A Linkage Network for the California Deserts

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Results and information in this report are advisory and intended to assist local jurisdictions, agencies, organizations, and property owners in making decisions regarding protection of ecological resources and habitat connectivity in the area.

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INTRODUCTION

Nature Needs Room to Roam

Movement is essential to wildlife survival, whether it be the day-to-day movements of individuals seeking food, shelter, or mates, dispersal of offspring to find new homes, or seasonal migration to find favorable conditions. Movement is essential for gene flow, for recolonizing unoccupied habitat after a local population goes extinct, and for species to shift their geographic range in response to global climate change (Forman et al. 2003, Crooks and Sanjayan 2006).

Disruption of movement patterns by roads, development and other impediments can alter essential ecosystem functions, such as predator-prey relationships, gene flow, pollination and seed-dispersal, competitive or mutualistic relationships among species, resistance to invasion by alien species, energy flow, and nutrient cycling. Without the ability to move among and within natural habitats, species become more susceptible to fire, flood, disease and other environmental disturbances and show greater rates of local extinction (Soulé and Terborgh 1999). The principles of island biogeography (MacArthur and Wilson 1967), models of demographic stochasticity (Shaffer 1981, Soulé 1987), inbreeding depression (Schonewald-Cox 1983; Mills and Smouse 1994), and metapopulation theory (Levins 1970, Taylor 1990, Hanski and Gilpin 1991) all predict that isolated populations are more susceptible to extinction than connected populations. Establishing connections among natural lands has therefore long been recognized as important for sustaining natural ecological processes and biological diversity (Noss 1987, Harris and Gallagher 1989, Noss 1991, Beier and Loe 1992, Noss 1992, Beier 1993, Forman 1995, Beier and Noss 1998, Hunter 1999, Crooks and Soulé 1999, Soulé and Terborgh 1999, Penrod et al. 2001, Crooks et al. 2001, Tewksbury et al. 2002, Forman et al. 2003, Epps et al. 2004, 2005, Beier et al. 2006, Spencer et al. 2010).

Patterns of Habitat Conversion

A major reason for regional declines in native species is the pattern of habitat loss. Species that once moved freely through a mosaic of natural vegetation types are now confronted with a man-made labyrinth of barriers that fragment formerly expansive natural landscapes. Roads, railroads, canals, urbanization – especially massive new renewable energy projects – are the major obstacles to wildlife movement in the California deserts. Populations of many species of concern—such as the desert tortoise (*Gopherus agassizi*), Mohave ground squirrel (*Spermophilus mohavensis*), and desert bighorn sheep (*Ovis canadensis*)—are becoming increasingly isolated from one another, leading to reduced genetic diversity and risk of extirpations.

Road (and railroad) effects extend far beyond the road itself and include road kill, disruption of animal movements, spread of exotic species, and increases in pollution, noise, light and fire in wildlife habitats. Roads, railroads, and canals can fragment large habitat areas into smaller patches that support smaller populations, which are consequently more prone to local extinction. Many of these effects can be mitigated, for instance by strategically placing crossing structures (over or under, as appropriate) to facilitate wildlife movement across these barriers.

Vast wildlands in the Mojave and Sonoran Deserts have been lost or are threatened by industrial and urban development. Urban and industrial developments, unlike the above obstacles, create movement barriers that cannot be readily removed, restored, or mitigated by building crossing structures. Urban and industrial areas make particularly inappropriate landscapes for live-in or move-through habitat for most plants and animals (Marzluff and Ewing 2001). In addition to direct habitat removal, urban and industrial developments create edge effects that reach well beyond the development footprint. These effects include spread of non-native vegetation, dogs and cats killing and harassing wildlife, artificial night lighting impeding night-time movement, pesticides, rodenticides, noise, disruption of fire regimes, pollution, conflicts with wild animals that eat domestic plants and animals, and increased water diversion and overdraw.

The threat and potential impact of industrial scale renewable energy development on public lands, specifically to wildlife and their ability to move across the landscape, is enormous. Well over a million acres of public lands in the California Desert are subject to renewable energy applications. This type of large-scale development and the associated infrastructure could threaten many native species by fragmenting their habitats and limiting their movement. If core habitat areas become islands with no connecting landscape to allow movement of species, they will not be able to continue to support the animals and plants that currently reside within them.

The California Resources Agency, in partnership with other state and federal agencies initiated the Desert Renewable Energy Conservation Plan (DRECP) to address the impacts of proposed renewable energy developments on rare, Threatened and Endangered Species throughout California's deserts. Sustaining and enhancing habitat connectivity is also a major conservation concern that must be addressed. As land management and wildlife agencies evaluate the plethora of proposed renewable energy developments, they need more information on how/where to maintain connected populations of wild animals and plants.

California Desert Connectivity Project: A Vision for the Mojave and Sonoran Ecoregions

The rapidly increasing demands being placed on our deserts points to the urgent need for a comprehensive habitat connectivity assessment that spans jurisdictional boundaries and promotes the partnerships needed to implement a regional conservation strategy for this diverse and striking landscape. The primary goal of the California Desert Connectivity Project is to identify areas where maintenance or restoration of ecological connectivity is essential for conserving the unique biological diversity of California's deserts. Identification of these key areas of connectivity will help inform land management and conservation decisions, infrastructure improvements and mitigation options in the face of future land-use pressures as well as climate change. Another goal of the project was to produce implementable linkage designs and provide the necessary data and information to inform land management, land acquisition, restoration (e.g., habitat restoration and restoration of permeability across transportation barriers), and stewardship in connectivity zones.

In 2009, SC Wildlands brought together regional ecologists to conduct a formal evaluation of 47 linkages associated with the California deserts. The evaluation was designed to assess the biological irreplaceability and vulnerability of each linkage (sensu Noss et al. 2002). Irreplaceability assessed the relative biological value of each linkage, including both terrestrial and aquatic criteria: 1) size of habitat blocks served by the linkage; 2) quality of existing habitat in the smaller habitat block; 3) quality and amount of existing habitat in the proposed linkage; 4) linkage to other ecoregions or key to movement through the ecoregion; 5) facilitation of seasonal movement and responses to climatic change; and 6) addition of value for aquatic ecosystems. Vulnerability and threat was primarily evaluated by comparing proposed renewable energy projects and study areas, and proposed road projects that might disrupt animal movement among targeted Landscape Blocks (i.e., areas protected from energy development and roads). Landscape Blocks include BLM Wilderness Areas and Areas of Critical Environmental Concern (ACEC), national and state parks, federal and state wildlife refuges, private conservation reserves, and military reservations. This process identified 23 crucial linkages that were each defined by a pair of Landscape Blocks that should remain connected. One of the 23 linkage planning areas, the Mojave National Preserve to Joshua Tree National Park, was determined to be redundant with a previously delineated linkage design between Joshua Tree-Twentynine Palms Marine Corps Base (Penrod et al. 2008) and the linkage planning area between Mojave National Preserve and Twentynine Palms. Thus, this process focused on 22 linkages that could be irretrievably compromised by development projects over the next decade unless immediate conservation action occurs (Figure 1). The biological integrity of several thousand square miles of wildlands in the California desert would be irreversibly jeopardized if these linkages were lost.

Strategically conserving and restoring essential connections between remaining wildland areas is an effective and cost-efficient measure to reduce the adverse effects of habitat loss and fragmentation. The future of our wild legacy is dependent upon the remaining natural areas being functionally connected as part of a large network of open space. This requires identifying and prioritizing those connections that are most essential to maintaining healthy populations of native plants and animals. Habitat connectivity planning can help prevent additional species from becoming endangered, it can stabilize existing populations, and it can prevent costly long-term recovery efforts. With a comprehensive multi-jurisdictional connectivity assessment, the outcome of land use changes can be altered to ensure the greatest protection for our precious natural areas at the least cost to our human endeavors. It is our hope that this project will serve as a catalyst for directing funds and attention toward the protection of ecological connectivity for California’s deserts. We envision a future interconnected system of natural space where our native biodiversity can thrive.

Previous Connectivity Planning Efforts

This project is on the leading edge of a statewide effort to identify critical linkages and will contribute the fine resolution analyses that the state of California wants to produce and implement in all ecoregions of the state. The *California Essential Habitat Connectivity Project* (Spencer et al. 2010) sponsored by the California Departments of Transportation (Caltrans) and Fish and Game (DFG) developed a statewide map to provide a relatively “top-down, broad-brush” depiction of essential connectivity areas, with the intent that finer resolution mapping and analysis would later be performed using finer resolution and “bottom-up” (e.g., species-based) modeling and analyses, such as the California Desert Connectivity Project. Fine scale focal species based linkage designs have been completed for five essential connectivity areas that fall along the margins of the California deserts namely the Tehachapi Connection, San Bernardino-Little San Bernardino Connection, San Bernardino-Granite Connection, San Bernardino-San Jacinto Connection and the Joshua Tree-Twentynine Palms Connection (Penrod et al. 2003, 2005abc, 2008). These 5 linkages are included with the 22 new linkage designs in the linkage network described here.

CALIFORNIA DESERT CONNECTIVITY PROJECT

Figure 1. Linkage Planning Areas

Existing Conservation Investments in the California Deserts

Table 1. Conservation Investments

Public/Private Conservation Lands	Acres
Bureau of Land Management	10,482,184.43
National Park Service	5,300,614.80
California Department of Parks and Recreation	637,892.23
California State Lands Commission	359,251.92
Special Districts	136,187.06
Other Federal	101,315.79
California Department of Fish and Game	91,569.88
United States Forest Service	74,193.33
United States Fish and Wildlife Service	53,693.79
Non Governmental Organizations	42,353.82
City	7,260.74
County	5,905.57
Other State	5,337.97
Total Acres	**17,297,761.34**

Significant conservation investments already exist in the region (Figure 2), but the resource values they support could be irreparably harmed by loss of connections between them. Most (68%) of California's deserts are publicly owned, providing important protection to many unique plant and wildlife species that inhabit them. The California deserts boast some of the state's largest reserve areas, including Death Valley National Park, Mojave National Preserve, and Joshua Tree National Park. Public and private conservation lands cover 17,297,761 acres, of which 44% (7,622,170 acres) are designated Wilderness Areas. These conservation lands are administered by the National Park Service, California Department of Parks and Recreation, Bureau of Land Management, California Department of Fish and Game, State Lands Commission, The Wildlands Conservancy, and others with the Bureau of Land Management administering the largest proportion of public lands. The Wildlands Conservancy has facilitated the purchase of nearly 600,000 acres under their California Desert Land Acquisition Project. It also funded land exchanges that resulted in the addition of over 35,000 acres to six BLM wilderness areas and gifted an additional 28,000 acres of acquired lands to Joshua Tree National Park (The Wildlands Conservancy 2007). The Department of Defense also has a significant presence in the region, covering 3,242,679 acres across six military installations. Although portions of these bases are degraded due to military preparedness activities, vast areas receive little to no use and represent some of the most pristine natural areas in the desert.

Protecting the ecological integrity of our existing conservation investments in the region will rely on maintaining connectivity across a diversity of desert ecosystems. Such an interconnected set of reserves would allow natural ecological processes—such as migration and range shifts with climate change--to continue operating as they have for millennia.

Ecological Significance of the California Deserts

The wildlands of the Mojave and Sonoran Desert Ecoregions support high diversity of plant communities (Figure 3) and of plant and animal species. The Mojave and Sonoran Deserts differ primarily in elevation. The Mojave Desert is higher in elevation, and is therefore cooler, receiving more precipitation. This accounts for the differences in vegetation types; evergreen trees such as the Joshua tree (*Yucca brevifolia*) flourish in the Mojave but cannot persist in the Sonoran. At higher elevations in the Mojave Desert, juniper (*Juniperus spp*.) and pinyon pine (*Pinus quadrifolia*) are present with an understory of creosote bush (*Larrea tridentate*) and other shrubs and herbs. There are two major river systems in the Mojave Desert, the Amargosa River in the north and the Mojave River in the south, which are major arteries of life for wildlife. Characteristic habitats in the Sonoran Desert include creosote bush scrub, saltbush scrub,

CALIFORNIA DESERT CONNECTIVITY PROJECT

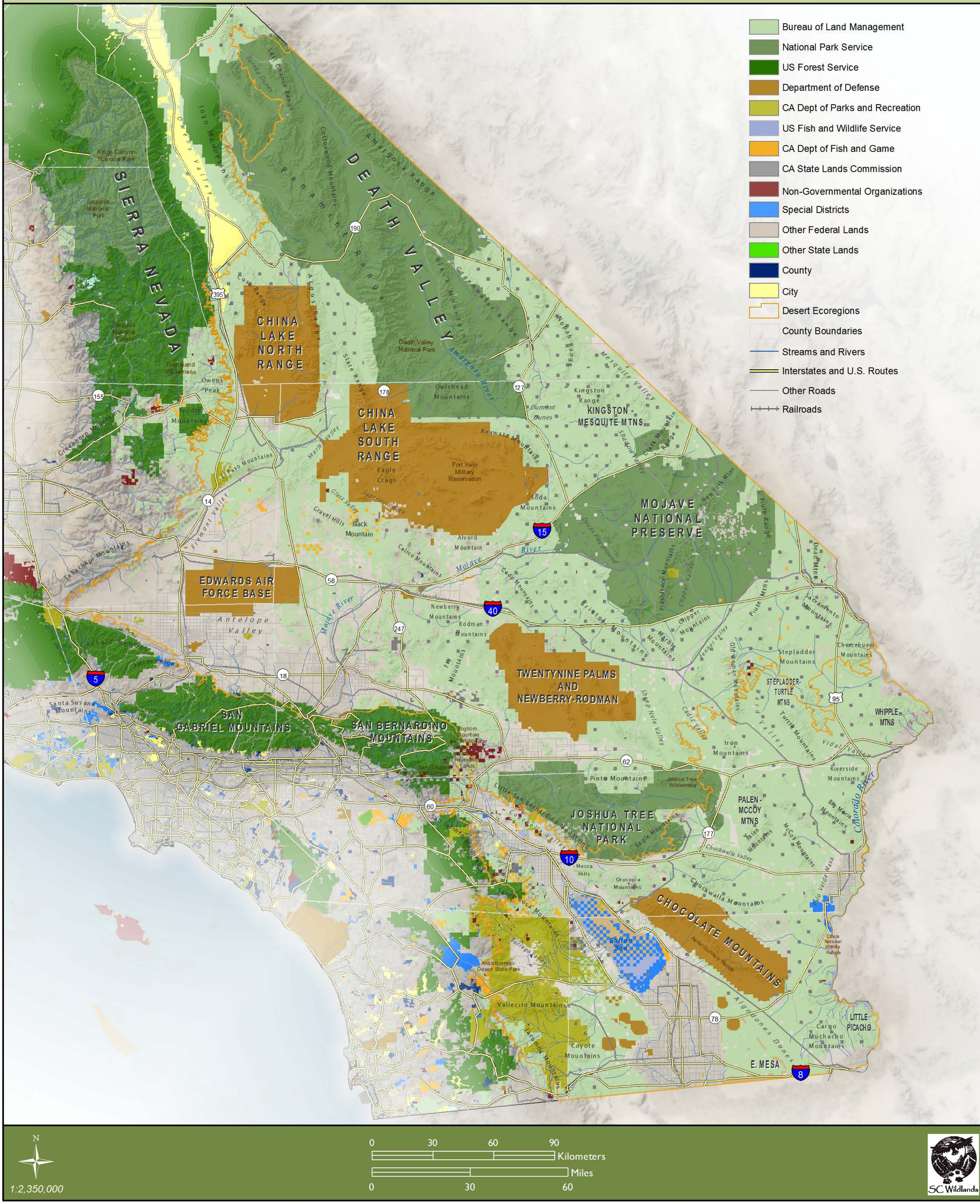
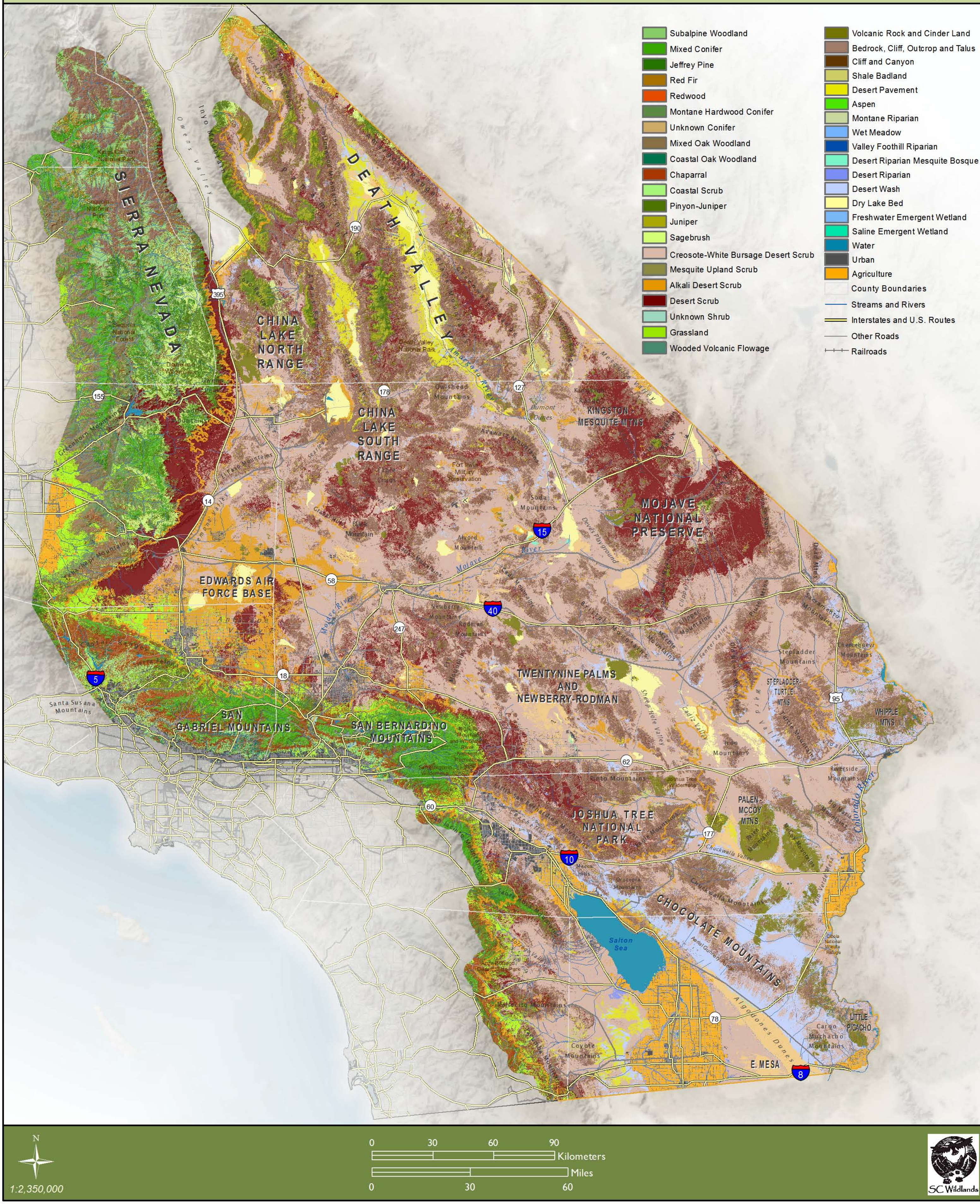


Figure 2. Existing Conservation Investments & Other Major Landholders

CALIFORNIA DESERT CONNECTIVITY PROJECT

Figure 3. Major Landcover Types



desert riparian, bajadas or desert washes, and sand dunes. There are extensive sand dune systems in the region that support a diversity of endemic species, including the Algodones Dunes, Superstition Hills, and the Coachella Valley Dunes, which require maintaining the sand sources that replenish these systems. A number of sensitive natural communities occur in the planning area, such as alkali seeps and marshes, crucifixion thorn woodland, dunes, and riparian communities.

This variety of habitats supports a diversity of organisms, including many species listed as endangered, threatened, or sensitive by government agencies. The threatened desert tortoise (*Gopherus agassizii*) is perhaps the best known species of desert scrub communities, as bighorn sheep (*Ovis candensis*) are of the rugged terrain. A number of rare species depend on desert riparian communities, which provide breeding habitat for species such as arroyo toad (*Bufo californicus*) and western pond turtle (*Emys marmorata*) and the endangered least Bell's vireo (*Vireo bellii pusillus*), southwestern willow flycatcher (*Empidonax traillii extimus*), and yellow-billed cuckoo (*Coccyzus americanus*). The bonytail chub (*Gila elegans*) and Amargosa pupfish (*Cyprinodon nevadensis amargosae*) are a few of the extant native freshwater fish species. Sensitive reptiles that prefer drier habitats and sparser vegetative cover, such as the Mojave fringe-toed lizard (*Uma scoparia*) also depend on habitats here. The study area also provides habitat for a number of imperiled plant species, such as Cushenberry buckwheat (*Eriogonum ovalifolium* var. *vineum*) and the Ash Meadows gumplant (*Grindelia fraxino-pratensis*). In addition to providing habitat for rare and endangered species, the wildlands of the Mojave and Sonoran ecoregions provide habitat for numerous native species that require extensive wildlands to survive, such as mountain lion (*Puma concolor*) and American badger (*Taxidea taxus*).

A recent statewide analysis of landscape integrity conducted for the California Essential Habitat Connectivity Project (Spencer et al. 2010) identified the Mojave and Sonoran Ecoregions along with the southern Sierra Nevada as the most ecologically intact areas in the state. Thus, it is not surprising that multiple areas of ecological significance have been identified within the California deserts. These include areas designated by the BLM as Areas of Critical Environmental Concern (ACEC) or Desert Wildlife Management Areas (DWMA) and lands identified as important by the West Mojave Plan (BLM 2005), California Desert Conservation Area Plan Amendment for the Northern and Eastern Mojave Planning Area (BLM 2001), and the Northern & Eastern Colorado Desert Coordinated Management Plan (BLM and CDFG 2002). These areas also include Significant Ecological Areas designated and proposed by the County of Los Angeles and habitat designated by the U.S. Fish and Wildlife Service as critical or essential to the survival of federally endangered species.

The Bureau of Land Management has designated 92 Areas of Critical Environmental Concern covering roughly 4,235,053 acres and 125 Desert Wildlife Management Areas (DWMA) covering 4,513,141 acres. The DWMAs were primarily designated for species such as the desert tortoise but they also benefit numerous other native plant and animal species, including several listed and sensitive species (BLM 2005). BLM established multiple DWMAs in response to recovery plan recommendations that DWMAs be established within each recovery unit (BLM 2001, 2005, BLM and CDFG 2002).

The West Mojave Plan (BLM 2005) delineated areas of relatively higher tortoise densities based on surveys between 1998 and 2002 as having "above average" or "higher density" tortoise occurrence. The plan also established the Mojave Ground Squirrel Wildlife Habitat Management

Areas covering is 1,726,395 acres. Alkali Mariposa Lily Conservation Areas (7,243 acres) were also identified to maintain the hydrological processes that support alkali mariposa lily (*Calochortus striatus*) at the Rosamond Lake Basin and outlying seeps, meadows and springs around Edwards Air Force Base. The North Edwards Conservation Area was also identified (12,702 acres) west of Kramer Junction that has known occurrences of Barstow woolly sunflower (*Eriophyllum mohavense*). These conservation areas would also serve the purpose of buffering Edwards Air Force Base from urban encroachment while protecting this rare plant.

The California Desert Conservation Area Plan Amendment for the Northern and Eastern Mojave Planning Area (BLM 2001) identified several areas of conservation concern, such as the Silurian Hills Bat Conservation Areas, Carson Slough Conservation Areas, and Amargosa Vole Recovery Areas. The Silurian Hills and surrounding desert washes, springs, desert riparian areas, sand dunes, crevice slopes and mountains were identified as crucial habitat for several desert bat species. Kingston Wash is suspected to be a flight corridor for bat movement into the Kingston Mountains, as well as a bat foraging area. The Salt Creek Hills and riparian area provide bat foraging and roosting areas, and are assumed to serve as a flight travel corridor into the Avawatz Mountains, as well as the Ibex Dunes, Dumont Dunes and portions of Death Valley National Park. The Carson Slough conservation area is important for many sensitive and listed plant species and portions of the Lower Carson Slough have been designated as a Salt and Brackish Water Marsh Unusual Plant Assemblage. The area also supports proposed critical habitat for two federally listed plant species, the endangered Amargosa niterwort (*Nitrophilia mohavensis*) and the threatened Ash Meadows gumplant (*Grindelia fraxino-pratensis*). Amargosa Vole Recovery Areas include designated critical habitat on 2,440 acres of public land along the Amargosa River, primarily encompassing lands in the Grimshaw Lake ACEC vicinity and immediately south. Additional suitable riparian habitat for the vole occurs to the south in the Amargosa Canyon ACEC, and to the north as far upstream as the town of Shoshone. BLM (2002) has identified the public and private lands between the two existing ACECs as a critical link protecting the species.

The Northern & Eastern Colorado Desert Coordinated Management Plan an amendment to the California Desert Conservation Area Plan (BLM and CDFG 2002) identified invertebrate hotspots, unique plant assemblages, and multi species and bighorn sheep Wildlife Habitat Management Areas. The invertebrate hotspots occur mostly in dry lake beds and dune ecosystems. Although relatively barren, playas are a unique habitat that is considered sensitive by the state Resources Agency. Playas provide habitat for rare and endemic (i.e., found only at that place) invertebrates such as fairy shrimp (*Streptocephalus* and *Branchinecta* spp.). Large tracts of dunes can be found in Cadiz, Ward, Rice, and Chuckwalla Valleys, usually adjacent to playas. Sand dunes provide habitat for rare and endemic animals, especially invertebrates. Examples of species and communities that occur in unique plant assemblages include foothill paloverde (*Cercidium microphyllum*), teddy bear cholla (*Cylindropuntia bigelovii*), ironwood tree (*Olneya tesota*), Munz cholla (*Cylindropuntia munzii*), palm oases, mesquite thickets, and All-thorn stands. The plan also identified several areas outside of Desert Wildlife Management Areas as Wildlife Habitat Management Areas for bighorn sheep and other sensitive species. The Plan (BLM and CDFG 2002) also identified Category 1 and 3 lands for desert tortoise.

Los Angeles County has designated 13 Significant Ecological Areas (SEA) within the Mojave Desert ecoregion as part of the Land Use and Open Space Elements of the County General Plan, due to their unique plant and/or animal associations (BLM 2005). Existing SEAs cover roughly 129,387 acres. The county is currently in the process of updating its General Plan and has proposed to consolidate these SEAs into 3 SEAs which would expand and connect the existing SEAs.

These wild areas are naturally interconnected; indeed, they historically functioned as one ecological system. However, recent and proposed activities threaten to sever natural connections, forever altering the functional integrity of this remarkable natural system. The ecological, educational, recreational, and spiritual impacts of such a severance would be substantial. Certainly, maintaining and restoring functional habitat connectivity in this regionally important landscape is a wise investment.

CONSERVATION PLANNING APPROACH

The primary objective of this effort is to identify lands essential to maintain or restore functional connectivity among wildlands for all species or ecological processes of interest in the California deserts and as a vital adaptation strategy to conserve biodiversity during climate change. The study area covers roughly 13 million hectares (32 million acres), encompassing California's Mojave and Sonoran Desert Ecoregions, three targeted mountain ranges in the neighboring Sierra Nevada and South Coast Ecoregions with a buffer of 6 km. Our approach can be generally summarized as follows:

1) *Engage Stakeholders:* We involved implementing agencies and organizations from the inception of the project to promote coordination across jurisdictional boundaries and the partnerships needed to implement the resulting linkage designs.

2) *Focal Species Selection*: We selected focal species from diverse taxonomic groups to represent a diversity of habitat requirements and movement needs.

3) *Define Analysis Area:* We defined 22 analysis areas, one for each pair of Landscape Blocks to be connected.

4) *Delineate Corridors for Species*: We conducted least-cost modeling to identify one or several swaths of habitat that support multiple species potentially traveling through or residing in each linkage.

5) *Delineate Land Facet Corridors to Provide Connectivity in a Changing Climate:* We used land facet analyses to identify swaths of habitat of relatively uniform physical conditions (such as high insolation flats, or steep north-facing slopes). These "land facets" or "ecological land units" are enduring features that will interact with future climate to support species and species movement under uncertain future climate conditions.

6) Evaluate and Refine the Preliminary Linkage Designs: We joined the least-cost corridors for all species and land facets into a union of corridors, or a preliminary linkage design network. Although by definition this preliminary design provides least-cost corridors, it might provide poor connectivity for some species or land facets. We used habitat suitability analysis and patch size & configuration analysis to evaluate if the preliminary linkage designs are likely to serve all focal species or if additional habitat is needed to ensure all species are accommodated. We evaluated resistance maps to delete land facet corridors that offered poor connectivity. We trimmed or deleted some linkage strands when the other strands provided nearly as much connectivity for that strand's focal species or focal land facet. Finally we imposed a 2 km minimum width on each strand to minimize edge effects and support long-term occupancy of the corridor by less-mobile species that may require generations to move their genes between the targeted Landscape Blocks.

7) *Field Investigations:* We conducted fieldwork to ground-truth existing habitat conditions, document existing barriers and potential passageways, identify restoration opportunities, and consider management options.

8) *Linkage Design:* We compiled results of analyses and fieldwork into a comprehensive action plan detailing what is required to conserve and improve linkage function including priority lands for conservation, specific management recommendations, and prescriptions for mitigating roads and other barriers.

Stakeholder Engagement

Conserving the network of landscape linkages identified by this effort will require collaboration and coordination among numerous agencies and organizations (Beier et al. 2006, SC Wildlands 2008, Spencer et al. 2010). We followed Baxter (2001) in recognizing that successful conservation planning must be interdisciplinary and based on the participation of experts in biology, planning and design and implementation. This effort has engaged wildlife biologists, botanists, landscape ecologists, wildlife and transportation agencies, land managers and planners, land trusts and conservancies, conservation organizations, and other implementers from the inception of the project.

To engage stakeholders early in the process, we held a habitat connectivity workshop in July of 2009 to lay the biological foundation for planning in each linkage. The workshop gathered information on conservation needs, threats and opportunities in the study area. About 60 participants from 30 agencies, organizations, and academic institutions prioritized the linkages. They also identified focal species that best represent the connectivity needs of all species and ecological processes of interest. The workshop was intended to promote coordination across jurisdictional boundaries and the partnerships needed to implement the resulting linkage conservation network.

Focal Species Selection

The focal species approach (Beier and Loe 1992, Lambeck 1997) recognizes that species move through and utilize habitat in a wide variety of ways. Workshop participants identified a taxonomically diverse suite of focal species (Table 2) that are sensitive to habitat loss and fragmentation, including 12 mammals, 8 birds, 1 amphibian, 9 reptiles, 5 invertebrates, and 9 plants. These 44 focal species capture a diversity of movement needs and ecological requirements and include area-sensitive species, barrier-sensitive species, less mobile species or corridor-dwellers, habitat specialists, and ecological indicator species. From species that require large tracts of land such as bighorn sheep (*Ovis canadensis*) and badger (*Taxidea taxus*) to those with very limited spatial requirements like the desert spiny lizard (*Sceloporus magister*) or desert pocket mouse (*Chaetodipus penicillatus*). They include habitat specialists such as the cactus wren (*Campylorhynchus brunneicapillus*) or yucca moth (*Tegeticula synthetic*) and those requiring a specific configuration of habitat types and elements like the pallid bat (*Antrozus pallidus*) that may roost in a variety of habitats but forages in more open terrain typically near water sources. Dispersal distance capability of focal species ranges from

97 m to 548 km; modes of dispersal include walking, flying, swimming, climbing, hopping, and slithering.

Compilation of Digital Data Layers
We compiled several Geographic Information System (GIS) data layers for the study area, including data related to topography, hydrology, land cover, species (e.g., designated critical habitat, California Natural Diversity Database), land ownership, jurisdictional boundaries, and transportation infrastructure (e.g., roads, rails, bridges and culverts).

Land Cover. We used the California land cover data from GAP Ecological Systems, USGS Mapping Zones 4, 6, and 13 (2008), which was developed for the USGS GAP Analysis Program. The data is at 30m resolution and uses NatureServe's Ecological System Classification (NatureServe 2007). Land cover was the most important factor in most habitat models. Unfortunately, the land cover layer has lower accuracy than digital elevation models used to derive the other variables.

Elevation. Elevation is a key determinant of land cover. It also affects the thermal environment of an organism, and the amount and form (rain, snow) of precipitation. Digital elevation models (DEMs) from U.S. Geological Survey's National Elevation Dataset were compiled for the study area at 1-Arc Second or approximately 30 meter resolution. Elevation was used as a model input when the literature stated that the species occurs within a certain range

Table 2. Focal Species

Mammals	
Mountain lion	*Puma concolor*
Badger	*Taxidea taxus*
Kit fox	*Vulpes macrotis*
Bighorn sheep	*Ovis canadensis*
Mule deer	*Odocoileus hemionus*
Ringtail	*Bassariscus astutus*
Mojave ground squirrel	*Spermophilus mohavensis*
Round-tailed ground squirrel	*Spermophilus tereticaudus*
Desert pocket mouse	*Chaetodipus penicillatus*
Little pocket mouse	*Perognathus longimembris*
Southern grasshopper mouse	*Onychomys torridus*
Pallid Bat	*Antrozus pallidus*
Birds	
Burrowing owl	*Athene cunicularia*
Loggerhead shrike	*Lanius ludovicianus*
Cactus wren	*Campylorhynchus brunneicapillus*
Black-tailed gnatcatcher	*Polioptila melanura*
LeConte's thrasher	*Toxostoma lecontei*
Bendire's thrasher	*Toxostoma bendirei*
Crissal thrasher	*Toxostoma crissale*
Greater roadrunner	*Geococcyx californianus*
Herpetofauna	
Desert Tortoise	*Gopherus agassizii*
Chuckwalla	*Sauromalus obesus obesus*
Rosy boa	*Lichanura trivirgata*
Speckled rattlesnake	*Crotalus mitchellii*
Mojave rattlesnake	*Crotalus scutulatus*
Mojave fringe-toed lizard	*Uma scoparia*
Collared lizard	*Crotaphytus bicinctores*
Desert spiny lizard	*Sceloperus magister*
Desert night lizard	*Xantusia vigilis*
Red spotted toad	*Anaxyrus punctatus*
Plants	
Joshua tree	*Yucca brevifolia*
Blackbrush	*Coleogyne ramosissima*
Desert willow	*Chilopsis linearis*
Arrowweed	*Pluchea sericea*
Cat claw acacia	*Acacia greggii*
Mesquite	*Prosopis glandulosa*
Mojave yucca	*Yucca schidigera*
Big galleta grass	*Pleuraphis rigida*
Paperbag bush	*Salazaria mexicana*
Invertebrates	
Yucca moth	*Tegeticula synthetica*
Desert green hairstreak	*Callophrys comstocki*
Bernardino dotted blue	*Euphilotes bernardino*
Desert ("Sonoran") metalmark	*Apodemia mejicanus*
Ford's swallowtail	*Papilo indra fordi*

of elevation. Three elevation classes were generally recognized (below, within, and above the elevation limits of the species). DEMs are also the basis for several derived variables, including aspect, slope, and topographic position.

Aspect. In temperate zones, aspect is a determinant of solar radiation, and consequently temperature, soil moisture, and vegetation. Only a few habitat models used aspect, primarily those developed for the plant focal species.

Slope. Slope is a determinant of distributions of several focal plant species, and a few animals. For example, the kit fox (*Vulpes macrotis*) is associated with flats and slopes <15%, and bighorn sheep are associated with steep slopes.

Topographic Position. Topography is correlated with moisture, heat, cover, and vegetation. Some species are reported to be associated with canyon bottoms, ridges, slopes, or other topographic elements, making topographic position a key predictor of habitat suitability for some species. We used the 30 meter National Elevation Dataset from USGS and the Topographic Position Index (Guisan et al. 1999) to assign each pixel to one of four topographic classes. A pixel was classed as ridge if it was > 6 m higher than the average elevation in a 200-m radius, or as a canyon if it was more than 6 m lower than the neighborhood average. The remaining pixels were classified as slopes (slope gradient > 3%) or flats (<25).

Distance to Streams. The literature occasionally states that a species is found within a certain distance of water. Several hydrologic data layers were compiled for the study area including Teale lines and polygons at 100 m resolution, USGS National Hydrographic Dataset, and National Wetlands Inventory data. Distance to stream was used as a factor in the habitat models for species such as ringtail (*Bassariscus astutus*) and the red spotted toad (*Anaxyrus punctatus*).

Road Density. We merged datasets for roads (TIGER/Line 2009, U.S. Census Bureau) and Railroads (CERES 1997) at 100 m resolution. We extracted subsets of lines representing primary and secondary roads, ramps, local neighborhood and rural roads and city streets from the Tiger/Line 2009 dataset. Road density was calculated using the density function in Spatial Analyst with a moving window radius of 564 m, which was expressed in kilometers of paved road per square kilometer.

Define the Analysis Area

We defined 22 Analysis Areas, one for each pair of Landscape Blocks (i.e., areas protected from industrial energy projects and new highways, such as designated Wilderness Areas, parks, and military reservations). Each analysis area consists of the two Landscape Blocks to be linked, the matrix between them, and enough additional area to allow the modeling procedure to identify highly nonlinear corridors.

Delineate Corridors for Focal Species

Several spatial analyses were used to identify areas to accommodate focal species movements between targeted Landscape Blocks. We constructed least-cost corridors for a subset of focal species, generally focal species that occur in both the Landscape Blocks to be served by the linkage and that must walk (rather than fly or be dispersed on the wind) to move its genes between the two target areas. This analysis proceeds in broad 3 steps (Habitat Suitability Analysis, Delineation of Habitat Patches, and Least Cost Modeling) as described in the next few paragraphs. Least-cost corridor modeling was not appropriate for some focal species, namely those that occur in the linkage area but do not have suitable habitat in both Landscape Blocks, and species (like birds, bats, flying insects, or plants with wind-borne pollen or seed) that can move between habitat patches without moving in pixel-to-pixel fashion. Although connectivity is still important for these species, least-cost corridor modeling is not an appropriate approach. We considered the needs of species that we did not conduct least-cost corridor modeling for via Patch Size & Configuration Analysis, which combines Habitat Suitability Analysis and Delineation of Habitat Patches as described below under *Evaluate and Refine the Preliminary Linkage Design*.

We conducted least-cost modeling for 4 of the 44 selected focal species, namely bighorn sheep, American badger, kit fox, and desert tortoise. Because these 4 species do not occur throughout the California deserts, we developed least-cost corridors for bighorn sheep in 10 linkage planning areas, for desert tortoise in 13 planning areas, for kit fox in 16 areas, and for badger in all 22 areas.

Habitat Suitability Analysis: We recruited species experts to develop habitat suitability models for each focal species on the basis of the scientific literature and the expert's experience and opinions. Clevenger et al. (2002) found that expert-based models that did not include a literature review performed significantly worse than literature-based expert models. Experts were asked to estimate habitat suitability rather than habitat permeability to movement because virtually all the relevant literature concerns habitat use, not animal movement.

For each species, the expert rated the suitability for various states of each habitat factor (land cover, elevation, aspect, etc.). The factors used in each habitat suitability model varied by species. For example, there were 4 factors in the American badger model, namely land cover, topography, elevation and road density. Within each factor, scores were assigned to each category (e.g., each land cover type) on a scale of 0 (unsuitable) to 10 (most suitable). Factors were weighted to indicate the relative influence of each factor, such that the weights for all factors sum to 100%. Habitat suitability was calculated for each 30-m^2 pixel using a Weighted Geometric Mean: Suitability = $(S_A^{WA}) * (S_B^{WB}) * (S_C^{WC})$; where S_A, S_B, and S_C are suitability ratings for factors A, B, and C, respectively, and WA, WB, and WC are the factor weightings.

The Weighted Geometric Mean is strongly influenced by low suitability ratings, such that if a score for any class is 0, then suitability of the pixel remains 0 regardless of factor weight or scores for other factors. Thus, experts were instructed to only assign a score of zero to a class when the species would not use the class, even if the other factors were optimal.

Delineation of Habitat Patches: We defined patches of potential breeding habitat for use as start and end points for least-cost corridor models, as modeled patches of low resistance in the least-cost model, as meaningful descriptors of how well corridors serve focal species, and as areas to refine the preliminary linkage design to serve species for which corridor modeling was not appropriate. We defined a potential breeding area as a cluster of pixels that are good enough (mean score above 5) and big enough (i.e., larger than minimum sizes specified by the species expert) to support breeding by the focal species. To delineate potential cores and patches for desert tortoise we took a slightly different approach using the habitat model developed by Nussear et al. (2009) as the primary model input using scores of .6 and above from the Maxent Model. We classified breeding patches into two size classes. A **potential core** was defined as a contiguous area of suitable habitat large enough to sustain at least 50 individuals. Potential cores are probably capable of supporting the species for several generations (although with erosion of genetic material if isolated). A **breeding patch** was defined as an area of suitable habitat large enough to support successful reproduction by a pair of individuals (perhaps more if home ranges overlap greatly), but smaller than a potential core area. Patches are useful to the species if the patches are linked via dispersal to other patches and core areas.

Least-Cost Modeling: Least-cost modeling (Craighead et al. 2001, Singleton et al. 2002) models the relative cost for a species to move between targeted Landscape Blocks (more specifically, potential cores and patches of breeding habitat within each block) based on how each species is affected by various landscape characteristics. A fundamental assumption is that ecological resistance to travel is the inverse of habitat suitability (e.g., if habitat suitability is 8 on a scale of 0-10, then resistance to travel is 10 - 8 = 2).

The landscape is portrayed in a GIS as a grid of squares; such a grid is called a raster, and each square is called a pixel. Resistance values are calculated for each pixel in the raster as a function of the input data layer's attributes representing habitat characteristics, such as land cover, topography, and level of human disturbance. Resistance is the difficulty of moving through a pixel; cost is the cumulative resistance incurred in moving from the pixel to targeted endpoints in each targeted Landscape Block. For each species, we developed a resistance surface that represents the per-pixel cost of movement across the landscape for species movement or gene flow. The lowest-cost swath of pixels represents the land that best supports species movement between target areas under the model's assumptions (Adriaensen et al. 2003, Beier et al. 2008). A "slice" (or cost contour) of the resulting cost surface is used to delineate a least-cost corridor that is biologically meaningful for the species.

Performing the least-cost corridor analysis requires identifying the endpoints to be connected. For each species, we used cores and patches of potential breeding habitat within each Landscape Block as the termini for the analyses. In a few analysis areas, we further constrained termini to a subset of the Landscape Block where the smallest gap between target areas was < 2 km. In these cases, least-cost modeling will tend to identify the narrowest gap as the best corridor, even if that corridor is low in habitat value. In these cases, we gave the GIS model "room to run" by selecting only termini well inside the Landscape Blocks. The steps in least-cost modeling are:

1. Calculate habitat suitability as a function of pixel attributes such as land cover, road density, topographic position, and elevation.

2. Use habitat suitability to map patches of potential breeding habitat.

3. Develop a resistance map by taking the inverse of habitat suitability.

4. Use potential cores and patches of breeding habitat within each Landscape Block as termini for the analysis.

5. Calculate cost-weighted distance from each terminus, which computes a value for every pixel that is the least accumulated cost of traveling from each pixel to the source.

6. Select an appropriate contour (% "slice") to delineate a least-cost corridor that is wide enough to facilitate movement. We typically chose the slice that had roughly a minimum width of 2 km.

The least-cost corridor output for all species was then combined to generate a union of all the focal species corridors.

Delineate Land Facet Corridors to Provide Connectivity in a Changing Climate

Enhancing connectivity is the most promising strategy to conserve biodiversity during climate change (Heller and Zavaleta 2009, Mawdsley et al. 2009). The focal species corridors we develop in this document should conserve and enhance connectivity for focal species under current landscape conditions. However, these linkages may not be effective under future climate conditions. Therefore we conducted additional analyses to design corridors that should conserve connectivity under future climate.

We decided **not** to design climate-robust corridors using complex "climate envelope" analyses. In this approach emission scenarios drive global circulation models which are then downscaled using regional models to predict future climate. Then climate envelope models are used to produce maps of the expected future distribution of species. We did not use this approach because it involves enormous uncertainty and produces outputs at a spatial resolution too coarse to inform the decisions BLM needs to make. **Uncertainty**: In 1999 the IPCC developed 7 major scenarios of possible CO_2 emissions during 2000-2011. The total emissions over the century vary by a factor of 6 among scenarios, and actual emissions during 2000-2010 were higher than the most pessimistic scenario. For a single emission scenario, different air-ocean global circulation models produce markedly different climate projections (Raper & Giorgi 2005; IPCC 2001). Models for downscaling to the local level introduces further uncertainty. Finally climate-envelope models may perform no better than chance (Beale et al. 2008). Because these sophisticated models have not been able to simulate the large shifts that paleoecologists have documented during the last 100,000 years of glacial oscillations, Overpeck et al. (2005:99) conclude the “lesson for conservationists is not to put too much faith in simulations of future regional climate change” in designing robust conservation strategies. **Spatial resolution:** The maps produced by these procedures have minimum cells sizes measured in square kilometers; this is coarser than the scale at which BLM is making decisions in the California deserts.

Therefore, we used an alternative approach to design climate-robust corridors. These corridors maximize continuity of the enduring features (topographic elements such as sunny lowland flats, or steep north-facing slopes) that will interact with future climate to support future biotic communities. Following Wessels et al. (1999) we call these enduring features “land facets.” Hunter et al. (1988) first proposed using these enduring features as a coarse-filter conservation strategy in the face of climate change. They described the concept as conserving the arenas of biological activity, rather than species or communities, the temporary occupants of those arenas.

This approach is not a speculative new idea, but rather is based on two of the fundamental concepts that gave birth to the discipline of ecology. First, it is rooted in the “life zone” concept of C. Hart Merriam (1890), who observed that plant and animal communities were predictably associated with particular combinations of latitude, elevation, and aspect. Second, it is rooted in the “state factor model of ecosystems,” which holds that the species present at any given site are a function of “state variables,” namely climate, other organisms present in or near the site, disturbance regime, topography, the underlying geological material, and time (Jenny 1941, Amundson and Jenny 1997). Enduring features reflect the stable state factors, namely topography, geology, and time. Other state factors – climate, interspecific interactions, dispersal, and disturbance regimes – are subject to change under a warming climate and are thus less reliable for conservation planning. The main uncertainties in this approach arise from errors in, or variability not reflected in, the maps of elevation and soils used to define facets. However, these uncertainties are almost certainly less than the 6-fold uncertainty in emission scenarios multiplied by the uncertainty in general circulation models multiplied by the uncertainty in regional downscaling multiplied by the uncertainty in climate envelope models.

Beier and Brost (2010) operationalized this approach by suggesting multivariate procedures to define these enduring features in a particular landscape. Land facets are equivalent to the “ecological land units” that Anderson & Ferree (2010) used as coarse-filter conservation units. These land facets can be used in coarse-filter conservation planning for core areas or for conservation linkages.

Brost and Beier (2012) developed detailed procedures to use land facets to design conservation linkages; a land facet linkage (similar the union of focal species corridors) consist of a corridor for each land facet, plus a corridor for high diversity of land facets. Each land-facet corridor should support movement of species associated with that facet in any future climate, and the high diversity corridor should support species movements during periods of climate instability. The land facet corridors complement, rather than replace, focal species corridors.

Like linkages designed for multiple focal species, linkages planned for a diversity of land facets contain multiple strands. Specifically, each of the 22 land facet designs includes several (typically 5-15) corridors, each of which is designed to maximize continuity of one of the major land facets that occurs within the two targeted Landscape Blocks. Each such strand or corridor is intended to support occupancy and between-block movement by species associated with that land facet in periods of climate quasi-equilibrium. Like each focal species corridor, each land facet corridor was produced by least-cost modeling. Each design also includes one corridor with high local interspersion of facets; this corridor was also produced by least-cost modeling. This high-diversity corridor is intended to support short distance shifts (e.g. from low to high elevation, or from south-facing to north-facing slopes), species turnover, and other ecological processes relying on interaction between species and environments.

Although the corridor with high diversity of land facets is intended to promote short-distance movement across elevations and aspects, our design does not include corridors to connect each relatively warm land facet in one wildland block to each relatively cool land facet in the other block[1]. We did not model warm-to-cool corridors because in this landscape the transition from warm-to-cool (or the reverse) can best occur in the huge wildland blocks, where all land facets are juxtaposed in complex ways, rather than in relatively short and narrow corridors. Instead the corridor for each land facet is intended to support movements that can occur in a few days to several years (e.g., a few generations for a plant, small mammal, or small reptile). Landscape-extent range shifts involving several degrees of latitude would occur over several decades across the network of Landscape Blocks and Linkages.

Defining Land Facets: Although one definition of optimal habitat for bighorn sheep (or desert tortoise or any other focal species) can be applied to any pair of core areas to be connected, it is impossible to define land facets in a way that could be applied to all 22 analysis areas in the California Desert. For example, some analysis areas many have no ridges above 2,000 feet, or no steep north-facing slopes. And the steepest slopes in one analysis area may be in the middle of the steepness spectrum in another analysis area. To define biologically meaningful land facets that describe the diversity of physical settings present in each analysis area, we used flexible procedures developed by Brost and Beier (2012). These procedures use one categorical variable and three continuous variables to define land facets from 30-m digital elevation models:

1. Topographic position: Each pixel was assigned to one of three three topographic position categories, namely ridge (> 6 m higher than the average elevation in a 200-m radius), canyon (> 6 m lower), or slope (including flat areas) (Jenness 2006).
2. Annual solar insolation: Sum of instantaneous radiation at half-hour intervals for one day per month over a calendar year using the 'Solar Radiation' tool in ArcGIS 9.3 (ESRI, Redlands, California). The tool calculates half-hour radiation as a function of latitude, aspect, slope, and topographic shading, but ignores thickness of atmosphere and cloud cover.
3. Steepness, expressed as percent slope.
4. Elevation.

[1] Such a ‘warm to cool” design would have required two “directional corridors” (one in each direction) for each pair of facets. Thus a landscape with 6 land facets (15 potential pairs) would require up to 30 directional corridors to connect each warm facet to a cooler facet in the other wildland block.

In each of the 22 linkage planning areas, we used only pixels inside each pair of Landscape Blocks to define land facets. We first assigned each pixel inside the Landscape Blocks to one of three topographic position categories (ridge, canyon, or slope). Within each of the 3 topographic position classes we used the three continuous variables (steepness, elevation, insolation) to define subclasses, such as “high-elevation steep ridges” or “low elevation flats with high annual insolation” or “mid-elevation steep slopes with low annual insolation.” Within each topographic position, the procedures involved the following sequential steps: (1) removing the 10% most extreme outliers, i.e., cells with combinations of values of the continuous variables that rarely occur in the target areas. (2) Using fuzzy *c*-means cluster analysis (Dimitriadou et al. 2009) to group the pixels into natural clusters in multivariate space (i.e., the space defined by elevation, insolation, and slope). For example, the best three-way split of ridges might include high elevation-steep ridges, low elevation-steep ridges, and low elevation-gentle ridges. The best two-way split might result in steep ridges and gentle ridges. (3) Deciding which split (e.g., the 3-way split or the 2-way split in the previous example) best corresponds to the natural multivariate “lumpiness” in the continuous variables. This step involves several goodness of fit metrics, evaluating interpretability of classes, and examining maps of facet classes draped over a topographic hillshade to determine if facet types form compact polygons that make sense in the landscape. (4) Removing poorly classified pixels (e.g., pixels that assign with equal probability to 2 or more classes). Brost and Beier (2012) describe these procedures in detail.

In each analysis area, these procedures produced a set of 5-15 land facets, such as “high elevation, steep ridges” and “low elevation, gentle, hot, slopes.” After using these procedures to define the land facet types that occurred in the target areas, each pixel in the matrix (the analysis area outside the target areas) was assigned to one of the land facet types.

Developing Maps of Resistance: For the land facet approach, the resistance of a cell is the departure of that cell from the prototypical cell of the focal land facet, as quantified by its Mahalanobis distance. Mahalanobis distance can be thought of as the number of “multivariate standard deviations” between the attributes of a pixel and the “ideal” values for the focal land facet type. (In M-distance terminology “ideal” means “prototypical” or “characteristic.”) The ideal values for each facet type are:

- Mean elevation of pixels in the focal land facet within the Landscape Blocks.
- Mean insolation of pixels in the focal land facet within the Landscape Blocks.
- Mean steepness of pixels in the focal land facet within the Landscape Blocks.
- 100% of pixels in a 100-m radius are of the focal facet type.

By calculating how far each pixel lies from these ideal values, each pixel is assigned a resistance value with respect to the focal facet type. Thus, we created a unique resistance surface for each of the 5-15 focal land facets in each of the 22 linkage planning areas.

In addition to linkages for individual land facets, we designed a single linkage with maximum interspersion of land facets for each linkage planning area. The resistance maps were generated by calculating Shannon's diversity index, H', of land facets in a 5-pixel radius

(McCune and Grace 2002). Shannon's index incorporates richness and evenness into a single measure. Thus, a high index is achieved by not only maximizing the number of land facets within the neighborhood, but also balancing representation of those facets. We then calculated resistance of a pixel as 1/(H' + 0.1). This formula assigns low resistance to pixels with a high diversity index.

Least-cost Corridor Modeling: The procedures to conduct the least-cost corridor analysis for each unique land facet type are similar to those used for focal species:

- We defined corridor termini (potential start and end points) as the largest areas within each target area that contained the most occurrences of the focal land facet. Specifically we aggregated cells with at least one occurrence of the facet within a 3-cell radius into polygons, and retained the largest 50% of these polygons in each respective wildland block as termini. For the single high-diversity corridor, we defined termini by aggregating pixels with the highest H' values into polygons, using the largest 50% of these polygons as termini. In about 49 instances, the largest polygon dominated by the focal land facet in one or both of the Landscape Blocks was too small [< 2,613 ha;] to be used as termini for the least-cost corridor analysis. We did not model corridors for these 49 land facets.
- We calculated the cost-weighted distance (cumulative resistance) from each terminus and summed the two resulting raster outputs to produce a cumulative bi-directional cost map.
- We selected a "slice" (cost contour) of the corridor output with an approximate minimum width of 2 km (as for focal species). This slice is the least-cost corridor for that land facet (5-15 corridors per analysis area) or for high diversity of land facets (one corridor per analysis area).
- In most cases, the least-cost corridor passed mostly through areas of low to moderate resistance, with a few short segments of relatively high resistance (high dissimilarity from the focal facet type, or low diversity of facets in a diversity of corridor). But in about 26 cases, the least cost corridor included a long (> 5 km) of high resistance, such that the corridor would probably not provide connectivity for species associated with that land facet. The land facet union excluded these corridors.
- On average across all 22 linkage planning areas, the linkage union included an average of 6.3 corridors for individual land facets, and an average of 3.3 corridors per linkage were 'discarded' because termini were too small or high-resistance segments were too long. The high diversity corridor was retained in the land facet union in 19 of the 22 linkage planning areas.

Evaluate and Refine the Preliminary Linkage Designs

Each preliminary linkage design was the simple union of all of the least-cost corridors for all focal species, all focal land facets corridors, and the land facet diversity corridor. Although most of the preliminary linkage designs included corridors for 4 focal species and about 10 land facets, these corridors often partially overlapped, such that the preliminary design consisted of 1 to 5 strands, each of which provides connectivity for 1 or more species or land facets.

This union represents an area within which all modeled species would encounter the most favorable habitat as they move between target areas, based on the available data layers and models. However, dispersal limitations of the focal species could prevent a species from successfully moving between potential breeding areas within each Landscape Block. The suitable habitat in the union might occur in patches too small to support viable populations and these patches might be too far apart to allow for inter-patch dispersal for species that require multiple generations to traverse the linkage. To be effective, the linkage must support a collection of breeding patches separated by distances within the dispersal range of the species, such that movement and gene flow can occur in steppingstone fashion over several generations. We evaluated each preliminary linkage design for this type of effectiveness, and used the evaluation (and other considerations) to refine that design.

Evaluating the Preliminary Linkage Design: Patch Size and Configuration Analysis

We used Patch Size and Configuration Analysis to evaluate the effectiveness of the preliminary design for each focal species, including focal species for which we did not develop a least-cost corridor. Specifically we evaluated whether suitable habitat occurred in patches large enough to support the species, and whether patches were close enough together to allow for inter-patch dispersal

In this analysis, we overlay habitat patches on a map of the least-cost union. We then identified potential cores (an area of modeled suitable habitat large enough to sustain at least 50 individuals) and breeding patches (areas large enough to support successful reproduction by a pair of individuals) that were not captured by the union, but close to it. We also compared distances between habitat patches to the maximum dispersal distance of the species. Because most methods used to document dispersal distance underestimate the true value (LaHaye et al. 2001), we assumed the maximum dispersal distance was twice the longest <u>documented</u> dispersal distance. This assumption is conservative in the sense that it assigns importance to habitat patches that may appear to be isolated based on documented dispersal distances.

We lacked estimates of patch size and dispersal distance for some focal species, such as some plants and invertebrates. For these species, we overlay the modeled habitat on the least-cost union and evaluated how well the union “connected the dots” in steppingstone fashion.

Refining the Preliminary Linkage Designs: We refined the union in five ways:

1. Expanding the union to encompass nearby large potential cores and breeding patches identified in patch size and configuration analysis. We added (a) cores and patches whose addition created a set of steppingstones between target areas with interpatch distances less than the maximum dispersal distance of the focal species, (b) the largest and best patches of suitable habitat for species for which corridors were not modeled.
2. Adding rivers and riparian areas. Rivers and ephemeral drainages span elevation gradients in a way that increases interspersion and promotes ecological processes and flows, such as movement of animals, sediment, water, and nutrients (Cowling et al.

1999, 2003). Because mechanical geospatial algorithms may fail to identify important riverine connections, we manually included riverine elements if they were not already part of the union.

3. Deleting or narrowing strands that were redundant to the other strands in the design. In some cases more than one strand served each species equally well. For example in some landscapes several strands were composed 100% of modeled breeding habitat for badgers. In this case, any of those strands would probably serve badger equally well. If one of the strands did not serve any other focal species or land facet, we deleted it.
4. Deleting land facet corridors that consisted entirely or almost entirely of pixels that were highly dissimilar to the land facet. This occurred when the termini for a rugged, high elevation land facet were separated by a matrix of low desert flats, such that virtually none of the land in the corridor resembled the focal land facet.
5. Widening each strand to 2 km to minimize edge effects and support long-term occupancy of the corridor by less-mobile species that may require generations to move their genes between Landscape Blocks. For many species, including those we did not formally model, a wide linkage helps ensure availability of appropriate habitat, host plants (e.g., for butterflies), pollinators, and areas with low predation risk. In addition, fires and floods are part of the natural disturbance regime and a wide linkage allows for a semblance of these natural disturbances to operate with minimal constraints from adjacent urban areas. Wider linkages should also enhance the ability of the biota to respond to climate change, and buffer against edge effects.

After these modifications, the preliminary linkage design becomes the **final linkage design**.

Field Investigations

We conducted field surveys to ground-truth conditions depicted in data layers, document existing barriers (roads, railroads, canals) and potential crossing structures along those barriers, and identify locations where restoration or management (e.g., adding crossing structures) would enhance connectivity. Because paved roads often present the most formidable potential barriers, we drove each section of paved road that transected the linkage designs and photo documented potential crossing structures (e.g., bridge, underpass, overpass, culvert, pipe). For most structures, we noted shape, height, width, length, and construction materials, and whether fencing funneled animals toward the structure.

Existing highways and crossing structures are not necessarily permanent landscape features. In particular, crossing structures can be added or improved during projects to widen and realign highways and interchanges. Therefore, we also identified areas where crossing structures could be improved or installed. Because most of California's roads were not originally designed to accommodate wildlife movement, road improvement projects can dramatically restore permeability across transportation barriers.

In many analysis areas, aqueducts presented the most formidable barriers to animal movement. It is unlikely that any mammal or reptile can cross an above-ground aqueduct. In some areas, siphons (an area where the aqueduct is buried, typically where a major drainage crosses the alignment of the aqueduct) provide excellent opportunities for wildlife crossing. In some areas, aqueducts ran for several miles without a single siphon, or with only a short siphon of bare dirt to allow vehicles to cross the aqueduct. In cases where these impermeable aqueducts cross a least-cost corridor, we recommend major modifications to create crossing opportunities.

Linkages for Species: Landscape Permeability Analyses

We conducted landscape permeability or least-cost corridor analyses for four focal species (bighorn sheep, American badger, kit fox, and desert tortoise). In many linkage planning areas, there was considerable overlap in the corridors for two to three species despite their diverse ecological and movement requirements. However, bighorn sheep always diverged to generate routes through the rugged terrain they prefer (Figure 4).

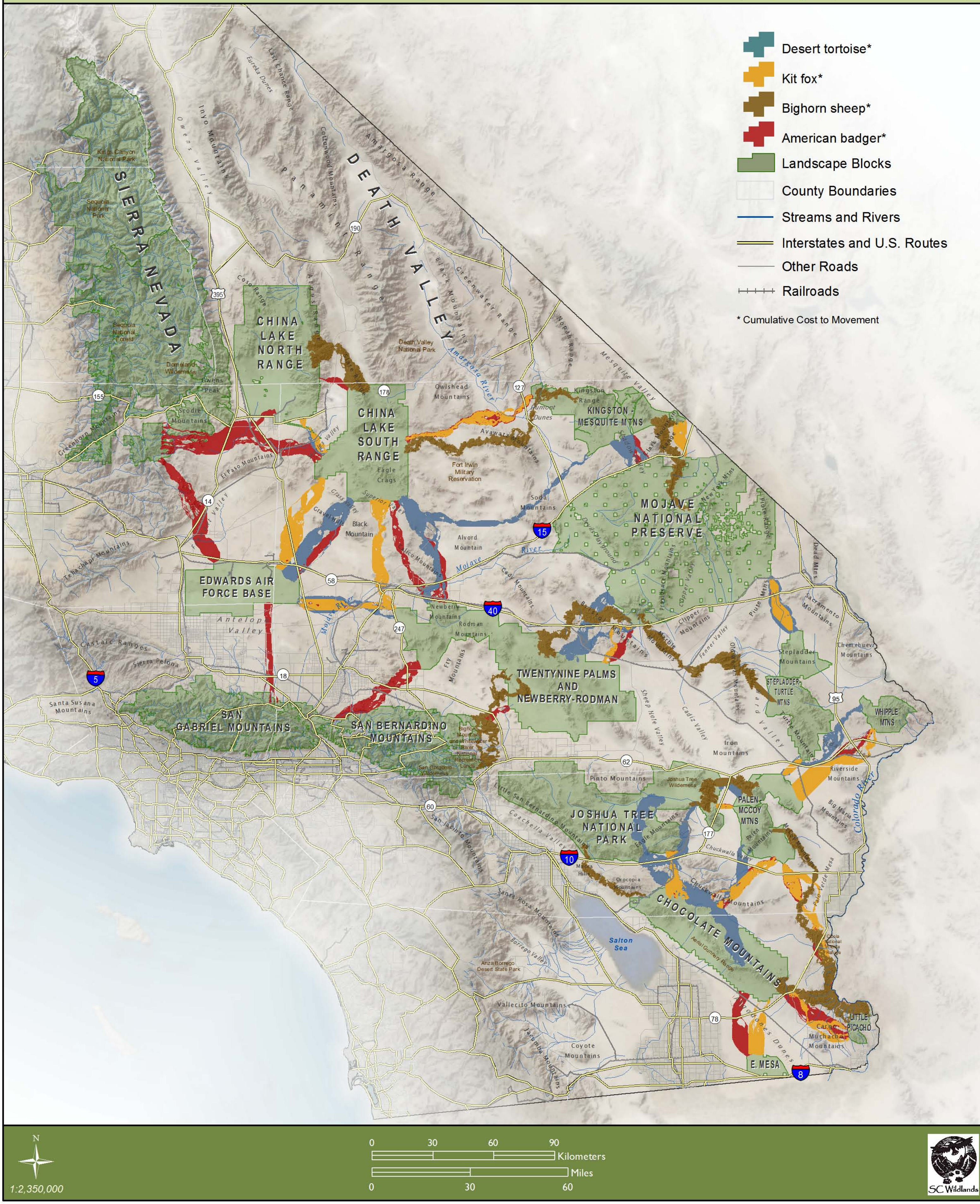
Figure 5 depicts the Network of Focal Species Least-cost Unions (i.e., the unions of the least-cost corridors for all species in all 22 Linkage Planning Areas). It covers roughly 862,927 ha (2,132,330 ac). Individual Least-cost Unions range in size from 3,930 ha (9,711 ac) to 80,995 ha (200,143 ac; Table 3) and span distances between roughly 8 and 90 km. They encompass diverse topographic, elevation, vegetation and physiographic zones to account for the needs of various species. The different branches of each Least-cost Union identify the areas best suited to facilitate species movements between targeted wildland blocks based on model assumptions and available GIS data.

Table 3. Area of Focal Species Least-Cost Unions

Linkage Planning Area	**hectares**	**acres**
Stepladder Turtle Mountains- Palen McCoy Mountains	3929.78	9710.65
Joshua Tree National Park - Palen McCoy Mountains	9791.91	24196.23
Edwards Air Force Base - San Gabriel Mountains	12696.87	31374.53
Twentynine Palms and Newberry Rodman - San Gabriel Mountains	24254.27	59933.37
Twentynine Palms and Newberry Rodman - San Bernardino Mountains	24729.46	61107.57
Palen McCoy Mountains - Chocolate Mountains	25080.94	61976.09
Edwards Air Force Base - Twentynine Palms and Newberry Rodman	27531.14	68030.66
China Lake North Range - China Lake South Range	29534.06	72979.97
China Lake North Range - Sierra Nevada	32398.32	80057.67
Chocolate Mountains - East Mesa	33575.45	82966.41
Edwards Air Force Base - Sierra Nevada	33870.60	83695.74
Kingston Mesquite Mountains - Mojave National Preserve	36371.22	89874.87
Chocolate Mountains - Little Picacho	51429.97	127085.72
China Lake South Range - Sierra Nevada	51463.92	127169.61
Joshua Tree National Park - Chocolate Mountains	51798.51	127996.40
Palen McCoy Mountains - Whipple Mountains	52590.82	129954.23
Mojave National Preserve - Stepladder Turtle Mountains	52845.29	130583.03
Mojave National Preserve - Twentynine Palms and Newberry Rodman	60756.99	150133.20
Palen McCoy Mountains - Little Picacho	63890.59	157876.44
China Lake South Range - Edwards Air Force Base	69237.25	171088.28
China Lake South Range - Kingston Mesquite Mountains	78908.20	194985.63
China Lake South Range - Twentynine Palms and Newberry Rodman	80995.37	200143.12
Sum (diff from Network of Focal Spp Union because of overlap)	907680.92	2242919.43
Total Area of Network of Focal Species Least Cost Unions	862,927	2,132,330

CALIFORNIA DESERT CONNECTIVITY PROJECT

Figure 4. Least-Cost Corridors Displaying Species Overlap



CALIFORNIA DESERT CONNECTIVITY PROJECT

Figure 5. Network of Focal Species Least-Cost Unions

The next several pages summarize the permeability analyses for each of the four modeled species. For convenience, the narratives describe the most permeable paths from one direction (e.g., north to south), although our analyses gave equal weight to movements in both directions. The Refining the Preliminary Linkage Network section describes how well the network would likely serve the needs of all focal species, including those for which we could not conduct permeability analysis. The latter analysis expanded the Least-cost Unions, where necessary to provide for critical live-in and/or move-through habitat for particular focal species.

American badger (*Taxidea taxus*)

Justification for Selection: The badger is a highly specialized species that requires open habitats with suitable soils for excavating large burrows (de Vos 1969, Banfield 1974, Sullivan 1996). Badgers require expansive wildlands to survive and are highly sensitive to habitat fragmentation. In fact, roadkill is a primary cause of mortality (Long 1973, Zeiner et al. 1990, Sullivan 1996).

Conceptual Basis for Model Development: Badgers are associated with grasslands, prairies, and other open habitats that support abundant burrowing rodents (de Vos 1969, Banfield 1974, Sullivan 1996) but they may also be found in drier open stages of shrub and forest communities (Zeiner et al. 1990). They are known to inhabit forest and mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper, and sagebrush habitats (Long and Killingley 1983, Zeiner et al. 1990). The species is typically found at lower elevations (Zeiner et al. 1990) in flat, rolling or steep terrain but it has been recorded at elevations up to 3,600 m (12,000 ft; Minta 1993).

Badgers can disperse up to 110 km (68 mi; Lindzey 1978), and preferentially move through open scrub habitats, fields, and pastures, and open upland and riparian woodland habitats. Denser scrub and woodland habitats and orchards are less preferred. They avoid urban and intense agricultural areas. Roads are difficult to navigate safely. Cost to movement for badger was defined as:

$$\text{Vegetation}^{0.55} \times \text{Elevation}^{0.10} \times \text{Topography}^{0.20} \times \text{Road Density}^{0.15} = \text{cost to movement}$$

Results & Discussion: Landscape permeability analyses were conducted for badger in all 22 linkage planning areas (Figure 6).

Sierra Nevada-China Lake North Range: The least-cost corridor extends from the Piute Mountains in Sequoia National Forest, taking in parts of Kelso Creek. The corridor then splits with the northern branch capturing habitats in Pinyon Creek, Bird Spring Pass and Horse Canyon and the southern branch taking in Frog Creek, Wyleys Knob and Bird Spring Canyon. The branches then converge to take in lower Horse Canyon, Sage Canyon, and Cow Heaven Canyon, crossing State Route 14 at the Freeman Gulch. East of the 14, the most permeable route follow Little Dixie Wash for a ways to cross the railroad, then follows an unnamed wash across State Route 395 and heads northeast to cross 178 in the open section west of Jacks Ranch Road to Armitage Field on the China Lake North target area. It ranges in width from approximately 0.9 to 9.9 km.

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Figure 6. Least-Cost Corridors for American badger (Taxidea taxus)

Sierra Nevada-China Lake South Range: The least-cost corridor for this connection follows the same route described above but diverges to cross State Route 395 near Teagle Wash into the lower Searles Valley. It ranges in width from about 2 to 13 km.

Sierra Nevada-Edwards Air Force Base: The most permeable route varies in width from about 2 to 9 km and extends from Landers Meadow in the southern Sierras through Kelso Valley across Toms Hill to Jawbone Canyon. The corridor follows lower Pine Tree Canyon, crossing the 14 just south of Pine Tree Canyon Road down into the Fremont Valley. It then heads almost due south to cross Cache Creek then veers southeast towards Edwards Air Force Base.

