South Coast Missing Linkages Project

A Linkage Design for the San Gabriel-San Bernardino Connection

South Coast Wildlands & San Bernardino National Forest

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Project Steering Committee: We are extremely grateful to the following individuals, who serve on the steering committee for the South Coast Missing Linkages Project: Paul Beier (Northern Arizona University), Madelyn Glickfeld (formerly with The Resources Agency California Legacy Project), Gail Presley (California Department of Fish and Game), Therese O'Rourke (U.S. Fish & Wildlife Service, formerly with The Nature Conservancy), Kristeen Penrod (South Coast Wildlands), Rick Rayburn (California State Parks), Ray Sauvajot (National Park Service), and Tom White (U.S. Forest Service).

Executive Summary

Habitat loss and fragmentation are the leading threats to biodiversity, both globally and in southern California. Efforts to combat these threats must focus on conserving well-connected networks of large wildland areas where natural ecological and evolutionary processes can continue operating over large spatial and temporal scales—such as top-down regulation by large predators, and natural patterns of gene flow, pollination, dispersal, energy flow, nutrient cycling, inter-specific competition, and mutualism. Adequate landscape connections will thereby allow these ecosystems to respond appropriately to natural and unnatural environmental perturbations, such as fire, flood, climate change, and invasions by alien species.

The tension between fragmentation and conservation is particularly acute in California, because our state is one of the 25 most important hotspots of biological diversity on Earth. And nowhere is the threat to connectivity more severe than in southern California—our nation's largest urban area, and still one of its fastest urbanizing areas. But despite a half-century of rapid habitat conversion, southern California retains some large and valuable wildlands, and opportunities remain to conserve and restore a functional wildland network here.

Although embedded in one of the world's largest metropolitan areas, southern California's archipelago of conserved wildlands is fundamentally one interconnected ecological system, and the goal of South Coast Missing Linkages is to keep it so. South Coast Missing Linkages is a collaborative effort among a dozen governmental and non-governmental organizations. Our aim is to develop Linkage Designs for 15 major landscape linkages to ensure a functioning wildland network for the South Coast Ecoregion, along with connections to neighboring ecoregions. The San Gabriel-San Bernardino Connection is one of these 15 linkages, whose protection is crucial to maintaining ecological and evolutionary processes among large blocks of protected habitat within the South Coast Ecoregion.

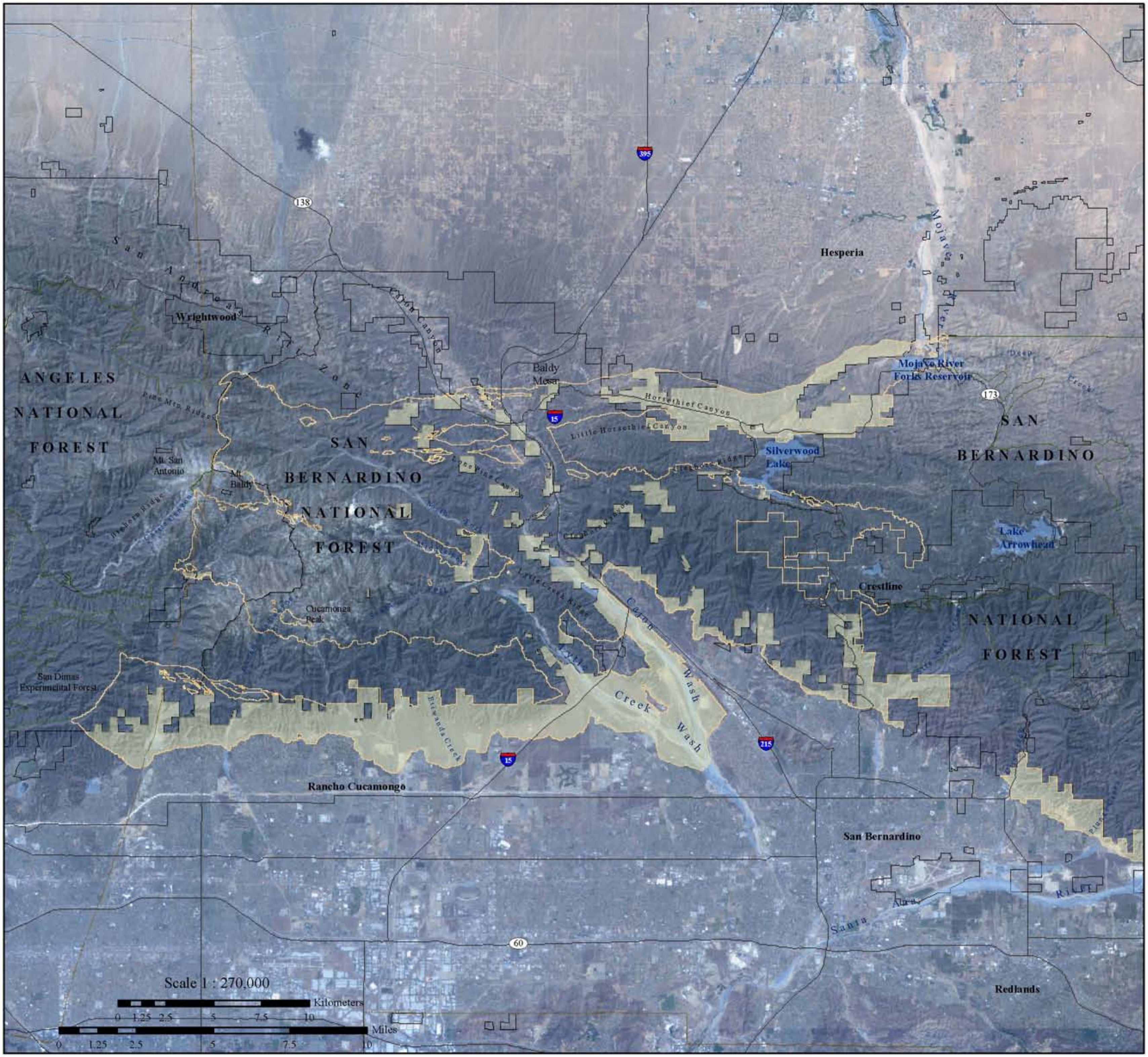
On August 7, 2002, 86 participants representing over 44 agencies, academic institutions, land managers, land planners, conservation organizations, and community groups met to establish biological foundations for planning landscape linkages in the San Gabriel-San Bernardino Linkage. They identified 24 focal species that are sensitive to habitat loss and fragmentation here, including 3 plants, 5 insect, 1 fish, 1 amphibian, 2 reptiles, 5 birds and 7 mammals. These focal species cover a broad range of habitat and movement requirements: some are widespread but require huge tracts of land to support viable populations (e.g., Mountain lion, American badger, California spotted owl); others are species that are restricted to the linkage planning area (e.g., San Bernardino kangaroo rat). Many are habitat specialists (e.g., Pygmy nuthatch in yellow pine forests) and others require specific configurations of habitat elements (e.g. Green hairstreak butterfly). Together, these 24 species cover a wide array of habitats and movement needs in the region, so that planning adequate linkages for them is expected to cover connectivity needs for the ecosystems they represent.

To identify potential routes between existing protected areas we conducted landscape permeability analyses for 5 focal species for which appropriate data were available. Permeability analyses model the relative cost for a species to move between protected core habitat or population areas. We defined a least-cost corridor—or best potential route—for each species, and then combined these into a Least Cost Union covering all 5 species. We then analyzed the size and configuration of suitable habitat patches within this Least Cost Union for all focal species to verify that the final Linkage Design would suit the live-in or move-through habitat needs of all. Where the Least Cost Union omitted areas essential to the needs of a particular species, we expanded the Linkage Design to accommodate that species' particular requirements to produce a final Linkage Design (Figure ES-1).

We also visited priority areas in the field to identify and evaluate barriers to movement for our focal species. In this plan we suggest restoration strategies to mitigate those barriers, with special emphasis on opportunities to reduce the adverse effects of Interstate 15 and other major transportation corridors.

The ecological, educational, recreational, and spiritual values of protected wildlands in the South Coast Ecoregion are immense. Our Linkage Design for the San Gabriel-San Bernardino Linkage represents an opportunity to protect a truly functional landscape-level connection. The cost of implementing this vision will be substantial—but the cost is small compared with the benefits. If implemented, our plan would not only permit movement of individuals and genes between the San Gabriel and San Bernardino Ranges, but should also conserve large-scale ecosystem processes that are essential to the continued integrity of existing conservation investments throughout the region. We hope that our biologically based and repeatable procedure will be applied in other parts of California and elsewhere to ensure continued ecosystem integrity in perpetuity.

Executive Summary 1. Linkage Design



Legend

- Linkage Design Boundary
- Unprotected Area
- Roadless Areas
- Interstate/Highways
- Ownership Boundaries
- County Boundaries

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Nature Needs Room to Move

Movement is essential to wildlife survival, whether it be the day-to-day movements of individuals seeking food, shelter, or mates, dispersal of offspring (e.g., seeds, pollen, fledglings) to new home areas, or migration of organisms to avoid seasonally unfavorable conditions (Forman 1995). Movements can lead to recolonization of unoccupied habitat after environmental disturbances, the healthy mixing of genes among populations, and the ability of organisms to respond or adapt to environmental stressors. Movements in natural environments lead to complex mosaics of ecological and genetic interactions at various spatial and temporal scales.

In environments fragmented by human development, disruption of movement patterns can alter essential ecosystem functions, such as top-down regulation by large predators, gene flow, natural patterns and mechanisms of pollination and seed-dispersal, natural competitive or mutualistic relationships among species, resistance to invasion by alien species, and prehistoric patterns of 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 et al. 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 long been recognized as important for sustaining 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).

Patterns of Habitat Conversion

As a consequence of rapid habitat conversion to urban and agricultural uses, the South Coast Ecoregion (Figure 1) of California has become a hotspot for species at risk of extinction. California has the greatest number of threatened and endangered species in the continental U.S, representing nearly every taxonomic group, from plants and invertebrates to birds, mammals, fish, amphibians, and reptiles (Wilcove et al. 1998). In an analysis that identified “irreplaceable” places for preventing species extinctions (Stein et al. 2000), the South Coast Ecoregion stood out as one of the six most important areas in the United States (along with Hawaii, the San Francisco Bay Area, Southern Appalachians, Death Valley, and the Florida Panhandle). The ecoregion is part of the California Floristic Province, one of 25 global hotspots of biodiversity, and the only one in North America (Mittermeier et al. 1998, Mittermeier et al. 1999).

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 being confronted with a man-made labyrinth of barriers, as roads, homes, businesses, and agricultural fields fragment formerly expansive natural landscapes. Movement patterns crucial to species survival are being permanently altered at unprecedented rates. Countering this threat requires a systematic approach for identifying, protecting, and restoring functional connections across the landscape to allow essential ecological processes to continue operating as they have for millennia.

A Statewide Vision

In November 2000, a coalition of conservation and research organizations (California State Parks, California Wilderness Coalition, Center for Reproduction of Endangered Species, San Diego Zoo, The Nature Conservancy, and U.S. Geological Survey) launched a statewide interagency workshop—Missing Linkages: Restoring Connectivity to the California Landscape—at the San Diego Zoo. The workshop brought together over 200 land managers and conservation ecologists representing federal, state, and local agencies, academic institutions, and non-governmental organizations to delineate habitat linkages critical for preserving the State's biodiversity. Of the 232 linkages identified at the workshop, 69 were associated with the South Coast Ecoregion (Penrod et al. 2001).

Figure 1. The South Coast Ecoregion encompasses roughly 8% of California and extends 300 km (190 mi) into Baja California.

South Coast Missing Linkages: A Vision for the Ecoregion

Following the statewide Missing Linkages conference, South Coast Wildlands, a non-profit organization established to pursue habitat connectivity planning in the South Coast Ecoregion, brought together regional ecologists to conduct a formal evaluation of these 69 linkages. 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 ecoregion; 5) facilitation of seasonal movement and climatic change; and 6) addition of value for aquatic ecosystems. Vulnerability was evaluated using recent high-resolution aerial photographs, local planning documents, and other data. This process identified 15 linkages of crucial biological value that are likely to be irretrievably compromised by

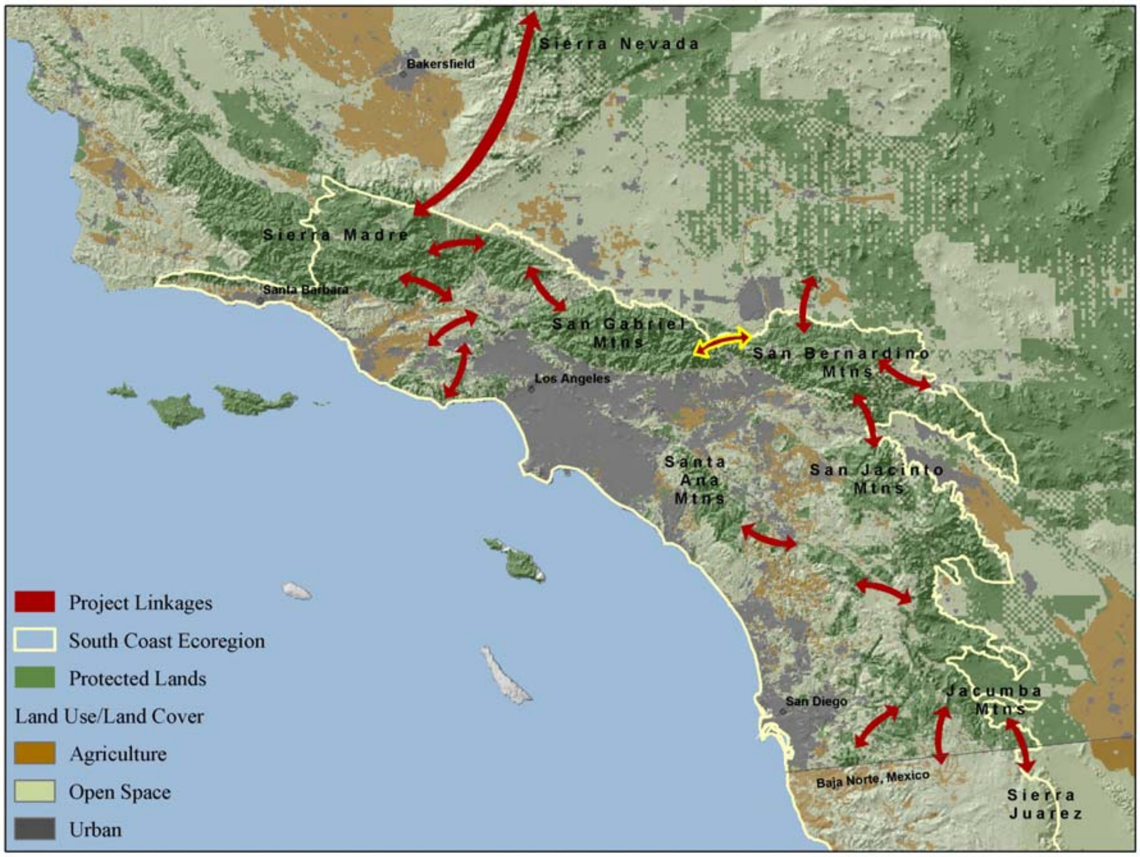

Figure 2. The South Coast Missing Linkages Project addresses habitat fragmentation at a landscape scale, and the needs of a variety of species. The San Gabriel-San Bernardino Linkage is one of 15 landscape linkages identified as irreplaceable and imminently threatened.

development projects over the next decade unless immediate conservation action occurs (Figure 2). The biological integrity of several thousand square miles of the very best Southern California wildlands would be irreversibly jeopardized if these linkages were lost.

Identification of these 15 priority linkages launched the South Coast Missing Linkages Project. The ultimate goal of this highly collaborative effort among federal and state agencies and non-governmental organizations is to identify and conserve landscape-level habitat linkages to protect essential biological and ecological processes in the South Coast Ecoregion. Partners include but are not limited to: South Coast Wildlands, The Wildlands Conservancy, The Resources Agency California Legacy Project, California State Parks, California State Parks Foundation, United States Forest Service, National Park Service, Santa Monica Mountains Conservancy, Conservation Biology Institute, San Diego State University Field Stations Program, San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy, The Nature Conservancy, Environment Now, The Wildlands Project, and the Zoological Society of San Diego Center for Reproduction of Endangered Species. Cross-border alliances have also been formed with Pronatura, Universidad Autonoma de Baja California, and Conabio to further the South Coast Missing Linkages initiative in northern Baja. It is our hope that the South Coast Missing Linkages effort will serve as a catalyst for directing funds and attention toward the protection of ecological connectivity for the South Coast Ecoregion and beyond.

The 15 Priority Linkages

Santa Monica Mountains-Santa Susana Mountains
Santa Susana Mountains-Sierra Madre Mountains
E. Sierra Madre Mountains-W. Sierra Madre Mountains
Sierra Madre Mountains-Sierra Nevada Mountains
San Gabriel Mountains-Castaic Ranges
San Gabriel Mountains-San Bernardino Mountains
San Bernardino Mountains-San Jacinto Mountains
San Bernardino Mountains-Little San Bernardino Mountains
San Bernardino Mountains-Granite Mountains
Santa Ana Mountains-Palomar Ranges
Otay Mountains-Laguna Mountains
Campo Valley-Laguna Mountains
Otay Mountains-Northern Baja
Peninsular Ranges-Anza Borrego
Jacumba Mountains-Sierra Juarez Mountains

To this end, South Coast Wildlands is coordinating and hosting regional workshops, providing resources to partnering organizations, conducting systematic GIS analyses for all 15 linkages, and helping to raise public awareness regarding habitat connectivity needs in the ecoregion. South Coast Wildlands has taken the lead in researching and planning for 7 of the 15 linkages; San Diego State University Field Station Programs, National Park Service, California State Parks, U. S. Forest Service, Santa Monica Mountains Conservancy, Conservation Biology Institute, and The Nature Conservancy have taken the lead on the other 8 linkages. The San Gabriel-San Bernardino Linkage is one of these 15 linkages, whose protection is crucial to maintaining ecological and evolutionary processes among large blocks of protected habitat within the South Coast Ecoregion.

Ecological Significance of the San Gabriel-San Bernardino Linkage

The San Andreas Rift Zone runs in a northwest to southeasterly direction through the linkage, at the San Gabriel and San Bernardino Mountains divide, producing steep rugged topography and a complexity of microhabitats. The planning areas supports a diversity of natural communities due to the marked elevational gradient and the transition from cismontane scrub and woodland communities in the south to the transmontane Mojave desert in the north. The majority of the planning area is dominated by chaparral, with higher elevations supporting montane hardwood conifer and mixed coniferous forests, with oak woodlands in deep ravines, and a diversity of riparian habitats at intermediate and lower elevations (Figure 3). The northernmost part of the planning area supports pinyon-juniper woodland and desert scrub habitats, while coastal sage scrub and alluvial fan habitats dominate the southern foothills. A number of designated sensitive natural communities occur in the planning area including Riversidian alluvial fan sage scrub, Southern Sycamore Alder riparian woodland, Southern riparian forest, California walnut woodland, Canyon live oak ravine forest, Coastal and valley freshwater marsh, and Coastal sage scrub (CDFG 2003). These habitats are among the rarest and most sensitive ecosystem types in the United States.

