,000 feet), but occurrences can be found at lower elevations in some regions. Distribution of this ecological system is primarily limited by adequate soil moisture required to meet its high evapotranspiration demand, and secondarily is limited by the length of the growing season or low temperatures. These are upland forests and woodlands dominated by *Populus tremuloides* without a significant conifer component (<25% relative tree cover).

Grasslands-Herbaceous (3 classes)

Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Juniper Savanna – The vegetation is typically open savanna, although there may be inclusions of more dense juniper woodlands. This savanna is dominated by *Juniperus osteosperma* trees with high cover of perennial bunch grasses and forbs, with *Bouteloua gracilis* and *Pleuraphis jamesii* being most common. In southeastern Arizona, these savannas have widely spaced mature juniper trees and moderate to high cover of graminoids (>25% cover). The presence of Madrean *Juniperus* spp. such as *Juniperus coahuilensis*, *Juniperus pinchotii*, and/or *Juniperus deppeana* is diagnostic.

Montane-Subalpine Grassland – This Rocky Mountain ecological system typically occurs between 2200-3000 m on flat to rolling plains and parks or on lower sideslopes that are dry, but may extend up to 3350 m on warm aspects. An occurrence usually consists of a mosaic of two or three plant associations with one of the following dominant bunch grasses: *Danthonia intermedia*, *Danthonia parryi*, *Festuca idahoensis*, *Festuca arizonica*, *Festuca thurberi*, *Muhlenbergia filiculmis*, or *Pseudoroegneria spicata*. These large-patch grasslands are intermixed with matrix stands of spruce-fir, lodgepole, ponderosa pine, and aspen forests.

Semi-Desert Grassland and Shrub Steppe – Comprised of *Semi-Desert Shrub Steppe* and *Piedmont Semi-Desert Grassland and Steppe*. Semi-Desert Shrub is typically dominated by graminoids (>25% cover) with an open shrub layer, but includes sparse mixed shrublands without a strong graminoid layer. Steppe Piedmont Semi-Desert Grassland and Steppe is a broadly defined desert grassland, mixed shrub-succulent or xeromorphic tree savanna that is typical of the Borderlands of Arizona, New Mexico and northern Mexico [Apacherian region], but extends west to the Sonoran Desert, north into the Mogollon Rim and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that supported frequent fire throughout the Sky Islands and on mesas and steeper piedmont and foothill slopes in the Chihuahuan Desert. It is characterized by a typically diverse perennial grasses. Common grass species include *Bouteloua eriopoda*, *B. hirsuta*, *B. rothrockii*, *B. curtipendula*, *B. gracilis*, *Eragrostis intermedia*, *Muhlenbergia porteri*, *Muhlenbergia setifolia*, *Pleuraphis jamesii*, *Pleuraphis mutica*, and *Sporobolus airoides*, succulent species of *Agave*, *Dasyllirion*, and *Yucca*, and tall shrub/short tree species of *Prosopis* and various oaks (e.g., *Quercus grisea*, *Quercus emoryi*, *Quercus arizonica*).

Scrub-Shrub (14 classes)

Areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Big Sagebrush Shrubland – This ecological system occurs throughout much of the western U.S., typically in broad basins between mountain ranges, plains and foothills between 1500-2300 m elevation. Soils are typically deep, well-drained and non-saline. These shrublands are dominated by *Artemisia tridentata* ssp. *tridentata* and/or *Artemisia tridentata* ssp. *wyomingensis*. Perennial herbaceous components typically contribute less than 25% vegetative cover.

Blackbrush-Mormon-tea Shrubland – This ecological system occurs in the Colorado Plateau on benchlands, colluvial slopes, pediments or bajadas. Elevation ranges from 560-1650 m. The vegetation is characterized by extensive open shrublands dominated by *Coleogyne ramosissima* often with *Ephedra viridis*, *Ephedra torreyana*, or *Grayia spinosa*. Sandy portions may include *Artemisia filifolia* as codominant. The herbaceous layer is sparse and composed of graminoids such as *Achnatherum hymenoides*, *Pleuraphis jamesii*, or *Sporobolus cryptandrus*.

Chaparral – This ecological system occurs across central Arizona (Mogollon Rim), western New Mexico and southwestern Utah and southeast Nevada. It often dominates along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into mountains (1000-2200 m). It occurs on foothills, mountain slopes and canyons in dryer habitats below the encinal and *Pinus ponderosa* woodlands. Stands are often associated with more xeric and coarse-textured substrates such as limestone, basalt or alluvium, especially in transition areas with more mesic woodlands.