China Lake North Range-China Lake South Range: The least-cost corridor ranges in width from approximately 0.7 to 4 km and extends from Sweetwater Wash out of the Argus Range, crosses the 178 near Pioneer Point down into Borax Flat in the northern part of the Searles Valley and then heads east toward Copper Queen Canyon in the Slate Range.

China Lake South Range-Edwards Air Force Base: The most permeable path varies in width from 2 to 5.7 km and extends from Grass Valley at the southwest corner of China Lake South Range, through Gravel Hills and The Buttes to Kramer Junction, crossing the 58 and 395 just east of their juncture. Another narrower route (1 to 4 km) was delineated just north of the most permeable path.

China Lake South Range-Twentynine Palms and Newberry Rodman: The least-cost corridor has two branches. The most permeable route extends from Superior Valley in a southeast direction through the flatlands between the Calico Mountains and the Paradise Range and Coyote Dry Lake to the base of the Newberry Mountains and ranges in width from about 2.2 to 12.7 km. The other pathway extends from Superior Valley to the base of the Newberry Mountains and follows the flatlands between Black Mountain and the Calico Range through the Rainbow Basin and Mud Hills; it ranges from 1.8 to 7 km wide.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The least-cost corridor ranges in width from roughly 2.2 to 6 km. It extends from the southeast corner of Edwards Air Force Base eastward through the flatlands to the south of Kramer Hills and Iron Mountain, crossing the Mojave River and the railroad just north of the rivers confluence with Wild Wash and continuing east to cross the 15 just north of Side Winder Road and the 247 near its juncture with Stoddard Wells Road.

Edwards Air Force Base-San Gabriel Mountains: The least-cost corridor extends from south of the Haystack Butte area on Edwards Air Force Base through the El Mirage Valley to Table Mountains in the San Gabriel Mountains. It captures habitats in Mescal Creek, Jesus and Puzzle canyons, Montaine Creek and habitats to the west of Sheep Creek in the San Gabriel Mountains. It ranges in width from about 2.7 to 8.2 km.

Twentynine Palms and Newbery Rodman-San Gabriel Mountains: The least-cost corridor extends from the foothills of the Ord Mountains in the Newberry Rodman ACEC through Lucerne Valley then branches at the 247 to go around Lucerne Dry Lake with the most permeable route to the north in the foothills of the Granite Mountains and around Rabbit Lake. It crosses the 18 in Fifteenmile Valley then heads toward Juniper

Flats in the foothills of the San Bernardino Mountains. It follows the Mojave River Valley and Summit Valley to Cleghorn Ridge towards Lone Pine Canyon in the San Gabriel Mountains. It ranges in width from roughly 2.6 to 9.2 km.

Twentynine Palms and Newbery Rodman-San Bernardino Mountains: The least-cost corridor ranges in width from about 0.9 to 4.6 km. It extends from Twentynine Palms Marine Corps Base following Pipes Wash for about 3 km then encompasses the northern part of Homestead Valley crossing the 247 to the north of Mikiska Boulevard into the foothills of the San Bernardino Mountains.

China Lake South Range-Kingston Mesquite Mountains: The least-cost corridor ranges from 1.5 to 10 km wide and extends from the lower slopes of the Sperry Hills in the Kingston Mesquite target area down into Death Valley, then heads west following the lowlands along Owl Hole Springs Road between the Owlshead and Quail Mountains to the North and the Avawatz and Granite Mountains to the south towards Pilot Knob Valley in the China Lake South Range.

Kingston Mesquite Mountains-Mojave National Preserve: The most permeable path ranges in width from roughly 2 to 9.3 km. It extends from the Kingston Mesquite target area following Kingston Wash through Shadow Valley and crosses the 15 in the vicinity of Kingston Wash.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: From Mojave National Preserve, the least-cost corridor crosses Interstate 15 near Old Dad Mountains Wash and follows the wash for about 6 km. It then crosses over Orange Blossom Wash, heads up over the Bristol Mountains and down into the lowlands between the Lava Hills and Amboy Crater. It ranges in width from 1.4 km at its narrowest where it crosses over the Bristol Mountains to 7.7 km at its widest.

Mojave National Preserve-Stepladder Turtle Mountains: The most permeable path ranges in width from roughly 2.5 to 10 km wide. From Mojave National Preserve, it follows Homer Wash across Interstate 40 and down into Ward Valley which it follows to the Stepladder Turtle wildland block.

Stepladder Turtle Mountains-Palen McCoy Mountains: The least-cost corridor is approximately 3 km wide and extends from the base of Turtle Mountains through Rice Valley crossing the 62, the railroad and the aqueduct where they come together toward the Arica Mountains in the Palen McCoy target area.

Palen McCoy Mountains-Whipple Mountains: The most permeable route extends from the base of the Whipple Mountains and crosses the 62 and 95 into Vidal Valley. It then crosses the railroad and Vidal Wash to follow the lowlands on the north side of the West Riverside Mountains into Rice Valley towards the Little Maria Mountains in the Palen McCoy wildland block. It ranges in width from 1.8 to 9 km.

Joshua Tree National Park-Palen McCoy Mountains: The least-cost corridor extends from the foothills of the Coxcomb Mountains in Joshua Tree National Park through the Palen Valley to the Palen McCoy wildland block. It varies in width from approximately 1.5 to 2.8 km wide.

Joshua Tree National Park-Chocolate Mountains: The least-cost corridor extends from Joshua Tree National Park down into Chuckwalla Valley, crosses the 10 freeway in the vicinity of bridged under-crossings for Union, Ajax and Irolo ditches. The corridor then follows Red Cloud Wash for a distance before following the lowlands between the Chuckwalla and Orocopia Mountains into the Chocolate Range. It ranges in width from roughly 2.9 to 6.5 km.

Palen McCoy Mountains-Chocolate Mountains: The least-cost corridor extends from the flatlands at the base of the Palen and McCoy Mountains down into Chuckwalla Valley to the west of Ford Dry Lake and crosses the 10 freeway in the vicinity of Beehive Ditch. It then follows several unnamed washes up into the Chuckwalla Mountains, then branches to cross this range with the most permeable route taking Augustine Pass and the other branch taking Iris Pass up into the Chocolate Mountains. It varies in width from about 1.3 to 8.3 km.

Palen McCoy Mountains-Little Picacho: The least-cost corridor extends from the lowlands in between the Palen and McCoy Mountains down into Chuckwalla Valley to the east of Ford Dry Lake and crosses the 10 freeway in the vicinity of two bridged undercrossings for Gale and Teed Ditches. It then follows the flatlands along Wileys Well Road in between the Little Chuckwalla and Mule Mountains for about 15 km before heading southeast over a low point in the Mule Mountains to get to the flatlands on the eastern flank of the Palo Verde Mountains. The corridor then branches to cross over Palo Verde Peak and crosses the 78 near Walter Camp Road just west of the Cibola National Wildlife Refuge. It then heads into the foothills of the Chocolate Mountains for a distance, then veers southeast to follow habitats along the Colorado River to the Little Picacho target. It ranges in width from roughly 1 to 9.6 km.

Chocolate Mountains-Little Picacho: The least-cost corridor extends from the Chocolate Mountains and crosses the 78 in the vicinity of Ben Hulse Highway. It then follows the lowlands between the Cargo Muchacho Mountains and the Chocolate Range across Indian Pass Road and Indian Wash. The corridor then follows Picacho Wash for a distance before heading towards Mission Wash in the Little Picacho target area. It varies in width from 1.8 to 10.8 km.

Chocolate Mountains-East Mesa: The least-cost corridor extends from the foothills of the Chocolate Mountains over the northern part of the Algodones Dunes and crosses the 78 to the west of its juncture with the Coachella Canal down into the East Mesa target area. It ranges in width from about 2 to 10 km.

Justification for Selection: Major highways and heavily traveled roads are significant obstacles to movement for kit fox and vehicle collision is the greatest source of mortality in urbanizing areas (Cypher et al. 2000). The kit fox is vulnerable to habitat loss and fragmentation due to agricultural, urban, and industrial development (Grinnell et al. 1937, CDFG 1990).

Conceptual Basis for Model Development: This small carnivore primarily inhabits native or annual grasslands and sparsely vegetated scrub habitats with abundant rodent populations, such as alkali sink scrub, saltbush scrub, and chenopod scrub, though oak woodlands, vernal pools, alkali meadows and playas also provide habitat (USFWS 1998, Brown et al. undated mat.). They can move through other habitats though they prefer not to do so. They are mainly associated with gently sloping and flat terrain; slopes of 0-5% are considered ideal, slopes of 5-15% provide fair habitat, and areas with slopes >15% are largely unsuitable (B. Cypher, personal communication). Major highways and heavily traveled roads present obstacles to movement (Cypher et al. 2000 *in* USFS 2002). Juveniles may disperse up to 60 miles from their natal dens (Thelander 1994). Cost to movement for kit fox was defined by weighting various inputs, such that:

$$\text{Vegetation}^{0.70} \times \text{Road Density}^{0.10} \times \text{Topography}^{0.20} = \text{cost to movement}$$

Results and Discussion: Landscape permeability analyses were conducted for kit fox in 16 of the linkage planning areas (Figure 7).

China Lake North Range-China Lake South Range: The least-cost corridor closely resembles the output for the desert tortoise. It extends from Salt Wells Valley, crosses the 178 east of the Bowman and Trona Road juncture. Just south of Randsburg Wash Road, it narrows to enter a canyon through the Spangler Hills and then crosses the railroad, Pinnacle Road and Teagle Wash into the Searles Valley. It ranges in width from roughly 0.6 to 4.8 km.

China Lake South Range-Edwards Air Force Base: The least-cost corridor ranges in width from approximately 2.8 to 12 km wide and extends from the Black Hills area of China Lake South through Grass Valley and across Gravel Hills crossing 395 and 58 to the west of their juncture.

China Lake South Range-Twentynine Palms and Newberry Rodman: The least-cost corridor extends from Superior Valley on China Lake South into the lowlands of the Rainbow Basin in between the Black and Calico Mountains. It then heads over the

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Figure 7. Least-Cost Corridors for Kit fox (Vulpes macrotis)

Waterman Hills into Hinkley Valley crossing the 58, the railroad, Interstate 15 and route 247 towards the Stoddard Valley. It ranges in width from about 2 to 11.4 km.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The least-cost corridor closely resembles the output for badger. It ranges in width from roughly 1.7 to 6.8 km and extends from the southeast corner of Edwards Air Force Base eastward through the flatlands to the south of Kramer Hills and Iron Mountain, crossing the Mojave River and the railroad just north of the rivers confluence with Wild Wash and continuing east to cross the 15 just north of Side Winder Road and the 247 near its juncture with Stoddard Wells Road.

China Lake South Range-Kingston Mesquite Mountains: The least-cost corridor closely resembles the output for badger. It ranges from about 1.2 to 8.4 km wide and extends from the lower slopes of the Sperry Hills down into Death Valley, then heads west following the lowlands along Owl Hole Springs Road between the Owlshead and Quail Mountains to the North and the Avawatz and Granite Mountains to the south towards Pilot Knob Valley in the China Lake South Range.

Kingston Mesquite Mountains-Mojave National Preserve: The least-cost corridor ranges in width from about 1.6 to 8.2 km and extends from the Mesquite Valley down into Ivanpah Valley to the east of the Clark Mountain Range. It crosses Interstate 15 to the east of Wheaton Springs.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: From Mojave National Preserve, the least-cost corridor extends from Willow Spring Basin, crossing the 40 freeway in the vicinity of Old Dad Mountains Wash towards the Brown Buttes and into the Bristol Mountains. It then heads south in the foothills of the Lava Hills and overlaps the southern part of the badger corridor, taking the lowlands between the Lava Hills and Amboy Crater. It is roughly 1 to 3.5 km wide

Mojave National Preserve-Stepladder Turtle Mountains: The least-cost corridor follows the results for the desert tortoise and badger, following Homer Wash across Interstate 40 and down into Ward Valley. It ranges in width from roughly 1.3 to 9.8 km.

Stepladder Turtle Mountains-Palen McCoy Mountains: The delineated least-cost corridor is similar to the desert tortoise and badger outputs, extending through Rice Valley and crossing the 62, the railroad and the aqueduct where they come together toward the Arica Mountains. It ranges in width from about 2 to 4.4 km.

Palen McCoy Mountains-Whipple Mountains: The least-cost corridor has two branches extending from the Whipple Mountain target and across route 62. The western branch is similar to the badger corridor while the eastern branch lies about 4 km east. It crosses State Route 95 in the vicinity of Vidal Wash and then the corridor closely follows the badger output taking in parts of Vidal and Rice Valleys. It ranges in width from roughly 0.8 to 9.2 km.

Joshua Tree National Park-Palen McCoy Mountains: The least-cost corridor mirrors the badger output. It extends from the foothills of the Coxcomb Mountains through the Palen

Valley straddling Coxcomb Monument Road; it varies in width from approximately 2 to 2.4 km wide.

Joshua Tree National Park-Chocolate Mountains: The least-cost corridor overlaps the output for desert tortoise and badger. It extends down into Chuckwalla Valley, crosses the 10 freeway following several ditches with bridged undercrossings, then follows Red Cloud Wash and the lowlands between the Chuckwalla and Orocopia Mountains into the Chocolate Range. It is narrowest in the vicinity of the freeway and widest to the south, ranging from roughly 0.9 to 10.2 km.

Palen McCoy Mountains-Chocolate Mountains: The least-cost corridor closely resembles the results for the badger corridor. It extends down into Chuckwalla Valley to encompass the western portion of Ford Dry Lake; follows several washes into the Chuckwalla Mountains, then branches to cross this range using Augustine Pass and Iris Pass up into the Chocolate Mountains. It varies in width from about 0.9 to 7.9 km and is narrowest through the passes.

Palen McCoy Mountains-Little Picacho: The most permeable route follows the least-cost corridor identified for badger but an additional branch was delineated south of the 10 freeway around the eastside of the Mule Mountains over the Palo Verde Mesa. The primary branch extends down into Chuckwalla Valley and crosses the freeway in the vicinity of Gale and Teed Ditches. It then follows the flatlands between the Little Chuckwalla and Mule Mountains toward the eastern flank of the Palo Verde Mountains, and crosses the 78 near Walter Camp Road. The corridor follows the foothills of the Chocolate Mountains for a distance, and then veers southeast to follow upland habitats along the Colorado River. It ranges in width from roughly 0.7 to 15 km.

Chocolate Mountains-Little Picacho: The least-cost corridor closely resembles the badger output but an additional less permeable branch was identified across the 78 just north of the 78 and S34 juncture. The most permeable branch crosses the 78 in the vicinity of Ben Hulse Highway, follows the lowlands between the Cargo Muchacho Mountains and the Chocolate Range, and takes in habitats in Picaho and Mission Washes. It varies in width from 1.2 to 14 km.

Chocolate Mountains-East Mesa: The least-cost corridor has two branches that extend south from the flatlands at the base of the Chocolate Mountains. They vary in width from 0.5 to 4.2 km. The most permeable route crosses the 78 and the railroad at Glamis with another less permeable route crossing about 3.7 km to the northwest. Approximately 8 km south of the 78, the two branches merge as they cross over the Algodones Dunes becoming much broader, 9.4 km at its widest.

Justification for Selection: Bighorn sheep need large core wild areas for refuge and security. They have extensive spatial requirements, make pronounced seasonal movements, and require habitat connectivity between subpopulations. Bighorn sheep are extremely sensitive to habitat loss and fragmentation (Bleich et al. 1996, Rubin et al. 1998, Singer et al. 2000, USFWS 2000).

Conceptual Basis for Model Development: Bighorn sheep utilize alpine dwarf shrub, low sage, sagebrush, pinyon-juniper, palm oasis, desert riparian, desert scrubs, subalpine conifer, and perennial grassland (Zeiner et al. 1990, E. Rubin, pers. com.), as well as montane oak, conifer, riparian, and chaparral habitats (Holl and Bleich 1983). Adult rams exhibit the most movement (Weaver 1972, DeForge 1980, Holl and Bleich 1983, Holl et al. 2004); with movements up to 56 km (34.8 mi) observed (Witham and Smith 1979).

Bighorn sheep preferentially move through open habitats in close proximity to escape terrain, preferring ridgetops as travel routes. Although typically associated with rugged mountainous terrain, bighorn sheep commonly use a variety of desert terrain types, including canyon bottoms, washes, alluvial fans, plateaus, and valley floors. These areas may be used both for movement between mountainous areas and as important foraging areas (e.g., Schwartz et al. 1986, Bleich et al. 1997). They avoid roads, impenetrable vegetation, urban land cover, and centers of human activity, even in suitable habitat. Cost to movement for bighorn sheep was defined as:

$$\text{Vegetation}^{0.40} \times \text{Topography}^{0.40} \times \text{Road Density}^{0.20} = \text{cost to movement}$$

Results & Discussion: There is strong evidence of past and recent connectivity among many mountain ranges. This connectivity, crucial for long-term viability of bighorn populations, is, however, threatened by barriers. Epps et al. (2007) used least-cost modeling and genetic data to evaluate connectivity among 26 bighorn sheep populations and determined that a number of these connections were disrupted by barriers such as interstate highways, canals, and developed areas. Epps et al. (2005) found that such barriers were associated with a rapid decline in genetic diversity, putting the isolated populations at risk. Many of the movement corridors predicted by Epps et al. (2007) were supported by empirical evidence (direct observation or telemetry data) of animals moving between mountain ranges. In some cases, such as in the case of an animal moving across Interstate 40 near the Sheephole Mountains, empirical data revealed a (threatened) corridor not predicted by the model. This serves as an important reminder that empirical evidence of moves should be viewed as a minimum rate of movement, because only a subset of each population has been collared, many populations have only been monitored during recent years, and movements of both collared and uncollared animals are difficult to monitor in the vast desert landscape.

Epps et al. (2007) indicated likely movement paths under the assumption that bighorn sheep would be most likely to move along mountainous terrain, but bighorn sheep are also known to move across relatively flat terrain between mountain ranges (Bleich et al. 1990, 1996, USFWS 2000) and may therefore be threatened by barriers found in non-mountainous terrain.The importance of such non-mountainous habitat in sustaining long-term population health is clearly recognized by bighorn sheep managers and biologists (Schwartz et al. 1986, Bleich et al. 1990, Bleich et al. 1997, USFWS 2000). CDFG considers bighorn sheep in the California desert to comprise metapopulations (or systems of multiple populations) that are sustained in the long-term by occasional movement of animals between mountain ranges (e.g., Bleich et al. 1996, Epps et al. 2003).

Landscape permeability analyses were conducted in 10 of the linkage planning areas for bighorn sheep (Figure 8).

China Lake North Range-China Lake South Range: As expected, the most permeable route between targeted wildland blocks follows the Slate Range to the Argus Range, providing the rugged terrain preferred by bighorn sheep. The least-cost corridor crosses the 178 just south of Trona Wildrose Road and varies in width from 3.5 to 16.7 km.

China Lake South Range-Kingston Mesquite Mountains: The least-cost corridor follows the Granite Mountains to the Avawatz Mountains to Salt Spring Hills, heading towards Amargosa Canyon and into the Dumont Hills and the Kingston Range. It crosses the 127 at the Salt Spring Hills and varies in width from 0.9 to 12 km. It serves to connect known bighorn populations in the Eagle Crags, Granite, Avawatz, and Kingston Mesquite Ranges in addition to several populations in Death Valley National Park.

Kingston Mesquite Mountains-Mojave National Preserve: The most permeable route extends from the Mesquite Mountains and follows the Clark Mountain Range to the Ivanpah Mountains in Mojave National Preserve, connecting several populations within these wildland blocks. The least-cost corridor crosses Interstate 15 near Mineral Hills and ranges in width from approximately 3.8 to 11.8 km.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The least-cost corridor varies in width from 3.1 to 12.4 km and extends from the Granite Mountains in Mojave National Preserve across the Old Dad Mountains into the Bristol Mountains, crossing Interstate 40 near Ash Hill and following the Bullion Mountains into Twentynine Palms Marine Corps Base.

Mojave National Preserve-Stepladder Turtle Mountains: The most permeable route ranges in width from 2 to 12.3 km and extends from the Granite Mountains in Mojave National Preserve, crosses Interstate 40 just east of Kelbaker Road into the Marble

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Figure 8. Least-Cost Corridors for Bighorn sheep (Ovis canadensis)

Mountains following this range to cross the National Trails Highway at Cadiz Summit down into the Ship Mountains. It then crosses Skeleton Pass into the Old Woman Mountains and Ward Valley into the Turtle Mountains.

Twentynine Palms and Newberry Rodman-San Bernardino National Forest: The least-cost corridor extends from Hidalgo Mountain in Twentynine Palms Marine Corps Base, following hilly terrain west to cross State Route 247 just north of Mikiska Boulevard. It then branches to take in habitat in the Bighorn Mountains and Ruby Mountain. From Ruby Mountain, the most permeable route then heads toward Black Lava Butte and Flat Top Mesa crossing Pipes Canyon Road into Pipes Canyon and Chaparrosa Wash to the west of Pioneertown. Another route from the Bighorn Mountains hugs the base of the San Bernardino Mountains. The least-cost corridor ranges in width from approximately 1.5 to 18 km.

Joshua Tree National Park-Palen McCoy Mountains: The most permeable route varies in width from 3.9 to 7.8 km and extends from the Coxcomb Mountains in Joshua Tree National Park crossing State Route 177 immediately south of the 62 junction into the Granite Mountains in the Palen McCoy targeted wildland block.

Joshua Tree National Park-Chocolate Mountains: The least-cost corridor extends from the foot of the Little San Bernardino Mountains in Joshua Tree National Park crosses Interstate 10 in the steepest terrain along this route into the Mecca Hills then crosses State Route 195 (also known as Box Canyon Road) at Sheep Hole Oasis into the Orocopia Mountains and then onto the Chocolate Mountains target area. It is narrowest (only 0.5 km) at the chokepoint where it crosses the freeway and widest in the Mecca Hills at 4.9 km.

Palen McCoy Mountains-Little Picacho: The most permeable route extends from the eastern flank of the Palen Mountains to the McCoy Mountains following this range to where the southern tip of the McCoys nearly touches Interstate 10, crossing over the Chuckwalla Valley into the Mule Mountains. It then follows the Mule Mountains through the Palo Verde Mountains crossing State Route 78 just south of Palo Verde Peak where Milipitas Wash meanders along the highway. From here it follows mountainous terrain to Quartz Peak at the southern extent of the Chocolate Mountains then on to Picacho Peak through Copper Basin and on to Little Picacho Peak. The least-cost corridor varies in width from approximately 1.6 to 10.8 km.

Chocolate Mountains-Little Picacho: The least-cost corridor varies in width from about 2.8 to 16.7 km. It extends from the Chocolate Mountains to Mt Barrow crossing State Route 78 just north of the S34 juncture and heads toward Black Mountain Peak at the southern extent of the Chocolate Mountains. From here, the most permeable route overlaps the Palen McCoy-Little Picacho least-cost corridor taking in Picacho Peak, Copper Basin and Little Picacho Peak.

Desert tortoise (*Gopherus agassizii*)

Justification for Selection: The desert tortoise is an umbrella species for coachwhip, glossy snake, desert horned lizard, western banded gecko, and leaf-nosed snake, such that maintaining functional cores and linkages for desert tortoise will effectively protect these species too. Desert tortoise will move through many desert habitats but is fragmentation sensitive and inhibited by heavily traveled roads, and medium to high density housing (W. Boarman, pers. comm.). They are also highly susceptible to road kill (Berry and Nicholson 1978, Boarman et al. 1993, Boarman and Sazaki 1996, Boarman et al. 1997).

Conceptual Basis for Model Development: Desert tortoises are found on flats, valleys, alluvial fans, bajadas, sand dunes, rocky outcrops, mountainous slopes, and gently sloping hills in creosote bush scrub, saltbush scrub, blackbush scrub, cheesebush scrub, and scrub steppe communities (USFWS 1994).

Desert tortoises preferentially move through desert scrub habitats with widely scattered shrubs. They have trouble traversing roads and avoid medium to high density developed areas. Cost to movement for desert tortoise was defined as follows:

$$\text{Vegetation}^{0.40} \times \text{Elevation}^{0.15} \times \text{Topography}^{0.25} \times \text{Road Density}^{0.20} = \text{cost to movement}$$

Results & Discussion: Several recent planning efforts recognize the importance of maintaining connectivity for desert tortoise (BLM 2001, 2005, 2008, BLM and CDFG 2002, USFWS 2008). The revised recovery plan for the Mojave population of the desert tortoise (USFWS 2008), calls for maintaining large-scale connectivity among blocks of desert tortoise habitat, as well as functional culverts across transportation barriers such as roads and railroads. The West Mojave Plan (BLM 2005) seeks to ensure genetic connectivity among desert tortoise populations, both within and between Recovery Units and Desert Wildlife Management Areas.

Landscape permeability analyses were conducted for the desert tortoise in 13 of the linkage planning areas (Figure 9).

China Lake North Range-China Lake South Range: The least-cost corridor extends from the Salt Wells Valley area on China Lake North crossing the 178 and Bowman Road to the east of the Bowman and Trona Road juncture. Just south of Randsburg Wash Road, it constricts to a narrow pathway to enter a canyon through the Spangler Hills. It then crosses the railroad, Pinnacle Road and Teagle Wash into the Searles Valley before

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Figure 9. Least-Cost Corridors for Desert tortoise (Gopherus agassizii)

terminating near the Black Hills in the China Lake South target area. It is narrowest (0.6 km) through the canyon in the Spangler Hills and widest (5.8 km) in the Searles Valley.

China Lake South Range-Edwards Air Force Base: The least-cost corridor follows a similar pathway to the badger corridor, extending from the Superior Cronese Critical Habitat Unit near Grass Valley at the southwest corner of China Lake South Range, through Gravel Hills and The Buttes to Kramer Junction in the Fremont Kramer Critical Habitat Unit, crossing the 58 and 395 at their juncture. It varies in width from approximately 3.8 to 12.2 km.

China Lake South Range-Twentynine Palms and Newberry Rodman: The least-cost corridor follows a similar route to the most permeable branch of the badger corridor. It extends from Superior Valley in the Superior Cronese Critical Habitat Unit in a southeast direction through the flatlands between the Calico Mountains and the Paradise Range and Coyote Dry Lake. It branches to cross the 15 near Yermo Road and the railroad into the Mojave Valley with the most permeable route to the west of Minneola Road and another narrower route to the west of Condor Road, reaching the base of the Newberry Mountains in the Ord Rodman Critical Habitat Unit. It ranges in width from about 1.9 to 12 km.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The least-cost corridor follows a pathway comparable to badger though slightly broader, ranging in width from roughly 1.8 to 10 km. It extends from the southeast corner of Edwards Air Force Base in the Fremont Kramer Critical Habitat Unit eastward through the flatlands to the south of Kramer Hills and Iron Mountain, crossing the Mojave River and the railroad just north of the rivers confluence with Wild Wash and continuing east through the Brisbane and Stoddard Valleys and crossing the 15 and 247 to the south of Johnstons Corner into the Ord Rodman Critical Habitat Unit.

China Lake South Range-Kingston Mesquite Mountains: The least-cost corridor extends from Riggs Wash in the Silurian Hills of the Kingston Mesquite target area near the Ivanpah Critical Habitat Unit, meanders along Halloran Springs Road and crosses the 127 in between Dry Lake and Silver Lake. It continues in a southwesterly direction over the foothills of the Soda Mountains, then heads almost due west south of Red Pass Lake as it enters and then skirts the border of the Superior Cronese Critical Habitat Unit. The corridor then heads northwest towards Superior Valley in the China Lake South target. It ranges in width from roughly 0.5 to 6 km.

Kingston Mesquite Mountains-Mojave National Preserve: The least-cost corridor is entirely within the Ivanpah Critical Habitat Unit, extending from Shadow Mountain in the Kingston Mesquite target area and falling mostly in between Francis Spring Road and Kingston Road to the west of Kingston Wash. It crosses the 15 in the vicinity of the Hot Wash bridged undercrossing into Shadow Valley in Mojave National Preserve. It varies in width from roughly 2.4 to 12.7 km.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The least-cost corridor has two branches that extend out from the Mojave National Preserve. The most permeable extends from near Devils Playground Wash out across Budweiser Wash over the foothills of the northern Old Dad Mountains and into the Bristol Mountains, crossing

Interstate 40 at Bristol Mountain Wash and Edel Weiss Ditch. Another branch extends from Willow Spring Basin in the Mojave National Preserve, crosses the 40 freeway at Old Dad Mountains Wash towards the Brown Buttes, then heads southwest to join the other branch just north of the Lava Hills before crossing the National Trails Highway and the railroad in between Klondike and Bagdad into the foothills of Lead Mountain on Twentynine Palms Marine Corps Base. It ranges in width from about 1.5 to 10.7 km.

Mojave National Preserve-Stepladder Turtle Mountains: The least-cost corridor extends from the southeast corner of Mojave National Preserve through the Ward Valley crossing Interstate 40 at Homer Wash and follows the wash for about 18 km, then heads toward the Chemehuevi Valley at the base of the Stepladder Mountains. It ranges in width from 4 to 12.4 km and is entirely encompassed within the Piute Eldorado and Chemehuevi Critical Habitat Units.

Stepladder Turtle Mountains-Palen McCoy Mountains: The least-cost corridor closely resembles the output for badger, extending from the base of Turtle Mountains through Rice Valley crossing the 62, the railroad and the aqueduct where they come together toward the Arica Mountains in the Palen McCoy target area. It is roughly 3.2 to 4 km wide.

Palen McCoy Mountains-Whipple Mountains: The least-cost corridor stretches from the Whipple Mountain target, crossing State Route 95 south of Pyramid Butte into the Vidal Valley. It then goes into the Rice Valley staying to the north of route 62, the railroad and the aqueduct and then mirrors the Stepladder Turtle-Palen McCoy output described above to cross the 62 highway. It varies from approximately 2 to 11.3 km wide. Roughly half of the corridor is within the Chemehuevi Critical Habitat Unit.

Joshua Tree National Park-Palen McCoy Mountains: The least-cost corridor ranges in width from about 4.3 to 5.9 km and stretches between the target areas through the northern Palen Valley; it is associated with the Pinto Mountains Critical Habitat Unit.

Joshua Tree National Park-Chocolate Mountains: The least-cost corridor has two major branches north of Interstate 10 that both extend from the Pinto Basin. The most permeable route extends from the Pinto Basin into the Chuckwalla Valley and crosses the 10 freeway to the west of Eagle Mountain Road into the lowlands between the Orocopia and Chuckwalla Mountains. It then follows the Arroyo Seco for a distance before terminating in the foothills of the Chocolate Mountains. The other route takes in the western Pinto Basin, following Smoke Tree Wash to Cottonwood Pass between the Cottonwood and Eagle Mountains. It then joins the eastern branch and encompasses habitats from Shavers Valley to Chuckwalla Valley, Chiriaco Summit and into the Maniobra Valley. The majority of the corridor lies within the Chuckwalla Critical Habitat Unit. It ranges from roughly 2 to almost 30 km wide.

Palen McCoy Mountains-Chocolate Mountains: The least-cost corridor extends from the Palen McCoy target area down in to Chuckwalla Valley, crosses Interstate 10 in between Palen and Ford Dry Lakes and heads up Ship Creek into the Chuckwalla Mountains near Black Butte. It varies in width from about 0.5 to 6.7 km. The entire corridor south of the freeway is within the Chuckwalla Critical Habitat Unit.

Linkages for Climate Change: Land Facet Analyses

In the previous section, we describe least-cost corridors for four focal species. The present known or modeled distributions of these species within the target areas were used as start and end points for each least-cost corridor analysis. Maps of present-day land cover were an important factor in the habitat and permeability models for each species. However as climate changes the focal species' distributions and the land cover map is likely to change; indeed it is likely that many land cover types (vegetation communities) will cease to exist as the plant species that define today's vegetation communities shift their geographic ranges in idiosyncratic ways (Hunter et al. 1988). Thus, it is uncertain how well these linkages will function under these new conditions.

To make our linkage more likely to serve species under novel climate conditions, we therefore supplemented the union of focal species corridors with a union of land facet corridors (Figure 10). These land facet corridors provide connectivity for land facets, which are the enduring features (topographic elements such as sunny lowland flats, or steep north-facing slopes) that will interact with future climate to support future biotic communities.

As explained in the box at left, we did not design corridors using complex models of future climate and biotic responses to climate change. Instead, we used an alternative "land facets" approach to design climate-robust corridors. These corridors maximize continuity of the enduring features (topographic elements such as sunny lowland flats, or steep north-facing slopes) that will interact with future climate to support future biotic communities.

Box 1. The path not taken: climate envelope models

We decided **not** to use climate projections and climate envelope analyses to design corridors. Such an approach uses 4 models, with outputs of each model used as input to the next model. Specifically modeled future emissions of CO_2 (1st model) drive global circulation models (2nd) which are then downscaled using regional models (3rd) to predict future climate. Then climate envelope models (4th) are used to produce maps of the expected future distribution of species. We avoided this approach for two reasons:

(1) Each of the 4 models involves too much uncertainty, which is compounded from model to model and from one predicted decade to the next. In 1999 the IPCC developed 7 major scenarios of possible CO_2 emissions during 2000-2011. The total emissions over the century vary by a factor of 6 among scenarios. *Actual emissions during 2000-2010 were higher than the most pessimistic scenario*. For a single emission scenario, different air-ocean global circulation models produce markedly different climate projections (Raper & Giorgi 2005). Finally climate-envelope models may perform no better than chance (Beale et al. 2008). Because these sophisticated models have not simulated the large shifts during the last 100,000 years of glacial oscillations, Overpeck et al. (2005:99) conclude the "lesson for conservationists is not to put too much faith in simulations of future regional climate change" in designing robust conservation strategies.

(2) **These models produce outputs at a spatial resolution too coarse to support BLM decision-making in the California desert.** The downscaled climate projections have minimum cells sizes measured in square kilometers.

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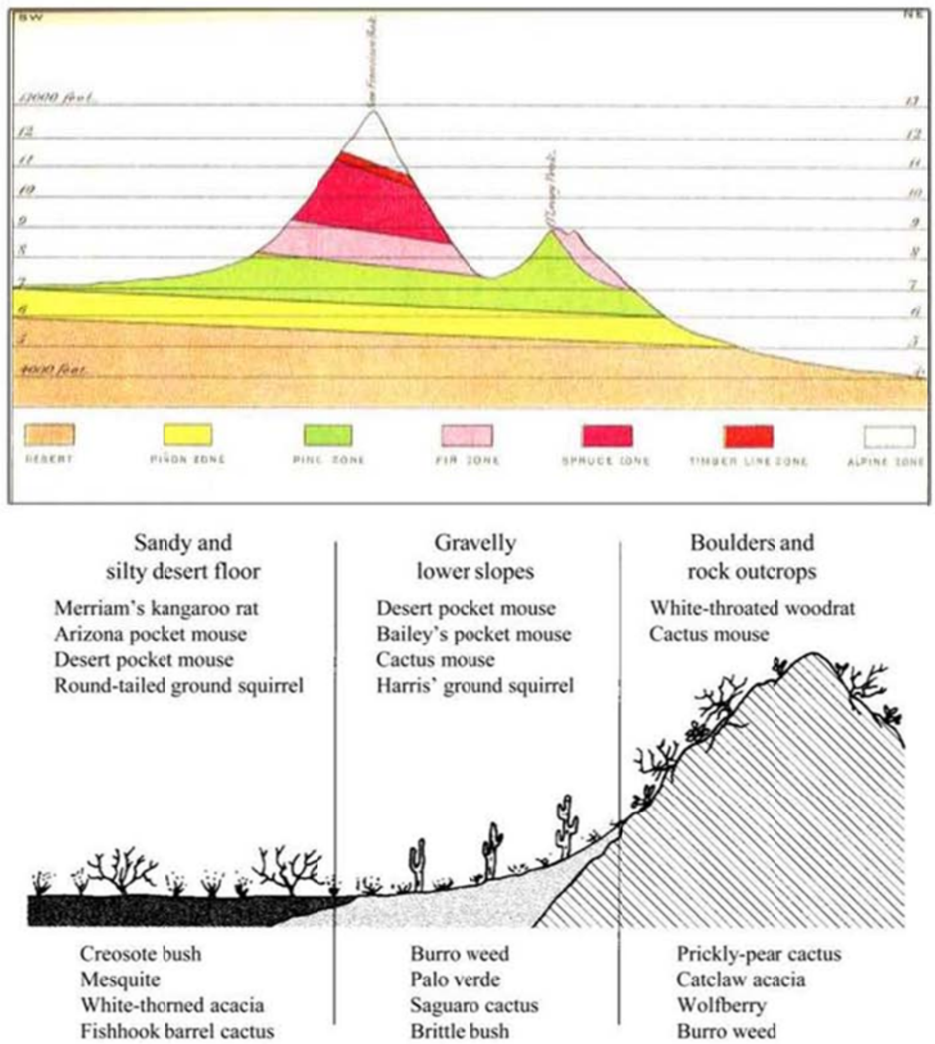
Figure 10. Network of Focal Land Facet Least-Cost Unions

Following Wessels et al. (1999) we call these enduring features “land facets.” Hunter et al. (1988) first proposed using these enduring features as a coarse-filter conservation strategy in the face of climate change. They described the concept as conserving the arenas of biological activity, rather than species or communities, the temporary occupants of those arenas.

This approach is not a speculative new idea, but rather is based on fundamental concepts in ecology, such as the “life zone” concept (Box 2). Similarly, the “state factor model of ecosystems” (Jenny 1941, Amundson and Jenny 1997) holds that the species



Box 2. The land facets approach is a new application of ecological concepts and natural history observations. The top figure (C Hart Merriam 1890) illustrates life zone concept, namely that plant and animal communities are predictably associated with particular combinations of latitude, elevation, aspect, and mountain size. The lower illustration from a mammalogy textbook (Vaughan 1974) illustrates the same ideas at a smaller spatial extent.

present at any given site are a function of “state variables,” namely climate, other organisms present in or near the site, disturbance regime, topography, the underlying geological material, and time. Enduring features reflect the stable state factors, namely topography, geology, and time. Other state factors – climate, interspecific interactions, dispersal, and disturbance regimes – are subject to change under a warming climate and are thus less reliable for conservation planning. The main uncertainties in this approach arise from errors in, or variability not reflected in, the maps of elevation and soils used to define facets. However, these uncertainties are almost certainly less than the 6-fold uncertainty in emission scenarios multiplied by the uncertainty in general circulation models multiplied by the uncertainty in regional downscaling multiplied by the uncertainty in climate envelope models.

Beier and Brost (2010) operationalized this approach by suggesting multivariate procedures to define these enduring features in a particular landscape. Land facets are equivalent to the “ecological land units” that Anderson & Ferree (2010) used as coarse-filter conservation units. These land facets can be used in coarse-filter conservation planning for core areas or for conservation linkages.

Brost and Beier (2012) developed detailed procedures to use land facets to design conservation linkages; a land facet linkage (similar the union of focal species corridors) consist of a corridor for each land facet, plus a corridor for high diversity of land facets. Each land-facet corridor should support movement of species associated with that facet in any future climate, and the high diversity corridor should support species movements during periods of climate instability. The land facet corridors complement, rather than replace, focal species corridors.

Like linkages designed for multiple focal species, linkages planned for a diversity of land facets contain multiple strands. Specifically, each of the land facet designs includes several (typically 6 to 8) corridors, each of which is designed to maximize continuity of one of the major land facets that occurs within the two targeted areas. Each such strand or corridor is intended to support occupancy and between-block movement by species associated with that land facet in periods of climate quasi-equilibrium. Like each focal species corridor, each land facet corridor was produced by least-cost modeling. Each design also includes one corridor with high local interspersion of facets; this corridor was also produced by least-cost modeling. This high-diversity corridor is intended to support short distance shifts (e.g. from low to high elevation, or from south-facing to north-facing slopes), species turnover, and other ecological processes relying on interaction between species and environments.

Although the corridor with high diversity of land facets is intended to promote short-distance movement across elevations and aspects, our design does not include corridors to connect each relatively warm land facet in one wildland block to each relatively cool land facet in the other block. We did not model warm-to-cool corridors because in this landscape the transition from warm-to-cool (or the reverse) can best occur in the huge wildland blocks, where all land facets are juxtaposed in complex ways, rather than in relatively short and narrow corridors. Instead the corridor for each land facet is intended to support species movements that take < 10 years – long enough to support gene flow and range expansion. Landscape-extent range shifts involving several degrees of latitude would occur over several decades across the network of large core areas and smaller corridors.

Details of the land facet analyses are explained in the “Approach” chapter.

In each linkage planning area, the land-facets linkage includes several (typically about 6 to 8) corridors. Because these corridors overlap either partially or fully, they typically form a linkage design with 2 to 4 strands, similar to the union of focal species corridors. In each land facets linkage design, one corridor optimizes connectivity for high interspersion (local diversity) of land facets; this corridor is intended to accommodate rapid, short-distance range shifts, interactions between species, and ecological processes. This corridor also allows for short-distance (intra-corridor) movements from low to high elevation or from warm to cool aspects. Each of the other corridors optimizes connectivity for one facet type, and is intended to facilitate movement of species associated with that facet, today and in the future.

Land facets were defined separately in each linkage planning area. Thus “high elevation ridges” in the China Lake North to Sierra Nevada linkage planning area are much higher in elevation than “high elevation ridges” in the China Lake South to Edwards Air Force Base linkage planning area. Thus the land facet name in the legend of one figure should not be considered identical to the same land facet name in another figure.

In the following pages, we briefly summarize the land facet unions in 21 of the 22 linkage planning areas, namely every one except the linkage planning area between Edwards Air Force Base and the Sierra Nevada. In that case the topography of Edwards Air Force Base (low and flat and homogeneous) was so dissimilar from the Sierra Nevada (high, steep, and bumpy) that no meaningful land facet corridors were possible. In the maps, the land facets are draped over a basemap that uses variation in tone (“hillshade”) to suggest 3-dimensional topographic features and color to indicate elevation.

Sierra Nevada-China Lake North Range Land Facets

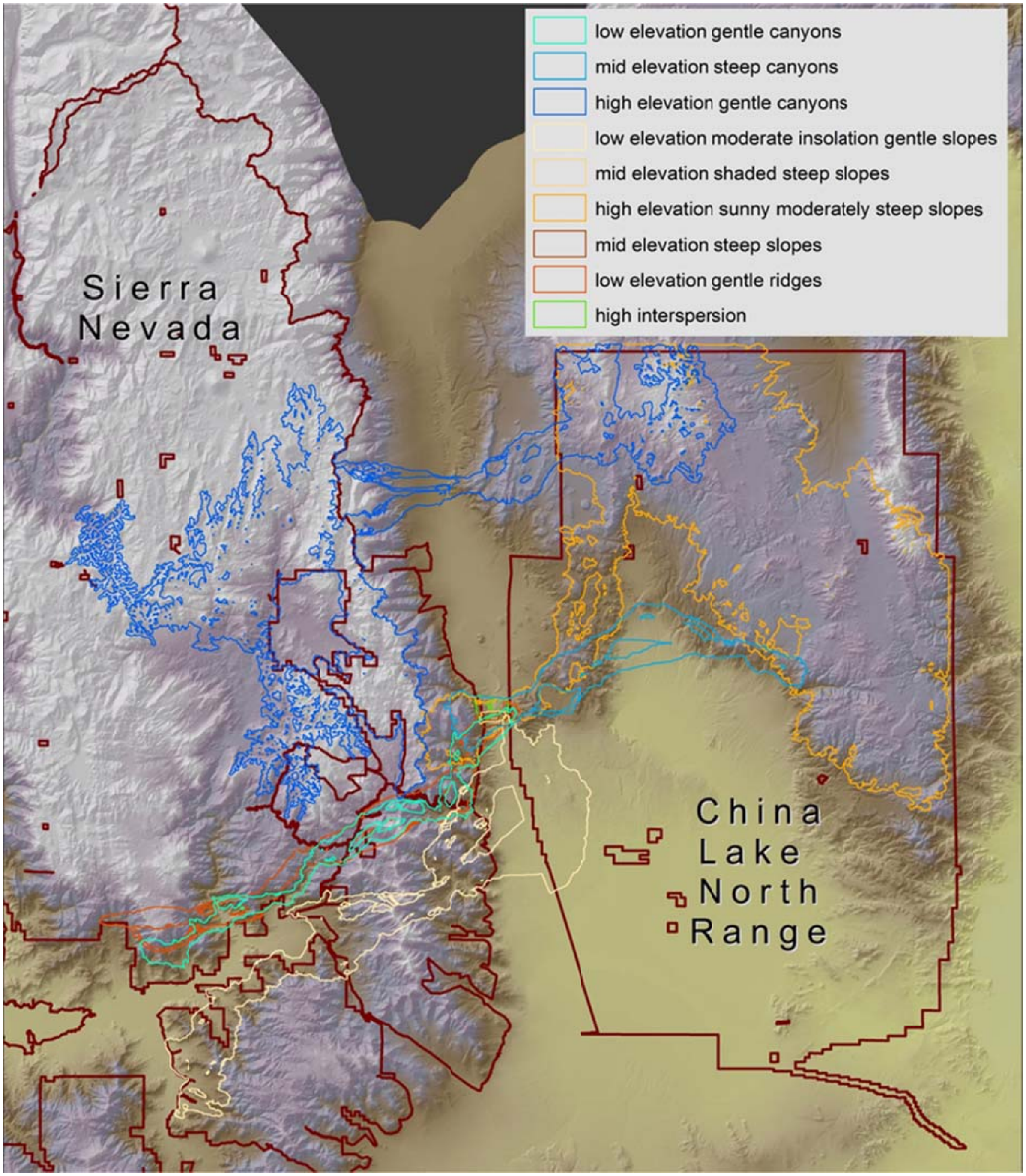


Figure 11. From north to south, the strands are: (1) the corridor for high elevation, gentle canyon bottoms. (2) seven corridors (high interspersion; mid elevation, shaded, steep slopes; high elevation, sunny, moderately steep slopes; low elevation, gentle canyon bottoms; mid-elevation, steep canyon bottoms; low elevation, gentle ridges; mid elevation, steep ridges). (3 & 4) the corridor for low elevation, gentle slopes.

Sierra Nevada-China Lake South Range

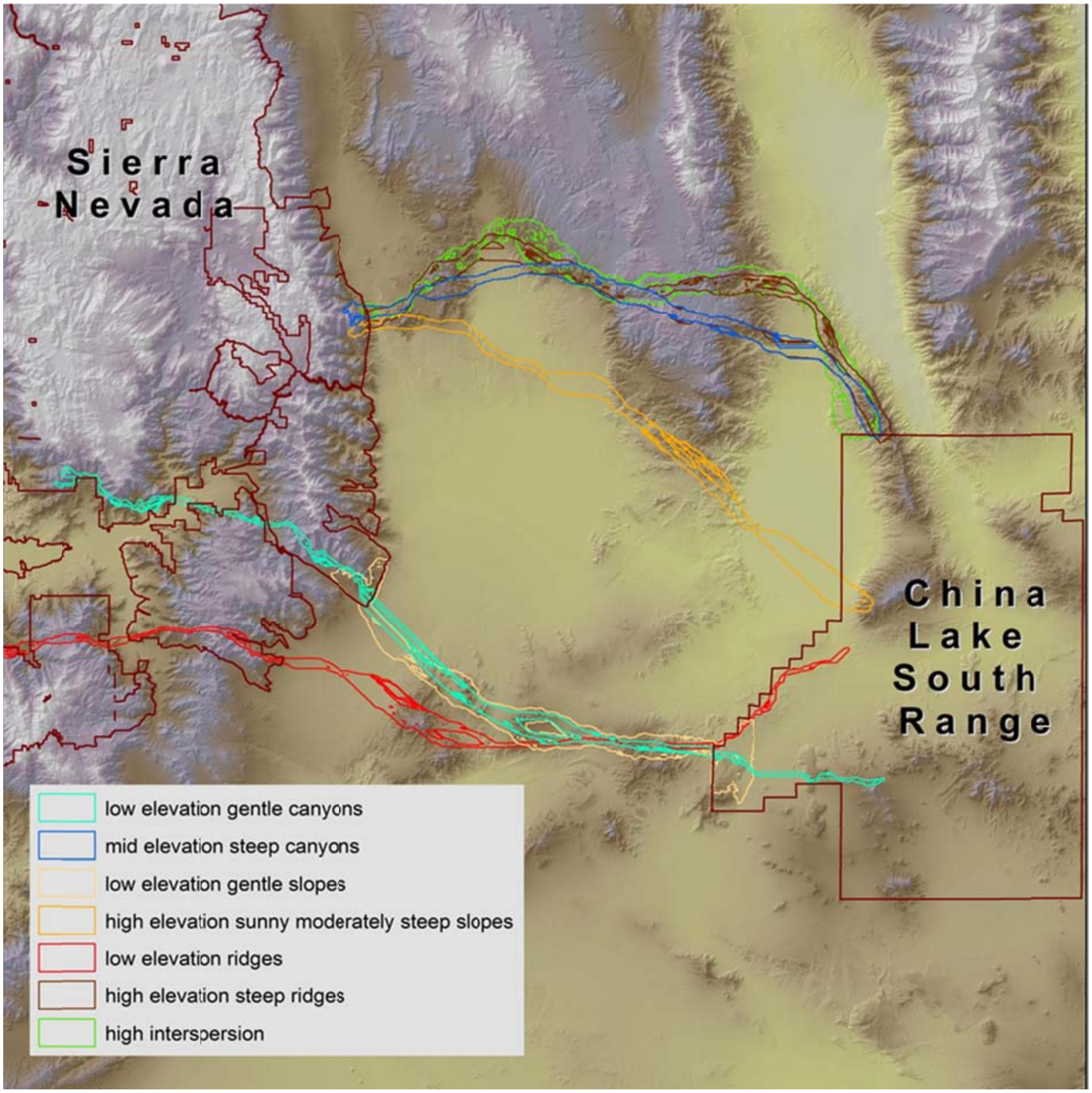


Figure 12. From north to south the land facet union includes 4 strands: (1) high interspersion of land facets and corridors for two individual land facets (mid-elevation, steep canyon bottoms; high elevation, steep ridges). (2) the corridor for high elevation, sunny, moderately steep slopes. (3) two corridors (low elevation, gentle canyon bottoms; low elevation, gentle slopes). (4) the corridor for low elevation ridges.

China Lake North Range - China Lake South Range Land Facets

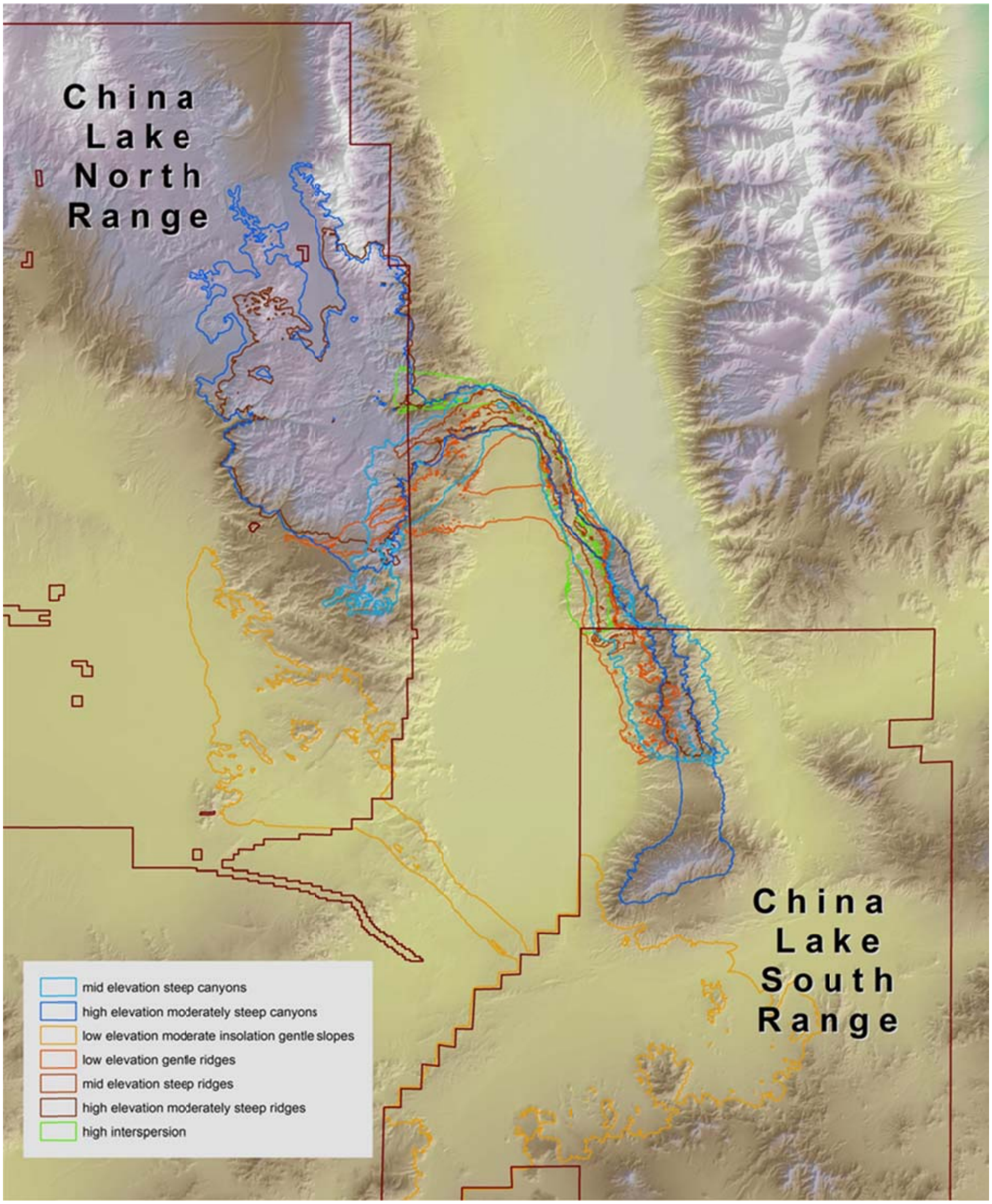


Figure 13. The northern strand contains 6 corridors (high interspersion; high elevation, moderately steep canyon bottoms; mid-elevation, steep canyon bottoms; low elevation, gentle ridges; high elevation, moderately steep ridges; mid-elevation, steep ridges). The southern strand is the corridor for low elevation, gentle slopes.

China Lake South Range - Edwards Air Force Base Land Facets

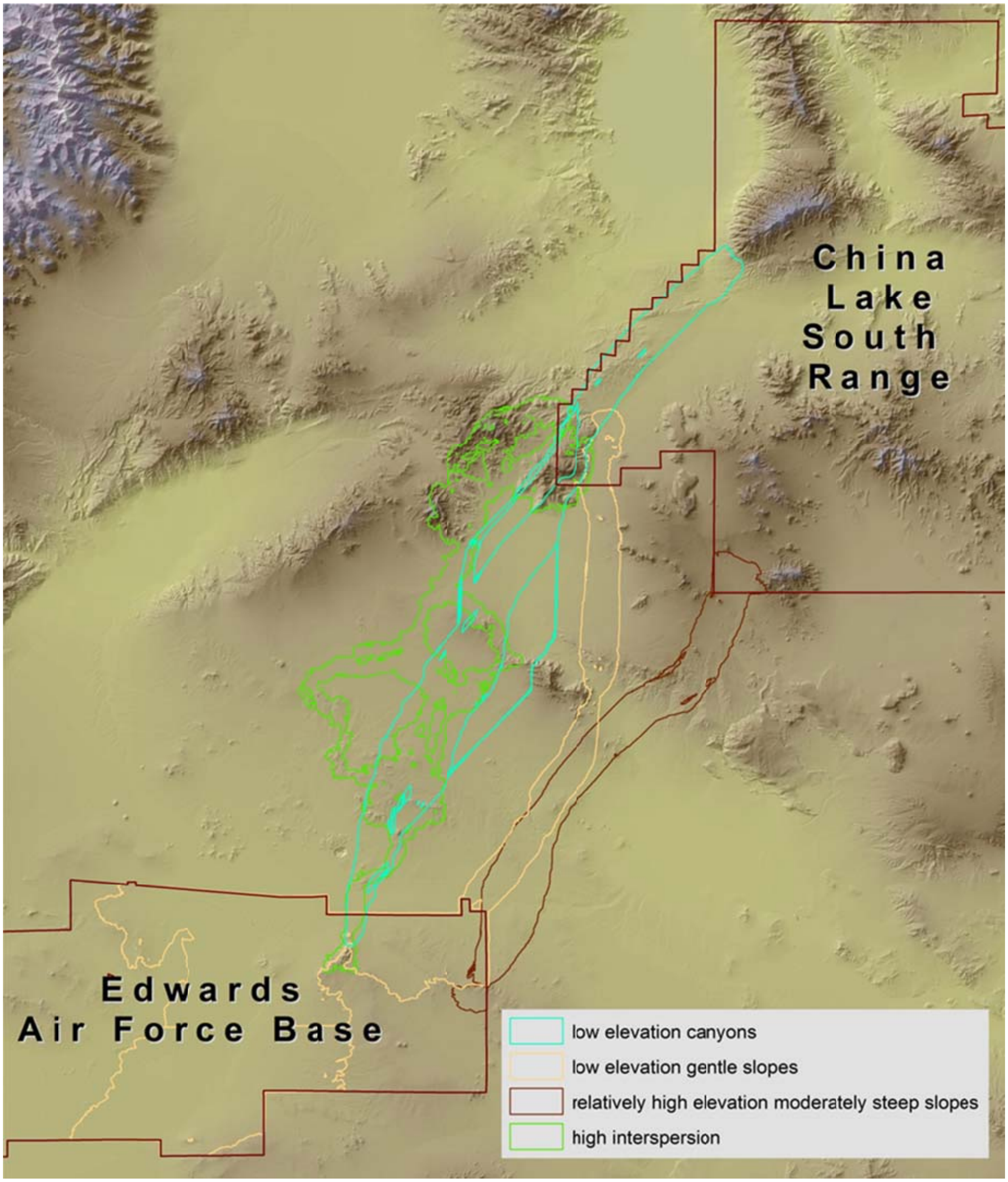


Figure 14. The easternmost strand is the corridor for high elevation, moderately steep slopes. The western, arcing branches are segments of the corridor with high interspersion of land facets. The western branch of the central strand is the corridor for low elevation canyon bottoms. The eastern branch of the central strand is the corridor for low elevation, gentle slopes.

China Lake South Range- Twentynine Palms & Newberry Rodman Land Facets

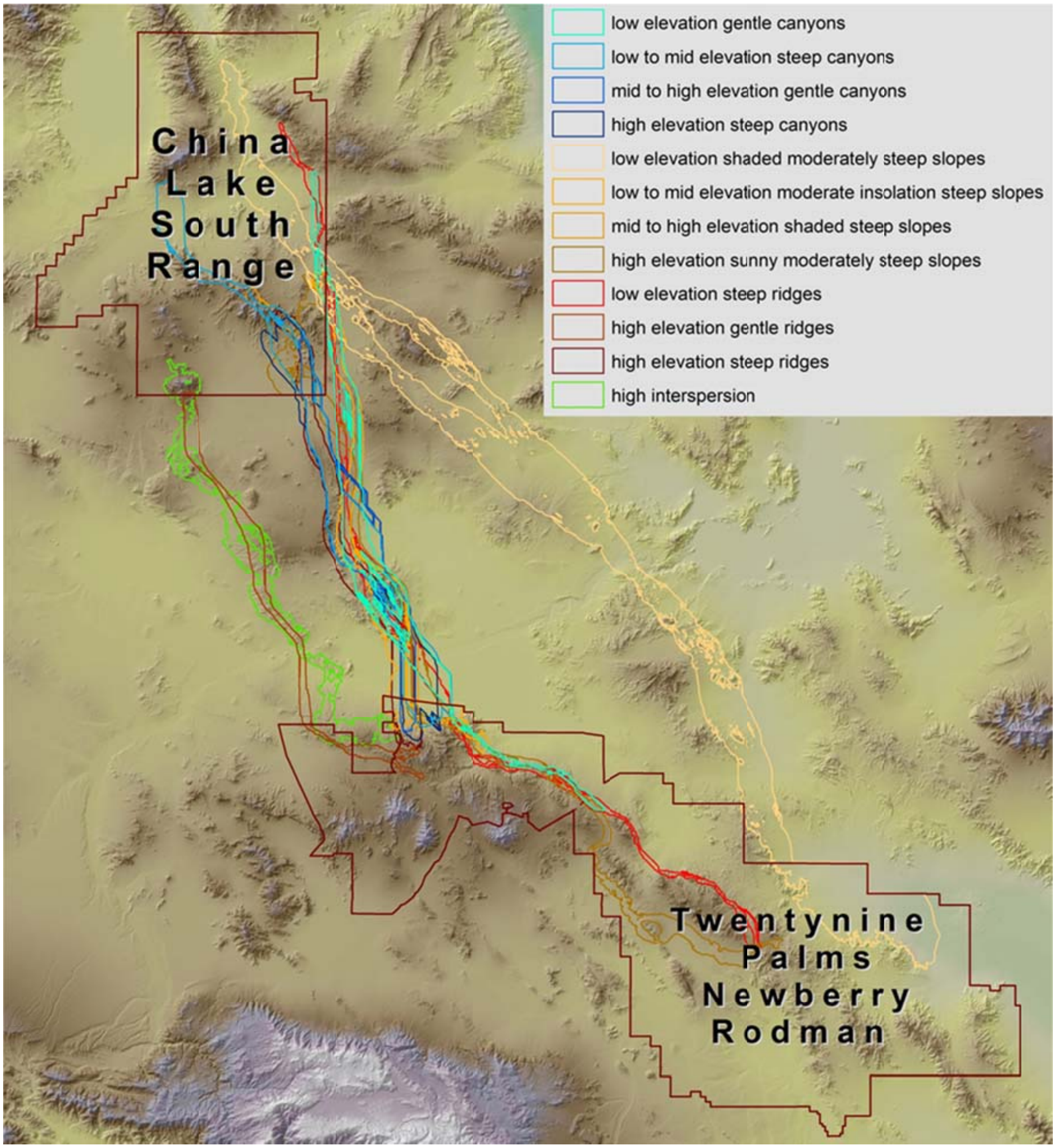


Figure 15. The westernmost strand includes 2 corridors (high interspersion of land facets; high elevation, gentle ridges). The central strand includes 9 corridors (low elevation, gentle canyon bottoms; low to mid-elevation, steep canyon bottoms; mid- to high elevation, gentle canyon bottoms; high elevation, steep canyon bottoms; mid to high elevation, shaded, steep slopes; low to mid-elevation, moderately steep slopes; high elevation, steep ridges; high elevation, sunny, moderately steep slopes; and low elevation, steep ridges). The eastern strand is the corridor for low elevation, low-insolation, moderately steep slopes.

Edwards Air Force Base - Twentynine Palms & Newberry Rodman Land Facets

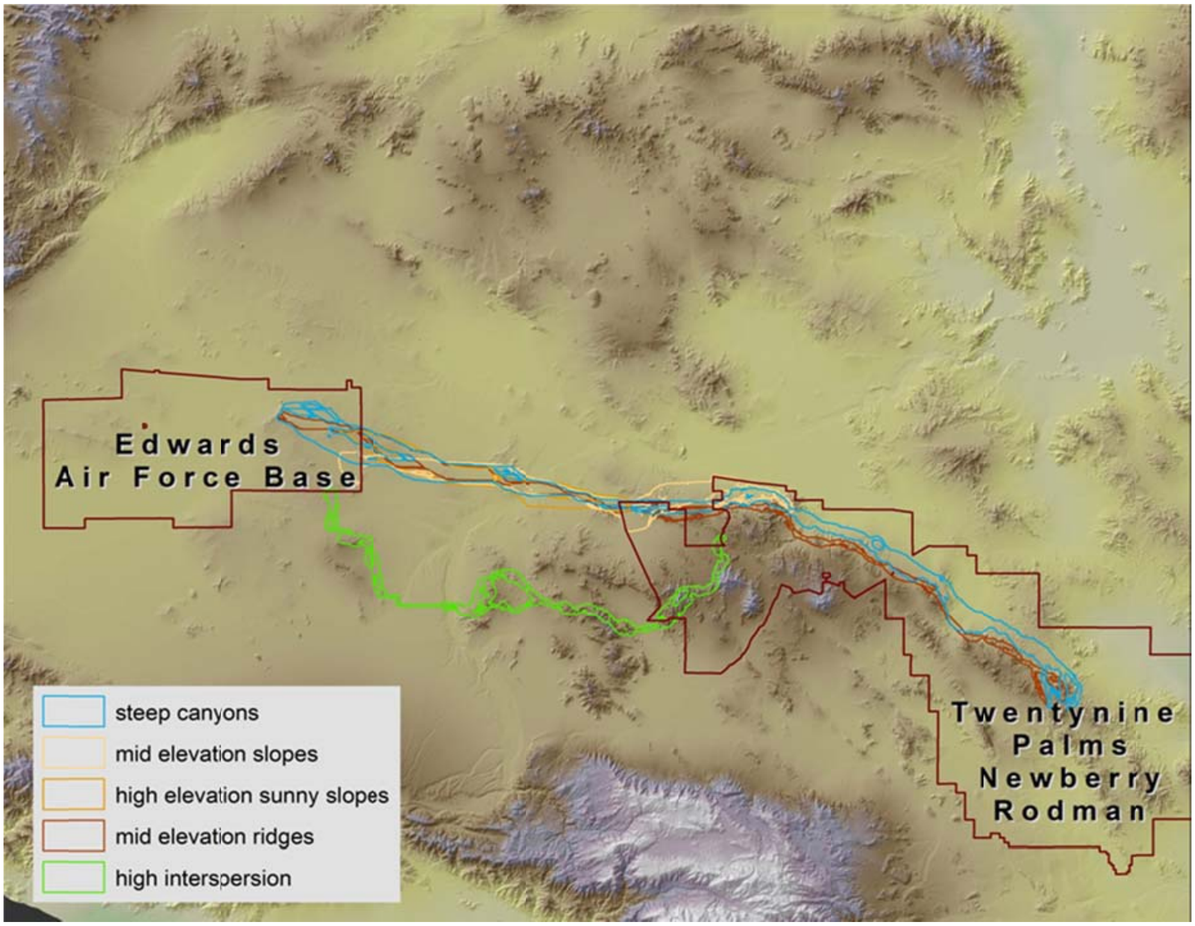


Figure 16. The northern strand contains all 4 land facet corridors (mid-elevation slopes; high elevation, sunny slopes; mid elevation ridges; steep canyon bottoms) and also overlaps the focal species union. The southern strand is the corridor for high interspersion of land facets.

Edwards Air Force Base - San Gabriel Mountains Land Facets

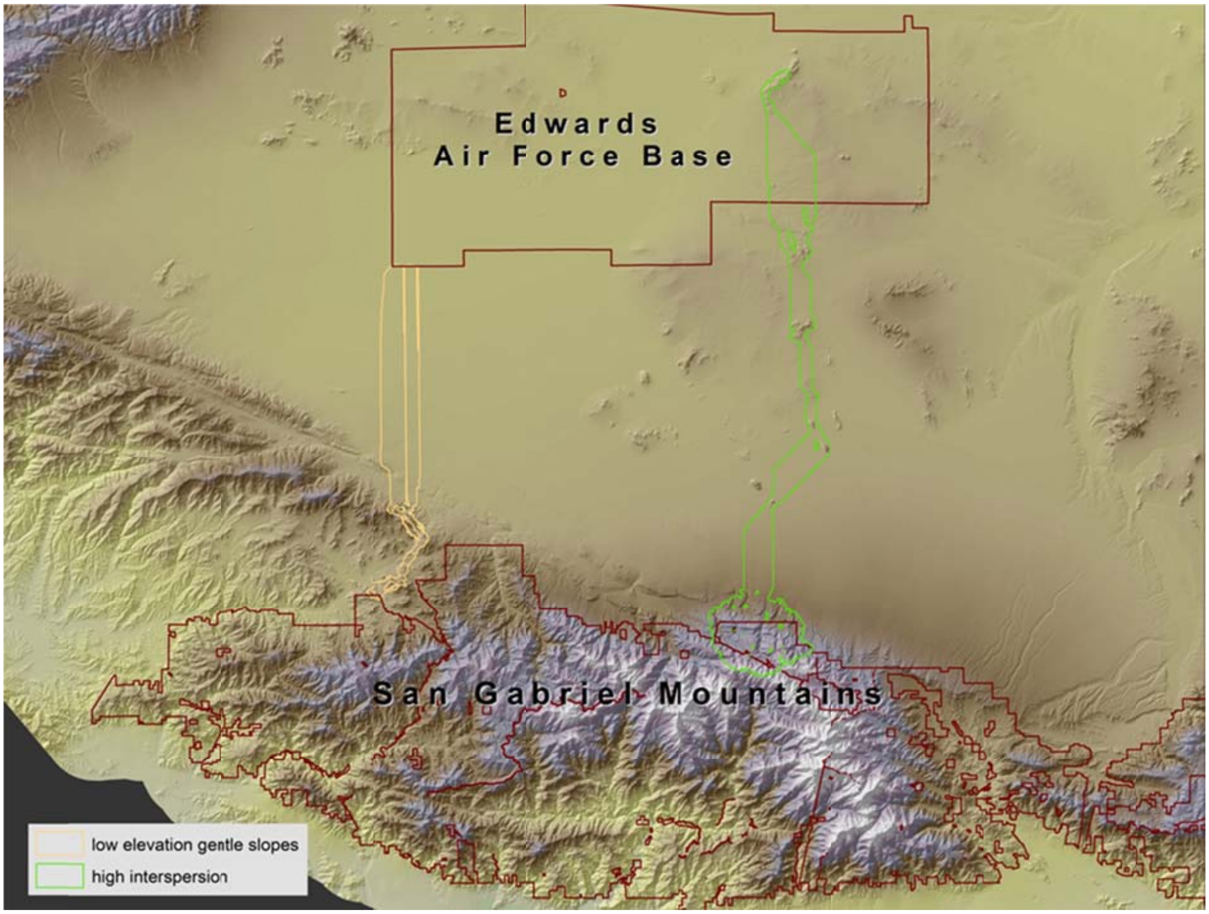


Figure 17. We attempted to design a corridor for the one land facet that occupies 99% of EAFB, namely low-elevation, gentle slopes, but that corridor ran through densely populated areas and small towns and is so covered with roads that it would not support animal movement. Thus, only the corridor that optimizes interspersion of land facets was included in the linkage network; this corridor partially overlaps the focal species corridors.