Figure 3.
Vegetation Types in the Planning Area

- Annual Grassland
- Perennial Grassland
- Wet Meadow
- Alkali Desert Scrub
- Desert Scrub
- Sagebrush
- Joshua Tree
- Pinyon-Juniper
- Juniper
- Desert Wash
- Desert Riparian
- Lacustrine
- Water
- Valley Foothill Riparian
- Montane Riparian
- Riverine
- Coastal Scrub
- Chamise-Redshank Chaparral
- Mixed Chaparral
- Montane Chaparral
- Coastal Oak Woodland
- Montane Hardwood
- Montane Hardwood-Conifer
- Subalpine Conifer
- Closed-Cone Pine-Cypress
- Jeffrey Pine
- Eastside Pine
- Mixed Conifer
- Ponderosa Pine
- White Fir
- Alpine-Dwarf Shrub
- Barren
- Urban
- Eucalyptus
- Agriculture

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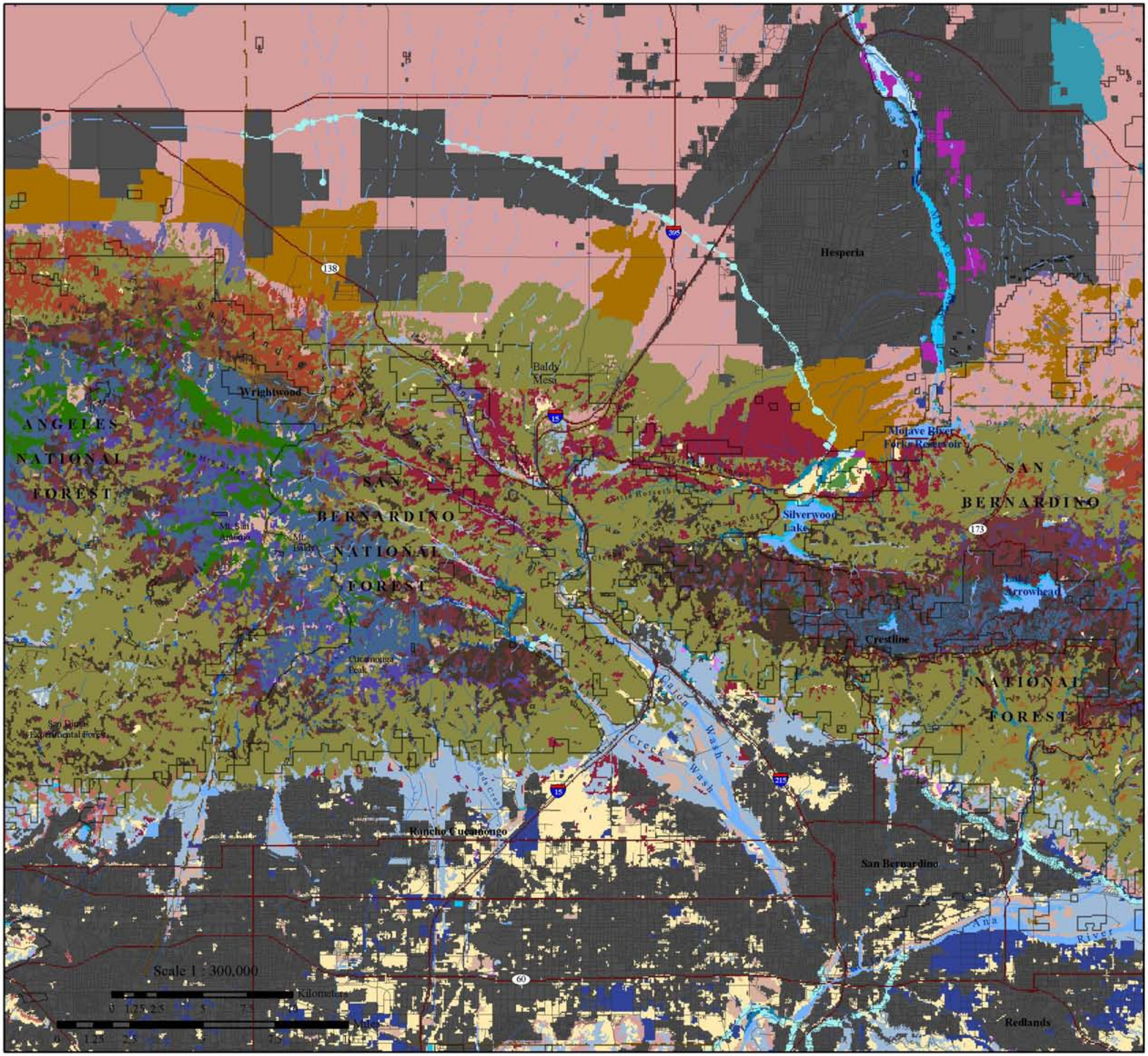


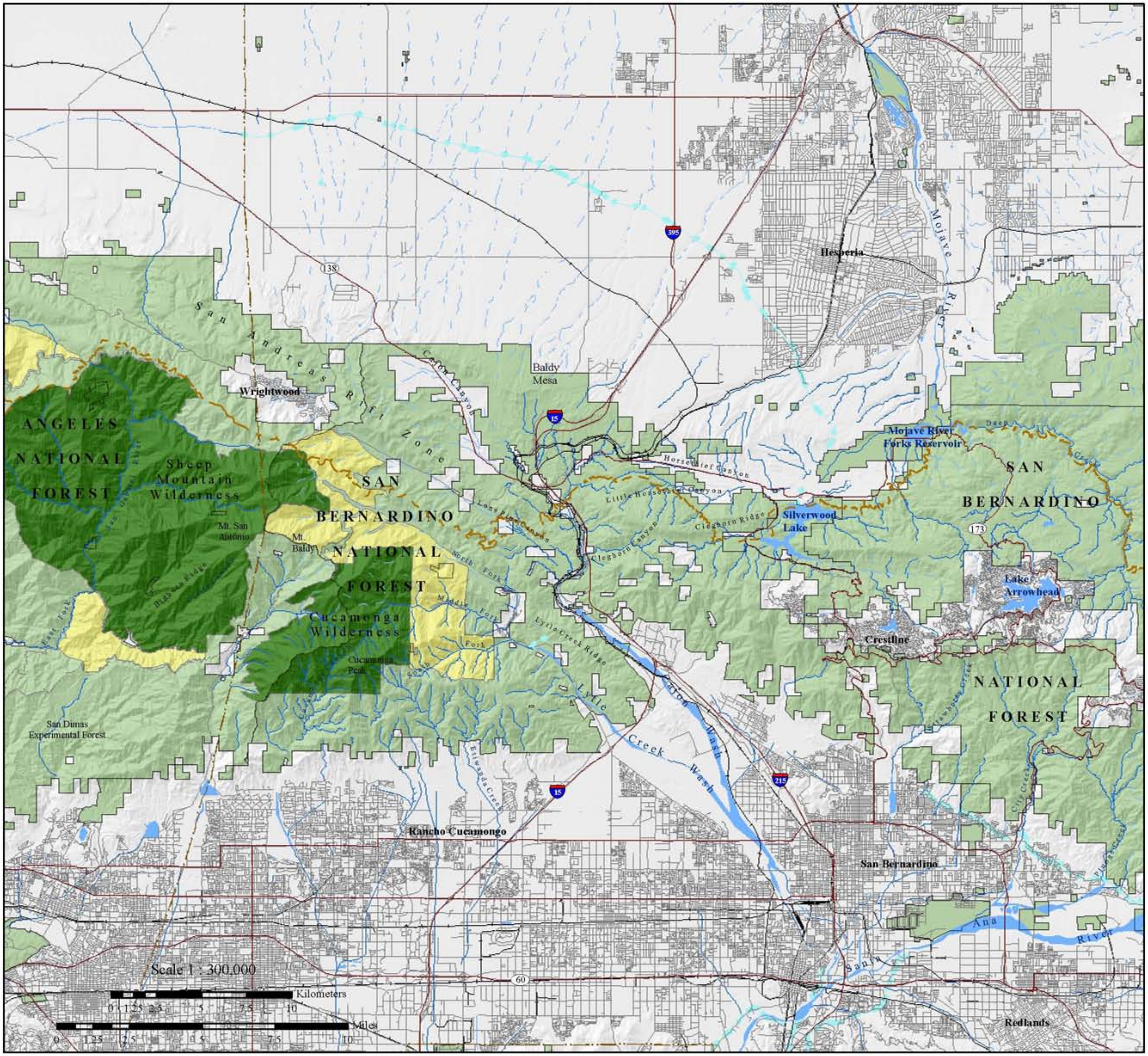
Species distribution patterns are equally intricate, with a number of listed and sensitive species documented in the vicinity of the connection (CDFG 2003). Several listed or sensitive migratory songbirds have the potential or are known to occur, including the endangered southwestern willow flycatcher (*Empidonax traillii extimus*) and least Bell's vireo (*Vireo bellii pusillus*). The planning area is also home to several listed and sensitive amphibians and reptiles, including the endangered arroyo toad (*Bufo microscaphus californicus*), Mountain yellow-legged frog (*Rana muscosa*), Desert tortoise (*Gopherus agassizi*), southwestern pond turtle (*Clemmys marmorata*), and San Diego horned lizard (*Phrynosoma coronatum blainvillei*). And, it is one of the last refuges for Santa Ana speckled dace (*Rhinichthys osculus* spp.), one of the rarest native fish in southern California. Species dependent on alluvial fan habitats, such as the federally endangered San Bernardino kangaroo rat (*Dipodomys merriami parvus*) and slender-horned spineflower (*Dodecahema leptoceras*) also occur in the planning area. Species reliant on upland habitats, such as the federally threatened coastal California gnatcatcher (*Polioptila californica*), also depend on habitat in this region. In addition to conserving habitat for over a dozen federally or state threatened and endangered species, the area also provides live-in and move-through habitat for numerous native species that need extensive wildlands to thrive, such as American badger (*Taxidea taxus*), Nelson's bighorn sheep (*Ovis canadensis nelsoni*), Mountain lion (*Puma concolor*), and California spotted owl (*Strix occidentalis occidentalis*).

Existing Conservation Investments

Significant conservation investments already exist in the region (Figure 4), but the resource values they support could be irreparably harmed by loss of connections between them. This linkage serves to connect two expansive protected core areas, though the linkage itself is almost entirely within the boundaries of the San Bernardino National Forest. California State Parks, Bureau of Land Management, and the county also administer land in the vicinity. The Pacific Crest Trail traverses through the central portion of the linkage, from the Sheep Mountain Wilderness Area, along Upper Lytle Creek Ridge toward Cajon Junction and up Little Horsethief Canyon towards Silverwood Lake State Recreation Area. The Sheep Mountain and Cucamonga Wilderness Areas are also within the vicinity of the connection. Deep Creek and the North, Middle, and South Forks of Lytle Creek have been nominated as Wild and Scenic Rivers and several other worthy roadless areas are proposed for Wilderness status in these ranges as part of the California Wild Heritage Act (http://www.californiawild.org). In addition, numerous Special Interest Areas and Research Natural Areas are being considered in the San Gabriel and San Bernardino Mountains as part of the Forest's Resource Management Plan revisions (Penrod et al. 2002, USDA Forest Service 2004). For instance, Cajon Canyon is currently a Wildlife Emphasis Area and has been proposed as a Special Interest Area and is currently a because of its' phenomenal geology, in addition to rich biological and cultural resources. While, Cleghorn Canyon has been proposed as a Research Natural Area for its utility as a wildlife movement corridor and because of the diversity of vegetation types that occur there. A relatively modest investment in connective habitats now can help ensure the integrity of these sites in perpetuity.

Threats to natural habitats in the planning area have been recognized by federal, state, and local agencies and non-governmental organizations that have launched a variety of successful planning efforts. The East Etiwanda Creek Nature Sanctuary owned and managed by the Habitat Trust covers 55 ha (135 ac), while the North Etiwanda Reserve

Figure 4. Existing Conservation Investments in the Planning Area



Legend

- Ownership Boundaries
- Designated Wilderness
- Proposed Wilderness
- Interstate/Highways
- Paved Roads
- Railroads
- Pacific Crest Trail
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries

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conserves 308 ha (762 ac) of habitat. In Cajon Wash, a total of 311 ha (768 ac) have evidently been set-aside for the San Bernardino kangaroo rat and Slender-horned spineflower. While the County of San Bernardino has long been engaged in a Valley wide Multiple-Species Habitat Conservation planning effort to identify important conservation areas. The County is currently updating their General Plan and it is hoped that the information generated for the MSHCP will be incorporated into this plan. The City of Rancho Cucamonga's Open Space Plan also supports conservation of alluvial fan habitat along the foothills. In addition, two ecological reserves have been proposed to Wildlife Conservation Board, one in the Summit Valley area, and another along the San Gabriel fan.

Threats to Connectivity

Although the majority of the linkage area is within the boundary of the San Bernardino National Forest, a number of inholdings occur in critical areas along major transportation corridors. Private parcels line Highway 138 for about 6 miles of upper Cajon Canyon and some sparse development occurs around Cajon Junction, where the 15 meets the 138, and between Cajon Junction and Blue Cut. In the southern part of the planning area, Lytle and Cajon washes are threatened by urban development and sand and gravel mining. Summit Valley, in the northeast portion of the linkage, is also threatened with a massive high-density urban development that would seriously impede wildlife movement. Four other large-scale developments are proposed in the San Bernardino core area near the communities of Fawnskin and Big Bear.

Currently, the primary barriers to movement are Interstate 15, Highway 138, Route 66, and several railroad lines. However, other major transportation routes are proposed in the linkage planning area. The Southern California Association of Governments (SCAG) has initiated a privately funded program called Operation Jump Start (http://www.scag.ca.gov/jumpstart/about.html) that is part of their approved Regional Transportation Plan. The project calls for development of dedicated truck lanes and additional rail lines for the transport of goods, as well as, construction of a high-speed commuter train (220 MPH), along Interstate 15 that would create additional barriers to wildlife movement.

Southern California's remaining wildlands form an archipelago of natural open space thrust into one of the world's largest metropolitan area within a global hotspot of biological diversity. These wild areas are naturally interconnected; indeed, they historically functioned as one ecological system. However, recent intensive and unsustainable 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, time is of the essence if we are to secure this regionally important landscape connection.

The goal of linkage conservation planning is to identify specific lands that must be conserved to maintain or restore functional connections for species or ecological processes of interest, generally between two or more protected core habitat areas. We adopted a spatially hierarchical approach, gradually working from landscape-level processes down to the needs of individual species. The planning area encompasses habitats between the San Gabriel and San Bernardino ranges of the Angeles and San Bernardino National Forests. We conducted various spatial analyses to identify those areas necessary to accommodate continued movement of selected focal species through this landscape. Our approach can be generally summarized as follows:

1) *Focal Species Selection:* select species from diverse taxonomic groups that represent a diversity of habitat requirements and movement needs.

2) *Landscape Permeability Analysis:* conduct landscape permeability analyses to identify zones of habitat that address the needs of multiple species potentially traveling through, or residing in the linkage.

3) *Patch Size & Configuration Analysis:* use patch size and configuration analyses to identify the priority areas needed to maintain linkage function.

4) *Field Investigations:* conduct fieldwork to ground-truth results of prioritization analyses, identify barriers, and document conservation management needs.

5) *Linkage Design:* compile results of analyses and fieldwork into a detailed comprehensive report.

Our approach has been highly collaborative and interdisciplinary. We followed Baxter (2001) in recognizing that successful conservation planning is based on the participation of experts in biology, conservation design, and implementation in a reiterative process (Figure 5). To engage regional biologists and planners early in the process, we held a habitat connectivity workshop on August 7, 2002. The workshop gathered indispensable information on conservation needs and opportunities in the linkage. The workshop engaged 86 participants representing over 44 different agencies, academic institutions, conservation organizations, and community groups (Appendix A).

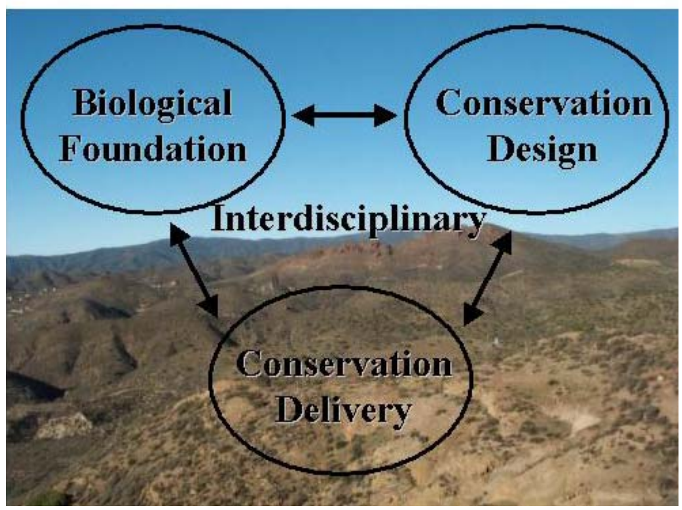


Figure 5. Successful conservation planning requires an interdisciplinary and reiterative approach among biologists, planners and activists (Baxter 2001).

Focal Species Selection

The workshop participants identified a taxonomically diverse group of focal species (Table 1) that are sensitive to habitat loss and fragmentation and that represent the diversity of ecological interactions that can be sustained by successful linkage design. The focal species approach (Beier and Loe 1992) recognizes that species move through and utilize habitat in a variety of ways. Workshop participants were divided into taxonomic working groups; each group identified the life history characteristics of species that were particularly sensitive to habitat loss and fragmentation or otherwise meaningful to linkage design. Participants then summarized relevant information on each of the selected focal species, including habitat preferences, movement characteristics, and recorded occurrences. They also delineated potential movement routes through the linkage region. (For more on the workshop process see Appendix B.)

Table 1. Regional ecologists selected 24 focal species for the San Gabriel-San Bernardino Linkage

Mammals
Dipodomys agilis (Pacific kangaroo rat)
Dipodomys merriami parvus (San Bernardino kangaroo rat)
Neotoma fuscipes macrotis (Dusky-footed woodrat)
Odocoileus hemionus (Mule deer)
Ovis canadensis nelsoni (Nelson's bighorn sheep)
Taxidea taxus (American badger)
Puma concolor (Mountain lion)
Birds
Salpinctes obsoletus (Rock wren)
Chamaea fasciata henshawi (Wrentit)
Sitta pygmaea melanotis (Pygmy nuthatch)
Oreortyx pictus eremophilus (Mountain quail)
Strix occidentalis occidentalis (California spotted owl)
Amphibians & Reptiles
Hyla cadaverina (California treefrog)
Phrynosoma coronatum blainvillii (San Diego horned lizard)
Masticophis lateralis lateralis (Chaparral whipsnake)
Fish
Rhinichthys osculus (Santa Ana speckled dace)
Invertebrates
Rhaphiomidas acton (Giant flower-loving fly)
Eleodes armata (Desert skunk beetle)*
Apodemia mormo (Metalmark butterfly)
Callophrys perplexa (Green hairstreak butterfly)
Pepsis spp. (Tarantula hawks)
Plants
Dodecahema leptoceras (Slender-horned spineflower)
Artemisia californica (California sagebrush)
Alnus rhombifolia (White alder)
**Species not modeled.*

The 24 focal species identified at the workshop included 3 plants, 5 insects, 1 amphibian, 2 reptiles, 1 fish, 5 birds and 7 mammals. The focal species selected capture a diversity of movement needs and ecological requirements, from species that require large tracts of land (e.g., Mountain lion, American badger, Nelson's bighorn sheep, California spotted owl) to those with distributions restricted to the linkage planning area (e.g., San Bernardino kangaroo rat). They include habitat specialists (e.g., pygmy nuthatch in yellow pine forests) and those requiring a specific configuration of habitat types and elements (e.g., California tree frogs that require aquatic and adjacent upland habitats).

Dispersal distance capability of the selected focal species ranges from 30 m (98 ft) to 274 km (170 mi); modes of dispersal include flying, floating, swimming, hopping, climbing, and walking.

Landscape Permeability Analysis

Landscape permeability analysis is a GIS technique that models the relative cost for a species to move between core areas based on how each species is affected by habitat characteristics, such as slope, elevation, vegetation composition and road density. This analysis identifies a Least Cost Corridor, or the best potential route for each species moving between protected core areas (Walker and Craighead 1997, Craighead et al. 2001, Singleton et al. 2002). The purpose of the analysis was to identify which land areas would best accommodate focal species living in or moving through the linkage.

Species used in landscape permeability analysis must be carefully chosen, and were included in this analysis only if:

- We know enough about the movement needs of the species to estimate the cost-weighted distance using the data layers available to our analysis;
- The data layers in the analysis reflect the species ability to move;
- The species occurs in both cores (or historically did so and could be restored) and can potentially move between cores, at least over multiple generations; and
- The time scale of gene flow between core areas is shorter than, or not much longer than, the scale at which currently mapped vegetation is likely to change due to disturbance events and environmental variation (e.g. climatic changes).

Five species were found to meet these criteria and were used in permeability analyses to identify the Least Cost Corridor between protected core areas: Mountain lion, American badger, Nelson's bighorn sheep, Mule deer, and Pacific kangaroo rat. Ranks and weightings adopted for each species are shown in Table 2.