Creosotebush, Mixed Desert and Thorn Scrub – This widespread Chihuahuan Desert land cover type is composed of two ecological systems: the Chihuahuan Creosotebush Xeric Basin Desert Scrub and the Chihuahuan Mixed Desert and Thorn Scrub. This cover type includes xeric creosotebush basins and plains and the mixed desert scrub in the foothill transition zone above, sometimes extending up to the lower montane woodlands. Vegetation is characterized by *Larrea tridentata* alone or mixed with thornscrub and other desert scrub such as *Agave lechuguilla*, *Aloysia wrightii*, *Fouquieria splendens*, *Dasyllirion leiophyllum*, *Flourensia cernua*, *Leucophyllum minus*, *Mimosa aculeaticarpa* var. *biuncifera*, *Mortonia scabrella* (= *Mortonia sempervirens* ssp. *scabrella*), *Opuntia engelmannii*, *Parthenium incanum*, *Prosopis glandulosa*, and *Tiquilia greggii*.

Creosotebush-White Bursage Desert Scrub – This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains and low hills in the Mojave and lower Sonoran deserts. This desert scrub is characterized by a sparse to moderately dense layer (2-50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and

Ambrosia dumosa are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories.

Desert Scrub (misc) – Comprised of Succulent Desert Scrub, Mixed Salt Desert Scrub, and Mid-Elevation Desert Scrub. Vegetation is characterized by a typically open to moderately dense shrubland.

Gambel Oak-Mixed Montane Shrubland – This ecological system occurs in the mountains, plateaus and foothills in the southern Rocky Mountains and Colorado Plateau, including the Uinta and Wasatch ranges and the Mogollon Rim. These shrublands are most commonly found along dry foothills, lower mountain slopes, and at the edge of the western Great Plains from approximately 2000 to 2900 m in elevation, and are often situated above pinyon-juniper woodlands. The vegetation is typically dominated by *Quercus gambelii* alone or codominant with *Amelanchier alnifolia*, *Amelanchier utahensis*, *Artemisia tridentata*, *Cercocarpus montanus*, *Prunus virginiana*, *Purshia stansburiana*, *Purshia tridentata*, *Robinia neomexicana*, *Symphoricarpos oreophilus*, or *Symphoricarpos rotundifolius*. There may be inclusions of other mesic montane shrublands with *Quercus gambelii* absent or as a relatively minor component. This ecological system intergrades with the lower montane-foothills shrubland system and shares many of the same site characteristics.

Mat Saltbush Shrubland – This ecological system occurs on gentle slopes and rolling plains in the northern Colorado Plateau and Uinta Basin on Mancos Shale. These landscapes that typically support dwarf-shrublands composed of relatively pure stands of *Atriplex* spp. such as *Atriplex corrugata* or *Atriplex gardneri*. The herbaceous layer is typically sparse.

Mesquite Upland Scrub – This ecological system occurs as upland shrublands that are concentrated in the extensive grassland-shrubland transition in foothills and piedmont in the Chihuahuan Desert. Vegetation is typically dominated by *Prosopis glandulosa* or *Prosopis velutina* and succulents. Other desert scrub that may codominate or dominate includes *Acacia neovernicosa*, *Acacia constricta*, *Juniperus monosperma*, or *Juniperus coahuilensis*. Grass cover is typically low.

Mixed Low Sagebrush Shrubland – This ecological system occurs in the Colorado Plateau, Tavaputs Plateau and Uinta Basin in canyons, gravelly draws, hilltops, and dry flats at elevations generally below 1800 m. It includes open shrublands and steppe dominated by *Artemisia nova* or *Artemisia bigelovii* sometimes with *Artemisia tridentata* ssp. *wyomingensis* codominant.

Palo Verde-Mixed Cacti Desert Scrub - This ecological system occurs on hillsides, mesas and upper bajadas in southern Arizona. The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegia gigantea* (3-16 m tall) and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* less prominent. The sparse herbaceous layer is composed of perennial grasses and forbs with

annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat is present.

Pinyon-Juniper Shrubland – This ecological system is characteristic of the rocky mesa tops and slopes on the Colorado Plateau and western slope of Colorado, but these stunted tree shrublands may extend further upslope along the low-elevation margins of taller pinyon-juniper woodlands. The vegetation is dominated by dwarfed (usually <3 m tall) *Pinus edulis* and/or *Juniperus osteosperma* trees forming extensive tall shrublands in the region along low-elevation margins of pinyon-juniper woodlands. Herbaceous layers are sparse to moderately dense and typically composed of xeric graminoids.