Twentynine Palms and Newbery Rodman-San Gabriel Mountains Land Facets

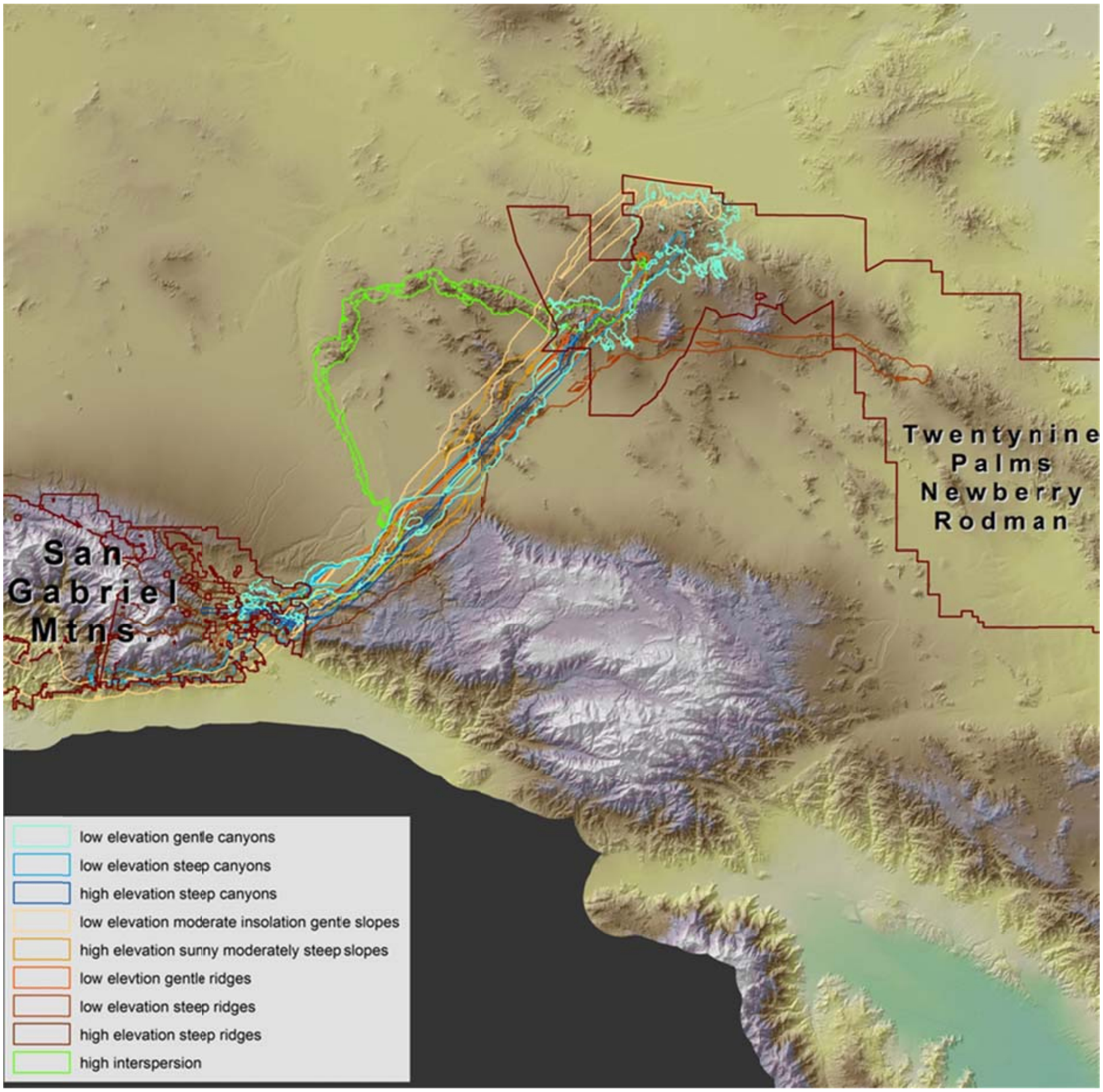


Figure 18. The westernmost, arcing strand is the corridor with high interspersion of land facets. All land facet corridors intermix in the south, but the corridors diverge as they approach the northern wildland block (29 Palms Newberry-Rodman ACEC). Here the western branch is the low elevation, gentle slope corridor, the middle branch includes 6 land facet corridors (high elevation, sunny, moderately steep slopes; low elevation, gentle ridges; high elevation, steep ridges; low elevation, steep canyon bottoms; low elevation, gentle canyon bottoms; and high elevation, steep canyon bottoms) and the eastern branch is the low elevation, steep ridges corridor.

Twentynine Palms & Newbery Rodman-San Bernardino Mountains Land Facets

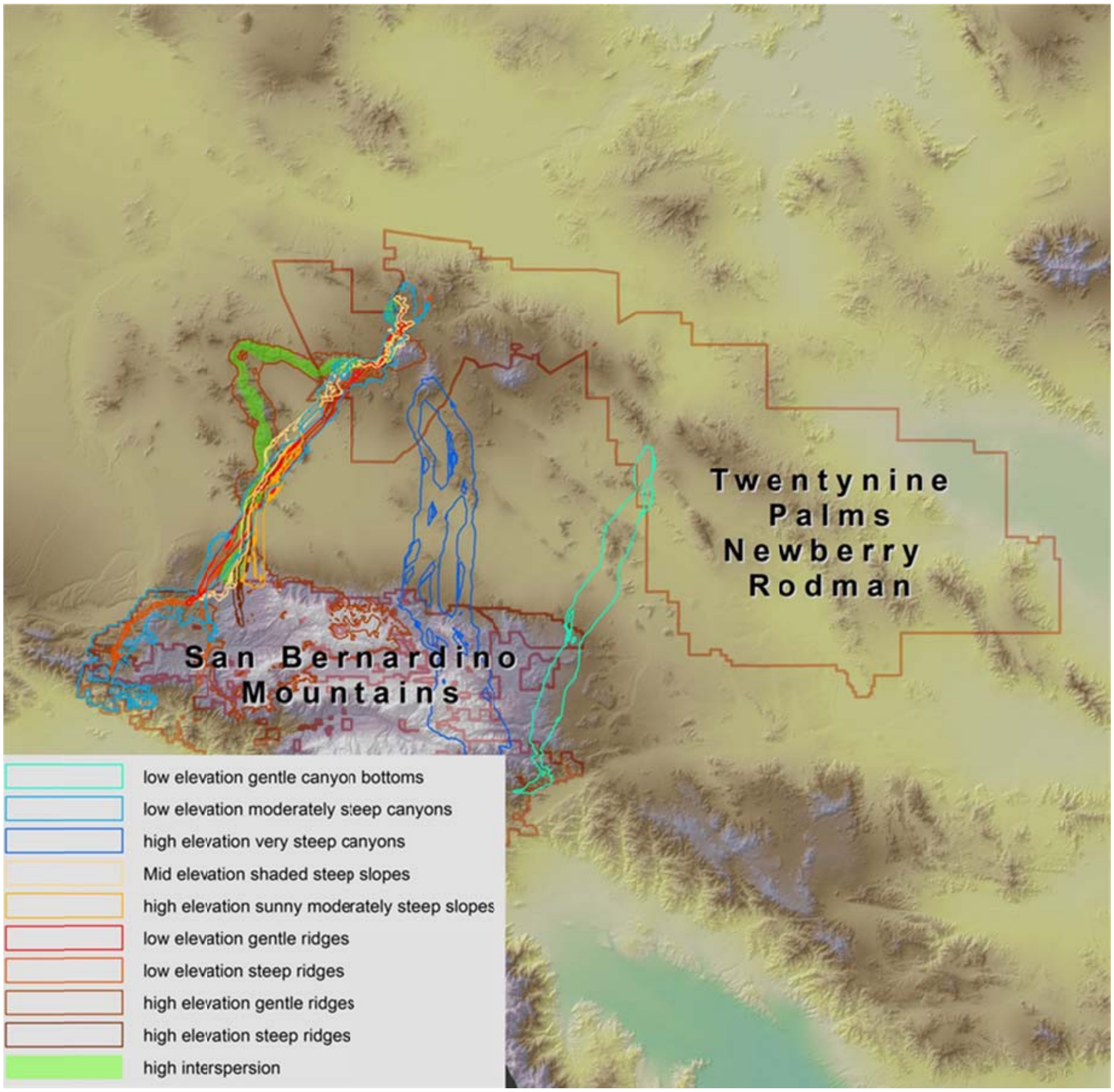


Figure 19. The northwesternmost arcing strand contains the corridor with high interspersion of land facets and the corridor for high elevation, gentle ridges. This strand also captures much of the headwaters of the Mohave River. This intertwines with a strand that includes 7 corridors (low elevation, moderately steep canyon bottoms; mid elevation, shaded, steep slopes; high elevation, sunny, moderately steep slopes; low elevation gentle ridges; low elevation, steep ridges, and high elevation, steep ridges). The central strand is the corridor for high elevation, steep canyon bottoms. The eastern strand is the corridor for low elevation, gentle, canyon bottoms.

China Lake South Range-Kingston Mesquite Mountains Land Facets

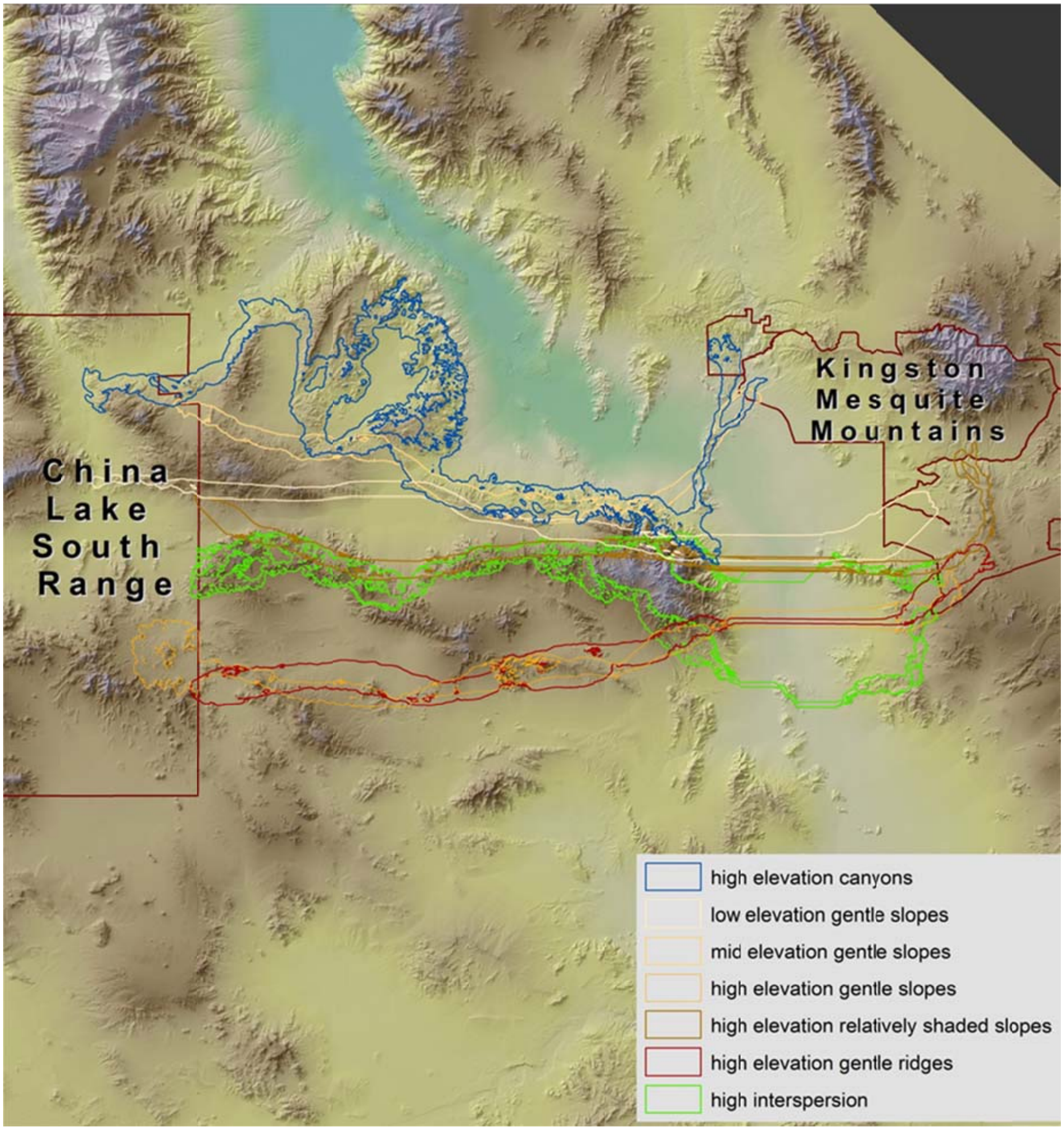


Figure 20. The arcing, north branch of the north strand is the corridor for high elevation canyons. The south branches of the north strand are the corridors for mid-elevation gentle slopes and low elevation gentle slopes. The central strand contains the corridor with high diversity of land facets and the corridor for high elevation, relatively shaded slopes. The southern strand contains the corridor for high elevation, gentle ridges and high-elevation gentle slopes.

Kingston Mesquite Mountains-Mojave National Preserve Land Facets

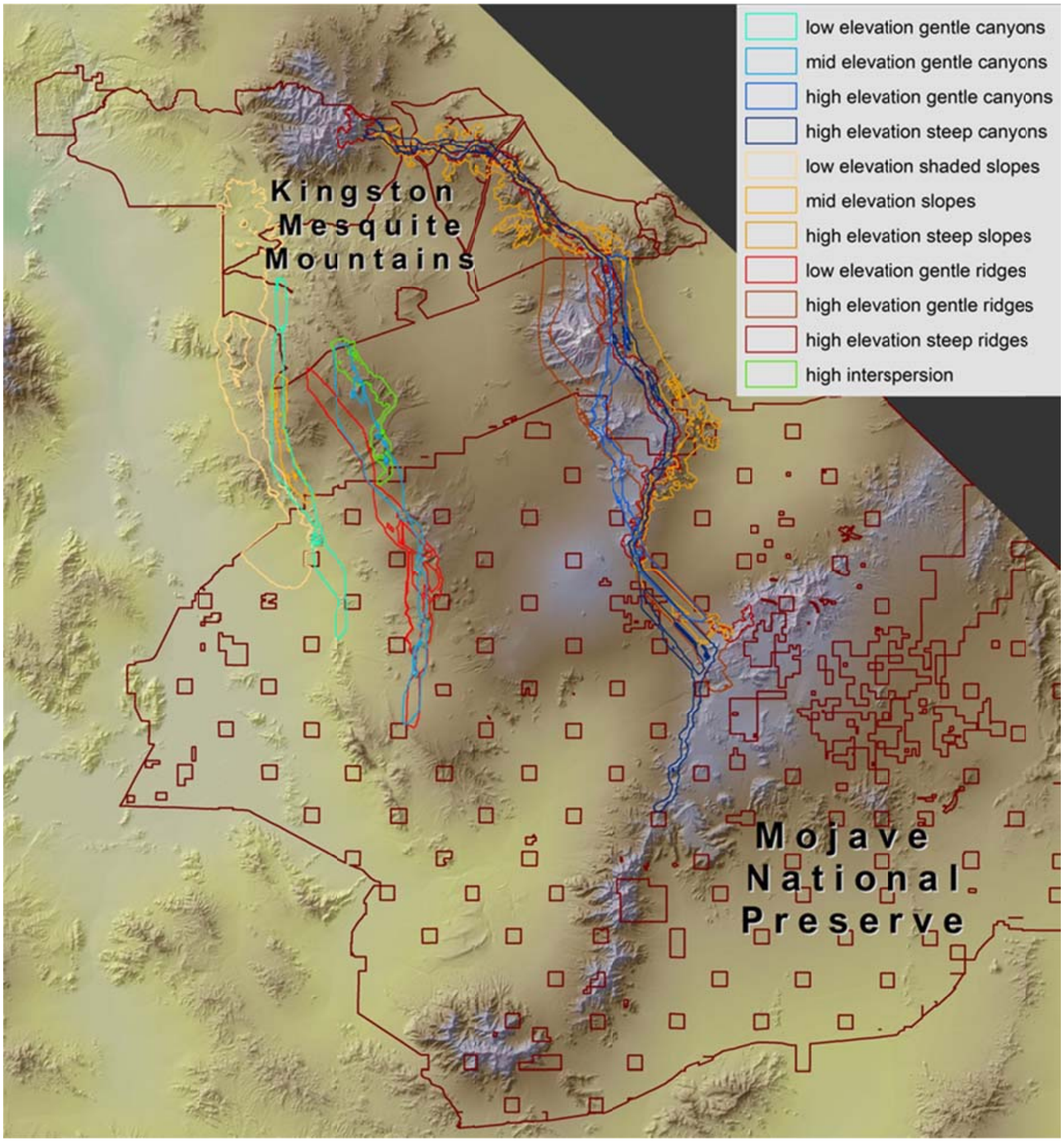


Figure 21. From west to east, the strands are (1) the corridor for low elevation, shaded slopes. (2) two corridors (mid elevation slopes; low elevation, gentle canyon bottoms). (3) three corridors (high interspersion of land facets; mid-elevation, gentle canyon bottoms; and low elevation, gentle ridges). (4) one branch of the corridor for high elevation, gentle ridges (5) five corridors (mid elevation slopes; high elevation canyon bottoms; high elevation, steep canyon bottoms; high elevation, steep ridges; and the other branch of the corridor for high elevation, gentle ridges).

Mojave National Preserve-Twentynine Palms and Newberry Rodman Land Facets

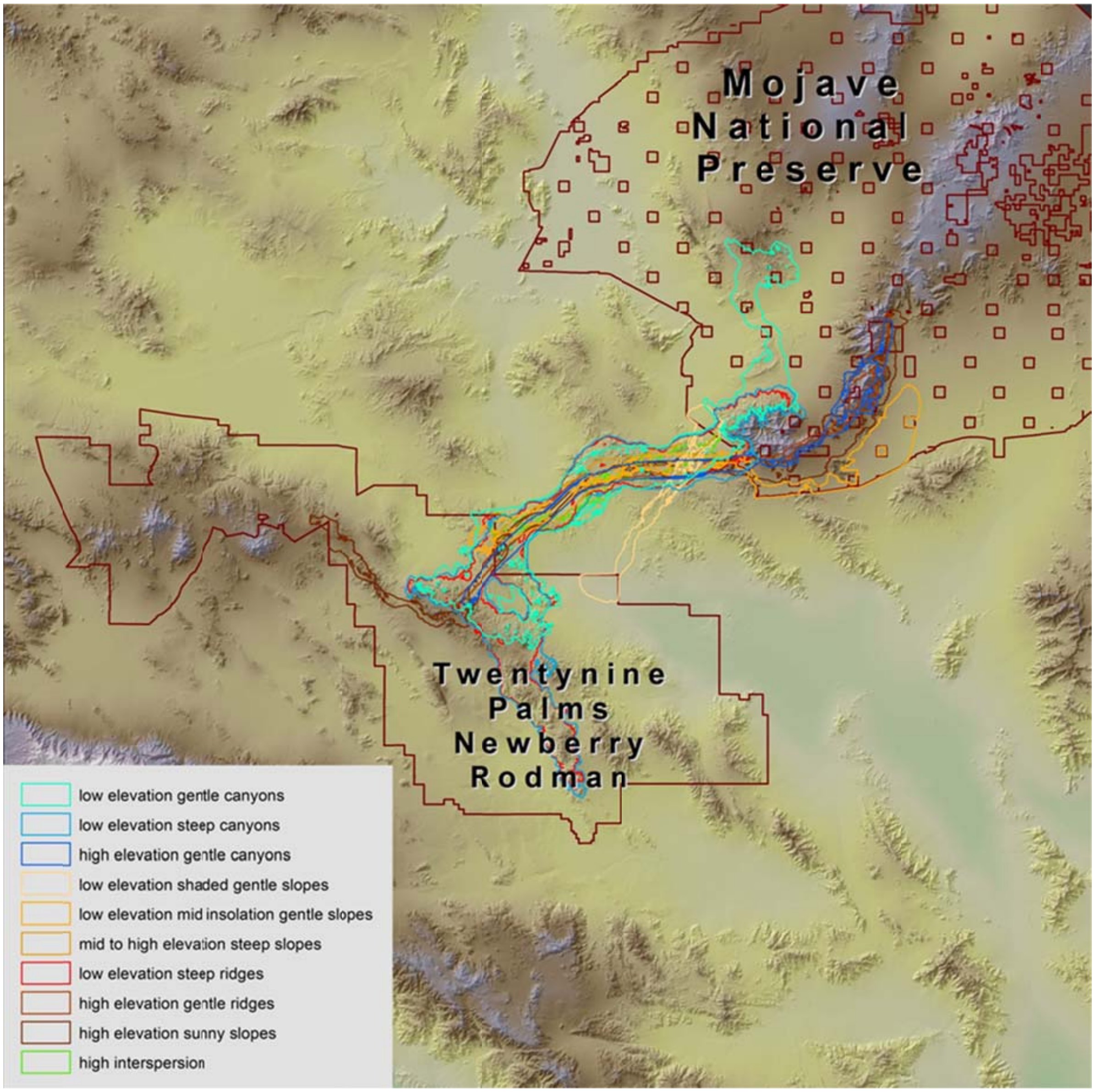


Figure 22. The thick strand of the linkage union includes 9 corridors (low elevation, gentle canyon bottoms; high elevation, gentle canyon bottoms; low elevation, steep canyon bottoms; mid to high elevation, steep slopes; low elevation, shaded, gentle slopes; low elevation, mid-insolation, gentle slopes; high elevation, sunny slopes; high elevation, gentle ridges; and low elevation, steep ridges). The thinner western branch is the corridor for low elevation, low-insolation, gentle slopes.

Mojave National Preserve - Stepladder Turtle Mountains Land Facets

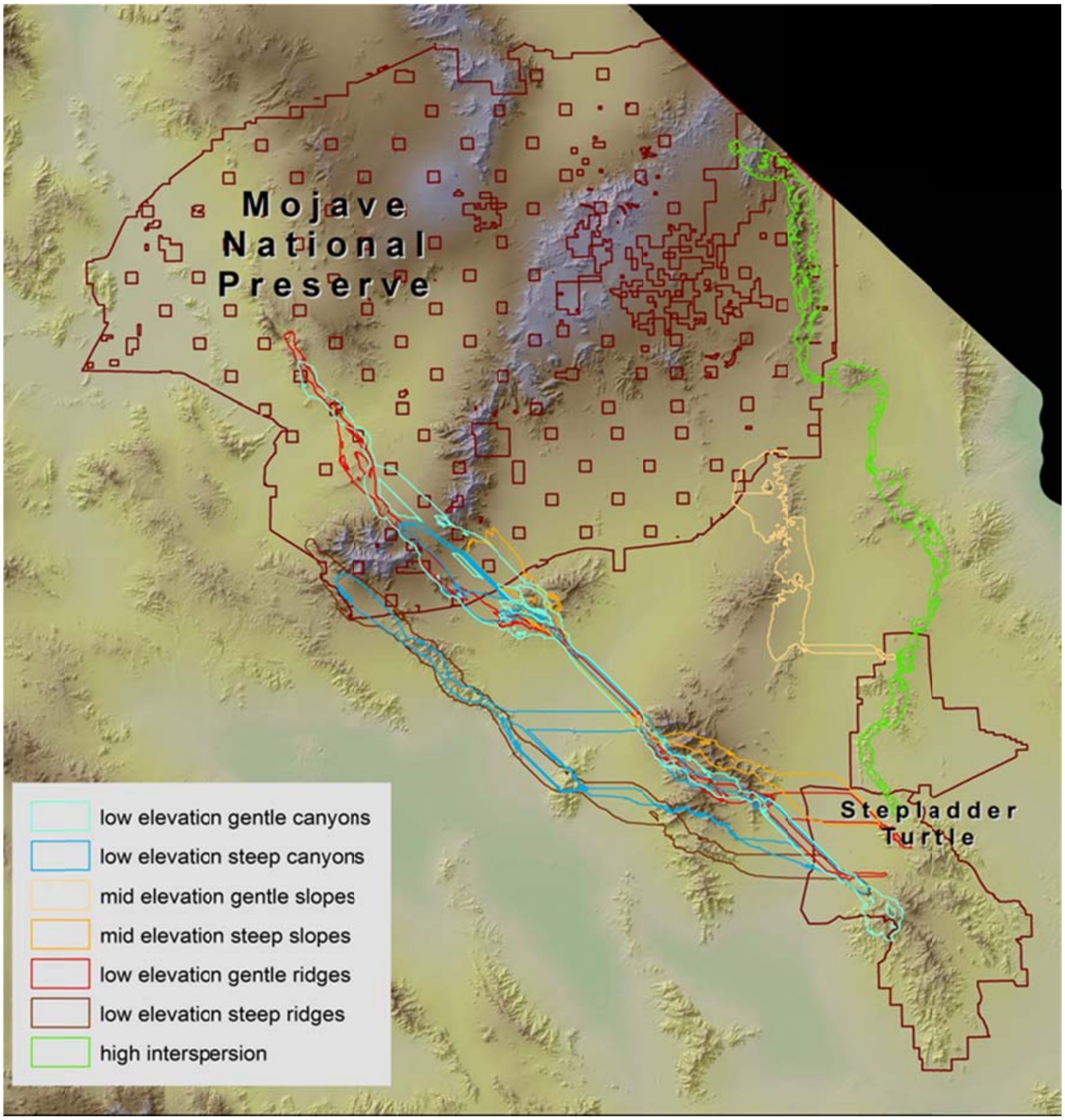


Figure 23. From west to east, the union includes 4 strands: (1) the corridor for low elevation steep ridges; and part of the corridor for low elevation, steep canyon bottoms. (2) four corridors (low elevation, gentle canyon bottoms; mid elevation, steep slopes; low elevation, gentle ridges; and the other part of the corridor for low elevation, steep canyon bottoms). (3) the corridor for mid elevation, gentle slopes. (4) the corridor with high interspersion of land facets.

Stepladder Turtle Mountains-Palen McCoy Mountains Land Facets

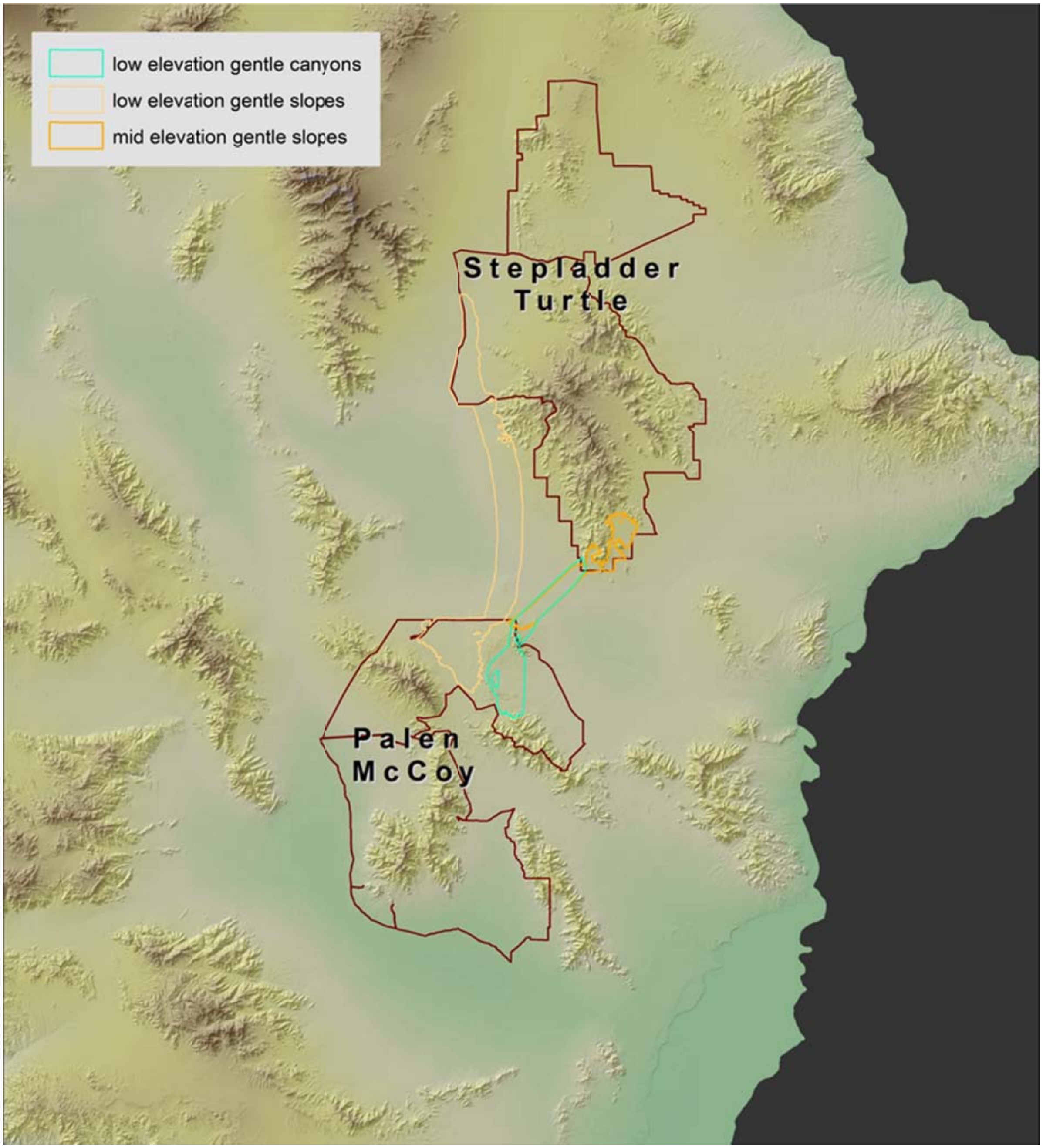


Figure 24. Because the matrix between these two landscape blocks consists almost entirely of low elevation, gentle slopes, the land facet union includes corridors for only 3 land facets and no corridor with high interspersion of land facets. A long, western strand provides continuity of low elevation, gentle slopes. A short, eastern strand provides connectivity of two land facets, namely low elevation, gentle canyon bottoms; and mid elevation, gentle slopes.

Palen McCoy Mountains-Whipple Mountains Land Facets

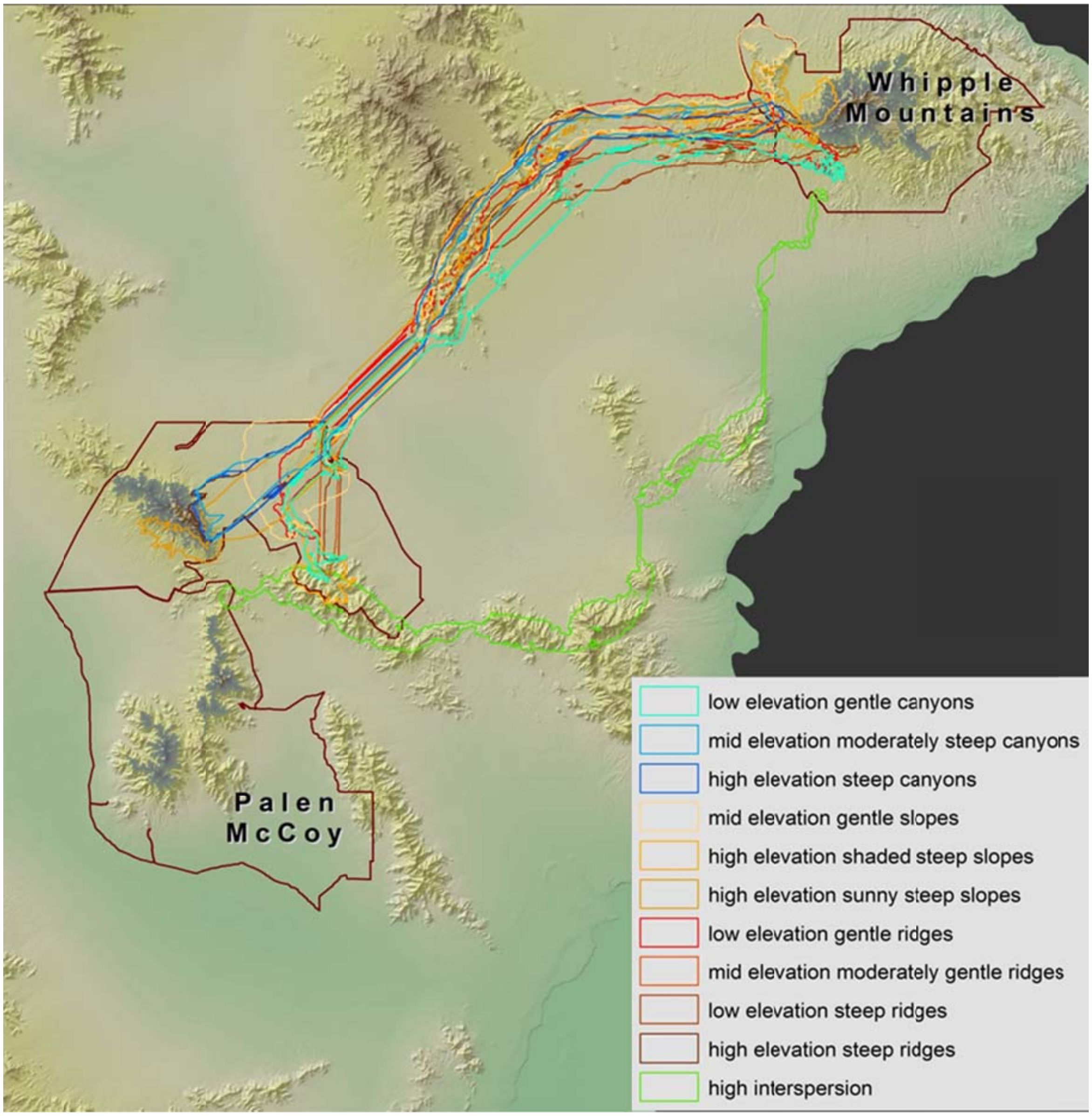


Figure 25. The northern branch of the northern strand contains 8 corridors (mid-elevation, moderately steep canyon bottoms; high elevation, steep canyon bottoms; mid-elevation gentle slopes; high elevation shaded steep slopes; high elevation sunny steep slopes; low elevation, gentle ridges; mid elevation, moderately gentle ridges; and high elevation steep ridges). The southern branch of the northern strand contains 2 corridors (low elevation, gentle canyon bottoms; and low elevation steep ridges). The southern strand is the corridor for high interspersion of land facets.

Joshua Tree National Park - Palen McCoy Mountains Land Facets

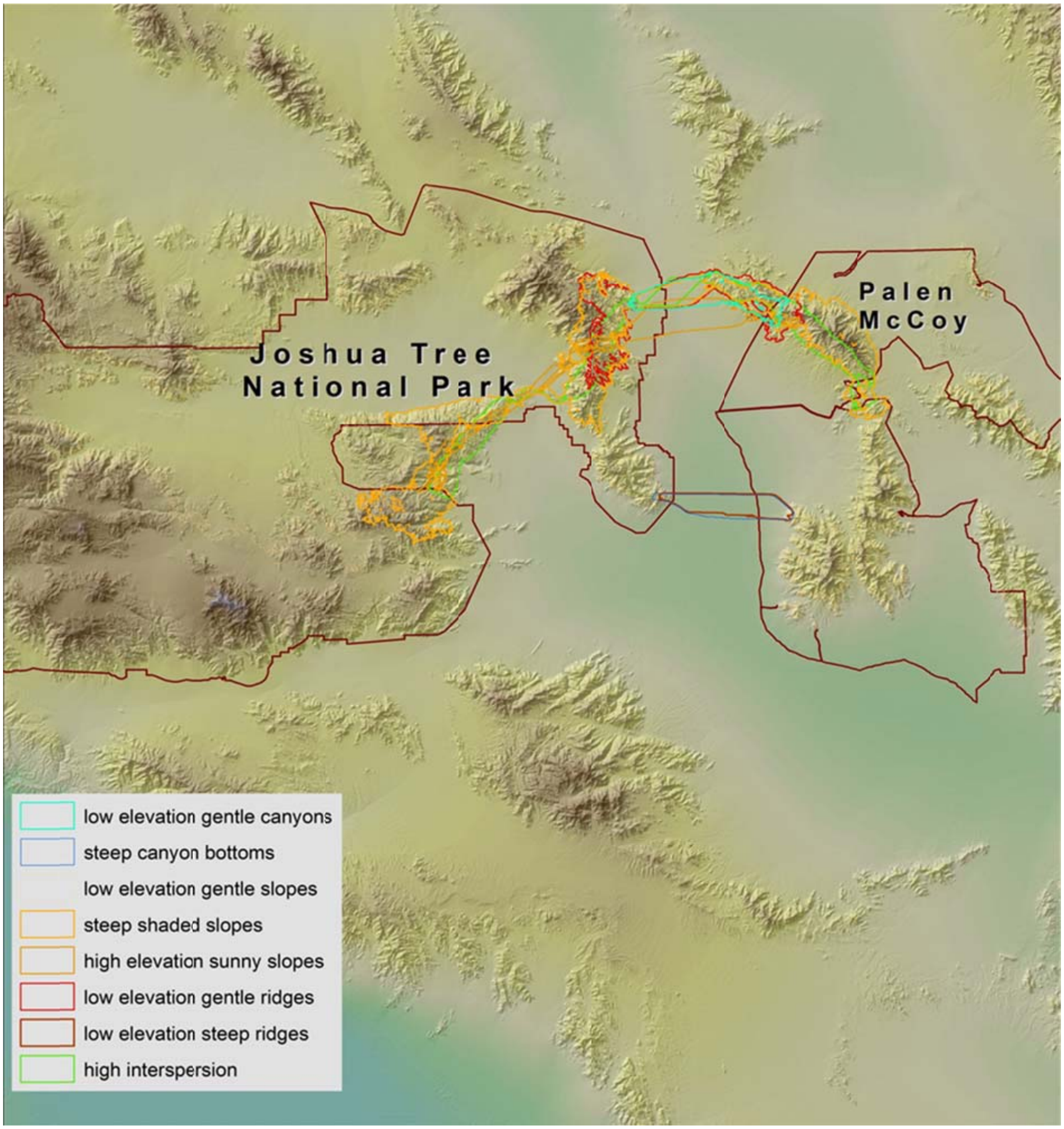


Figure 26. The northern strand contains the corridor with high interspersion of land facets, and corridors for 5 individual land facets, namely low elevation, gentle slopes; high elevation, sunny slopes; low elevation, gentle canyon bottoms; steep, shaded slopes; low elevation, gentle ridges. This strand also falls almost entirely within the northern strand of the focal species design and thus adds little area to the final linkage design. The southern strand includes 2 corridors (steep canyon bottoms; low elevation steep ridges).

Joshua Tree National Park - Chocolate Mountains Land Facets

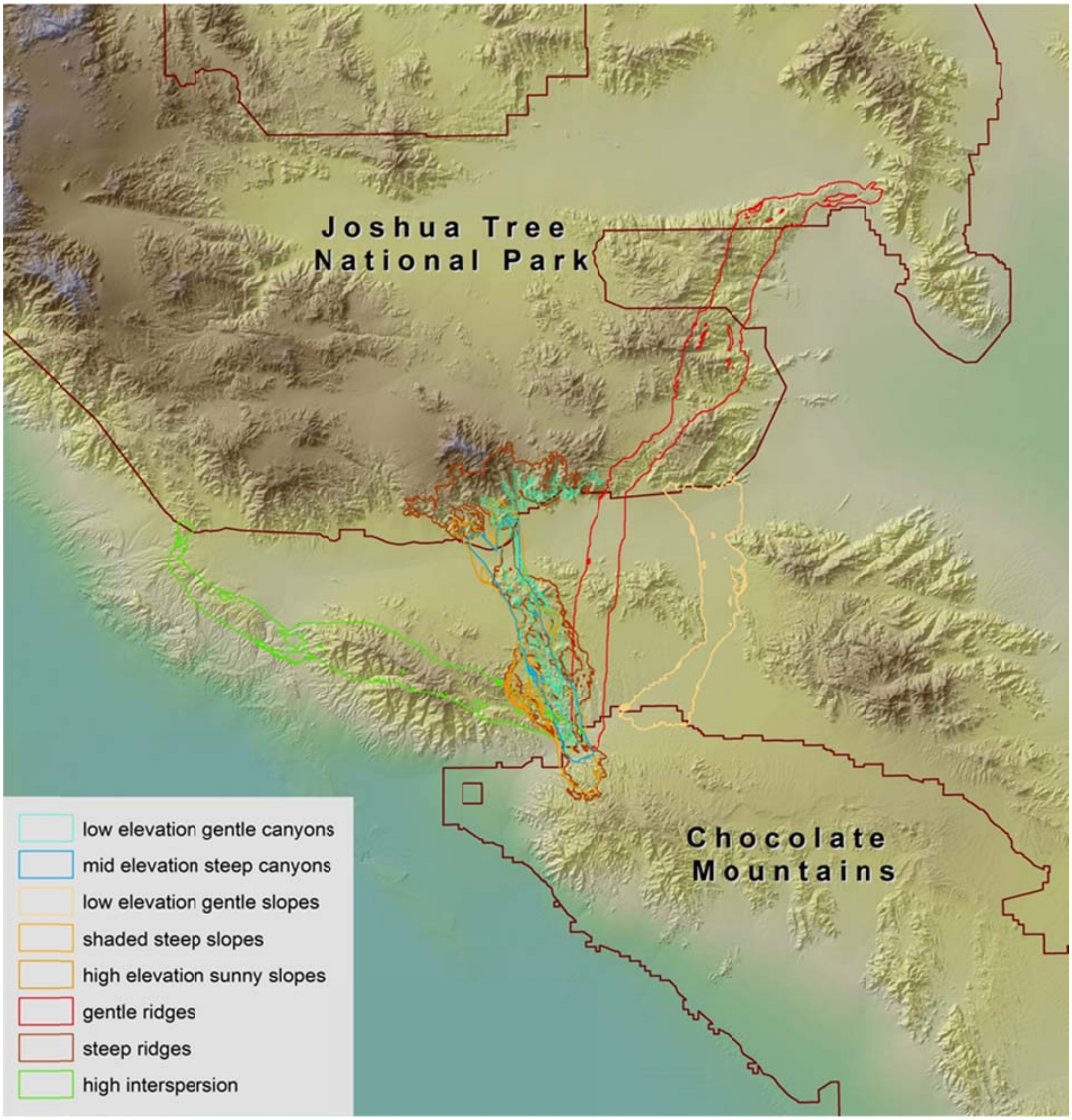


Figure 27. From west to east, the union includes 4 major strands: (1) the corridor with high interspersion of land facets. (2) 5 corridors (low elevation, gentle canyon bottoms; mid elevation, steep canyon bottoms; shaded, steep slopes; high elevation, sunny slopes; steep ridges). (3) the corridor for gentle ridges. (4) the corridor for low elevation, gentle slopes.

Palen McCoy Mountains - Chocolate Mountains Land Facets

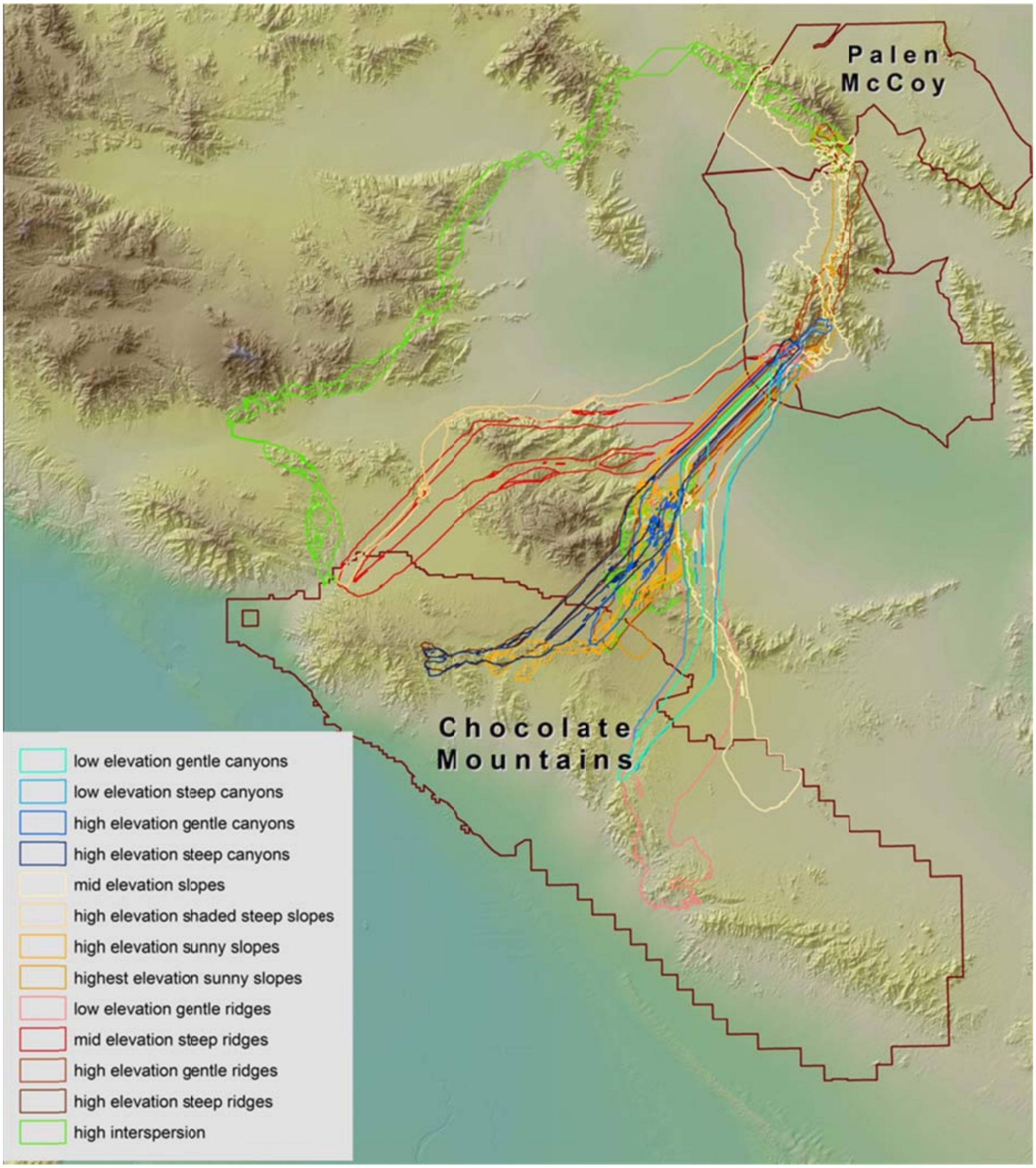


Figure 28. From northwest to southeast the 5 strands are: (1) high-interspersion corridor. (2) the high elevation, shaded, steep slopes corridor, and part of the mid elevation, steep ridges corridor. (3) the rest of the mid elevation, steep ridges. (4) 6 corridors (high elevation, gentle canyons; high elevation, steep canyon bottoms; high elevation, sunny slopes; highest elevation, sunny slopes; high elevation, gentle ridges; and high elevation steep ridges). (5) 4 corridors (low elevation, gentle canyon bottoms; low elevation, steep canyon bottoms; mid elevation, gentle slopes; low elevation, gentle ridges).

Palen McCoy Mountains - Little Picacho Land Facets

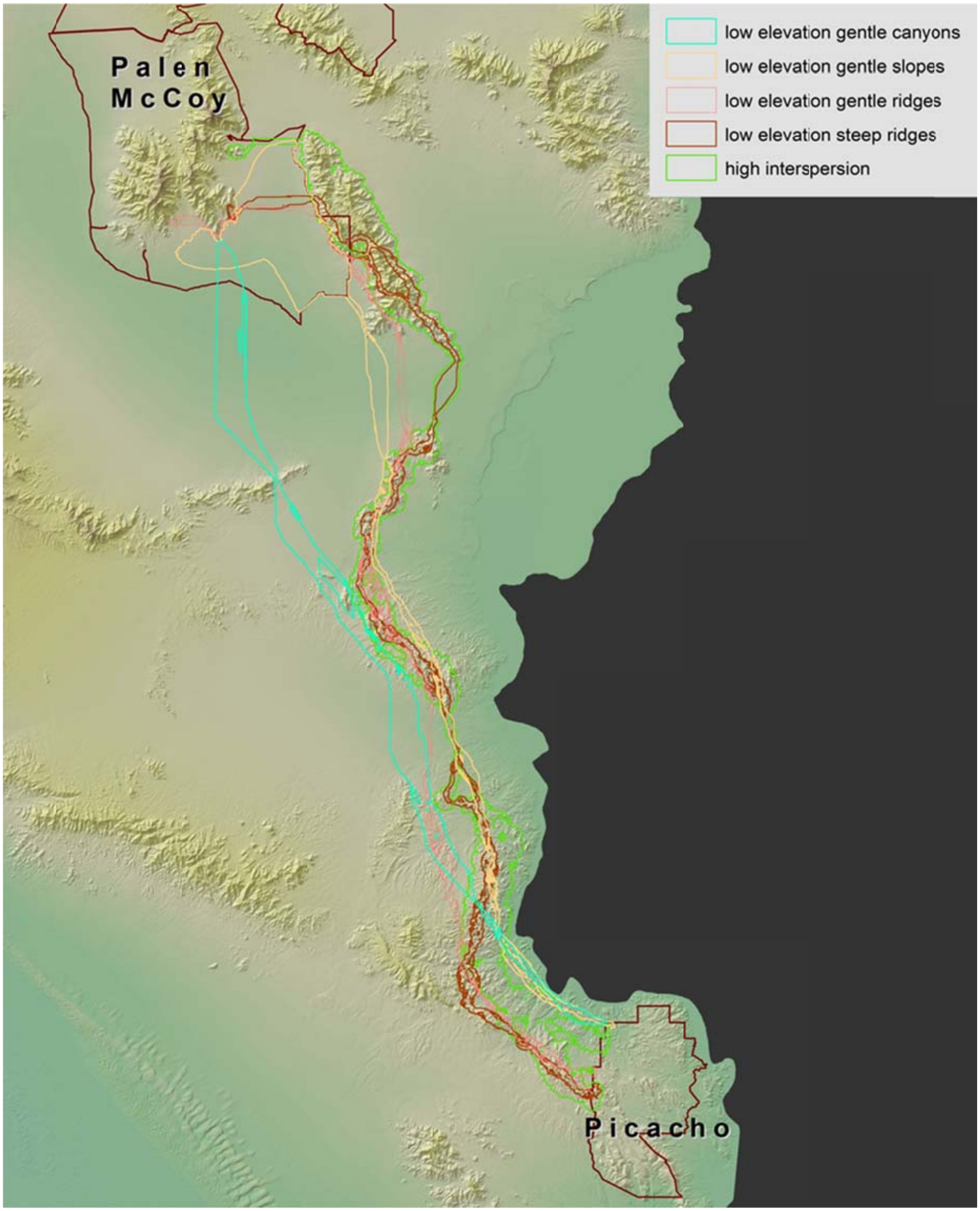


Figure 29. The western strand is the corridor for low elevation, gentle canyon bottoms. The eastern strand contains 4 corridors (interspersion of land facets: low elevation, gentle slopes; low elevation, gentle ridges; and low elevation, steep ridges).

Chocolate Mountains - Little Picacho Land Facets

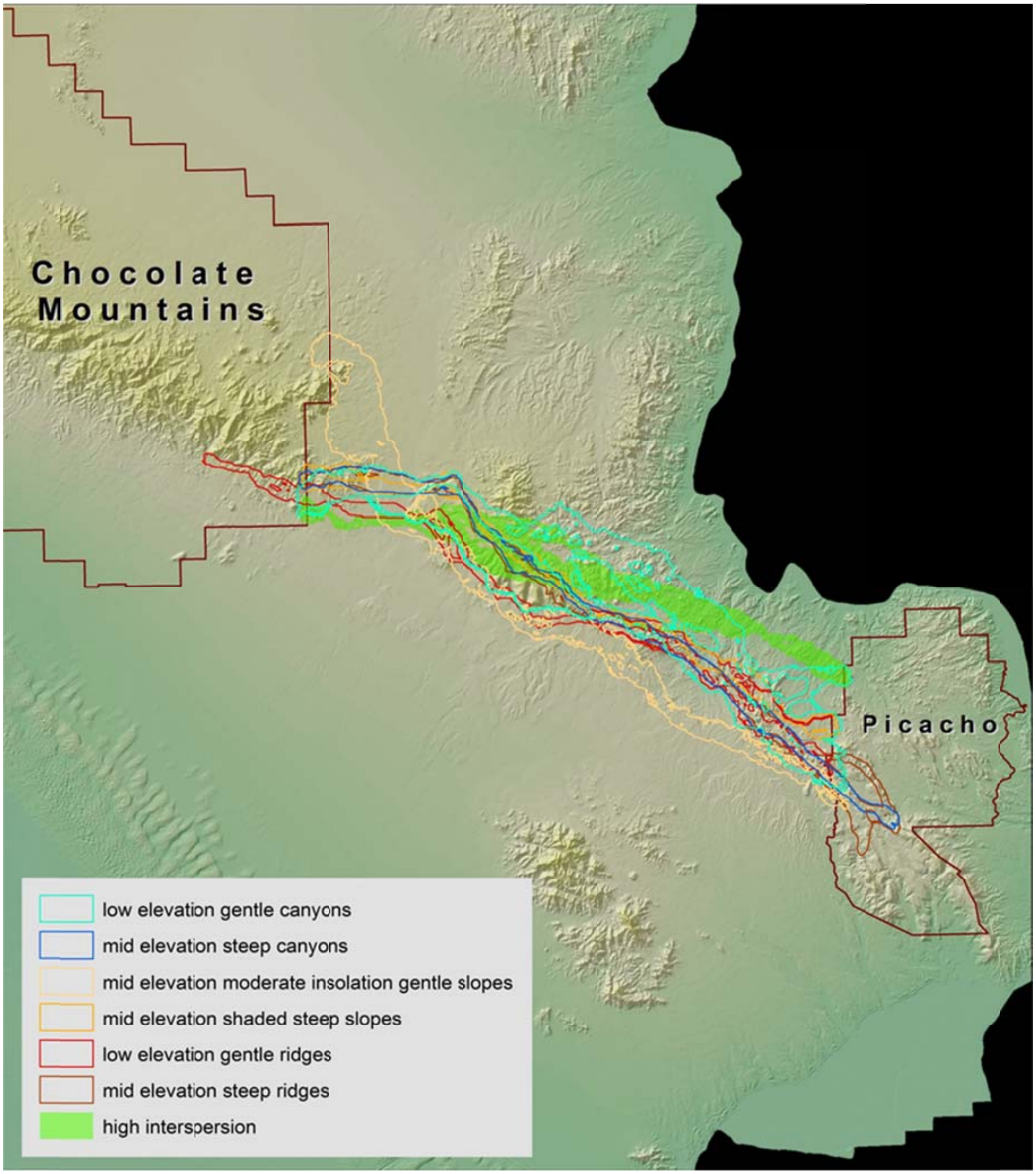


Figure 30. The union includes 7 intertwined corridors. The bulge where the linkage union meets the Chocolate Mountains and the southernmost branch are parts of the corridor for mid-elevation, gentle slopes. The other six corridors provide continuity for mid-elevation, shaded, steep slopes; low elevation, gentle canyon bottoms; mid-elevation, steep canyon bottoms; low elevation, gentle ridges; mid-elevation, steep ridges; and high interspersion of land facets).

Chocolate Mountains - East Mesa Land Facets

Figure 31. The single strand is the corridor for low elevation, gentle slopes, which is the only land facet in East Mesa ACEC.

Although, the landscape permeability and land facet analyses delineate swatches of habitat that based on model assumptions and available GIS data are best suited to facilitate species movement between the targeted landscape blocks, they do not address whether suitable habitat in the Preliminary Linkage Network occurs in large enough patches to support viable populations or whether patches are close enough together to allow for inter-patch dispersal; and they are based on only the land facets and 4 of the 44 focal species. We therefore performed habitat suitability, patch size and configuration analyses to evaluate the configuration and extent of potentially suitable habitat in the Preliminary Linkage Network for all 44 focal species. This helped determine whether there is sufficient habitat within the Network to support each species, and whether that habitat is distributed in a pattern that allows the species to move between patches.

Specifically, the patch size and configuration analyses addresses, 1) whether the Preliminary Linkage Network provides sufficient live-in or move-through habitat to support individuals or populations of the species; 2) whether these habitat patches are within the species' dispersal distance; 3) whether any clearly unsuitable and non-restorable habitat (e.g., developed land) should be deleted from the Network; and 4) for any species not adequately served by the Network, whether incorporating more habitat would meet the species needs. The patch size and configuration analysis does not address existing barriers to movement (such as freeways) or land use practices that may prevent species from moving through the linkage. These issues are addressed in the next chapter.

The Network of Focal Species Least Cost Unions covered 862,927 ha (2,132,330 ac) and the Network of Land Facet Unions added an additional 637,487 ha (1,575,259 ac). We deleted 70,392 ha (173,941 ac) from the Preliminary Linkage Network (Figure 32) removing several land facet strands that crossed areas with too high resistance and areas where some of the land facet least-cost corridors protruded out the back end of the targeted landscape blocks. Habitat was added to the Preliminary Linkage Network in a number of areas covering 281,475 ha (695,536 ac). These additions: (1) captured many riparian connections not included in the Preliminary Linkage Network; (2) added a few areas of key upland habitats, namely along Highway 395 in the Sierra Nevada-China Lake North Range Connection, to the south of the Algodones Dunes in the Chocolate Mountains-East Mesa Connection and in the northern branch of the Edwards-Twentynine Palms Newberry and Rodman Connection; and (3) to achieve a minimum corridor width of 2 km making the Linkage Network more robust to edge effects. To ensure that the Linkage Network accommodates all focal species, habitat was added in 16 general areas (Figure 32):

CALIFORNIA DESERT CONNECTIVITY PROJECT

Figure 32. Edits to the Preliminary Linkage Network

- Habitat was added along Little Dixie Wash to ensure a 1 km buffer to either side of the wash and was added to serve the needs of the Mohave ground squirrel, red-spotted toad and Ford's swallowtail.

- Habitat was added all along Highway 395 in the Sierra Nevada-China Lake North Range providing a north-south connection between branches. This addition serves the needs of 16 focal species, including Mojave ground squirrel, little pocket mouse, southern grasshopper mouse, burrowing owl, loggerhead shrike, roadrunner, desert tortoise, desert night lizard, desert spiny lizard, Bernardino dotted blue, desert green hairstreak, desert metalmark, yucca moth, Joshua tree, blackbrush, and paper bag bush.

- A 1 km buffer of habitat was added to either side of the Mojave River for its entire length providing connectivity among many of the targeted landscape blocks. The Mojave River is a major artery of life in this xeric region and was added to serve the needs of numerous focal species, such as ringtail, pallid bat, Mojave fringe-toed lizard, and the red-spotted toad.

- A 1 km buffer of upland habitat was added to either side of Buckhorn Wash, which together with the Mojave River addition provides a riparian connection between Edwards Air Force Base-Twentynine Palms and Newberry Rodman. This area was added primarily for the Mojave fringe-toed lizard and the red-spotted toad but also serves the needs of many other species.

- Habitat was added to the northern swath of the Edwards Air Force Base-Twentynine Palms and Newberry Rodman for the desert pocket mouse to ensure connectivity to core areas delineated on Edwards Air Force Base.

- A 1 km buffer was added to either side of Fremont Wash flowing out of the San Gabriel Mountains that together with Buckhorn Wash provides a riparian connection to Edwards Air Force Base. Fremont Wash together with the Mojave River and Daggett Wash additions also serve the San Gabriel Mountains to the Twentynine Palms and Newberry Rodman target areas. This strand was primarily added to the serve Mojave fringe-toed lizard, red-spotted toad, and ringtail but will serve many other species.

- A 1 km buffer was added to either side of Pipes Wash flowing out of the San Bernardino Mountains toward Twentynine Palms to serve the needs of red-spotted toad, pallid bat, LeConte's thrasher, rosy boa, Mojave rattlesnake, and many other species.

- A 1 km buffer was added along the Amargosa River and Salt Creek providing riparian travel routes between Kingston Mountains and the Mojave National

Preserve and a north-south connection in the eastern part of the China Lake South Range-Kingston Mesquite linkage that connects all of the east-west branches of that linkage. These additions were necessary for the Mojave fringe-toed lizard, ringtail, round-tailed ground squirrel, little pocket mouse, desert spiny lizard, desert willow and a number of other focal species.

- A 1 km buffer was added along Kingston Wash to serve the needs of red-spotted toad, desert willow, southern grasshopper mouse, LeConte's thrasher and other species.

- A 1 km buffer was added along Daggett Wash that together with the Mojave River addition provides potential riparian connections between several landscape blocks (e.g., Mojave National Preserve-Twentynine Palms and Newberry Rodman). This addition serves species such as red-spotted toad, pallid bat, loggerhead shrike, and desert spiny lizard.

- A 1 km addition along the lower part of Homer Wash, most of which was captured by the focal species least-cost corridors in the Mojave National Preserve-Stepladder Turtle Mountains linkage.

- Riparian additions (1 km to either side) along Piute Wash, Colorado River and Chemehuevi Wash to serve as another riparian connection between the Mojave National Preserve and the Stepladder Mountains for species such as red-spotted toad, crissal thrasher, and black-tailed gnatcatcher.

- Riparian additions along Bennett Wash, Colorado River and McCoy Wash which serves as the only riparian connection between the Palen and Whipple Mountains to serves the needs of species such as red-spotted toad, ringtail, and desert willow.

- Riparian additions along McCoy Wash, Colorado River and Milipitas Wash which serve as potential riparian connections between the Palen and Chocolate Mountains, Palen and Little Picacho and Chocolate Mountains and Little Picacho. These additions serve the needs of species such as red-spotted toad, ringtail, Ford's swallowtail, black-tailed gnatcatcher, mesquite, and desert willow.

- A 1 km addition to either side of Pinkham Wash in the Joshua Tree-Chocolate Mountains linkage to serve the needs of ringtail, crissal thrasher, desert willow and many other species.

- An addition to the western branch of the Chocolate Mountains-East Mesa linkage along the southern base of the Algodones Dunes for several species, such as little pocket mouse, desert pocket mouse, southern grasshopper mouse, and many others that can't traverse the dunes.

Table 4. Land Ownership in the Linkage Network	hectares	acres
Bureau of Land Management	1,078,025	2,663,847
Department of Defense	148,275	366,394
National Park Service	44,303	109,475
California State Lands Commission	33,393	82,517
California Department of Fish and Game	7,958	19,664
United States Fish and Wildlife Service	6,605	16,322
The Wildlands Conservancy	5,623	13,894
California Department of Parks and Recreation	4,024	9,943
United States Forest Service	3,562	8,801
Special Districts	1,307	3,230
Other Federal	869	2,148
Cities	436	1,076
Friends of the Desert Mountains	331	818
Riverside Land Conservancy	127	313
Counties	98	242
Private Lands	376,561	930,500
Total Linkage Network	1,711,497	4,229,184

The final Linkage Network (Figure 33) encompasses 1,711,497 ha (4,229,184 ac), of which approximately 68% (1,186,661 ha or 2,932,291 ac) currently enjoys some level of conservation protection (Table 4), mostly in land overseen by the Bureau of Land Management, National Park Service, California State Lands Commission, California Department of Fish and Wildlife, US Fish and Wildlife Service, and The Wildlands Conservancy. An additional 9% (148,275 ha or 366,394 ac) of the Linkage Network is administered by the Department of Defense, providing some level of conservation protection for these lands. Thus, the Linkage Network includes substantial public ownerships (78%).

To accommodate the full range of target species and ecosystem functions it is intended to serve, the Linkage Network should 1) provide live-in and move-through habitat for multiple species, 2) support metapopulations of smaller species, 3) ensure availability of key resources, 4) buffer against edge effects, 5) reduce contaminants in streams, 6) allow natural processes to operate, and 7) allow species and natural communities to respond to climatic changes. We elaborate on these goals below.

All branches of the Linkage Network must be wide enough to provide live-in habitat for species with dispersal distances shorter than the linkage. Harrison (1992) proposed a minimum corridor width for a species living in a linkage as the width of one individual's territory (assuming territory width is half its length). Thus, our minimum corridor width of 2 km should accommodate species with home ranges of up to about 8 km2 (3 mi2). This would accommodate all focal species except the largest, such as mountain lion, mule deer and badger.

The Linkage Network must support metapopulations of less vagile species. Many small animals, such as little pocket mouse, desert pocket mouse, red-spotted toad, rosy boa, Mojave fringe-toed lizard, and many other focal species, may require dozens of generations to move between core areas. These species need linkages wide enough to support a constellation of populations, with movements among populations occurring over decades. We believe 2 km is adequate to accommodate most target species living as metapopulations within the network.

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Figure 33. A Linkage Network for the California Deserts

The Linkage Network was planned to provide resources for all target species, such as host plants for butterflies and pollinators for plants. For example, many species commonly found in riparian areas depend on upland habitats during some portion of their life cycle, such as some butterflies that use larval host plants in upland areas and drink from water sources as adults.

The Linkage Network was also designed to buffer against "edge effects" even if adjacent land becomes developed. Edge effects are adverse ecological changes that enter open space from nearby developed areas, such as weed invasion, artificial night lighting, predation by house pets, increases in human-associated or opportunistic species like house mice (*Mus musculus*), elevated soil moisture from irrigation, pesticides and pollutants, noise, trampling, and domesticated animals that attract native predators. Edge effects have been best-studied at the edge between forests and adjacent agricultural landscapes, where negative effects extend 300 m (980 ft) or more into the forest (Debinski and Holt 2000, Murcia 1995) depending on forest type, years since the edge was created, and other factors (Norton 2002). The best available data on edge effects for southern California habitats include reduction in leaf-litter and declines in populations of some species of birds and mammals up to 250 m (800 ft) in coastal scrub (Kristan et al. 2003), collapse of native plant and animals communities due the invasion of argentine ants up to 200 m (650 ft) from irrigated areas (Suarez et al. 1998), and predation by house cats which reduce small vertebrate populations 100 m (300 ft) from the edge (K. Crooks, unpublished data). Domestic cats may affect wildlife up to 300 m (980 ft) from the edge based on home range sizes reported by Hall et al. (2000). The proximity of human activities near natural areas can also result in indirect impacts and habitat alteration from trail proliferation, higher fire frequencies, etc., and these changes in turn may impact native species (Buechner and Sauvajot 1996). These impacts can be partially mitigated by maintaining high quality habitat in conservation areas, particularly adjacent to human-developed areas (Sauvajot et al. 1998).

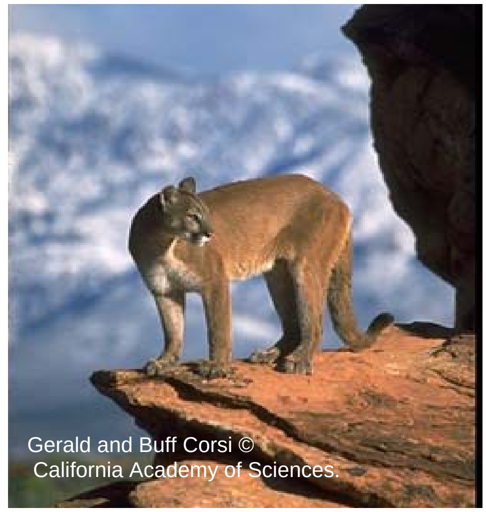
Upland buffers are needed adjacent to riparian vegetation or other wetlands to prevent aquatic habitat degradation. Contaminants, sediments, and nutrients can reach streams from distances greater than 1 km (0.6 mi) (Naicker et al. 2001, Maret and MacCoy 2002, Scott 2002), and fish, amphibians, and aquatic invertebrates often are more sensitive to land use at watershed scales than at the scale of narrow riparian buffers (Goforth 2000, Fitzpatrick et al. 2001, Stewart et al. 2001, Wang et al. 2001, Scott 2002, Willson and Dorcas 2003, Riley et al. 2005).

The Linkage Network must also allow natural processes of disturbance and recruitment to operate with minimal constraints from adjacent urban areas. All branches of the Linkage Network should be wide enough that temporary habitat impacts due to fires, floods, and other natural processes do not affect the entire linkage simultaneously. Wider linkages may be more robust to changes in disturbance frequencies that are caused by human actions. Before human occupation, naturally occurring fires (due to lightning strikes) were rare in southern California (Radtke 1983). As human populations in the region soared, fire frequency has also increased dramatically (Keeley and Fotheringham 2000). Although fire can reduce the occurrence of exotic species in native grasslands (Teresa and Pace 1998), it can have the opposite effect in some shrubland habitats (Giessow and Zedler 1996), encouraging the invasion of non-native plants, especially when fires are too frequent. While effects of altered fire regimes in this region are somewhat unpredictable, wider linkages with broader natural communities should be more robust to these disturbances than narrow linkages.

The Linkage Network must also allow species to respond to climate change. Plant and animal distributions are predicted to shift (generally northwards or upwards in elevation in California) due to global warming (Field et al. 1999). The linkages must therefore accommodate elevational shifts by being broad enough to cover an ecologically meaningful range of elevations as well as a diversity of microhabitats that allow species to colonize new areas.

The following several pages describe how well the Linkage Networks serves the selected focal species, though the network is intended to serve numerous native species that we did not specifically analyze. On each map, the Linkage Network is displayed on top of the potential habitat for each focal species.

Mountain lion (*Puma concolor*)



Justification for Selection: The naturally low densities of mountain lion populations render the species highly sensitive to habitat fragmentation (Noss 1991, Noss and Cooperrider 1994). In addition, the loss of large carnivores can have adverse ripple effects through the entire ecosystem (Soulé and Terborgh 1999). Habitat fragmentation caused by urbanization and an extensive road network has had detrimental effects on mountain lions by restricting movement, escalating mortality, and increasing contact with humans.

Distribution & Status: Mountain lions (also known as pumas or cougars) are widely distributed throughout the western hemisphere (Chapman and Feldhamer 1982, Currier 1983, Maehr 1992, Tesky 1995), though their distribution is fairly restricted in planning area. The subspecies P*. c. californica* occurs in southern Oregon, California, and Nevada (Hall 1981), typically between 590-1780 m (1980 - 5940 ft) in elevation (Zeiner et al. 1990).

Proposition 117 was passed in 1990, which prohibited hunting and granted mountain lions the status of a California Specially Protected species, though depredation permits are still issued (Torres 2000).

Habitat Associations: Mountain lions are habitat generalists, utilizing many brushy or forested habitats if adequate cover is present (Spowart and Samson 1986, Zeiner et al. 1990). They use rocky cliffs, ledges, and vegetated ridgetops that provide cover when hunting prey, which most frequently consists of mule deer (*Odocoileus hemionus;* Chapman and Feldhamer 1982, Spowart and Samson 1986, Lindzey 1987). Den sites may be located on cliffs, rocky outcrops, caves, in dense thickets, or under fallen logs (Ingles 1965, Chapman and Feldhamer 1982). In southern California, most cubs are reared in thick brush (Beier et al. 1995). They prefer vegetated ridgetops and stream courses as travel corridors and hunting routes (Spowart and Samson 1986, Beier and Barrett 1993).