The relative cost of travel was assigned for each of these 5 focal species based upon their ease of movement through a suite of landscape characteristics (e.g., vegetation type, road density, and topographic features). The following spatial data layers were assembled at 30-m resolution: vegetation, roads, elevation, and topographic features (Figure 6). We derived 4 topographic classes from elevation and slope models: canyon bottoms, ridgelines, flats, or slopes. Road density was measured as kilometers of paved road per square kilometer. Within each data layer, we ranked all categories between 1 (preferred) and 10 (avoided) based on focal species preferences as determined from available literature and expert opinion regarding how movement is facilitated or hindered by natural and urban landscape characteristics. These data layers were then used to create a cost surface; each input category was ranked and weighted, such that:

(Land Cover * w%) + (Road Density * x%) + (Topography * y%) + (Elevation * z%) = Cost to Movement

Weighting allowed the model to capture variation in the influence of each input (e.g., vegetation, road density, topography, elevation) on focal species movements. A unique cost surface was developed for each species. A corridor function was then used to generate a data layer showing the relative degree of permeability between the two core

Table 2. Model Parameters for Landscape Permeability Analyses					
	Dipodomys agilis (Pacific k-rat)	*Odocoileus hemionus* (Mule deer)	*Ovis candadensis* (Nelson's bighorn sheep)	*Taxidea taxus* (Badger)	*Puma concolor* (Mountain lion)
MODEL VARIABLES					
VEGETATION					
Alpine-Dwarf Shrub	10	9	2	4	4
Agriculture	10	9	9	7	10
Annual Grassland	4	9	5	1	7
Alkali Desert Scrub	9	10	1	2	7
Barren	7	10	2	9	10
Bitterbrush	10	3	3	3	2
Blue Oak-Foothill Pine	7	1	9	5	3
Blue Oak Woodland	7	1	9	5	2
Coastal Oak Woodland	7	1	9	5	2
Closed-Cone Pine-Cypress	10	3	9	6	5
Chamise-Redshank Chaparral	5	6	9	4	5
Coastal Scrub	2	3	9	4	2
Desert Riparian	7	4	1	3	1
Desert Scrub	6	9	1	2	7
Desert Succulent Shrub	6	8	1	2	7
Desert Wash	9	5	1	3	2
Eastside Pine	10	1	9	5	5
Estuarine	10	10	10	10	5
Freshwater Emergent Wetland	10	9	8	9	2
Jeffrey Pine	9	2	9	5	5
Joshua Tree	3	8	3	2	4
Juniper	7	5	3	3	3
Lacustrine	10	10	10	9	10
Lodgepole Pine	10	5	9	6	5
Mixed Chaparral	5	6	9	4	5
Montane Chaparral	5	5	1	4	5
Montane Hardwood-Conifer	9	1	2	6	3
Montane Hardwood	9	1	2	6	3
Montane Riparian	10	2	2	6	1
Perennial Grassland	4	7	5	1	6
Pinyon-Juniper	7	4	8	3	3
Palm Oasis	10	7	1	6	3
Ponderosa Pine	9	2	9	5	5
Riverine	10	9	10	9	1
Red Fir	10	4	9	6	5
Subalpine Conifer	10	6	2	6	5
Saline Emergent Wetland	10	10	10	10	6
Sagebrush	10	5	3	3	7
Sierran Mixed Conifer	10	2	9	6	5
Urban	10	10	8	10	10
Valley Oak Woodland	7	1	9	4	2

Table 2. cont.	*Dipodomys agilis* (Pacific k-rat)	*Odocoileus hemionus* (Mule deer)	*Ovis candadensis* (Nelson's bighorn sheep)	*Taxidea taxus* (Badger)	*Puma concolor* (Mountain lion)
MODEL VARIABLES					
Valley Foothill Riparian	7	1	9	4	2
Water	10	10	10	10	9
White Fir	10	2	9	6	5
Wet Meadow	10	5	8	4	6
Unknown Shrub Type	10	5	9	5	5
Unknown Conifer Type	10	4	9	5	5
Eucalyptus	8	8	9	6	6
ROAD DENSITY					
0-0.5 km/sq. km	1	1	1	1	1
0.5-1 km/sq. km	1	1	2	1	3
1-2 km/sq. km	2	2	4	2	4
2-4 km/sq. km	3	5	8	2	6
4-6 km/sq.km	3	7	10	4	9
6-8 km/sq. km	9	10	10	7	10
8-10 km/sq.km	10	10	10	10	10
10 or more km/sq. km	10	10	10	10	10
TOPOGRAPHY					
Canyon bottoms	3	5	1	2	1
Ridgetops	3	2	1	7	7
Flats	1	8	5	1	3
Slopes	7	1	1	9	5
ELEVATION (feet)					
-260-0	4	6	N/A	1	N/A
0-500	1	4		1	
500-750	1	3		1	
750-1000	1	3		1	
1000-3000	1	3		2	
3000-5000	1	3		3	
5000-7000	3	3		3	
7000-8000	6	5		5	
8000-9000	9	5		5	
9000-11500	9	5		5	
>11500	10	8		8	
WEIGHTS					
Land Cover	0.70	0.65	0.40	0.55	0.40
Road Density	0.10	0.15	0.20	0.15	0.30
Topography	0.10	0.20	0.40	0.20	0.30
Elevation	0.10	0.00	0.00	0.10	0.00

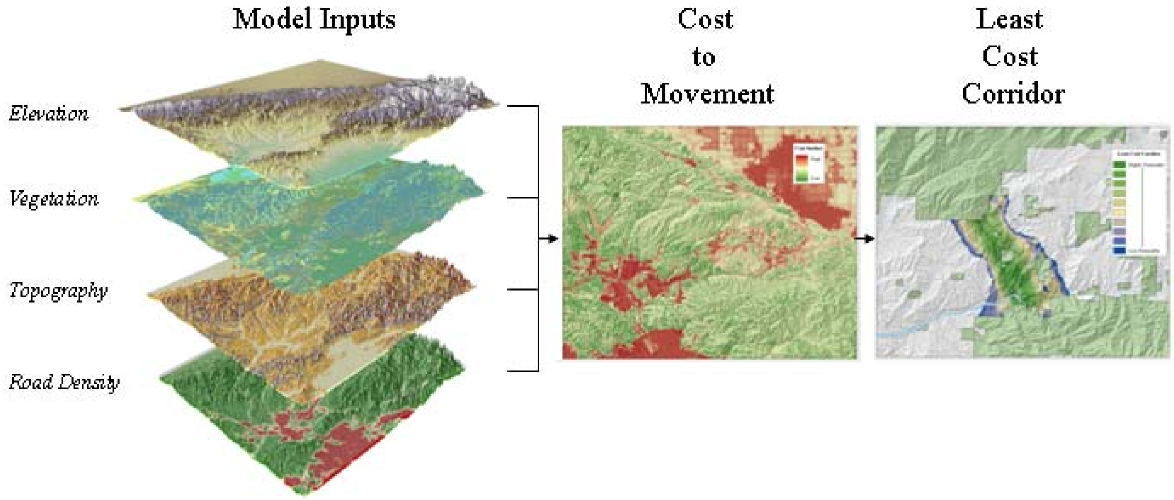


Figure 6. Landscape Permeability Analysis models the relative cost for a species to move between two core areas. Model inputs include elevation, vegetation, topography, and road density.

areas. The San Gabriel-San Bernardino Linkage is unique among the 15 priority linkages addressed by the South Coast Missing Linkages project, in that the majority of land in the linkage is already protected. Thus, the landscape permeability analysis for each of the 5 focal species was run from medium to highly suitable habitat within roadless areas. For each focal species, the top 1% of the output was designated as the Least Cost Corridor.

The Least Cost Corridor output for all species was then combined to generate a Least Cost Union. The biological significance of this Union can best be described as the zone in which species would encounter the least energy expenditure (i.e., preferred travel route) and the most favorable habitat as they move between protected core areas. The output does not identify barriers (which were later identified through fieldwork), mortality risks, dispersal limitations or other biologically significant processes that could prevent a species from successfully reaching a core area. Rather, it identifies the best zone available for focal species movement based on the data layers used in the analyses.

Patch Size & Configuration Analysis

Although the Least-Cost Union identifies the best zone available for focal species movement based on the data layers used in the analyses, it does not address whether suitable habitat in the Least-Cost Union occurs in large enough patches to support viable populations or whether dispersal distances would allow individuals to move among habitat patches. To address this need, we conducted patch size and configuration analyses for all focal species (Figure 7) and adjusted the boundaries of the Least-Cost Union where necessary to enhance the likelihood of movement. Patch size and configuration analyses are particularly important for species that require multiple generations to traverse the linkage. Many species exhibit metapopulation dynamics, whereby the long-term persistence of a local population requires connections to other

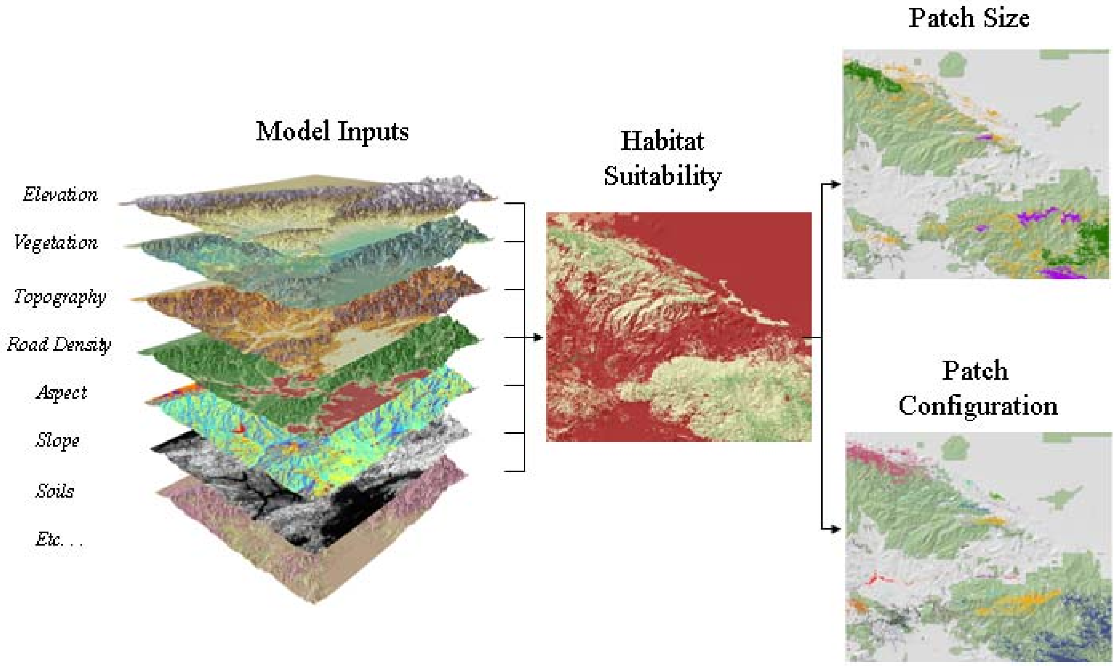


Figure 7. Model Inputs to Patch Size and Configuration Analyses vary by species. Patch Size delineates cores, patches, and stepping-stones of potential habitat. Patch Configuration evaluates whether suitable habitat patches and cores are within the dispersal distance of the species.

populations (Hanski and Gilpin 1991). Distributional patterns of plants and animals vary spatially and temporally at different biogeographic scales (Ligon and Stacey 1996). For relatively sedentary species like salamanders and terrestrial insects, gene flow will occur over decades by gene flow through a metapopulation. Thus, the linkage must accommodate metapopulations of these species if it is to functionally support ecological and evolutionary processes.

A habitat suitability model formed the basis for the patch size and configuration analysis. Habitat suitability models were developed using the literature and expert opinion. Spatial data layers used in the analysis varied by species and included: vegetation, elevation, topographic features, slope, aspect, hydrography, soils, etc. Using scoring and weighting schemes similar to those described in the previous section, we generated a spectrum of suitability scores that were divided into 5 classes using natural breaks: low, low to medium, medium, medium to high, or high. Suitable habitat was identified as all land that scored medium, medium to high, or high.

To identify areas of suitable habitat that were large enough to provide a significant resource for individuals in the linkage, we conducted a patch size analysis. The size of all suitable habitat patches in the planning area were identified and marked as potential core areas and patches. We identified each area of contiguous suitable habitat larger than 25 times the recorded average home range size as a *potential core* and each area of contiguous suitable habitat at least 2 times the minimum recorded home range, but less than a potential core as a *patch*. Potential cores areas may sustain at least 50 individuals and are probably capable of supporting the species for several decades (although with erosion of genetic material if isolated). Patches can support at least one breeding pair (perhaps more if home ranges overlap greatly) and are probably useful to the species if the patch can be linked via dispersal to other patches and core areas (Figure 7).

To determine whether the distribution of suitable habitat in the linkage supports meta-population processes and allows species to disperse among patches and core areas, we conducted a configuration analysis to identify which patches and core areas were functionally isolated by distances too great for the focal species to traverse. Because the majority of methods used to document dispersal distance underestimate the true value (LaHaye et al. 2001), we assumed each species could disperse twice as far as the longest documented dispersal distance. Groupings of core areas and patches that were greater than the adopted dispersal distance from other suitable habitat were identified using a unique color (Figure 7).

For each species we compared the configuration and extent of potential cores and patches, relative to the species dispersal ability, to evaluate whether the Least Cost Union was likely to serve the species. If necessary, we added additional habitat to help ensure that the linkage provides sufficient live-in and/or move-through habitat in perpetuity for the species' needs.

Minimum Linkage Width

While the size and distance among habitats (addressed by patch size and configuration analyses) must be adequate to support species movement, the shape of those habitats also plays a key role. In particular, constriction points – areas where habitats have been narrowed by surrounding development – can prevent organisms from moving through the Least-Cost Union. To ensure that functional processes are protected, we imposed a minimum width of 2 km (1.2 mi) for all areas of the Least-Cost Union. In areas where the Least-Cost Union was less than 2 km in width, we first added available natural habitats to either side of the Least-Cost Union. If no natural habitats were available, agricultural lands were added since these areas could potentially be restored. Urban developments were not included in these additions.

For a variety of species, including those we did not formally analyze, 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. A wide linkage also enhances the ability of the biota to respond to climate change, and buffers against edge effects.

Field Investigations

We conducted field surveys to ground-truth existing habitat conditions, document existing barriers and potential passageways, and describe restoration opportunities. All location data were recorded using a mobile GIS/GPS with ESRI's ArcPad.

Because paved roads present the most formidable potential barriers, surveyors drove or walked each accessible section of road that transected the linkage. All types of potential crossing structures (e.g., bridge, underpass, overpass, culvert, pipe) were photo documented and measured. Data taken for each crossing included: shape; height, width, and length of the passageway; stream type, if applicable (perennial or intermittent); floor type (metal, dirt, concrete, natural); passageway construction (concrete, metal, other); visibility to other side; light level; fencing; vegetative community within and/or adjacent to the passageway. Existing highways and crossing structures are not permanent features of the landscape. In particular, crossing structures can be improved during projects to widen and realign highways and interchanges. Therefore, we also identified areas where crossing structures could be improved or installed, and opportunities to restore vegetation to facilitate use of road crossings and minimize roadkills.

Identify Conservation Opportunities

The Linkage Design serves as the target area for linkage conservation opportunities. We provided biological and land use summaries, and implementation opportunities for agencies, organizations, and individuals interested in participating in conservation activities in the San Gabriel-San Bernardino Linkage. Biological and land use summaries include descriptions and maps of vegetation, land cover, land use, roads, road crossings, and restoration opportunities. We also identified existing planning efforts addressing the conservation and use of natural resources in the planning area. Finally, we developed several 3D visualizations of the linkage using aerial imagery, satellite imagery, and digital elevations models, which provide a landscape perspective of the linkage (Appendix C, on enclosed CD).

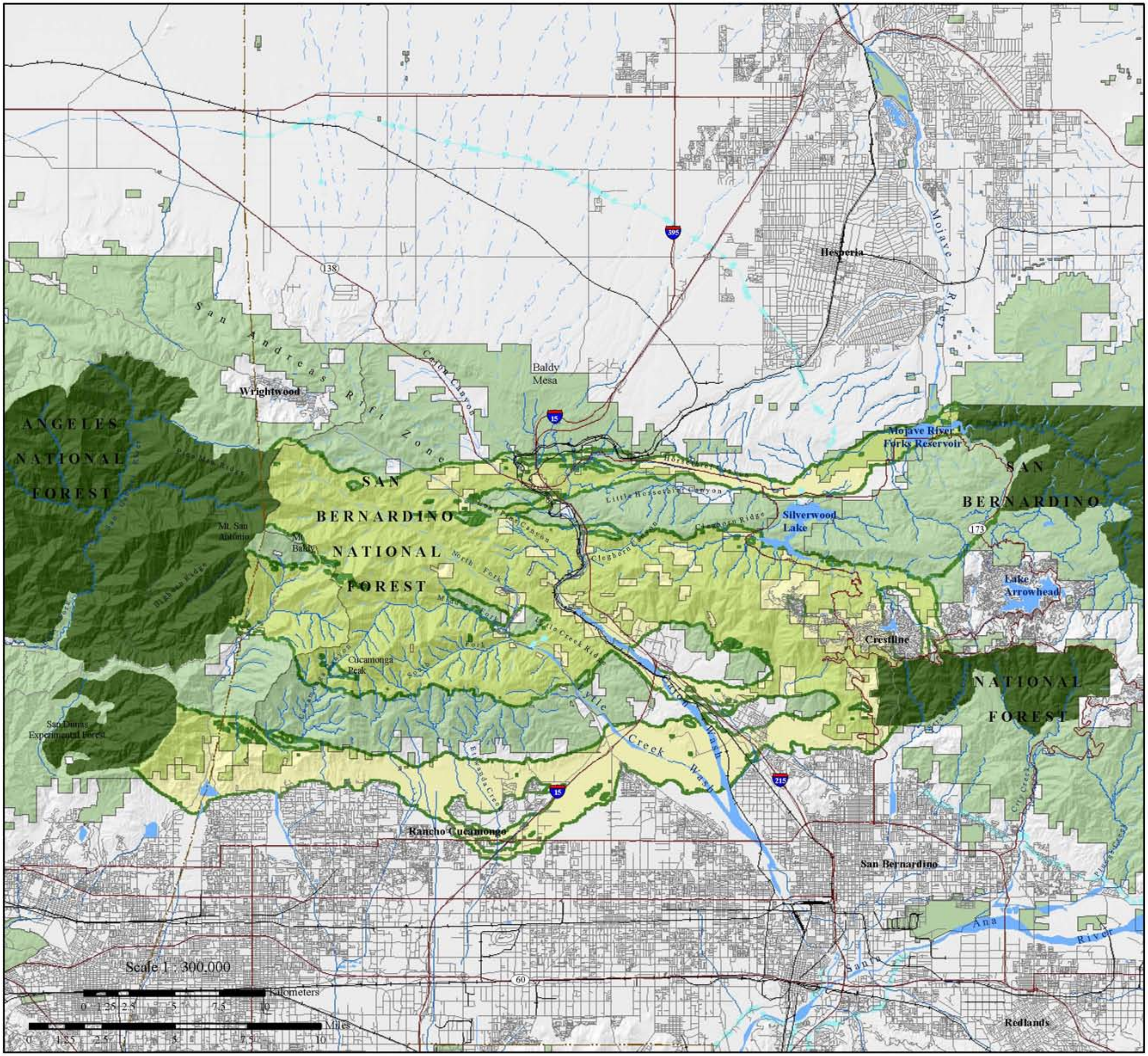
Landscape Permeability Analyses

We conducted landscape permeability analyses for 5 species (i.e., Mountain lion, American badger, Nelson's bighorn sheep, Mule deer, and Pacific kangaroo rat) as described in the following several pages. The Least Cost Union stretches between roadless areas in the San Gabriel and San Bernardino Mountains, spanning a distance of roughly 37.5 km (23.3 mi). The Least Cost Union (i.e., the union of the top 1% of the Least Cost Corridors for all 5 species) demonstrates the need for habitat connectivity in several major vegetation and physiographic zones, including the coastal sage, alluvial fan, and chaparral habitats of the foothills, high-elevation hardwood and coniferous forests, and the transition to desert communities of the Mohave along the northern edge of these ranges (Figure 8). The Least Cost Corridors for the 5 focal species were quite distinct due to their diverse ecological and movement requirements (see following species accounts and Table 2). However, the most permeable paths for the majority of focal species converged and overlapped considerably in the central part of the linkage, with two species, American badger and Pacific kangaroo rat, diverging to generate additional routes containing their preferred habitats (Figure 9). High permeability areas are sites where focal species encounter the fewest obstacles or hazards, and have the greatest chance of finding food and shelter between protected core areas.

Several routes were identified by the analyses based on the configuration of habitat and the topographic complexity of the landscape. Desert influenced habitats dominate the upper branch of the Union, which ranges in width from 1-2.5 km (0.62-1.6 mi), and includes portions of Stockton Flat, Coldwater Canyon, Upper Lytle Creek Ridge and Lone Pine Canyon, crossing I-15 and SR-138 near Cajon Pass, then up Horsethief Canyon into Summit Valley, and on to the West Fork of the Mojave River. The central branch of the Union is the widest, ranging in width from 5-11.25 km (3.1-7 mi) and encompasses both riparian and upland habitats. To the west of I-15 it stretches from Upper Lytle Creek Ridge to Cucamonga Peak, encompassing lower Lone Pine Canyon and most of the North, Middle, and South Forks of Lytle Creek; along I-15 it encompasses habitats from just below Cajon Junction to Kenwood Avenue; and east of I-15 it includes habitat from Cleghorn Canyon and Ridge to Arrowhead Peak. Another narrow branch follows Cajon Canyon Wash, to Cable Creek and up the East Fork of Devil Canyon. The southern branch of the Union includes coastal sage and alluvial fan habitats, and ranges in width from 0.5-5 km (0.31-3.1 mi). It extends from Browns Flat in the foothills, along the San Gabriel Mountains fan, through portions of San Antonio, Cucamonga, Deer, Day, Etiwanda, Morse, and San Sevaine creeks, to the confluence of Lytle Creek and Cajon Wash, and then through lower Devil, Badger, and Sycamore Canyons to Inspiration Point in the foothills of the San Bernardino Mountains.

The next several pages summarize the permeability analyses for each of the 5-modeled species. For convenience, the narratives describe the most permeable paths from west to east; our analyses, however gave equal weight to movements in both directions. The following section (Patch Size and Configuration Analyses) describes our procedure to evaluate how well the Least Cost Union 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 Union to provide for critical live-in and/or move-through habitat for particular focal species.