Sand Shrubland – This large patch ecological system is found on the south-central Colorado Plateau in northeastern Arizona extending into southern Utah. It occurs on windswept mesas, broad basins and plains at low to moderate elevations (1300-1800m). Substrates are stabilized sandsheets or shallow to moderately deep sandy soils that may form small hummocks or small coppice dunes. This semi-arid, open shrubland is typically dominated by short shrubs (10-30 % cover) with a sparse graminoid layer. The woody layer is often a mixture of shrubs and dwarf-shrubs.

Stabilized Coppice Dune and Sand Flat Scrub – This ecological system includes the open shrublands of vegetated coppice dunes and sandsheets found in the Chihuahuan Desert. Usually dominated by *Prosopis glandulosa* but includes *Atriplex canescens*, *Ephedra torreyana*, *Ephedra trifurca*, *Poliomintha incana*, and *Rhus microphylla* coppice sand scrub with 10-30% total vegetation cover. *Yucca elata*, *Gutierrezia sarothrae*, and *Sporobolus flexuosus* are commonly present.

Woody Wetland (3 classes)

Areas where forest or shrubland vegetation accounts for greater than 20 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Greasewood Flat – This ecological system occurs throughout much of the western U.S. in Intermountain basins and extends onto the western Great Plains. It typically occurs near drainages on stream terraces and flats or may form rings around playas. Sites typically have saline soils, a shallow water table and flood intermittently, but remain dry for most growing seasons. This system usually occurs as a mosaic of multiple communities, with open to moderately dense shrublands dominated or codominated by *Sarcobatus vermiculatus*.

Riparian Mesquite Bosque – This ecological system consists of low-elevation (<1100 m) riparian corridors along intermittent streams in valleys of southern Arizona and New Mexico, and adjacent Mexico. Dominant trees include *Prosopis glandulosa* and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia*, *Pluchea sericea*, and *Salix exigua*.

Riparian Woodland and Shrubland – This system is dependent on a natural hydrologic regime, especially annual to episodic flooding. Occurrences are found within the flood zone of rivers, on islands, sand or cobble bars, and immediate streambanks. In mountain canyons and valleys of southern Arizona, this system consists of mid- to low-elevation (1100-1800 m) riparian corridors along perennial and seasonally intermittent streams. The vegetation is a mix of riparian woodlands and shrublands. Throughout the Rocky Mountain and Colorado Plateau regions, this system occurs within a broad elevation range from approximately 900 to 2800 m., as a mosaic of multiple communities that are tree-dominated with a diverse shrub component.

Emergent Herbaceous Wetland (1 class)

Areas where perennial herbaceous vegetation accounts for greater than 80 percent of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Arid West Emergent Marsh – This widespread ecological system occurs throughout much of the arid and semi-arid regions of western North America. Natural marshes may occur in depressions in the landscape (ponds, kettle ponds), as fringes around lakes, and along slow-flowing streams and rivers (such riparian marshes are also referred to as sloughs). Marshes are frequently or continually inundated, with water depths up to 2 m.

Barren Lands (10 classes)

Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Active and Stabilized Dune – This ecological system occurs in the Intermountain basins and is composed of unvegetated to moderately vegetated (generally <10% plant cover, but up to 30%), active and stabilized dunes and sandsheets. Species occupying these environments are often adapted to the shifting, coarse-textured substrate (usually quartz sand) and form patchy or open grasslands, shrublands or steppe composed of *Achnatherum hymenoides*, *Artemisia filifolia*, *Artemisia tridentata* ssp. *tridentata*, *Atriplex canescens*, *Ephedra* spp., *Coleogyne ramosissima*, *Ericameria nauseosa*, *Leymus flavescens*, *Prunus virginiana*, *Psoralidium lanceolatum*, *Purshia tridentata*, *Sporobolus airoides*, *Tetradymia tetrameres*, or *Tiquilia* spp. This system is distinguished by its generally low vegetative cover and distinct eolian geomorphic features.

Badland – This widespread ecological system of the Intermountain western U.S. is composed of barren and sparsely vegetated substrates (<10% plant cover) typically derived from marine shales, but also including substrates derived from siltstones and mudstones (clay). Landforms are typically rounded hills and plains that form a rolling topography. The harsh soil properties and high rate of erosion and deposition are driving environmental variables

supporting sparse dwarf-shrubs, e.g., *Atriplex corrugata*, *Atriplex gardneri*, *Atriplex hymenelytra*, *Artemisia pedatifida*, and herbaceous vegetation.

Barren Lands, Non-specific – Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulation of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Bedrock Cliff and Outcrop – This ecological system is found from subalpine to foothill elevations and includes barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock types. Also included are unstable scree and talus slopes that typically occur below cliff faces. Species present are diverse and may include *Bursera microphylla*, *Fouquieria splendens*, *Nolina bigelovii*, *Opuntia bigelovii*, and other desert species, especially succulents. Lichens are predominant lifeforms in some areas. May include a variety of desert shrublands less than 2 ha (5 acres) in size from adjacent areas.