Spatial Patterns: Home range size varies by sex, age, and the distribution of prey. A recent study in the Sierra Nevada Mountains documented annual home range sizes between 250 and 817 km^2 (61,776-201,885 ac; Pierce et al. 1999). Home ranges in southern California averaged 93 km^2 (22,981 ac) for 12 adult females and 363 km^2 (89,699 ac) for 2 adult males (Dickson et al. 2004). Male home ranges appear to reflect the density and distribution of females (Maehr 1992). Males occupy distinct areas, while the home ranges of females may overlap completely (Zeiner et al. 1990, Beier and Barrett 1993). Regional population counts have not been conducted but in the Santa Ana Mountain Range, Beier (1993) estimated a density of 1.05-1.2 adults per 100 km^2 (24,711 ac).

Mountain lions are capable of long-distance movements, and often move in response to changing prey densities (Pierce et al. 1999). Beier et al. (1995) reported mountain lions moving 6 km (3.7 mi) per night and dispersing up to 65 km (40 mi). Dispersal plays a crucial role in cougar population dynamics, because recruitment into a local population occurs mainly by immigration of juveniles from adjacent populations, while the population's own offspring emigrate to other areas (Beier 1995, Sweanor et al. 2000). Juvenile dispersal distances average 32 km (20 mi) for females and 85 km (53 mi) for males, with one male dispersing 274 km (170 mi; Anderson et al. 1992). Dispersing lions may cross large expanses of nonhabitat, although they prefer not to do so (Logan and Sweanor 2001). To allow for dispersal of juveniles and the immigration of transients, lion management should be on a regional basis (Sweanor et al. 2000).

Conceptual Basis for Model Development: Puma will use most habitats above 590 m (1,936 ft) elevation provided they have cover (Spowart and Samson 1986, Zeiner et al. 1990). Road density is also a significant factor in habitat suitability for mountain lions. Core areas potentially supporting 50 or more individuals were modeled as $\geq$ 10,000 km^2 (2,471,053 ac). Patch size was classified as $\geq$ 200 km^2 (49,421 ac) but < 10,000 km^2. Dispersal distance for puma was defined as 548 km (340 mi), or twice the maximum reported dispersal distance of 274 km (170 mi).

Results & Discussion: Potential habitat for mountain lion is fairly restricted in the study area, with the Sierra Nevada identified as the only core habitat capable of supporting a robust population of lions (Figure 34). Nevertheless, two significant prey species, bighorn sheep and mule deer, occur within the planning area, which likely attracts lions to the region (Chapman and Feldhamer 1982, Spowart and Samson 1986, Lindzey 1987, Hayes et al. 2000, Sweanor et al. 2000). Large patches were identified in ten of the target areas, namely San Gabriel, San Bernardino, China Lake North, China Lake South, Kingston Mesquite, Mojave National Preserve, Whipple, Chocolate, Joshua Tree, and Newberry Rodman. All potential patches of suitable habitat are within the dispersal distance of this species (figure not shown).

Sierra Nevada-China Lake North Range: This species distribution is restricted to the Coso Range in the northwest portion of the China Lake North block but extensive habitat occurs in the Sierra Nevada. Thus, the northern branch of the linkage is likely to serve this species.

China Lake North Range-China Lake South Range: The northern branch of the linkage following the Slate Range provides a fair amount of move-through habitat for mountain lion and may provide a connection between the Coso and Argus Ranges and the Eagle Crags.

China Lake South Range-Twentynine Palms and Newberry Rodman: The branch of the linkage that follows the Calico Mountains may serve to connect the Eagle Crags and Newberry Rodman Mountains.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The swath of the linkage that follows the Fry Mountains provides the most move-through habitat and the closest distance between patches in the Newberry Rodman and San Bernardino Mountains.

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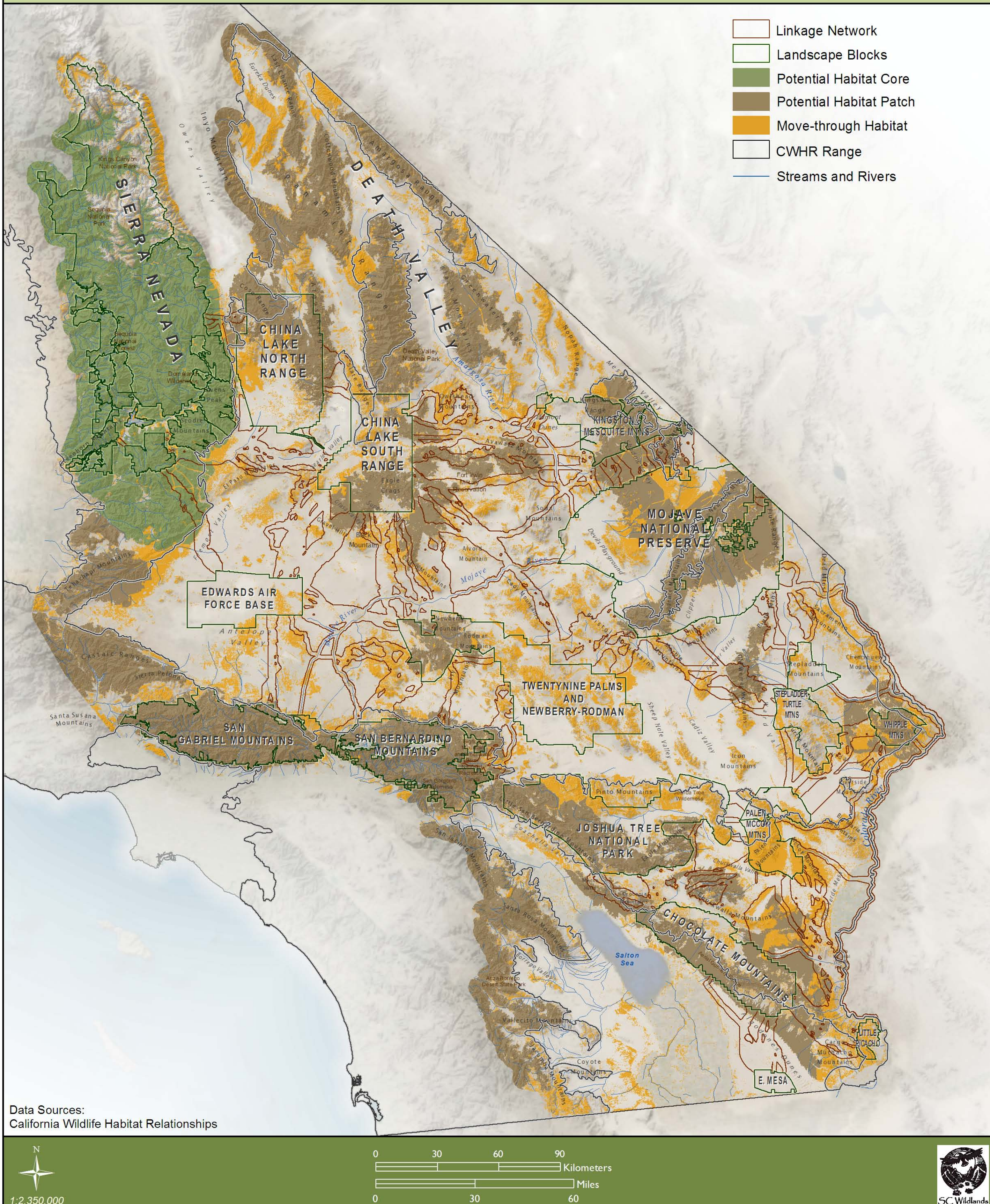
Figure 34. Potential Habitat for Mountain Lion (Puma concolor)



Data Sources:
California Wildlife Habitat Relationships

China Lake South Range-Kingston Mesquite Mountains: The central branch of the linkages that takes in most of the Avawatz Range provides the best potential connection for this species.

Kingston Mesquite Mountains-Mojave National Preserve: All of the central branches of the linkage captured fairly contiguous potential habitat for mountain lion.

Mojave National Preserve-Stepladder Turtle Mountains: No patches were identified in the Stepladder Turtle Mountains but the western branch of the linkage through the Marble Mountains provides some move through habitat to a patch identified in the Old Woman Mountains in the central part of the linkage.

Palen McCoy Mountains-Whipple Mountains: No patches delineated in Palen McCoy but individuals may move-through the Riverside, Big Maria, Palen and McCoy Mountains, which may serve to connect Whipple to Joshua Tree and the Chocolate Mountains.

Joshua Tree National Park-Chocolate Mountains: The western branch through the Mecca Hills and Orocopia Mountains provides the best potential connection for this species.

Palen McCoy Mountains-Chocolate Mountains: A large patch was identified in the Chuckwalla Mountains in the central part of the linkage.

Chocolate Mountains-Little Picacho: No cores or patches identified in the Little Picacho wildland block but much of the northern part of the linkage was identified as highly suitable habitat.

American badger (*Taxidea taxus*)

Distribution & Status: Once a fairly widespread resident in open habitats of California, the badger is now uncommon throughout the state and is considered a California Species of Special Concern (Zeiner et al. 1990).

Habitat Associations: Badgers are habitat specialists, associated with grasslands, prairies, and other open habitats (De Vos 1969, Banfield 1974, Sullivan 1996) but they may also be found in drier open stages of shrub and forest communities (Zeiner et al. 1990). They are known to inhabit forest and mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper, and sagebrush habitats (Long and Killingley 1983, Zeiner et al. 1990). They are occasionally found in open chaparral (< 50% cover) but have not been documented in mature stands of chaparral (Quinn 1990, Zeiner et al. 1990). Badgers prefer friable soils for excavating burrows and require abundant rodent populations (De Vos 1969, Banfield 1974, Sullivan 1996). They are typically found at lower elevations, in flat, rolling, or steep terrain, but have also been recorded at elevations up to 3,600 m (12,000 ft; Zeiner et al. 1990, Minta 1993).

Spatial Patterns: Home range sizes for this species vary both geographically and seasonally. Male home ranges have been estimated to vary from 240 to 850 ha (593-2,100 ac) while reported female home ranges varied from from 137 to 725 ha (339-1,792 ac; Long 1973, Lindzey 1978, Messick and Hornocker 1981, Zeiner et al. 1990). In northwestern Wyoming, home ranges up to 2,100 ha (5,189 ac) have been reported (Minta 1993). In Idaho, home ranges of adult females and males averaged 160 ha (395 ac) and 240 ha (593 ac) respectively (Messick and Hornocker 1981). In Minnesota, Sargeant and Warner (1972) radio-collared a female badger, whose overall home range encompassed 850 ha (2,100 ac). However, her home range was restricted to 725 ha (1,792 ac) in summer, 53 ha (131 ac) in autumn and to a mere 2 ha (5 ac) in winter. In Utah, Lindzey (1978) reported that fall and winter home ranges of females varied from 137 to 304 ha (339-751 ac), while male home ranges varied from 537 to 627 ha (1,327-1,549 ac). Males may double movement rates and expand their home ranges during the breeding season to maximize encounters with females (Minta 1993). Lindzey (1978) documented natal dispersal distance for one male at 110 km (68 mi) and one female at 51 km (32 mi).

Conceptual Basis for Model Development: Badgers prefer grasslands, meadows, open scrub communities such as creosote and sagebrush, desert washes, juniper and other open woodland communities. Terrain may be flat to gently sloping and is typically below 3,600 m (12,000 ft) elevation. Core areas capable of supporting 50 badgers are equal to or greater than 16,000 ha (39,537 ac). Patch size is $\geq$ 400 ha (988 ac) but $<$ 16,000 ha. Dispersal distance for badgers was defined as 220 km (136 mi), twice the longest recorded dispersal distance (Lindzey 1978).

Results & Discussion: The model identified abundant medium to high suitable habitat for badger in the planning area with the most highly suitable contiguous habitat delineated in the flats and lowlands preferred by this species. Virtually all branches delineated by badger in the 22 linkages contain highly suitable contiguous habitat, much of which was identified as potential cores for this species (Figure 35). All potential habitat is within badger's dispersal distance (figure not shown), although barriers to movement may exist between suitable habitat patches.

Sierra Nevada-China Lake North Range: All branches of the linkage contain potential core habitat for badger but the southern branch delineated as the least-cost corridor for this species contains the most highly suitable contiguous habitat. The northern branch also contain fairly contiguous habitat but of lower suitability.

Sierra Nevada-China Lake South Range: The swath of the linkage delineated by this species contains the most contiguous highly suitable core habitat. All other branches contain some core habitat but of lower suitability.

Sierra Nevada-Edwards Air Force Base: Virtually all of the land in the linkage was identified as highly suitable core habitat for badger.

China Lake North Range-China Lake South Range: The southernmost branch of the linkage contains the most highly suitable habitat and provides the best connection between core habitats in the two targeted areas. However, all branches contain potential badger habitat.

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage was delineated as potential core areas for badger with fairly contiguous highly suitable habitat identified in all but the northern branch.

China Lake South Range-Twentynine Palms and Newberry Rodman: The majority of land in the linkage was delineated as potential cores or patches of badger habitat but the swath delineated by this species provides the most highly suitable habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern branch of the linkage captured the most highly suitable contiguous badger habitat.

Edwards Air Force Base-San Gabriel Mountains: Fairly contiguous highly suitable habitat was identified in the linkage and throughout Edwards Air Force Base, while habitat in the San Gabriels was identified as medium to high. The majority of land in the linkage was identified as potential cores or patches for this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The swath of the linkage delineated by the least cost corridor for this species contains the most contiguous highly suitable badger habitat. The patch size analysis delineated potential cores areas of medium to highly suitable habitat throughout the linkage.

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Figure 35. Potential Habitat for American badger (Taxidea taxus)

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: All branches of the linkage contain potential badger habitat with the most highly suitable habitat in the lowlands and flats preferred by this species. The majority of habitats in the linkage were identified as potential core areas or move-through habitat for this species.

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage contain potential habitat for badger but the swath delineated by this species provides the most contiguous highly suitable habitat for this species.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat was identified for badger in all branches of the linkage but the central swath through Shadow Valley captured the most contiguous highly suitable badger habitat. The majority of land in the linkage was identified as potential cores of medium to highly suitable badger habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The branch delineated by this species provides the most contiguous highly suitable habitat, mostly in the lowlands between the Lava Hills and Amboy Crater. However, the majority of land in the Linkage was identified as medium to high suitable habitat and was thus delineated as potential core areas for this species.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain potential badger habitat but the swath delineated by this species along Homer Wash and down into Ward Valley provides the most contiguous highly suitable habitat.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage contain fairly contiguous highly suitable habitat for badger with the western branch providing the best connection between large blocks of highly suitable core habitat within the target areas.

Palen McCoy Mountains-Whipple Mountains: The central branch provides the most contiguous highly suitable badger habitat.

Joshua Tree National Park-Palen McCoy Mountains: The two northern most branches of the linkage cross the Palen Valley and contain the most contiguous highly suitable habitat for badger, linking core habitat in the Pinto Basin of Joshua Tree with core areas in the Palen and Rice Valleys in the Palen-McCoy landscape block. The southern branch of the linkage contains some scattered habitat of medium suitability but it isn't contiguous with any badger habitat within the targeted landscape blocks.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain habitat for badger but only the eastern most branch delineated by badger, kit fox, and desert tortoise provides a contiguous connection of highly suitable habitat between the two targeted landscape blocks, stretching from core habitat in the Chocolate Mountains down into the Chuckwalla Valley and up into the Pinto Basin core area in Joshua Tree.

Palen McCoy Mountains-Chocolate Mountains: The swath of the linkage delineated by this species across the Chuckwalla Valley contains the most highly suitable contiguous habitat for badger. However, the majority of land in the linkage was identified as medium to highly suitable habitat for badger and delineated as potential core areas.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain potential badger habitat but the branch delineated by this species provides the most highly suitable contiguous habitat and is the only branch that serves to connect potential breeding habitat in the two target areas. All other branches of the linkage terminate in non-habitat in the Palen McCoy Mountains.

Chocolate Mountains-Little Picacho: The southern part of the linkage, delineated by this species, contains contiguous highly suitable core habitat.

Chocolate Mountains-East Mesa: All branches of the linkage contain potential habitat for badger. The most highly suitable habitat was identified in the lowlands on either side of the Algodones Dunes with the dunes identified as low to medium suitability.

Justification for Selection: Major highways and heavily traveled roads are significant obstacles to movement for kit fox and vehicle collision is the greatest source of mortality in urbanizing areas (Cypher et al. 2000). The kit fox is vulnerable to habitat loss and fragmentation due to agricultural, urban, and industrial development (Grinnell et al. 1937, Zeiner et al. 1990).

Distribution & Status: The geographic distribution of the kit fox ranges from south central Oregon, east to west Texas and New Mexico and south down into Baja California and the North Central states of Mexico (Jameson and Peeters 1988). Historically, it occurred in all major desert regions of North America, including the Sonoran, Mojave, Chihuahua, Painted deserts and much of the Great Basin Desert (McGrew 1979). It is found at elevations ranging from 400–1,900 m (1312-6234 ft; Warrick and Cypher 1998).

The San Joaquin kit fox (*V. m. mutica*) is federally listed as Endangered and classified as Threatened by the state of California (USFWS 1998, IUCN 1999). The kit fox is also considered Vulnerable in Mexico (SEDESOL 1994, IUCN 1999).

Habitat Associations: Kit fox occurrence is strongly influenced by topography, vegetative cover, prey availability, and predator densities (Grinnell et al. 1937, Egoscue 1962, Daneke et al. 1984, Zoellick et al. 1989, Warrick and Cypher 1998, Haight et al. 2002). They are mainly associated with gently sloping and flat terrain; slopes of 0-5% are considered ideal, slopes of 5-15% provide fair habitat, and areas with slopes >15% are largely unsuitable (B. Cypher, personal communication). Warrick and Cypher (1998) found a negative relationship between topographic ruggedness and capture rates of San Joaquin kit fox in the Elk Hills and Buena Vista Hills of the Temblor Range.

They prefer open vegetation communities, such as desert grassland and scrub habitats (Hoffmeister 1986) where they can detect and evade coyotes and other predators (Warrick and Cypher 1998). High kit fox capture rates have been documented in recently burned areas, which were attributed to the openness of the habitat and its effect on predator evasion (Zoellick et al. 1989). The kit fox is also known to forage in agricultural lands, particularly orchards, on a limited basis (Morrell 1972, IUCN 1999). Warrick et al. (2007) documented use of agricultural lands for foraging up to 1 kilometer from adjacent suitable natural habitats.

Kit fox may be found on a wide variety of soils but most dens are located in easily diggable clay soils or other soft alluvial soils (McGrew 1979, Hoffmeister 1986), which facilitate burrow construction and tend to support more abundant rodent populations (USFWS 1998). Kit foxes use dens year-round to escape predators, bear young, and as daytime resting places.

Spatial Patterns: Spatial use is highly variable for kit fox, and depends on the available 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). In Arizona, one study found an average home range size of 980 ha for females, and 1,230 ha for males; however, the authors also reported 75% overlap of home ranges of paired males and females (Zoellick and Smith 1992).

In the San Joaquin kit fox, home range estimates vary from less than 260 ha to approximately 3,100 ha (Morrell 1972, Knapp 1978, cited in USFWS 1998, Zoellick et al. 1987, Spiegel and Bradbury 1992, White and Ralls 1993). Home range sizes at the Naval Petroleum Reserve averaged 460 ha (Zoellick et al. 2002), whereas home range size of 21 animals on the Carrizo Plain averaged 1,160 ha (White and Ralls 1993). Haight et al (2002) assumed two kit foxes per home range, which they estimated to average 390 ha in good habitat and 780 ha in fair habitat. In optimal habitat, each kit fox family requires approximately 486 ha, with larger space requirements in suboptimal habitats (Cypher et al. 2007). Juvenile dispersal in San Joaquin kit fox is documented to range from 8 to 96 km (Thelander et al. 1994).

Conceptual Basis for Model Development: Kit fox are associated with grasslands and other open vegetation communities including desert scrub, badlands, dunes, shrublands, and playas. They prefer areas with less than 5% slope but areas with up to 15% slope may be used. Road density is also a significant factor in habitat suitability for kit fox. Core areas were defined as $\geq$ 12,150 hectares. Patch size was classified as $\geq$ 486 hectares but less than 12,150 hectares. Dispersal distance was defined as 192 km.

Results & Discussion: This species doesn't range into the Sierra Nevada, San Gabriel, or San Bernardino Mountains but the majority of land in the desert was identified as medium to highly suitable habitat for kit fox and was thus delineated as potential core areas (Figure 36). All potential habitat is within kit fox dispersal distance (figure not shown), although barriers to movement may exist between suitable habitat patches.

Adult and juvenile kit foxes are known to move through disturbed habitat, including agricultural fields, oil fields, and rangelands, and across highways and aqueducts (Haight et al. 2002). However, major highways and heavily traveled road are obstacles to movement (Cypher et al. 2000). Vehicles are the greatest source of mortality in urban areas, whereas predation, primarily by coyotes, is the primary cause of mortality in most other areas (Cypher et al. 2000, B. Cypher, personal communication).

Sierra Nevada-China Lake North Range: While the kit fox doesn't range into the Sierra Nevada, highly suitable habitat was captured throughout the linkage and the China Lake North block, much of which was delineated as potential core areas for this species. Highly suitable habitat extends almost the entire length in between the landscape blocks linking the northern and southern branches of the linkage.

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Figure 36. Potential Habitat for Kit fox (*Vulpes macrotis*)

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by the badger provides the most highly suitable contiguous core habitat for kit fox, though the other branches also provide contiguous habitat but of lower suitability.

Sierra Nevada-Edwards Air Force Base: The majority of land in the linkage and on Edwards Air Force Base was delineated as potential core areas for kit fox.

China Lake North Range-China Lake South Range: Virtually all habitats in the linkage and two target areas were delineated as potential core habitat for kit fox. However, the southern branch contains the most highly suitable habitat and provides the best connection between highly suitable habitats in the two target areas.

China Lake South Range-Edwards Air Force Base: All land within the linkage was identified as medium to highly suitable core habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: Most of the land in the linkage and two target areas was identified as medium to highly suitable core habitat for kit fox.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Nearly all land within the linkage and the two target areas was identified as potential core areas for kit fox with the most highly suitable habitat in the northern swaths of the linkage.

Edwards Air Force Base-San Gabriel Mountains: Kit fox don't range into the San Gabriel Mountains but extensive highly suitable habitat was identified in the linkage and on Edwards Air Force Base and the majority of this was delineated as potential core areas for this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Virtually all habitats within the linkage and the Twentynine Palms block were identified as medium to highly suitable habitat and were delineated as potential core areas. However, the swath delineated by the badger provides the most contiguous highly suitable habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Kit fox don't range into the San Bernardino Mountains but virtually all habitats in the linkage and the Twentynine Palms and Newberry Rodman block were identified as medium to highly suitable kit fox and were thus delineated as potential core areas for this species.

China Lake South Range-Kingston Mesquite Mountains: Nearly all of the land within the linkage and two target areas were identified as potential core habitat for kit fox. Though the branches delineated by kit fox, badger and desert tortoise provide the most contiguous highly suitable habitat.

Kingston Mesquite Mountains-Mojave National Preserve: The majority of habitats in the linkage and two target areas were identified as medium to highly suitable habitat and delineated as potential core areas. Two branches of the linkage are almost entirely dominated by highly suitable habitat; the branch delineated by badger through Shadow Valley and the branch delineated by kit fox through the Mesquite and Ivanpah Valleys to the east of the Clark Mountain Range.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Nearly all of the land in the linkage and the two target areas was identified as medium to highly suitable core habitat. The swath delineated by this species provides the most highly suitable habitat.

Mojave National Preserve-Stepladder Turtle Mountains: Virtually all of the lands within the linkage and target areas were delineated as medium to highly suitable core habitat. However, the swath delineated by kit fox, tortoise, and badger following Homer Wash and Ward Valley captured the most highly suitable habitat.

Stepladder Turtle Mountains-Palen McCoy Mountains: The majority of land in the linkage was identified as highly suitable habitat. Land throughout the Stepladder Turtle Mountains target, the linkage and the northern half of the Palen block were delineated as potential breeding habitat for kit fox.

Palen McCoy Mountains-Whipple Mountains: Almost all of the land in the linkage was identified as medium to highly suitable core habitat but the swath delineated by this species contains the most contiguous highly suitable habitat.

Joshua Tree National Park-Palen McCoy Mountains: The two northern branches contain the most contiguous highly suitable habitat for kit fox. The southern branch contains some scattered habitat patches but it isn't contiguous with any kit fox habitat within the targeted landscape blocks.

Joshua Tree National Park-Chocolate Mountains: All branches contain potential core habitat for kit fox but only the eastern most branch provides a contiguous connection of highly suitable habitat between the two targeted landscape blocks.

Palen McCoy Mountains-Chocolate Mountains: Virtually all land in the linkage, Chocolate Mountains and the northern part of the Palen McCoy block were identified as medium to highly suitable habitat and delineated as potential core areas.

Palen McCoy Mountains-Little Picacho: Most of the land in the linkage was identified as medium to highly suitable habitat but there are gaps of non-habitat in the western branch where it crosses over the Chuckwalla Mountains and in the eastern branch where is crosses over the McCoy Mountains. The most highly suitable contiguous habitat was captured by the branches delineated by kit fox and badger.

Chocolate Mountains-Little Picacho: The majority of land in the linkage was identified as potential breeding habitat for kit fox with the southern branch providing the most highly suitable habitat.

Chocolate Mountains-East Mesa: Virtually all of the land in the linkage and two target areas was identified as medium to highly suitable core habitat for kit fox.

Ringtail (*Bassariscus astutus*)

Justification for Selection: This small nocturnal carnivore is considered vulnerable to extirpation due to habitat loss and degradation (Trapp and Roll 2009).

Distribution & Status: The ringtail is widely distributed from southwestern Oregon across much of California and the southwestern U.S., east to Louisiana and southern Arkansas, and south to the Mexican border (Poglayen-Neuwall and Toweill 1988). It is found throughout the state of California except for portions of the Sacramento and San Joaquin valleys, Modoc Plateau, eastern Sierra Nevada, and portions of the Mojave Desert (Grinnell et al. 1937, Zeiner et al. 1990). Belluomini (1980) reported a range extension into Imperial, eastern Riverside, and southwestern San Bernardino Counties. They may occur at elevations up to 2900 m (9,514 ft) but are more common at elevations between sea level and 1400 m (4,593 ft; Goldberg 2003).

The ringtail was harvested as a furbearer in California until 1968 when it was listed as a fully protected species by the California Legislature (Belluomini 1980).

Habitat Associations: Ringtails have a strong association with riparian habitats but may also be found in desert scrub, forest, grassland, chaparral, and sagebrush habitats (Vaughan 1954, Belluomini and Trapp 1984, Zeiner et al. 1990, Yolo Natural Heritage Program 2009). Within these habitats, they are typically limited to areas within 1 km (0.6 mi) of a permanent water source (Zeiner et al. 1990). Den sites are often sited among boulders or in tree cavities (Williams 1986, Trapp and Roll 2009).

Spatial Patterns: Home range size varies wildly geographically and home ranges can shift through the year (Trapp 1978). In the Central Valley, Lacy (1983) reported ranges from 5 to 13.8 ha (12.4-34.1 ac; N=4), with a mean of 8.8 ha (21.7 ac), while Wyatt (1993) found ranges from 5.3-21.4 ha (13.1- 52.9 ac; N=8), averaging 12.0 ha (29.7 ac) (Trapp and Roll 2009). In northwestern California, Callas (1987) found home range sizes from 68-349 ha (168.03-862.4 ac; N=8) with an average of 175 ha (437 ac).

Conceptual Basis for Model Development: Ringtails are strongly associated with riparian habitats from below sea level to 2900 m in elevation but may also be found in desert scrub, grasslands, chaparral, sagebrush, chaparral, and some forest communities if within 1 km of water. Core areas were defined as $\geq$ to 260 ha. Patch size was classified as $\geq$ to 10 ha but less than 260 ha. Dispersal distance was not estimated for this species.

Results & Discussion: The majority of potential habitat in the study area was identified in the Sierra Nevada, San Gabriel, and San Bernardino Mountains with habitat in the desert largely limited to those that occur along rivers, creeks and washes (Figure 37).

Sierra Nevada-China Lake North Range: Potential habitat for this species was identified along several drainages that flow out of the Sierra Nevada down into the valley between these two target areas, including Little Lake, Fivemile, Deadfoot, Ninemile, Noname, Sand, Grapevine, Indian Wells, and Freeman Canyons, and Little Dixie Wash. Little Dixie Wash appears to provide the most continuous connection between the two target areas but the ringtail doesn't range into the southern half of China Lake North. .

China Lake North Range-China Lake South Range: Potential habitat was identified along several drainages flowing out of the Argus Range in the western part of the northern branch including Water, Bruce, Homewood, Crow, and Rattlesnake Canyons. However, none of these look as if they provide a connection between the two target areas. Habitat was also delineated along Teagle Wash but this is outside of the range of this species.

China Lake South Range-Twentynine Palms and Newberry Rodman: Very little potential habitat was identified for ringtail in the two target areas. The best potential habitat for this species in this linkage planning area is along the Mojave River and Daggett Wash, which provides a connection from the river to potential habitat in the Newberry Mountains.

Edwards Air Force Base-San Gabriel Mountains: Abundant potential habitat was identified for ringtail in the San Gabriel Mountains and along Mescal and Le Montaine Creeks flowing out of the mountains down into the linkage but the Edwards target areas is outside of the range of this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The Mojave River, Fremont and Daggett Washes may provide a potential connection between target areas.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Extensive potential habitat was identified in the San Bernardino Mountains but habitat in the other target area is limited to the vicinity around Newberry Mountains. The Mojave River and Daggett Wash provide the only potential connection for this species.

China Lake South Range-Kingston Mesquite Mountains: The only significant amount of potential habitat was identified along Salt Creek and the Amargosa River in the eastern part of the linkage. There may be a connection through Death Valley National Park along an unnamed wash that flows out of China Lake South Range through Long Valley that empties into the Amargosa River.

Kingston Mesquite Mountains-Mojave National Preserve: The Amargosa River, Salt Creek, and Kingston Wash provide the best connections for this species but habitat was also delineated along Riggs and Halloran washes and through the Clark Mountain Range.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The Mojave River provides the best potential connection between target areas for ringtail but potential habitat was also identified Budweiser, Orange Blossom, Siberia and Broadwell Washes.

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Figure 37. Potential Habitat for Ringtail (Bassariscus astutus)

Mojave National Preserve-Stepladder Turtle Mountains: Homer Wash provides the most direct connection between target areas for the ringtail. Another potential route, though less direct might follow Piute Wash to the Colorado River and then up Chemehuevi Wash to the Stepladder Mountains.

Palen McCoy Mountains-Whipple Mountains: Not much habitat was identified in the Palen McCoy target area. Riparian connections along Bennett Wash, the Colorado River and McCoy Wash may serve this species but there is a gap in potential habitat between the river and McCoy Wash through the town of Blythe.

Joshua Tree National Park-Chocolate Mountains: Potential habitat along Pinkham Wash appears to provide the most direct connection between target areas for this species but habitat was also delineated in the eastern branch along Pinto, Eagle and Big Washes and Salt Creek.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was identified along Corn Springs Wash, Salt and Ship Creeks and the Arroyo Seco. Habitat along McCoy Wash, the Colorado River and Milipitas Wash may also serve this species.

Palen McCoy Mountains-Little Picacho: Potential habitat is largely restricted to the southern part of the linkage and along the Colorado River.

Chocolate Mountains-Little Picacho: Potential ringtail habitat was captured in the eastern part of the linkage along Vinagre, Julian, and Gavilan Washes flowing out of the Chocolate Mountains into the Colorado River. Habitat along Milipitas Wash and the Colorado River may also serve this species.

Bighorn sheep (*Ovis canadensis*)

Distribution & Status: In California, bighorn sheep inhabit mountain ranges from the White Mountains, in the central eastern portion of the state, south through the Mojave Desert, west to the San Gabriel Mountains, and south through the Sonoran Desert and to the U.S.-Mexico international border. Bighorn sheep in the Sierra Nevada have recently been re-classified as a unique subspecies (*O. c. sierrae;* Wehausen et al. 2005), and are Federally listed as endangered (USFWS 2003). Desert bighorn sheep, found throughout the remainder of southern California belong to the subspecies *O. c. nelsonii*. One desert bighorn sheep population, inhabiting the Peninsular Ranges, is listed as Federally endangered (USFWS 2000).

Throughout the southwest, desert bighorn sheep populations have declined substantially and they are now considered one of the rarest ungulates on the continent (Seton 1929, Valdez and Krausman 1999). Factors that may have contributed to the decline of desert bighorn sheep, and continue to pose threats today, include habitat loss and fragmentation, disease, predation by mountain lions, human activities, competition with livestock, loss of water sources, drought, and climate change (Light and Weaver 1973, Jorgensen 1974, Wilson et al. 1980, Schwartz et al. 1986, Krausman et al. 1989, Bleich et al. 1996, Stephenson and Calcarone 1999, Hayes et al. 2000, Krausman 2000, USFWS 2000, Papouchis et al. 2001, Epps et al. 2004, 2005, McKinney et al. 2006, George et al. 2008).

Habitat Associations: Bighorn sheep are habitat specialists that prefer open habitats in steep rocky terrain. Escape terrain is typically identified as the single most important habitat component (e.g., Geist 1971, Cunningham 1989, McCarty and Bailey 1994, Zeigenfuss et al. 2000). Bighorn sheep are a large wide-ranging species that requires connectivity across a large landscape. Although the distribution of this species is typically associated with mountainous terrain with relatively open vegetation, bighorn sheep commonly use a variety of desert terrain types, including canyon bottoms, washes, alluvial fans, plateaus, and valley floors. These areas may be used both for movement between mountainous areas and as important foraging areas (e.g., Schwartz et al. 1986, Bleich et al. 1997).

Provided there is sufficient steep, rocky terrain with high horizontal visibility, bighorn sheep may utilize a variety of vegetation communities, including alpine dwarf shrub, low sage, sagebrush, pinyon-juniper, palm oasis, desert riparian, desert scrub, subalpine conifer, perennial grassland, and montane riparian, however, habitat use differs among mountain ranges and populations (Zeiner et al. 1990, USFWS 2000). Bighorn sheep are generalist herbivores and feed on a wide variety of desert plants, including cacti. In most desert ranges, summer use tends to focus near water sources (e.g., Cunningham and Ohmart 1986), but some populations have been reported to exist in areas with no known standing water (Krausman et al. 1985, Krausman and Leopold 1986).

Spatial Patterns: Bighorn sheep females form matrilineal groups that exhibit limited exploratory behavior and are typically associated with a particular mountain range or set of ranges. These groups are linked by more distantly ranging males (Geist 1971). In California's deserts, bighorn sheep have been described as forming a metapopulation (a system of multiple populations linked via occasional movement of individuals; Bleich et al. 1996) and maintenance of connectivity among these populations has become an important component of conservation strategies for this species (Schwartz et al. 1986, Bleich et al. 1996, USFWS 2000).

Home ranges of bighorn sheep in the Peninsular Ranges were reported to average 2,550 ha (25.5 km^2) for rams and 2,010 ha (20.1 km^2) for ewes (DeForge et al. 1997, USFWS 2000). Rubin et al. (2002) reported mean female home range sizes of 2,392 ha (23.92 km^2) and 1,502 ha (15.02 km^2) when using adaptive kernel and minimum convex polygon methods, respectively, in the Peninsular Ranges. In Utah, home ranges were documented to be 2,400 ha (24 km^2) and 6,100 ha (61 km^2) females and males, respectively (Jense et al. 1979).

The longest recorded movement of a female is 30 km, and the longest recorded distance for a male bighorn sheep was 56 km (Witham and Smith 1979). Bighorn sheep tend to avoid heavily used roads (e.g., Jorgensen 1974, Wilson et al. 1980, Krausman et al. 1989, Papouchis et al. 2001, Keller and Bender 2006), and genetic studies have found that roads have reduced dispersal among populations (Epps et al. 2005, 2007). Although analyses of genetic data suggest that movement of females among groups is rare (USFWS 2000, USFS 2002), Bleich et al. (1996) reported one case of a female emigrating and reproducing in a new mountain range, while McQuivey (1978) reported 4 such movements by ewes (Singer et al. 2000). Similar genetic analyses for rams indicated more frequent movements among ewe groups (USFWS 2000, USFS 2002).

Conceptual Basis for Model Development: We delineated potentially suitable habitat as escape terrain (slopes 20-85 degrees) and adjacent flat areas that were less than 300 m (984 ft) from escape terrain (Beuchner 1960, Van Dyke et al. 1983, Hurley and Irwin 1986, Bentz and Woodard 1988, Singer et al. 2000b). Three other criteria were used to remove areas of unsuitable habitat from this layer: 1) areas with dense vegetation (i.e., poor visibility) (Risenhoover and Bailey 1985, Singer et al. 2000b, Zeigenfuss et al. 2000); 2) areas too far from perennial streams and springs (>3.2 km; 2 mi; Singer et al. 2000b, Zeigenfuss et al. 2000); and 3) areas within 150 m (492 ft) of development (Smith et al. 1991, Singer et al. 2000b, Zeigenfuss et al. 2000).

Potential core areas were delineated as areas of suitable habitat greater than or equal to 300 km^2 (74,132 ac). Patches were defined $\geq$ 13 km^2 (3,212 ac) but less than 300 km^2. Dispersal distance for bighorn sheep was defined as 112 km (70 mi), twice the longest recorded distance for a male.

Results & Discussion: Bighorn sheep are a large wide-ranging species that requires connectivity across a vast landscape. The potential core areas and patches of suitable habitat delineated by the patch size analysis (Figure 38) correspond well with known populations of this species (Stephenson and Calcarone 1999, USFS 2002, NPS 2003, Epps 2007). All branches of the linkage network delineated by bighorn sheep captured the fairly rugged terrain preferred by this species. The longest stretch of flat terrain in the least cost corridors for bighorn sheep was 13.7 km connecting the Old Woman and Turtle Mountains, similar to Epps (2007) results.

All potential habitat patches are within the species dispersal distance (figure not shown), though barriers to movement exist between areas of suitable habitat. Bighorn sheep avoid heavily used roads (Jorgensen 1974, Wilson et al. 1980, Krausman et al. 1989, Ebert and Douglas 1993, Rubin et al. 1998, Papouchis et al. 2001), although females will cross busy roads on rare occasions and rams cross roads more frequently (Rubin et al. 1998). MacArthur et al. (1982) concluded that well designed transportation systems could minimize disturbance to sheep (Holl and Bleich 1983).

China Lake North Range-China Lake South Range: The northern branch serves to connect known populations in the Argus and Slate Ranges. This entire branch of the linkage was delineated as potential core habitat for bighorn sheep.

China Lake South Range-Kingston Mesquite Mountains: The branch of the linkage delineated by bighorn sheep serves to connect known populations in the Eagle Crags, Granite, Avawatz, and Kingston Mesquite Ranges in addition to several populations in Death Valley National Park (e.g., Owlshead and Black Mountains).

Kingston Mesquite Mountains-Mojave National Preserve: The branches of the linkage that follow the Clark Mountain Range captured the most contiguous bighorn sheep habitat between known populations in the two target areas but the two western branches of the linkage also contain quite a bit of the rugged terrain and may also serve this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The swath of the linkage delineated by bighorn sheep provides the best habitat connection for this species linking known populations in the Granite, Old Dad, Bristol and Bullion Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by bighorn sheep provides the best possible connection between target areas linking the Granite, Marble, Ship, Old Woman and Turtle Mountains. The other western branch may also provide connectivity between the Providence, Clipper, Old Woman and Turtle Mountains. The eastern branch that captured the northern part of the Piute Mountains may also provide a potential connection to the Old Woman and Turtle Mountains.

Twentynine Palms and Newberry Rodman-San Bernardino National Forest: The western branch captured core habitat and extends from the Ord Mountains to the San Bernardino Mountains. The central branch extends from the Newberry Rodman Mountains to the Fry and San Bernardino Mountains. The eastern branch extends from Hidalgo Mountain in Twentynine Palms Marine Corps Base, following hilly terrain to the Bighorn and Ruby Mountains and the San Bernardino Mountains.

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Figure 38. Potential Habitat for Bighorn sheep (Ovis canadensis)

Joshua Tree National Park-Palen McCoy Mountains: The northern branch of the linkage provides the best potential connection for bighorn sheep between targeted landscape blocks. It captures core habitat in the Granite Mountains that extends out from the Palen-McCoy Landscape Block, though there is still a roughly 4.5 km gap in habitat between the Granites and the Coxcomb Mountains in Joshua Tree.

Joshua Tree National Park-Chocolate Mountains: The western branch of the linkage delineated by bighorn sheep and the diversity land facet corridors provides the best potential connection for this species. It would serve to connect known populations in the Little San Bernardino Mountains, Mecca Hills, Orocopia Mountains and Chocolate Mountains, all of which were delinated as core habitat with the exception of the Mecca Hills that was defined as a habitat patch. The linkage also captures much of the habitat in the Orocopia Mountains providing an east-west connection from the Mecca Hills to the Chuckwalla Mountains.

Palen McCoy Mountains-Little Picacho: The branch of the linkage delineated by bighorn sheep captured the most contiguous potential habitat for this species between the two target areas. It extends from the eastern flank of the Palen Mountains to the McCoy Mountains, crosses over the Chuckwalla Valley into the Mule Mountains, and encompasses portions of the Palo Verde and southern Chocolate Mountains to Little Picacho Peak.

Chocolate Mountains-Little Picacho: The branch of the linkage delineated by bighorn sheep provides the best connection between targeted areas for this species. It extends from the Chocolate Mountains target area to Mt Barrow and Black Mountain Peak at the southern extent of the Chocolate Mountains, then on to Picacho Peak, Copper Basin and Little Picacho Peak.

Mule deer (*Odocoileus hemionus*)


Photo Courtesy of USFWS

Justification for Selection: Deer herds can decline in response to fragmentation, degradation or destruction of habitat from urban expansion, incompatible land uses and other human activities (Ingles 1965, Hall 1981, CDFG 1983). Mule deer are particularly vulnerable to habitat fragmentation by roads; in fact, nationally vehicles kill several hundred thousand deer each year (Romin and Bissonette 1996, Conover 1997, Forman et al. 2003).

Distribution & Status: Mule deer are widespread in California and are common to abundant in appropriate habitat; they are generally absent from areas with no cover (Longhurst et al. 1952, Ingles 1965, Zeiner et al. 1990). Mule deer are classified by CDFG as a big game animal.

Habitat Associations: This species requires a mosaic of habitat types of different age classes to meet its life history requirements (CDFG 1983). They use forest, woodland, brush, and meadow habitats, reaching their highest densities in oak woodlands, riparian areas, and along edges of meadows and grasslands (Bowyer 1986, USFS 2002). They also occur in open scrub, young chaparral and low elevation coniferous forests (Bowyer 1981, 1986, USFS 2002). A variety of brush cover and tree thickets interspersed with meadows and shrubby areas are important for food and cover. Thick cover can provide escape from predators, shade in the summer, or shelter from wind, rain and snow. Varying slopes and topographic relief are important for providing shade or exposure to the sun. Fawning occurs in moderately dense chaparral, forests, riparian areas, and meadow edges (CDFG 1983). Meadows are particularly important as fawning habitat (Bowyer 1986, USFS 2002).

Spatial Patterns: Home ranges typically comprise a mosaic of habitat types that provide deer with various life history requirements. Home range estimates vary from 39 ha (96 ac; Miller 1970) to 3,379 ha (8,350 ac; Severson and Carter 1978, Anderson and Wallmo 1984, Nicholson et al. 1997). Harestad and Bunnell (1979) calculated mean home range from several studies as 285.3 ha (705 ac). Doe and fawn groups have smaller home ranges, averaging 100-300 ha (247-741 ac), but can vary from 50 to 500 ha (124-1,236 ac; Taber and Dasmann 1958, CDFG 1983). Bucks usually have larger home ranges and are known to wander greater distances (Brown 1961, Zeiner et al. 1990). A recent study of 5 different sites throughout California, recorded home range sizes from 49 to 1,138 ha (121-2,812 ac; Kie et al. 2002).

Where deer are seasonally nomadic, winter and summer home ranges tend to largely overlap in consecutive years (Anderson and Wallmo 1984). Elevational migrations are observed in mountainous regions in response to extreme weather events in winter, or to seek shade and perennial water during the summer (Loft et al. 1998, USFS 2002, CDFG 1983, Nicholson et al.1997). Distances traveled between winter and summer ranges vary from 8.6 to 29.8 km (5.3-19 mi; Gruell and Papez 1963, Bertram and Rempel 1977, Anderson and Wallmo 1984, Nicholson et al. 1997). Robinette (1966) observed natal dispersal distances ranging from 97 to 217 km (60-135 mi).

Conceptual Basis for Model Development: Mule deer utilize a broad range of habitats, reaching their highest densities in oak woodlands. They require access to perennial water. Core areas potentially supporting 50 or more deer are equal to or greater than 16,000 ha (39,537 ac). Patch size was classified as $\geq$ 100 ha (247 ac) but < 16,000 ha. Dispersal distance was defined as 434 km (270 mi), or twice the maximum distance recorded.

Results & Discussion: The results of the analyses overestimate potential habitat for this species (Figure 39), whose range is much more restricted in this part of the state.

Sierra Nevada-China Lake North Range: This species only ranges into the Coso Range in the northwest portion of the China Lake North block but extensive habitat occurs in the Sierra Nevada. The northern most branch of the linkage is the best potential connection for this species.

Sierra Nevada-China Lake South Range: Much of the China Lake South block is outside of the distributional range of this species but it does reach into the Slate Range which partially occurs within the northwest part of China Lake South. Much of the habitat in the linkage was identified as medium suitability and may serve this species.

Kingston Mesquite Mountains-Mojave National Preserve: The branch that follows Shadow Valley captured medium to highly suitable habitat and may provide a connection between the Kingston Mesquite Mountains and the Providence and New York Mountains in Mojave National Preserve.

Joshua Tree National Park-Palen McCoy Mountains: The northern branch provides the most potential habitat for mule deer.

Joshua Tree National Park-Chocolate Mountains: The eastern branch of the linkage captured fairly contiguous medium to high suitable habitat for mule deer between the two target areas and will likely serve the needs of this species.

Palen McCoy Mountains-Chocolate Mountains: The southern part of the linkage provides the most contiguous potential habitat for mule deer and likely will serve the movement needs of this species moving between the two target areas.

Chocolate Mountains- Little Picacho: The southern part of the linkage captured the most contiguous potential habitat for this species.

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Figure 39. Potential Habitat for Mule Deer (Odocoileus hemionus)

Mohave Ground Squirrel (*Spermophilus mohavensis*)

Justification for Selection: The Mohave ground squirrel is vulnerable to habitat loss and fragmentation due to urban development, off-road vehicle use, and agriculture (Zeiner et al. 1990). Expanding infrastructure and several proposed renewable energy projects, especially wind farms and solar installations, could cause further loss of habitat (Leitner 2008).

Distribution & Status: This endemic species, as its name implies, is restricted to the Mojave Desert (Best 1995, Leitner 2008). Its range extends from the southern edge of Owens Lake in Inyo County, south along the eastern base of the Sierra Nevada to the vicinity of Lancaster and Palmdale and as far east as Fort Irwin, Barstow, and Lucerne Valley (Scarry et al. 1996). Its distribution reaches into the foothills of the southern Sierra Nevada to Harper Dry Lakes and Searles Dry Lake (Jameson and Peeters 1988). It is primarily restricted to elevations between 600 m and 1700 m (2000-5600 ft; Scarry et al. 1996).

The Mohave ground squirrel is listed as Threatened under the California Endangered Species Act and there is currently a petition to list the species as Endangered under the federal Endangered Species Act (Harris and Leitner 2004, Leitner 2008). The Bureau of Land Management's (2006) West Mojave Plan was designed to conserve a number of listed and sensitive species, with special emphasis on desert tortoise (*Gopherus agassizii*) and Mohave ground squirrel. The plan established the Mohave Ground Squirrel Conservation Area which covers 6988 km^2 (1,726,772 ac) of land administered by the Bureau of Land Management.

Habitat Associations: The Mohave ground squirrel prefers open desert scrub and woodland communities on flat to gently sloping terrain with alluvial soils (Best 1995, Harris and Leitner 2004). It may also be found in dune habitats and desert washes (P. Leitner, personal communication). It feeds on seeds and vegetative parts of various desert plants and annual grasses, including the fruit of the Joshua tree (Jameson and Peeters 1988). It typically sites its burrows at the base of shrubs for cover (Zeiner et al. 1990).

Spatial Patterns: Harris and Leitner (2004) found that the species can alter the size of its home range based on food availability or as a strategy to search from mates during the breeding season. Median minimum convex polygons were much larger for males 6.73 ha (16.6 ac) than those of females 0.74 ha (1.83 ac; Harris and Leitner 2004). A minimum preserve size of 24,281 ha (60,000 ac) has been calculated (Gustafson 1993).

Mohave ground squirrels exhibit male-biased natal dispersal with the majority of radio-collared males moving greater than 1 km (0.6 mi) with a maximum distance of 6.2 km (3.9 mi), while most females settle within 200-300 m (Harris et al. 1997, Leitner and Leitner 1998, Harris and Leitner 2005).

Conceptual Basis for Model Development: The Mohave ground squirrel prefers open desert scrub and woodland communities but may also be found in dune habitats and desert washes. They are typically associated with alluvial soils on flat to gently sloping terrain. Core areas were defined as greater than or equal to 24,281 ha. Patch size was delineated as greater than or equal to 13 ha but less than 24,281 ha. Dispersal distance we defined as 12.4 km.

Results & Discussion: The Mohave ground squirrel is mostly an orthogonal species with the majority of highly suitable core habitat identified in the intervening valleys in between the targeted Landscape Blocks (Figure 40). The patch size analysis identified 1,265,326 ha of potential core habitat within the study area, though the species is far more restricted than these results indicate. The species has only been recorded in three of the targeted Large Landscape Blocks, including Edwards Air Force Base, China Lake North Range, and China Lake South Range and these areas only partially overlap with areas identified by Leitner (2008) as cores or other known populations. Leitner (2008) identified four core areas that continue to support relatively abundant populations totaling about 1,672 km^2: Coso/Olancha (southern Owens Valley), Little Dixie Wash (southwest of Ridgecrest), Coolgardie Mesa/Superior Valley (north of Barstow), and Edwards Air Force Base. The Mohave ground squirrel is associated with 9 of the linkage planning areas:

Sierra Nevada-China Lake North Range: The linkage partially overlaps two cores areas and one other known population identified by Leitner (2008). The northern branch overlaps portions of the Coso/Olancha (southern Owens Valley) core, which is the northern part of their range. The southern branch overlaps much of the Little Dixie Wash core south of Ridgecrest and the western part of a known population in Indian Wells Valley. Highly suitable contiguous habitat was also identified in the lowlands straddling Highway 395, which correspond with recorded occurrences of this species.

Sierra Nevada-China Lake South Range: The linkage provides extensive potential habitat and overlaps the Little Dixie Wash core area identified by Leitner (2008).

Sierra Nevada-Edwards Air Force Base: The linkage captured fairly contiguous potential core habitat for the species.

China Lake North Range-China Lake South Range: The southern branch of the linkage provides the best potential connection between a known population in Indian Wells Valley that is partially within China Lake North and the Coolgardie Mesa/Superior Valley core area that is just outside of the southeast corner of China Lake South. Habitat in the northern Searles Valley was also identified as highly suitable and the species has been recorded there.

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage was identified as highly suitable habitat for the Mohave ground squirrel and coincides with recorded occurrences of this species. The patch size analysis delineated much of

Figure 40. Potential Habitat for Mojave ground squirrel (Spermophilus mohavensis)

Data Sources:
California Wildlife Habitat Relationships
California Natural Diversity Database
* Dr. Phil Leitner

the habitat in the linkage and on Edwards Air Force Base as potential core areas while a few smaller cores areas and patches were delineated on China Lake South. This linkage may serve to connect the Edwards core area with other known populations identified by Leitner (2008).

China Lake South Range-Twentynine Palms and Newberry Rodman: The Twentynine Palms and Newberry Rodman target area is largely outside of the range of this species. The patch size analysis identified a few smaller core areas in the southern part of China Lake South while most of the potential habitat in the linkage to the north of Interstate 15 was delineated as core habitat, which coincides with the Coolgardie Mesa/Superior Valley core area identified by Leitner (2008). Potential habitat to the south of the freeway was delineated as a large patch.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Highly suitable habitat was identified throughout much of the northern swaths of the linkage and on Edwards Air Force Base which coincides with where the species has been recorded. Most of this habitat was delineated as potential core areas for this species.

Edwards Air Force Base-San Gabriel Mountains: The San Gabriel Mountains are outside of the range of this species but abundant highly suitable habitat was identified in the linkage and on Edwards Air Force Base and the majority of this was delineated as potential core areas for this species.

China Lake South Range-Kingston Mesquite Mountains: This species doesn't range into the Kingston Mesquite target area but potential habitat was identified in all branches of the linkage to the west of the Avawatz Mountains with the southern branch providing the most contiguous habitat.

Round-tailed ground squirrel (*Spermophilus tereticaudus*)

Justification for Selection: The round-tailed ground squirrel is a keystone species due to its extensive burrowing activity. Its burrows provide homes to several other creatures and the burrowing helps to loosen the soil and increase plant productivity. This species is also primarily associated with the lowlands between the targeted areas; an orthogonal species that if maintained can help protect the integrity of the linkage. This species readily crosses roads in high traffic areas but mortality is high.


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Distribution & Status: Round-tailed ground squirrels are restricted to portions of the Mojave, Yuma, and Colorado deserts in Arizona, California, and northern Mexico (Cockrum 1982, Flink 2000), and are found from -60 to 900 m (180 to 2900 ft) in elevation (Zeiner et al. 1990). There are 4 subspecies, 2 of which occur in the southern California deserts (*S.t. tereticaudus* and *S.t. chlorus*). *S.t. tereticaudus* occurs in the study area, while *S.t. chlorus* (Palm Springs round-tailed ground squirrel) is restricted to the Coachella Valley (Hafner et al. 1998).

The primary threats to the round-tailed ground squirrels are habitat loss and fragmentation due to urban and agricultural development (Zeiner et al. 1990). House cats are also major predators at the urban-wildland interface (Dunford 1977).

Habitat Associations: Optimum habitats are desert succulent shrub, desert wash, desert scrub, and alkali desert scrub. Within these habitats, it occupies open, flat areas with finely textured sandy soil, but can also be found in sand dunes (Dunford 1977, Ernest and Mares 1987, Jameson and Peeters 1988, Flink 2000, Zeiner et al. 1990). It prefers desert scrub communities with a diversity of shrub species, while habitats dominated by creosote bush had a lower density of squirrels (Dunford 1977).

Spatial Patterns: Round-tailed ground squirrels are semi-colonial but they keep and defend individual burrows (Dunford 1977, Flink 2000). Adult home ranges average 0.74 ha (1.85 ac), and may shift to encompass necessary resources (Zeiner et al. 1990). Densities varied from 25-225 per ha (10-100 per ac), and are highest when juveniles emerge (Zeiner et al. 1990).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Round-tailed ground squirrels prefer desert scrub, alkali desert scrub, desert succulent scrub, and desert wash habitats. Within these habitats, they occupy open and generally flat sandy terrain below 900 m in elevation. Core areas were defined as $\geq$ 20 ha (50 ac). Patch size was defined as $\geq$ 0.81 ha (2 ac) and < 20 ha. Dispersal distance was estimated at 12.4 km after *S. mohavensis* as movement data are lacking for this species.

Results & Discussion: This species is restricted to the eastern part of the study area. The majority of potential breeding and move-through habitat was identified in the lowlands in between the targeted landscape blocks with very little core habitat delineated in the target areas (Figure 41). The patch configuration analysis (Figure 42) suggests that the majority of potentials core and patches to the north of the Mojave River are within the dispersal distance defined for this species, as are those to the south of the river but distances between these groups are separated by distances too great for the species to disperse.

China Lake South Range-Kingston Mesquite Mountains: This species doesn't range into the China Lake South block but potential breeding and move through habitat was identified in the eastern part of the linkage with the most potential habitat captured in the northern and southern branches and along the Amargosa River and Salt Creek.

Kingston Mesquite Mountains-Mojave National Preserve: Potential breeding and move-through habitat were delineated along the Amargosa River and Salt Creek providing the best connection to a relatively large core area in Mojave National Preserve.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The southern strand of the linkage captured a small potential core area and move-through habitat that is fairly contiguous to a potential core area on Twentynine Palms.

Mojave National Preserve-Stepladder Turtle Mountains: The potential core in the eastern part of Mojave National Preserve appears to be separated from the core in the Stepladder Turtle block by distances to great for the species to disperse. However, potential move-through habitat in the strand of the linkage that follows Homer Wash may provide a connection between core areas along Piute Wash and those in the Stepladder Turtle block.

Stepladder Turtle Mountains-Palen McCoy Mountains: The western strand of the linkage captured a potential core area and move-through habitat may that may serve this species.

Palen McCoy Mountains-Whipple Mountains: Very small potential cores were identified in both of the target areas. Larger areas of potential breeding habitat were captured in the Vidal Valley in the eastern part of the linkage, while the central branch of the linkage was almost all identified as potential move through habitat.

Joshua Tree National Park-Palen McCoy Mountains: Both the northern and central branches of the linkage captured potential move-through habitat and may serve to connect small potential cores in the two target areas.

Joshua Tree National Park-Chocolate Mountains: The eastern strand of the linkage captured a few potential core areas and fairly contiguous move-through habitat.

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Figure 41. Potential Habitat for Round-tailed ground squirrel (Spermophilus tereticaudus)

Data Sources:
California Wildlife Habitat Relationships
California Natural Diversity Database

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Figure 42. Patch Configuration for Round-tailed ground squirrel (Spermophilus tereticaudus)

Palen McCoy Mountains-Chocolate Mountains: Potential cores and patches interspersed with move-through habitat were captured in the Chuckwalla Valley and in the southern part of the linkage.

Palen McCoy Mountains-Little Picacho: No breeding habitat was delineated in the Little Picacho block but the western strand of the linkage captured a fair amount of potential core habitat.

Chocolate Mountains-Little Picacho: The southern part of the linkage contains some large potential core areas interspersed with move-through habitat.

Little pocket mouse (*Perognathus longimembris longimembris*)

Justification for Selection: The little pocket mouse uses fine sandy soils in bajadas and river floodplains. Thus, maintaining the functionality of the sand source and transport systems is crucial to sustaining viable populations of this species (W. Spencer and T. Metcalf pers. comm., CVAG 2004). Many small mammals are also very reluctant to cross roads (Merriam et al. 1989, Diffendorfer et al. 1995, Brehme 2003).

Distribution & Status: In southern California, this species is distributed throughout the Los Angeles Basin and Mojave Desert south to Mexico, at elevations ranging from sea level to 1,700 m (5,600 ft; Zeiner et al. 1990). Five subspecies of *P. longimembris* are recognized within this region: *P. l. longimembris* (little pocket mouse), *P. l. bangsi* (Palm Springs pocket mouse), *P. l. brevinasus* (Los Angeles pocket mouse), *P. l. internationalis* (international pocket mouse), and *P. l. Pacificus* (Pacific pocket mouse; Williams et al. 1993, Swei et al. 2003).

The little pocket mouse is recognized as a Species of Special Concern by the California Department of Fish and Game. Threats include agricultural and urban development, transportation infrastructure, off-road vehicle use, illegal trash dumping, and domestic animal predators (CVAG 2004).

Habitat Associations: The species inhabits desert scrub, desert riparian, desert wash, sagebrush, and sparse sage scrub habitats in fine, sandy soils, which are preferred for burrowing (Hall 1946, Zeiner et al. 1990, Swei et al. 2003). They may also be encountered on gravel washes and on stony soils (Beatley 1976, Miller and Stebbins 1964, Zeiner et al. 1990). Their habitat typically consists of level to gently sloping topography (CVAG 2004).

Spatial Patterns: In Joshua Tree National Park, Chew and Butterworth (1964) found home range sizes ranged from 0.12 to 0.56 ha (0.30 to 1.4 ac; Zeiner et al. 1990). Much larger home ranges were found in Nevada, with males averaging 0.29 to 1.88 ha (0.7 to 4.7 ac) and females averaging 0.48 to 3.09 ha (1.2 to 7.6 ac; Maza et al. 1973, Zeiner et al. 1990). O'Farrell (1978) found seasonal differences in home range size, from 0.28 ha (0.69 ac) in spring to 0.80 ha (1.9 ac) in fall. Density estimates vary widely. Chew and Butterworth (1964) found maximum densities of 1.7/ha (0.7/ac) in creosote scrub (Zeiner et al. 1990). More recent studies of Palm Springs pocket mouse found much higher densities, reaching 60 to 200 individuals per hectare in creosote scrub habitat (Spencer et al. 2001, Swei et al. 2003). Movement and dispersal estimates are lacking for the local subspecies, but the Pacific pocket mouse has been observed to move up to 87 m (285 ft; Spencer et al. 2000a, 2000b).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This species prefers sparsely vegetated communities on flat to gently sloping terrain at elevations ranging from sea level to 1,700 m. Potential core areas were defined as ≥ 8 ha (20 ac). Patch size was classified as ≥ 0.3 ha (0.7 ac) but less than 8 ha. Dispersal distance was defined as 174 m (571 ft), twice the recorded distance of Pacific pocket mice.

Results & Discussion: The suitability model identified extensive suitable habitat in the lowlands throughout the planning area, much of which was delineated as potential core areas for this species (Figure 43). While the species does not range into the San Bernardino or San Gabriel Mountains, the range map is not completely reliable, as the species occurs outside its boundaries in the western Mojave (including in Tehachapis and southern SN) and farther up the Owens Valley (W.Spencer, personal communication). Potential core areas were identified in all but five of the targeted landscape blocks (Sierra Nevada, San Bernardino, San Gabriel, Whipple Mountains, and Little Picacho) but the majority of core habitat lies in the lowlands in between the targeted landscape blocks. As such, this species may be associated with all 22 linkage planning areas. The great majority of potential habitat cores and patches are within the dispersal distance defined for this species (figure not shown), though barriers may exist between habitat patches.

Sierra Nevada-China Lake North Range: While all branches of the linkage contain some potential habitat for this species, only the southern branch provides substantial contiguous habitat. Like the Mohave ground squirrel, this species also benefits from a north-south connection linking the northern and southern branches.

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by badger provides the most highly suitable contiguous habitat for the little pocket mouse.

Sierra Nevada-Edwards Air Force Base: The southern part of the linkage contains fairly contiguous potential habitat for the little pocket mouse.

China Lake North Range-China Lake South Range: The most highly suitable habitat in this area was identified around Searles Dry Lake, which partially overlaps the northern branches of the Linkage but the southern branch provides the most contiguous connection between large core areas in the southern part of both landscape blocks.

China Lake South Range-Edwards Air Force Base: All but the northern branch of the Linkage provides fairly contiguous highly suitable habitat for the little pocket mouse. The patch size analysis identified the majority of habitat in the linkage and on Edwards Air Force Base as potential core areas for this species with smaller cores and patches delineated on China Lake South.

China Lake South Range-Twentynine Palms and Newberry Rodman: The three swaths of the linkage delineated by the focal species least cost corridor analyses provide the most contiguous highly suitable habitat for this species. The eastern branch also

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Figure 43. Potential Habitat for Little pocket mouse (Perognathus longimembris)

captured some large potential core areas but they are separated by areas of non-habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage provides the most contiguous habitat for the little pocket mouse and much of this was delineated as potential core areas for this species.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but abundant highly suitable core habitat was identified in the linkage and on Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern part of the linkage provides the most contiguous highly suitable core habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains but a fair amount of suitable habitat exists in the Twentynine Palms and Newberry Rodman block. The central and eastern branches of the Linkage contain potential habitat in the lowlands but there are large areas of non-habitat near the Twentynine Palms block in all branches of the linkage but the swath that follows Pipes Wash.

China Lake South Range-Kingston Mesquite Mountains: Most of the lowland areas in the linkage were delineated as potential habitat for this species but the southern branch provides the most contiguous habitat for this species.

Kingston Mesquite Mountains-Mojave National Preserve: The branch of the linkage through Shadow Valley provides highly suitable habitat that is contiguous with delineated core areas in both target areas. Fairly contiguous habitat was also identified in the far eastern branch and along the Amargosa River and Salt Creek.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage contain potential habitat with the most contiguous suitable core habitat in the lowlands surrounding the Bristol Mountains. Suitable habitat is scarcer through the Bristol Mountains where small patches and stepping stones of suitable habitat were identified. Fairly contiguous habitat was also identified along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain some potential little pocket mouse habitat through the gentle terrain preferred by this species. However, the branch of the linkage delineated by badger, kit fox, and tortoise captured the only contiguous suitable habitat between potential core areas in the two targeted landscape blocks.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage contain significant potential habitat for this species but the western branch likely serves the species better by linking large potential core areas within the two landscape blocks.

Palen McCoy Mountains-Whipple Mountains: There is very little potential habitat for the little pocket mouse in the Whipple Mountains and habitat is largely restricted to the northern part of the Palen McCoy landscape block but the central branch of the linkage captured abundant suitable habitat for this species.

Joshua Tree National Park-Palen McCoy Mountains: The two northern most branches of the linkage cross the Palen Valley and contain the most contiguous suitable habitat for the little pocket mouse, linking core habitat in the Pinto Basin of Joshua Tree with core areas in the Palen and Rice Valleys in the Palen-McCoy landscape block. The southern branch of the Linkage contains some scattered habitat patches but they aren't contiguous with any pocket mouse habitat within the target areas.

Joshua Tree National Park-Chocolate Mountains: Only the eastern most branch delineated by badger, kit fox, and desert tortoise provides a fairly contiguous connection of highly suitable habitat between the two targeted landscape blocks, stretching from core habitat in the Chocolate Mountains down into the Chuckwalla Valley and up into the Pinto Basin core area in Joshua Tree.

Palen McCoy Mountains-Chocolate Mountains: All but the northern branch of the linkage contains potential habitat for this species in the lowlands surrounding the Chuckwalla Mountains. The southern part of the linkage captured the most contiguous suitable habitat and links potential cores areas within the two landscape blocks.

Palen McCoy Mountains-Little Picacho: The branch of the linkage delineated by badger and kit fox provides the most contiguous potential habitat between targeted areas for the little pocket mouse.

Chocolate Mountains-Little Picacho: The southern part of the linkage contains the most contiguous highly suitable core habitat for the little pocket mouse.

Chocolate Mountains-East Mesa: All branches of the linkage contain highly suitable habitat for this species but it is restricted to the lowlands on either side of the Algodones Dunes which create a formidable barrier for this species of roughly 4 to 11 km wide. Highly suitable contiguous habitat was identified in the lowlands on either side of the dunes for their entire length.

Desert pocket mouse (*Chaetodipus penicillatus*)

Justification for Selection: The desert pocket mouse is a nocturnal granivore adapted for existence in extreme arid environments. This species is vulnerable to loss or alteration of this ecosystem.

Distribution & Status: The desert pocket mouse is abundant in suitable habitat in North American deserts from Baja California and Mexico into southeastern California, southern Nevada and Utah, and through southern Arizona to southwestern New Mexico (Linzey et al. 2008). In California, it occurs in 3 disjunct populations: one population in Death Valley National Park, a second from southeastern Kern and northeastern Los Angeles Counties to central San Bernardino County, and a third in the southeast corner of California from central Riverside County east to the Colorado River and south to the border of Mexico (Zeiner et al. 1990).

Habitat Associations: This pocket mouse is a locally common resident of desert habitats including desert wash, desert succulent shrub, desert scrub, and alkali desert scrub, generally favoring fine-grained substrates such as those found in alkali playas and sand dunes (Stevens and Tello 2009). It excavates burrows in silty, sandy, or gravelly soil at lower elevations ranging from below sea level (Death Valley) to 820 m (2700 ft; Zeiner et al. 1990). It uses burrows for refuges, seed storage, and neonatal care. Reynolds and Haskell (1949) found that ungrazed perennial grass cover favored populations of pocket mice. The desert pocket mouse is generally associated with moderate canopy cover, though experimental removal of canopy did not result in fewer desert pocket mice (Rosensweig 1973, Zeiner et al. 1990).

Spatial Patterns: Individuals are solitary and home ranges do not overlap (Jones 1985). Population density has been estimated at 0-8.5 individuals per hectare (Vaughan 1976, Linzey et al. 2008). Vaughan (1976) recorded average home range size as 855 m^2 (0.21 ac; Vaughan 1976), while another study found home ranges sizes between 1,214-2,430 m^2 (0.30-0.60 ac; Reynolds and Haskel 1949, Mantooth and Best 2005). Brown and Zeng (1989) estimated lifetime dispersal distance as 150 m.

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. The desert pocket mouse is abundant in desert dry wash, desert riparian, and alkali desert scrub habitats below 820 meters in elevation (2,690 feet). Core areas were defined as greater than or equal to 6 ha. Patch size was classified as greater than or equal to .5 ha but less than 6 ha. Dispersal distance was defined as 300 m.

Results & Discussion: The desert pocket mouse has a restricted distribution in the planning area. Most potential core habitat was identified outside of the targeted landscape blocks (Figure 44). All potential cores and patches within the known range of the species are within the dispersal distance defined for the species (Figure 45).

China Lake South Range-Edwards Air Force Base: This species doesn't range into the China Lake South block but abundant potential habitat was identified in roughly the southern half of the linkage and on Edwards Air Force Base. The patch size analysis identified a large potential core area in the linkage and three other good size cores in the northwest, northeast and south-central part of Edwards with smaller patches of highly suitable habitat in between.

China Lake South Range-Twentynine Palms and Newberry Rodman: Both of the targeted landscape blocks are outside of the range of this species but highly suitable core habitat was identified in all branches of the linkage and along the Mojave River connecting the various branches of the linkage.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Large potential cores areas of highly suitable habitat were identified in the northern swath of the linkage but the western 3 or so km of land in the preliminary linkage and the southeastern part of Edwards were identified as non-habitat. The desert pocket mouse required an addition to the northern branch to reach the potential core in the northeast corner of the Edwards.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Both of the targeted landscape blocks are outside of the range of this species but potential habitat was identified along the Mojave River.

Joshua Tree National Park-Chocolate Mountains: Joshua Tree is outside of the species range but extensive potential breeding habitat was identified in the Chocolate Mountains. While all branches of the Linkage contain some potential habitat for the desert pocket mouse, the eastern branch provides the most contiguous highly suitable core habitat.