Figure 8.
Least Cost Union



Legend

- Least Cost Union
- Roadless Areas
- Interstate/Highways
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

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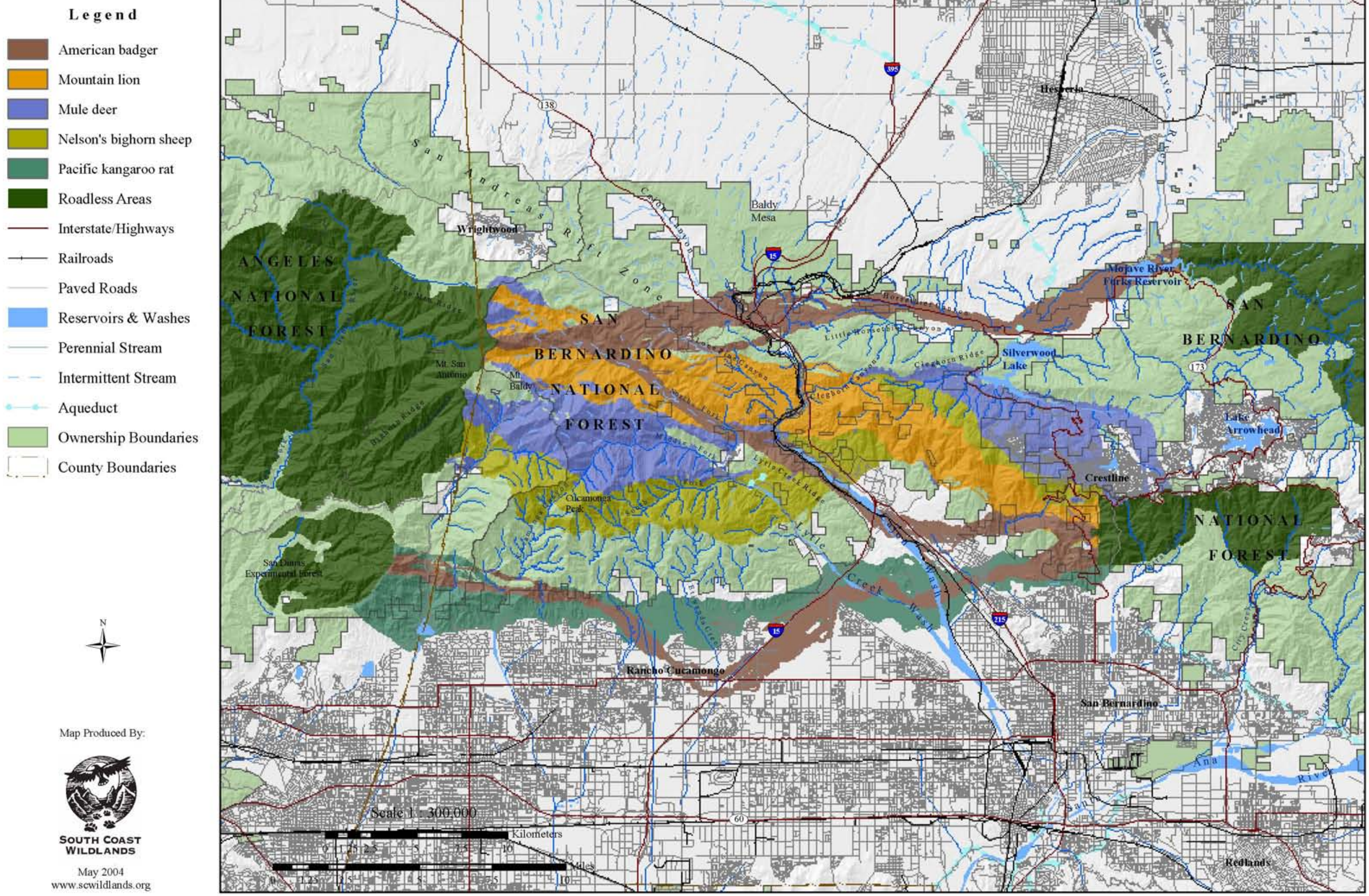
Figure 9.
Least Cost Union
Displaying Species Overlap



Mountain Lion (*Felis concolor*)

Justification for Selection: These area-sensitive species are appropriate focal species (Noss 1991, Noss et al. 1994) because their naturally low densities render them highly sensitive to habitat fragmentation, and loss of large carnivores can have adverse ripple effects through the entire ecosystem (Soulé and Terborgh 1999). Mountain lions have already lost a number of dispersal corridors in southern California, making them susceptible to extirpation from existing protected areas (Beier 1993). Habitat fragmentation caused by urbanization and the extensive road network has had detrimental effects on mountain lions by restricting movement, escalating mortality, and increasing contact with humans.

Conceptual Basis for Model Development: Mountain lions use brushy stages of a variety of habitat types with good cover (Spowart and Samson 1986, Ahlborn 1988). Preferred travel routes are along stream courses and gentle terrain, but all habitats with cover are used (Beier and Barrett 1993, Dickson et al. 2004). In southern California, grasslands, agricultural areas, and human-altered landscapes are avoided (Dickson et al. 2004). Dirt roads do not impede movement, but highways, residential roads, and 2-lane paved roads impede movement (Beier and Barrett 1993, Beier 1995, Dickson et al. 2004) Juvenile dispersal distances for females average 32 km (20 mi), with a range of 9-140 km (6-87 mi), while males average 85 km (53 mi), with a range of 23-274 km (14-170 mi; Anderson et al. 1992, Sweanor et al. 2000). The somewhat shorter dispersal distances reported in southern California (Beier 1995) reflect the fragmented nature of Beier's study area. Please see Table 2 for specific rankings for this species; cost to movement for mountain lion was defined by weighting various inputs, such that:

(Vegetation * 40%) + (Road Density * 30%) + (Topography * 30%)

Results & Discussion: The Least Cost Corridor for mountain lion movement between protected core areas is depicted in Figure 10. The most permeable path varies in width from 1.5-4.5 km (0.93-2.8 mi) and extends from Mount San Antonio in the Sheep Mountain Wilderness of the San Gabriel Mountains to a roadless area just south of the community of Crestline in the San Bernardino Mountains. It encompasses the mixed conifer and chaparral habitats of Dawson Peak, the montane hardwood, hardwood-conifer, chaparral, and riparian habitats of the North Fork of Lytle Creek and Lone Pine Canyon west of I-15, to similar habitats in Cleghorn Canyon east of I-15, and then meanders along ridges and valleys from Cajon Mountain to Arrowhead Peak. The results of the analysis captured medium to highly suitable habitat for puma moving between the San Gabriel and San Bernardino Mountains along their preferred travel routes.

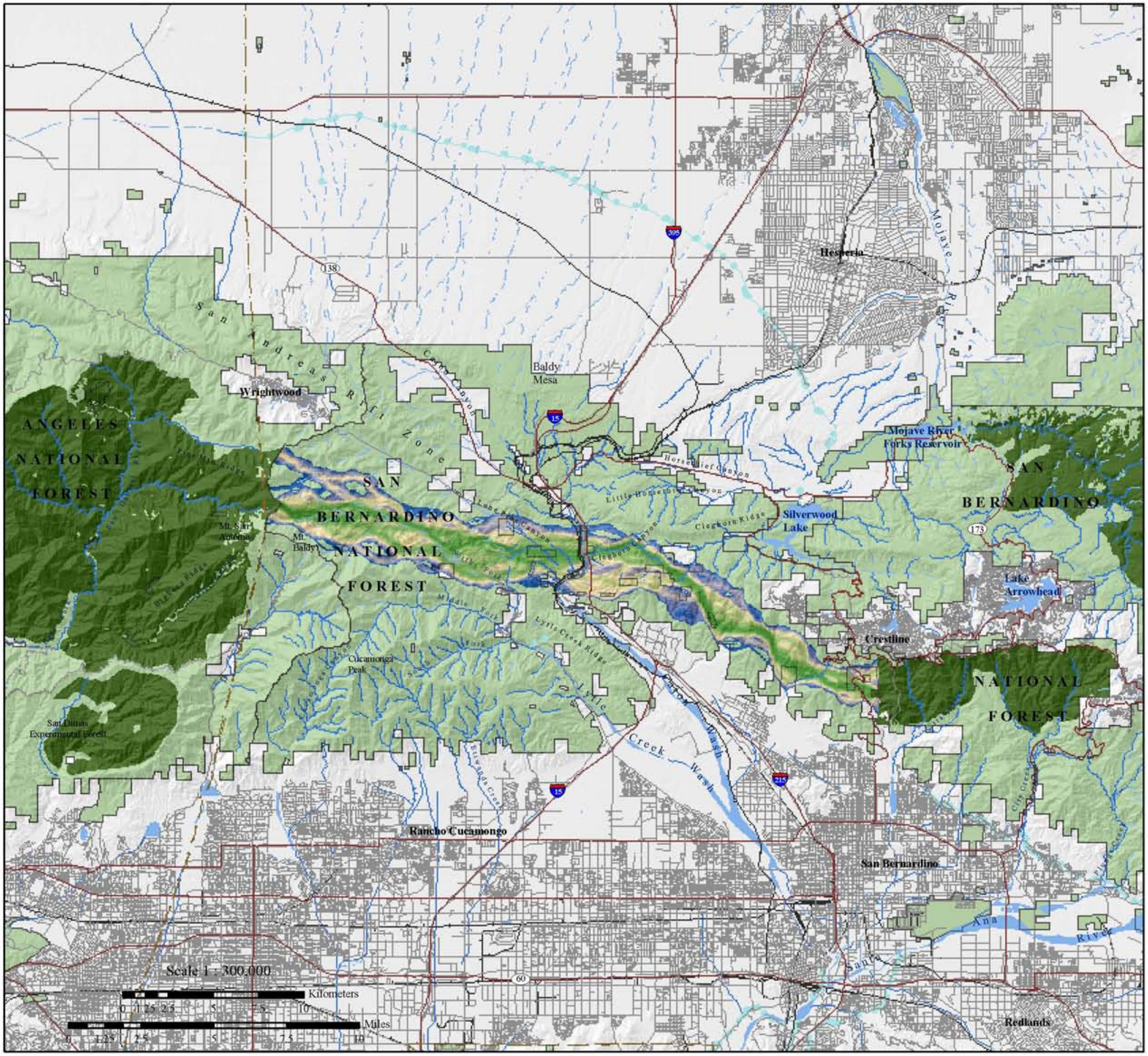
Figure 10.
Least Cost Corridor
for
Mountain Lion
(Puma concolor)

Legend

Least Cost Corridor

- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

*The analysis was run from medium to high suitable habitat within roadless areas.



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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, CDFG 1999). They require expansive Wildlands to survive and are highly sensitive to habitat fragmentation. In fact, roadkill is the primary cause of mortality (Long 1973, Sullivan 1996, Clarke et al. 1998, CDFG 1999).

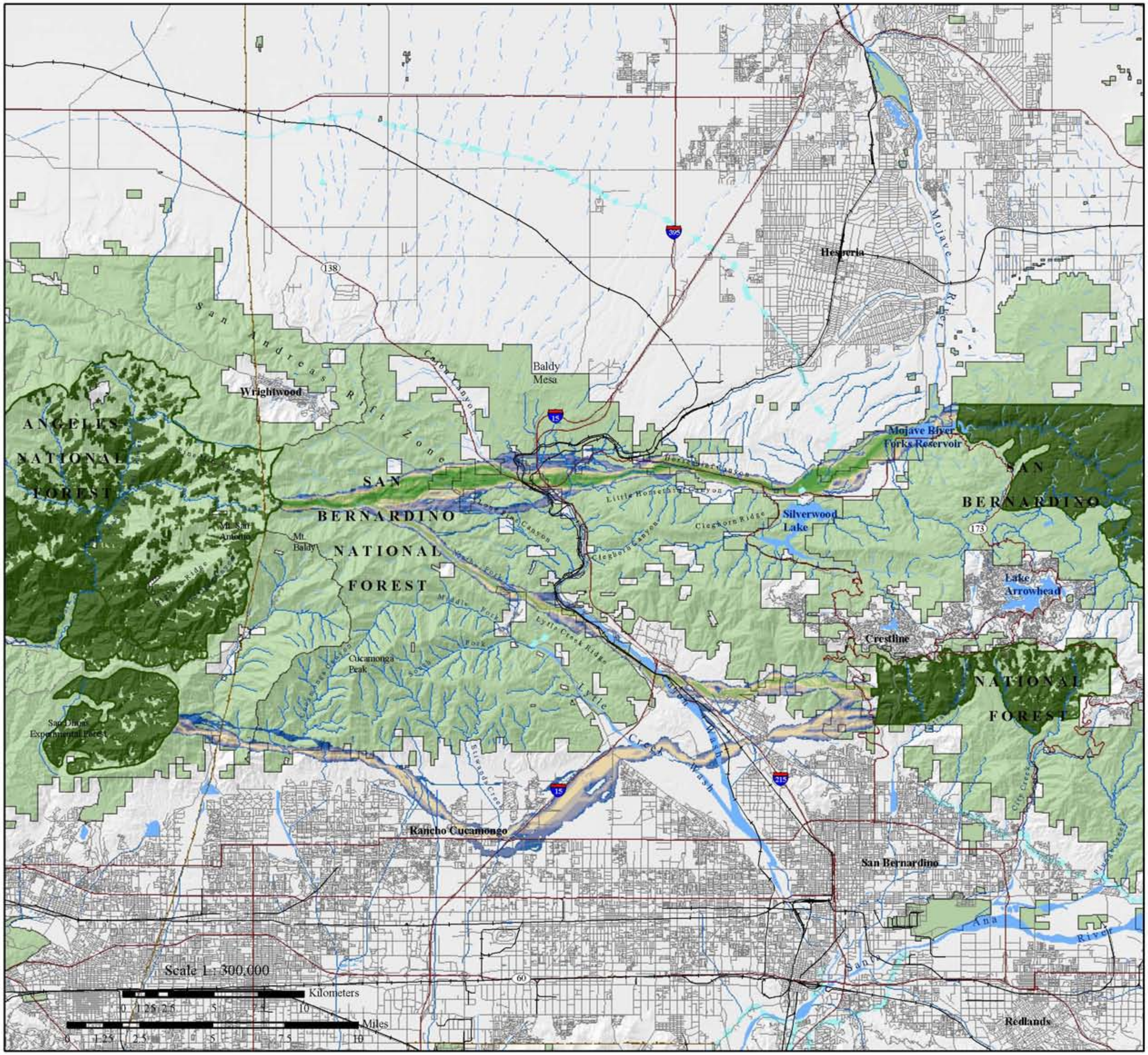
Conceptual Basis for Model Development: Badgers are associated with grasslands, prairies, and other open habitats that support abundant burrowing rodents (de Vos 1969, Banfield 1974, Sullivan 1996) but they may also be found in drier open stages of shrub and forest communities (CDFG 1999). They are known to inhabit forest and mountain meadows, marshes, riparian habitats, and desert communities including creosote bush, juniper, and sagebrush habitats (Long and Killingley 1983, CDFG 1999). The species is typically found at lower elevations (CDFG 1999) in flat, rolling or steep terrain but it has been recorded at elevations up to 3600 m (12000 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. Please see Table 2 for specific rankings for this species; cost to movement for badger was defined by weighting various inputs, such that:

(Vegetation * 0.55) + (Elevation * 0.10) + (Topography * 0.20) + (Road Density *0.15)

Results & Discussion: The results of the Least Cost Corridor for badger were the most unique, with 3 strong routes emerging from the analysis (Figure 11). The most permeable path is the most northerly route, which comprises habitat and topography with a higher degree of suitability for badger, such as chamise-redshank chaparral, desert scrub, juniper woodland, and grassland habitats. It extends from the Upper North Fork of Lytle Creek, across Stockton Flat, down into Lone Pine Canyon, across Cajon Pass to Horsethief Canyon, up into Summit Valley and then on to the West Fork of the Mojave River. The second strongest route followed the North Fork of Lytle Creek crossing into Cajon Canyon just below Blue Cut, encompassing the alluvial fan scrub and grassland habitats of Cajon Canyon, Sycamore Flat, and Cable Creek, and then up the East Fork of Devil Canyon to Panorama Point. The third branch extends from Brown Flat along the foothills to Deer and Day canyons, where it heads south through remnant grassland habitats, then shifts northeastward towards Lytle Creek and Cajon Wash, passing above the community of Muscoy into Badger Canyon, and then on to Inspiration Point in the San Bernardino Mountains.

Figure 11.
Least Cost Corridor
for
American Badger
(Taxidea taxus)



Legend

Least Cost Corridor

- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

*The analysis was run from medium to high suitable habitat within roadless areas.

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Nelson's Bighorn Sheep (*Ovis canadensis nelsoni*)

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). Opportunities for bighorn sheep movement between the San Gabriel and San Bernardino Mountains have already been seriously compromised (Holl and Bleich 1983, Holl et al. 2004).

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 (CDFG 1990, E. Rubin, pers. com.), as well as montane oak, conifer, riparian, and chaparral habitats (Holl and Bleich 1983). The greatest amount of movement occurs by adult rams (Weaver et al. 1972, DeForge 1980, Holl and Bleich 1983, Holl et al. 2004). Ram movements up to 56 km (34.8 mi) have been documented (Witham and Smith 1979). The longest recorded movement in the San Gabriel Mountains was about 10 km (6.21 mi) (DeForge1980), although limited research has been done on movements to date. They preferentially move through open habitats in close proximity to escape terrain, preferring ridgetops as travel routes. They avoid roads, impenetrable vegetation, urban land cover, and centers of human activity, even in suitable habitat. Permeability analyses were run from suitable habitat within roadless areas and from designated core areas within both ranges. Please see Table 2 for specific rankings for this species; cost to movement for Bighorn sheep was defined by weighting various inputs, such that:

(Vegetation * 40%) + (Topography * 40%) + (Road Density * 20%)

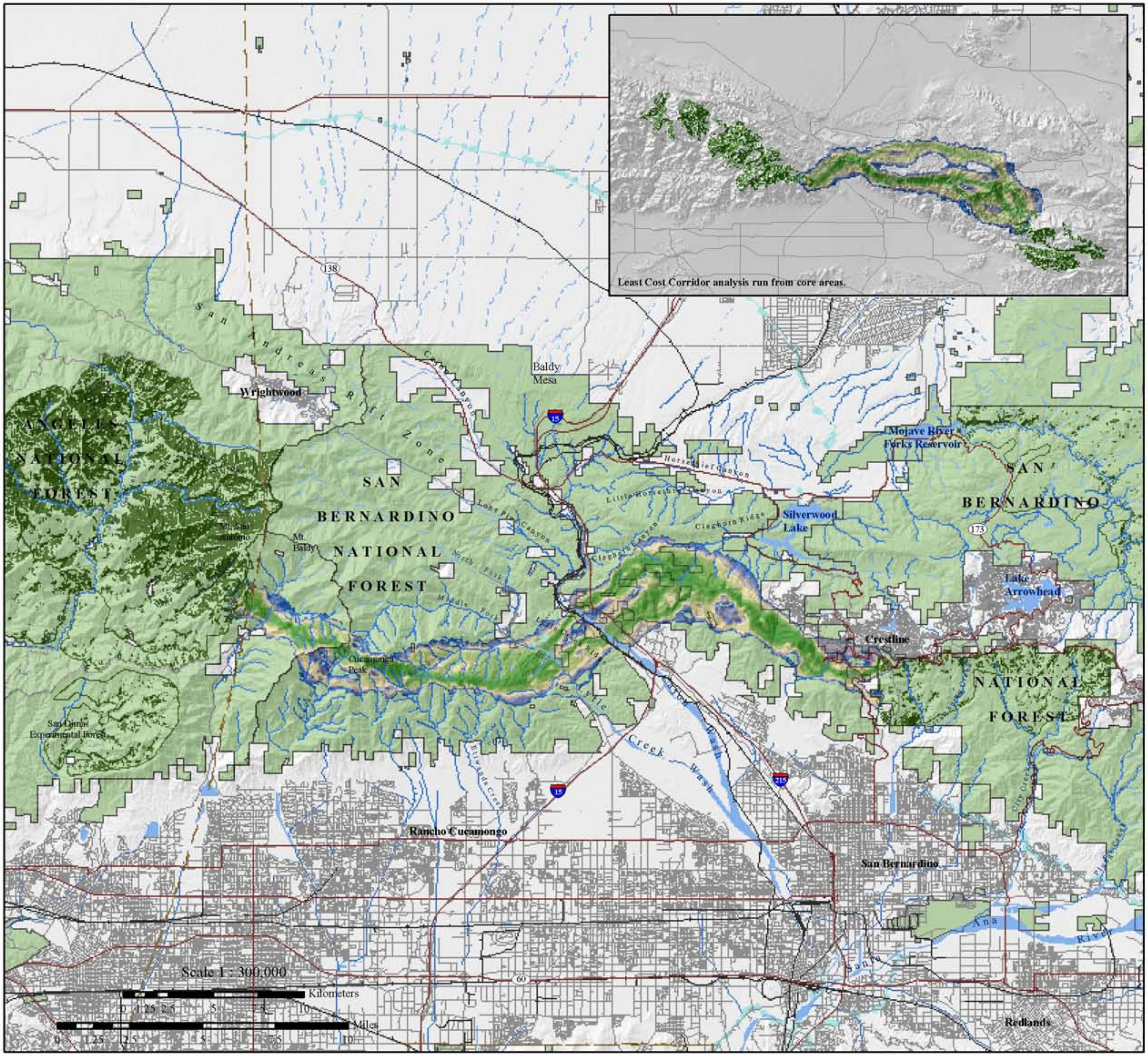
Results & Discussion: The Least Cost Corridor for bighorn sheep (Figure 12) varies in width from 1.25-5 km (0.78-3.1 mi). The most permeable path extends from the Sheep Mountain Wilderness through Icehouse Canyon to Bighorn and Cucamonga Peaks, down the South Fork of Lytle Creek, crossing I-15 below Blue Cut, and ascending Middleman Falls to Sugarpine Mountain. From here, two paths arose from the analysis between core areas (Figure 12, *Inset*). Both analyses followed the same southerly route to Panorama Point, with the path between core areas continuing on to Keller Peak and the San Gorgonio Wilderness. The northern route follows the West Fork of the Mojave River into Grass Valley, and on to The Pinnacles, Deer Mountain, Keller Peak, and the San Gorgonio Wilderness. Rams are believed to move between the San Gorgonio and Cushenbury populations in the San Bernardino Mountains, thus a more probable northerly route would also encompass occupied habitat in the desert-facing canyons at the northern edge of the range (S. Loe, pers. com.). The LA County Fish and Game

Figure 12.
Least Cost Corridor
for
Nelson's Bighorn Sheep
(Ovis canadensis nelsoni)

Legend

Least Cost Corridor
- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Paved Roads
- Railroads
- Reservoirs & Lakes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

*The analysis was run from suitable habitat within roadless areas.