Cliff and Canyon – This ecological system is found from foothill to subalpine elevations and includes barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and smaller rock outcrops of various igneous, sedimentary, and metamorphic bedrock type. Also included are unstable scree and talus slopes that typically occur below cliff faces. There may be small patches of dense vegetation, but it typically includes scattered trees and/or shrubs.

Mixed Bedrock Canyon and Tableland – The distribution of this ecological system is centered on the Colorado Plateau where it is comprised of barren and sparsely vegetated landscapes (generally <10% plant cover) of steep cliff faces, narrow canyons, and open tablelands of predominantly sedimentary rocks, such as sandstone, shale, and limestone. Some eroding shale layers similar to Inter-Mountain Basins Shale Badland (CES304.789) may be interbedded between the harder rocks. The vegetation is characterized by very open tree canopy or scattered trees and shrubs with a sparse herbaceous layer.

Playa – This system is composed of barren and sparsely vegetated playas (generally <10% plant cover) found across the Intermountain western U.S. and warm deserts of North America. Playas form with intermittent flooding, followed by evaporation, leaving behind a saline residue. Salt crusts are common throughout, with small saltgrass beds in depressions and sparse shrubs around the margins. Subsoils often include an impermeable layer of clay or caliche. Large desert playas tend to be defined by vegetation rings formed in response to salinity.

Volcanic Rock Land and Cinder Land – This ecological system occurs in the Intermountain western U.S. and is limited to barren and sparsely vegetated volcanic substrates (generally <10% plant cover) such as basalt lava (malpais), basalt dikes with associated colluvium, basalt cliff faces and uplifted "backbones," tuff, cinder cones or cinder fields. It may occur as large-patch, small-patch and linear (dikes) spatial patterns. Vegetation is variable and includes a

variety of species depending on local environmental conditions, e.g., elevation, age and type of substrate. At montane and foothill elevations scattered *Pinus ponderosa*, *Pinus flexilis*, or *Juniperus* spp. trees may be present.

Warm Desert Pavement – This ecological system occurs throughout much of the warm deserts of North America and is composed of unvegetated to very sparsely vegetated (<2% plant cover) landscapes, typically flat basins where extreme temperature and wind develop ground surfaces of fine to medium gravel coated with "desert varnish." Very low cover of desert scrub species such as *Larrea tridentata* or *Eriogonum fasciculatum* is usually present. However, ephemeral herbaceous species may have high cover in response to seasonal precipitation, including *Chorizanthe rigida*, *Eriogonum inflatum*, and *Geraea canescens*.

Wash - This barren and sparsely vegetated (generally <10% plant cover) ecological system is restricted to intermittently flooded streambeds and banks that are often lined with *Sarcobatus vermiculatus*, *Ericameria nauseosa*, *Fallugia paradoxa* and/or *Artemisia cana* ssp. *cana* (in more northern and mesic stands). *Grayia spinosa* may also dominate in the Great Basin. Shrubs often form a continuous or intermittent linear canopy in and along drainages but do not extend out into flats. Typically it includes patches of saltgrass meadow where water remains for the longest periods. In desert, this system occurs as linear or braided strips within desert scrub- or desert grassland-dominated landscapes. The vegetation of desert washes is quite variable ranging from sparse and patchy to moderately dense and typically occurs along the banks, but may occur within the channel.

Altered or Disturbed (3 classes)

Invasive Grassland or Forbland – *Avena* spp., *Bromus* spp., *Schismus* spp., *Salsola* spp., *Kochia scoparia*, *Halogeton glomeratum*, *Melilotus officinalis*?, *M. albus*? *Centaurea* spp.?

Invasive Southwest Riparian Woodland and Shrubland – *Tamarix* spp. Semi-Natural Temporarily Flooded Shrubland Alliance, or *Elaeagnus angustifolius* Semi-Natural Woodland Alliance.

Recently Mined or Quarried – 2 hectare or greater, open pit mining or quarries visible on imagery.

Developed and Agriculture (3 classes)

Agriculture

Developed, Medium - High Intensity – *Developed, Medium Intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surface accounts for 50-79 percent of the total cover. These areas most commonly include single-family housing units. *Developed, High Intensity*: Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to 100 percent of the total cover.

Developed, Open Space - Low Intensity – *Open Space*: Includes areas with a mixture of some construction materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. *Developed, Low intensity*: Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49 percent of total cover. These areas most commonly include single-family housing units.

Open Water (1 class)

All areas of open water, generally with less than 25% cover of vegetation or soil.