Palen McCoy Mountains-Chocolate Mountains: All but the southern tip of the Palen landscape block is outside of the species range. All branches of the linkage contain some potential habitat with most in the lowlands surrounding the Chuckwalla Mountains. The southern part of the linkage captured the most contiguous highly suitable core habitat but there is a constriction around the west of Ford Dry Lake.

Chocolate Mountains-Little Picacho: The southern part of the linkage provides the most highly suitable contiguous habitat between the targeted landscape blocks.

Chocolate Mountains-East Mesa: Similar to the little pocket mouse, all branches of the linkage contain highly suitable habitat but it is restricted to the lowlands on either side of the Algodones Dunes, which were delineated as non-habitat. Highly suitable contiguous habitat was identified in the lowlands on either side of the dunes for their entire length.

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Figure 44. Potential Habitat for Desert pocket mouse (Chaetodipus penicillatus)

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Figure 45. Patch Configuration for Desert pocket mouse (Chaetodipus penicillatus)

Southern grasshopper mouse (*Onychomys torridus*)

Justification for Selection: The southern grasshopper mouse typically exists at low population densities throughout its range rendering it particularly vulnerable to habitat loss and fragmentation (Egoscue 1960, Horner and Taylor 1968, Frank and Henske 1992). Unlike most of its relatives that forage primarily on seeds, this species is insectivorous and carnivorous.

Distribution & Status: The southern grasshopper mouse inhabits the low deserts of the southwestern United States, from central Nevada and southern Utah south through central Mexico, including the Baja Peninsula (Jameson and Peeters 1988, Linzey 2008b). In California, it occurs in sandy areas of the Mojave and Sonora deserts and parts of the San Joaquin Valley.

The southern grasshopper mouse is identified as Species of Special Concern by the California Department of Fish and Game.

Habitat Associations: The southern grasshopper mouse inhabits alkali desert scrub, desert scrub, succulent scrub, desert wash and riparian habitats with friable soils for digging but may also occur in coastal scrub, mixed chaparral, sagebrush, low sage, and bitterbrush habitats (Zeiner et al. 1990). Stevens and Tello (2009) found it associated with yucca woodlands, Joshua tree woodlands, and blackbrush scrub in the Mojave Desert.

Spatial Patterns: This highly territorial species occurs at very low densities (Horner and Taylor 1968). In New Mexico, home range size for males was 3.2 ha (7.8 ac) and 2.4 ha (5.9 ac) for females (Blair 1943, CDFG 1990). Chew and Chew (1970) found much larger home range sizes in southeast Arizona, with an average of 11.45 ha (28 acres) (Zeiner et al. 1990). Brown and Zeng (1989) estimated lifetime dispersal distance as 132 m.

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. The southern grasshopper mouse may be found in alkali desert scrub, desert scrub, grasslands, sagebrush, pinyon-juniper, riparian, and chaparral habitats. Core areas were defined as greater than or equal to 142 ha. Patch size was classified as greater than or equal to 6.4 ha but less than 142 ha. Dispersal distance was defined as 264 m.

Results & Discussion: A vast amount of potential habitat was identified for the grasshopper mouse in the study area, mostly in the scrub dominated lowlands and much of this was delineated as potential core areas for this species (Figure 46). Virtually all of the delineated cores and patches are within the dispersal distance defined for this species (Figure 47).

Sierra Nevada-China Lake North Range: All branches of the linkage contain some highly suitable habitat for this species but the southern branch provides the best connection between potential cores areas within the targeted landscape blocks. Like the Mohave ground squirrel and the little pocket mouse, the grasshopper mouse also benefits from a north-south connection in between the two target areas.

Sierra Nevada-China Lake South Range: The linkage captures potential core habitat that is fairly contiguous with core areas in the southern part of China Lake South.

Sierra Nevada-Edwards Air Force Base: The linkage captured highly suitable potential core habitat for this species.

China Lake North Range-China Lake South Range: Highly suitable habitat was identified in the branch that passes through Searles Dry Lake and in the southern branch through Searles Valley. The southern branch provides the most direct connection to large areas of highly suitable core habitat in the targeted landscape blocks.

China Lake South Range-Edwards Air Force Base: The majority of habitats in the linkage and on Edwards Air Force Base were delineated as highly suitable potential core areas with smaller cores and patches identified on China Lake South.

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage contain potential habitat for this species but the branches delineated by the focal species least cost corridors contain the most contiguous highly suitable habitat between the two target areas. Habitat was also identified along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage contains the most highly suitable contiguous habitat between the target areas and most of this habitat was delineated as potential core areas.

Edwards Air Force Base-San Gabriel Mountains: Abundant highly suitable core habitat was identified in the linkage and on Edwards Air Force Base with small patches and cores in the San Gabriels restricted to the low elevation foothills and valleys

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: All branches of the linkage contain some potential habitat but the southernmost branch provides the most contiguous highly suitable core habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: A fair amount of suitable habitat exists in the Twentynine Palms and Newberry Rodman block but habitat in the San Bernardinos is restricted to the low elevation foothills. All branches of the linkage contain highly suitable contiguous habitat in the lowlands but there are large areas of non-habitat near the Twentynine Palms block in all branches of the linkage but the swath that follows Pipes Wash.

Figure 46. Potential Habitat for Southern grasshopper mouse (*Onychomys torridus*)

Data Sources:
California Wildlife Habitat Relationships
California Natural Diversity Database

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Figure 47. Patch Configuration for Southern grasshopper mouse (Onychomys torridus)

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage contain some potential habitat with the southern strand providing the most contiguous habitat.

Kingston Mesquite Mountains-Mojave National Preserve: The branch of the linkage through Shadow Valley provides highly suitable core habitat that is contiguous with large core areas in both target areas. The far eastern branch also contains fairly contiguous habitat as does the strand along Salt Creek.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage contain fairly contiguous potential habitat in the lowlands surrounding the Bristol Mountains but habitat patches are smaller and more restricted through the higher elevations. The Mojave River also provides a fairly contiguous connection between the target areas.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain some potential habitat for this species through the flats and lowlands with some scattered patches of habitat in the more mountainous terrain. The swath of the linkage that follows Homer Wash captured the most highly suitable contiguous.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both major branches of the linkage contain significant potential habitat for the grasshopper mouse but the western branch serves the species better by linking large potential core areas within the two landscape blocks.

Palen McCoy Mountains-Whipple Mountains: There is very little potential habitat for the little grasshopper mouse in the Whipple Mountains and habitat is largely restricted to the northern part of the Palen McCoy landscape block but the central branch of the linkage captured contiguous highly suitable habitat for this species.

Joshua Tree National Park-Palen McCoy Mountains: The model identified the two northern branches as the most suitable habitat for the grasshopper mouse, linking potential core habitat in the Pinto Basin of Joshua Tree with core areas in the Palen and Rice Valleys in the Palen-McCoy landscape block.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain suitable habitat for the grasshopper mouse but only the eastern most strand provides a fairly contiguous connection of potential core habitat between the two targeted landscape blocks.

Palen McCoy Mountains-Chocolate Mountains: All branches of the linkage contain some potential habitat for the grasshopper mouse, mostly in the lowlands surrounding the Chuckwalla Mountains. The southern part of the linkage provides the most contiguous highly suitable core habitat and will likely serve the needs of this species.

Palen McCoy Mountains-Little Picacho: All branches of the linkage captured potential habitat for this species through the lowlands and valleys but the swath delineated by badger and kit fox provides the most contiguous highly suitable habitat for the grasshopper mouse.

Chocolate Mountains-Little Picacho: The southern part of the linkage provides the most extensive highly suitable contiguous habitat between the targeted landscape blocks. Contiguous highly suitable habitat was also identified in the eastern half of the northern branch along the Colorado River.

Chocolate Mountains-East Mesa: Like many other species, highly suitable habitat for the grasshopper mouse is restricted to the lowlands on either side of the Algodones Dunes, which were largely delineated as unsuitable. Highly suitable contiguous habitat was identified in the lowlands on either side of the dunes for their entire length.

Justification for Selection: The pallid bad is a good indicator species of environmental conditions due to its small size, movement patterns and long life span (Fenton 2003). This species is also an important predator of desert insects and are indirect pollinators of several species of cactus (Verts and Carraway 1998).

Distribution & Status: The pallid bat has a wide geographic distribution ranging throughout western North America, from British Columbia 's southern interior, south to Mexico, and east to Texas (Rambaldini 2005). It occurs throughout low elevation areas of California being absent from the high Sierra Nevada from Shasta to Kern counties, and the northwestern corner of the state from Del Norte and western Siskiyou counties to northern Mendocino County (Zeiner et al. 1990). It is found throughout the desert regions, with greater abundances in the Sonoran Ecoregion (Orr 1954). Its elevation range is from below sea level to 240 m (Baker et al. 2008).

The pallid bat is listed as a Species of Special Concern by the California Department of Fish and Game and as Sensitive by the Bureau of Land Management and the Forest Service (CDFG 2011). It is particularly sensitive to disturbance of its roosting sites, which they will abandon if distressed (Zeiner et al. 1990). Pesticides have also impacted populations by reducing prey availability and diversity in foraging areas (Miller 2002, Arroyo and Gramant 2008). Other threats include habitat loss and alteration to hydrological systems and riparian habitats (Hinman and Snow 2003, Yolo Natural Heritage Program 2009).

Habitat Associations: The pallid bat is a highly social species roosting in groups of 20 or more individuals (Trune and Slobodchikoff 1976 and 1978, Zeiner et al. 1990). They prefer rocky outcrops, cliffs, and crevices in grassland, scrub, woodland and forest habitats but they forage in more open habitats (Yolo Natural Heritage Program 2009). In desert ecosystems, riparian habitats are crucial foraging and roosting habitat (Williams et al. 2006). They will also utilize orchards, vineyards, and cropland for foraging if in close proximity to appropriate roosting sites (Yolo Natural Heritage Program 2009). Day roostings sites include caves, crevices, mines, hollow trees, and even buildings but night roosts may be in more open sites (Zeiner et al. 1990). Roosts are typically near a water source (Weber and Olson 2009).

Spatial Patterns: Baker et al. (2008) found foraging area ranged from 0.68 to 8.66 km^2

(168-2140 ac) with an average of 3.45 km^2 (853 ac). The longest distance moved was 4288 m (2.7 mi; Baker et al. 2008). They also make local movements to hibernation sites, which are often located near summer day roosts (Hermanson and O'Shea 1983).

Conceptual Basis for Model Development: The pallid bat will use many habitats including desert, grasslands, woodlands, and mixed conifer forest up to 2809 m in elevation. Cores areas were defined as greater than or equal to 8625 ha. Patch size was classified as greater than or equal to 1.36 km^2 (136 ha) but less than 86.25 km^2 (8625 ha). Dispersal distance was defined as 8.58 km, twice the longest distance moved.

Results & Discussion: Much of the study area was identified as potential core habitat for pallid bat with the most highly suitable habitat in the rocky terrain this species prefers for roosting and along riparian routes which it uses for foraging (Figure 48).

Sierra Nevada-China Lake North Range: All branches of the linkage contain fairly contiguous potential core habitat for pallid bat.

Sierra Nevada-China Lake South Range: The entire linkage was identified as potential core habitat for this species.

Sierra Nevada-Edwards Air Force Base: This linkage also captured fairly contiguous potential habitat for this species.

China Lake North Range-China Lake South Range: All branches of the linkage contain highly suitable contiguous habitat for the pallid bat.

China Lake South Range-Edwards Air Force Base: Both landscape blocks and all branches of the linkage contain fairly contiguous potential habitat for the pallid bat with the most highly suitable habitat delineated in the China Lake South Range.

China Lake South Range-Twentynine Palms and Newberry Rodman: The majority of lands in the linkage and landscape blocks were identified as highly suitable habitat for this species. Habitat along the Mojave River also serves this species as foraging habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Fairly contiguous highly suitable habitat was identified throughout the linkage and landscape blocks with the most highly suitable habitat identified in the southern branch of the linkage and along the Mojave River.

Edwards Air Force Base-San Gabriel Mountains: Most land in the linkage was identified as medium to highly suitable habitat and delineated as potential cores for this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: All branches of the linkage contain fairly contiguous suitable habitat with the northern branch providing the most highly suitable core habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Extensive highly suitable contiguous habitat was identified throughout the linkage and in the Twentynine Palms and Newberry Rodman Mountains but is more restricted in the San Bernardino

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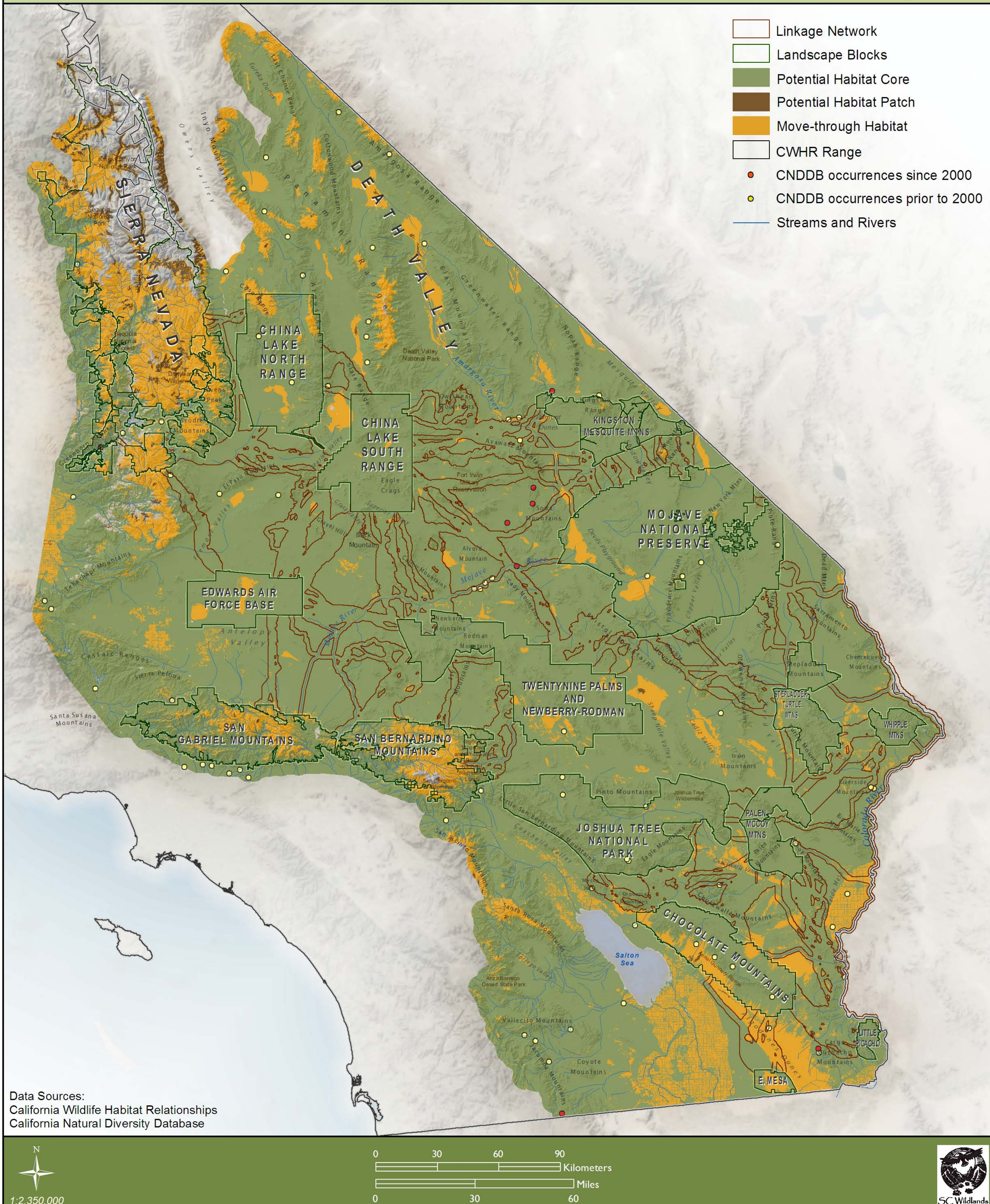
Figure 48. Potential Habitat for Pallid Bat (Antrozus pallidus)



Mountains.

China Lake South Range-Kingston Mesquite Mountains: Virtually all land in the linkage and the two target areas was identified as highly suitable habitat and delineated as core areas for this species.

Kingston Mesquite Mountains-Mojave National Preserve: All branches of the linkage contain contiguous suitable habitat for the pallid bat with the two western branches and the branches through the Clark Mountain Range providing the most highly suitable habitat for this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Virtually all of the land in the linkage and the two target areas was identified as medium to highly suitable habitat for the pallid bat and was thus delineated as potential core areas. This species has been recorded all along the Mojave River (CDFG 2011), which may be used as foraging habitat between the two target areas.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage and most of the land in the two target areas were identified as medium to highly suitable habitat for pallid bat. The branch delineated by bighorn sheep and the easternmost branch containing the most highly suitable contiguous habitat.

Stepladder Turtle Mountains-Palen McCoy Mountains: All of the land in the linkage and the two target areas was identified as medium to highly suitable habitat and delineated as potential breeding habitat for the pallid bat.

Palen McCoy Mountains-Whipple Mountains: The suitability model delineated medium to highly suitable habitat throughout the Linkage and the two target areas. The southern branch through the Riverside and Big Maria Mountains captured the most contiguous highly suitable habitat and the species has been recorded in this branch (CDFG 2011).

Joshua Tree National Park-Palen McCoy Mountains: The model identified highly suitable core habitat for pallid bat in all three branches of the linkage.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain suitable habitat for the pallid bat. The central branch provides the most contiguous connection among highly suitable habitats.

Palen McCoy Mountains-Chocolate Mountains: Virtually all land within the linkage and target areas was identified as medium to highly suitable core habitat. The northernmost branch provides the most contiguous highly suitable habitat but highly suitable habitat was also captured along Corn Springs Wash where the species has been recorded (CDFG 2011).

Palen McCoy Mountains-Little Picacho: The suitability model identified virtually all land within the linkage and two target areas as medium to highly suitable core habitat.

Chocolate Mountains-Little Picacho: All branches of the linkage contain medium to highly suitable habitat for pallid bat, as does both of the target areas. The branches of the linkage delineated by bighorn sheep and the land facets captured the most highly suitable contiguous habitat.

Chocolate Mountains-East Mesa: All land within the linkage was identified as potential core or move-through habitat and this species has been recorded in the eastern branch of the linkage (CDFG 2011).

Burrowing owl (*Athene cunicularia*)

Justification for Selection: Burrowing owls are sensitive to habitat loss and fragmentation from agricultural and urban land uses (Grinnell and Miller 1944, Zarn 1974, Remsen 1978, Zeiner et al. 1990). They are also particularly vulnerable to roadkill (Zeiner et al. 1990). Once widespread in California, its distribution is now highly localized and fragmented.

Distribution & Status: The species is broadly distributed across western North America and down into Central and South America to Tierra del Fuego, and on Cuba, Hispaniola, the northern Lesser Antilles islands, Bahama Islands, and on a few islands off the west coast of Mexico (American Ornithologists' Linkage 1998). It was formerly common in appropriate habitat throughout California, excluding the northwest coastal forests and high mountains. Although it has been recorded at elevations of up to 1615 m (5300 ft), they are primarily associated with low-elevation valleys (Zeiner et al. 1990, USFS 2002).

The burrowing owl is listed as a Bird of Conservation Concern by the US Fish and Wildlife Service, as a Species of Special Concern by the California Department of Fish and Game, and as Sensitive by the Bureau of Land Management (CDFG 2011). The species is experiencing precipitous population declines throughout most of the western United States, and has disappeared from most of its historical range in California. Nearly 60% of California burrowing owl colonies that existed in the 1980s were gone by the early 1990s (DeSante and Ruhlen 1995, DeSante et al. 1997, USFS 2002).

Habitat Associations: Burrowing owls prefer open, dry grassland and desert scrub habitats, in areas with little or no vegetation but may also inhabit open shrub stages of pinyon-juniper and ponderosa pine habitats (Small 1994). They hunt in open habitats (Haug and Oliphant 1990). They may also occupy habitat on the fringe of agricultural areas (including pastures and untilled margins of cropland), or in other edge habitats such as the margins of airports, golf courses, and roads (Millsap and Bear 1988, Haug et al. 1993, USFS 2002), though they are relatively scarce in these environments. Key habitat characteristics include open, well-drained terrain; short, sparse vegetation; and underground burrows. Throughout their range they depend on burrows excavated by fossorial mammals and reptiles for roosting and nesting (Karalus and Eckert 1987, USFS 2002). Though they've also been documented using pipes, culverts, or other tunnel like structures, and nest boxes where burrows are scarce (Robertson 1929, Zeiner et al. 1990, Haug et al. 1993).

Spatial Patterns: Estimated home range sizes vary drastically, from 0.04 to 481 ha (0.99 to 1189 ac; Thomsen 1971, Haug and Oliphant 1990). Thomsen (1971) calculated home range sizes at Oakland Airport from 0.04 to 1.6 ha (0.99 to 3.95 ac). Grant (1965) reported home ranges sizes from 4.9 to 6.5 ha (12.11 to 16.06 ac), while Butts (1973) found home ranges up to 240 ha (593.7 ac). The largest home range recorded for this species is 481 ha (1189 ac) in Saskatchewan (Haug and Oliphant 1990). Breeding pairs in California are presumed to require a minimum of 2.6 ha (6.42 ac) of contiguous habitat (Zeiner et al. 1990, USFS 2002). Natal dispersal distances up to 30 km (18.64 mi) have been reported (Haug et al. 1993, USFS 2002).

Conceptual Basis for Model Development: This species prefers the open terrain of desert scrub communities below 1615 m (5300 ft) in elevation. Core areas were defined as $\geq$ 3000 ha (7413.16 ac). Patch size was defined as greater than or equal to 6 ha (14.83 ac) but less than 3000 ha. Dispersal distance was defined as 60 km (37.28 mi).

Results & Discussion: Extensive highly suitable habitat was identified for burrowing owl throughout the low-elevation valleys and flatlands in the planning area and most suitable habitats were delineated as potential core areas (Figure 49). All of the targeted landscape blocks contain potential core areas for burrowing owl with the exception of the Sierra Nevada, San Bernardino, San Gabriel, Whipple, and Little Picacho blocks. Distances among all core areas and patches are within the dispersal distance of this species (figure not shown), although barriers to movement may exist between suitable habitat patches. Although the species doesn't occur in all of the landscape blocks, they do have the potential to occur in all linkage planning areas.

Sierra Nevada-China Lake North Range: All branches of the linkage contain some highly suitable habitat for burrowing owl but the southern branch provides the most contiguous potential core habitat, which connects to an extensive core area delineated in the south western portion of the China Lake North Range block. Based on the results of the analyses and recorded occurrences of this species, it appears burrowing owl would also benefit from a north-south connection.

Sierra Nevada-China Lake South Range: The branch delineated by badger provides the most highly suitable contiguous habitat for this species and the burrowing owl has been recorded in this area (CDFG 2011).

Sierra Nevada-Edwards Air Force Base: The southern part of the linkage through Fremont Valley captured highly suitable core habitat that is contiguous with habitats on Edwards and the burrowing owl has been recorded in this branch (CDFG 2011).

China Lake North Range-China Lake South Range: The southern branch provides the most contiguous habitat linking large potential cores areas in the two target areas.

China Lake South Range-Edwards Air Force Base: Virtually all land within the linkage was identified as highly suitable core habitat with gaps in habitat through the Gravel Hills. The branch delineated by kit fox provides the most highly suitable habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage contain potential habitat for burrowing owl but the branches delineated by

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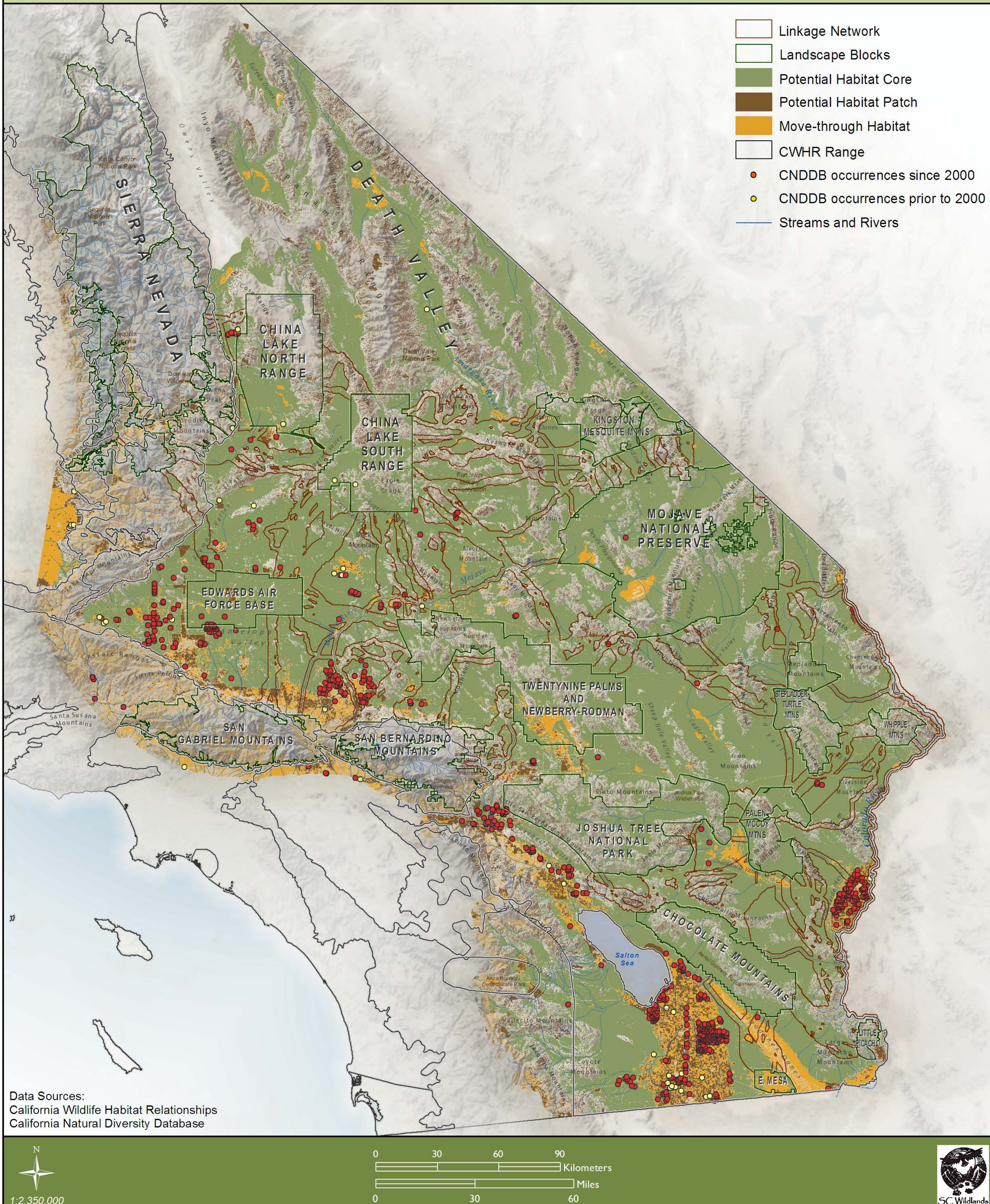
Figure 49. Potential Habitat for Burrowing owl (*Athene cunicularia*)



badger, kit fox and desert tortoise providing the most contiguous highly suitable habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage captured fairly contiguous highly suitable core habitat.

Edwards Air Force Base-San Gabriel Mountains: While the species doesn't range into the San Gabriel Mountains, extensive habitat was identified on Edwards Air Force Base and in the linkage.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The branch delineated by badger provides the most contiguous habitat for this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains but extensive habitat was identified in the Twentynine Palms and Newberry Rodman block. All branches captured some highly suitable habitat for burrowing owl through the lowlands and flats preferred by this species with the swath along Pipes Wash providing the most direct connection to highly suitable habitat on Twentynine Palms.

China Lake South Range-Kingston Mesquite Mountains: The southern swath delineated by desert tortoise provides the most contiguous habitat between target areas. Habitat along Salt Creek and the Amargosa River was also identified as highly suitable.

Kingston Mesquite Mountains-Mojave National Preserve: The swaths of the linkage delineated by badger and kit fox both captured highly suitable contiguous habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The two southern swaths of the linkage provide the most contiguous habitat for this species though habitat is more restricted through the Bristol Mountains. Potential habitat was also identified along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain potential habitat for burrowing owl through the lowlands and flats preferred by this species. The swath delineated by badger, kit fox, and desert tortoise captured the most contiguous highly suitable habitat between cores within the target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: The majority of land in the linkage was identified as highly suitable for burrowing owl but the western branch provides the best connection between large potential cores in the two targeted areas.

Palen McCoy Mountains-Whipple Mountains: The central branch of the linkage captured the most highly suitable contiguous core habitat for burrowing owl.

Joshua Tree National Park-Palen McCoy Mountains: The patch size analysis identified potential core habitat for burrowing owl in all three branches of the linkage, though habitat in the two northern branches was delineated as more highly suitable.

Joshua Tree National Park-Chocolate Mountains: The eastern branch of the linkage provides the most contiguous connection of highly suitable core habitat.

Palen McCoy Mountains-Chocolate Mountains: All branches of the linkage captured potential habitat for this species in the lowlands surrounding the Chuckwalla Mountains. The southern part of the linkage provides the most contiguous highly suitable habitat.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain fairly contiguous highly suitable habitat through the lowlands but potential habitat is much more restricted through the more mountainous terrain.

Chocolate Mountains-Little Picacho: The southern part of the linkage provides the most contiguous highly suitable core habitat for burrowing owl.

Chocolate Mountains-East Mesa: Like many other focal species, the most highly suitable habitat for burrowing owl in the linkage is restricted to the lowlands surrounding the Algodones Dunes, while the dunes were identified as low to medium suitability for this species. The western branch provides the most contiguous highly suitable habitat.

Justification for Selection: The loggerhead shrike requires a mosaic of open habitats with abundant prey to persist. They are sensitive to habitat loss, fragmentation, and degradation (Fraser and Luukkonen 1986, Pruitt 2000). They have been declining throughout North America since the 1960s (Robbins et al. 1986, Sauer et al. 2001).

Distribution & Status: The loggerhead shrike is distributed throughout much of North America from southern Canada to northern Mexico. They are common residents and winter visitors in the lowlands and foothills of California (Faber et al. 1989, Zeiner et al. 1990). They are absent from heavily forested areas and higher elevations in the desert ranges, typically occurring below 1524 m (5000 ft) in elevation (Small 1994).

The loggerhead shrike is listed as a Bird of Conservation Concern by the US Fish and Wildlife Service and as a Species of Special Concern by the California Department of Fish and Game (CDFG 2011). The North American Breeding Bird Survey (BBS) data for the period 1966-2000 indicate a 71% population decline range wide (-3.7% annually), with a decline of 75% in the western region (Sauer et al. 2001). Known or suspected threats to loggerhead shrike populations include habitat loss and degradation, fragmentation of suitable habitat, shooting, and pesticide and other toxic contamination (Fraser and Luukkonen 1986, Pruitt 2000). While there is evidence of some eggshell thinning in Illinois, there is no apparent eggshell thinning in California and Florida (Hands et al. 1989). Pesticides may pose a greater threat in reducing food availability (Yosef 1994, Yosef 1996). Threats to the grassland habitats preferred by loggerhead shrike include conversion to agriculture, overgrazing of livestock, spread of exotic species, urbanization and disrupted fire regimes (Knopf 1994, Knight et al. 1995, Saab et al. 1995, Vickery and Herkert 1999).

Habitat Associations: Loggerhead shrike prefers open country for hunting, with perches for scanning, and fairly dense shrubs and brush for nesting (Small 1994). They may utilize grasslands, pastures, savannah, pinyon-juniper woodlands, Joshua Tree woodlands, riparian woodlands, desert oases, desert scrub and washes, and to a lesser extent, agricultural fields and orchards (Small 1994). The highest density of shrike occurs in open-canopied valley foothill hardwood, valley foothill hardwood-conifer, valley foothill riparian, savannah, pinyon-juniper, juniper, desert riparian, and Joshua tree habitats (Zeiner et al. 1990, Small 1994). Shrikes are often found in open cropland, but only rarely occur in intensive agricultural areas where pesticides have limited their prey base (Zeiner et al. 1990). Loggerhead shrike isn't found on north slopes of mountain ranges, nor in pure chaparral (Small 1994), though they may use edges of denser habitats (Grinnell and Miller 1944, McCaskie et al. 1979, Garrett and Dunn 1981).

Spatial Patterns: Loggerhead shrikes are strongly territorial and aggressive during the breeding season. Shrikes maintain relatively large territories and all activities associated with reproduction (mating, foraging, brooding) occur within the territory (Yosef 1996). In mainland California, the average size of territories was 8.5 ha (21 ac), and ranged between 4.4 ha (10.9 ac) and 16 ha (39.5 ac; Yosef 1996). In Contra Costa and Kern counties, Miller (1931) found ten territories in open shrubland that averaged 7.6 ha (18.7 ac), and varied from 4.5 to 16 ha (11-40 ac). Typically, nesting territories are smaller in areas with a greater amount of good quality habitat (Kridelbaugh 1982).

Banding studies indicate that adult loggerhead shrikes exhibit some site fidelity and juveniles disperse widely (Yosef 1996). In Alberta, the average distance of juvenile dispersal was 6.7 km (4.2 mi) between years (Yosef 1996). Over a period of 3 years from the time of banding, loggerhead shrikes dispersed up to 70 km (43.5 mi) from their natal site (Yosef 1996). In Virginia, juveniles 10-13 weeks old moved an average of 5.5 km (3.42 mi) from their parents' territory to their fall territory (Blumton et al. 1989).

Conceptual Basis for Model Development: Loggerhead shrike prefers open habitat types, such as grassland and oak savanna but they may also be encountered in riparian, desert scrub and wash communities, typically below 1524 m in elevation. Potential core areas were defined as greater than or equal to 213 ha (526 ac). Patch size was classified as $\geq$ 9 ha (22.2 ac) but less than 213 ha. Dispersal distance was defined as 13.4 km (8.3 mi).

Results & Discussion: Potential core areas are largely restricted to the flat open terrain preferred by this species with most other land in the planning area identified as potential move-through habitat (Figure 50). All potential core areas and patches of suitable habitat are within the defined dispersal distance of loggerhead shrike (figure not shown), though barriers to movement may exist between suitable habitat patches.

Sierra Nevada-China Lake North Range: The eastern half of the southern branch and and the southern half of the north-south strand captured potential breeding habitat that is contiguous with core areas delineated on China Lake North Range.

Sierra Nevada-China Lake South Range: The majority of land in the linkage was delineated as potential breeding habitat with move-through habitat interspersed.

Sierra Nevada-Edwards Air Force Base: The southern half of the linkage through Fremont Valley was delineated as potential breeding habitat for loggerhead shrike and there are a number of recorded occurrences in this area.

China Lake North Range-China Lake South Range: All land in the linkage was identified as potential live-in or move-through habitat with the southern strand capturing the most potential breeding habitat that is fairly contiguous with core areas delineated in the two target areas.

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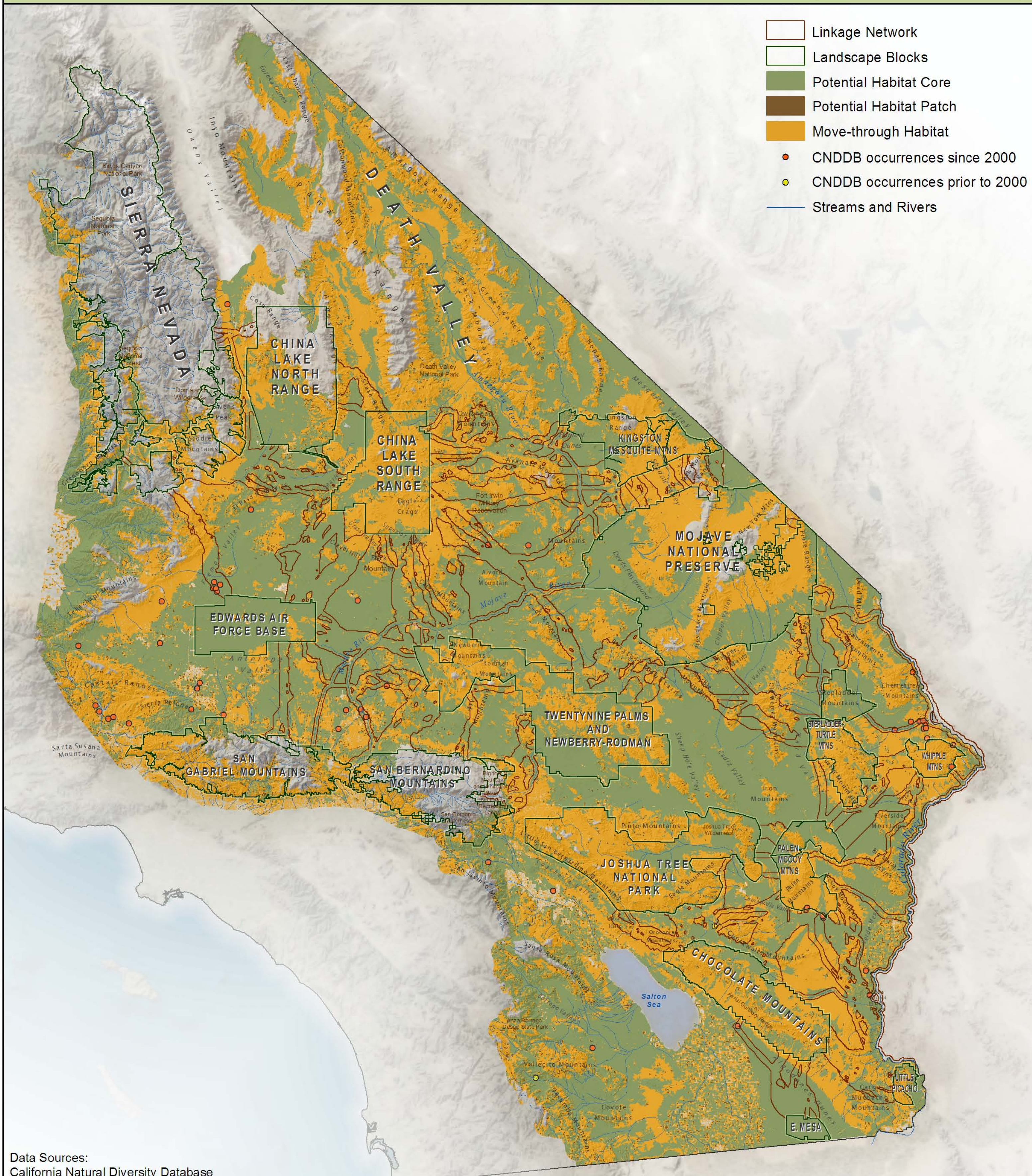
Figure 50. Potential Habitat for Loggerhead shrike (Lanius ludovicianus)



Data Sources:
California Natural Diversity Database

1:2,350,000

0 30 60 90 Kilometers

0 30 60 Miles

SC Wildlands

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage and on Edwards Air Force Base was delineated as potential core habitat for this species.

China Lake South Range-Twentynine Palms and Newberry Rodman: Virtually all land in the linkage was identified as either potential cores and patches or move-through habitat with the western strand capturing the most contiguous potential breeding habitat between the target areas.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern branch and the strand along the Mojave River captured fairly contiguous potential breeding habitat for this species.

Edwards Air Force Base-San Gabriel Mountains: The majority of land in the linkage was identified as potential breeding habitat.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Most land in the linkage was delineated as potential live-in or move-through habitat including the riparian strands along Fremont Wash, the Mojave River and Daggett Wash.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The strands along the Mojave River and Daggett Wash captured the most contiguous potential breeding habitat between target areas but virtually all land in the linkage was identified as potential live-in or move-through habitat for this species.

China Lake South Range-Kingston Mesquite Mountains: The southern branch and the riparian strands along the Amargosa River and Salt Creek captured the most contiguous potential breeding habitat.

Kingston Mesquite Mountains-Mojave National Preserve: The riparian strands along the Amargosa River and Salt Creek captured the most potential habitat that is contiguous with large cores delineated in the two target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential core areas were delineated in the lowlands surrounding the Bristol Mountains with the range itself identified as potential move-through habitat. However, the Mojave River provides the most contiguous potential habitat between the target areas.

Mojave National Preserve-Stepladder Turtle Mountains: The branch along Homer Wash captured contiguous potential breeding habitat between the target areas but habitats along Piute Wash, the Colorado River and Chemehuevi Wash also serve this species.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches captured potential core habitat through the lowlands of Ward Valley with the upper part of the western branch mostly delineated as potential move-through habitat for the shrike.

Palen McCoy Mountains-Whipple Mountains: The central branch contains fairly contiguous potential breeding habitat through the flatlands but habitat was also identified along Bennett Wash, the Colorado River, and McCoy Wash.

Joshua Tree National Park-Palen McCoy Mountains: All branches contain potential habitat with the two northern strands capturing the most contiguous habitat.

Joshua Tree National Park-Chocolate Mountains: All land in the linkage was identified as potential live-in or move-through habitat with the central branch capturing the most contiguous potential breeding habitat.

Palen McCoy Mountains-Chocolate Mountains: The linkage captured potential breeding habitat throughout the Chuckwalla Valley and in the southern part of the main strand through the Chuckwalla Mountains.

Palen McCoy Mountains-Little Picacho: Fairly contiguous potential breeding habitat was delineated in the linkage through Chuckwalla Valley, over Palo Verde Mesa and all along the Colorado River.

Chocolate Mountains-Little Picacho: Most land in the main swath of the linkage was identified as move-through habitat with small patches of potential breeding habitat interspersed. Habitat along Milipitas Wash and the Colorado River likely provide a better connection for this species.

Chocolate Mountains-East Mesa: The majority of land in the linkage was identified as potential core habitat with the remainder delineated as move-through habitat.

Le Conte's Thrasher (*Toxostoma lecontei*)

Justification for Selection: Populations of the Le Conte's thrasher are sensitive to habitat loss, fragmentation, and disturbance, due to urban and agricultural development, altered fire regimes, off-road vehicle use, livestock grazing, and oil drilling (Audubon 2002, CVMSHCP 2007).

Distribution & Status: The distribution of the Le Conte's thrasher includes the San Joaquin Valley, the Mojave and Colorado deserts of California and Nevada southward into Baja California, and the Sonoran Desert from southwestern Utah and western Arizona down into western Sonora, Mexico (CVMSHCP 2007). It is an uncommon, local resident in southern California deserts (Zeiner et al. 1990). Historically it occurred north to Fresno County, but it hasn't been recorded there since the 1950s (Grinnell and Miller 1944, McCaskie et al. 1979, Garrett and Dunn 1981, McCaskie et al. 1988). In the Mojave Desert, it can be found up to about 1,600 m (5,250 ft) in elevation (CVMSHCP 2007).

LeConte's thrasher is listed as a Bird of Conservaiton Concern by the US Fish and Wildlife Service, as a Species of Special Concern by the California Department of Fish and Game (CDFG 2011). The species is threatened by habitat loss due to conversion to urban, agricultural, and other uses. It is also impacted by habitat degradation from off-road vehicles, alteration of habitat from fire, pesticides near agricultural areas, predation of young by mesopredators such as house cats, and roadkill (CVMSHCP 2007).

Habitat Associations: The Le Conte's thrasher inhabits sparsely vegetated desert wash, desert scrub, alkali desert scrub, and desert succulent shrub habitats but they may also be found in open Joshua tree woodlands (Sheppard 1970, Unitt 1984, Ziener et al. 1990). They frequent alluvial fans, washes, and gently sloping hills dominated by saltbush (*Atriplex* spp.) and cholla (*Opuntia* spp; CVMSHCP 2007).

Spatial Patterns: The Le Conte's thrasher has an average home range size of 40 ha (100 ac) in saltbush-cholla scrub. They are territorial, with average nesting territories of 6 ha (15 ac), which they actively defend (Sheppard 1970).

The average juvenile dispersal distance is 1200 m (3937 ft); the maximum recorded is 2500 m (8202 ft; Sheppard 1996).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Le Conte's thrashers frequent desert scrub and wash habitats, typically below 1,600 m in elevation. Core areas were defined as greater than or equal to 1012 ha (2500 ac). Patch size is greater than or equal to 12 ha (30 ac) but less than 1012 ha. Dispersal distance was defined as 5000 m (16404 ft).

Results & Discussion: Potential habitat was identified in desert scrub and wash habitats in the flats and valleys throughout the study area with the most extensive potential core areas identified in the Fremont, Antelope, Yucca, Chuckwalla, Sheep Hole, Cadiz and Ward Valleys (Figure 51). Potential cores or patches were identified in all but five of the targeted landscape blocks, including the Sierra Nevada, San Gabriel, and San Bernardino Mountains which are outside of the range of this species, as well as the Whipple Mountains and Little Picacho. Distances among all core areas and patches are within the dispersal distance of this species (figure not shown), although barriers to movement may exist between suitable habitat patches.

Sierra Nevada-China Lake North Range: The southern branch captured abundant habitat for LeConte's thrasher, which is contiguous with highly suitable core habitat in the south west portion of the China Lake North block.

Sierra Nevada-China Lake South Range: The part of the linkage delineated by badger provides the most highly suitable habitat for Leconte's thrasher.

Sierra Nevada-Edwards Air Force Base: The southern part of the linkage through the Fremont Valley contains fairly contiguous suitable habitat for this species.

China Lake North Range-China Lake South Range: The southern branch of the linkage captured the most contiguous suitable habitat and provides the best connection between potential core areas in the two targeted landscape blocsks.

China Lake South Range-Edwards Air Force Base: All branches of the linkage contain potential habitat for this species but there are gaps of non-habitat through the Gravel Hills area of the Linkage.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Potential habitat was delineated in both branches but the northern swath provides the most highly suitable contiguous habitat for this species.

Edwards Air Force Base-San Gabriel Mountains: Although this species doesn't range into the San Gabriel Mountains, abundant habitat was identified on Edwards Air Force Base and in the linkage.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern branch of the linkage captured the most highly suitable habitat for this species, which has been recorded in the lowlands throughout this area (CDFG 2011).

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains. All branches of the linkage contain potential habitat in the lowlands but there are gaps of non-habitat in the more mountainous terrain. The branch that follows Pipes Wash provides the best connection to potential core areas on Twentynine Palms.

China Lake South Range-Kingston Mesquite Mountains: The southern branch of the linkage and the strand that follows Salt Creek and the Amargosa River contain the most potential habitat.

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Figure 51. Potential Habitat for LeConte's thrasher (*Toxostoma lecontei*)

Data Sources:
California Wildlife Habitat Relationships
California Natural Diversity Database

1:2,350,000

0 30 60 90 Kilometers
0 30 60 Miles

SC Wildlands

Kingston Mesquite Mountains-Mojave National Preserve: The central swath of the linkage through Shadow Valley provides the most contiguous highly suitable core habitat for this species. Habitats along the Amargosa River and Salt Creek also provide a fair amount of habitat for this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The central branch of the linkage contain the most potential habitat for this species with more contiguous habitat in the lowlands surrounding the Bristol Mountains and smaller patches and stepping stones of habitat through this range. Habitat along the Mojave River may also serve this species.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain potential habitat through the flats and lowlands but only the branch delineated by kit fox, badger and desert tortoise captured fairly contiguous core habitat between the two targeted landscape blocks.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches contain potential habitat for this species but the western branch connects to larger potential core areas in the Stepladder Turtle Mountains block.

Palen McCoy Mountains-Whipple Mountains: Very little potential habitat was identified in the Whipple Mountains block. However, the central branch of the linkage captured contiguous highly suitable core habitat for this species.

Joshua Tree National Park-Palen McCoy Mountains: The two northern branches captured fairly contiguous habitat and provide the best connections to core habitats in the targeted landscape blocks.

Joshua Tree National Park-Chocolate Mountains: The eastern branch provides the best potential connection between targeted landscape blocks for LeConte's thrasher

Palen McCoy Mountains-Chocolate Mountains: All branches that cross through the Chuckwalla Valley contain potential habitat for the LeConte's thrasher with the southern branch providing the most contiguous suitable habitat between target areas.

Palen McCoy Mountains-Little Picacho: Very little potential habitat was identified in the Little Picacho block and habitat in the linkage is restricted to the flats and valley.

Chocolate Mountains-Little Picacho: Highly suitable core habitat was identified for this species in the southern part of the linkage.

Chocolate Mountains-East Mesa: Both major swaths of the Linkage contain potential core areas for this species in the lowlands surrounding the Algodones Dunes. Smaller patches and stepping stones of habitat were identified on the dunes, where the species has been recorded (CDFG 2011).

Bendire's Thrasher (*Toxostoma bendirei*)

Justification for Selection: Breeding populations are very patchily distributed, apparently disjunct, and made up of small, isolated populations that may be vulnerable to local extinctions (England 1998). Thus, loss of breeding habitat could lead to the losss of small, localized populations. In Arizona, habitat loss has been identified as the primary cause for the decline of this species (Ambrose 1963, England 1998).

Distribution & Status: Bendire's thrasher occurs primarily as a summer resident in California from March to late August (rarely Oct or later). They breed from late March to late July and most birds leave the state by mid-August (Garrett and Dunn 1981, England and Laudenslayer 1993). The winter range encompasses southern Arizona, southwestern New Mexico, and Sonora and northern Chihuahua (England and Laudenslayer 1993; Shuford and Gardali 2008). The breeding range in California is restricted almost exclusively to the Mojave Desert. The most extensive and best known populations are in the eastern Mojave Desert ranging from the south side of the Kingston Range to the Old Woman Mountains, and from near the Nevada-California border west to Halloran Summit and the Granite Mountains (Grinnell and Miller 1944, England and Laudenslayer 1993). In the northern and western Mojave Desert, they are restricted to widely scattered locations supporting either Joshua trees (*Yucca brevifolia*), other species of yuccas, or cholla cactus (*Opuntia* spp.). They breed very locally and sporadically in the Colorado Desert, where they are restricted to habitats with arborescent species such as palo verde (*Cercidium* spp.). They are absent from most of the Antelope Valley in the western Mojave Desert (England 1998). Elevations for historical breeding records fall between 680-1708 m (2231-5604 ft; England and Laudenslayer 1989).

Bendire's thrasher is listed as a Bird of Conservaiton Concern by the US Fish and Wildlife Service, as a Species of Special Concern by the California Department of Fish and Game, and as Sensitive by the Burea of Land Managmenet (CDFG 2011).The total California breeding population is estimated to be fewer than 200 pairs (Remsen 1978, England 1989). The species is threatened by habitat loss and degradation from off-road vehicle use, overgrazing, and harvesting of Joshua Trees and other species of yucca (Remsen 1978, England and Laudenslayer 1989).

Habitat Associations: This species prefers desert scrub communities that support species of yucca (*Yucca* spp.) and cholla cactus (Opuntia spp.). They are often associated with sites where perennial shrubs are denser and shrub cover is higher, which are often on higher elevation bajadas and valleys where the environment is more mesic (England 1998). In addition to *Yucca* and *Cholla* spp., other dominant shrubs include creosote bush (*Larrea tridentata*), cheese bush (*Hymenoclea salsola*), Nevada squaw-tea (*Ephedra nevadensis*), burro bush (*Ambrosia dumosa*), and big galleta grass (*Pleuraphis rigida*). Bendire's thrasher also occur where the vegetation was dominated by blackbrush (*Coleogyne ramosissima*) with scattered junipers (*Juniperus osteosperma*, *J. occidentalis*, or *J. californica*). Desert washes dominated by catclaw acacia (A*cacia greggii)* were also found to be utilized by this species (England and Laudenslayer 1989).

Spatial Patterns: Home range size and dispersal distance are unknown for this species. Emlen (1974) found densities in an Arizona desert area to be 0.2 per 40 ha (100 acres). The Great Basin Bird Observatory (2010) suggests a minimum patch size of 200 ha (494 ac) and a recommended patch size of greater than 1,000 ha (2471 ac).

Conceptual Basis for Model Development: Bendire’s thrasher tends to be restricted to widely scattered locations supporting either Joshua Trees, other species of yuccas, or cholla cactus that coincide with flat to gentle slopes or canyon bottoms between 680-1708 m in elevation. Potential core areas were defined as greater than or equal to 1000 ha. Patch size was classified as ≥ 200 ha but less than 1000 ha. Dispersal distance was not estimated for this species.

Results & Discussion: Bendire’s thrasher has a widely scattered distribution in eight general areas in the California desert (Figure 52), 3 of which are somewhat isolated and outside the range of the linkage planning areas, including populations in the uplands along Lee Wash, at the southern end of Borrego Valley, and in between the Chemhuevi and Whipple Mountains. The other 5 areas include: the southern Sierra Nevada; Superior Valley extending south out of the China Lake South block; one large area encompassing Kingston, Mojave National Preserve and habitats in between the Preserve and the Stepladder Mountains; Apple and Lucerne Valleys; and the western half of Joshua Tree and extending up into the Morongo and Yucca Valleys. Thus, this species was determined to have the potential to occur in 8 of the linkage planning areas.

Sierra Nevada-China Lake North Range: A large potential core area was captured for Bendire’s thrasher in the southern branch of the linkage but only the western part of the linkage is within the range of this species.

Sierra Nevada-China Lake South Range: Most of this linkage was delineated as potential core habitat for this species and may provide connectivity between populations in the southern Sierra and Superior Valley.

Sierra Nevada-Edwards Air Force Base: The northern part of the linkage captures a potential core area for Bendire’s thrasher in the southern Sierras, and small stepping stones of high quality habitat link this core with that in the western portions of the two linkages described above.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential habitat was delineated throughout all but the eastern most branches but only the areas in Superior Valley are within the range of the species.

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Figure 52. Potential Habitat for Bendire's thrasher (Toxostoma bendirei)

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Bendire's thrasher doesn't occur in the San Gabriel Mountains and only ranges into the southern tip of the Newberry-Rodman ACEC. Potential cores and patches were identified in all branches of the linkage with the eastern branch providing the most extensive habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains but all branches of the linkage contain potential habitat for this species.

Kingston Mesquite Mountains-Mojave National Preserve: The central branch through the Shadow Valley provides the best connection for Bendire's thrasher between the two targeted blocks, which is supported by recorded occurrences of the species.

Mojave National Preserve-Stepladder Turtle Mountains: Potential core habitat was delineated in the Clipper Valley in Mojave National Preserve that extends down into the lowlands along the Piute Mountains in the central branch of the Linkage. Habitat was also captured in the Linkage in the lowlands surrounding the Old Woman Mountains.

Crissal Thrasher (*Toxostoma crissale coloradense*)

Justification for Selection: This species is still common in the Colorado River valley but localized and uncommon elsewhere (Zeiner et al. 1990). Numbers have declined markedly in Imperial, Coachella, and Borrego Valleys in recent decades (Grinnell and Miller 1944, Remsen 1978, Garrett and Dunn 1981, Zeiner et al. 1990). The population has been reduced by removal of mesquite (*Prosopis* spp.) brushland for agricultural development and by introduction of tamarisk (*Tamarix* spp.; Remsen 1978). ORV use may also threaten the Crissal thrasher through habitat degradation and direct disturbance (Zeiner et al. 1990).

Distribution & Status: Crissal thrashers are found in widely scattered patches of appropriate habitat throughout the southwestern United States including parts of California, Nevada, Utah, Arizona, New Mexico, and Texas (AOU 1998) at elevations below 1800 m (5900 ft) (Zeiner et al. 1990). The center of abundance in California is the riparian habitat along the Colorado River (Rosenberg et al. 1991, Patten et al. 2003, Shuford and Gardali 2008). Three to four subspecies are currently recognized (AOU 1957, Davis and Miller 1960, Phillips 1986). *Toxostoma crissale coloradense* is the breeding resident subspecies in California (Shuford and Gardali 2008).

The Crissal thrasher is listed as a Bird Species of Special Concern by the state of California (CDFG 2011). Habitat loss, degradation, and fragmentation from agricultural and urban development and invasive tamarisk have resulted in the species becoming increasingly localized and uncommon (Patten et al. 2003). There are probably fewer than ten pairs in the disjunct population on the floor of Borrego Valley, where the mesquite habitat is threatened by lowering of the water table as a result of human water use (Unitt 2004, Shuford and Gardali 2008).

Habitat Associations: In California, this thrasher occupies predominately riparian scrub or woodland at lower elevations (e.g., Colorado River valley), and the low, dense scrub associated with arroyos at higher elevations in the Mojave Desert, normally at or near the upper reaches of desert scrub vegetation and below the piñon-juniper woodlands (Garrett and Dunn 1981, Cody 1999, Shuford and Gardali 2008).

Spatial Patterns: Territory size reportedly ranges from 1.52 ha (3.81 ac) to 3.71 ha (9.28 ac) in mesquite-tamarisk associations along the Colorado River (Laudenslayer 1981, Zeiner et al. 1990). Densities vary according to habitat and location. In San Bernardino County, Ryder and Ryder (1976) found two on a 17 ha (44 ac) study site in cat claw-rabbit brush habitat (Zeiner et al. 1990). Territory sizes vary from a low of 5 ha

(12.36 ac) in optimum mesquite thicket to a high of 8–10 ha (19.77-24.7 ac) in less-preferred habitat (Laudenslayer et al. 1992, Cody 1999).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Crissal thrashers utilize a variety of desert riparian and desert scrub communities at elevations below 1800 m. Core areas were defined as greater than or equal to 425 ha. Patch size was classified as greater than or equal to 3 ha but less than 425 ha. Dispersal distance was estimated at 5000 m, after LeConte's thrasher.

Results & Discussion: Crissal thrashers are restricted to five general areas in the planning area including the Greenwater Valley, habitats encompassing the Kingston-Mesquite and Mojave National Preserve, Borrego Valley, the eastern Sonoran Desert in California, and along the Colorado River (Figure 53). All potential cores and patches are within the dispersal distance defined for this species (figure not shown).

Kingston Mesquite Mountains-Mojave National Preserve: The central branch of the linkage through Shadow Valley captured the most contiguous potential core habitat for the Crissal thrasher.

Mojave National Preserve-Stepladder Turtle Mountains: The best potential connection for this species is along Piute Wash to the Colorado River and then Chemehuevi Wash to the Stepladder Mountains

Stepladder Turtle Mountains-Palen McCoy Mountains: The western branch of the linkage contains the most potential habitat for this species.

Palen McCoy Mountains-Whipple Mountains: All branches of the linkage captured potential habitat for the crissal thrasher through the Vidal Valley but the most likely route for this species between the two target areas is along Bennett Wash, the Colorado River, and McCoy Wash.

Joshua Tree National Park-Palen McCoy Mountains: The northern and southern branches of the linkage captured some potential habitat for this.

Joshua Tree National Park-Chocolate Mountains: Both the western and eastern branches of the linkage contain potential habitat for this species but the western branch that follows Pinkham Wash provides the most contiguous habitat between large cores in the two target areas.

Palen McCoy Mountains-Chocolate Mountains: All branches of the linkage contain potential habitat for this species. Habitat along McCoy Wash, the Colorado River and Milipitas Wash may also provide a connection for this species.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain potential habitat for this species with fairly contiguous habitat identified along the Colorado River.

Chocolate Mountains-Little Picacho: The southern part of the linkage provides the most contiguous potential habitat for this species but the eastern half of the northern branch along the Colorado River also captured a fair amount of highly suitable habitat.

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Figure 53. Potential Habitat for Crissal thrasher (Toxostoma crissale coloradense)

Cactus wren (*Campylorhynchus brunneicapillus*)

Justification for Selection: Habitat loss and fragmentation are a concern for this species. Historically, the interior and coastal populations were connected through the San Gorgonio Pass in Riverside County, but the connection has been severed due to urbanization of the pass (Rea and Weaver 1990, Solek and Sziji 2004).

Distribution & Status: The cactus wren is widely distributed from southern California south to southern Baja, and in parts of Nevada, Utah, Arizona, New Mexico, and Texas south to Mexico (Termes 1980, Dudek and Associates 2001). In California, the interior race is resident in the Mojave and Colorado deserts, from Mexico north to Inyo and Kern counties, while the coastal race is restricted to westward-draining slopes from Ventura County to San Diego County (Zeiner et al. 1990, Solek and Sziji 2004). Taxonomic affiliation of the coastal and interior populations is still being debated (Rea and Weaver 1990, Solek and Sziji 2004).

The coastal race is considered a California Species of Special Concern due to habitat loss, degradation, and fragmentation (Solek and Sziji 2004). Activities that are known to adversely impact the species include weed abatement projects, grading or clearing activities, and some recreational activities (Harper and Salata 1991, Solek and Sziji 2004). Overly frequent fires can eliminate the dense, older cactus patches required by this species. Domestic cats are one the most dangerous predators (Anderson and Anderson 1963, Solek and Sziji 2004).

Habitat Associations: Cactus wrens may be encountered in desert scrub, desert succulent scrub, Joshua tree, and desert wash habitats (Zeiner et al. 1990). They depend on thickets of xeric vegetation for cover and thermal relief. Nests are found in branching cacti, thorny scrub, and small trees (e.g., Joshua tree), with nests also used as roosts (Grinnell and Miller 1944, Anderson and Anderson 1957, Zeiner et al. 1990).

Spatial Patterns: The home range of cactus wrens may be maintained throughout the year (Anderson and Anderson 1963, Zeiner et al. 1990). In Arizona, Anderson and Anderson (1973) found an average home range size of 1.9 ha (4.8 ac), varying from 1.2-2.8 ha (2.9-6.9 ac; Zeiner et al. 1990). In San Diego County, California, Rea and Weaver (1990) found smaller home ranges from 0.8 to 2 ha, (2 to 4.9 ac) with an average of 1.3 ha (3.2 ac). On Camp Pendleton, home range size varied from 0.5-2 ha (1.2 to 4.9 ac; Solek and Sziji 2004).

Atwood (1998) found an average dispersal distance of 1.59 km (0.98 mi) for juvenile cactus wrens on the Palos Verdes Peninsula, but this isolated coastal population has limited dispersal options. In Arizona, Anderson and Anderson (1973) found juvenile females dispersed farther away from their natal territories than juvenile males (Solek and Sziji 2004).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Cactus wrens prefer desert scrub, desert succulent scrub, Joshua tree, and desert wash habitats. Potential core areas were defined as greater than or equal to 33 ha (81.5 ac). Patch size was classified as $\geq$ 2 ha (4.9 ac) but less than 33 ha. Dispersal distance was defined as 3.18 km (1.96 mi).

Results & Discussion: The suitability model identified vast stretches of the study area as medium to high suitability for the cactus wren much of which was delineated as potential core areas for this species (Figure 54). The majority of habitat patches in the study area are within the species dispersal distance (Figure 55). This species doesn't range into the Sierra Nevada, San Gabriel or San Bernardino Mountains.

Sierra Nevada-China Lake North Range: All branches of the linkage contain some potential habitat for cactus wren, primarily along the lowlands straddling Highway 395, but the southern branch provides the most contiguous habitat that is contiguous with core areas delineated in the southwest part of the China Lake North block.

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by badger captured the most highly suitable habitat for cactus wren, which is contiguous with potential cores areas on China Lake South.

Sierra Nevada-Edwards Air Force Base: The linkage contains highly suitable habitat for cactus wren along the low elevation slopes in the southern Sierra Nevada and through the Fremont Valley.

China Lake North Range-China Lake South Range: The southern branch captured the most highly suitable habitat and provides a connection between large potential cores areas in the two target areas.

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage was identified as highly suitable core habitat for this species.

China Lake South Range-Twentynine Palms and Newberry Rodman: Most of the land in the linkage was identified as high to highly suitable habitat for this species with the most contiguous habitat in the three branches delineated by badger, kit fox and desert tortoise.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Both branches of the linkage contain fairly contiguous highly suitable core habitat for cactus wren. There is about a 5 km gap of non-habitat in the southern branch but all habitat patches are within the species dispersal distance.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The San Gabriel Mountains are outside of the range of this species but all branches of the linkage contain potential habitat, much of which was identified as medium to highly suitable habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The San

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Figure 54. Potential Habitat for Cactus wren (*Campylorhynchus brunneicapillus*)

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Figure 55. Patch Configuration for Cactus wren (Campylorhynchus brunneicapillus)

Bernardino Mountains are outside of the range of this species but abundant habitat was identified in the linkage and the other landscape block.

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage captured potential habitat for this species with the southern strand containing the most highly suitable contiguous habitat.

Kingston Mesquite Mountains-Mojave National Preserve: All branches except those through the Clark Mountain Range captured potential habitat for this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The most contiguous potential habitat between target areas is in the southern branch and along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The branch delineated by badger, kit fox and desert tortoise provides the most highly suitable contiguous habitat between the two target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: Virtually all of the land within the linkage was identified as highly suitable core habitat for cactus wren.

Palen McCoy Mountains-Whipple Mountains: All branches of the linkage contain potential habitat for this species but the central branch captured the most highly suitable contiguous habitat.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches of the linkage captured fairly contiguous highly suitable habitat for cactus wren.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain fairly contiguous potential habitat for this species with the eastern strand providing the most highly suitable habitat.

Palen McCoy Mountains-Chocolate Mountains: The southern part of the linkage captured the most contiguous highly suitable habitat.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain some potential habitat for this species but the branch delineated by badger and kit fox provides the most contiguous highly suitable core habitat between the two target areas.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured the most highly suitable contiguous core habitat for cactus wren.

Chocolate Mountains-East Mesa: The majority of land in the linkage was identified as potential habitat for this species with the land surrounding the dunes identified as potential breeding habitat and the dunes identified as potential move-through habitat.

Black-tailed Gnatcatcher (*Polioptila melanura*)

Justification for Selection: Black-tailed gnatcatchers are indicator species of high quality habitats (Farquhar and Ritchie 2002). They are highly sensitive to disturbance and quickly disappear from areas converted to urban and agricultural uses, or heavily degraded by intensive off-highway vehicle user (Tinant 2006).

Distribution & Status: Historically, the black-tailed gnatcatcher was considered to be conspecific with the California gnatcatcher (Atwood 1988). In 1989, the Ornithologists' Linkage (AOU) split *P. melunura* into two species: California gnatcatcher (*Polioptila californica*) and black-tailed gnatcatcher (*P. melanura*). There are three subspecies of the black-tailed gnatcatcher: *P.m. melanura*, *P.m. curtata*, and *P.m. lucida*; *P.m. lucida* is the subspecies that occurs in California (Tinant 2006).

In California, the species is distributed from southern Inyo County through eastern San Bernardino, Riverside, and Imperial counties to the Mexican border. It occurs in the Colorado and Mojave deserts as far west as Barstow and Morongo Valley in San Bernardino County, the San Gorgonio Pass in Riverside County, and Anza Borrego State Park in Imperial County (Small 1994). Black-tailed gnatcatchers are restricted to elevations ranging from 75 to 900 m (250 to 3000 ft), with breeding typically occurring below 300 m (1000 ft; Grinnell and Miller 1944, Atwood 1988, Small 1994).

The black-tailed gnatcatcher has no special status, while the California gnatcatcher is listed as threatened (CDFG 2011). Black-tailed gnatcatcher populations have declined in the last few decades due to habitat loss, fragmentation, and degradation (Remsen 1978, Farquhar and Ritchie 2002, Tinant 2006).

Habitat Associations: The black-tailed gnatcatcher prefers desert wash habitats dominated by mesquite (*Prosopis glandulosa*), palo verde (*Cercidium microphyllum*), ironwood (*Olneya tesota*), and acacia (*Acacia* spp.), but it may also be found in desert scrub habitats (Grinnell and Miller 1944, Garrett and Dunn 1981, Zeiner et al. 1990). The species is absent in areas dominated by exotic vegetation, such as saltcedar (*Tamarix ramosissima*; Small 1994).

Spatial Patterns: Black-tailed gnatcatchers territory size during the breeding season ranges from 0.8 to 2.7 ha (2.0 to 6.7 ac; Laudenslayer 1981, Tinant 2006). They forage over a much larger area of 4.8 ha (11.8 ac) in winter (Smith 1967). Though resident throughout much of their range, they are known to wander outside the breeding season (Farquhar and Ritchie 2002, Tinant 2006). Dispersal distances are unknown for the black-tailed gnatcatcher, but the maximum distance documented for the California gnatcatcher is 16 km (9.94 mi; Braden 1992, Mock 2004).

Conceptual Basis for Model Development: The black-tailed gnatcatcher inhabits desert riparian, wash and scrub habitats between 75 to 900 m. Core areas were defined as greater than or equal to 125 ha (309 ac). Patch size was delineated as greater than or equal to 2 ha (5 ac) but less than 125 ha. Dispersal distance was defined as 32 km (19.88 mi); double the maximum recorded distance for the California gnatcatcher.

Results & Discussion: Potential cores and patches for the black-tailed gnatcatcher are restricted to desert riparian and wash habitats while desert scrub communities were delineated as move-through habitat (Figure 56). Distances among all core areas and patches are within the dispersal distance of this species (figure not shown). The black-tailed gnatcatcher is restricted to the eastern part of the planning area.

Kingston Mesquite Mountains-Mojave National Preserve: The patch size analysis identified some small patches and stepping stones of habitat in the western part of the two target areas and one small core area in Mojave National Preserve. The western branches of the linkage captured some small cores and patches along Salt Creek and some move-through habitat of lower suitability.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage captured some potential habitat for black-tailed gnatcatcher, though most was move-through habitat of lower suitability with more highly suitable core habitat primarily restricted to the south side of the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: All branches of the linkage contain potential move-through habitat with potential core areas captured by the western strand and along the Piute Wash, Colorado River, and Chemehuevi Wash.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches contain some potential habitat but the western branch captured highly suitable core habitat that is fairly contiguous with a large core area delineated in the Stepladder Turtle block.

Palen McCoy Mountains-Whipple Mountains: The swath of the linkage delineated by desert tortoise contains highly suitable core habitat for this species as does the Chemehuevi Wash, Colorado River, and McCoy Wash.

Joshua Tree National Park-Palen McCoy Mountains: All branches of the linkage contain some potential habitat for this species with the southern strand capturing a few small patches of potential breeding habitat and the two northern strands providing move-through habitat.

Joshua Tree National Park-Chocolate Mountains: The western and easternmost branches of the linkage captured highly suitable habitat for this species, much of which was delineated as potential core areas of breeding habitat. The western strand along Pinkham Wash provides the most contiguous connection of potential core habitat.

Palen McCoy Mountains-Chocolate Mountains: Potential cores and patches were identified through the Chuckwalla Valley, in the southern half of the main strand, and along McCoy and Milipitas Washes.