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Commission, California Department of Fish and Game, and the Forest Service are currently studying mountain lion and bighorn sheep populations and habitat relationships in the San Gabriel Mountains. The results of this study may help us refine target areas for bighorn sheep conservation.

Mule Deer (*Odocoileus hemionus*)

Justification for Selection: Mule deer were chosen as a focal species to help support viable populations of large carnivores, which rely on deer as their primary prey. 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, vehicles kill several hundred thousand deer each year (Romin and Bissonette 1996, Conover 1997, Forman et al. 2003).

Conceptual Basis for Model Development: Mule deer utilize forest, woodland, brush, and meadow habitats, reaching their highest densities in oak woodlands, riparian areas, and along edges of meadows and grasslands, though they also occur in open scrub, young chaparral, and low elevation coniferous forests (Bowyer 1986, USFS 2002). Access to a perennial water source is critical in summer. The San Gabriel and San Bernardino Mountains both have migratory and resident components within the population (Nicholson et al. 1997).

Dispersal distances of up to 217 km have been recorded for mule deer (Anderson and Wallmo 1984). They preferentially move through habitats that provide good escape cover, preferring ridgetops and riparian routes as major travel corridors. Varying slopes and topographic relief are important for providing shade or exposure to the sun. They avoid open habitats, agricultural and urban land cover, and centers of high human activity, even in suitable habitat. Please see Table 2 for specific rankings for this species; the cost to movement for Mule deer was defined by weighting various inputs, such that:

(Vegetation * 65%) + (Topography * 20%) + (Road Density * 15%)

Results & Discussion: The Least Cost Corridor delineated two major branches for Mule deer traveling between the San Gabriel and San Bernardino Ranges, following the same general pathways as Mountain lion and Nelson's bighorn sheep (Figure 13). However, the Least Cost Corridor is much broader, encompassing a broad band of highly suitable Mule deer habitat, ranging in width from 2-7.5 km (1.2-4.7 mi). The most permeable route is almost identical to the Least Cost Corridor for Mountain lion, following the North Fork of Lytle Creek, though after ascending into Cleghorn Canyon east of I-15, the path splits into two branches, one similar to puma, while the other heads up into Miller Canyon and then south through a choke-point between Crestline and Lake Arrowhead. The other highly permeable pathway followed a similar course as Nelson's bighorn sheep, but the Least Cost Corridor for Mule deer also encompassed the Middle Fork of Lytle Creek. This pathway merged with the other along the North Fork of Lytle Creek near Telegraph Peak.

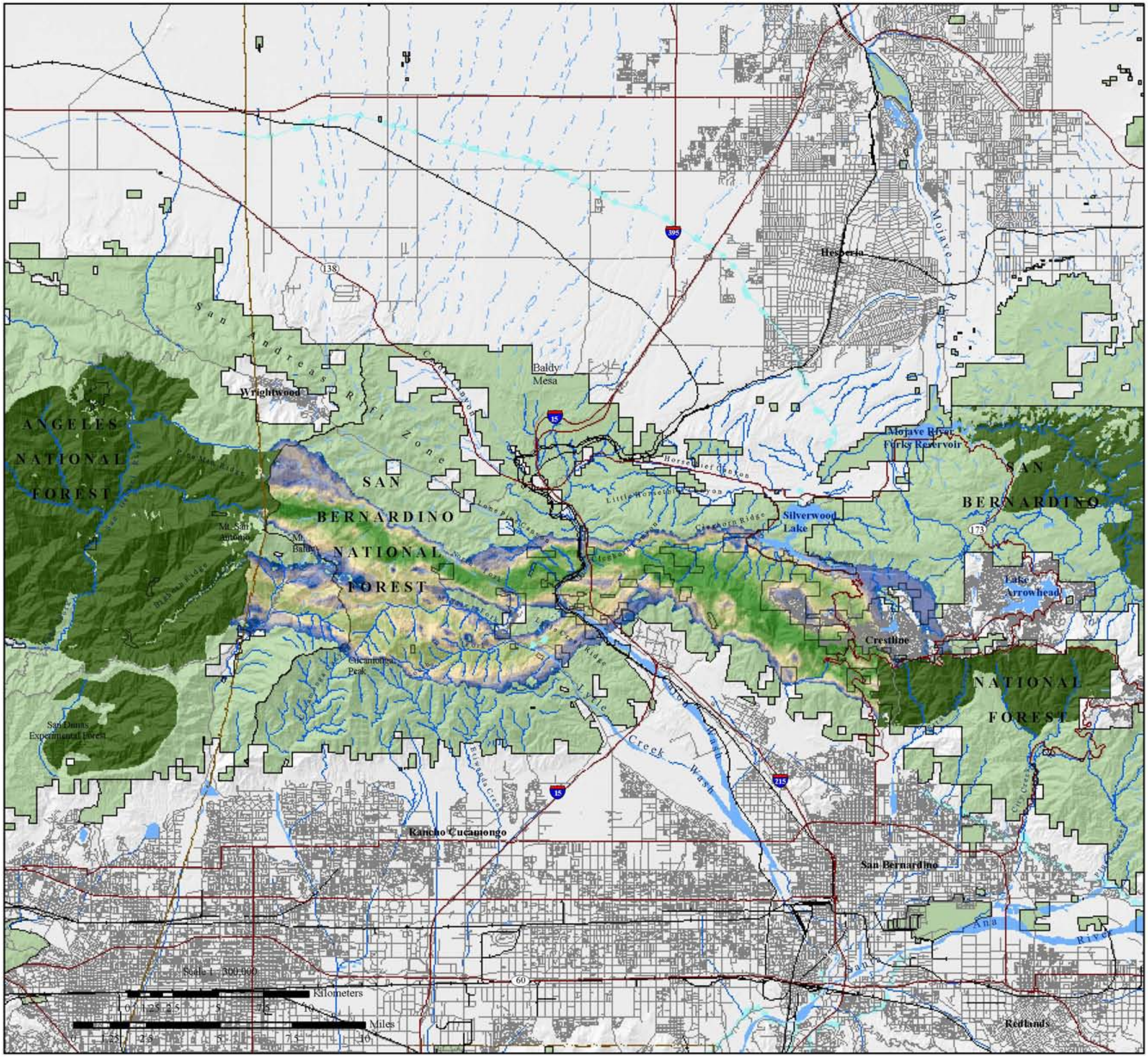
Figure 13.
Least Cost Corridor
for
Mule Deer
(Odocoileus hemionus)

Legend

Least Cost Corridor

- Highly Permeable
- Less Permeable
- Suitable Habitat*
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

*The analysis was run from medium to high suitable habitat within roadless areas.



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Pacific Kangaroo Rat (*Dipodomys agilis*)

Justification for Selection: The Pacific kangaroo rat is also sensitive to habitat loss and fragmentation. They may navigate roads and other barriers (freeways, agricultural and urban areas) but they are highly susceptible to roadkill (W. Spencer pers. comm.). Barriers are likely similar to other kangaroo rats (roads, physical barriers, dense grasses, artificial light), but this species is generally more tolerant of tree or shrub cover, and probably better able to navigate through denser vegetation (W. Spencer, pers. comm.).

Conceptual Basis for Model Development: The Pacific kangaroo rat is associated with a variety of habitats including coastal sage scrub, chaparral, oak woodland, pinyon-juniper woodland, desert scrub, and annual grassland (Bleich and Price 1995, W. Spencer pers. comm.). They've also been recorded in alluvial fan sage scrub (Price et al. 1991) and montane coniferous forests (Sullivan and Best 1997). This species prefers more open areas and is particularly abundant in ecotonal habitats (Meserve 1976, M'Closkey 1976, Price and Kramer 1984, Keeley and Keeley 1988, Price et al. 1991, Goldingay and Price 1997).

This kangaroo rat tends to be more mobile than most rodents of its size, and more so than other kangaroo rats. Most information on movements and ecology are very similar to Merriam's kangaroo rat, although with less supporting literature (W. Spencer pers. comm.). Merriam's kangaroo rat typically remains within 1-2 territories (100 m [328 ft] or so) of their birthplace, but the species is capable of longer dispersal. Zeng and Brown (1987) recorded long-distance (= dispersal) movements in adults, concluding that these kangaroo rats are opportunistic in moving into newly available territory areas.

The Pacific kangaroo rat preferentially moves through open habitat in early successional communities. They avoid roads, densely vegetated communities, and urban areas. Please see Table 2 for specific rankings for this species; cost to movement for Pacific kangaroo rat was defined by weighting various inputs, such that:

(Vegetation * 70%) + (Road Density * 10%) + (Topography * 10%) + (Elevation * 10%)

Results & Discussion: The Least Cost Corridor for the Pacific kangaroo rat encompasses coastal sage and alluvial fan habitats stretching from Browns Flat in the foothills of the San Gabriel Mountains, through the lower portions of San Antonio, Cucamonga, Deer, Day, Etiwanda, Morse, and San Sevaine creeks, to Lytle Creek and Cajon Wash, then on to Inspiration Point in the foothills of the San Bernardino Mountains

(Figure 14). The Least Cost Corridor encompasses the highest quality habitat for this species in the planning area and ranges in width from 1.5 to 5 km (0.93-3.1 mi).

Figure 14.
Least Cost Corridor
for
Pacific Kangaroo Rat
(Dipodomys agilis)

L e g e n d

Least Cost Corridor

Highly Permeable

Less Permeable

Suitable Habitat*

Paved Roads

Railroads

Reservoirs & Washes

Perennial Stream

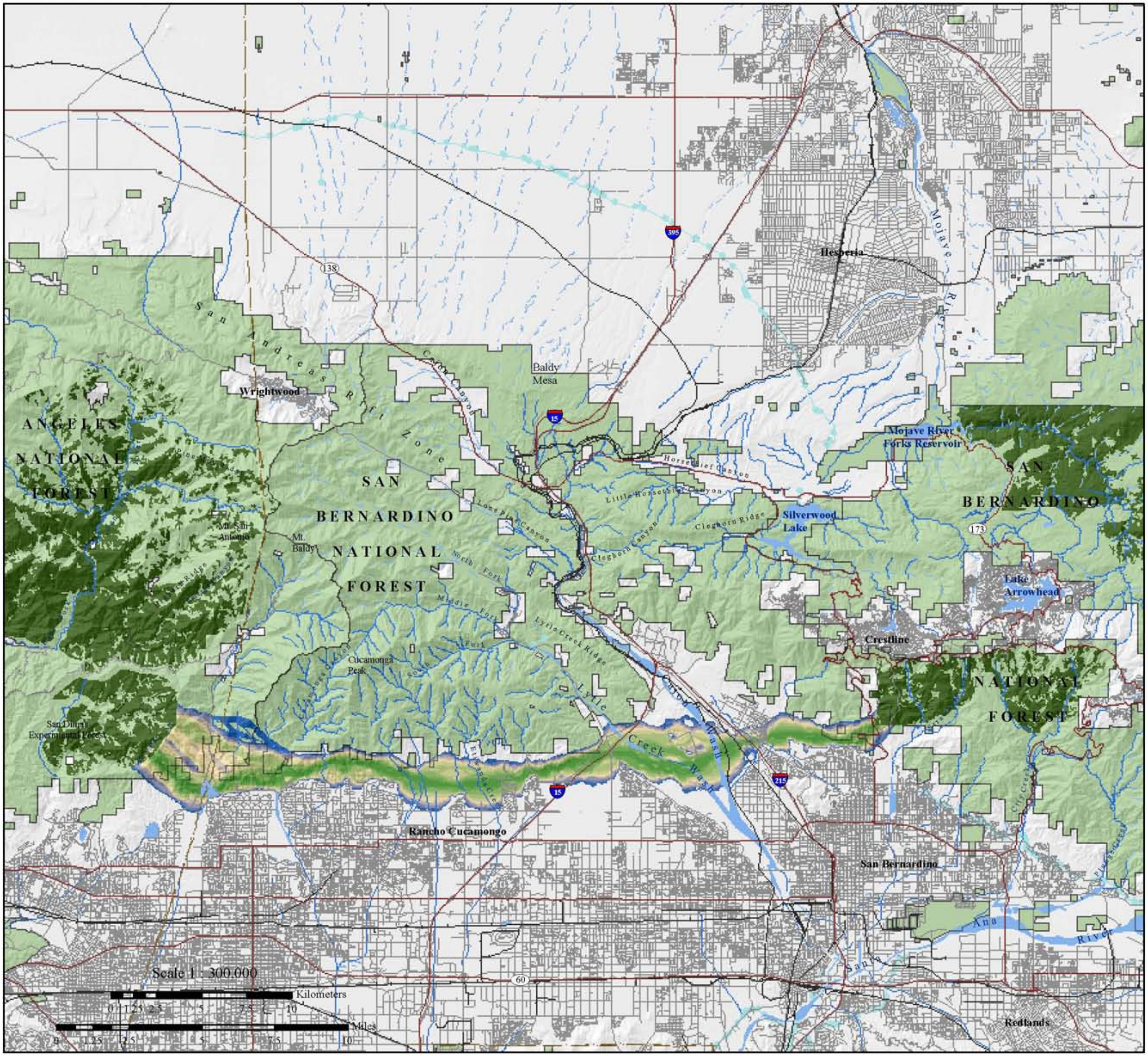
Intermittent Stream

Aqueduct

Ownership Boundaries

County Boundaries

*The analysis was run from medium to high suitable habitat within roadless areas.



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Patch size and configuration analyses were used to evaluate the configuration and extent of potentially suitable habitat for all focal species in relation to the Least Cost Union to determine whether each species is likely to be served by the linkage. To identify any additional habitats not captured by the Least Cost Union that are necessary to maintain linkage function, we evaluated whether 1) core areas and patches are within the dispersal distance of the species; 2) the distribution of potentially suitable habitat is natural or because of disturbances; 3) the Least Cost Union is likely to provide the species with sufficient live-in and or move-through habitat; and 4) if a species was not served by the Least Cost Union, whether the species would be accommodated if additional habitat was added.

The Least Cost Union contains suitable habitat to support either inter- or intra-generational movements between the San Gabriel and San Bernardino ranges for 14 of the 23 modeled focal species: Mountain lion, Mule deer, Dusky-footed woodrat, Pacific kangaroo rat, California spotted owl, Mountain quail, Rock wren, Wrentit, San Diego horned lizard, Chaparral whipsnake, Metalmark butterfly, Green hairstreak butterfly, Tarantula hawk, and the Giant flower-loving fly. These focal species appear to be well served by the Linkage Design; model outputs indicated that areas with potential suitable habitat in the Least Cost Union were large enough to support viable populations and or close enough together to allow movement between suitable habitat patches. The patch configuration analyses for 2 of the focal species, Pygmy nuthatch and the Giant flower-loving fly, had outputs suggesting that some habitat patches may be isolated from one another by distances too great for these species to traverse. Although, over many generations weather events can increase the likelihood of colonization from distant patches. The linkage may also serve the needs of Nelson's bighorn sheep, since rams occasionally make long distance movements. Seven focal species were determined to require habitat outside of the Least Cost Union, though there was significant overlap in the additional habitats required to meet their needs (Figure 15). For all focal species, it was recognized that model outputs did not address existing barriers to movement or land use practices that may prevent species from moving through the linkage. These potential barriers are addressed in the next section.

Species that required habitat outside of the Least-Cost Union to protect the long term viability of populations include: American badger, San Bernardino kangaroo rat, California treefrog, Santa Ana speckled dace, Slender-horned spineflower, California sagebrush, and White alder. The focal species with the least amount of suitable habitat in the Least Cost Union are California treefrog, Santa Ana speckled dace, and California sagebrush. Very small patches of potential habitat were identified in the analyses for these species, including habitat along Cajon Wash, Little Horsethief and Horsethief Creeks, the West Fork of the Mojave River, and along Cable, Strawberry, City, and Plunge Creeks. The potential habitat patches not captured in the Least Cost Union were added to meet the needs of these species.

Two species representing aquatic movement needs (i.e., Santa Ana speckled dace, California treefrog) required a contiguous riparian habitat connection along Cajon Wash to allow opportunities for movement between drainages flowing into the wash from both ranges. The Least Cost Union was also modified to include riparian and upland habitat along Horsethief and Little Horsethief Creeks and the Mojave River to include the habitat necessary to meet the needs of the treefrog. While habitats in Strawberry, City and Plunge creeks were added primarily for the speckled dace.

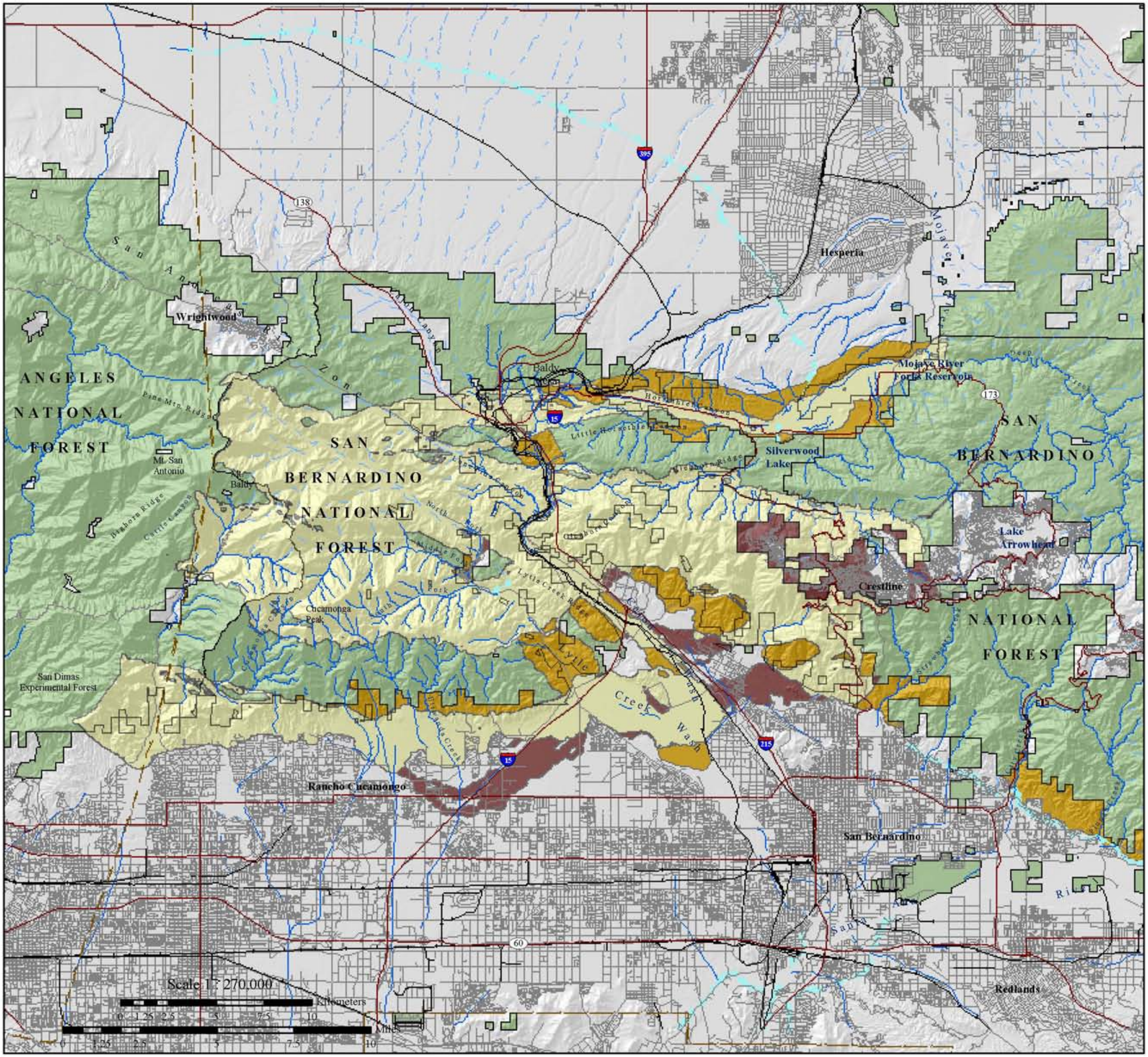
The northern branch of the Union was delineated through permeability analysis based solely on the needs of badger. The minimum width of 2 km was imposed here to ensure that the functional processes of the linkage are protected. This addition was also necessary for California treefrog and White alder, species with very little suitable habitat within the Least Cost Union. Many other species that utilize desert scrub or riparian habitats (e.g., Rock wren, San Diego horned lizard) will also benefit from this addition.

Habitat was added to the Union in 4 general areas to ensure that the Linkage Design accommodates each focal species. The Least Cost Union initially covered 47,956 ha (118,502 ac), much of which is already included in existing protected areas (e.g., U.S. Forest Service, Bureau of Land Management, California State Parks). The narrowest region was in the northern branch of the Union along Horsethief and Little Horsethief Creeks and the West Fork of the Mojave River. We added contiguous natural habitats to this branch that increase the minimum width of the Union in this area to 2 km (1.2 mi). We also eliminated highly urbanized areas, resulting in 4,236 ha (10,467 ac) being deleted from the Least Cost Union. The collective results of the patch size, configuration, and minimum width analyses identified 8,854 ha (21,878 ac) of additional land that was necessary to help ensure that each species is served by the Linkage Design (Figure 15). The next several pages summarize the patch size and configuration analyses performed for each focal species. The final Linkage Design for the San Gabriel-San Bernardino Connection excludes highly urbanized areas and includes habitat additions in 4 general areas:

The additions to the northern branch of the Union in Horsethief and Little Horsethief Creeks, Summit Valley, and the West Fork of the Mojave River preserves habitat and connectivity for aquatic and terrestrial species (represented by California treefrog, White alder, Badger, Pacific kangaroo rat, Rock wren, San Diego horned lizard, and the Tarantula hawk), as well as semi-aquatic species not addressed by our analyses (e.g., Arroyo toad). Two criteria were used to add habitats here, the minimum linkage width and a riparian buffer. This addition incorporated a minimum width of 2 km (3.2 mi), making it more robust to edge effects and providing adequate configuration of suitable habitat for these species. The connection includes a 1 km (0.6 mi) buffer (0.5 km to either side of each stream or river) to support upland habitat requirements for semi-aquatic species and protect water quality within the linkage and downstream. This addition also provides potentially suitable habitat for 6 other focal species with a variety of habitat needs: Mountain lion, Mule deer, Dusky-footed woodrat, Mountain quail, Wrentit, and Chaparral whipsnake.