Palen McCoy Mountains-Little Picacho: Small potential cores and patches were

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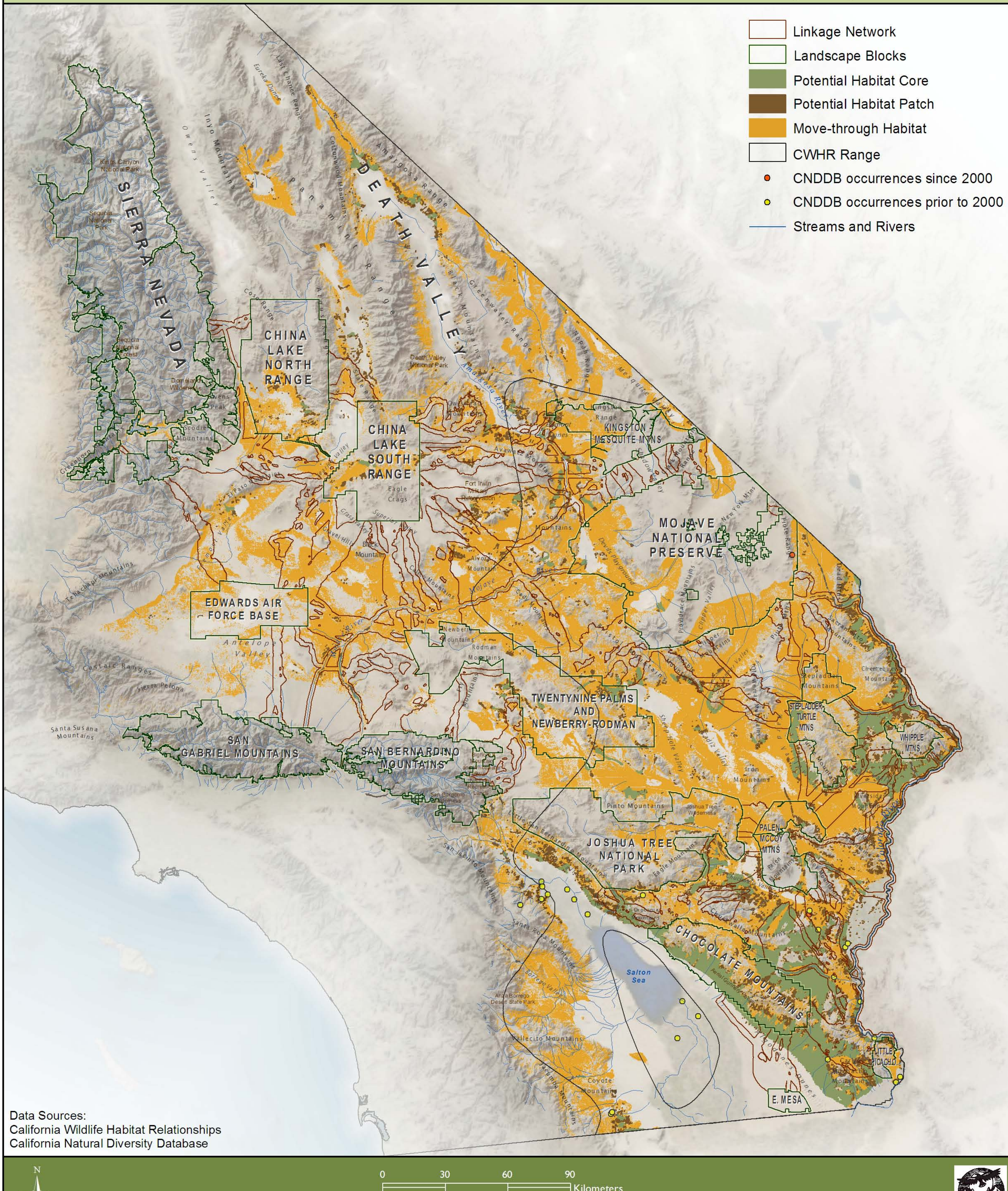
Figure 56. Potential Habitat for Black-tailed gnatcatcher (*Polioptila melanura*)



identified in all branches of the linkage with the majority of the rest of the habitat in the linkage delineated as potential move-through habitat.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured the most highly suitable core habitat but small patches and cores were also delineated along the Colorado River.

Greater Roadrunner (*Geococcyx californianus*)

Justification for Selection: The Greater roadrunner preys upon several vertebrates; thus urbanization that reduces prey availability can impact this species. They are also highly vulnerable to roadkill and pesticide contamination (Hughes 1996).

Distribution & Status: The greater roadrunner is a year-round resident in desert habitats in southern California and throughout the southwestern United States (Grinnell and Miller 1944, Garrett and Dunn 1981, Zeiner et al. 1990). The greater roadrunner occurs below 2300 m (7546 ft) in deserts and desert ranges from Benton, Mono County to Deep Springs Valley in Inyo County (Famolaro 2002).

Roadrunners are habitat limited, and have experienced a reduction in numbers due to urbanization and overhunting (Grinnell and Miller 1944, Unitt 1984, Famalaro 2002). Pesticide concentrations (DDT and DDE) have been reported and incubating adults can also be vulnerable to predation by pets, feral animals, and raccoons (Hughes 1996, Famolaro 2002).

Habitat Associations: Roadrunners are typically associated with open scrublands intermixed with grass and forb ground cover (Famolaro 2002). Crooks et al. (2001) and Soulé et al. (1988) describe the roadrunner as a scrub specialist that is dependent on coastal sage scrub and/or chaparral habitat for breeding. Several authors (Grinnell and Miller 1944, Famolaro 2002) report that they use areas of mixed open ground and tracts of brush; arid, open land with scattered bushes or thickets; edges of chaparral, mesquite, cholla, cactus, catclaw, and small trees for shade, safety-refuge, roosting and nesting. They regularly utilize open areas (i.e., roads, clearings, and grasslands) adjacent to scrublands (Famolaro 2002).

Spatial Patterns: Studies from southern California, Arizona, and Texas indicate average territory size per pair ranges from between 28 to 50 ha (69-124 ac; Bryant 1916, Calder 1967, Folse 1974, Hughes 1996, Famalaro 2002). Crooks et al. (2001) found that breeding pairs occupy relatively large areas of approximately 40-50 ha (99-124 ac).

There is no data on natal dispersal but two pairs moved out of an established territory to renest 1.1 and 1.6 km (.68-.99 mi) from their original sites (Folse 1974, Hughes 1996).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Roadrunners utilize a variety of vegetation types in the desert including grasslands, coastal sage scrub, chaparral, riparian habitats, and open scrub habitats up to 2300 m. Cores areas were defined as greater than or equal to 1047 ha. Patch size was classified as greater than or equal to 56 ha but less than 1047 ha. Dispersal distance was defined as 3.2 km.

Results & Discussion: Vast stretches of the study area were identified as medium to highly suitable habitat for the roadrunner, most of which was delineated as potential core areas for this species (Figure 57).

Sierra Nevada-China Lake North Range: All branches of the linkage contain potential habitat for the roadrunner with the most contiguous core habitat delineated in the southern branch and the north-south strand following the lowlands along Highway 395.

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by badger captured highly suitable contiguous habitat and likely serves the roadrunner.

Sierra Nevada-Edwards Air Force Base: Virtually all of the land in the linkage and on Edwards Air Force Base was delineated as highly suitable core habitat for this species.

China Lake North Range-China Lake South Range: The southern branch captured the most suitable habitat for this species and provides the best connection between potential cores in the two target areas.

China Lake South Range-Edwards Air Force Base: All branches of the linkage captured fairly contiguous core habitat for this species.

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage contain potential habitat for the roadrunner but the western branch captured the most highly suitable contiguous habitat and provides the best connection to core areas within the two target areas.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern strand contains the most highly suitable contiguous habitat and likely serves this species.

Edwards Air Force Base-San Gabriel Mountains: This species doesn’t range into the San Gabriel Mountains but abundant potential habitat was identified in the linkage and on Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: All branches of the linkage contain potential habitat but the southern branch delineated by badger provides the most contiguous highly suitable habitat for the roadrunner.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn’t range into the San Bernardino Mountains but highly suitable habitat was identified through the lowlands and valleys in all branches of the linkage. The strand that follows Pipes Wash provides the most direct connection to potential core areas in the Twentynine Palms block.

China Lake South Range-Kingston Mesquite Mountains: The southern branch of the linkage and the strand that follows Salt Creek and the Amargosa River contain the most potential contiguous potential habitat for the roadrunner.

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Figure 57. Potential Habitat for Greater roadrunner (Geococcyx californianus)

Kingston Mesquite Mountains-Mojave National Preserve: The branch of the linkage through Shadow Valley provides the most highly suitable habitat that is contiguous with potential breeding habitat in the two target areas. The eastern branch of the linkage also captured fairly contiguous habitat, as did the strand along Salt Creek.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage captured some potential habitat for this species with the southern strand and the branch along the Mojave River providing the most contiguous habitat.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by badger, kit fox, and desert tortoise captured the most highly suitable contiguous habitat for roadrunner between target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage contain fairly contiguous suitable habitat for this species but the western branch better serves to connect potential cores areas in the two target areas.

Palen McCoy Mountains-Whipple Mountains: Very little potential habitat was identified in the Whipple Mountains block but fairly contiguous highly suitable core habitat was delineated in the central branch of the linkage and in the northern part of the Palen McCoy landscape block.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches of the linkage captured fairly continuous highly suitable habitat for this species.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain potential habitat but the eastern branch captured the most highly suitable core habitat between target areas and likely best serves this species.

Palen McCoy Mountains-Chocolate Mountains: The southern part of the linkage captured the most highly suitable contiguous habitat for this species.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain some potential habitat for the roadrunner through the lowlands and valleys but the branches delineated by the badger and kit fox captured the most highly suitable contiguous habitat between the two target areas.

Chocolate Mountains-Little Picacho: The southern swath of the linkage captured the most contiguous highly suitable habitat between the two target areas

Chocolate Mountains-East Mesa: Like many other focal species, highly suitable habitat for the roadrunner was identified in the linkage in the lowlands surrounding the Algodones Dunes but the dunes themselves were largely delineated as non-habitat. The western strand along the base of the dunes likely serves this species.

Desert Tortoise (*Gopherus agassizii*)

Distribution & Status: The desert tortoise is distributed throughout the Mojave and Sonoran deserts of Nevada, Utah, Arizona, California, and Mexico (Stebbins 1985). There are two subspecies, the Sonoran population which is found south and east of the Colorado River, and the Mojave population found to the north and west of the river (Lamb et al. 1989, Boarman 2002a). The Mojave population typically occurs between 305 to 1524 m (1000-5000 ft) in elevation (W. Boarman, pers. comm.)

The desert tortoise is federally and state listed as Threatened (CDFG 2011). The precipitous decline in the Mojave population is attributed to the destruction, degradation, and fragmentation of desert tortoise habitat (USFWS 1994). Threats include urbanization, agricultural development, livestock grazing, energy and mineral development, collecting by humans, upper respiratory tract disease, drought, fire, garbage and litter, invasive plants, landfills, military operations, noise and vibration, off-road vehicle activities, predation, and roads, highways and railroads (USFWS 1994, Boarman 2002b). Roadkill is also a significant source of mortality and population decline (Berry and Nicholson 1984, Boarman and Sazaki 2006, USFWS 2011). For instance, Boarman and Sazaki (1996) reported finding 115 tortoise carcasses along 28.8 km of highway in the west Mojave. Roads fragment habitat by restricting movement between populations, increasing the rate of local extinctions, and the potential for inbreeding and inbreeding depression. These effects are exacerbated by increases in traffic volume, width of highways, and time (Nicholson 1978, Boarman et al. 1993, von Seckendorff Hoff and Marlow 2002).

Habitat Associations: Vegetation communities utilized include creosote scrub, saltbush scrub, scrub steppe, and blackbush scrub (USFWS 2011). Creosote bush is often the dominant plant in its habitat (Stebbins 1985). The desert tortoise also frequents desert oases, riverbanks, and washes (Stebbins 1985). They are typically associated with flats, valleys, bajadas, and rolling hills; they generally avoid plateaus, playas, steep slopes (>20%), and other significant barriers to movement (Weinstein 1989). Although, they can be found on rocky terrain and slopes in some areas (USFWS 2011). They require sandy to gravelly soils to dig their burrows (USFWS 2011).

Spatial Patterns: Home range sizes range from 4 to 180 ha (10-450 ac), and vary depending on sex, age, season, and the availability of resources (USFWS 1994). In the western Mojave, home ranges as small as 2 ha (5 ac) have been recorded (USFWS 1994), with an average home range size of 50 ha (125 ac; Boarman 2002a).

Pre-breeding males have greater dispersal distances, which can be 10-15 km (6.21-9.32 mi) in some areas (Sazaki et al. 1995).

Conceptual Basis for Model Development: We used the Nussear et al. (2009) quantitative habitat model for the desert tortoise, which used an extensive set of field-collected presence data and 16 environmental data layers (e.g., soil characteristics, perennial and annual vegetation, elevation and extracted topographic variables, and seasonality and variability of precipitation) that define or influence desert tortoise habitat. Core areas were defined as greater than or equal to 1272 ha (3144 ac). Patch size was classified as greater than or equal to 4.05 ha (10 ac) but less than 1272 ha. Dispersal distance was defined as 32.19 km (20 mi).

Results & Discussion: A vast expanse of the California deserts provide potential habitat for the desert tortoise, with the majority of habitat delineated as potential core areas for this species (Figure 58). Potential core areas were identified in all but five of the landscape blocks, namely Sierra Nevada, San Gabriel, San Bernardino, East Mesa and Little Picacho. All potential cores and patches of suitable habitat are within the defined dispersal distance of desert tortoise (figure not shown), though barriers to movement may exist between suitable habitat patches.

Road kills are an important cause of desert tortoise mortality and depletion of populations (Boarman and Sazaki 1996, USFWS 2011). In 1990, the California Department of Transportation erected a tortoise-proof fence along State Highway 58 between Barstow and Kramer Junction and installed a series or tortoise crossings that have successfully reduced road kill along this stretch of highway (Boarman and Sazaki 1996). We urge similar tortoise crossing improvements during transportation improvement projects within their range.

Sierra Nevada-China Lake North Range: While the Sierra Nevada is outside of the range of this species, the desert tortoise does have the potential to occur in the linkage and in the China Lake North Range. Potential habitat was identified in all branches of the linkage with the southern branch providing the most extensive habitat for the tortoise. The tortoise has been recorded in both the southern and northern branch, indicating a north-south connection along the 395 is important for this species too.

Sierra Nevada-China Lake South Range: All branches of the linkage provide suitable habitat for the tortoise but the branch delineated by the badger along the Teagle Wash and into the lower Searles Valley provides the most contiguous habitat. There are also recorded occurrences of tortoise in this branch.

Sierra Nevada-Edwards Air Force Base: The southern part of the linkage through Fremont Valley provides fairly contiguous habitat for the tortoise.

China Lake North Range-China Lake South Range: The southern branch of the linkage through Searles Valley provides the most likely connection for desert tortoise between delineated core areas in the targeted landscape blocks and the species has been recorded in this area.

China Lake South Range-Edwards Air Force Base: All branches of the linkage provide fairly contiguous core habitat for the desert tortoise, which is not surprising since the

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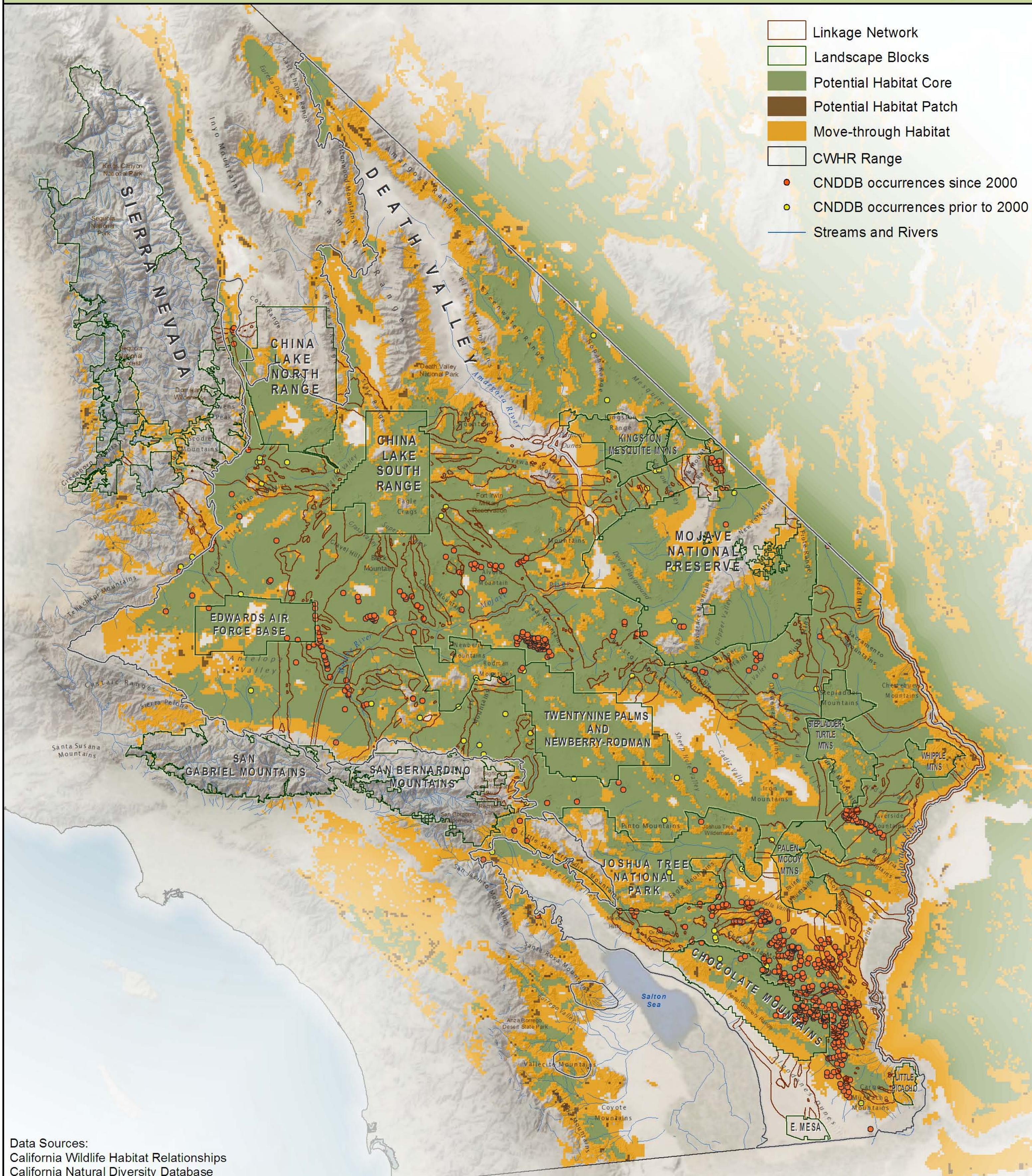
Figure 58. Potential Habitat for Desert Tortoise (*Gopherus agassizii*)



majority of the linkage is within the Superior Cronese and Fremont Kramer Critical Habitat Units that were designated for this species.

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage contain fairly contiguous habitat for the tortoise and the species has been recorded throughout this area. The majority of the linkage falls within the Superior Cronese and Ord Rodman Critical Habitat Units for the desert tortoise and all but the easternmost branch provide connections between these two Units.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Both major branches of the linkage provide habitat for the tortoise but the northern branch contains the most extensive habitat and provides the best connection between potential core areas in the Fremont Kramer Critical Habitat Unit on Edwards Air Force Base and the Ord Rodman Critical Habitat Unit.

Edwards Air Force Base-San Gabriel Mountains: The tortoise doesn't range into the San Gabriels Mountains but extensive habitat exists in the Edwards target area and in the linkage.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: All branches of linkage contain potential tortoise habitat and the species has been recorded in this area.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The desert tortoise doesn't range into the San Bernardino Mountains but the species has been recorded and highly suitable habitat occurs in all branches of the linkage, including the strand along the Mojave River.

China Lake South Range-Kingston Mesquite Mountains: The southern branch of the linkage, delineated as the least cost corridor for this species, provides the most contiguous highly suitable habitat and the best potential connection for this species between the target areas and the Superior Cronese and Ivanpah Critical Habitat Units.

Kingston Mesquite Mountains-Mojave National Preserve: The two branches of the linkage that provide the most contiguous habitat connections are the swath delineated by tortoise through Shadow Valley which is entirely within the Ivanpah Critical Habitat Unit and the easternmost branch delineated by kit fox to the east of the Clark Mountain Range. The species has been recorded in both of these branches.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The northern swath provides the most contiguous connection of core tortoise habitat between the target areas. The central and southern branches also captured potential habitat but there is a significant gap of non-habitat where the southern branch meets Twentynine Palms.

Mojave National Preserve-Stepladder Turtle Mountains: While all branches of the linkage contain potential tortoise habitat, only the branch delineated by this species through the Ward and Chemehuevi Valleys provides highly suitable contiguous habitat for the entire stretch between the targeted landscape blocks. And, it is entirely encompassed within the Piute Eldorado and Chemehuevi Critical Habitat Units.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage provide contiguous tortoise habitat. However, the westernmost branch provides the best connection between large potential core areas within the target areas. The aqueduct is also buried throughout much of this swath.

Palen McCoy Mountains-Whipple Mountains: All branches of the linkage contain potential habitat for the tortoise. They all pass through the Vidal Valley, which is part of the Chemehuevi Critical Habitat Unit. The northern and central branches provide fairly contiguous core habitat between the two target areas.

Joshua Tree National Park-Palen McCoy Mountains: Only the northern branch of the linkage provides contiguous highly suitable tortoise habitat and connects large potential cores within the target areas.

Joshua Tree National Park-Chocolate Mountains: Most of the land in the central and eastern branches of the linkage was delineated as potential core areas for the tortoise. The easternmost branch, delineated as the least cost corridor for this species, provides the most contiguous highly suitable habitat and this species has been recorded throughout this area. This branch also provides the best connection between large potential cores areas within the target areas and serves to connect the Pinto Mountain and Chuckwalla Critical Habitat Units.

Palen McCoy Mountains-Chocolate Mountains: The large central branch of the linkage provides the most contiguous highly suitable tortoise habitat, though most branches that fall within the Chuckwalla Critical Habitat Unit provide potential habitat for this species.

Chocolate Mountains-Little Picacho: No potential core areas were identified in the Little Picacho target area but the species has been recorded in the linkage with highly suitable habitat throughout the central part of the Linkage.

Chuckwalla (*Sauromalus obesus obesus*)

Justification for Selection: The chuckwalla is a habitat specialist that is restricted to rocky outcrops. It can serve as an umbrella species for other reptiles such as the collared lizard and speckled rattlesnake.

Distribution & Status: The chuckwalla is broadly distributed throughout the Mojave, Colorado, and Sonoran deserts from sea level to 1219 m (4000 ft; Stebbins 1985, Zeiner et al. 1988, Macey and Papenfuss 1991, Brodie et al. 2003).

The chuckwalla is not currently listed as a special status species. Its large body size, striking appearance, and tendency to perch out in the open make it particularly vulnerable to collecting (Fitch et al. 1982, Brodie et al. 2003).

Habitat Associations: The chuckwalla inhabits boulder piles, rock outcrops and crevices in a variety of desert woodland and scrub habitats but is most frequently associated with creosote communities. It is restricted to areas that provide rocky cover, usually on slopes and less frequently on flats (Shaw 1939, Stebbins 1954, Johnson 1965, Nagy 1971, Berry 1974, Zeiner et al. 1988). Chuckwalla abundance is greatest in mountainous terrain that contains both suitable basking sites and crevices for retreat (Brodie et al. 2003).

Spatial Patterns: Chuckwallas are territorial, though males are tolerant of females (Berry 1974, Zeiner et al. 1988). Berry (1974) found home range size to range from 1-3.3 ha (2.5-8.3 ac), and average 1.9 ha (4.8 ac; Zeiner et al. 1988). Other research found average home range size of 10 ha (24.71 ac; Johnson 1965, Berry 1974, Brodie et al. 2003). Kwiatkowski and Sullivan (2002) found female home ranges to be related to the availability of food resources, while male home ranges were related to female distribution, population density, and geology (Brodie et al. 2003).

Dispersal distance has not been estimated. However, chuckwallas evidently experience little or no detectable migration (Johnson 1965, Berry 1974, Abts 1987, Zeiner et al. 1988, Brodie et al. 2003).

Conceptual Basis for Model Development: Chuckwallas prefer rocky substrates in a variety of desert scrub and woodland communities below 1219 m. Core areas were defined as greater than or equal to 250 ha (618 ac). Patch size was delineated as greater than or equal to 2 ha (4.94 ac) but less than 250 ha. Dispersal distance was not estimated for this species but movement between target areas is assumed to be multigenerational.

Results & Discussion: The chuckwalla does not range into the Sierra Nevada, Edwards, San Gabriel, San Bernardino or East Mesa target areas. Potential habitat for the chuckwalla is largely restricted to the rocky terrain preferred by this species much of which was delineated as potential core areas for chuckwalla (Figure 59).

Sierra Nevada-China Lake South Range: Although this species doesn't range into the Sierra Nevada, potential core areas were identified in the southern swath of the linkage, which were delineated by ridge land facets. The potential cores and patches extend out from China Lake South, through the Lava Mountains, Summit Range and into the El Paso Mountains.

China Lake North Range-China Lake South Range: All branches of the linkage provide potential habitat for the chuckwalla but the northern branch following the Slate Range offers the most contiguous habitat between the targeted areas and will likely serve the habitat needs of this species. The linkage also provides a potential connection down the eastern side of the Argus Range.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential chuckwalla habitat was identified in all branches of the linkage in the Black, Calico, Alvord and Cady Mountains, with the Calico Mountains providing the most contiguous potential core habitat.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Although this species doesn't range into the San Gabriel Mountains, potential core areas were identified in the linkage and in the Twentynine Palms and Newberry Rodman block. The westernmost branch delineated by a ridge land facet provides the most potential core habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The chuckwalla doesn't range into the San Bernardino Mountains but large potential cores and patches occur within the Twentynine Palms block, in the swath that follows the Fry Mountains and in the northern part of the eastern branch delineated by bighorn sheep.

China Lake South Range-Kingston Mesquite Mountains: The swaths through the Avawatz Mountains delineated by bighorn sheep in the central part of the linkage provide the most contiguous connections of potential cores and patches for chuckwalla. The northernmost branch also provides significant potential habitat for this species in the Owlshead and Black Mountains and the Ibex and Sperry Hills but there are significant gaps in habitat across Death Valley.

Kingston Mesquite Mountains-Mojave National Preserve: The western branches provide the most potential chuckwalla habitat, extending from the Kingston Mountains down into the Shadow Mountains and the Silurian Hills.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage contain potential core habitat for the chuckwalla but the branch delineated by bighorn sheep and the ridge land facets provide the most extensive potential habitat.

Mojave National Preserve-Stepladder Turtle Mountains: Potential chuckwalla habitat occurs in several areas of the linkage, including in the Marble, Clipper, Old Woman,

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Figure 59. Potential Habitat for Chuckwalla (*Sauromalus obesus obesus*)

Piute and Sacramento Mountains. The branch delineated by bighorn sheep provides the most potential habitat for this species.

Stepladder Turtle Mountains-Palen McCoy Mountains: Although large potential core areas were delineated for chuckwalla in both of the targeted landscape blocks, virtually no habitat occurs in the linkage.

Palen McCoy Mountains-Whipple Mountains: The southern strand of the linkage that follows the Big Maria and Riverside Mountains provides extensive potential core habitat for the chuckwalla but there are large areas of non-habitat through Vidal Valley.

Joshua Tree National Park-Palen McCoy Mountains: The northern branch provides potential core habitat in the Granite Mountains but there is still roughly a 6 km gap between this area and the Coxcomb Mountains in Joshua Tree National Park.

Joshua Tree National Park-Chocolate Mountains: The western branches of the linkage delineated by bighorn sheep and the ridge land facets provides the best potential connection for chuckwalla, linking core habitat in the Little San Bernardino Mountains with large patches and cores in the Mecca Hills, Orocopia and Chocolate Mountains.

Palen McCoy Mountains-Chocolate Mountains: The central branches of the linkage that encompass the Chuckwalla Mountains provide potential habitat for this species but the western branch that crosses the Granite, Coxcomb, Eagle and Orocopia Mountains provides the best potential connection for this species.

Palen McCoy Mountains-Little Picacho: The branch of the linkage delineated by bighorn sheep contains the most potential core habitat for chuckwalla but there are gaps of non-habitat between mountain ranges.

Chocolate Mountains-Little Picacho: The branch of the linkage delineated by bighorn sheep captured several potential cores and patches of chuckwalla habitat

Mojave fringe-toed lizard (*Uma scoparia*)

Justification for Selection: The Mojave fringe-toed lizard is a sand dune specialist that depends on the maintenance of dune ecosystem processes, such as sand transport and deposition (Hollingsworth and Beaman, undated material), thus sand stabilization is a critical concern (C. Barrows, pers. comm.). Because this species is considered an umbrella species for plants, arthropods, reptiles, and small mammals associated with these dune ecosystems, their protection has broad benefits. Roads and rocky areas are considered barriers to movement (C. Barrows, pers. comm.).

Distribution & Status: The Mojave fringe-toed lizard is endemic to California and one small portion of Arizona (Bureau of Land Management 1999). In California, it is distributed in the Mojave Desert regions of Inyo, San Bernardino, Los Angeles, and Riverside counties, north to the southern end of Death Valley National Monument (Stebbins 1985, Zeiner et al. 1988). This species is found at elevations of 300 to 3000 ft (91-9154 m; Stebbins 1985) in a relatively restricted range. Its primary habitat, desert dunes, accounts for only 6% of the surface of North American deserts (MacMahon 1992). Most of its range is associated with present-day or historic drainages and associated sand dune complexes of the Mojave and Amargosa rivers (Norris 1958).

Although no data exists on population size or relative densities, current studies indicate that this species has disappeared from some historical localities, and that some populations contain only a small number of individuals (Hollingsworth and Beaman, undated material). Mojave fringe-tailed lizards are classified as a Species of Special Concern by the California Department of Fish and Game and as Sensitive by the Bureau of Land Management (CDFG 2011). Their habitat is highly sensitive to both direct and indirect disturbances, including urban and agricultural development, use of off-highway vehicles, invasive non-native plants, and disruption of sand sources, wind transport, and sand transport corridors (Weaver 1981, Beatley 1994, Barrows 1996).

Habitat Associations: Mojave fringe-toed lizards are restricted to areas of fine, loose, windblown sands that are found in dunes, flats, isolated pockets against hillsides, sparse alkali scrub and desert shrub habitats, and the edges of dry lake beds, washes, and riverbanks (Heifetz 1941, Stebbins 1944, 1985, Smith 1946, Norris 1958). Habitat may include sand dunes, sand sheets, and wind dominated transitional sand-vegetation areas in the Mojave Desert (Cablk and Heaton 2002). These areas are generally found within creosote scrub desert, and vegetation is usually scant, often consisting of sparse creosote or other shrubs (Stebbins 1985). As such, Mojave fringe-toed lizards are sand dune specialists that depend on the maintenance of aeolian processes, such as sand transport and deposition (Barrows 1996).

Mojave fringe-toed lizards rely on sandy substrates for protection from predators and from the elements. They usually hide from predators by burrowing in the sand (Zeiner et al. 1988). This species hibernates under the sand between November and February (Mayhew 1964a, 1964b), and females lay their eggs in hummocks or sandy hills during May – July (Kaufman 1982, Stebbins 1985). Specific habitat requirements may be similar to those of the Coachella Valley fringe-toed lizard in that the species requires access to shaded sand for thermoregulatory burrowing (Muth 1991, cited in Hollingsworth and Beaman, no date).

Spatial Patterns: Males actively defend their home ranges, which average 0.10 ha (0.25 ac; Kauffman 1982). Male home ranges are typically larger than those of females, which averaged 0.08 ha (0.08 acres). C. Barrows (pers. comm.) found home range sizes to vary between 0.3-0.7 ha (0.74-1.73 ac). This species has limited dispersal abilities, with roads and rocky areas considered barriers to movement (C. Barrows, pers. comm.).

Conceptual Basis for Model Development: The Mojave fringe-toed lizard is primarily restricted to aeolian sand deposits, which are primarily associated with dune ecosystems but the species can also be found in sandy areas in sparse alkali scrub and desert shrub habitats, and the edges of dry lake beds, washes, and riverbanks between 300 and 3000 feet in elevation. Core areas were defined as greater than or equal to 50 ha (124 ac). Patch size was defined as greater than or equal to 2 ha (4.94 ac) but less than 50 ha. Dispersal distance was not estimated for this species but movement between target areas is assumed to be multigenerational.

Results and Discussion: The most highly suitable habitat for Mojave fringe-toed lizard largely follows the dune habitats and desert riparian and wash habitats (Figure 60), which are also important sand transport corridors. Since this species is primarily associated with sand dune ecosystems and the dunes were created from sediment and sands derived from Pleistocene fluvial systems, we depicted Pleistocene lakes and rivers (Lewis Center for Educational Research 2009) in relation to the results of the analyses to identify potential movement corridors for this species based on expert opinion (C. Barrows, pers. comm.).

The Mojave fringe-toed lizard was identified as a focal species in the Joshua Tree-Twentynine Palms linkage (Penrod et al. 2008) and is also served by the this connection.

Protecting these corridors may allow the Mojave fringe-toed lizard to move between potential habitat in and around Harper Dry Lake, the Mojave Valley, Silver Dry Lake, and Soda Dry Lake along the Mojave River, between Silver Dry Lake and the Dumont Dunes along Salt Creek, between Soda Dry Lake and the Kelso Dunes along Kelso Wash, and between Soda Dry Lake and the Cadiz Valley. Protection of these corridors will also protect the ecosystem processes essential for maintaining existing dune habitats.

China Lake South Range-Edwards Air Force Base: This linkage is on the western edge of this species distribution. A potential core area and move-through habitat was identified in the southern strand that is contiguous with potential cores delineated on Edwards Air Force Base.

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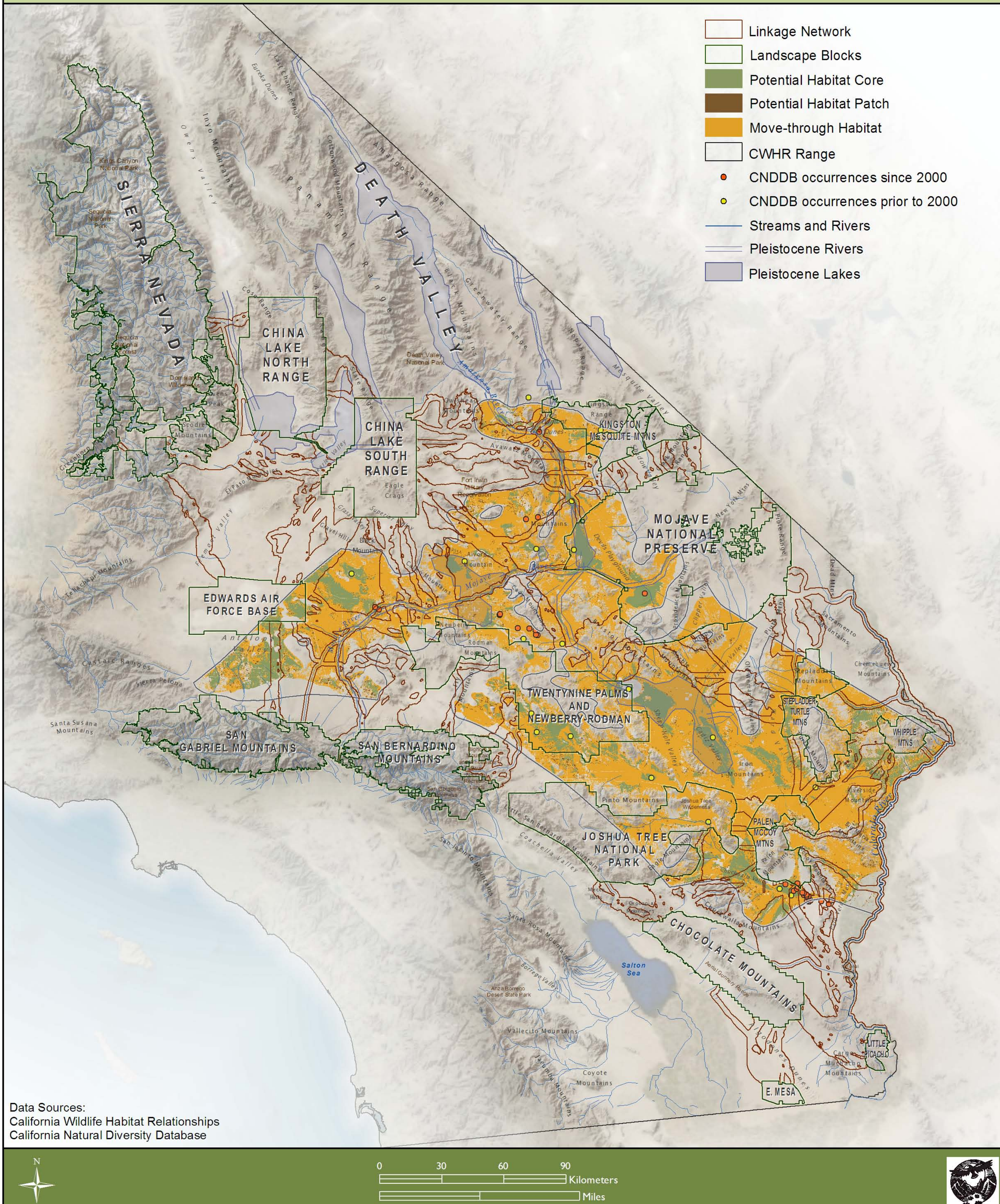
Figure 60. Potential Habitat for Mojave fringe-toed lizard (Uma scoparia)



Data Sources:
California Wildlife Habitat Relationships
California Natural Diversity Database

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage captured some relatively small core areas and abundant move-through habitat and the Mojave River provides connectivity between several delineated core areas.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage is dominated by move-through habitat but also captured some small cores and patches.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but the linkage captured part of a large core area that extends onto Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains and very little potential habitat was identified in the Newberry Rodman area of that wildland block but the Mojave River strand is a critical movement corridor and also provides habitat for this species.

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage east of the Avawatz Mountains captured potential habitat for this species with the Amargosa River and Salt Creek providing important movement routes between the strands. The southern strand also captured some small core areas and ample move-through habitat.

Kingston Mesquite Mountains-Mojave National Preserve: The strand along the Amargosa River and Salt Creek provides connectivity between populations in the Dumont Dunes and those in the Devils Playground.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Small potential cores and move-through habitat was identified in the two southern strands of the linkage as well as along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The western swath capture move-through habitat and some small cores in the Fenner Valley.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both strands captured potential habitat for this species, with the western strand capturing more core habitat in the Ward Valley that is contiguous with delineated core areas in the Stepladder Turtle target area.

Palen McCoy Mountains-Whipple Mountains: All strands of the linkage captured potential core habitat in the Vidal Valley and the rest of the northern and central strand were mostly identified as move-through habitat.

Joshua Tree National Park-Palen McCoy Mountains: All three strands provide potential habitat with the southern strand capturing potential core areas and two northern strands identified as move-through habitat.

Joshua Tree National Park-Chocolate Mountains: This species doesn't range into the Chocolate Mountains but the eastern strand captured several potential core areas and move-through habitat all the way up into the Pinto Basin.

Palen McCoy Mountains-Chocolate Mountains: Large potential core areas and move-through habitat was identified throughout the Chuckwalla Valley through all strands of the linkage.

Palen McCoy Mountains-Little Picacho: This species doesn't range south of the Chuckwalla Mountains but habitat was identified in all branches of the linkage through the Chuckwalla Valley.

Justification for Selection: The desert night lizard is associated with arid and semiarid areas where it takes cover among fallen leaves and trunks of yuccas, agaves, cacti, and other plant debris. The regeneration of yucca species is very slow and collectors often harvest the logs, which can impact local populations of the desert night lizard (Zeiner et al. 1988).

Distribution & Status: The desert night lizard is distributed from southern Utah, western Arizona, southern Nevada, and southern California south to southwestern Sonora and Baja California (Grismer 2002, Stebbins 2003, NatureServe 2009). In California, it is widely distributed throughout the Mojave and Colorado Deserts but also occurs in the Central and South Coast Ranges (Zeiner et al. 1988). It typically occurs at elevations between 300 to 2070 m (990 to 6800 ft; Zeiner et al. 1988, Macey and Papenfuss 1991).

The desert night lizard is not considered a special status species. Populations appear to be relatively stable and no major threats have been identified but the species may face local population declines where its habitat has been degraded (NatureServe 2009).

Habitat Associations: The desert night lizard inhabits arid and semiarid habitats. It is most common in desert scrub habitats but may also be found in pinyon-juniper, sagebrush, blackbrush, chaparral, and foothill pine habtiats (Ziener et al. 1988, Stebbins 2003, NatureServe 2009). Within these communities, it is found among fallen leaves and trunks of yuccas, agaves, cacti, and other large plants, as well as in crevices of rock outcroppings and under logs and bark (Brattstrom 1952, Stebbins 1954, Zeiner et al. 1988).

Spatial Patterns: This species is highly sedentary with home range restricted to the cover site and the area directly adjacent to it (Miller 1951, Zeiner et al. 1988). Density estimates range from 47 per ha (19 per ac) to 16,000 per ha (6400 per ac; Miller 1951, Zeiner et al. 1988).

Conceptual Basis for Model Development: The desert night lizard prefers desert scrub habitats but may also be found in pinyon-juniper, sagebrush, blackbrush, chaparral, and foothill pine habitats between 300 to 2070 m in elevation. Dispersal distance was not estimated for this species but movement between target areas is assumed to be multigenerational.

Results & Discussion: Abundant potential habitat was identified for this species throughout the study area but it doesn't range into the Palen McCoy, Chocolate, Little

Picacho or East Mesa target areas (Figure 61).

Sierra Nevada-China Lake North Range: The Sierra Nevada is outside of the range of this species but it does have the potential to occur in the linkage and in the China Lake North block. All branches of the linkage provide potential habitat for the desert night lizard through the north-south connection with the southern branch providing the most contiguous suitable habitat.

Sierra Nevada-China Lake South Range: The two southern branches of the linkage provide the most highly suitable contiguous habitat for this species.

Sierra Nevada-Edwards Air Force Base: Most land in the linkage and on Edwards Air Force Base was identified as potential habitat for this species.

China Lake North Range-China Lake South Range: The two northern branches and the southern branch provide potential habitat for the desert night lizard with the southern branch providing the most contiguous potential habitat for this species.

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage was identified as potential habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: The three swaths of the linkage delineated by badger, kit fox and desert tortoise captured the most contiguous habitat for this species with a fair amount of habitat also identified along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern branches of the linkage captured the most contiguous highly suitable habitat for desert night lizard.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but most of the linkage and Edwards Air Force Base were delineated as potential habitat.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern strand provides the most suitable habitat for this species, which is fairly contiguous with habitat identified at the base of the Newberry and Rodman Mountains.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: All branches of the linkage contain potential habitat for this species through the lowlands with the swath following Pipes Wash capturing the most contiguous habitat.

China Lake South Range-Kingston Mesquite Mountains: All strands of the linkage captured potential habitat with the southern branch capturing the most contiguous habitat but there is a significant gap in habitat along the Amargosa River.

Kingston Mesquite Mountains-Mojave National Preserve: The branch of the linkage through Shadow Valley captured the most suitable habitat that is contiguous with large areas of habitat in the two target areas. The eastern branch also captured a fair amount but habitat is more limited in the eastern part of the Kingston Mesquite block.

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Figure 61. Potential Habitat for Desert night lizard (Xantusia vigilis)

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage captured suitable habitat for this species but habitat is more limited in the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by badger, kit fox and desert tortoise captured the most highly suitable contiguous habitat between the two target areas.

Desert Spiny Lizard (*Sceloporus magister*)

Justification for Selection: The desert spiny lizard is sensitive to habitat fragmentation by heavily traveled roads or highways, which they rarely cross successfully and heavily urbanized areas. Other potential barriers to movement include major rivers or other large bodies of water (NatureServe 2009).

Distribution & Status: The desert spiny lizard ranges from northwest Nevada and southern Utah and southern California, Arizona, New Mexico, and west Texas, and down into northern Mexico (Parker 1982, Nussbaum et al. 1983, Degenhardt et al. 1996, Hammerson 1999, Dixon 2000, Grismer 2002, Stebbins 2003, NatureServe 2009). In California, it is found from the desert slopes of the mountains east to the Colorado River, south into Baja California, and north into Inyo County; also in the Inner Coast Ranges to Panoche Hills (Zeiner et al. 1988, Stebbins 2003). The elevational range for this species is from near sea level to 1,520 m (5,000 ft; Stebbins 2003).

Habitat Associations: This species occurs in a variety of habitats, including Joshua tree woodland, juniper and mesquite woodland, desert scrub, desert succulent scrub, palm oasis, playas, and desert wash and riparian communities (Degenhardt et al. 1996, Hammerson 1999, Stebbins 2003). They are typically encountered on gentle slopes or flat terrain (Parker and Pianka 1973, Brennan 2010). They seek cover under rocks, shrubs or trees (Stebbins 1954, Vitt and Ohmart 1974, Vitt et al. 1981, Zeiner et al. 1988).

Spatial Patterns: Phrynosomatid lizards, although able to cover fairly large distances, have relatively small home range sizes, often less than 0.5 ha and rarely more than 1 ha (NatureServe 2009). For S. undulatus erythrocheilus, Ferner (1974) found average home range size of 826 m^2 (.20 ac) for males and 363 m^2 (.09 ac) for females. Tanner and Krogh (1973) documented a juvenile dispersing 620 m (2034 ft).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This lizard inhabits arid and semiarid regions in Joshua tree woodland, juniper and mesquite woodland, desert scrub, desert succulent scrub, palm oasis, playas, and desert wash and riparian communities from sea level to 1520 m. It prefers gently sloping or flat terrain. Core areas were defined as greater than or equal to 25 ha. Patch size was classified as greater than or equal to 2 ha but less than 25 ha. Dispersal distance we defined as 1240 m.

Results & Discussion: Abundant habitat was identified on flat to gently sloping terrain throughout the planning area with potential cores and patches identified in all bet three of the wildland blocks, which are outside of this species range, including the Sierra Nevada, San Gabriel, or San Bernardino Mountains (Figure 62).

Sierra Nevada-China Lake North Range: Potential habitat was identified in all branches of the linkage in the lowlands along Highway 395 with the southern branch providing the most potential core habitat that is contiguous with core areas delineated in the southwest part of the China Lake North block.

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by badger provides the most highly suitable contiguous core habitat for this species.

Sierra Nevada-Edwards Air Force Base: The southern part of the linkage contains highly suitable potential habitat for this species through the Fremont Valley.

China Lake North Range-China Lake South Range: The southern branch through the Searles Valley provides the most contiguous habitat and the best connection between large areas of potential core areas in the southern part of China Lake North and the western part of the China Lake South block. Habitat was also identified in the central branch of the linkage to the north of Searles Dry Lake.

China Lake South Range-Edwards Air Force Base: The patch size analysis identified the majority of habitats in the linkage and on Edwards Air Force Base as highly suitable potential core areas with relatively smaller core areas identified on China Lake South.

China Lake South Range-Twentynine Palms and Newberry Rodman: The majority of core habitat in this area was identified in the lowlands along and surrounding the Mojave River. All branches of the linkage captured highly suitable habitat along the river with the western and two easternmost branches captured the most highly suitable habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage captured the most highly suitable contiguous habitat for this species between the two target areas.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but abundant potential habitat was identified in the linkage and on Edwards Air Force Base, much of which was delineated as potential core areas for this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern branch of the linkage captured the most highly suitable habitat for desert spiny lizard.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: All branches of the linkage captured highly suitable habitat for this species through the lowlands and along the Mojave River, with the swath following Pipes Wash providing a contiguous connection to potential cores on Twentynine Palms.

China Lake South Range-Kingston Mesquite Mountains: The southern branch and the strand along Salt Creek and the Amargosa River captured the most contiguous potential habitat.

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Figure 62. Potential Habitat for Desert spiny lizard (Sceloperus magister)

Kingston Mesquite Mountains-Mojave National Preserve: The central and eastern branches of the linkage captured the most highly suitable contiguous habitat but the branch through Shadow Valley provides a more direct connection between potential cores in both target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage contain highly suitable habitat through the lowlands with potential habitat more constricted through the Bristol Mountains. Fairly contiguous potential habitat was also identified along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by badger, kit fox and desert tortoise captured the most contiguous highly suitable habitat for this species between target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage captured fairly contiguous highly suitable habitat for this species but the western branch provides a better connection between potential cores in the two target areas.

Palen McCoy Mountains-Whipple Mountains: Very little potential habitat was delineated in the Whipple Mountains block but abundant highly suitable habitat was identified in the central branch of the linkage that is contiguous with potential cores in the Palen McCoy landscape block.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches of the linkage captured fairly contiguous suitable habitat for this species.

Joshua Tree National Park-Chocolate Mountains: The most highly suitable contiguous habitat was identified in the eastern branch of the linkage.

Palen McCoy Mountains-Chocolate Mountains: The patch size analysis identified a large potential core area in the Chuckwalla Valley, much of which was captured by the linkage but the southern branch captured the most highly suitable core habitat between the two target areas.

Palen McCoy Mountains-Little Picacho: All branches of the linkage contain potential habitat for this species through the lowlands but the swath delineated by kit fox and badger captured the most highly suitable contiguous habitat.

Chocolate Mountains-Little Picacho: The southern part of the linkage provides the most contiguous highly suitable habitat for the desert spiny lizard.

Chocolate Mountains-East Mesa: Like many other focal species, the most highly suitable habitat in this area was identified in the lowlands surrounding the Algodones Dunes with the dunes themselves delineated as non-habitat. Thus, the western strand of the linkage best serves the desert spiny lizard.

Great Basin collared lizard (*Crotaphytus bicinctores*)

Justification for Selection: The Great Basin collared lizard is vulnerable to habitat fragmentation by heavily traveled highways and urbanized areas. They rarely successfully cross busy highways. Major rivers, ponds and marshes may also act as barriers to movement for this species (NatureServe 2009).

Distribution & Status: The Great Basin collared lizard is widely distributed throughout the arid and semiarid regions of the Mojave, Sonoran, and Southeastern Great Basin Deserts, ranging from southwestern Idaho and southeastern Oregon, south through Great Basin of Nevada, Utah through southeastern California to southwestern Arizona (McGuire 1996, Stebbins 2003). It has been found at elevations ranging from sea level to about 2290 m (7,500 ft; Stebbins 2003).

Populations are apparently secure and have not been granted any special status (NatureServe 2009, CDFG 2011).

Habitat Associations: This species prefers rocky, fairly rugged terrain and can be found in areas such as lava flows, mountain slopes, gullies, washes, alluvial fans, rock outcrops, or rocky plains (Sanborn and Loomis 1979, McGuire 1996, Stebbins 2003). It is most common in desert succulent shrub, desert scrub, and desert wash habitats (Zeiner et al. 1988) with cover generally sparse (Sanborn and Loomis 1979, Stebbins 1985). In Mojave National Preserve, Persons and Nowak (2007) found them in rocky habitat ranging from low elevation creosote bush scrub to higher elevation pinyon-juniper woodland.

Spatial Patterns: Home range size of the Great Basin collared lizard has not been determined (Zeiner et al. 1988). However, Crotaphytids tend to have small home ranges but appear to be capable of making extensive movements (NatureServe 2009). A close related species, *C. collaris* had average territories of 1,827.5 m^2 (.45 ac) but the overall size of recorded ranges spanned nearly an order of magnitude from 431 to 3,557m^2 (.12-.88 ac; Lappin and Husak 2005). They have been found up to 1.6 km (.99 mi) away from its preferred habitat, so it can likely disperse through suboptimal habitat (Montanuccia 1983, McGuire 1996). Rocky river beds may be used as dispersal routes (Sanborn and Loomis 1979).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This lizard inhabits sparsely vegetated slopes, canyons, and alluvial fans within desert scrub, desert wash, pinyon, juniper, riparian, barren, and sagebrush habitats up to 2290 m in elevation. Core areas were defined as greater than or equal to 9 ha. Patch size was classified as greater than or equal to.36 ha but less than 9 ha. Dispersal distance was estimated at 3.2 km.

Results & Discussion: While potential cores and patches of suitable habitat were delineated in all of the landscape blocks within this species range, the majority of core habitat was delineated in the lowlands in between the target areas (Figure 63). The Great Basin collared lizard doesn't range into the Sierra Nevada, San Gabriel, or San Bernardino Mountains, or the East Mesa area.

Sierra Nevada-China Lake North Range: The southern branch provides the most potential habitat, which is contiguous with core areas delineated in the southwest part of the China Lake North block. Like many other focal species, the desert spiny lizard also benefits from a north-south connection as potential core areas were delineated all along Highway 395.

Sierra Nevada-China Lake South Range: The strand of the linkage delineated by the badger captured fairly contiguous potential core habitat for this species.

Sierra Nevada-Edwards Air Force Base: Potential core habitat was identified through the Fremont Valley part of the linkage and on Edwards Air Force Base.

China Lake North Range-China Lake South Range: The southern branch through the Searles Valley provides the most contiguous habitat and the best connection between large potential core areas in the southern part of China Lake North and the western part of the China Lake South block.

China Lake South Range-Edwards Air Force Base: The majority of land in the linkage and on Edwards Air Force Base was delineated as potential core areas for this species with relatively smaller core areas delineated in China Lake South.

China Lake South Range-Twentynine Palms and Newberry Rodman: The three focal species delineated strands captured the most contiguous potential core habitat between the target areas but most land in the linkage was delineated as potential breeding or move-through habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern strand captured the most contiguous highly suitable habitat for this species.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but most of the land in the linkage and on Edwards Air Force Base was delineated as potential breeding habitat for this species.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern strand delineated by badger provides the most potential habitat for this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Highly suitable habitat was identified through the lowlands and along Pipes Wash and the Mojave River with the higher elevation areas of the linkage delineated as move-through habitat.

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Figure 63. Potential Habitat for Great Basin collared lizard (Crotaphytus bicinctores)

Data Sources:
California Wildlife Habitat Relationships

China Lake South Range-Kingston Mesquite Mountains: Potential breeding habitat was identified in the northern and southern branches of the linkage and all along the Amargosa River and Salt Creek, linking the northern and southern strands.

Kingston Mesquite Mountains-Mojave National Preserve: The central branch of the linkage through Shadow Valley and the strand along the Amargosa River and Salt Creek provide the most likely connections for this species between target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential breeding habitat was identified along the Mojave River and in the lowlands surrounding the Bristol Mountains with move-through habitat interspersed throughout this range.

Mojave National Preserve-Stepladder Turtle Mountains: The branch along Homer Wash captured the most contiguous potential core habitat between the target areas but all branches captured highly suitable habitat through the lowlands.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches captured a fair amount of highly suitable habitat with the western strand providing the best connection to large core areas delineated in the Stepladder Turtle block.

Palen McCoy Mountains-Whipple Mountains: Not much habitat was delineated in the Whipple Mountains for this species but potential breeding habitat was identified throughout the Vidal Valley and central branch of the linkage.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches captured fairly contiguous swaths of potential breeding habitat between the target areas.

Joshua Tree National Park-Chocolate Mountains: The eastern strand of the linkage was mostly delineated as potential core habitat with some move-through habitat interspersed.

Palen McCoy Mountains-Chocolate Mountains: Potential breeding habitat was identified throughout the Chuckwalla Valley with the southern part of the main strand providing the most contiguous habitat between target areas for this species.

Palen McCoy Mountains-Little Picacho: Fairly contiguous potential cores and patches were delineated in the Chuckwalla Valley, along Palo Verde Mesa and down the eastern part of the linkage.

Chocolate Mountains-Little Picacho: The southern half of this linkage is outside of the range of this species. Habitat along Milipitas Wash and the Colorado River likely provide the best connection for this species between target areas.

Rosy boa (*Lichanura trivirgata*)

Justification for Selection: The rosy boa is a charismatic species associated with rocky alluvial fan habitats. This species is highly sought after by collectors, and there is concern regarding the sustainability of populations in the wild. There has been a dramatic increase in the variety of rosy boas now being bred in captivity, even though collecting this species in the wild is illegal (Fisher 2003). Furthermore, research indicates that populations of this species are heavily impacted by roads, habitat fragmentation, and urbanization (Fisher 2003).

Distribution and Status: The rosy boa inhabits the desert mountain ranges of western Arizona and southeastern California, from the Chocolate Mountains north to the Darwin Plateau and adjacent Panamint Mountains of Death Valley National Monument and from as far west as Lake Isabella in Kern County and Joshua Tree National Park east to the Weaver Mountains near Kingman, Arizona (Klauber 1931, Perrett 2002). In southern California, it is widely distributed in desert and chaparral habitats, from the coast to the desert. It is restricted to elevations from sea level to 1370 m (4500 ft; Stebbins 1985).

The rosy boa is listed as Sensitive by the U.S. Forest Service (CDFG 2011). Threats include road kill, illegal collection for the pet trade, altered fire regimes, and conversion of habitat from urban and agricultural development (Rosen and Lowe 1994, Holland and Goodman 1998).

Habitat Associations: In the California deserts, the rosy boa is associated with moderate to dense vegetation in desert scrub, wash, and riparian habitats with rocky outcrops and boulder piles on flats, hillsides and in canyons, especially those with permanent or intermittent streams, springs or washes (Klauber 1931, Zeiner et al. 1988, Perrett 2002).

Spatial Patterns: Diffendorfer et al. (2005) found rosy boa home range sizes of about 1.5 ha (3.71 ac). Juvenile dispersal distances haven't been measured but movements of 48.5 m (159 ft) have been recorded (Diffendorfer et al. 2005).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Rosy boas inhabit a variety of desert scrub communities below 1370 m in elevation. Core areas were defined as greater than or equal to 50 ha (124 ac). Patch size was delineated as greater than or equal to 3 ha (7 ac) but less than 50 ha. Dispersal distance was defined as 97 m (318 ft).

Results and Discussion: The majority of land in the linkage network and landscape blocks within the range of this species was delineated as potential breeding or move-through habitat (Figure 64). The patch configuration analysis suggests that the majority

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Figure 64. Potential Habitat for Rosy boa (*Charina trivirgata*)

of cores and patches of suitable habitat are within the dispersal distance defined for this species with some habitat in the Antelope Valley and coastal foothills of the San Gabriel and San Bernardino Mountains separated by distances too great for this species to disperse (Figure 65).

Sierra Nevada-China Lake North Range: Only the southern strand of the linkage is within the range of this species, where fairly contiguous potential breeding habitat was identified that is contiguous with potential cores delineated on China Lake North.

Sierra Nevada-China Lake South Range: The majority of land in the linkage was identified as potential core habitat which is interspersed with move-through habitat.

Sierra Nevada-Edwards Air Force Base: The linkage captured habitat on the southern slopes of the Sierra where this species has been recorded and through the Fremont Valley.

China Lake North Range-China Lake South Range: The southern branch through the Searles Valley captured the most habitat between target areas for this species.

China Lake South Range-Edwards Air Force Base: More potential core habitat was identified in the linkage than in either of the target areas but there are some gaps in habitat south of the Gravel Hills.

China Lake South Range-Twentynine Palms and Newberry Rodman: Almost all of the land in the linkage was identified as potential cores or move-through habitat with some gaps in habitat between Interstate 15 and 40.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern strand captured more contiguous potential breeding habitat while the southern branch contains breeding habitat interspersed with move-through habitat. The swath along the Mojave River captured highly suitable habitat linking these two branches.

Edwards Air Force Base-San Gabriel Mountains: Some small scattered potential cores and patches were identified in the linkage but these are separated by distances too great for the species to disperse.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Only potential move-through habitat was delineated on the desert slopes of the San Gabriel Mountains but all branches of the linkage contain potential breeding and move-through habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Virtually no habitat was delineated on the desert slopes of the San Bernardino Mountains but the majority of land in the linkage was delineated as potential breeding or move-through habitat with the strand along Pipes Wash capturing the most contiguous core habitat.

China Lake South Range-Kingston Mesquite Mountains: The bulk of the land in the linkage was delineated as move-through habitat with patches of breeding habitat interspersed. The southern and northern branches and the strand along the Amargosa River and Salt Creek captured the most contiguous highly suitable habitat.

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Figure 65. Patch Configuration for Rosy boa (Charina trivirgata)

Kingston Mesquite Mountains-Mojave National Preserve: The branches through Shadow Valley and Ivanpah Valley and the strand along the Amargosa River and Salt Creek captured the most contiguous highly suitable habitat between target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The majority of land in the linkage was identified as potential breeding or move-through habitat. The most highly suitable contiguous core habitat was delineated in the lowlands surrounding the Bristol Mountains and along the Mojave River, while smaller patches of breeding and move-through identified in the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: The swath of the linkage along Homer Wash captured the most contiguous highly suitable habitat between target areas. However, potential core habitat was identified throughout the lowlands in all strands of the linkage, while smaller patches of breeding and move-through habitat were delineated through the mountains.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches captured highly suitable habitat with the western branch providing a more direct connection to core habitat delineated in the Stepladder Turtle block.

Palen McCoy Mountains-Whipple Mountains: Virtually all land in the linkage was delineated as potential breeding or move-through habitat with the central branch capturing the most contiguous potential core areas.

Joshua Tree National Park-Palen McCoy Mountains: All three branches captured potential habitat for this species with the northern and central branches containing the most contiguous highly suitable habitat.

Joshua Tree National Park-Chocolate Mountains: Most land in the linkage was delineated as potential breeding or move-through habitat with the eastern strand capturing the most contiguous potential core areas.

Palen McCoy Mountains-Chocolate Mountains: The linkage captured potential breeding habitat through the Chuckwalla Valley and the southern Chuckwalla Mountains with most of the rest of this range identified as move-through habitat.

Speckled rattlesnake (*Crotalus mitchellii*)

Justification for Selection: This reptile depends on a variety of desert and chaparral habitats. Rattlesnakes are often destroyed when encountered by humans, and are also killed while crossing roads.

Distribution & Status: The distribution of the speckled rattlesnake ranges from southern Nevada and southwestern Utah to southeastern California and western Arizona and down south to the tip of Baja California (Stebbins 2003). Their range largely coincides with the Mojave and Sonoran Deserts, but the species may also be encountered on the southern fringes of the Great Basin Desert and in the mountains and coastal facing canyons of San Diego, Riverside, and Orange counties. It occurs from 300-2,200 m (1,000-7,300 ft) elevation (Klauber 1936, 1972, Stebbins 1954, Zeiner et al. 1988, Melli 2000).

The speckled rattlesnake is not listed as sensitive by any government entities, though more snakes are vulnerable to extinction than is currently recognized (Melli 2000).

Habitat Associations: The speckled rattlesnake inhabits a wide range of desert habitats including sagebrush, creosote bush, desert succulent scrub, chaparral and pinyon-juniper woodlands (Stebbins 2003) but it may also be found in oak woodlands and some conifer habitats (Zeiner et al. 1988). Melli (2000) also found them to use alluvial deposits in the desert. They strongly prefer rocky habitats and may be found on steep hillsides, in deep canyons, or in other areas with adequate rocky substrate and dense vegetation but they may occasionally occur on loose soil or in sandy substrates (Stebbins 2003). Rock formations, vegetation and mammal burrows provide shelter (Klauber 1936, 1972, Stebbins 1954, Zeiner et al. 1988).

Spatial Patterns: No data are available on home range or dispersal for the speckled rattlesnake (Zeiner et al. 1988). However, high-elevation populations of this species are known to move considerable distances to winter hibernacula (Klauber 1972, Zeiner et al. 1988). A closely related species, the red diamond rattlesnake (*C. ruber ruber*) has been more thoroughly researched. In the red diamond rattlesnake, home range sizes of males are larger than those of females and range between 0.5 and 5 ha (1.2-12.4 ac; Tracey 2000). Home ranges of males and females can overlap (T. Brown pers. comm.).

Movement distances for the red diamond rattlesnake are for adults on their home ranges: males can move 400-700 m (1,312-2,297 ft) from den sites (Tracey 2000). Fitch and Shirer (1971) measured average daily movements for adults at 45 m (147 ft) and found that 10% percent of moves were greater than 150 m (492 ft). Juveniles are more likely to disperse long distances, but no movement data are available for this life stage (Tracey 2000).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. Suitable habitats for speckled rattlesnakes are desert scrub, sagebrush, desert wash, pinyon-juniper, Joshua tree woodland, oak woodland, and some conifer habitats between 300-2,200 m in elevation. Core areas were defined as greater than or equal to 2.5 km^2. Patch size was classified as $\geq$ 0.10 km^2 but < 2.5 km^2. Dispersal distance is 1400 m, or twice the maximum recorded movement for an adult red diamond rattlesnake.

Results & Discussion: Potential habitat for the speckled rattlesnake is limited to the rocky and mountainous terrain preferred by this species (Figure 66). The patch configuration analysis (Figure 67) suggests that the majority of potential habitat in the study area is within the dispersal distance defined for this species but there are a few clusters of potential breeding habitat that appear to be isolated from the rest. Potential cores and patches delineated in the Dead, Sacramento, Chemehuevi, Whipple, Stepladder and Turtle Mountains may function as a separate metapopulation. Another isolated cluster was delineated in the Piute and Old Woman Mountains, while core habitat delineated in the McCoy Mountains looks to be completely isolated by distances too great for the species to disperse. Another cluster was delineated in the Peninsular Ranges and several small isolated patches were delineated in the Fremont and Antelope Valleys. This species doesn't range into the Sierra Nevada, San Gabriel, San Bernardino or East Mesa landscape blocks.

Sierra Nevada-China Lake North Range: The eastern half of the northern strand captured potential breeding habitat that is contiguous with cores delineated in the Coso Range on China Lake North.

Sierra Nevada-China Lake South Range: The southern strand captured fairly contiguous habitat through the El Paso Mountains, Summit Range and Lava Mountains.

Sierra Nevada-Edwards Air Force Base: The linkage captured some habitat in the rocky terrain along the slopes of the southern Sierra.

China Lake North Range-China Lake South Range: The northern branch provides a contiguous connection of core habitat following the Slate Range to the Argus Range.

China Lake South Range-Edwards Air Force Base: The linkage captured habitat patches in Lava Mountains and Gravel Hills that are within the species dispersal distance to other cores delineated in China Lake South.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential breeding habitat was identified in the Black Mountains in the western strand, the Calico Mountains in the central strands, and the Granite, Alvord and Cady Mountains in the eastern strand.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The southern branch captured a band of potential breeding habitat east of the Mojave River that is contiguous with core areas delineated in the Newberry Rodman block.

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Figure 66. Potential Habitat for Speckled rattlesnake (Crotalus mitchellii)

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SC Wildlands

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Figure 67. Patch Configuration for Speckled rattlesnake (Crotalus mitchellii)

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The linkage captured potential habitat on Stoddard Ridge, Sidewinder and Granite Mountains, and at the base of the San Bernardino and San Gabriel Mountains.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Potential cores were identified in the branch delineated by bighorn sheep and the strand following the Fry Mountains.

China Lake South Range-Kingston Mesquite Mountains: The northern strands through the Owlshead and Avawatz Mountains provide the most contiguous potential habitat between target areas.

Kingston Mesquite Mountains-Mojave National Preserve: Fairly contiguous habitat was identified in the western branch on Turquoise Mountain and in the eastern strand that follows the Clark Mountain Range.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The northern branch provides fairly contiguous potential habitat between the target areas.

Mojave National Preserve-Stepladder Turtle Mountains: The two western strands provide connectivity for this species from the Providence Mountains to the Clipper and Marble Mountains but the population in the Old Woman Mountains may be isolated from this and populations in the Stepladder Turtle Mountains. Fairly contiguous habitat was identified in the eastern strand linking the Stepladder to the Sacramento Mountains.

Stepladder Turtle Mountains-Palen McCoy Mountains: No habitat was identified in the linkage and the patch size analysis suggests populations in the Turtle, Palen, and McCoy Mountains are isolated from each other by distances too great for the species to disperse.

Palen McCoy Mountains-Whipple Mountains: The northern branch actually captured fairly contiguous habitat between the Whipple Mountains and the Stepladder and Turtle Mountains, while the southern branch captured connected populations in the Palen, Big Maria and Riverside Mountains.

Joshua Tree National Park-Palen McCoy Mountains: The northern branch captured habitat along the Granite Mountains.

Joshua Tree National Park-Chocolate Mountains: The western strands following the Orocopia Mountains and Mecca Hills captured potential breeding habitat that is contiguous with core areas delineated in the two target areas.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was captured through the Chuckwalla Mountains.

Palen McCoy Mountains-Little Picacho: The most contiguous habitat was identified in the strand delineated by bighorn sheep and most habitat cores are within the species movement capability but the patch configuration analysis suggests the population in the McCoy Mountains part of the linkage is isolated.

Chocolate Mountains-Little Picacho: The northern part of the linkage captured fairly contiguous potential habitat between the target areas.

Mojave Rattlesnake (*Crotalus scutulatus*)

Justification for Selection: The Mojave rattlesnake is vulnerable to roadkill on heavily traveled roads and highways (Rosen and Lowe 1994) and climate change-induced habitat shifts (Brown et al. 1997). This species preys upon rodents, lizards, other snakes, birds, bird eggs, and some insects (Klauber 1972, Zeiner et al. 1988).

Distribution & Status: The Mojave rattlesnake ranges from southern Nevada and southwestern Utah to the southern edge of the Mexican plateau and from the western edge of the Mojave Desert in California through Arizona to western Texas (Tennant 1984, Degenhardt et al. 1996, Stebbins 2003, Campbell and Lamar 2004, NatureServe 2009). In California, it is widely distributed throughout the Mojave Desert from 150 to 1500 m (492 to 4,921 ft) in elevation (Zeiner et al. 1988).

Habitat Associations: This species is most common in areas dominated by creosote (Larrea tridentata) and mesquite (Prosopis spp.) but it can be found in a variety of desert plant communities including barren desert, desert scrub, grassland, open juniper woodland, Joshua tree woodland, and desert wash habitats (Zeiner et al. 1988, Ernst 1992, Ernst and Ernst 2003, Stebbins 2003, Campbell and Lamar 2004, NatureServe 2009). It prefers lower mountain slopes and flat terrain and is not common in rocky areas or where the vegetation is too dense (Stebbins 1954, Klauber 1972, Zeiner et al. 1988, Stebbins 2003).

Spatial Patterns: No data are available on home range or dispersal for the Mojave rattlesnake (Zeiner et al. 1988). A closely related species, the red diamond rattlesnake (C. ruber ruber) has been more thoroughly researched. In the red diamond rattlesnake, home range sizes of males are larger than those of females and range between 0.5 and 5 ha (1.2-12.4 ac; Tracey 2000). Movement distances for the red diamond rattlesnake are for adults on their home ranges: males can move 400-700 m (1,312-2,297 ft) from den sites (Tracey 2000).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. The Mojave rattlesnake prefers flat terrain with slopes below 5 percent. It is often associated with creosote bush scrub, though it occupies a variety of desert habitats including desert scrub, desert wash, pinyon, juniper, riparian, and barren habitats ranging from 150 to 1,500 m in elevation. Core areas were defined as greater than or equal to 2.5 km^2. Patch size was classified as > 0.10 km^2 but < 2.5 km^2. Dispersal distance is 1400 m or twice the maximum recorded movement for an adult red diamond rattlesnake.

Results & Discussion: Although potential cores and patches of breeding habitat were delineated in all of the landscape blocks within this species range, the majority of core habitat was delineated in the lowlands between the targeted areas (Figure 68). All potential patches and cores within the ecoregion are within the dispersal distance defined for the species (Figure 69).

Sierra Nevada-China Lake North Range: This species doesn't range into the Sierra Nevada but the southern strand of the linkage captured fairly contiguous potential breeding habitat that extends to core areas delineated in the southwest corner of China Lake North.

Sierra Nevada-China Lake South Range: The northern strand captured a fair amount of potential breeding habitat for this species that is contiguous with cores delineated on China Lake South.

Sierra Nevada-Edwards Air Force Base: The majority of habitat in the southern half of the linkage was delineated as a potential core with move-through habitat interspersed.

China Lake North Range-China Lake South Range: The southern strand captured the most contiguous potential habitat between the target areas.

China Lake South Range-Edwards Air Force Base: The linkage captured more core habitat than was delineated in either target area. The potential breeding habitat is fairly contiguous and interspersed with move-through habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential habitat was identified in the lowlands in all branches of the linkage and along the Mojave River serving as a connection between the various branches.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Most of the land in the northern strand of the linkage was identified as potential breeding habitat that is contiguous with relatively smaller cores delineated in the two wildland blocks.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The eastern strand captured two core areas that are linked by move-through habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The strand following Pipes Wash provides the most contiguous potential habitat for this species.

China Lake South Range-Kingston Mesquite Mountains: The southern branch and the strand along Salt Creek and the Amargosa River captured the most contiguous habitat.

Kingston Mesquite Mountains-Mojave National Preserve: Fairly contiguous potential habitat was captured in the far eastern strand to the east of the Clark Mountains, through Shadow Valley and along the Amargosa River and Salt Creek.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat was captured throughout the lowlands surrounding the Bristol Mountains but is more limited through this range.

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Figure 68. Potential Habitat for Mojave rattlesnake (Crotalus scutulatus)

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Figure 69. Patch Configuration for Mojave rattlesnake (Crotalus scutulatus)

Mojave National Preserve-Stepladder Turtle Mountains: The strand of the linkage following Homer Wash provides fairly contiguous breeding habitat that is contiguous with habitats delineated in the two target areas.

Red Spotted Toad (*Anaxyrus punctatus*)

Justification for Selection: Bradford et al. (2003) speculate that this species follows the patchy population model (Harrison 1991, Harrison and Taylor 1997), where dispersal among patches is frequent enough that local extinctions are rare events. Although distance among patches may be far greater than 0.8 km maximum movement observed (Tevis 1966), during exceptionally moist years pools, seeps and streams may form in otherwise dry areas and floods may facilitate downstream dispersal (Bradford et al. 2003).

Distribution & Status: The red spotted toad's range includes southeastern California, southern Nevada and Utah, Arizona, southwest and southeast Colorado, New Mexico, southwestern Kansas and Oklahoma and south down into Baja California and central Mexico (Stebbins 2003).). It occupies elevations from below sea level in Death Valley up to 2000 m (6500 ft; Zeiner et al. 1988).

The red spotted toad is not recognized as a special status species (CDFG 2011). However, according to Bradford (2002) and Bradford et al. (2003), water developments (e.g., dams, diversions, ground water pumping) and degradation to wetland and riparian systems (e.g., agricultural development, livestock) can reduce the viability of red spotted toad populations.

Habitat Associations: The red spotted toad inhabits desert streams and washes, oases, rocky canyons and arroyos in open grassland, desert scrub, juniper, Joshua tree and oak woodland (Bragg and Smith 1943, Stebbins 1954, Tevis 1966, Mayhew 1968, Stebbins 1985, Zeiner et al. 1988, Stebbins 2003). This species is associated with ephemeral water bodies that are generally rocky with a relatively open bank cover (Bradford 2002). They breed during and after rains in temporary rain pools, rocky canyons, low gradient flood plains, steeply sloped tributaries, pools along intermittent and spring fed pools (Mayhew 1968, Tevis 1966, Stebbins 2003, Bradford et al. 2003). When not in water, it can be found under rocks, in rock crevices, or in underground burrows in close proximity to water sources (Bragg and Smith 1943, Stebbins 1954, Tevis 1966, Mayhew 1968, Stebbins 1985, Zeiner et al. 1988). They are good climbers and can traverse rocks with ease (Stebbins 2003). Dayton and Fitzgerald (2006) used soil structure, slope, elevation and distance from drainage channel to model habitat suitability in the Chihuahuan Desert.

Spatial Patterns: Turner (1959) estimated a density of 8 red spotted toads per acre (Zeiner et al. 1988). The toads aggregate at breeding pools and then disperse along intermittent streams after breeding. Maximum movement distances for B. punctatus along drainages in three studies range from 0.4 to 0.8 km (Turner 1959, Tevis 1966, L. McClanahan, unpublished data, in Bradford et al. 2003). In defining critical habitat for *B. californicus*, USFWS (1999) included breeding streams and upland areas within a 25-m elevational range of each essential stream reach and no more than 1.5 km away from the stream.

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This species occurs in desert streams and washes, oases, rocky canyons and arroyos in open grassland, desert scrub, juniper, Joshua tree and oak woodland at elevations ranging from below sea level to 2,000 meters. It is generally restricted to areas within 1.5 km of a water source. Patch size was not estimated. Dispersal distance was defined as 1.6 km.

Results & Discussion: Potential habitat for the red-spotted toad is restricted to the desert wash and riparian habitats in the study area (Figure 70). The patch configuration analysis suggests there are two major metapopulations and several smaller ones in the study area (Figure 71). One is centered along drainages that feed the Mojave and Amargosa Rivers and serve to connect populations in the Kingston Mesquite, Death Valley National Park, China Lake North and South Ranges, southern Sierra, Tehachapi, San Gabriel and San Bernardino Mountains, and Joshua Tree National Park. Two previously delineated linkage designs support this network, including the Tehachapi Connection and the San Bernardino-Little San Bernardino Connection (Penrod et al. 2003 and 2005). Another major population is centered along the Colorado River and serves to connect potential breeding habitat delineated in the Mojave National Preserve, Stepladder Turtle, Whipple, Palen, Chocolate, and Litte Picacho target areas.

Sierra Nevada-China Lake North Range: The southern branch of the linkage along Little Dixie Wash provides the most contiguous connection for red-spotted toad between the two target areas.

Sierra Nevada-China Lake South Range: The branch of the Linkage delineated by badger captured some potential habitat for red-spotted toad along Little Dixie and Teagle Washes.

China Lake South Range-Edwards Air Force Base: Some potential habitat was identified in all branches of the linkage but the patch configuration analysis suggests that the cluster of potential breeding habitat in the linkage is separated from those in the two target areas by distances too great for this species to disperse.

China Lake North Range-China Lake South Range: The linkage captures some washes flowing out of the Argus Range in the northern branch and habitat along Teagle Wash in the southern strand that is in close proximity to habitats delineated along Little Dixie Wash.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential habitat patches were identified in all branches of the linkage but only those patches identified along the Mojave River and up Daggett Wash into the Newberry Mountains target are within the species dispersal distance.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The best potential connection between target areas for this species is along Buckhorn Wash to the Mojave River and Daggett Wash.

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Figure 70. Potential Habitat for Red spotted toad (*Anaxyrus punctatus*)

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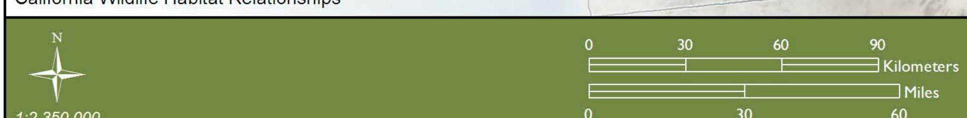
Figure 71. Patch Configuration for Red spotted toad (Anaxyrus punctatus)



Edwards Air Force Base-San Gabriel Mountains: Fremont and Buckhorn Washes provide the best potential connection for this species between the two target areas.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The Fremont Wash and Mojave River together provide the best potential riparian connection.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The Mojave River and Daggett wash provides the most potential habitat between target areas. Fairly contiguous habitat was also delineated along Pipes Wash.

China Lake South Range-Kingston Mesquite Mountains: The patch configuration analysis suggests a connection via Death Valley National Park with potential breeding habitat along an unnamed drainage that flows out of the northeast corner of China Lake South into the Amargosa River on Death Valley National Monument to habitats in Kingston Wash and along Salt Creek.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat was delineated for this species all along Kingston Wash, which connects to habitat in the branch of the linkage along the Amargosa River and Salt Creek and along the strand that follows a riparian habitats through the Clark Mountain Range.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat was identified in the linkage along drainages in the Bristol Mountains and along the Mojave River strand but the patch configuration analysis suggests populations in the two target areas are isolated by distances too great for the species to disperse.

Mojave National Preserve-Stepladder Turtle Mountains: At first glance Homer Wash appears to provide the most direct connection between target areas but the patch configuration analysis suggests another potential route that follows Piute Wash to the Colorado River and up Chemehuevi Wash to the Stepladder Mountains.

Palen McCoy Mountains-Whipple Mountains: The patch configuration analysis suggests the best potential connection for this species between target areas is along Bennett Wash, the Colorado River and McCoy Wash.

Joshua Tree National Park-Chocolate Mountains: Potential cores and patches in the two target areas appear to be separated by distances too great for the species to disperse but potential habitat was identified in the eastern branch along several washes that flow out of the Eagle Mountains, including Pinto, Eagle and Big Washes and Salt Creek.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was identified for this species in the linkage along Corn Springs Wash, Salt and Ship Creeks and the Arroyo Seco but none serve to connect habitat in the two target areas. The patch configuration analysis identified another potential connection for this species along the McCoy Wash, Colorado River and Milipitas Wash.

Palen McCoy Mountains-Little Picacho: The McCoy Wash and the Colorado River provide the best potential connection for this species between target areas.

Chocolate Mountains-Little Picacho: Potential habitat was delineated along Milipitas Wash and the Colorado River that may serve to connect the two target areas. Potential habitat was also identified in the eastern part of the linkage along Vinagre, Julian, and Gavilan Washes flowing out of the Chocolate Mountains into the Colorado River.

Ford's swallowtail (*Papilio indra fordi*)

www.worldinsect.com

Justification for Selection: The Ford's swallowtail is specific to a particular host-plant which has a very restricted range in the Mojave Desert. Extensive urban and agricultural developments are causing local extinctions in swallowtail populations (Emmel and Emmel 1973).

Distribution & Status: Ford's swallowtail is one of five subspecies of the cliff swallowtail (*P. indra*), which is widely distributed in the west from California, Nevada, Arizona, and New Mexico north to South Dakota, and west to Washington. Ford's swallowtail (*P.i. fordi*) is restricted to the Mojave Desert (Scott 1986).

Ford's swallowtail has no special status. However, NatureServe (2009) ranks this species National Conservation Status as imperiled (N2) and vulnerable (N3) due to its restricted range and the limited number of populations.

Habitat Associations: Ford's swallowtail is associated with mountains and canyons in the Mojave Desert. Host-plants are aromatic herbs that grow in rocky habitats, and include species in the genus *Cymopterus* and *Lomatium* but larvae may also eat turpentine bush (*Thamnosma Montana*) when normal hosts are unavailable (Scott 1986). This species is specific to *C. panamintensis* var. *acutifolius* (G. Pratt, pers. comm.), which is restricted to dry rocky slopes and canyon walls between 700-1000 m (2296-3280 ft; Baldwin et al. 2002) in creosote bush scrub and pinyon-juniper woodland (Calflora 2010). Adults sip flower nectar and mud, and they can be found flying along undisturbed watercourses or in moist canyons (Scott 1986). Adults perch in rocky places just below the hilltop to attract females (Scott 1986). Lomatium utriculatum can be found in coastal sage scrub, sagebrush scrub, yellow pine forest, foothill woodland, chaparral, and valley grassland (Calflora 2010).

Spatial Patterns: No home range or density estimates exist for this species. Dispersal and movements have not been measured in this subspecies. However, its large body size suggests that it is capable of making long-distance flights. Adults in the Grand Canyon can move several kilometers from host-plants to mating places (Scott 1986). In addition, when western swallowtail (*P. zelicaon*) males, a congener of similar size, were displaced 5 km (3.11 mi) from hilltops, they returned to the site of capture (Scott 1986).

Conceptual Basis for Model Development: This swallowtail prefers rocky substrates in mountainous terrain and canyon walls between 700-1000 m (2297-3281 ft) where their host-plants grow. They can also be found flying along watercourses where they sip mud and in rocky areas near hilltops where they seek mating opportunities. Minimum patch and core area sizes are less than the 30-m minimum mapping unit used in this GIS analysis and therefore no habitat patches were excluded from the analysis. Dispersal distance used in the model is 10 km, twice the reported distance reported for a congener.

Results & Discussion*:* Potential habitat for the Ford's swallowtail is restricted to desert scrub habitats near and on ridge tops and along watercourses in the Mojave Ecoregion (Figure 72). Due to the wide dispersal capabilities for this species, no patch of potential habitat was deemed isolated (figure not shown).

Sierra Nevada-China Lake North Range: Potential habitat was identified along Little Dixie Wash in the southern branch of the linkage.

Sierra Nevada-China Lake South Range: Potential habitat was delineated in all branches of the linkage in the El Paso Mountains, Summit Range and Lava Mountains and along Teagle and Little Dixie Washes.

Sierra Nevada-Edwards Air Force Base: Cache Creek bisects the southern part of the linkage but little habitat was identified on Edwards Air Force Base or in the linkage

China Lake North Range-China Lake South Range: All branches of the linkage captured potential habitat for this species with the most identified in the rocky terrain of the Slate Range in the northern strand and in the southern branch in the Spangler Hills, Lava Mountains and along Teagle Wash.

China Lake South Range-Edwards Air Force Base: Potential habitat is somewhat limited in the linkage with a fair amount delineated in the Lava Mountains and Gravel Hills with several small patches scattered in the southern part of the linkage.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential habitat was identified in all branches of the linkage in the Black, Calico, Granite, Alvord and Cady Mountains and all along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Scattered patches of potential habitat were identified in both major strands of the linkage with habitats along Buckhorn Wash, the Mojave River and Daggett Wash providing the most contiguous connection between target areas.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Habitats along Fremont Wash, the Mojave River, and Daggett Wash may serve this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The most potential habitat was identified along the Mojave River and Daggett Wash but a fair amount was also delineated in the eastern strand and along Pipes Wash.

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage captured potential habitat for the swallowtail with the northern strands in the Owlshead and Avawatz Mountains capturing the most contiguous habitat and the Amargosa River and Salt Creek serving to link these strands to the Kingston Mesquite target area.

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Figure 72. Potential Habitat for Ford's swallowtail (Papilo indra fordi)

Kingston Mesquite Mountains-Mojave National Preserve: The western strand captured the most upland habitat for this species while the Amargosa River, Salt Creek and Kingston Wash provide riparian connections between the two target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The northern strand provides the most potential habitat between target areas for the swallowtail but habitat was delineated throughout the Bristol Mountains and along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: Potential habitat was identified in all branches of the linkage in the Marble, Clipper, Ship, Old Woman, Piute, and Sacramento Mountains and along Homer Wash.

Bernardino dotted blue (*Euphilotes bernardino*)

Justification for Selection: The Bernardino dotted blue butterfly is sensitive to habitat loss and degradation. Coastal populations are being lost to development of coastal sage scrub habitats, while interior populations are threatened by habitat conversion due to increased fire frequency and invasive species such as cheatgrass (*Bromus tectorum*; (Barnes and McDunnough 1916, Opler et al. 2010).

Distribution & Status: The Bernardino dotted blue ranges from the central Coast Ranges, through the transverse ranges to the southern Sierra Nevada, east through the Mojave Desert into western Arizona, and down into northern Baja California (Barnes and McDunnough 1916, Opler and Wright 1999, Opler et al. 2010). It is rare throughout its range but may be locally abundant (NatureServe 2009, Opler et al. 2010). It is listed as Vulnerable by NatureServe (2009) because habitats in much of its range are being lost to development.

Habitat Associations: This butterfly can be found in a variety of habitats containing their hostplants (*Eriogonum* spp.), including desert scrub, chaparral, coastal sage scrub, conifer or oak woodland with shrub understory, rocky desert slopes, dunes, and dry lake beds (Pratt and Emmel 1998, Opler and Wright 1999, NatureServe 2009). Langston (1963) recorded the species in grasslands with scattered coast live oak (*Quercus agrifolia*), coyote brush (*Baccharis pilularis*) and bush monkey flower (*Mimulus aurantiacus*).

The Bernardino dotted blue is the only early summer dotted blue species whose caterpillars eat California buckwheat (*E. fasciculatum*). Other host plants include coastal buckwheat (*E. cinereum*) and Shockley buckwheat (*E. shockleyi*; Barnes & McDunnough 1916, Opler et al. 2010). All three of these hostplants occur below 2300 m in elevation (Calflora 2010).

Spatial Patterns: Adults have one flight period, generally February to late August depending on location. Males search for receptive females near hostplants throughout the day (NatureServe 2009). Even though *Euphilotes* spp. have low vagility, individuals may disperse 1000 m (0.62 mi; Arnold 1983, Peterson 1997, Austin et al 2008)

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This butterfly is associated with gentle to steep slopes in desert communities including desert scrub, dunes, dry lake beds and playas, pinyon-juniper, oak, sagebrush, and chaparral habitats where its host plants occur below 2300 m. Patch size was not estimated for this species. Dispersal distance was defined as 2000 m.

Results & Discussion: Potential habitat for the Bernardino dotted blue is widespread throughout the planning areas in flat to sloping terrain (Figure 73). All potential habitat patches delineated in the Mojave and Sonoran Ecoregions are within the species dispersal capability, with a few isolated habitat patches in Kings Canyon National Park and a few more in the western Owens Valley (figure not shown).

Sierra Nevada-China Lake North Range: The majority of land in the linkage was identified as habitat for this species with the southern strand providing the most potential habitat that is contiguous with a large patch delineated in the southwest corner of China Lake North. Fairly continuous habitat was also identified in the north-south connection that straddles the 395.

Sierra Nevada-China Lake South Range: Fairly contiguous potential habitat was delineated throughout the linkage with some small gaps along the ridges of the El Paso Mountains.

Sierra Nevada-Edwards Air Force Base: Most of the land on Edwards Air Force Base, through the Fremont Valley and in the upper part of the linkage was identified as fairly contiguous habitat for this butterfly with habitat more limited through a small stretch of rocky terrain.

China Lake North Range-China Lake South Range: Both the central and southern branches of the linkage captured potential habitat for this species with the southern strand providing a more direct connection to large areas of potential habitat in the two target areas.

China Lake South Range-Edwards Air Force Base: While some large patches of potential habitat were delineated on China Lake South, the majority of land in the linkage and on Edwards was identified as fairly contiguous habitat with some gaps through the Gravel Hills and Lava Mountains.

China Lake South Range-Twentynine Palms and Newberry Rodman: The three western strands of the linkage all contain areas of fairly contiguous habitat between the target areas. Habitat was also identified along the Mojave River linking the various strands of the linkage. The eastern swath also provides some large potential patches but habitat is more restricted through the Granite and Cady Mountains.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Potential habitat was identified in both east west branches of the linkage and along the Mojave River with the northern swath capturing the most contiguous habitat between target areas.

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Figure 73. Potential Habitat for Bernardino dotted blue (Euphilotes bernardino)

Edwards Air Force Base-San Gabriel Mountains: Very little habitat was delineated in the San Gabriel Mountains but the majority of land in the linkage and on Edwards was identified as potential habitat.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: A fair amount of potential habitat was captured in the southern strand and along Fremont Wash, the Mojave River and Daggett Wash.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The most contiguous habitat was delineated along Pipes Wash but potential habitat was identified in all branches of the linkage through the lowlands and along the Mojave River and Daggett Wash.

China Lake South Range-Kingston Mesquite Mountains: The southern strand captured the most contiguous potential habitat between the target areas but a fair amount of habitat was also captured in the northern strand and along the Amargosa River and Salt Creek.

Kingston Mesquite Mountains-Mojave National Preserve: All branches of the linkage contain some potential habitat for this species with the central branch through Shadow Valley, the far eastern swath, and the strand along the Mojave River and Salt Creek all providing fairly contiguous habitat for this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The strand along Daggett Wash and the Mojave River provides the most contiguous potential habitat between target areas but habitat was also delineated in the lowlands surround the Bristol Mountains with smaller scattered patches identified through this range.

Mojave National Preserve-Stepladder Turtle Mountains: The strand that follows Homer Wash captured the most contiguous habitat for this butterfly between target areas but potential habitat was also delineated in all other branches through the lowlands.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both strands captured fairly contiguous habitat through the lowlands with habitat more restricted through the Turtle Mountains.

Palen McCoy Mountains-Whipple Mountains: Very little habitat was identified in the Whipple Mountains but most of the land in the central strand of the linkage was delineated as potential habitat.

Joshua Tree National Park-Palen McCoy Mountains: All three branches captured fairly contiguous habitat between the target areas with the two northern swaths providing more connections to suitable habitat in the target areas.

Joshua Tree National Park-Chocolate Mountains: All branches include potential habitat but the central strand captured the most contiguous habitat between target areas.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was captured through the Chuckwalla Valley portion of the linkage and through the southern half of the main branch through the Chuckwalla Mountains.

Palen McCoy Mountains-Little Picacho: Fairly contiguous habitat was captured through the Chuckwalla Valley, along Palo Verde Mesa and down to Milipitas Wash with habitats more patchy south of here to Little Picacho.

Chocolate Mountains-Little Picacho: Scattered habitat patches occur throughout the linkage with the largest area of potential habitat delineated on the north side of the Cargo Muchacho Mountains.

Chocolate Mountains-East Mesa: The majority of land in the linkage was delineated as potential habitat for this species with a short gap of a few kilometers between the dunes and the Chocolate Mountains target area where potential habitat is much more limited.

Desert green hairstreak (*Callophrys comstocki*)

Justification for Selection: The desert green hairstreak inhabits remote, undisturbed desert canyons in California. Their habitats are susceptible to invasion by exotic plant species, especially cheatgrass (*Bromus tectorum*), and are potentially negatively impacted by the resultant higher fire frequencies that accompany cheatgrass stands. The green hairstreak is a habitat quality indicator that is a useful species for monitoring habitat health in the linkage (Pratt and Ballmer pers.com).

Distribution & Status: The desert green hairstreak occurs in parts of California, Nevada, Arizona, Utah, and southwestern Colorado. In California, it inhabits the high desert ranges of the Mojave Desert (Opler and Wright 1999, Natureserve 2009). According to the range map depicted in Opler et al (2010), there are documented occurrences in the northern two-thirds of the planning area including Mono, Inyo, and San Bernardino Counties.

NatureServe's designated global status (2009) for the species as imperiled because of its limited range or small population, though it is not listed under either the federal or California Endangered Species Act (CDFG 2011). The most prominent threat to the plant communities this species resides in is invasion by alien plants, which increases fire frequency and can result in habitat conversion *(*NatureServe 2009, Opler et al. 2010*)*. Heavily urbanized areas or habitats devoid of trees, shrubs, or foodplants are probably barriers to movement (NatureServe 2009).

Habitat Associations: This butterfly is found in remote desert canyons, dry slopes, and in ravines where their hostplant (*Eriogonum* spp.) occur (Opler and Wright 1999, NatureServe 2009). Habitat types that support their hostplants include sagebrush scrub and pinyon-juniper woodlands (Opler et al. 2010). Sulphur-flower buckwheat (*Eriogonum umbellatum*) is suspected as the primary hostplant in California (Emmel and Emmel 1973, Austin 1998, NatureServe 2009) but they may also utilize Wright's (*E. wrightii*) and redroot (*E. racemosum*) buckwheats (Opler and Wright 1999). All three of these plants are found below 3700 m (12,139 ft; Calflora 2010).

Spatial Patterns: Adults have one flight in spring between March and May with an occasional second flight in late summer between August and October (Austin 1998, Opler and Wright 1999). Males search out females in depressions or gulch bottoms (Opler et al. 2010).

Conceptual Basis for Model Development: This butterfly occupies high desert communities where it seeks out slopes, ravines, depressions, and canyon bottoms that support its host plant colonies. Typical habitats include sagebrush, pinyon, juniper, foothill woodlands, riparian, subalpine conifer, desert wash, and mixed chaparral communities reaching up to 3700 m in elevation. Dispersal distance was not estimated for this species but movement between target areas is assumed to be multigenerational.

Results & Discussion: Potential habitat for desert green hairstreak is restricted to the Mojave Ecoregion in flats, slopes, and canyons that support its host plants (Figure 74).

Sierra Nevada-China Lake North Range: The southern strand captured the most potential habitat that is contiguous with large areas of suitable habitat on China Lake North but fairly continuous habitat was also delineated in the north-south strand along Highway 395.

Sierra Nevada-China Lake South Range: The northern strand contains fairly contiguous habitat for this species.

Sierra Nevada-Edwards Air Force Base: The part of the linkage that falls within the Mojave Ecoregion was almost all delineated as potential habitat.

China Lake North Range-China Lake South Range: All branches of the linkage captured potential habitat for this species with the southern strand providing the most contiguous habitat between large areas of suitable habitat in the two target areas.

China Lake South Range-Edwards Air Force Base: The majority of the land in the linkage and on Edwards Air Force Base was identified as potential habitat with smaller areas of suitable habitat delineated on China Lake South. There are gaps in habitat through the Lava Mountains and Gravel Hills areas of the linkage.

China Lake South Range-Twentynine Palms and Newberry Rodman: A fair amount of habitat was delineated in all branches of the linkage with habitat restricted to steep ravines through the more mountainous areas. Habitats along the Mojave River provide connectivity among the various strands of the linkage.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Potential habitat was delineated in both east west strands and along the Mojave River with the northern branch providing the most contiguous potential habitat between target areas.

Edwards Air Force Base-San Gabriel Mountains: The San Gabriel Mountains are outside the range of this species but fairly contiguous potential habitat was delineated in the linkage and on Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern branch provides the most potential habitat but the strand along Fremont Wash, the Mojave River and Daggett Wash may also serve this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Pipes Wash captured the most contiguous habitat but habitat was identified throughout the lowlands of the linkage with scattered patches of habitat delineated in the mountainous areas.

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Figure 74. Potential Habitat for Desert green hairstreak (Callophrys comstocki)

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage contain potential habitat for this species with the southern strand capturing the most contiguous habitat between target areas.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat was delineated in all branches of the linkage with the swath through Shadow Valley providing the most contiguous potential habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The strand along Daggett Wash and the Mojave River captured the most contiguous potential habitat for this species between target areas but a fair amount of habitat was also delineated in the Bristol Mountains and surrounding lowlands.

Mojave National Preserve-Stepladder Turtle Mountains: The strand that follows Homer Wash provides fairly contiguous potential habitat between target areas.

Desert metalmark (*Apodemia mejicanus deserti*)

Justification for Selection: Also known as the Sonoran metalmark, the desert metalmark is one of three sympatric species in the genus *Apodemia* that occur in the Mojave Desert and southern Sierra Nevada (Pratt and Ballmer 1991). The host plants and butterflies tend to be patchily distributed (Pratt and Balmer 1991), which renders them sensitive to habitat loss and fragmentation.

Distribution & Status: *A. mejicanus* occurs in parts of California, Nevada, Arizona, New Mexico, Texas, Mexico and Baja California but the subspecies *A.m. deserti* occurs only in southeastern California and southern Nevada (Opler and Wright 1999). There are records of this species in every county in the study area, with the exception of Imperial County (Opler et al. 2010). They are primarily restricted to lowland areas below 1500 m (Pratt and Ballmer 1991).

The desert metalmark is not currently listed as a special status species (CDFG 2011). The most prominent threat to this species is likely the invasion of non-native plants such as cheatgrass (*Bromus tectorum)* into their habitat (NatureServe 2009)*.* Pollinators are threatened by habitat loss, degradation, fragmentation and pesticides (USFWS 2009).

Habitat Associations: This metalmark's primary hostplant, inflated buckwheat or desert trumpet (*E. inflatum*) occurs in creosote bush scrub, Joshua tree woodland, sagebrush scrub, and pinyon juniper woodland below 2000 m (Calflora 2010). The metalmark may also be found on rocky hills, dry washes, flats, oak grasslands, and desert alluvial fans (Pratt and Ballmer 1991, Opler and Wright 1999, NatureServe 2009, Opler et al. 2010).

Caterpillars eat the leaves of inflated buckwheat and Wright's buckwheat (*E. wrightii*) but Krameria spp. are also possible caterpillar hostsplants (Pratt and Ballmer 1991, Opler and Wright 1999).

Spatial Patterns: Adults have two to three flights between February and November**.** Males perch in hillside hollows or flats to search for receptive females (Opler and Wright 1999, Opler 2010). Home range for the related Mormon metalmark (*A. mormo*) has been estimated at 100 m^2 (1,076 ft^2; Pratt and Ballmer pers.com.). Typically, metalmarks make very limited movements during their life spans. *A. mormo's* average movement is 49 m (161 ft) for males and 64 m (210 ft) for females. The longest recorded movement was 617 m (2,024 ft; Scott 1986).

Conceptual Basis for Model Development: Movement between target areas is assumed to be multigenerational. This butterfly occupies creosote bush scrub, Joshua tree woodland, sagebrush scrub, pinyon juniper woodland, desert wash, oak grasslands and desert alluvial fans where its hostplants occur at elevations below 1,500 m. Dispersal distance was defined as 1,234 m.

Results & Discussion: Potential habitat for the desert metalmark is widespread in the study area (Figure 75) and virtually all patches are within the species dispersal distance (figure not shown). There are a few isolated habitat patches south of the Salton Sea.

Sierra Nevada-China Lake North Range: Fairly contiguous habitat was captured by the southern strand and the north-south connection along the 395.

Sierra Nevada-China Lake South Range: Most land in the linkage was delineated as potential habitat for the metalmark with habitat more restricted through the El Paso Mountains.

Sierra Nevada-Edwards Air Force Base: While very little habitat was identified in the southern Sierras the majority of land in the linkage and on Edwards Air Force Base was delineated as potential habitat.

China Lake North Range-China Lake South Range: All branches contain some potential habitat with the southern strand capturing the most and providing the most direct connection to large areas of suitable habitat in the two target areas.

China Lake South Range-Edwards Air Force Base: Fairly contiguous habitat was identified in the linkage with some gaps through the Lava Mountains and Gravel Hills.

China Lake South Range-Twentynine Palms and Newberry Rodman: The three western strands all captured fairly contiguous habitat between the target areas but the strand along the Mojave River and the eastern swath also contain a fair amount of habitat.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath captured the most contiguous potential habitat for this species between target areas.

Edwards Air Force Base-San Gabriel Mountains: Potential habitat in the San Gabriels is limited to the low elevation foothills but most land in the linkage and on Edwards Air Force Base was delineated as potential habitat.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern swath captured a fair amount of potential habitat for this species as did the riparian strands along Fremont Wash, the Mojave River and Daggett Wash.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Pipes Wash provides the most contiguous habitat between target areas but habitat was also delineated in the lowlands of the linkage and along the Mojave River and Daggett Wash.

China Lake South Range-Kingston Mesquite Mountains: Potential habitat was identified in all branches of the linkage with the southern swath and the strand along the Amargosa River and Salt Creek capturing the most contiguous habitat.

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Figure 75. Potential Habitat for Desert metalmark (*Apodemia mejicanus*)

Kingston Mesquite Mountains-Mojave National Preserve: Fairly contiguous potential habitat was delineated for this species in the central branch through Shadow Valley, the far eastern strand through Ivanpah Valley and in the strand along the Mojave River and Salt Creek.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage captured potential habitat for this species though habitat is more limited through the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: Fairly contiguous habitat was delineated in the swath following Homer Wash and in the riparian strands along Piute Wash, the Colorado River, and Chemehuevi Wash.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage captured a fair amount of habitat but the western strand provides a better connection to large areas of suitable habitat in the Stepladder Turtle block.

Palen McCoy Mountains-Whipple Mountains: Very little habitat was delineated in the Whipple Mountains. Potential habitat was captured by all branches of the linkage through the Vidal Valley with the central swath containing fairly contiguous habitat.

Joshua Tree National Park-Palen McCoy Mountains: The two northern strands provide fairly contiguous potential habitat through the Palen Valley.

Joshua Tree National Park-Chocolate Mountains: All branches contain potential habitat with the strand following Pinkham Wash and the eastern swath providing the most contiguous habitat between target areas.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was captured throughout the Chuckwalla Valley area of the linkage and in the southern part of the main swath that crosses over the lower elevation area of the Chuckwalla Mountains.

Palen McCoy Mountains-Little Picacho: Fairly contiguous habitat was identified between the target areas following Chuckwalla Valley, Palo Verde Mesa and habitats along the Colorado River.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured the most contiguous habitat between target areas.

Chocolate Mountains-East Mesa: The western strand of the linkage at the base of the Algodones Dunes captured fairly contiguous potential habitat for the metalmark.

Yucca Moth (*Tegeticula synthetica*)

Justification for Selection: The yucca moth is native to semi-arid habitats in the southwestern U.S. and Mexico where it is closely associated with the Joshua tree (*Yucca brevifolia*). The relationship between the yucca moth and the Joshua tree is one of the most cited examples of co-evolution. According to Riley (1892), the Joshua tree was the only species at that time known to be dependent on just one pollinator. This relationship is known as obligate mutualism. While Joshua trees are exclusively pollinated by yucca moths, research at the Pellmyr lab in the past decade has shown that two different types of yucca moths pollinate them (*T. synthetica riley* in the west and *T. antithetica pellmyr* in the east; Pellmyr and Segraves 2003).

Distribution and status: The yucca moth's range is congruent with the distribution of the Joshua tree. It occurs in the northern two thirds of the Mojave Desert, in southern Nevada, southeastern California, and extreme southwestern Utah to northwestern Arizona. In California, Joshua trees are found between 500 and 2,000 meters (1,640-6,562 ft) elevation (Vogl 1967, Munz 1974, Rowlands et al. 1982, Gossard 1992, Hickman 1993).

Habitat loss and encroachment may cause population deterioration of the yucca moth, as can pesticide use, which adversely affects Joshua tree populations (Gossard 1992).

Habitat Associations: The yucca moth is completely dependent on the Joshua tree. The adult moth resides inside the yucca flowers while the moth larvae rely exclusively on the seeds to complete their development. Within the Mojave ecosystem, the Joshua tree is the dominant species towering over a shrub canopy which may include sagebrush (*Artemisia tridentata*), blackbrush (*Coleogyne ramosissima*), creosote bush (*Larrea tridentata*), Mojave yucca (*Yucca schidigera*) cheesebrush (*Hymenoclea salsola*), and buckwheat (*Eriogonum fasciculatum*). Below the shrub layer, the ground cover may consist of various cacti and perennial grasses (Sawyer and Keeler-Wolf 1995).

Spatial Patterns: The yucca moth is the primary pollinator of the Joshua tree (Keeley et al. 1984, Tirmenstein 1989, Gossard 1992). Ramsay and Shrock (1995) observed that yucca moths stay very close to their home yucca clusters, and remain active on the plants for less than a week.

Conceptual Basis for Model Development: The Yucca moth is closely associated with its host plant the Joshua tree. It occupies flats and slopes in desert woodland and mixed desert scrub habitats where Joshua trees occur, between 500 and 2000 m in elevation. Dispersal distance was not estimate for this species but movement between target areas is assumed to be multigenerational.

Results & Discussion: Potential habitat for the yucca moth is restricted to flats and slopes in the Mojave Ecoregion (Figure 76).

Sierra Nevada-China Lake North Range: Potential habitat for the yucca moth tree is restricted to the desert facing low elevation slopes in the Sierra Nevada but is more widespread in the China Lake North Range. The southern strand of the linkage captured the most potential habitat for this species but habitat was also delineated all along the 395 in the north-south connection.

Sierra Nevada-China Lake South Range: A large patch of potential habitat was captured for this species to the west of Little Dixie Wash with small scattered patches delineated in the rest of the linkage.

Sierra Nevada-Edwards Air Force Base: The linkage captured potential habitat for this species on the desert facing slopes of the Tehachapi Mountains and down into Fremont Valley that is fairly contiguous with habitat identified on Edwards Air Force Base.

China Lake North Range-China Lake South Range: Potential habitat was identified in all branches of the linkage with the central branch capturing the most contiguous habitat around Searles Dry Lake.

China Lake South Range-Edwards Air Force Base: Abundant potential habitat was identified in both major branches of the linkage with the eastern strand capturing the most contiguous habitat between target areas.

China Lake South Range-Twentynine Palms and Newberry Rodman: The northern part of the three western strands of the linkage captured a fair amount of potential habitat for this species but habitat patches are smaller and more scattered in the southern part of the linkage.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The most potential habitat for this species between target areas was delineated in the western part of the northern branch, along the Mojave River and in the eastern part of the southern branch.

Edwards Air Force Base-San Gabriel Mountains: Fairly contiguous potential habitat was identified in the linkage and on Edwards Air Force Base but is restricted to the lower desert foothills in the San Gabriel Mountains target area.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: Potential habitat was identified in all branches of the linkage with the most contiguous delineated in the southern part of the eastern branch.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Potential habitat was identified in all branches of the linkage with the eastern swath capturing the most habitat that is contiguous with large patches identified on the desert slopes of the San Bernardino Mountains.

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Figure 76. Potential Habitat for Yucca moth (*Tegeticula synthetica*)

China Lake South Range-Kingston Mesquite Mountains: Scattered patches of potential habitat were delineated in all branches of the linkage but only to the west of the Amargosa River.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat was identified in all but the two outermost branches of the linkage with the central branch through Shadow Valley capturing the most contiguous habitat.

Joshua tree (*Yucca brevifolia*)

Justification for Selection: Movement of pollen, which represents the transfer of genes, is largely dependent on the yucca moth (*Tegeticula synthetica*; Keeley et al. 1984, Tirmenstein 1989, Gossard 1992). Population movement likely requires broad expanses of habitat. Habitat loss and encroachment may cause population deterioration of the yucca moth through pesticide use, which will also adversely affect Joshua tree populations (Gossard 1992). Numerous other species depend on the Joshua tree as a resource for food, or as a home, perch, nest site, or cover (Miller and Stebbins 1964, Bakker 1971, Gossard 1992).

Distribution and Status: The Joshua tree is endemic to the Mojave Desert, which encompasses parts of California, Nevada Utah, and Arizona (Hickman 1993). In California, Joshua trees are found between 500-2,000 m (1,640-6,562 ft) elevation (Vogl 1967, Munz 1974, Rowlands et al. 1982, Gossard 1992, Hickman 1993). Paleontological research has shown that Joshua trees have shifted distribution over time. Around 30,000 BP, the Joshua tree existed 225 miles farther south at elevations 200-300 m (656-984 ft) below present ones (George 1998).

Habitat Associations: Joshua trees may be found in open desert scrub, creosote scrub, Joshua tree woodland, pinyon-juniper woodland, and in desert grassland habitats (Stark 1966, Brown 1982, Tirmenstein 1989). They are associated with desert plains, alluvial fans, slopes, ridges, bajadas, mesas, and foothills (Webber 1953, Stark 1966, Maxwell 1971, Tirmenstein 1989). Joshua tree woodland intergrades with desert scrub, alkali scrub, and desert succulent scrub at lower elevations and with pinyon-juniper woodland and sagebrush habitats at higher elevations. Joshua trees may also be found adjacent to desert riparian and desert wash habitats (Holland 1986).

Joshua trees typically occur in open woodlands of widely scattered Joshua trees (Miller and Stebbins 1964, Kuchler 1977). While the Joshua tree is the dominant species towering over the shrub community in the Mojave ecosystem (Sawyer and Keeler-Wolf 1995), other species may coexist in the overstory, including California juniper (*Juniperus californica*), singleleaf pinyon (*Pinus monophylla*), and Mojave yucca (*Yucca schidigera*; Munz 1974, Paysen et al. 1980, Parker and Matyas 1981). Dominant species of the shrub understory may include sagebrush (*Artemisia tridentata*), blackbush (*Coleogyne ramosissima*), and creosote bush (*Larrea tridentate*; Sawyer and Keeler-Wolf 1995).

Spatial Patterns: The primary pollinator of the Joshua tree is the yucca moth (*Tegeticula synthetica*) (Keeley et al. 1984, Tirmenstein 1989, Gossard 1992). Seed dispersal agents include wind and animals, including birds that expose the Joshua tree seeds for subsequent wind dispersal (McKelvey 1938, Tirmenstein 1989) and desert rodents, which are known to cache Joshua tree seeds (Keith 1985, Tirmenstein 1989). In some areas, vegetative reproduction is also an important mode of regeneration (McKelvey 1938, Vogl 1967, Keith 1982, Conrad 1987, Tirmenstein 1989).

Conceptual Basis for Model Development: The Joshua tree occupies flats and slopes in desert woodland and mixed desert scrub habitats between 500 and 2000 m in elevation.

Results & Discussion: The Joshua tree has the potential to occur in 10 of the current linkage planning areas (Figure 77) but was also selected as a focal species for the San Bernardino-Little San Bernardino Connection (Penrod et al. 2005), San Bernardino-Granite Connection (Penrod et al. 2005) and the Joshua Tree-Twentynine Palms Connection (Penrod et al. 2008).

Sierra Nevada-China Lake North Range: In the two target areas, potential habitat for the Joshua tree is restricted to the desert facing low elevation slopes in the Sierra Nevada and the southern half of the China Lake North Range. Potential habitat was captured in the central and southern branches of the linkage and in the north-south swath linking the central and southern branches.

Sierra Nevada-China Lake South Range: Most of the Sierra Nevada and the entire China Lake South block are outside of the range of this species but all branches of the linkage captured some potential habitat with the southern branches capturing the most contiguous habitat in the foothills of the Sierras.

Sierra Nevada-Edwards Air Force Base: The linkage captured potential habitat for this species on the desert facing slopes of the Tehachapi Mountains and down into Fremont Valley that is fairly contiguous with habitat identified on Edwards Air Force Base.

China Lake South Range-Edwards Air Force Base: The China Lake South Range is outside of this species distribution but abundant potential habitat was identified on Edwards Air Force Base and in the southern half of all branches of the linkage.

China Lake South Range-Twentynine Palms and Newberry Rodman: Both of the target areas and most of the linkage are outside of the range of this species but a small population occurs just outside of the Newberry Rodman block along the Mojave River. The linkage captured some of this area but this species would likely benefit from the swath along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Roughly the western third of the linkage is within the range of the species. Some potential habitat was identified in all branches but the northern swath contains the most potential habitat for Joshua tree.

Edwards Air Force Base-San Gabriel Mountains: Fairly contiguous potential habitat was identified in the linkage and on Edwards Air Force Base.

Figure 77. Potential Habitat for Joshua tree (Yucca brevifolia)

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The two target areas are outside of the range of this species but the southern portion of all branches of the linkage contain potential habitat with the eastern swath capturing the most.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Potential habitat for the Joshua tree was identified in all branches of the linkage. The eastern branch captured the most potential habitat and it is contiguous with a fair amount of habitat identified on the desert slopes of the San Bernardino Mountains.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat was identified in all but the two outermost branches of the linkage with the central branch through Shadow Valley capturing the most contiguous habitat.

Justification for Selection: Mojave yucca is a long-lived slow-growing species (Wallace and Romney 1972). It provides important resources for a number of wildlife species. It is pollinated by a specific moth, and also has a specific giant skipper associated with it (G. Pratt, pers. comm.).

Distribution & Status: In California, Mojave yucca occurs from the Mojave Desert in southeastern California as far west as the Pacific Coast, reaching its northern limit in San Bernardino County and its southern limit in Baja Claifornia Norte (Webber 1953, Fried et al. 2004, Gucker 2006). Munz (1974) reports an upper elevation limit of 2377 m (7800 ft).

Mojave yucca is not a special status species. It provides food, nest materials, nesting sites and habitat for a variety of desert wildlife species, including small mammals, birds, and reptiles (England et al. 1984, Germano and Joyner 1988, Rundel and Gibson 1996, Gucker 2006). Bobcats use the Queen Valley area of Joshua Tree National Park extensively for hunting where Mojave yucca is the dominant plant species (Zezulak and Schwab 1981, Gucker 2006). Other research indicates that Mojave yucca is also an important water source (Cameron 1971, Cameron and Rainey 1972, Gucker 2006).

Habitat Associations: Mojave yucca can be found in desert scrub, desert washes, blackbrush scrub, Mojave yucca-buckhorn cholla, Mojave yucca-chamise, mixed steppe, and Joshua tree woodland habitats (Cardiff and LaPre 1980, Turner 1982, Fidelibus et al. 1996, Peinado et al. 1997, Gucker 2006). It is primarily associated with dry rocky slopes, flats, or washes (Cooper 1922, Wallace and Romney 1972, Munz 1974, Conrad 1987, Welsh et al. 1987, Kartesz 1988, MacKay 2003, Gucker 2006).

Spatial Patterns: Mojave yucca reproduces both sexually through seed production and asexually through sprouting and clonal growth (Webber 1953, Cardiff and LaPre 1980). Asexual is the principal type of reproduction. Research at the Deep Canyon Desert Research Center estimated the last successful seedling establishment occurred 40 or 50 years earlier, while the average age of monitored clone plants was 300 to 600 years old (LaPre 1979, Gucker 2006).

Mojave yucca blooms from April through May (Munz 1974). It has a mutualistic relationship with its pollinator, a yucca moth (*Tegeticula yuccasella*), which collects pollen from several flowers and transfers it to the stigma tube of other flowers for fertilization before laying its eggs in the ovary where the larvae feed on the developing seeds (Webber 1953, Gucker 2006).

Seed predation by small mammals is quite common (Arnott 1962, Force and Thompson 1984, Gucker 2006). The fruit and seeds are dispersed by mammals (Pendleton et al 1989), though seedlings are rarely observed in the field (Yeaton et al. 1985). Webber (1953) found only 6 seedlings in 4 years of field observations in southern California.

The increase in nonnative annual grasses has increased fire frequency in the Mojave and Great Basin deserts (Esque and Schwalbe 2002, Brooks et al. 2004, Emming 2005). Although Mojave yucca sprouts following fire (Conrad 1987, Loik et al. 2000), the available literature does not address Mojave yucca recovery and survival following repeated fires at short intervals (Gucker 2006).

Conceptual Basis for Model Development: Mojave yucca occurs on dry rocky slopes, flats and washes in desert scrub, desert wash, blackbrush scrub, Mojave yucca-buckhorn cholla, Mojave yucca-chamise, mixed steppe, and Joshua tree woodland habitats below 2377 m in elevation.

Results & Discussion: The Mojave yucca has the potential to occur in 6 of the currently linkage planning areas (Figure 78) and was also selected as a focal species in the Joshua Tree-Twentynine Palms Connection (Penrod et al. 2008).

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The eastern half of the linkage and the Twentynine Palms landscape block are within the range of this species. The northern branches of the Linkage captured the most potential habitat for the Mojave yucca.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The central branch of the linkage captured the most potential habitat for this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The central and eastern branches of the linkage contain the most potential habitat for the Mojave yucca.

Kingston Mesquite Mountains-Mojave National Preserve: The Mojave yucca is generally restricted to the eastern part of this linkage planning area. All of the eastern branches of the linkage contain potential habitat for this species with the central branch through the Shadow Valley and the easternmost branch capturing the most contiguous habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage contain some potential habitat with the most contiguous habitat identified in the lowlands to the south of the Bristol Mountains and along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by badger, kit fox and desert tortoise captured fairly contiguous potential habitat for the Mojave yucca between the two target areas.

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Figure 78. Potential Habitat for Mohave yucca (Yucca schidigera)

Desert willow (*Chilopsis linearis*)

Justification for Selection: The desert willow is a long-lived woody plant that provides nectar for numerous birds and insects, and is primarily pollinated by bees. This species also has a specific sphinx moth (*Manduca maculate*) associated with it.

Distribution & Status: The desert willow is distributed throughout the southwestern United States in Utah, Nevada, and southern California, and northern Mexico (Little 1976, Uchytil 1990). In California, it is found below 1524 m (5000 ft) in elevation (Munz 1974).

Desert willow is not a special status species. However, it provides important resources to numerous species. A number of desert songbirds nest in the desert willow, which also provides cover for other wildlife species (Uchytil 1990). The shape of the flower is particularly attractive to hummingbirds, which feed on the nectar (Gullion 1964, Brown et al. 1981, Uchytil 1990). The leaves and the fruit of the flower are also consumed by species such as mule deer (Short 1977, Uchytil 1990), and various birds eat the seeds (Vines 1960, Gullion 1964, Uchytil 1990).

Habitat Associations: The desert willow is restricted to areas where its long roots can reach the water table, such as dry washes, intermittent streams and other water courses in moist canyons (Kearney et al. 1960, Munz 1974, Johnson 1976, Burk 1977, Welsh et al.1987, Simpson 1988, Uchytil 1990).

Spatial Patterns: The desert willow flowers from May to September in southern California (Munz 1974). It is pollinated by numerous species of bees and hummingbirds (Brown et al. 1981, Uchytil 1990). Fruit set may be limited by inadequate movement of pollinators between trees (Petersen et al. 1982, Uchytil 1990). Desert willow produces abundant seed, which is wind dispersed and probably only viable until the spring following dispersal (Magill 1974, Pendleton et al. 1989, Uchytil 1990).

Conceptual Basis for model Development: Desert willow occupies desert riparian, desert wash, and palm oasis habitats in moist canyons in deserts and mountain foothills below 1524 m in elevation.

Results & Discussion: The desert willow has the potential to occur in 10 of the current linkage planning areas (Figure 79) and was also identified as a focal species for the Joshua Tree-Twentynine Palms Connection (Penrod et al. 2008).

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Figure 79. Potential Habitat for Desert willow (Chilopsis linearis)

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Potential habitat was identified for the desert willow in all branches of the linkage with the swath following Pipes Wash capturing the most contiguous habitat between the two target areas. This species also benefits from riparian habitat along the Mojave River.

Kingston Mesquite Mountains-Mojave National Preserve: Some potential habitat was identified in all branches of the linkage with Kingston Wash that flows through the central branch and the Amargosa River and Salt Creek in the far western branch providing the most contiguous potential habitat between the two target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: All branches of the linkage captured potential habitat for the desert willow with Siberia, Broadwell and Orange Blossoms Washes and the Mojave River providing the most contiguous habitat.

Mojave National Preserve-Stepladder Turtle Mountains: The branch that follows Homer Wash captured the most direct potential connection for this species between the two target areas but potential habitat was delineated in all branches of the linkage.

Palen McCoy Mountains-Whipple Mountains: Potential habitat for desert willow was delineated in all branches of the linkage through the upper Vidal Valley. The riparian strands following Bennett Wash, the Colorado River and McCoy Wash likely provide the best connection for this species but the southern branch also captured quite a bit of habitat in the Riverside and Big Maria Mountains.

Joshua Tree National Park-Chocolate Mountains: All branches of the linkage contain some potential habitat for desert willow with the western and eastern strands providing the most. Pinkham Wash likely provides the best connection between target areas.

Palen McCoy Mountains-Chocolate Mountains: Ample habitat was delineated in all branches of the linkage with more contiguous habitat identified along Iris, Salt, Corn Springs and Ship Washes and the upper part of the Arroyo Seco.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured the most potential desert willow habitat.

Blackbrush (*Coleogyne ramosissima*)

Justification for Selection: Blackbrush is a post pleistocene relict species that occurs on ancient granitic debris flows (Webb et al. 1987, Webb et al. 1988, Anderson 2001). It provides important cover and forage for mule deer and bighorn sheep, especially in winter (Bradley 1965, Stark 1966, Bowns and West 1976, Mozingo 1987, Urness and Austin 1989, Anderson 2001). In California, it comprises up to 25% of mule deer winter diet (Leach 1956). Blackbrush also provides cover and food for birds and small mammals (Brown and Smith 2000), who consume the seeds (Stark 1966, Mozingo 1987, Anderson 2001).

Distribution & Status: Blackbrush occurs in the transition between the Mojave and Great Basin deserts, from southeastern California, along the borders of Nevada, Utah, and Arizona to southwestern Colorado (Ackerman and Bamberg 1974, Bowns and West 1976, Banner 1992, Anderson 2001). Its elevational range is from 600 to 1600 m (1968-5249 ft; Hickman 1993, Calflora 2010).

Blackbrush is not a special status species. In fact, it is often the dominant plant where it occurs (Bowns 1973, Bowns and West 1976, Bates 1983, Lei and Walker 1997, Anderson 2001). However, it is sensitive to disturbance and considered a declining plant community (I. Anderson, pers. comm.).

Habitat Associations: Blackbrush can occur in monotypic stands or as a component of other vegetation communities (Banner 1992, Anderson 2001). It occurs in virtually pure stands between the creosote scrub and Joshua tree communities at lower elevations of the Mojave and the sagebrush and juniper habitats at upper elevations in the Great Basin desert (Bradley 1965, Bowns 1973, Bowns and West 1976, Turner 1982, Bates 1983, Anderson 2001). Plants associated with blackbrush communities vary depending on the adjacent biome (Turner 1982). In the Mojave, subordinate shrubs may include Mojave yucca, creosote bush, and turpentine bush (Smith and Bradney 1990, Anderson 2001). Blackbrush stands occur on well-drained sites including alluvial fans, washes, valley bottoms, gentle slopes, and flatlands (Bowns 1973, Ackerman and Bamberg 1974, Ackerman et al. 1980, Bates 1983, Tueller et al. 1991, Banner 1992, Lei and Walker 1997, Anderson 2001).

Spatial Patterns: Fidelibus et al. (1996) found widely different densities of blackbrush in different plant communities. For example, in blackbrush scrub there was a density of 8,894 plants per ha, while in Joshua tree woodland there were 647 plants per ha.

Blackbrush is a long-lived species (Webb et al. 1987, Anderson 2001). It regenerates from wind-pollinated seed (McArthur 1989, Anderson 2001), though seed establishment is rare (Webb et al. 1987, Anderson 2001). Likely dispersers of the large, heavy fruits are rodents and erosion (Bowns 1973, Beatley 1974, Webb et al. 1987, McArthur 1989, Anderson 2001). Few seedlings survive due to rodents digging up the cache for remaining seeds, soil erosion, or limited moisture (Bowns 1973, Bowns and West 1976, Longland 1995, Anderson 2001). However, rodent caches may also produce clusters of seedlings (Bowns 1973, Beatley 1974, Bowns and West 1976, Webb et al. 1987, Lei 1997, Anderson 2001). Herbivore browsing may also contribute to irregular and inconsistent seed set and seedling establishment (Hughes and Weglinski 1991).

Blackbrush doesn't germinate easily (Beatley 1974, Webb et al. 1987, Anderson 2001). The seeds remain dormant until appropriate levels of soil moisture are met (Lei and Walker 1997). The seeds also require cold stratification without light for germination (Bowns 1973, Bowns and West 1976, Lei and Walker 1997, Anderson 2001). With heavy rains in early spring, blackbrush can germinate in large numbers, suggesting certain climatic conditions must be met to ensure establishment (Beatley 1974, Webb et al. 1987, Anderson 2001).

Conceptual Basis for Model Development: Blackbrush can be found in creosote bush scrub, desert scrub, sagebrush, Joshua tree woodland, juniper, and pinyon-juniper habitats between 600-1600 m in elevation.

Results & Discussion: Blackbrush has the potential to occur in several of the current linkage planning areas (Figure 80); it was also a focal species for the Joshua Tree-Twentynine Palms Connection (Penrod et al. 2008).

Sierra Nevada-China Lake North Range: The southern branch of the linkage captured potential habitat that is fairly contiguous with habitat identified in the two target areas. However, the majority of potential habitat in this area was identified in between the two target areas along Highway 395 in the north-south strands of the linkage.

China Lake North Range-China Lake South Range: Some potential habitat was identified in all branches of the linkage but the southern branch captured the most potential habitat and best connects areas of habitat delineated in the two target areas.

Sierra Nevada-China Lake South Range: The branch of the linkage delineated by badger captured the most contiguous potential habitat for blackbrush.

Sierra Nevada-Edwards Air Force Base: Most of the land in the linkage and on Edwards Air Force Base was identified as potential habitat for this species.

China Lake South Range-Edwards Air Force Base: The great majority of land in the linkage and on Edwards Air Force Base was identified as potential habitat for blackbrush with habitat on China Lake South mostly restricted to the southwest part of this Range.

China Lake South Range-Twentynine Palms and Newberry Rodman: The western branches of the linkage captured the most contiguous potential habitat for this species.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath of the linkage contains fairly contiguous potential habitat for blackbrush.

Figure 80. Potential Habitat for Blackbrush (*Coleogyne ramosissima*)

Edwards Air Force Base-San Gabriel Mountains: Abundant potential habitat was identified in the linkage and on Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern branch captured the most contiguous potential habitat for blackbrush.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The majority of potential habitat in this area was identified in the lowlands into between the targeted landscape blocks.

China Lake South Range-Kingston Mesquite Mountains: All branches of the linkage captured potential habitat to the west of the Amargosa River but Death Valley and the River were delineated as non-habitat leaving about a 10 km gap to habitats in the Kingston Mesquite target area.

Kingston Mesquite Mountains-Mojave National Preserve: All branches of the linkage with the exception of the strand following the Amargosa River and Salt Creek captured potential habitat with the central branch through Shadow Valley providing the most potential habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: The northern branch of the linkage captured the most potential habitat and likely serves this species.

Mojave National Preserve-Stepladder Turtle Mountains: The branch of the linkage delineated by badger, kit fox and desert tortoise captured the most potential habitat for blackbrush.

Joshua Tree National Park-Chocolate Mountains: Potential habitat in the linkage was delineated in between the Chocolate and Chuckwalla Mountains and on the northern slopes of the Orocopia Mountains.

Arrowweed (*Pluchea sericea*)

Justification for Selection: Arrowweed is a dominant shrub in riparian habitats throughout the southwestern United States (NatureServe 2009). It is identified as a valuable community to bird populations, including black rail (*Laterallus jamaicensis*) in the lower Colorado River valley (Anderson et al. 1977, Conway and Sulzman 2007). It also provides important forage for species such as the desert mule deer (*Odocoileus hemionus eremicus*; Marshal et al. 2004).

Distribution and Status: Arrowweed is found across the southwestern United States in California, Nevada, Arizona, New Mexico, Texas, and Utah (NatureServe 2009). Within California, arrowweed occurs in the San Joaquin Valley, Inner South Coast Ranges, South Coast, Channel Islands, Transverse Ranges, Peninsular Ranges, and the Desert bioregions (Hickman 1993). There are no recorded occurrences in Tulare or Mono counties (Calflora 2010).

Populations are apparently secure globally (NatureServe 2009). Arrowweed can maintain co-dominance with the invasive species salt cedar (*Tamarix* spp.) for up to 50 to 60 years before salt cedar out competes it (Zouhar 2003).

Habitat Associations: Arrowweed may be found in coastal sage scrub, creosote bush scrub, and wetland or riparian habitats (Calflora 2010). It occurs in stream bottoms, washes, canyons, around springs and sometimes in saline areas, usually below 600 m in elevation (1,969 ft; Hickman 1993). It can tolerate salt, sand, clay, little or no drainage, and seasonal flooding (Drezner and Fall 2002).

Spatial Patterns: Arrowweed may form dense thickets along streams, washes, in canyons, around springs, and sometimes in saline areas (Hickman 1993). Seeds are wind dispersed (Drezner and Fall 2002). Arrowweed can also tolerate fire and my actually increase in volume and extent following fires (Zouhar 2003).

Conceptual Basis for Model Development: Arrowweed forms thickets in stream bottoms, washes, canyons, around springs, and sometimes in saline areas. It is associated with coastal sage scrub, creosote, and wetland or riparian habitats below 600 m in elevation.

Results & Discussion: Potential habitat for arrowweed is fairly restricted in the higher elevation Mojave Ecoregion but it is more widespread in the Sonoran desert (Figure 81).

China Lake North Range-China Lake South Range: Potential habitat was identified in the central swath of the linkage around Searles Dry Lake.

China Lake South Range-Twentynine Palms and Newberry Rodman: Habitat in the China Lake South Range is limited to the northern part of target area. Potential habitat in the linkage is restricted to the central branch on the north and south side of the Calico Mountains, along the Mojave River, and the southern half of the far eastern strand.

China Lake South Range-Kingston Mesquite Mountains: Potential habitat is limited to the eastern part of the linkage but was identified in all strands to the east of the Avawatz Mountains with the most habitat delineated in the northern and southern strands and all along the Amargosa River and Salt Creek.

Kingston Mesquite Mountains-Mojave National Preserve: Potential habitat is restricted to the western fringes in both target areas and the linkage but fairly contiguous habitat was delineated from the Dumont Dunes, all along the Amargosa River and Salt Creek and down into the Devils Playground area on Mojave National Preserve

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat in the linkage is mostly limited to the south of the Bristol Mountains and along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The most contiguous potential habitat was delineated along Piute Wash, the Colorado River and Chemehuevi Wash. Habitat was also identified along the Homer Wash strand and in the swaths that pass through Ward and Fenner Valleys.

Stepladder Turtle Mountains-Palen McCoy Mountains: Fairly contiguous potential habitat was identified in both strands of the linkage with the western strand providing a more direct connection to habitat in the Stepladder Turtle block.

Palen McCoy Mountains-Whipple Mountains: All branches of the linkage contain potential habitat for this species with the central branch and the riparian strands following Bennett Wash, the Colorado River and McCoy Wash capturing the most contiguous habitat.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches captured fairly contiguous potential habitat through the Palen Valley.

Joshua Tree National Park-Chocolate Mountains: All branches captured potential habitat but the eastern strand provides the most direct connection to potential habitats delineated in Joshua Tree National Park in the Pinto Basin.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was captured by all strands of the linkage through the Chuckwalla Valley with the southern part of the main strand capturing the most contiguous habitat between target areas.

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Figure 81. Potential Habitat for Arrowweed (Pluchea sericea)

N

1:2,350,000

0 30 60 90 Kilometers

0 30 60 Miles

SC Wildlands

Palen McCoy Mountains-Little Picacho: Fairly contiguous habitat was delineated in the linkage through the Chuckwalla Valley, along the Palo Verde Mesa and the lower Colorado River.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured fairly continuous habitat between the target areas.

Chocolate Mountains-East Mesa: The western strand of the linkage at the base of the Algodones Dunes captured fairly contiguous potential habitat for this species.

Western honey mesquite (*Prosopis glandulosa*)

Justification for Selection: Western honey mesquite increases the content of organic matter and nitrogen in the soil and facilitates plant growth (Ansley and Jacoby 1998, Barnes and Archer 1996, Steinberg 2001). The seeds also provide a nutritional food source for several desert wildlife species (Kingsolver et al. 1977, Steinberg 2001).

Distribution & Status: Western honey mesquite occurs in arid and semiarid regions of western Texas, southern New Mexico, southeastern and western Arizona, extreme southwestern Utah, southern Nevada, southern California, and northern Mexico (Isley 1973, Little 1979, Steinberg 2001). It ranges from 0 to 1700 m (5577 ft) in elevation (Hickman 1993).

Habitat Associations: In the Mojave and Sonoran deserts, western honey mesquite is primarily restricted to riverbanks, stream courses, washes, alkali flats, dry lakes, and oases where they can reach underground water (Johnson 1976, Sharifi et al. 1982, Hickman 1993, Steinberg 2001, Baldwin 2002). Vegetation communities surrounding these sites may be grassland (Baldwin 2002, Hickman 1993), scrub and alkali sink habitat (Calflora 2010). Associated plant species may include quailbush (*Atriplex lentiformis*), palo verde (*Cercidium floridum*), desert willow (*Chilopsis linearis*), and Fremont cottonwood (*Populus fremontii*; Brown 1982, Minckley and Clark 1984, Munz 1974, Roberts et al. 1980, Steinberg 2001).

Spatial Patterns: The density of plants can range from 124 to 3716 per hectare (50 to 1,500+ plants per acre Fisher et al 1946). Bees are the primary pollinators (Simpson et al. 1977, Steinberg 2001). Pods are consumed and then dispersed by several species, such as cottontails, ground squirrels, coyotes and many rodents (Bowers 1993). It may take days for seeds to pass through the digestive tracts, thus seeds may be dispersed great distances. Flood events may also disperse seeds (Glendening and Paulsen 1955, Steinberg 2001).

Conceptual Basis for Model Development: Mesquite is commonly found in grasslands, alkali flats, desert washes, sandy alluvial flats, and riparian woodlands and bosques ranging from 0 to 1700 m in elevation.

Results & Discussion: Potential habitat for the honey mesquite is limited to where it can reach sufficient ground water (Figure 82).

Sierra Nevada-China Lake North Range: Potential habitat was identified along Little Dixie Wash and in the southern part of China Lake North Range.

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Figure 82. Potential Habitat for Western Honey Mesquite (Prosopis glandulosa)

Sierra Nevada-China Lake South Range: Potential habitat was delineated along Teagle and Little Dixie Washes.

Sierra Nevada-Edwards Air Force Base: Potential habitat was identified along Cache Creek which bisects the linkage.

China Lake North Range-China Lake South Range: The central branch captured habitat in the northern part of Searles Dry Lake and the southern branch captured some of Teagle Wash.

China Lake South Range-Edwards Air Force Base: Very little habitat was delineated in the linkage with just one significant patch to the west of the Gravel Hills.

China Lake South Range-Twentynine Palms and Newberry Rodman: All branches of the linkage captured only small potential patches with the most habitat captured along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The most contiguous habitat was delineated along the Mojave River and Daggett Wash.

Edwards Air Force Base-San Gabriel Mountains: Potential habitat was identified along two washes that flow from the San Gabriels into the linkage.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The strands along Fremont Wash, the Mojave River and Daggett Wash captured continuous habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: The Mojave River and Daggett Wash contain potential habitat.

China Lake South Range-Kingston Mesquite Mountains: Small scattered patches were delineated in all branches of the linkage with the most habitats captured along the Amargosa River and Salt Creek.

Kingston Mesquite Mountains-Mojave National Preserve: The Amargosa River and Salt Creek captured potential habitat between the Dumont Dunes and Devils Playground in the two target areas.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat was identified along Siberia and Orange Blossom Washes and the Mojave River and to the south of the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: Fairly contiguous potential habitat was identified along Homer Wash, Piute Wash, the Colorado River and Chemehuevi Wash, providing two potential connections between target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: Scattered patches were delineated in both swaths with the western branch containing the most potential habitat.

Palen McCoy Mountains-Whipple Mountains: Potential habitat was identified in all branches of the linkage through the Vidal Valley with the northern connection capturing patches all along the base of the Turtle Mountains and the southern strand providing potential habitat along Bennett Wash, the Colorado River and McCoy Wash.

Joshua Tree National Park-Palen McCoy Mountains: The southern branch captured a few small habitat patches for this species.

Joshua Tree National Park-Chocolate Mountains: Potential habitat was captured in the western strand along Pinkham Wash and all through the eastern strand along several washes that flow out of the Eagle Mountains.

Palen McCoy Mountains-Chocolate Mountains: Small patches were delineated throughout the linkage and along McCoy Wash, the Colorado River and Milipitas Wash.

Palen McCoy Mountains-Little Picacho: Small patches of potential habitat were identified throughout the linkage with the western strand capturing the most potential habitat.

Chocolate Mountains-Little Picacho: The southern part of the linkage captured the most potential habitat for this species.

Big galleta grass (*Pleuraphis rigida*)

Justification for Selection: Big galleta grass is one of California's native perennial bunchgrasses and is considered valuable forage for many species of wildlife (Hughes 1982, Calflora 2010). In Nevada, plant communities with big galleta are utilized by bighorn sheep and are referred to as 'preferred habitat' (Bradley 1965, Matthews 2000). Big galleta grass may stabilize sand dunes in the lower Colorado River Valley of the Sonoran Desert and in some Mojave Desert communities (Turner 1982, Turner and Brown 1982, Matthews 2000).

Distribution and Status: Big galleta grass is distributed across the southwestern United States, in parts of California, Nevada, Utah, Arizona, and New Mexico (NRCS 2010). In California, its elevational range is from 0 to 1600 m (5249 ft; Calflora 2010).

Big galleta grass is considered threatened in Utah (NatureServe 2009). Encroachment by non-native annual grasses such as *Bromus* spp. has been identified as a potential threat to this species (DeFalco et al. 2007).

Habitat Associations: Big galleta occurs in several desert plant communities, including creosote bush scrub, Joshua tree woodland (Calflora 2010), desert shrub, pinyon-juniper, and desert grassland ecosystems (Matthews 2000). It prefers open sandy to rocky slopes, flats, and washes (Hickman 1993).

Spatial Patterns: Big galleta reproduces by rhizomes (Cronquist et al. 1977, Robberecht 1988). Plant establishment from seed is rare. Under favorable soil conditions, big galleta grass may be the dominant species in the community (Robberecht 1988).

Conceptual Basis for Model Development: This grass occurs along dry, open slopes, flats, and in washes below 1600 m in desert scrub, pinyon-juniper woodland, Joshua tree woodland, and grassland communities.

Results & Discussion: Abundant potential habitat was identified for big galleta grass in the planning area (Figure 83).

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Figure 83. Potential Habitat for Big galleta grass (Pleuraphis rigida)

Sierra Nevada-China Lake North Range: The majority of land in the linkage was delineated as potential habitat for this species.

Sierra Nevada-China Lake South Range: Most of the land in the linkage was identified as potential habitat for this species with some gaps in habitat through the El Paso Mountains.

Sierra Nevada-Edwards Air Force Base: Most of the land in this linkage was also delineated as potential habitat for this species.

China Lake North Range-China Lake South Range: The southern swath of the linkage captured the most contiguous habitat for this species between target areas.

China Lake South Range-Edwards Air Force Base: More potential habitat was identified in the linkage than in either of the target areas though there are some gaps in habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: The majority of land in the linkage was delineated as potential habitat with some gaps in habitat in the mountainous areas of the linkage.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: Both strands contain potential habitat but the northern swath captured the most contiguous habitat.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains and only a few small patches of potential habitat were delineated in the linkage.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: All branches of the linkage contain some potential habitat but the southern strand captured the most contiguous habitat for this species.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains but potential habitat was identified in all branches of the linkage.