The Cajon and Lytle Wash additions protect key riparian movement corridors and natural hydrological processes, as well as preserving live-in habitat for several species. These additions include riparian and upland habitat, incorporating a 1 km (0.6 mi) buffer (0.5 km) to either side of each creek. Maintaining the natural flow regime is vital for sustaining riparian and alluvial fan scrub habitats. These additions are critical for the endangered San Bernardino kangaroo rat and Slender-horned spineflower, which are highly dependent on alluvial scrub habitats. Almost all other focal species are also

Figure 15.
Least Cost Union Additions & Subtractions



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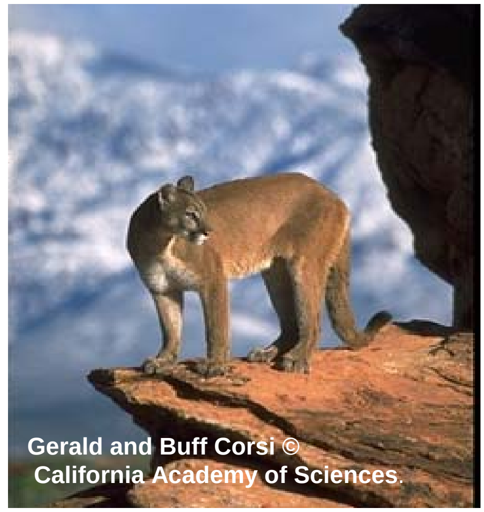
served by these additions, by providing suitable habitat, a secondary riparian movement corridor, or preserving water quality.

The Etiwanda Fan addition includes alluvial and coastal scrub habitats just outside the National Forest boundary that were not captured by the Least Cost Union in Day, Deer, Etiwanda, and San Sevaine Creeks. These habitats were also added to maintain fluvial processes necessary for sustaining alluvial scrub habitats. This addition also provides habitat critical to the survival of the San Bernardino kangaroo rat and Slender-horned spineflower, as well as providing suitable habitat for California sagebrush, Pacific kangaroo rat, Mountain quail, Rock wren, Wrentit, San Diego horned lizard, Tarantula hawk, and the Giant flower-loving fly.

The additions in the foothills of the San Bernardino Mountains in Cable, Strawberry, City, and Plunge Creeks were added to preserve habitat for the Santa Ana speckled dace, California Treefrog, California sagebrush, and White alder. Although Dusky-footed woodrat, San Bernardino kangaroo rat, Pacific kangaroo rat, Wrentit, San Diego horned lizard, and the Slender-horned spineflower are also served by this addition.

Mountain Lion (*Puma concolor*)

Distribution & Status: Mountain lions are widely distributed throughout the western hemisphere (Chapman and Feldhamer 1982, Currier 1983, Maehr 1992, Tesky 1995). The subspecies *F. c. californica* occurs in southern Oregon, California, and Nevada (Hall 1981). In 1990, the mountain lion population in California was estimated to be between 2,500-5,000 individuals (CDFG). That same year, Proposition 117 was passed which prohibits hunting and granted puma the status of a California Specially Protected species, though depredation permits are still issued (Torres 2000).


Gerald and Buff Corsi © California Academy of Sciences.

Habitat Associations: The mountain lion is considered a habitat generalist, utilizing brushy stages of a variety of habitat types with good cover (Spowart and Samson 1986, CDFG1990). Within these habitats, mountain lions prefer rocky cliffs, ledges, and vegetated ridgetops that provide cover when hunting prey (Chapman and Feldhamer 1982, Spowart and Samson 1986), which is primarily mule deer, *Odocoileus hemionus* (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 (Spotwart 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 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 male cougars (Dickson and Beier in press). Male home ranges appear to reflect the density and distribution of females (Maehr 1992). Males occupy distinct areas and are tolerant of transients of both sexes, while the home range of females may overlap completely (CDFG 1990, Beier and Barrett 1993). Regional population counts have not been conducted but in the Santa Ana Mountain Range, Beier (1993) estimated about 1.05-1.2 adults per 100 km^2 (24,711 ac).

Mountain lions are capable of making long-distance movements, and can have multiple strategies of migration that allow them to take advantage of changing densities of prey (Pierce et al. 1999). Beier et al. (1995) found mountain lions moved 6 km (3.7 mi) per night and dispersed 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 populations 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, though 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).

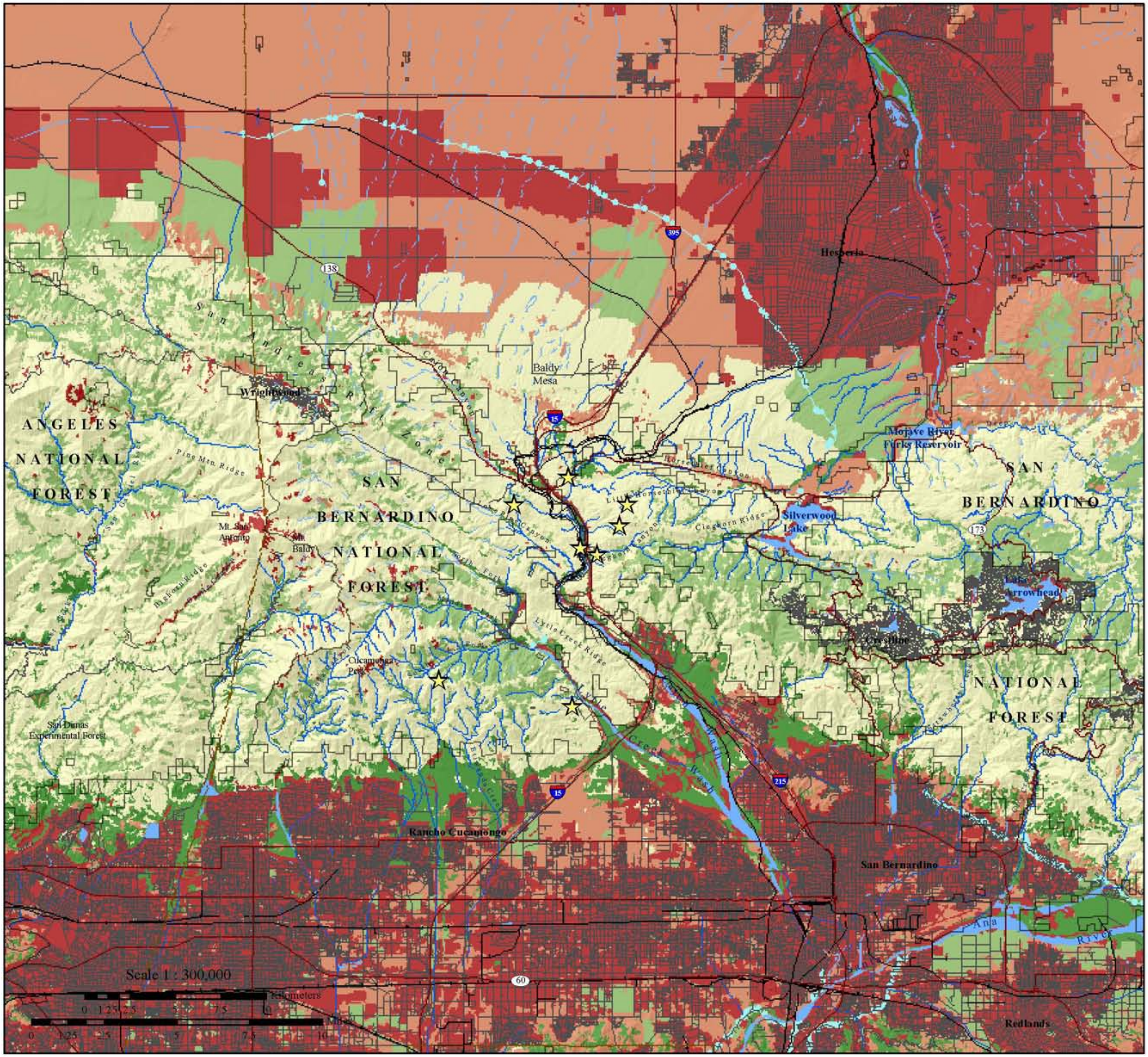
Conceptual Basis for Model Development: Puma will utilize most habitats, elevation, provided they have cover. Road density is also a significant factor in habitat suitability for mountain lions. Patch size was classified as $\geq$ 200 km^2 but < 10,000 km^2. Core areas potentially supporting 50 or more individuals were modeled using patches $\geq$ 10,000 km^2. Dispersal distance for Puma was defined as 548 km, or twice the maximum reported dispersal distance of 274 km.

Results & Discussion*:* Extensive habitat exists for mountain lion in the San Gabriel and San Bernardino Mountains (Figure 16). However, neither the San Gabriel nor San Bernardino Range protected areas are $\geq$ 10,000 km^2 (i.e., core areas capable of potentially supporting 50 individuals), emphasizing the importance of maintaining connectivity between these ranges (Figure 17). The Least Cost Union (Figure 8) is likely to serve this species as sufficient move through habitat was captured in the analysis. The majority of recorded occurrences are also within the Union, with Cleghorn, Lone Pine, and Horsethief Canyons likely facilitating movement between these ranges.

This species requires expansive roadless areas to survive and functional connectivity between subpopulations. All habitat patches identified by the analysis are well within the dispersal distance of this species. Maintaining connections between large blocks of protected habitat may be the most effective way to ensure population viability (Beier 1993, 1995, Gaona et al. 1998, Riley et al. 2003). To maintain and protect habitat connections for mountain lion between the San Gabriel and San Bernardino Mountains, we recommend that:

- Existing road density be maintained or reduced; no new roads in the Linkage Design;
- Crossing structures be upgraded to be more amenable to puma movement;
- Lighting is directed away from the linkage and crossing structures. Species sensitive to human disturbance, like puma, avoid areas that are artificially lit (Beier 1995, Longcore 2000); and
- Local residents are informed about: the value of carnivores to the system; the use of predator safe enclosures for domestic livestock and pets; and the habits of being thoughtful and safe stewards of the land.

Figure 16.
Potential Habitat
for
Mountain Lion
(Puma concolor)



Legend

Degree of Suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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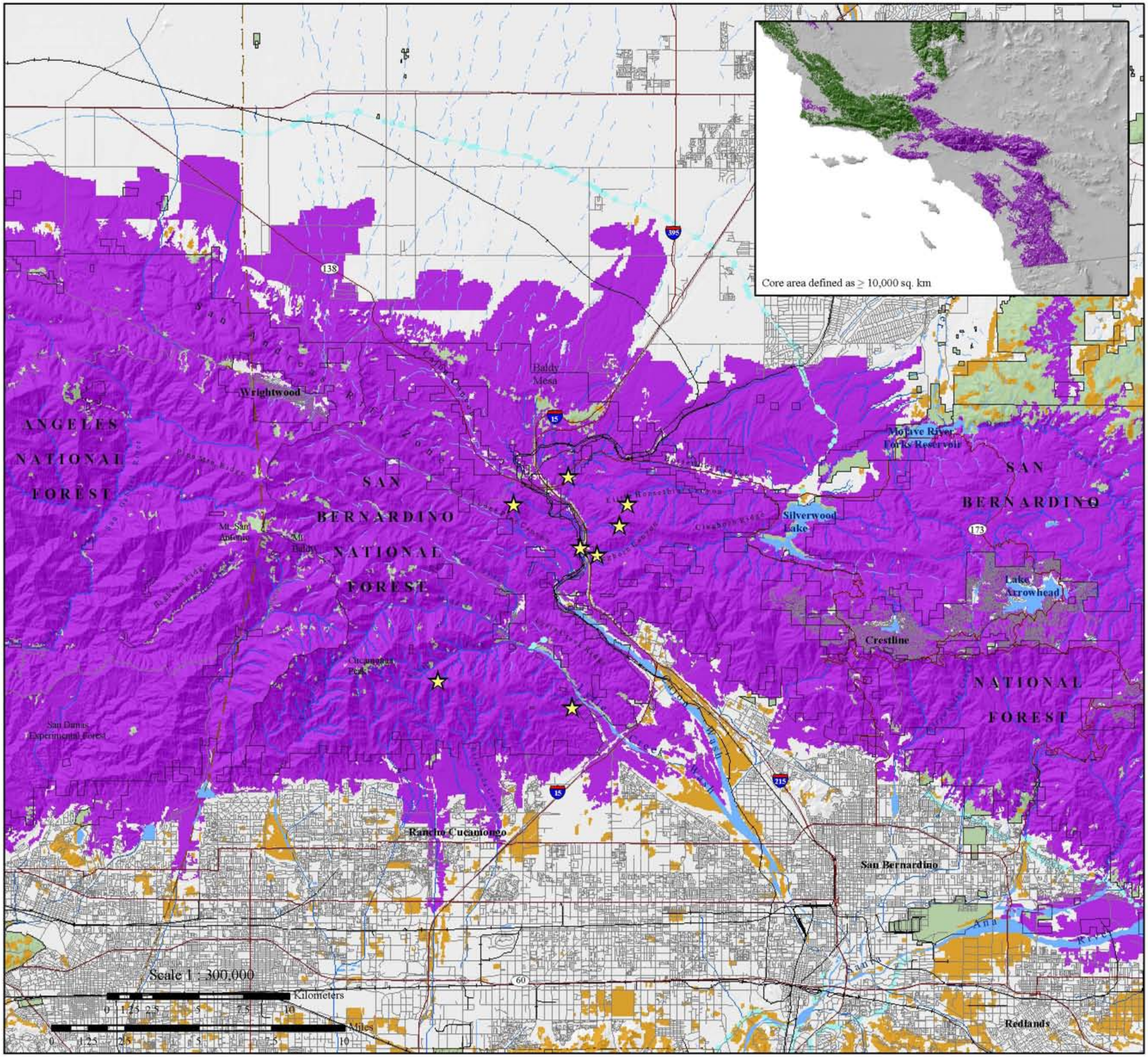
Figure 17.
Potential Cores & Patches
for
Mountain Lion
(Puma concolor)

Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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Distribution & Status: Once a fairly widespread resident throughout open habitats of California, badger is now uncommon throughout the state and is considered a California Species of Special Concern (CDFG 1995, CDFG 1999).

Habitat Associations: Badgers are largely considered 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 (CDFG 1999). 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, CDFG 1999). They are occasionally found in open chaparral (< 50% cover) but haven't been documented in mature stands (Quinn 1990, CDFG 1999). They prefer friable soils for excavating burrows and require abundant rodent populations (de Vos 1969, Banfield 1974, Sullivan 1996). The species is typically found at lower elevations (CDFG 1999) in flat, rolling or steep terrain but it has been recorded at elevations up to 3,600 m (12,000 ft) (Minta 1993).

Spatial Patterns: Home range sizes for this species vary both geographically and seasonally. Male home ranges have been estimated between 240-850 ha (593-2100 ac) and females between 137-725 ha (339-1792 ac; Long 1973, Lindzey 1978, Messick and Hornocker 1981, CDFG 1999). Though, in northwestern Wyoming, home ranges up to 2100 ha (5189 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, badgers exhibit seasonal changes in home range size. Sargeant and Warner (1972) radio-collared a female badger, whose overall home range encompassed 850 ha (2100 ac); range was restricted to 725 ha (1792 ac) in summer, 53 ha (131 ac) in autumn, and to a mere 2 ha (5 ac) area in winter. In Utah, Lindsey (1978) found fall and winter home ranges of females varied from 137-304 ha (339-751 ac), while males varied from 537-627 ha (1327-1549 ac; Lindzey 1978). 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).

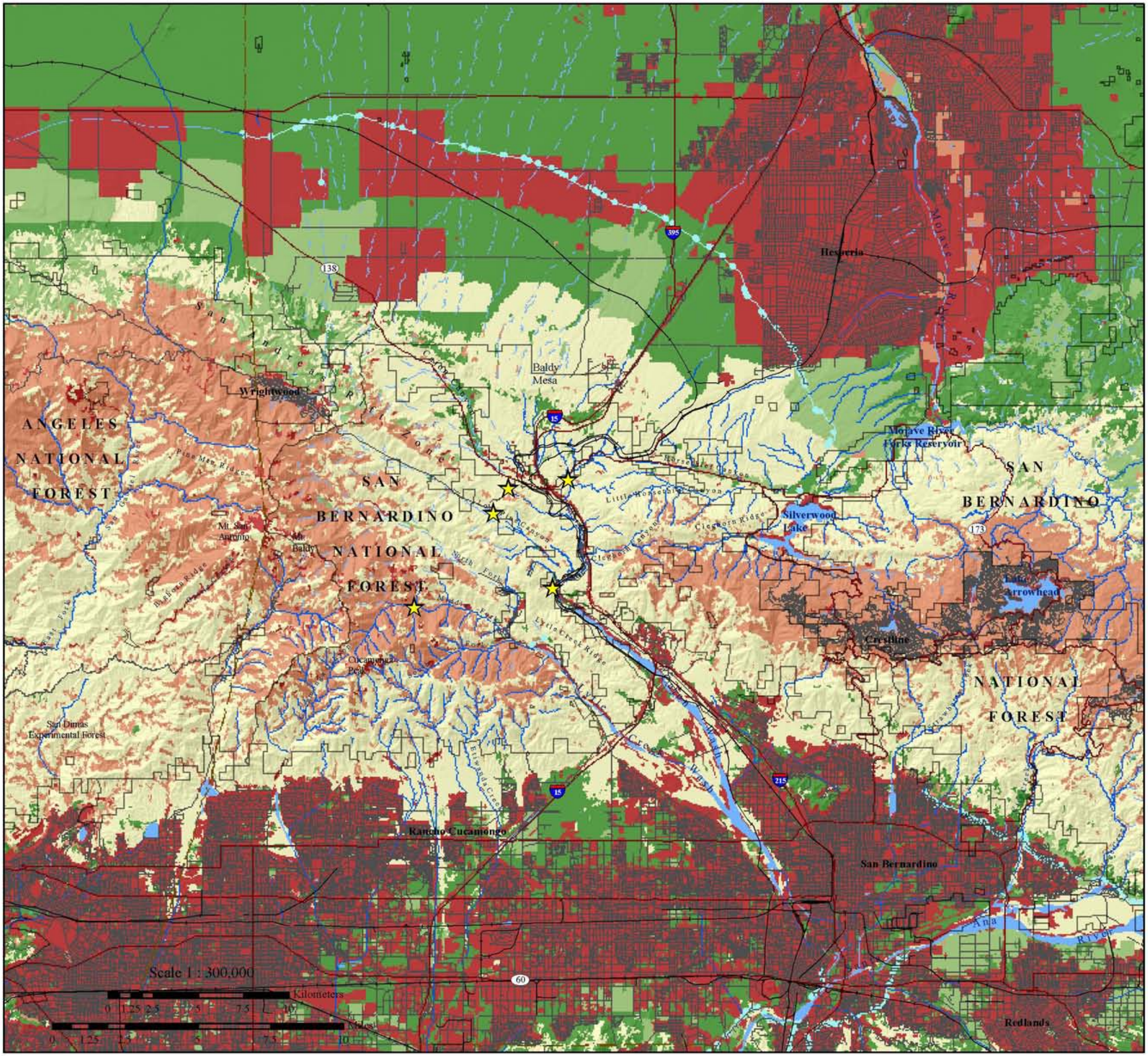
Conceptual Basis for Model Development: Prefers grasslands, meadows, scrubs, riparian, desert washes and open woodland communities. Terrain may be flat, rolling or steep but below 3,600 m in elevation. Core Areas capable of supporting fifty badgers are equal to or greater than 16,000 ha in size. Patch size is $\geq$ 400 ha but < 16,000 ha. Dispersal distance for badgers was defined as 220 km, twice the longest recorded distance.

Results & Discussion: The model identified vast amounts of potentially suitable Badger habitat in the San Gabriel and San Bernardino Ranges, with the most highly suitable habitat in the northern portion of the planning area, which is dominated by desert scrub and juniper woodland habitats (Figure 18). The majority of suitable habitat within the planning area is contiguous, and thus was identified as core habitat for this species (Figure 19). Two branches of the Union were delineated by the permeability analysis based on the Badger's preferred habitat and terrain, the northernmost branch and along Cajon Wash. Habitat was added along each of these branches to the minimum 2 km width. With the recommended additions, the linkage will also likely serve this species. All potentially suitable habitat patches are within the badger's dispersal distance, although barriers to movement may exist between suitable habitat patches.

In Britain, road mortality is the leading cause of death of badgers, with an estimated 50,000 killed on roads each year (Clarke et al. 1998). To restore and protect habitat connections for badger, we recommend that:

- Habitat is added along Cajon Wash and to the northern branch of the Least Cost Union to a 2 km width (Figure 15);
- Existing road density be maintained or reduced; no new roads in the Linkage Design;
- Badger tunnels are installed under major transportation routes (e.g., I-15); and
- Lighting is directed away from the linkage and crossing structures.