China Lake South Range-Kingston Mesquite Mountains: The southern swath of the linkage captured the most contiguous potential habitat between target areas.

Kingston Mesquite Mountains-Mojave National Preserve: All branches of the linkage contain potential habitat but the central swath through Shadow Valley captured the most contiguous habitat.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat was delineated throughout the linkage but is more restricted through the Bristol Mountains.

Mojave National Preserve-Stepladder Turtle Mountains: The strand following Homer Wash captured the most contiguous habitat between the target areas but potential habitat was captured through the flat lowlands in all branches of the linkage.

Stepladder Turtle Mountains-Palen McCoy Mountains: Potential habitat was captured in the linkage through the lower Ward Valley.

Palen McCoy Mountains-Whipple Mountains: Very little habitat was delineated in the Whipple Mountains or the eastern part of the linkage but the central branch captured almost contiguous potential habitat for this species.

Joshua Tree National Park-Palen McCoy Mountains: The northern and central branches of the linkage through Palen Valley captured fairly contiguous habitat for this species.

Joshua Tree National Park-Chocolate Mountains: The central branch of the linkage captured the most continuous habitat for this species between the target areas.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was captured in the swaths of the linkage through the Chuckwalla Valley with the southern part of the main strand containing the most potential habitat between target areas.

Palen McCoy Mountains-Little Picacho: Potential habitat was captured in the linkage through the Chuckwalla Valley, over the Palo Verde Mesa and along the eastern branch of the linkage following the Colorado River.

Chocolate Mountains-Little Picacho: Scattered patches of potential habitat were delineated throughout the linkage with the largest patch identified on the north side of the Cargo Muchacho Mountains.

Chocolate Mountains-East Mesa: The western strand of the linkage captured fairly contiguous potential habitat for this species.

Catclaw acacia (*Acacia greggii*)

Justification for Selection: Catclaw acacia provides food, shelter, nesting sites, and nesting material to a number of wildlife species (Little 1950, Everett 1957, Kearney et al. 1960, Vines 1960, Powell 1988, Gucker 2005). A variety of species feed on different parts of the plant including many small mammals, both white-tailed and mule deer, and a number of birds (Graham 1941).

Distribution and Status: Catclaw acacia ranges throughout the southwestern United States and northern Mexico. Its range extends from extreme southern Utah through Nevada, California, Arizona, New Mexico, Texas, and California (Vines 1960, Hastings et al. 1972, Gucker 2005). In California, it occurs between 100 and 1400 m (328 to 4593 ft) in elevation (Calflora 2010).

Habitat Associations: Catclaw acacia is a drought resistant, deep-rooted plant (Calflora 2010) that occurs in a variety of plant communities and soil types, from sandy or gravelly hills and slopes to canyon bottoms and along washes and streams (Dayton 1931, Vines 1960, McAuliffe 1995, Richardson 1995). It occurs in desert wash habitats alongside desert willow (*Chilopsis linearis*), smoketree (*Psorothamnus spinosus*), mesquite (*Prosopis* spp.), Mohave rabbitbrush (*Ericameria paniculata*), and white burrobrush (*Hymenoclea salsola*; Johnson 1976, Turner and Brown 1982, Holland 1986, Gucker 2005), and in mixed woody and succulent scrub vegetation in association with desert agave (*Agave deserti*), brittle bush (*Encelia farinosa*), ocotillo (*Fouquieria splendens*), Mohave yucca (*Yucca schidigera*), and prickly-pear (*Opuntia* spp.; Holland 1986, Gucker 2005).

Spatial Patterns: Catclaw acacia blooms from April through October (Everitt and Drawe 1993, Epple 1995) and is pollinated by insects (Bowers 1993). The seeds require scarification in order to germinate (Bowers 1993, Epple 1995). Seed dispersal occurs through animal movements and abiotic disturbances (Gucker 2005). Milton et al. (1998) documented seed dispersal by cactus wrens that were using the seeds as nesting material. Flood events in sandy gravelly washes may provide seed scarification and a dispersal mechanism (Bowers 1993).

Conceptual Basis for Model Development: Catclaw acacia is found on slopes, flats and in washes in a variety of desert plant communities including desert scrub, desert wash, riparian bosque, and riparian woodland and shrubland habitats ranging from 100 to 1400 m in elevation.

Results & Discussion*:* Catclaw acacia's distribution is largely restricted to the Sonoran Ecoregion (Figure 84).

China Lake South Range-Twentynine Palms and Newberry Rodman: The China Lake South block is outside of this species distribution but it does have the potential to occur in the southern part of the linkage and in the other wildland block. Potential habitat was identified in all branches of the linkage but is restricted to the gently sloping and flat terrain. The most contiguous habitat was delineated in the two swaths that encompass the lowlands surrounding the Calico Mountains and along the Mojave River.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: Fairly contiguous potential habitat was identified in the eastern branch of the linkage and along Pipes Wash.

Kingston Mesquite Mountains-Mojave National Preserve: The swaths of the linkage through Shadow Valley and to the east of the Clark Mountain Range provide the most contiguous potential habitat for this species.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: This species is largely restricted to the southern part of Mojave National Preserve in the flats to the south of the Providence and New York Mountains. In the linkage, potential habitat was identified in the lowlands surrounding the Bristol Mountains and along the Mojave River and the eastern strand of the China Lake South-Twentynine Palms linkage may serve to connect these two areas.

Mojave National Preserve-Stepladder Turtle Mountains: The strand of the linkage along Homer Wash provides the most contiguous potential habitat for this species. Fairly contiguous habitat was also identified in the riparian connection along Piute Wash, Colorado River and Chemehuevi Wash.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both strands of the linkage contain fairly contiguous potential habitat for this species with the western strand providing a more direct connection between large areas of suitable habitat in the target areas.

Palen McCoy Mountains-Whipple Mountains: Very little habitat was identified in the Whipple Mountains for catclaw acacia but almost the entire central branch of the linkage was delineated as potential habitat.

Joshua Tree National Park-Palen McCoy Mountains: Both the northern and central branches of the linkage contain abundant potential habitat for this species.

Joshua Tree National Park-Chocolate Mountains: Potential habitat was delineated in all branches of the linkage with the eastern strand providing the most continuous suitable habitat.

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Figure 84. Potential Habitat for Cat claw acacia (Acacia greggii)

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was identified throughout the Chuckwalla Valley with the southern part of the main swath capturing the most continuous habitat between target areas.

Palen McCoy Mountains-Little Picacho: Potential habitat was identified throughout the lowlands in the linkage with the eastern swath along Palo Verde Mesa providing the most contiguous potential habitat.

Chocolate Mountains-Little Picacho: Not much habitat was identified in the Little Picacho block but the southern part of the linkage was delineated as fairly contiguous potential habitat.

Paper bag bush (*Salazaria mexicana*)

Justification for Selection: Paper bag bush, also known as bladdersage, is a native perennial that occurs in some arroyo habitats that provide den sites for the desert tortoise (McArthur and Sanderson 1992, Tesky 1994).

Distribution and Status: Paper bag bush is distributed throughout the Mojave, Sonoran, and Colorado Deserts extending from southern California to southern Utah, western Arizona, southwestern Texas, and northern Mexico (McMahon 1985, Welsh et al. 1987, Powell 1988, Stickney 1989, Hickman 1993, Tesky 1994). It occurs below 1800 m (5905 ft) in elevation (Hickman 1993).

Habitat Associations: Paper bag bush may be found in desert grasslands, creosote bush scrub, blackbrush scrub, mixed desert shrub communities, Joshua tree woodlands, and pinyon-juniper woodlands (Humphrey 1953, Kearney et al 1960, Munz 1974, Pemberton 1988, Welsh et al. 1987, Tesky 1994, Calflora 2010). It is commonly found in association with California buckwheat (*Eriogonum fasciculatum*), spiny hopsage (*Grayia spinosa*), Nevada ephedra (*Ephedra nevadensis*), green ephedra (*E. viridis*), and Mojave desertrue (*Thamnosma Montana*; Vasek and Barbour 1977, Pemberton 1988, Tesky 1994).

Spatial Patterns: Paper bag bush grows on sand, gravel, or clay soils on desert slopes, hillsides, mesas, washes, and arroyos (Kearney et al 1960, Powell 1988, Hickman 1993, Tesky 1994). The flowers are pollinated by various animals. It reproduces by seed and is dispersed by wind (Pendleton et al. 1989, Tesky 1994). It prefers sunny locations (Van Dersal 1938, Tesky 1994).

Conceptual Basis for Model Development: Paper bag bush is commonly found in desert grasslands, desert scrub, and pinyon-juniper and Joshua tree woodlands along slopes and washes at elevations up to 1800 m.

Results & Discussion: Potential habitat for paper bag bush (Figure 85) is widespread in the planning area.

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Figure 85. Potential Habitat for Paperbag bush (*Salazaria mexicana*)

Sierra Nevada-China Lake North Range: The southern strand of the linkage provides the most contiguous potential habitat for this species but suitable habitat was identified in all branches of the linkage, including the north-south strand along the 395.

China Lake North Range-China Lake South Range: The southern swath of the linkage through Searles Valley captured the most potential habitat.

Sierra Nevada-China Lake South Range: A fair amount of potential habitat was identified for this species along Little Dixie and Teagle Washes and through the Searles Valley.

Sierra Nevada-Edwards Air Force Base: The linkage captured fairly contiguous habitat for this species through the Fremont Valley.

China Lake South Range-Edwards Air Force Base: The majority of land in this linkage was delineated as potential habitat.

China Lake South Range-Twentynine Palms and Newberry Rodman: Potential habitat was identified through the lowlands in all branches of the linkage and along the Mojave River.

Edwards Air Force Base-Twentynine Palms and Newberry Rodman: The northern swath provides the most contiguous potential habitat for this species.

Edwards Air Force Base-San Gabriel Mountains: This species doesn't range into the San Gabriel Mountains but abundant potential habitat was delineated in the linkage and on Edwards Air Force Base.

Twentynine Palms and Newberry Rodman-San Gabriel Mountains: The southern strand captured the most potential habitat.

Twentynine Palms and Newberry Rodman-San Bernardino Mountains: This species doesn't range into the San Bernardino Mountains but potential habitat was identified in the lowlands in all branches of the linkage with the eastern strand providing the most continuous habitat.

China Lake South Range-Kingston Mesquite Mountains: Some potential habitat was identified in all branches of the linkage with the southern strand providing the most contiguous potential habitat.

Kingston Mesquite Mountains-Mojave National Preserve: Fairly contiguous potential habitat was identified in the central strand through Shadow Valley and in the strand east of the Clark Mountain Range.

Mojave National Preserve-Twentynine Palms and Newberry Rodman: Potential habitat was identified throughout the lowlands surrounding the Bristol Mountains but is more limited through this range. The most contiguous potential habitat was delineated in the southern strand and along the Mojave River.

Mojave National Preserve-Stepladder Turtle Mountains: The strand that follows Homer Wash contains the most contiguous potential habitat between target areas.

Stepladder Turtle Mountains-Palen McCoy Mountains: Both branches of the linkage contain fairly contiguous potential habitat but the western strand provides a more direct connection to large areas of potential habitat in the two target areas.

Palen McCoy Mountains-Whipple Mountains: Very little habitat was delineated in the Whipple Mountains but virtually all land in the central branch of the linkage was identified as potential habitat for this species.

Joshua Tree National Park-Palen McCoy Mountains: Fairly contiguous potential habitat was identified through the Palen Valley in the northern and central strands of the linkage.

Joshua Tree National Park-Chocolate Mountains: The eastern strand of the linkage captured the most contiguous potential habitat between the two target areas.

Palen McCoy Mountains-Chocolate Mountains: Potential habitat was identified through the Chuckwalla Valley portion of the linkage with the southern strand providing the most continuous potential habitat between the target areas.

Palen McCoy Mountains-Little Picacho: The most potential habitat was captured by the strands of the linkage delineated by badger and kit fox.

Chocolate Mountains-Little Picacho: A fair amount of potential habitat was identified in the southern half of the linkage.

Chocolate Mountains-East Mesa: Like many other species, the Algodones Dunes were identified as non-habitat for the paperbag bush but contiguous habitat was identified in the lowlands surrounding the dunes.

Removing and Mitigating Barriers to Movement

Today there are few industrial developments, roads, canals and rail lines in the linkage designs. Nonetheless, the existing canals and highways are significant barriers to animal movement. Moreover, future industrial projects – and the roads and urban developments built to serve these projects – could severely disrupt animal movements between the wildland blocks. In this section, we review the potential impacts of these features on ecological processes, identify specific barriers in each linkage analysis area, and suggest appropriate mitigations. The complete database of our field investigations, including photographs, is available online at http://scwildlands.org/desert/fieldwork/index. The online tool allows the user to click on waypoints to view photographs and notes at particular locations.

Industrial and Urban Development as Barriers to Movement

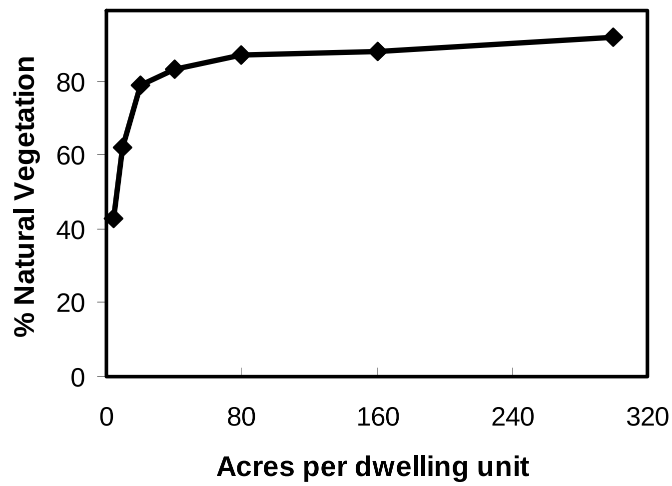
Linkage Design Goals

- Provide move-through habitat for all focal species
- Provide live-in habitat for species with dispersal distances too short to traverse linkage in one lifetime
- Provide adequate area for a metapopulation of corridor-dwelling species to move through the landscape over multiple generations
- Buffer against edge effects such as pets, lighting, noise, nest predation & parasitism, and invasive species
- Allow animals and plants to expand their range to an adjacent wildland block through an individual linkage over relatively short time periods (1-2 decades).
- Allow species to shift their geographic range across hundreds of miles over several decades via the network of cores and linkages.

The California deserts have very little industrial or urban development. However in the near future, many large-scale industrial solar energy projects are likely to be built. These projects will likely be the most profound change to natural conditions in this area since the end of the last glacial period 10,000 to 15,000 years ago.

In addition to solar energy facilities, urbanization includes mines, commercial centers, high-density residential development, and low-density ranchette development. These land uses impact wildlife movement in several ways:

- They trigger development of a road network to reach solar facilities and homes of workers. Many wild animals are killed on roads. Some reptiles (which "hear" ground-transmitted vibrations through their jaw (Heatherington 2005) are repelled even from low-speed 2-lane roads, resulting in reduced species richness (Findlay and Houlihan 1997), reducing road kill but increasing fragmentation of habitat.
- The projects remove and fragment natural vegetation. Solar installations occupy huge areas. Residential and support facilities also remove and fragment habitat. CBI (2005) evaluated 4 measures of habitat fragmentation in rural San Diego County, namely percent natural habitat, mean patch size of natural vegetation, percent core areas (natural vegetation > 30m or 96 ft from non-natural land cover), and mean core area per patch at 7 housing densities (see Figure). Fragmentation effects were negligible in areas with <1 dwelling unit per 80 acres, and severe in areas with > 1 dwelling unit per 40 acres (CBI 2005). Similar



Percent natural vegetation declines rapidly at housing densities greater than 1 dwelling unit per 40 acres (Source: CBI 2005).

patterns, with a dramatic threshold at 1 unit per 40 acres, were evident in 4 measures of fragmentation measured in 60 landscapes in rural San Diego County, California (CBI 2005).

- Development decreases abundance and diversity of native species, and promotes displacement of natives by non-native species. In Arizona, these trends were evident for birds (Germaine et al. 1998) and lizards (Germaine and Wakeling 2001), and loss of native species increased as housing density increased. Similar patterns were observed for birds and butterflies in California (Blair 1996, Blair and Launer 1997, Blair 1999, Rottenborn 1999, Strahlberg and Williams 2002), birds in Washington state (Donnelly and Marzluff 2004), mammals and forest birds in Colorado (Odell and Knight 2001), and migratory birds in Ontario (Friesen et al. 1995). The negative effects of urbanization were evident at housing densities as low as 1 dwelling unit per 40-50 acres. In general, housing densities below this threshold had little impact on birds and small mammals. Although some lizards and small mammals occupy residential areas, most large carnivores, small mammals, and reptiles cannot occupy or even move through urban areas.
- Increased vehicle traffic in linkage areas, increasing the mortality and repellent effect of the road system (Van der Zee et. al 1992).
- Increased numbers of dogs, cats, and other pets that act as subsidized predators, killing millions of wild animals each year (Courchamp and Sugihara 1999, May and Norton 1996).
- Subsidized “suburban native predators” such as raccoons, foxes, and crows that exploit garbage and other human artifacts to reach unnaturally high density, outcompeting and preying on other native species (Crooks and Soule 1999).
- Spread of some exotic (non-native) plants, namely those that thrive on roadsides and other disturbed ground, or that are deliberately introduced by humans.
- Perennial water in formerly ephemeral streams, making them more hospitable to non-native plants and animals that displace natives and reduce species richness (Forman et al. 2003).
- Mortality of native plants and animals via pesticides and rodenticides, which kill not only their target species (e.g., domestic rats), but also secondary victims (e.g., raccoons and coyotes that feed on poisoned rats) and tertiary victims (mountain lions

that feed on raccoons and coyotes – Sauvajot et. al 2006).

- Artificial night lighting, which can impair the ability of nocturnal animals to navigate through a corridor (Beier 2006) and has been implicated in decline of reptile populations (Perry and Fisher 2006).
- Increased removals of wild predators for killing pets or hobby animals. Rural residents often are emotionally attached to their animals, and prompt to notice loss or injury. Thus although residential development may bring little or increase in the number of the depredation incidents per unit area, each incident is more likely to lead to death of predators, and eventual elimination of the population (Woodroffe and Frank 2005).
- Increased killing of native herbivores that feed on ornamental plants (Knickerbocker and Waithaka 2005).
- Noise, which may disturb or repel some animals and present a barrier to movement (Minto 1968, Liddle 1997, Singer 1978).
- Disruption of natural fire regime by (a) increasing the number of wildfire ignitions, especially those outside the natural burning season (Viegas et. al 2003), (b) increasing the need to suppress what might otherwise be beneficial fires that maintain natural ecosystem structure, and (c) requiring firebreaks and vegetation manipulation, sometimes at considerable distance from human-occupied sites (Oregon Department of Forestry 2006).

Unlike road barriers (which can be modified with fencing and crossing structures), urban and industrial developments create barriers to movement which cannot easily be removed, restored, or otherwise mitigated. For instance, once a solar facility is built, it is unlikely that its footprint will be reconfigured or that perimeter fences will be re-aligned or modified. Similarly, it is unrealistic to think that local government will stop a homeowner from clearing fire-prone vegetation, or force a landowner to remove artificial night lighting. Avoidance and careful site selection are the best ways to manage industrial and urban impacts in a wildlife linkage.

Mitigating the impacts of industrial & urban barriers on wildlife linkages

To reduce the barrier effects of urban development in linkage planning areas, we recommend:

1) **Protect the linkage designs from industrial solar development**. Within linkage designs, modify the proposed project footprints to allow broad (2-km wide) swaths for animal movement. Where such facilities occur adjacent to the linkage design, minimize the use of artificial night lighting, and prohibit rodenticides and pesticides. Any new roads crossing the linkage design to access these facilities should be built to standards recommended below.
2) Prohibit or restrict the use of pesticides, insecticides, herbicides, and rodenticides, and educate workers, residents, and lessees about the effects these chemicals have throughout the ecosystem.
3) Develop a public education campaign to inform those living and working within the linkage area about living with wildlife, and the importance of maintaining ecological connectivity.
4) Discourage residents and visitors from feeding or providing water for wild mammals, or otherwise allowing wildlife to lose their fear of people.
5) Install wildlife-proof trash and recycling receptacles, and encourage people to store

their garbage securely.

6) Do not install artificial night lighting on rural roads that pass through the linkage design. Reduce vehicle traffic speeds in sensitive locations by speed bumps, curves, artificial constrictions, and other traffic calming devices.
7) Encourage the use of wildlife-friendly fencing on property and lease boundaries, use wildlife-proof fencing to keep animals out of areas that are dangerous to them.
8) Discourage the killing of ‘threat’ species such as rattlesnakes.
9) Pursue specific management protections for threatened, endangered, and sensitive species and their habitats.
10) Integrate linkage designs into local land use plans. Specifically, use zoning and other tools to retain open space and natural habitat and discourage urbanization of natural areas in the linkage areas.
11) Discourage further residential development and subdivision of large parcels in the linkage designs. Where development is permitted within the linkage design, encourage small building footprints on large (> 40 acre) parcels with a minimal road network.
12) Integrate this Linkage Design into county general plans, and conservation plans of governments and nongovernmental organizations.
13) Encourage conservation easements or acquisition of conservation land from willing land owners in the Linkage Design. Recognizing that there may never be enough money to buy easements or land for the entire Linkage Design, encourage innovative cooperative agreements with landowners that may be less expensive (Main et al. 1999, Wilcove and Lee 2004).
14) Combine habitat conservation with compatible public goals such as recreation and protection of water quality.
15) One reason we imposed a minimum width on each strand of the linkage design was to allow enough room for a designated trail system without having to compromise the permeability of the linkage for wildlife. Nonetheless, trail systems should be planned to minimize resource damage and disturbance of wildlife. People should be encouraged to stay on trails, keep dogs on leashes, and travel in groups in areas frequented by mountain lions or bears. Visitors should be discouraged from collecting reptiles and harassing wildlife.
16) Where human residences or other low-density urban development occurs within the linkage design or immediately adjacent to it, encourage landowners to be proud stewards of the linkage. Specifically, encourage them to landscape with natural vegetation, minimize water runoff into streams, manage fire risk with minimal alteration of natural vegetation, keep pets indoors or in enclosures (especially at night), accept depredation on domestic animals as part of the price of a rural lifestyle, maximize personal safety with respect to large carnivores by appropriate behaviors, use pesticides and rodenticides carefully or not at all, and direct outdoor lighting toward houses and walkways and away from the linkage area. Developments within the linkage should have permeable perimeters, not walls.
17) When permitting new urban development in the linkage area, stipulate as many of the above conditions as possible as part of the code of covenants and restrictions for individual landowners whose lots abut or are surrounded by natural linkage land. Even if some clauses are not rigorously enforced, such stipulations can promote awareness of how to live in harmony with wildlife movement.
18) Respect the property rights of the many people already living in these wildlife

corridors. Work with homeowners and residents to manage residential areas for wildlife permeability. Develop innovative programs that respect the rights of residents and enlist them as stewards of the linkage area.

Impacts of Roads on Wildlife

While the physical footprint of the nearly 4 million miles of roads in the United States is relatively small, the *ecological* footprint of the road network extends much farther. Direct effects of roads include road mortality, habitat fragmentation and loss, and reduced connectivity. The severity of these effects depends on the ecological characteristics of a given species (**Error! Reference source not found.**). Direct **roadkill** affects most species, with severe documented impacts on wide-ranging predators such as the cougar in southern California, the Florida panther, the ocelot, the wolf, and the Iberian lynx (Forman et al. 2003). In a 4-year study of 15,000 km of road observations in Organ Pipe Cactus National Monument, Rosen and Lowe (1994) found an average of at least 22.5 snakes per km per year killed due to vehicle collisions. Although we may not often think of roads as causing **habitat loss**, a single freeway (typical width = 50 m, including median and shoulder) crossing diagonally across a 1-mile section of land results in the loss of 4.4% of habitat area for any species that cannot live in the right-of-way. Roads cause **habitat fragmentation** because they break large habitat areas into small, isolated habit patches which support few individuals; these small populations lose genetic diversity and are at risk of local extinction.

In addition to these obvious effects, roads create noise and vibration that interfere with ability of reptiles, birds, and mammals to communicate, detect prey, or avoid predators. Roads also increase the spread of exotic plants, promote erosion, create barriers to fish, and pollute water sources with roadway chemicals (Forman et al. 2003). Highway lighting also has important impacts on animals (Rich and Longcore 2006).

Characteristics which make species vulnerable to the three major direct effects of roads (from Forman et al. 2003).

	Effect of Roads		
Characteristics making a species vulnerable to road effects	Road mortality	Habitat loss	Reduced connectivity
Attraction to road habitat	★		
High intrinsic mobility	★		
Habitat generalist	★		
Multiple-resource needs	★		★
Large area requirement/low density	★	★	★
Low reproductive rate	★	★	★
Behavioral avoidance of roads			★

Impacts of Canals on Wildlife

The impacts of canals on wildlife are similar to the impacts of roads. On canals, direct mortality occurs not in collisions with vehicles, but by drowning. The **fragmentation** effects of canals are much greater than those of roads. Some animals can walk across a road without being killed, especially during hours with low traffic volume. However few mammals or reptiles can cross a canal at any time of day or night. The photograph of the

MWD Aqueduct below illustrates a typical canal in the California desert, with chain link fencing on each side, nearly vertical concrete sides, and deep flowing water (MWD aqueduct in the Palen-McCoy to Whipple Mountains linkage).

Mitigating the impacts of Roads and Canals on the linkage areas

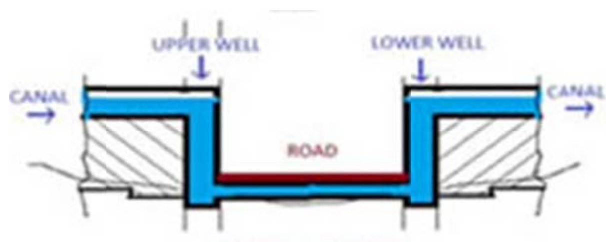
Wildlife crossing structures to facilitate movement through landscapes fragmented by roads include wildlife overpasses & green bridges, bridges, culverts, and pipes. Although many of these structures were not originally constructed with ecological connectivity in mind, many species benefit from them (Clevenger et al. 2001; Forman et al. 2003). No single crossing structure will allow all species to cross a road. For example rodents prefer to use pipes and small culverts, while bighorn prefer vegetated overpasses or open terrain below high bridges. A concrete box culvert may be readily accepted by a mountain lion or bear, but not by a deer or bighorn sheep. Small mammals, such as deer mice and voles, prefer small culverts to wildlife overpasses (McDonald & St Clair 2004).

Wildlife overpasses are most often designed to improve opportunities for large mammals to cross busy highways. Approximately 50 overpasses have been built in the world, with only 6 of these occurring in North America (Forman et al. 2003). Overpasses are typically 30 to 50 m wide, but can be as large as 200 m wide. In Banff National Park, Alberta, grizzly bears, wolves, and all ungulates (including bighorn sheep, deer, elk, and moose) prefer overpasses to underpasses, while species such as mountain lions prefer underpasses (Clevenger & Waltho 2005).

Wildlife underpasses include viaducts, bridges, culverts, and pipes, and are often designed to ensure adequate drainage beneath highways. For ungulates such as deer that prefer open crossing structures, tall, wide bridges are best. Mule deer in southern California only used underpasses below large spanning bridges (Ng et al. 2004), and the average size of underpasses used by white-tailed deer in Pennsylvania was 15 ft wide by 8 ft high (Brudin 2003). Because most small mammals, amphibians, reptiles, and insects need vegetative cover for security, bridged undercrossings should extend to uplands beyond the scour zone of the stream, and should be high enough to allow enough light for vegetation to grow underneath. In the Netherlands, rows of stumps or branches under crossing structures have increased connectivity for smaller species crossing bridges on floodplains (Forman et al. 2003). Black bear and mountain lion prefer less-open structures (Clevenger & Waltho 2005). A bridge is a road supported on piers or abutments above a watercourse, while a culvert is one or more round or rectangular tubes under a road. The most important difference is that the streambed under a bridge is mostly native rock and soil (instead of concrete or corrugated metal in a culvert) and the area under the bridge is large enough that a semblance of a natural stream channel returns a few years after construction. Even when rip-rap or other scour protection is installed to protect bridge piers or abutments, stream morphology and hydrology usually return to near-natural conditions in bridged streams, and vegetation often grows under bridges. In contrast, vegetation does not grow inside a culvert, and hydrology and stream morphology are permanently altered not only within the culvert, but for some distance upstream and downstream from it.

Despite their disadvantages, well-designed and located culverts can mitigate the effects of busy roads for small and medium sized mammals (Clevenger et al. 2001; McDonald & St Clair 2004). Culverts and concrete box structures are used by many species, including mice, shrews, foxes, rabbits, armadillos, river otters, opossums, raccoons, ground squirrels, skunks, coyotes, bobcats, mountain lions, black bear, great blue heron, long-tailed weasel, amphibians, lizards, snakes, and southern leopard frogs (Yanes et al. 1995; Brudin III 2003; Dodd et al. 2004; Ng et al. 2004). Black bear and mountain lion prefer less-open structures (Clevenger & Waltho 2005). In south Texas, bobcats most often used 1.85 m x 1.85 m box culverts to cross highways, preferred structures near suitable scrub habitat, and sometimes used culverts to rest and avoid high temperatures (Cain et al. 2003). Culvert usage can be enhanced by providing a natural substrate bottom, and in locations where the floor of a culvert is persistently covered with water, a concrete ledge established above water level can provide terrestrial species with a dry path through the structure (Cain et al. 2003). It is important for the lower end of the culvert to be flush with the surrounding terrain. Some culverts in fill dirt have openings far above the natural stream bottom. Many culverts are built with a concrete pour-off of 8-12 inches, and others develop a pour-off lip due to scouring action of water. A sheer pour-off of several inches makes it unlikely that most small mammals, snakes, and amphibians will find or use the culvert.

Potential road mitigations (overpasses, bridges, culverts, drainage pipes) are effective only if fencing is used to guide animals into crossing structures.



Siphons and *undergrounding* are **the only ways to mitigate the impacts of canals** on wildlife movement. A siphon is precast concrete pipe that directs the flow of the canal underneath a wash, road, or other depression in the ground. The two ends of the U-shaped pipe are at the elevation of the canal, with the bottom of the U running underneath the road or streambed. The "downstream" end of the siphon is slightly lower than the intake end, so that no pumps are needed to convey the water. In the California deserts, most siphons are built to keep flood debris from entering the canal and to prevent flash floods from damaging the canal. Typically the siphons are about 50 to 100 m long, with 2,000 to 5,000 m of above-ground canal between siphons. Thus in this area, siphons allow passage along only about 1% to 5% of the canal's length. However, because siphons are built along the major natural drainages that intersect the canal, and many wildlife species tend to travel along these larger drainages, the utility of siphons to wildlife may be greater than suggested by these percentages. Almost all siphons are covered with at least 1 m of earth that can support native vegetation (except where flood scouring maintains a gravel bottom). The largest siphons in the California deserts were about 400 m long and had mature riparian vegetation growing in the desert wash above the siphon.

We observed two types of *canal undergrounding* in these deserts. One type is a tunnel to convey the water underneath a mountain range; these are used in rugged areas where a tunnel a few kilometers long would avoid the expense of building over 100 km

canal following the contour around the mountain range. The other type of undergrounding was used in flat terrain, and simply consists of replacing the above-ground aqueduct with a concrete box culvert covered with gravel. In the **photo**, the dirt road lies atop a 5-km long undergrounded section of the MWD aqueduct in the western strand of the Stepladder-Turtle to Palen-McCoy linkage design; the paved road is SR-62. Both types of undergrounding are highly permeable to animal movement, and doubtless prevent large volumes of water from evaporating out of the canal system. The second type of undergrounding could be made more permeable for wildlife by excluding vehicles so that natural vegetation can grow on the ground above the culvert.

Standards and Guidelines for Wildlife Crossing Structures

Based on the small but increasing number of scientific studies on wildlife use of highway crossing structures, we offer these standards and guidelines for *all* existing and future crossing structures intended to facilitate wildlife passage across highways, railroads, and canals.

1) **On highways, multiple crossing structures should be constructed at a crossing point to provide connectivity for all species likely to use a given area** (Little 2003). Different species prefer different types of structures (Clevenger et al. 2001; McDonald & St Clair 2004; Clevenger & Waltho 2005; Mata et al. 2005). For deer or other ungulates, an open structure such as a bridge is crucial. For medium-sized mammals, black bear, and mountain lions, large box culverts with natural earthen substrate flooring are optimal (Evink 2002). For small mammals, pipe culverts from 0.3m – 1 m in diameter are preferable (Clevenger et al. 2001; McDonald & St Clair 2004).

2) **At least one crossing structure should be located within an individual's home**

range. Because most reptiles, small mammals, and amphibians have small home ranges, metal or cement box culverts should be installed at intervals of 150-300 m (Clevenger et al. 2001). For ungulates (deer, pronghorn, bighorn) and large carnivores, larger crossing structures such as bridges, viaducts, or overpasses should be located no more than 1.5 km (0.94 miles) apart (Mata et al. 2005; Clevenger and Wierzchowski 2006). Inadequate size and insufficient number of crossings are two primary causes of poor use by wildlife (Ruediger 2001).

3) **Suitable habitat for species should occur on both sides of the crossing structure** (Ruediger 2001; Barnum 2003; Cain et al. 2003; Ng et al. 2004). This applies to both *local* and *landscape* scales. On a local scale, vegetative cover should be present near entrances to give animals security, and reduce negative effects such as lighting and noise associated with the road (Clevenger et al. 2001; McDonald & St Clair 2004). A lack of suitable habitat adjacent to culverts may prevent their use as potential wildlife crossing structures (Cain et al. 2003). On the landscape scale, "Crossing structures will only be as effective as the land and resource management strategies around them" (Clevenger et al. 2005). Suitable habitat must be present throughout the linkage for animals to use a crossing structure.

4) **Whenever possible, suitable habitat should occur *within* the crossing structure.** This can best be achieved by having a bridge high enough to allow enough light for vegetation to grow under the bridge, and by making sure that the bridge spans some upland habitat that is not regularly scoured by floods. Where this is not possible, rows of stumps or branches under large span bridges can provide cover for smaller animals such as reptiles, amphibians, rodents, and invertebrates; regular visits are needed to replace artificial cover removed by flood. Within culverts, earthen floors are preferred by mammals and reptiles.

5) **Structures should be monitored for, and cleared of, obstructions such as detritus or silt blockages that impede movement.** Small mammals, carnivores, and reptiles avoid crossing structures with significant detritus blockages (Yanes et al. 1995; Cain et al. 2003; Dodd et al. 2004). In the southwest, over half of box culverts less than 8 x 8 ft have large accumulations of branches, Russian thistle, sand, or garbage that impede animal movement (Beier, personal observation). Bridged undercrossings rarely have similar problems.

6) **Fencing should never block entrances to crossing structures, and instead should direct animals towards crossing structures** (Yanes et al. 1995). In Florida, construction of a barrier wall to guide animals into a culvert system resulted in 93.5% reduction in roadkill, and also increased the total number of species using the culvert from 28 to 42 (Dodd et al. 2004). Fences, guard rails, and embankments at least 2 m high discourage animals from crossing roads (Barnum 2003; Cain et al. 2003; Malo et al. 2004). One-way ramps on roadside fencing can allow an animal to escape if it is trapped on a road (Forman et al. 2003).

7) **Raised sections of road discourage animals from crossing roads, and should be used when possible to encourage animals to use crossing structures**.

Clevenger et al. (2003) found that vertebrates were 93% less susceptible to road-kills on sections of road raised on embankments, compared to road segments at the natural grade of the surrounding terrain.

8) **Manage human activity near each crossing structure**. Clevenger & Waltho (2000) suggest that human use of crossing structures should be restricted and foot trails relocated away from structures intended for wildlife movement. However, a large crossing structure (viaduct or long, high bridge) should be able to accommodate both recreational and wildlife use. Furthermore, if recreational users are educated to maintain utility of the structure for wildlife, they can be allies in conserving wildlife corridors. At a minimum, nighttime human use of crossing structures should be restricted.

9) **Design culverts specifically to provide for animal movement**. Most culverts are designed to carry water under a road and minimize erosion hazard to the road. Culvert designs adequate for transporting water often have pour-offs at the downstream ends that prevent wildlife usage. At least 1 culvert every 150-300m of road should have openings flush with the surrounding terrain, and with native land cover up to both culvert openings, as noted above.

Impediments to Riparian Connectivity

Importance of Riparian Systems in the Southwest

Riparian systems are one of the rarest habitat types in North America. In the arid Southwest, about 80% of all animals use riparian resources and habitats at some life stage, and more than 50% of breeding birds nest chiefly in riparian habitats (Krueper 1996). They are of particular value in lowlands (below 5,000 feet) as a source of direct sustenance for diverse animal species (Krueper 1993).

Impediments to riparian connectivity in the linkage planning areas

Most streams in this region lack surface water or riparian vegetation, and thus are naturally fragmented from the perspective of many wildlife species. But nearly all riparian systems in the Southwest also have been altered by human activity (Stromberg 2000) in ways that increase fragmentation. For animals associated with streams or riparian areas, impediments are presented by road crossings, vegetation clearing, livestock grazing, invasion of non-native species, accumulation of trash and pollutants in streambeds, farming in channels, and gravel mining. Groundwater pumping, upland development, water recharge basins, dams, and concrete structures to stabilize banks and channels change natural flow regimes which negatively impacts riparian systems. Increased runoff from urban development not only scours native vegetation but can also create permanent flow or pools in areas that were formerly ephemeral streams. Invasive species such as giant reed can displace native species in some permanent waters. Aggressive protection of these areas and will enhance the utility of this linkage design.

Mitigating Impediments to Riparian Connectivity

We endorse the following management recommendations for riparian connectivity and habitat conservation in riparian areas in and upstream of the linkage designs:

1) **Retain natural fluvial processes** – Maintaining or restoring natural timing,

magnitude, frequency, and duration of surface flows is essential for sustaining functional riparian ecosystems (Shafroth et al. 2002, Wissmar 2004).

- Industrial or urban development contributes to a “flashier” (more flood-prone) system. Check dams and settling basins should be required in industrial and urban areas to increase infiltration and reduce the impact of intense flooding (Stromberg 2000).
- Maintain natural channel-floodplain connectivity—do not harden riverbanks and do not build in the floodplain (Wissmar 2004).
- Release of treated municipal waste water in some riparian corridors can help restore some riparian ecosystems. Habitat quality is generally low directly below the release point but improves downstream (Stromberg et al. 1993). However in an intermittent reach with native amphibians or fishes, water releases should not create perennial (year-round) flows. Bullfrogs can and do displace native amphibians from perennial waters (Kupferberg 1997, Kiesecker and Blaustein 1998, Maret et al. 2006).

2) **Promote base flows and maintain groundwater levels within the natural tolerance ranges of native plant species** – Subsurface water is important for riparian community health, and can be sustained more efficiently by reducing ground water pumping near the river, providing municipal water sources to homes, and reducing agricultural water use through use of low-water-use crops, and routing return flows to the channel (Stromberg 1997, Colby and Wishart 2002). Willows require water levels within 9 feet (2.6 m) below ground level (Lite and Stromberg 2005).
3) **Maintain or improve native riparian vegetation** – Moist surface conditions in spring and flooding in summer after germination of tamarisk will favor native riparian plants over the invasive tamarisk (Stromberg 1997). Pumps within ½ mile of the river or near springs should cease pumping in spring, or, if this is impossible, some pumped water should be spilled on to the floodplain to create shallow pools (Wilbor 2005).
4) **Maintain biotic interactions within evolved tolerance ranges**. Arid Southwest riparian systems evolved under grazing and browsing pressure from deer and pronghorn antelope—highly mobile grazers and browsers. High intensity livestock grazing is a major stressor for riparian systems in hot Southwest deserts; livestock should thus be excluded from stressed or degraded riparian areas (Belsky et al. 1999, National Academy of Sciences 2002). In healthy riparian zones, grazing pressure should not exceed the historic grazing intensity of native ungulates (Stromberg 2000).
5) **Eradicate non-native invasive plants and animals** – Hundreds of exotic species have become naturalized in riparian corridors, with a few becoming significant problems like tamarisk and Russian olive. Removing stressors and reestablishing natural flow regimes can help bring riparian communities back into balance, however some exotics are persistent and physical eradication is necessary to restore degraded systems (Stromberg 2000, Savage 2004, but see D’Antonio and Meyerson 2002). Elimination of unnatural perennial surface pools can eradicate water-dependent invasives like bullfrogs, crayfish, and mosquitofish.
6) **Where possible and historically appropriate, protect or restore a continuous strip of native vegetation up to 200 m wide along each side of**

the channel. Buffer strips can protect and improve water quality, provide habitat and connectivity for a disproportionate number of species (compared to upland areas), and provide numerous social benefits including improving quality of life for residents and increasing nearby property values (Fisher and Fischenich 2000, Parkyn 2004, Lee et al. 2004). Continuous corridors provide important wildlife connectivity but recommended widths to sustain riparian plant and animal communities vary widely (from 30 to 500 m) (Wenger 1999, Fisher and Fischenich 2000, Wenger and Fowler 2000, Environmental Law Institute 2003). At a minimum, buffers should capture the stream channel and the terrestrial landscape affected by flooding and elevated water tables (Naiman et al. 1993). Buffers of sufficient width protect edge sensitive species from negative impacts like predation and parasitism. We therefore recommend buffer strips on each side of the channel at least 200 m wide measured perpendicular to the channel starting from the annual high water mark.

7) **Enforce existing regulations**. We recommend aggressive enforcement of existing regulations restricting dumping of soil, agricultural waste, and trash in streams, and of regulations restricting farming, gravel mining, and building in streams and floodplains. Restricted activities within the buffer should include OHV use which disturbs soils, damages vegetation, and disrupts wildlife (Webb and Wilshire 1983).

Field Investigations and Recommendations

We conducted field investigations of all major roads and some minor roads in all linkage areas to document existing crossing structures that could be modified to enhance wildlife movement through the area. We provide our major recommendations below, illustrating some of these recommendations with photographs. All 806 photos taken at 241 locations are included in an on-line tool with all 241 clickable waypoints; see http://scwildlands.org/desert/fieldwork/index.

China Lake North Range - Sierra Nevada

All strands of the linkage design are crossed by the California Aqueduct. This segment of the Aqueduct is entirely underground or encased in culverts and pipes, and thus does not present a major barrier to animal movement.

US-395 (a 4-lane, divided highway with moderate traffic) also crosses all strands of the linkage design. It is a major barrier, with only 4 crossing structures that might be usable by wildlife, namely a pair of 3-ft pipe culverts at photo point #189, another pair of 3-ft culverts 200 m south of point 189, a set of four 4-ft pipe culverts at photo point #186, and one bridged crossing at Five Mile Canyon. These crossings are not sufficient to ensure regular movement of wildlife in the linkage area. Future improvements to US-395 should include addition of closely-spaced crossing structures following the guidelines earlier in this chapter.

The Five Mile Canyon bridge (photo; waypoint 188) is the only wildlife crossing with semi-natural substrate on US-395 in the linkage between the Sierra Nevada and China Lake North.

For many miles of US-395 in the linkage area, there are no bridges, culverts, or crossing structures (photo; waypoint 191).

Potential barriers in the southern strand of the linkage design include US-395, SR-14, SR-178, and some residential areas. At the present time, the residential areas – most of which lie just outside the southern boundary of China Lake North – probably represent a barrier to wildlife movement similar to US-395, and a greater barrier than the two state highways. Future residential development should be curtailed, especially along the two washes that provide relatively undeveloped passageways through the developed areas.

SR-14 and SR-178 are two-lane roads where they cross the southern strand of the linkage, with light to moderate traffic. SR-178 has no pipes, culverts, or crossing structures where it crosses this strand. SR-14 has two pipe culverts with steep pour-offs that are not usable by wildlife. The photos below illustrate an unusable 4-ft culvert with 8-ft pour-off (left; waypoint 184) and unusable 18-inch pipe culvert with 18-inch pour-off (right; waypoint 183) on SR-14. SR 14 has one good bridged crossing (at Freeman Gulch; waypoint 180) and one large, soft-bottomed double box culvert (waypoint 182). When these highways are improved, additional crossing structures should be provided.


China Lake South Range - Sierra Nevada

There is very little industrial or urban development in this linkage (photo below; waypoint 213), but several industrial solar projects are proposed in this linkage. The major current barriers to wildlife movement are US-395, SR-14, a north-south rail line, and the rail spur to the Searles Lake borax mines. This linkage crosses SR-14 in the same area where the North China Lake-Sierra Nevada linkage crosses SR-14 (see description of SR-14 in the section on that linkage). The California Aqueduct is underground or covered where it crosses this linkage, and thus does not present a major barrier to movement.

US-395 is the most severe impediment to wildlife movement. It has no crossing structure larger than a 1-ft pipe throughout its path through the linkage area. This section of US-395 is currently a 2-lane undivided road (becoming a 4 lane road when it meets SR-14 to the north). When lanes are added, additional crossing structures should be constructed on this portion of US-395.

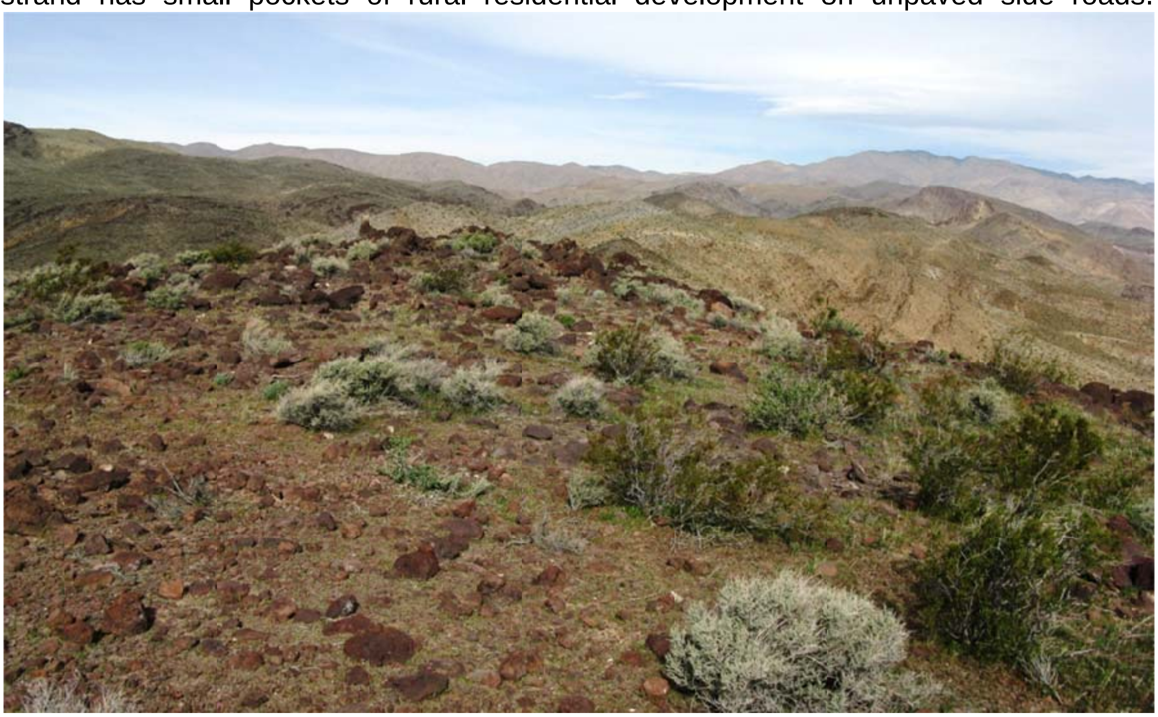
Edwards Air Force Base - Sierra Nevada

This linkage is crossed by SR-14, SR-58, and California City Boulevard. The two previous sections on linkages related to the Sierra Nevada describe improvements needed to the two state highways. Development along California City Boulevard abuts the eastern side of the linkage. Future residential development should be directed to areas away from the linkage.

China Lake North Range - China Lake South Range

The major barrier in the linkage design is SR-178 (a 2-lane undivided road). There is light traffic (mostly mining trucks) on SR-178 in the southern strand of the linkage, and very light traffic on SR-178 in the northern 2 strands. The southern strand is also crossed by a railroad line that serves the salt and borax mines at Searles Lake. The central strand (photo below) has scattered rural residential development. The north strand is intact without any significant development or roads except for the lightly-traveled SR-178.

The photo above (waypoint 203) is the view from SR-178 across the middle strand (kit fox strand) of the linkage design between China Lake North and China Lake South. This strand has small pockets of rural residential development on unpaved side roads.



The photo above (waypoint 209) is a view of the north strand (bighorn sheep and most land facets) of the linkage design. This strand has no development or impediments other than SR-178.

China Lake South Range - Edwards Air Force Base

SR-58 and US-395 and a Burlington Northern Santa Fe railroad line cross this linkage. The highways are 2-lane undivided roads with moderate traffic volumes. We found only about 5 culverts and no bridges along the segments of SR-58 and US-395 that cross the linkage design. Future highway improvement projects should include closely-spaced wildlife crossing structures. Because no large mammals use this linkage, small crossing structures should suffice.

Little urban and residential development occurs in the linkage design, but eastward sprawl from California City should be curtailed.

The FPL Solar Energy Generating Facility at Kramer Junction is the only significant industrial facility in the linkage design. This large fenced area is impermeable to wildlife, creating a small impermeable “bubble” in the linkage design.

China Lake South Range- Twentynine Palms and Newberry Rodman

This linkage includes four strands; the western three strands are nearly parallel, run almost due north-south, and lie close to each other. The northern 80% of these 3 strands run across undisturbed natural lands, but the southern ends are heavily impacted by the convergence of Interstate 40, Interstate 15, SR-58, the Union Pacific and Burlington Northern rail lines, urbanization around city of Barstow, agriculture, and several proposed energy facilities. The city of Barstow and a major rail junction with multiple sidings lie between the westernmost two strands. The fenced Marine Corps Base Supply Center forms an impermeable “bubble” in the 2nd of these 3 strands. The easternmost of the 3 strands runs through irrigated cropland, the Barstow-Daggett Airport, and rural residential areas. The full width of the three strands is spanned by the footprints of proposed solar energy projects. Although natural land cover is widespread in the southern portions of these 3 strands, the cumulative effect of these human activities make it difficult to conserve or improve connectivity in this area. In the photo below (waypoint 83) the view northward through the easternmost of these 3 strands includes (starting in the foreground): the westbound lanes of I-40, the Burlington Northern Santa Fe rail line, and irrigated cropland; the dark line at the base of the Calico Mountains (8 miles away) indicates the location of I-15, the Union Pacific railroad, and small industrial and residential areas on the I-15 frontage road.

The fourth strand lies several miles east of the other three strands. Although the two railroad lines and the two Interstate highways also cross this strand, animals would have some breathing room between barrier crossings, and the strand is free of any other urban, industrial, or residential impacts. Furthermore, it intersects the footprint of only one proposed solar facility. Because this strand is much longer than the other three, it was not part of the least-cost corridor for any focal species. Additional permeability analyses might suggest whether this strand could be modified to provide sufficient connectivity for some or all of the focal species, providing a hedge in case connectivity cannot be maintained in the 3 western strands.

Edwards Air Force Base - Twentynine Palms/Newberry Rodman ACEC

The eastern third of this east-west linkage is crossed by Interstate 15, SR-247 (a 2-lane undivided road), Old Route 66 and the parallel BNSF rail line, and two large proposed solar facilities. It has very little urban development. Interstate 15 is by far the most significant barrier to movement today. The highway carries heavy traffic, has no bridged crossings in or near the linkage area, and has jersey barriers in the median. The only crossing structures are 250-m long pipe culverts, many of them choked with tumbleweed (photo below; waypoint 222). Groups of 2-4 pipes are located about every quarter mile. Future improvements on I-15 should include replacing some of the pipe culverts with soft-bottomed box culverts.

Edwards Air Force Base - San Gabriel Mountains

This linkage design consists of one north-south strand, which runs through the least developed areas between the two wildland blocks. Nonetheless, three major linear barriers cross the southern part of the linkage, namely the California Aqueduct, SR-138 (moderate to heavy traffic), and a railroad line. There are no siphons or underground portions of the California Aqueduct in the portion of the aqueduct that crosses the linkage (photo below; waypoint 231). There are two wide (~400 m) siphons under flowing streams several miles west, but that area is densely urbanized. There is one bridged crossing where SR-138 crosses a stream in the linkage. There are scattered rural residential areas in the southern and central portions of the linkage.

Until the California Aqueduct is covered, or significant siphons are built on it, probably no animal movement is occurring in this linkage. The plants and animals of Edwards Air Force Base are highly dissimilar from those of the San Gabriel mountains. Based on biotic similarity and barriers, it may be more feasible to maintain connectivity between EAFB and 29 Palms, and between EAFB and China Lake South, than between EAFB and the San Gabriels. Thus investments to ameliorate the aqueduct and urban barriers may be a lower priority than investments to improve other linkages.

Twentynine Palms/Newberry Rodman - San Gabriel Mountains

The extreme southwestern strand of this linkage design includes the headwaters of the Mohave River; some portions the linkage and the Mohave River pass through heavily urbanized areas. The main conservation goal in these riverine areas should be to maintain and restore riparian vegetation along the river. It is unrealistic to promote animal movement in the adjacent urban areas of this strand.

The main, broad north-south strand of the linkage design is crossed by SR-18, SR-247, SR-138, SR-173 (each is a 2-lane undivided road), a rail line, many scattered rural residential areas, and several large to small proposed solar developments. Although some housing areas are too dense to support wildlife movement, much of this strand is relatively undeveloped and can support wildlife movement. Future urban growth and industrial development should be shaped in a way that conserves the potential for north-south movement. Thus solar developments may be appropriate immediately north or south of existing residential areas, but should not be allowed to span the linkage strand. In particular, BLM and county planners should coordinate to minimize development along the upper Mohave River, and in 2 or more upland swaths at least 1 km wide each.

The photo above (northwest view from waypoint 245) shows scattered rural residential developments in the southern part of the linkage. Nonetheless a broad corridor can be conserved in the area, as indicated by the next 2 photos looking north (first photo) and south (2nd photo) from this same location. The second photo covers a portion of the San Gabriel Mountains foothills that have been proposed for a solar facility.

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Twentynine Palms/Newberry Rodman - San Bernardino Mountains

This linkage has 3 major strands. The broad, complex western strand overlaps the linkage between Twentynine Palms/Newberry Rodman ACEC to the San Gabriel Mountains. Barriers in that strand are addressed above in the section on that linkage.

SR-247 is the only potential barrier in the middle strand. SR-247 is a 2-lane undivided road with low traffic and no crossing structures. Future improvements on this part of SR-247 provide an opportunity to add soft-bottomed culverts to promote animal movement.

The eastern strand was designed to serve bighorn sheep. There are no culverts or crossing structure on the segment of SR-247 that crosses this strand. A large industrial solar project has been proposed in this strand. The largest gap in the rugged terrain preferred by bighorn sheep occurs in the flat Homestead Valley northeast of SR-247, where a few rural residences also occur (photo below; SR-247 in foreground; waypoint 251). To conserve utility of this corridor, future development should be curtailed and sheep-friendly crossing structures should be constructed when this segment of SR-247 is improved.

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The photo below (looking southwest from the same waypoint towards the Bighorn Mountains) shows that the rest of the corridor provides good habitat for bighorn sheep.

China Lake South Range - Kingston Mesquite Mountains

Few threats to connectivity occur in this linkage. It is crossed only by SR-127, a 2-lane undivided road with extremely low traffic volume. SR-127 has zero culverts or crossing structures in the highway segments that cross the southern 2 strands, and only a few poor structures in the northern strands. Future improvements to the road should include wildlife crossing structures.

The photo below is taken from the northern strand of the linkage (waypoint 155) looking south across the next strand to the south (the "bighorn corridor"). Note that the Soda Hills (the low mountains on the left) nearly touch the Abawitz Mountains (higher mountains on the right) providing excellent continuity of rugged terrain for bighorn sheep. The road is SR-127.

Kingston Mesquite Mountains - Mojave National Preserve

Several industrial solar projects have been proposed in the eastern strands of the linkage. I-15 is the only other major impediment to wildlife movement in this linkage planning area. It is a formidable barrier to wildlife movement, with few bridges or culverts. In several cases a bridge on one set of lanes is aligned with a small culvert on the opposite-bound lanes. In other cases, both sets of lanes are bridged but the bridges are poorly aligned such that an animal would have to walk in the median for > 300 m.

The best bridge in the bighorn sheep corridor (photo above; waypoint 135) is too low (about 8 ft tall) for use by bighorn. A wildlife overpass would provide better connectivity for bighorn sheep in this corridor; in the photo below (waypoint 138) both the northbound lanes of I-15 (left side of photo) and the southbound lanes (right side of photo) have been cut through a ridge; this may be the best potential location for a wildlife overpass in the bighorn corridor.

During future construction on segments of I-15 within the linkage strands, many wildlife crossing structures should be added so that intervals between crossing structures are greatly reduced. In linkage strands outside the bighorn sheep corridor, most of these structures can be well-constructed and well-aligned culverts.

Mojave National Preserve - Twentynine Palms & Newberry Rodman

Three proposed solar facilities, Interstate 40, Old Route 66, and the Burlington Northern Santa Fe railroad line lie in this linkage area. The footprints of the proposed solar projects are so large that the footprints would nearly span all strands of the linkage. The project footprints should be modified to preserve animal movement through this area.

I-40 has several large bridges and smaller culverts. It is questionable whether bighorn sheep would cross under the tallest bridge in the bighorn corridor (below; waypoint 108).

The terrain just northeast of this bridge appears to be good escape and travel terrain for bighorn sheep (photo below; waypoint 108). The terrain further east along I-40 would be suitable for a bighorn overpass.

The railroad line has low bridges and culverts that animals can use, but crossing structures should be more closely spaced. Old Route 66 has such low traffic volume that most animals can cross it safely.

Mojave National Preserve - Stepladder Turtle Mountains

Interstate 40, Old Route 66, and the Burlington Northern Santa Fe railroad line run east-west through the north-south linkage strands. Of these, I-40 is the most significant potential barrier to wildlife movement, crossing through all 5 strands of the linkage. Considering the strands from “first” (westernmost) to “fifth” (easternmost), I 40 has well-spaced bridged crossing structures in the first strand (Marble Mountains) and the fourth strand (Homer Wash). There are two crossing structures (Van Winkle Wash, Fortress Wash) on the second strand (Clipper Mountains). There are no crossing structures in the third strand (Paiute Mountains, Mountain Springs Summit on I-40) or in the in fifth strand (Sacramento Mountains, South Pass on I-40). Future improvements on I-40 should include crossing structures in the 2nd, 3rd, and 5th strands.

The westernmost strand is intended to serve bighorn sheep, which may not walk under the existing bridges on I-40. I-40 is cut into the Marble Mountains in this strand (photo below; waypoint 119), creating an opportunity to build a wildlife overpass in this location.

Stepladder Turtle Mountains - Palen McCoy Mountains

State Route 62, the Metropolitan Water District Aqueduct, and a rail line run east-west through this north-south linkage area. SR-62 is a two-lane undivided road with light traffic that does not present a major barrier to wildlife movement today. During any future widening of SR-62, crossing structures should be built following the guidelines above. The photo below (from waypoint 76) provides the view south from SR-62 (foreground) through the western strand of the linkage towards the Palen McCoy Wilderness (mountains in distance).

The major barrier to wildlife movement is the MWD aqueduct which carries Colorado River water west to Los Angeles. The aqueduct does not impede wildlife movement in the western strand of the linkage design because it is buried underground in this strand (See photo above in the section on *Siphons and Undergrounding*).

The aqueduct is above ground in the eastern strand of the design. In this strand wildlife passage across the aqueduct is possible *only* at 3 short (~100 m) siphons. In the future, large sections of this segment of the canal should be buried to make it permeable to wildlife movement.

Palen McCoy Mountains - Whipple Mountains Mountains

The MWD Aqueduct crosses this linkage twice, once in the southwestern part of the linkage (described in the section on the Stepladder Turtle Mountains to Palen-McCoy linkage), and once in the northern part of the eastern strand of the linkage. Fortunately, the northern crossing of the aqueduct includes siphons under most major washes, and several very long underground sections, making this portion of the aqueduct relatively permeable. Much of this linkage is overlapped by the linkage described in the previous section (the linkage between the Stepladder Turtle Mountains Wilderness and the Palen McCoy Wilderness). Please see the previous section for further description of the aqueduct and mitigation measures.

The linkage strands are also crossed by two highways, namely SR-62 and US-95. These 2-lane undivided roads have low traffic volumes, and are currently not major barriers to movement. When these roads are widened, wildlife-friendly crossing structures should be constructed. SR-62 has a few pipe culverts with pouroffs on the downstream end that make them unusable by wildlife (photo below; waypoint 63). At two locations (for photos, go to online tool and look at photos at waypoints 68 and 72) in the eastern end of the linkage design, SR-62 has two box culverts (< 3 ft tall) without pouroffs that are usable by wildlife. The sections of US-95 crossing the linkage have zero bridges, culverts or other structures that could allow wildlife to cross under the road.

Joshua Tree National Park - Palen McCoy Mountains

The linkage design has 3 strands. The major barrier in this linkage is the MWD aqueduct. In the north strand, the aqueduct is above-ground with only one short siphon for a dirt road. This strand probably supports little or no movement of the focal species today. The segment of the aqueduct crossing the middle strand of the linkage design has only 3 short siphons. Undergrounding is necessary to make these two strands permeable to wildlife. The terrain is flat and it would be easy to underground large portions of the canal to allow wildlife movement.

Shortly south of the middle strand, the MWD aqueduct enters a tunnel underneath the mountains. The southern strand of the linkage design is not crossed by the canal.

SR-177 also crosses all three strands. This road does not have a single culvert, pipe, or bridge for its entire length across all 3 strands of the linkage (or anywhere between SR-62 and I-10). Although wildlife movement is not greatly impeded by this two lane, undivided road with light traffic, any future road improvements should include wildlife crossing structures where the road crosses each of the 3 strands of the linkage design.

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The photo above (waypoint 78) shows the view westward toward Joshua Tree NP from SR-177 in the north strand of the Joshua Tree to Palen McCoy Wilderness. The red scar in midfield is the embankment of the MWD canal cutting across the north strand of the linkage.

Joshua Tree National Park - Chocolate Mountains

Interstate 10 is the most significant barrier to wildlife movement in this linkage area. There are ten excellent bridged crossings on I-10 in the central and eastern strands of the linkage design, for an average of about 1 natural-bottomed crossing structure per mile. There is one good bridge in the western strand of the linkage design. Future improvements for wildlife permeability should focus on adding smaller soft-bottomed box culverts at shorter intervals for use by less mobile small animals.

The Metropolitan Water District Aqueduct (Colorado River to Los Angeles) crosses the linkage. The aqueduct is underground where it crosses the linkage design except for a segment about 6.5 miles long along the southern edge of Joshua Tree National Park. This above-ground canal impacts animal movement in the eastern strands of the linkage design. Six underground siphons in this above-ground segment cover about 10% of the open canal. Permeability for wildlife would be improved by extending these siphons.

The pumping station in the photo above (from waypoint 39) is the western end of a 6.5-mile open-canal section of the MWD Aqueduct. The water is pumped into a tunnel under the Eagle Mountains and remains underground for at least 20 miles to the west.

The abandoned Eagle Mountain rail line (which served the defunct Eagle Mountain iron mine) runs north and south through the eastern linkage strands. As with all rail lines, the gravel embankments and tracks impede animal movement. Because this line is no longer in use, simply breaching the track and embankment at regular intervals would improve permeability for wildlife.

Palen McCoy Mountains - Chocolate Mountains

This linkage consists of several roughly parallel southwest to northeast strands across rugged and undeveloped basin and range landscape. Interstate 10 runs east-west across all linkage strands. I-10 has 5 good bridges over major washes, one of which is shown in the photo below (from waypoint 53). Future improvements to I-10 should include frequently-spaced smaller crossing structures, following the guidelines above.

Three proposed solar projects also lie in the area, including the massive Graham Pass proposed project that spans the entire width of all linkage strands. Project footprints should be modified to allow animal movement.

Palen McCoy Mountains - Little Picacho

For 60 miles of the approximately 75-mile length of this north-south linkage, there are no human-caused barriers to movement. But the northernmost part of the linkage is crossed by Interstate 10, and large industrial solar facilities have been proposed within this part of the linkage. Ironwood State Prison abuts the west side of the proposed Mule Mountain III solar facility; together the prison and solar project would nearly span the width of the central linkage strand.

A few miles east, the proposed Desert Quartzite First Solar facility would affect a crucial link in the corridor for bighorn sheep. The rugged habitat preferred by bighorn sheep is nearly continuous for the entire length of this corridor, except for the flat valley between the southern tip of the McCoy Mountains and the northern end of the Mule Mountains. The Desert Quartzite First Solar project would occupy most of this flat valley floor, compromising the one weak link in bighorn habitat.

The footprints of the proposed solar projects should be modified to conserve these linkages.

There are several good bridges on the segments of Interstate 10 that cross the linkage. Future construction on I-10 should include well-spaced smaller wildlife crossing structures. Bridged underpasses may not support movement by bighorn sheep. The point where I-10 crosses the southern tip of the McCoy Mountains (photo below; from waypoint 257) is the best location for an overpass that could accommodate movement by bighorn sheep.

SR-78 crosses the linkage about midway along this long north-south linkage. This quiet, 2-lane road present a weak barrier to animal movement. The southern part of the linkage is quite remote and wild (next two photos from waypoint 261).

Chocolate Mountains - Little Picacho

Three industrial solar projects have been proposed in this linkage area, which currently has no major impediments to wildlife movement. Although SR-78 passes through the area (photo below, from waypoint 266), this 2-lane undivided road has very light traffic and currently does not prevent wildlife movement. If industrial development creates the need for an improved road, wildlife crossing structures should be added. Currently, SR-78 has very few culverts, most of which are 1-ft diameter pipes.

Chocolate Mountains - East Mesa

This linkage probably provides little connectivity for wildlife. The Coachella Canal (photo below from waypoint 268) crosses the entire linkage and it is an absolute barrier to any terrestrial animal. Within the linkage the canal appears to be crossed only by 2 roads, with no other siphons or gaps.

The Algadones Dunes (photo below from waypoint 267) present a formidable natural barrier to animals, except those that can cross large expanses of steep, open sand. To the west, the vast irrigated agricultural fields of the Imperial Valley preclude any corridor within natural land covers.

The western strand of the linkage design runs through a narrow gap between the Imperial Valley croplands and the northern tip of the Algodones Dunes, and does provide a narrow swath of semi-natural vegetation intermixed with smaller agricultural fields. This western strand could be greatly improved by undergrounding the short section of the Coachella Canal within this strand, and by restoring the small cropland areas within this strand to natural vegetation.

SR-78 also crosses all linkage strands, but this 2-lane, lightly traveled road provides little impediment to animal movement.

A Scientifically Sound Plan for Conservation Action

Humans have become significant agents of biogeographic change, converting habitat to urban and agricultural uses and altering the movements of organisms, nutrients, and water through the ecosystem. The resulting fragmentation of natural landscapes threatens to impede the natural processes needed to support biological diversity. This interaction between human development and biodiversity is one of the great and potentially tragic experiments of our time. It creates a unique challenge for land managers and conservation planning efforts – to mitigate these major impacts to once intact ecosystems. The Linkage Network for the California Deserts addresses the challenges posed to our natural environment by the ever-increasing human footprint by seeking to influence regional development and land-management patterns in a manner that best preserves landscape level processes. This linkage conservation plan can be used to protect an interconnected system of natural space where native biodiversity can thrive at minimal cost to other human endeavors. For example, the plan can be used by various agencies to guide how they can best help sustain biodiversity and ecosystem processes by implementing the linkage designs.

- Relevant aspects of the plan can be folded into management plans of agencies and organizations administering conservation lands in the region

- The linkage plan can also be used to help implement several regional Habitat Conservation Plans (HCPs), Natural Community Conservation Plans (NCCP), and other conservation strategies (e.g., Desert Renewable Energy Conservation Plan, recovery plans for listed species).

- Transportation agencies can use the plan to design new projects and find opportunities to upgrade existing crossing structures.

- Local jurisdictions can use the plan to help guide development projects to avoid and minimize their effects on critical wildlife linkages through General Plans, Specific Plans, and the development review process.

- Regulatory agencies can use this information to help inform decisions regarding impacts on wildlife movement, species, streams and other habitats. The plan can also help motivate and inform construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, and land acquisition.

Existing conservation investments in the vicinity are extensive. Each land parcel located within the targeted Landscape Blocks or the Linkage Network serves a unique role in preserving some aspect of connectivity. Incorporating relevant aspects of this plan into existing and future planning efforts provides the opportunity to jointly implement a regional conservation strategy.

Additional conservation action will also be needed to address transportation barriers. Recommended tools include road renovation, construction of wildlife crossings, watershed planning, habitat restoration, conservation easements, zoning, acquisition, and others. These recommendations are not exhaustive, but are meant to serve as a starting point for preserving and restoring linkage function. We urge the reader to keep sight of the primary goal of conserving landscape linkages to promote movement between targeted Landscape Blocks over broad spatial and temporal scales and to work within this framework to develop a wide variety of restoration options for maintaining linkage function.

Public education and outreach is vital to the success of this effort – both to change land use activities that threaten species existence and movement in the Linkage Network and to generate an appreciation and support for maintaining landscape connectivity. Public education can encourage recreational users and residents at the urban-wildland interface to become active stewards of the land and to generate a sense of place and ownership for local habitats and processes. Such voluntary cooperation is essential to preserving linkage function.

Successful conservation efforts are reiterative, incorporating and encouraging the collection of new biological information that can increase understanding of linkage function. We strongly support the development of a monitoring and research program that addresses movement (of individuals and genes) and resource needs of species in the Linkage Network. The suite of predictions generated by the GIS analyses conducted in this planning effort provides a starting place for designing long-term monitoring programs.

The network of protected wildlands in the California deserts is extensive. The sheer magnitude of proposed renewable energy developments is staggering. Without thoughtful action, our existing protected lands may become isolated in a matrix of urban and industrial development. Ultimately the fate of the plants and animals living on these lands will be determined by the size and distribution of protected lands and surrounding development and human activities. With this linkage conservation plan, the outcome of land use changes can be tailored to assure the greatest protection for our natural areas at the least cost to our human endeavors. We envision a future interconnected system of natural space where our native biodiversity can thrive.

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