Figure 18.
Potential Habitat
for
American Badger
(Taxidea taxus)



Legend

Degree of Suitabiltiy

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

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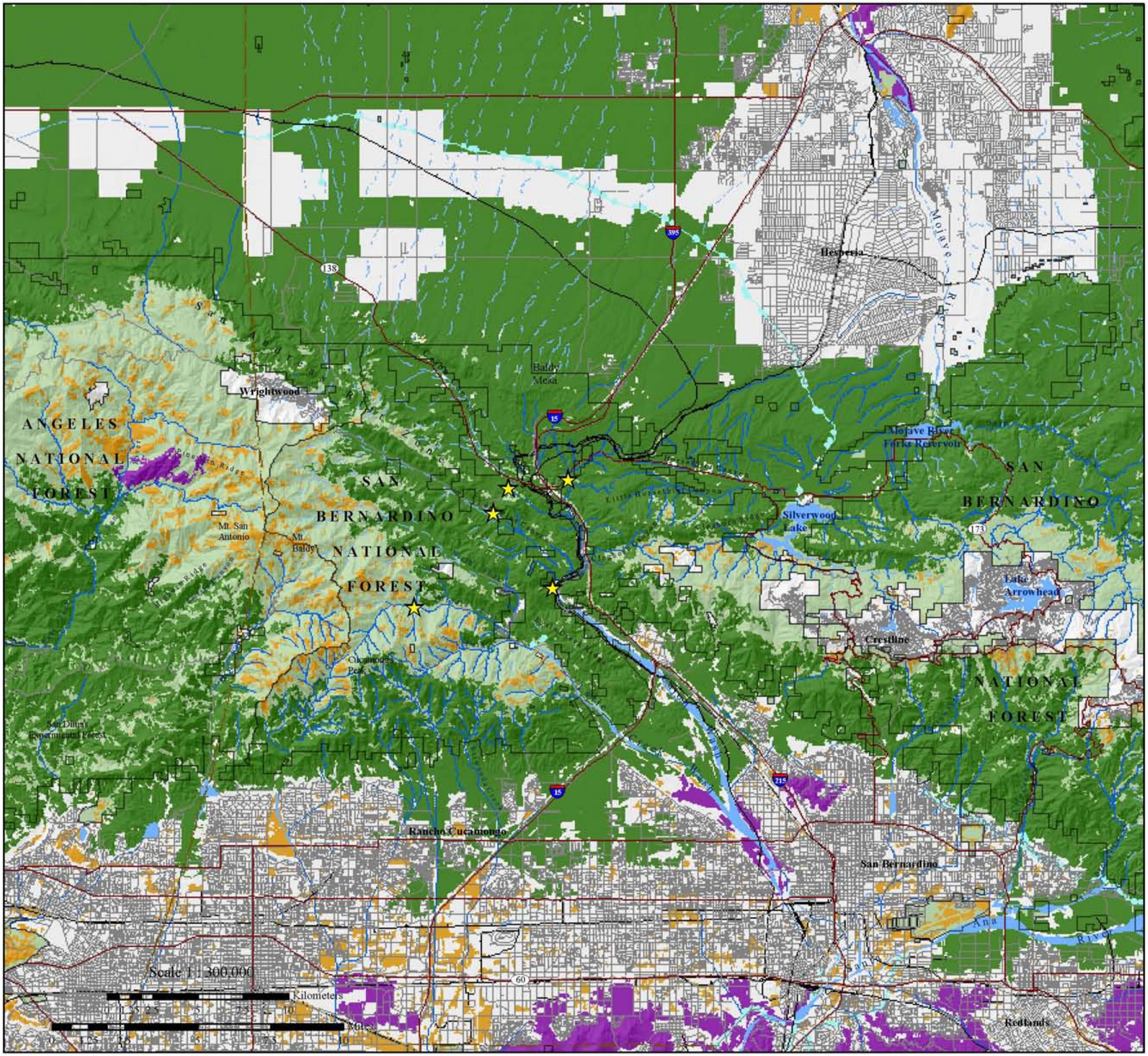
Figure 19.
Potential Cores & Patches
for
American Badger
(Taxidea taxus)

Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries



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Nelson's Bighorn Sheep (*Ovis canadensis nelsoni*)


Photo courtesy of BLM

Distribution & Status: Bighorn sheep have been divided into seven recognized subspecies (Freeman 1999). In California, Nelson's bighorn sheep inhabit mountain ranges from the White Mountains to the southern Sierra Madre Range, San Gabriel and San Bernardino Mountains, and southeastward to the Mexican border (CDFG 1983, USFS 2002). In the planning area, Nelson bighorn sheep populations are currently concentrated in the eastern part of both the San Gabriel and San Bernardino Mountains (Torres et al. 1994, Stephenson and Calcarone 1999), between 914-3,068 m (3,000-10,064 ft) (Holl and Bleich 1983, USFS 2002).

Mountain sheep populations have declined substantially; they are now considered one of the rarest ungulates on the continent (Seton 1929, Valdez 1988, Valdez and Krausman 1999, Krausman 2000). Major factors in the decline are habitat loss, degradation, and fragmentation due to urbanization, mining, roads, and recreational activities (Light et al. 1967, Graham 1971, Light and Weaver 1973, Jorgensen 1974, DeForge 1980, Wilson et al. 1980, Holl and Bleich 1983, Krausman et al. 1989, Ebert and Douglas 1993, Stephenson and Calcarone 1999, USFWS 2000, Krausman et al. 2000, Papouchis et al. 2001), livestock grazing, hunting, loss of water sources (Beuchner 1960, Bailey 1980, Graham 1980, McCutcheon 1981, Bailey 1984, Geist 1985), and diseases transmitted by livestock (Cowan 1940, Buechner 1960, Wishart 1978, Monson 1980, Holl and Bleich 1983, Thorne et al. 1985, Singer et al. 2000). Sheep in the San Gabriel Mountains have experienced a precipitous decline, from the largest population in California (DeForge 1980, Torres et al. 1994, Stephenson and Calcarone 1999), ranging from 665 to 740 animals (Holl and Bleich 1983), to approximately 90 individuals due to human disturbance, vegetation condition, water availability, and predation (Torres et al. 1996, Holl et al. 2004). The San Gabriel population is designated as a fully protected population under CDFG Code 4700. Bighorn sheep are listed as a Forest Service Sensitive Species, and are identified as a Management Indicator Species in both the Angeles and San Bernardino National Forest's Land and Resource Management Plans (Holl et al. 2004).

Habitat Associations: Bighorn sheep are habitat specialists that prefer open habitats in steep rocky terrain that is patchily distributed in the landscape (Van Dyke et al. 1983, Risenhoover et al. 1988, Smith et al. 1991, Singer et al. 2000). Escape terrain is identified as the single most important habitat component (Buechner 1960, Welch 1969, Shannon et al. 1975, Hudson et al. 1976, Sandoval 1979, McCullough 1980, Tilton and Willard 1982, Holl and Bleich 1983, Van Dyke et al. 1983, Hurley and Irwin 1986, Bentz and Woodard 1988, Smith and Flinders 1991, Smith et al. 1991, Singer et al. 2000, Singer et al. 2000b, Zeigenfuss et al. 2000, USFWS 2000, USFS 2002, Holl et al. 2004).

Bighorn sheep may utilize a number of habitat types including alpine dwarf shrub, low sage, sagebrush, pinyon-juniper, palm oasis, desert riparian, desert scrub, subalpine conifer, perennial grassland, and montane riparian (CDFG 1990, E. Rubin, pers. com.). Sheep in the San Gabriel Mountains also occur in montane chaparral, oak and conifer habitats (Holl and Bleich 1983). Mineral licks are used seasonally (April to September) to supplement their dietary requirement for sodium (Holl and Bleich 1983). They remain near water during summer (Leslie and Douglas 1979, Monson and Sumner 1980, Wehausen 1980, Tilton and Willard 1982, Wehausen 1983, CDFG 1983). The young learn about escape terrain, water sources, and lambing habitat from elders (USDI Fish and Wildlife Service 2000, USFS 2002).

Spatial Patterns: Radio telemetry studies indicate that Bighorn sheep spend nearly 95% of their time on or within about 300 m (984 ft) of steep rugged slopes (Tilton and Willard's 1982, Smith and Flinders 1991, Singer et al. 2000b). Holl and Bleich (1983) defined escape terrain as slopes greater than 80 degrees with rock outcrops, though they also use slopes less than 20 degrees when crossing a canyon bottom or drinking from a stream (Holl and Bleich 1983). They make seasonal movements between winter and summer ranges, spending summer at higher elevation and moving downslope in winter (USFWS 2000).

Females tend to stick together in ewe groups and have small home ranges, while rams roam over larger areas, moving among ewe groups (Geist 1971). Peninsular bighorn sheep home range sizes were found to average 25.5 km^2 (9.8 mi^2) for rams and 20.1 km^2 (7.8 mi^2) for ewes (DeForge et al. 1997, USDI Fish and Wildlife Service 2000). While Rubin et al. (2002) found mean female home ranges in the Peninsular bighorn sheep of 23.92 km^2 (9.2 mi^2) and 15.02 km^2 (5.79 mi^2) when using adaptive kernel and minimum convex polygon methods, respectively. Another study found much larger home range sizes, with rams ranging from 9.8-54.7 km^2 (3.78-21.1 mi^2) and ewes ranging from 6.1–35.3 km^2 (2.36-13.6 mi^2; Singer et al. 2001). Bighorn sheep in the San Gabriel Mountains were found to have much smaller home ranges; 5 ewes averaged 3.9 km^2 (1.5 mi^2), while one adult ram had a home range size of 17.9 km^2 (6.9 mi^2), which encompassed Cucamonga Canyon and the South Fork of Lytle Creek (DeForge 1980, Holl et al. 2004).

The longest recorded movement of an ewe is 30 km (18.6 mi). Analyses of genetic data suggest that movement of ewes among groups is rare (USDI Fish and Wildlife Service 2000, USFS 2002). Bleich et al. (1996) reported one case of an ewe 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 frequent movements among ewe groups (USDI FWS 2000, USFS 2002). A Canadian study (Blood 1963) estimated rams moved approximately 24 km (14.9 mi). Geist (1971) observed ram movements up to 35 km (21.7 mi). Witham and Smith (1979) documented a ram that moved 56 km (34.8 mi). DeForge (1980) described a ram that moved approximately 10 km (6.21 mi) in the San Gabriel Mountains.

Conceptual Basis for Model Development: Numerous habitat suitability models have been developed for Bighorn sheep (Buechner 1960, Hansen 1980, Holl 1982, Van Dyke et al. 1983, Risenhoover and Bailey 1985, Hurley and Irwin 1986, Bentz and Woodard 1988, Armentrout and Brigham 1988, Cunningham 1989, Smith et al. 1991, Singer et al. 2000, Zeigenfuss et al. 2000).

We delineated potentially suitable habitat as escape terrain (slopes 27-85 degrees) and adjacent flat areas that were less than 300 m (984 ft) from escape terrain (Buechner 1960, Van Dyke et al. 1983, Hurley and Irwin 1986, Bentz and Woodard 1988, Singer et al. 2000). Four 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) (Singer et al. 2000b, Zeigenfuss et al. 2000); 3) areas that were developed and land within 150 m of these areas (Smith et al. 1991, Singer et al. 2000, Zeigenfuss et al. 2000); and 4) habitat patches below 1000 m (3218 ft) in elevation (Holl and Bleich 1983).

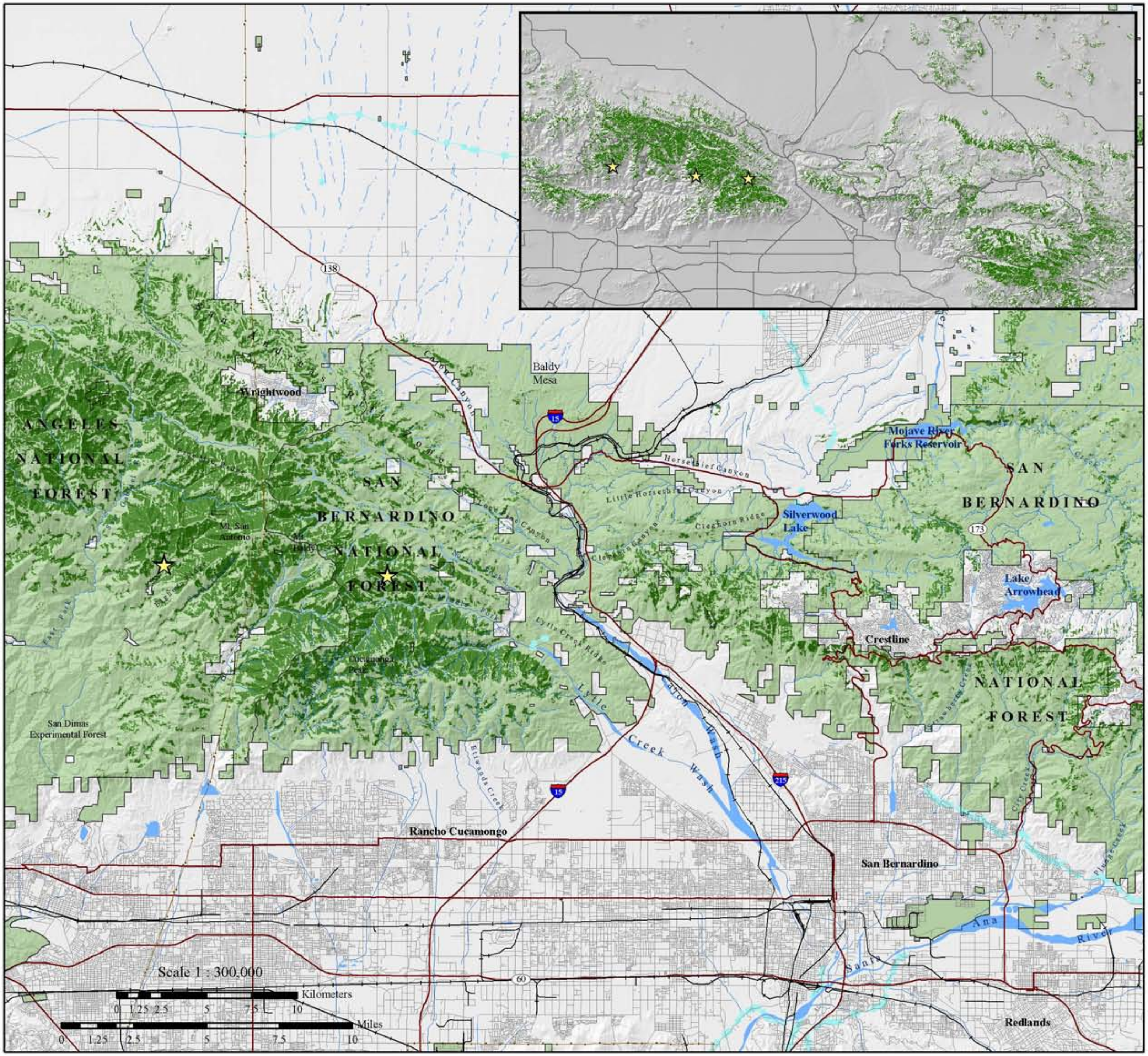
Core areas were delineated after Singer et al. (2000b) as areas of suitable habitat greater than or equal to 17km^2 (6.56 mi^2 or 4201 ac). Patches were defined as $\geq$ 3.9 km^2 (1.5 mi^2 or 963 ac) but less than 17km^2. Dispersal distance for Bighorn sheep was defined as 20 km (12.42 mi), twice the distance recorded for a ram in the San Gabriel Mountains.

Results & Discussion: The output provided by the habitat suitability analysis (Figure 20) corresponds with important habitat areas identified for this species (Holl and Bleich 1983, Stephenson and Calcarone 1999, Holl 2002, USFS 2002, Holl et al. 2004). In the San Gabriel Mountains, this includes habitat in the Bear Creek drainage, the upper East Fork of the San Gabriel River and Cattle Canyon, Mount San Antonio, Cucamonga Canyon, and the South and Middle Forks of Lytle Creek (Holl and Bleich 1983, Stephenson and Calcarone 1999, Holl 2002, Holl et al. 2004). The model also captured habitat occupied by the species in the San Bernardino Mountains, including the largest population on San Gorgonio Mountain and the Cushenbury population on the northern edge of the range in desert-facing canyons such as Furnace, Bousie, Arctic, and Marble Canyons (Stephenson and Calcarone 1999, USFS 2002, S. Loe, pers. com.). Other areas of potentially suitable habitat were identified in both ranges.

The patch size analysis identified potential core areas in both mountain ranges (Figure 21) that largely overlap with areas currently or historically occupied by Bighorn sheep. Though Bighorn sheep rarely colonize unoccupied habitat (Geist 1971, Hoefs and Cowan 1979, Holl and Bleich 1983, Fest-Bianchet 1986, Bleich et al. 1996, Singer et al. 2000b), uninhabited potential habitat exists in both the San Gabriel and San Bernardino Mountains. All potential habitat linking core areas and patches are within the species dispersal distance, though barriers to movement exist between areas of suitable habitat. The Least Cost Union may serve the needs of this species if habitat restoration efforts are undertaken, land management objectives are fulfilled, and adequate crossing structures are provided to accommodate Bighorn sheep movement.

Dense shrubs and trees have invaded Bighorn sheep habitat due to fire suppression over the last century (Wishart 1978, Peek et al. 1979, Wakelyn 1987, Singer et al. 2000b), making vast areas of historically occupied habitat unsuitable for this species. Fires may increase the amount of habitat available to Bighorn sheep and improve their ability to detect and evade predators (Holl and Bleich 1983, Holl et al. 2004). Three large fires occurred within the planning area in late 2003 (i.e., Padua, Grand Prix, Old Fire) that may encourage bighorn sheep to explore these areas and expand their ranges (*See 3D Animations on Enclosed CD*). Large wildfires on the north side of the San Gabriel and San Bernardino Mountains may result in large enough open areas to

Figure 20.
Potential Habitat
for
Nelson's Bighorn Sheep
(Ovis canadensis nelsoni)



Legend

- Potential Habitat
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries

N

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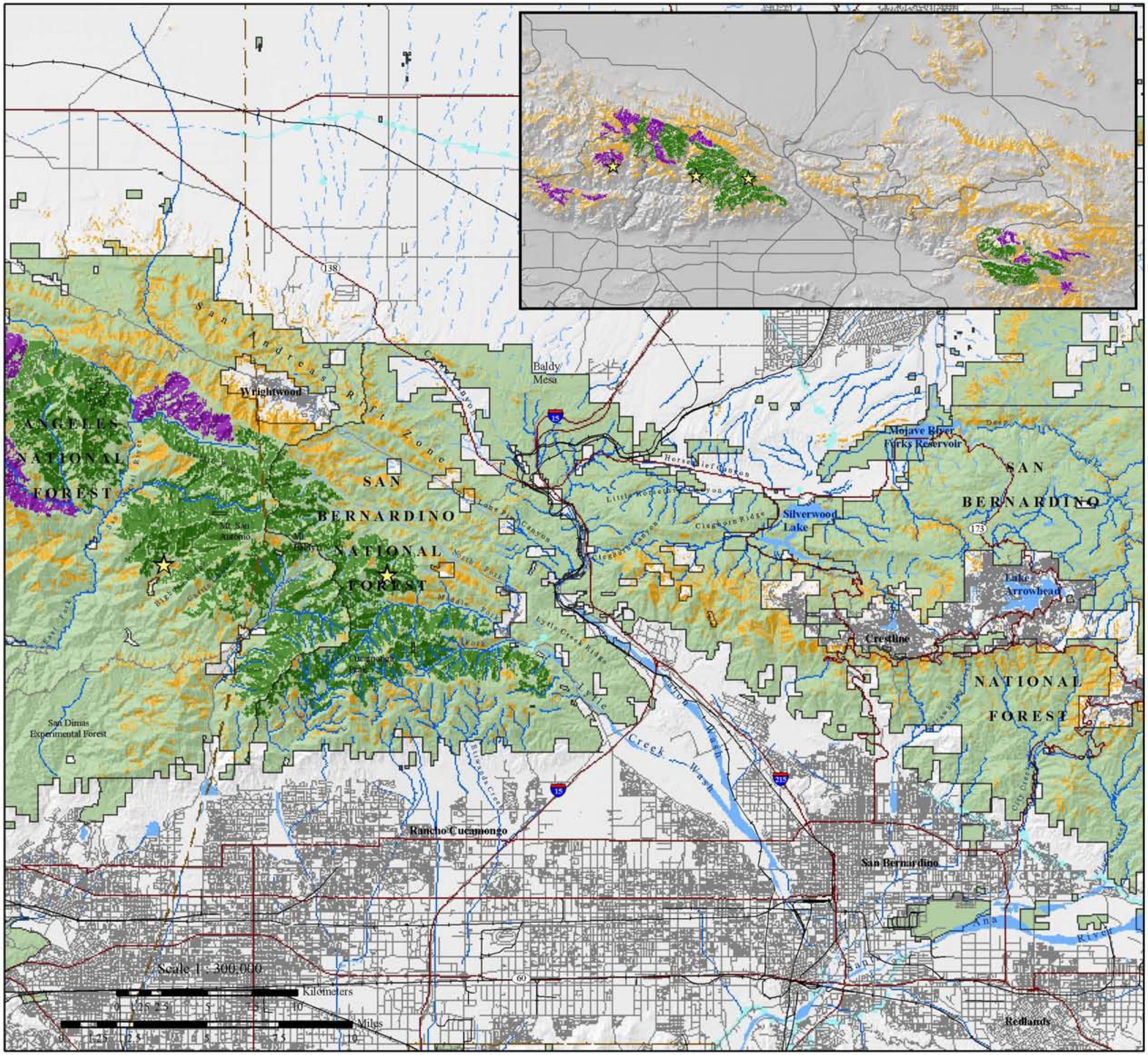
Figure 21.
Potential Cores & Patches
for
Nelson's Bighorn Sheep
(Ovis canadensis nelsoni)

Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- Ownership Boundaries
- County Boundaries



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facilitate long distance ram movement. In addition, habitat restoration projects for Bighorn sheep that involve prescribed burns are planned for Cattle Canyon, Barrett-Cascade, and the East Fork of the San Gabriel River (Holl et al. 2004).

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), though rams have been observed to occasionally cross roads (Rubin et al. 1998). A ram was observed in Cajon Pass in 1964 (Robinson 1945 *in* Light et al. 1967), and another in 1980 (Holl and Bleich 1983). MacArthur et al. (1982) concluded that well designed transportation systems could minimize disturbance to sheep (Holl and Bleich 1983). To restore and protect habitat connections for bighorn sheep both within and between the San Gabriel and San Bernardino Mountains, we recommend that:

- Bighorn sheep, particularly rams, are radio-collared to determine movement patterns (Holl et al. 2004);

- No new roads should be constructed in occupied or potential habitat (USFWS 2001);

- State Route 39 remain closed, as it would create a barrier to movement between the Iron Mountain and Twin Peak groups of sheep (Holl et al. 2004);

- No new roads or trails should pass within 100 m of a mineral lick (Holl and Bleich 1983), established roads or trails should be seasonally closed (April-September);

- Roads and trails that pass through known lambing areas should be closed during the reproductive season (Holl and Bleich 1983, Papouchis et al. 2001, USFWS 2001);

- No off-road vehicle routes occur within bighorn sheep habitat (USFWS 2001);

- Leash laws are enforced so that dogs are under restraint at all times (USFWS 2001, Holl et al. 2004);

- Forest Service, Fish and Game and the Counties should continue to control feral dogs and dogs allowed to run loose from surrounding communities;

- Ski facilities (e.g., Mt. Baldy, Kratka Ridge, and Mt. Waterman) not be operated during summer and be planted with native forage species (Holl and Bleich 1983);

- Prohibit domestic sheep and goats within 9 miles of sheep habitat to reduce the potential for disease transmission (USFWS 2001, Holl et al. 2004, USFWS 2000);

- The CalTIP (Californians Turn in Poachers) program's toll free reporting number (i.e., 800-952-5400) be widely publicized (Anonymous 1984);

- Private organizations (e.g., Bighorn Institute, Bighorns Unlimited, Foundation for North American Wild Sheep, Fraternity of Desert Bighorn, Society for the

Conservation of Bighorn Sheep) become engaged in educational programs and research opportunities;

- Critical parcels are protected through conservation agreements, acquisition, fee title agreements, etc; and

- Prescribed fires should be used to maintain a more natural fire regime in Wilderness Areas.

Mule Deer (*Odocoileus hemionus*)

Distribution & Status: Mule deer have a widespread distribution in California and are common to abundant in appropriate habitat; they are absent from areas with no cover (Longhurst et al. 1952, Ingles 1965, CDFG 1990). Mule deer are classified by the California Department of Fish & Game 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 utilize 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. Several home range estimates exist in the literature, ranging from 39 ha (96 ac; Miller 1970) to 3,379 ha (8350 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 (124-1236 ac; Taber and Dasmann 1958, CDFG 1983). Bucks usually have larger home ranges and are known to wander further distances (Brown 1961, CDFG 1990). A recent study of 5 different sites throughout California, recorded home range sizes between 49-1138 ha (121-2812 ac; Kie et al. 2002).

Where 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 grassland, and meadow habitats, reaching their highest densities in oak woodland. They require access to perennial water. Patch size was classified as ≥ 100 ha but < 16,000 ha. Core areas potentially supporting 50 or more deer are equal to and greater than 16,000 ha. Dispersal distance was defined as 434 km, or twice the maximum distance recorded.

Results & Discussion: Mule deer habitat is extensive throughout the San Gabriel and San Bernardino Ranges, with the most highly suitable habitat in the vicinity of I-15 in Cleghorn Canyon and the South Fork of Lytle Creek (Figure 22). Almost all habitats within the Least Cost Union were identified as core habitat, thus, the linkage will likely serve the needs of Mule deer living in or moving through the linkage (Figure 23). The recommended additions to the Union that were added to support other focal species will also benefit Mule deer. All core areas and patches of suitable habitat are within the dispersal distance of this species, although barriers to movement may exist between suitable habitat patches.

Estimates of the number of deer killed annually on U.S. roads ranges from 720,000 to 1.5 million (Romin and Bissonette 1996, Conover 1997, Forman et al. 2003). Collisions with deer also result in the loss of human lives (Reed et al. 1975). To restore and protect habitat connections for Mule deer, we recommend that:

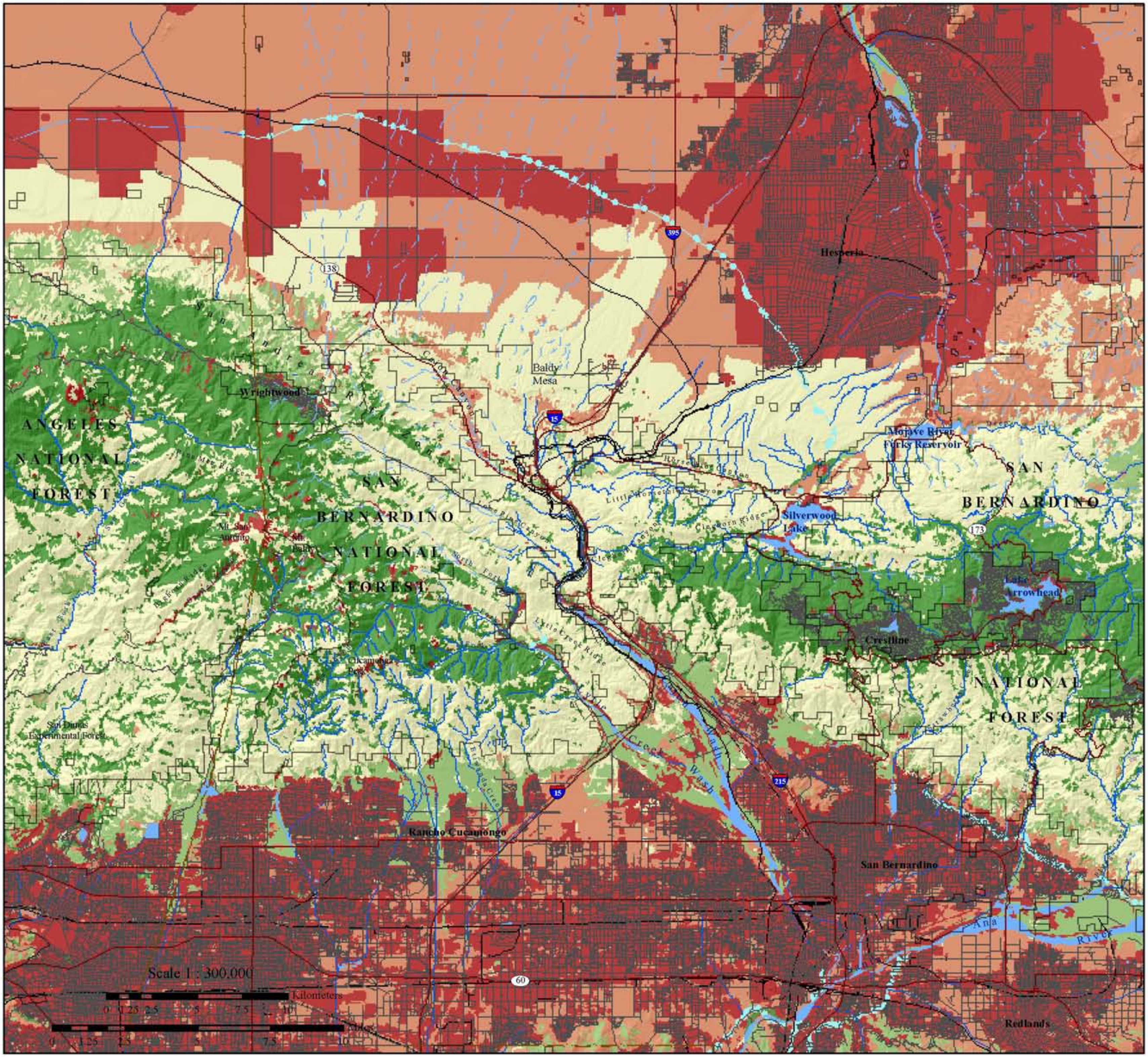
- Road barriers are modified to accommodate Mule deer movement. Though ungulates much prefer overpasses to underpasses (Gloyne and Clevenger 2001), they will utilize bridged undercrossings if they can see clearly to the other side. Crossing structures for Mule deer should have natural flooring and no artificial lighting (Reed et al. 1975);

- Fencing (up to 4m [12 feet] high) be installed to reduce roadkill and guide deer to crossing structures; in conjunction with escape ramps being installed in case deer get caught in the roadway (Forman et al. 2003);

- Existing road density be maintained or reduced; no new roads in the Linkage Design; and

- Critical parcels are protected through conservation agreements, acquisition, fee title agreements, etc.

Figure 22.
Potential Habitat
for
Mule Deer
(Odocoileus hemionus)



Legend

Degree of Suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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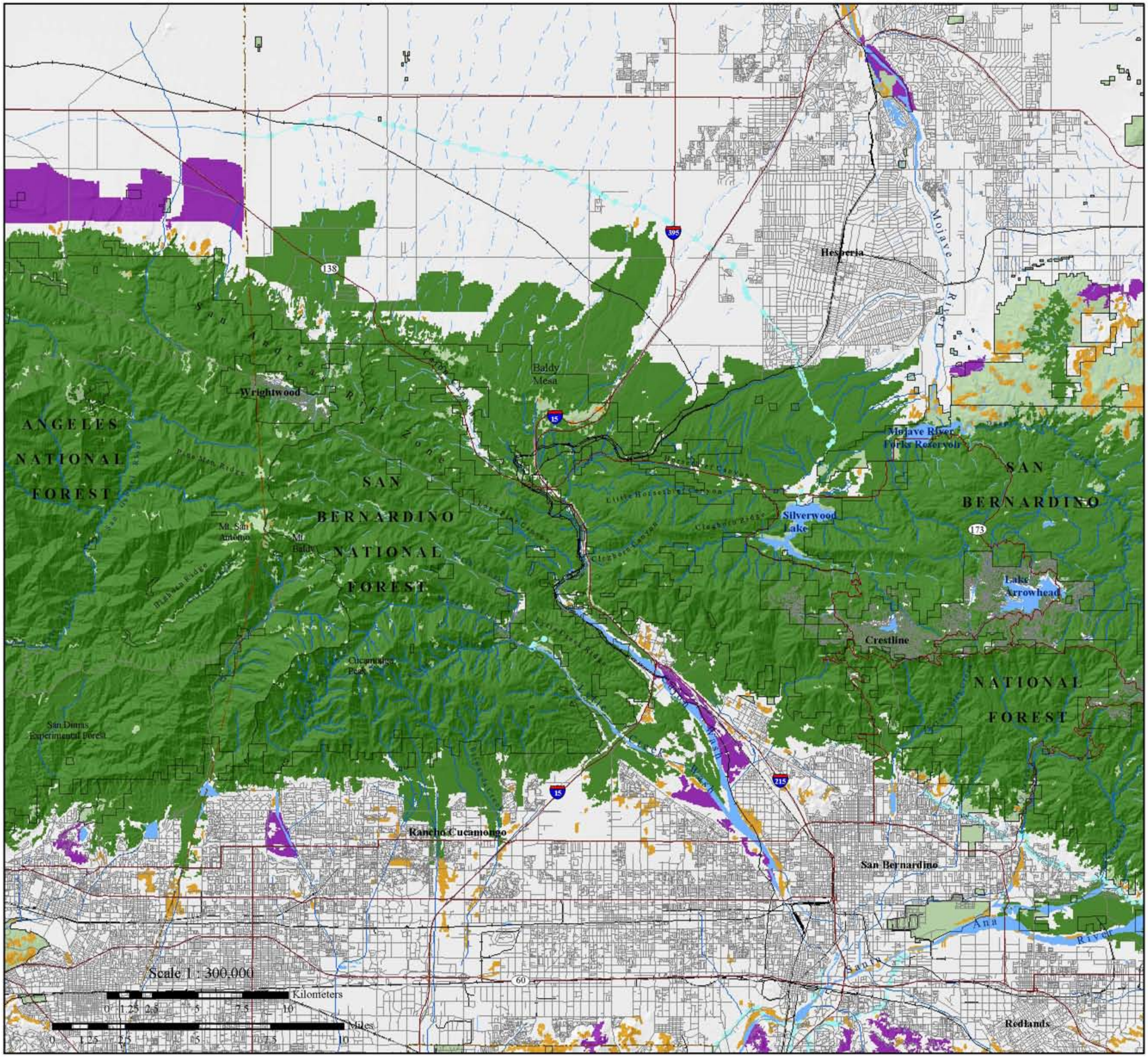
Figure 23. Potential Cores & Patches for Mule Deer

(Odocoileus hemionus)



Legend

- Core
- Patch
- < Patch
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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Dusky-footed woodrat (*Neotoma fuscipes macrotis*)

Justification for Selection: Presence of the Dusky-footed woodrat may be correlated with high species richness (Chase et al. 2000). This species is also sensitive to habitat fragmentation, particularly in riparian systems.

Distribution & Status: The Dusky-footed woodrat is distributed from the Columbia River south through Oregon and northern California, continuing along the Pacific coast and Sierra Nevada foothills of California into northern Baja California (Jameson and Peeters 1988, Matocq 2002). There are currently 11 recognized subspecies, *N. f. macrotis* occurs within the study area (Hall 1981, Matocq 2002). They are typically associated with elevations below 2150m (7000 ft) (Brylski 1990).

Habitat loss and fragmentation due to dam construction and water diversions are the primary reasons cited for the decline of the riparian woodrat (*N. f. riparia*), a federally endangered species (Close and Williams 1988, Gerber et al. 2003). It is likely that the Dusky-footed woodrat is also adversely affected by alterations to the hydrology of streams.

Habitat Associations: The Dusky-footed woodrat is a nocturnal, arboreal herbivore (Lindsale and Tevis 1951, Jameson and Peeters 1988, Sakai and Noon 1997) that inhabits dense chaparral, oak and riparian woodlands, and mixed coniferous forests with a well-developed understory (Murray and Barnes 1969, Jameson and Peeters 1988, Stephenson and Calcarone 1999, Matocq 2002). Woodrats are known for their large, multichambered dwellings built of branches, which they depend upon for shelter, storing food items, and refuge from predators (Carraway and Verts 1991, Matocq 2002). Dens are often inherited between generations (Kelly 1989, Gerber et al. 2003).

Spatial Patterns: Populations may be limited by the availability of nest-building materials (Linsdale and Tevis 1951, Brylski 1990). Population density may vary radically among sites, from greater than 80 individuals per hectare (2.47 ac) to 1.47 per hectare (Ward 1990, Sakai and Noon 1993). In Sonoma County, home range size averaged 0.23 ha (0.58 ac) for males, and 0.19 ha (0.48 ac) for females (Brylski 1990). Cranford (1977) estimated male home range size at 2289 m^2 (0.57 ac; Gerber et al. 2003). Sakai and Noon (1997) estimated female home range at 2632 m^2 (0.65 ac), males at 5338 m^2 (1.32 ac), with an average of 3200 m^2 (0.79 ac). The largest home range recorded was 18.8 ha (46.2 ac) from Monterey (Bleich 1973, Brylski 1990). There is some overlap in home ranges during the breeding season (Jameson and Peeters 1988). Dispersal distance has been recorded at 217 m (712 ft; Sakai and Noon 1997).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. Dusky-footed woodrat inhabits dense chaparral, oak and riparian woodlands, and mixed coniferous forests, typically below 2150 m in elevation. Patch size was defined as $\geq$ 0.38 ha and < 19.75 ha. Core areas were defined as $\geq$ 19.75 ha. Dispersal distance was defined as 434 m.

Results & Discussion: Highly suitable habitat is well distributed in the San Gabriel and San Bernardino protected areas and within the linkage (Figure 24). The majority of suitable habitat was identified as core areas, with the central branch of the Union containing the most contiguous block of habitat (Figure 25). All suitable habitat patches are within the presumed dispersal distance for this species, although numerous barriers to movement may exist between suitable habitat patches. We conclude that the Least-Cost Union meets the needs of this species for movement among populations in the protected core areas. Although, habitat added for other focal species will also benefit the Dusky-footed woodrat. To protect and restore habitat connectivity for this species, we recommend that:

- Road barriers be modified, where necessary, to allow woodrats to move along riparian corridors; and
- Crossing structures for small mammals be placed fairly frequently to facilitate movement across major transportation routes (i.e., I-15) and reduce travel distance (Jackson and Griffin 2000, McDonald and St. Clair 2004);
- Riparian buffers extend at least 1 km (0.62 mi) into upland habitat on either side of aquatic habitat be added to the Union.
- Natural hydrological processes are maintained or restored;
- Lighting is directed away from the linkage and crossing structures; and
- Local residents are informed about the proper use of rodenticides and pesticides to reduce the likelihood of ingestion of these lethal substances on small mammals indigenous to the area.

Figure 24.
Potential Habitat
for
Dusky-footed Woodrat
(Neotoma fuscipes macrotis)

Legend

Degree of Suitability
- Low
- Low to Medium
- Medium
- Medium to High
- High
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

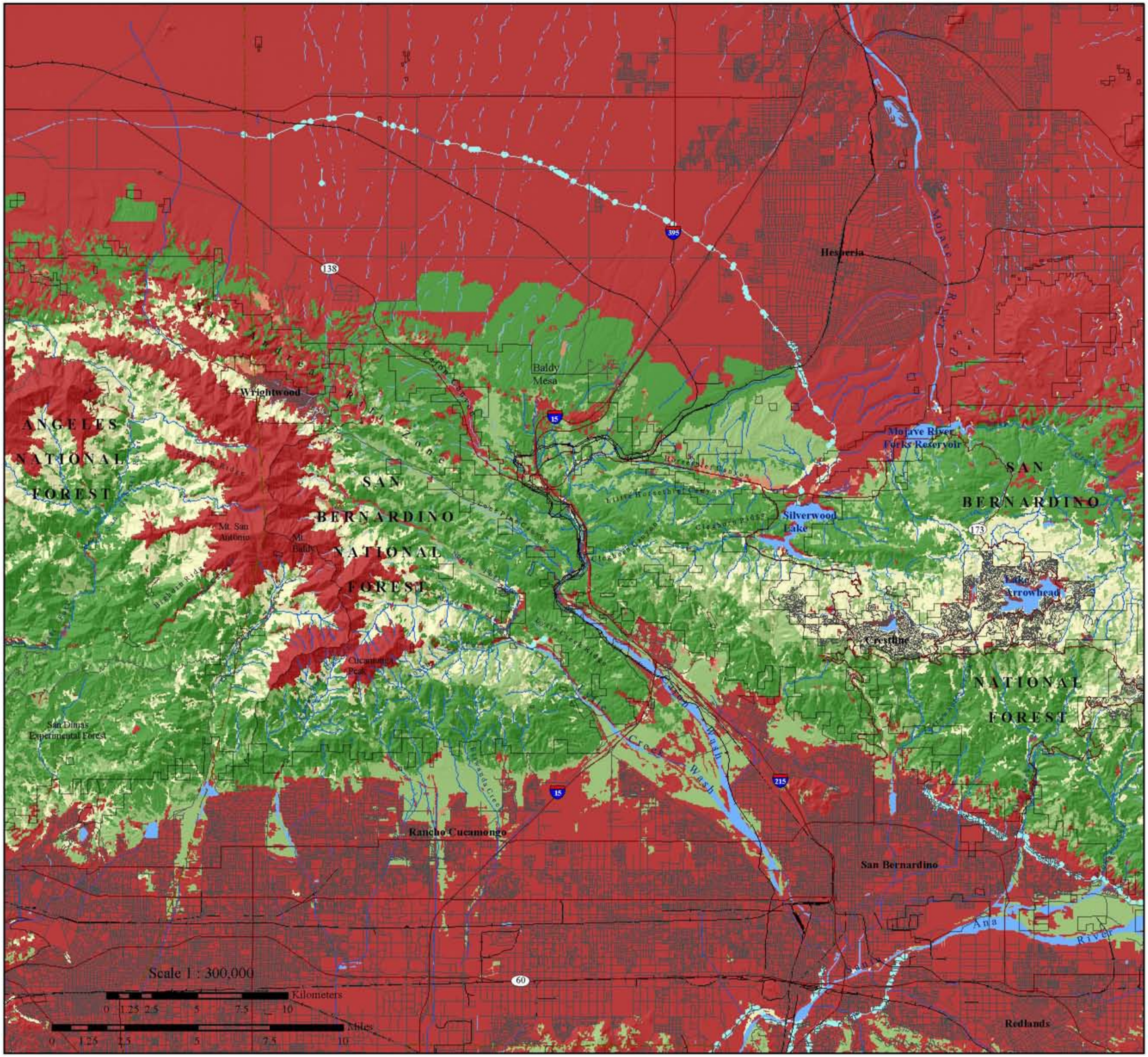

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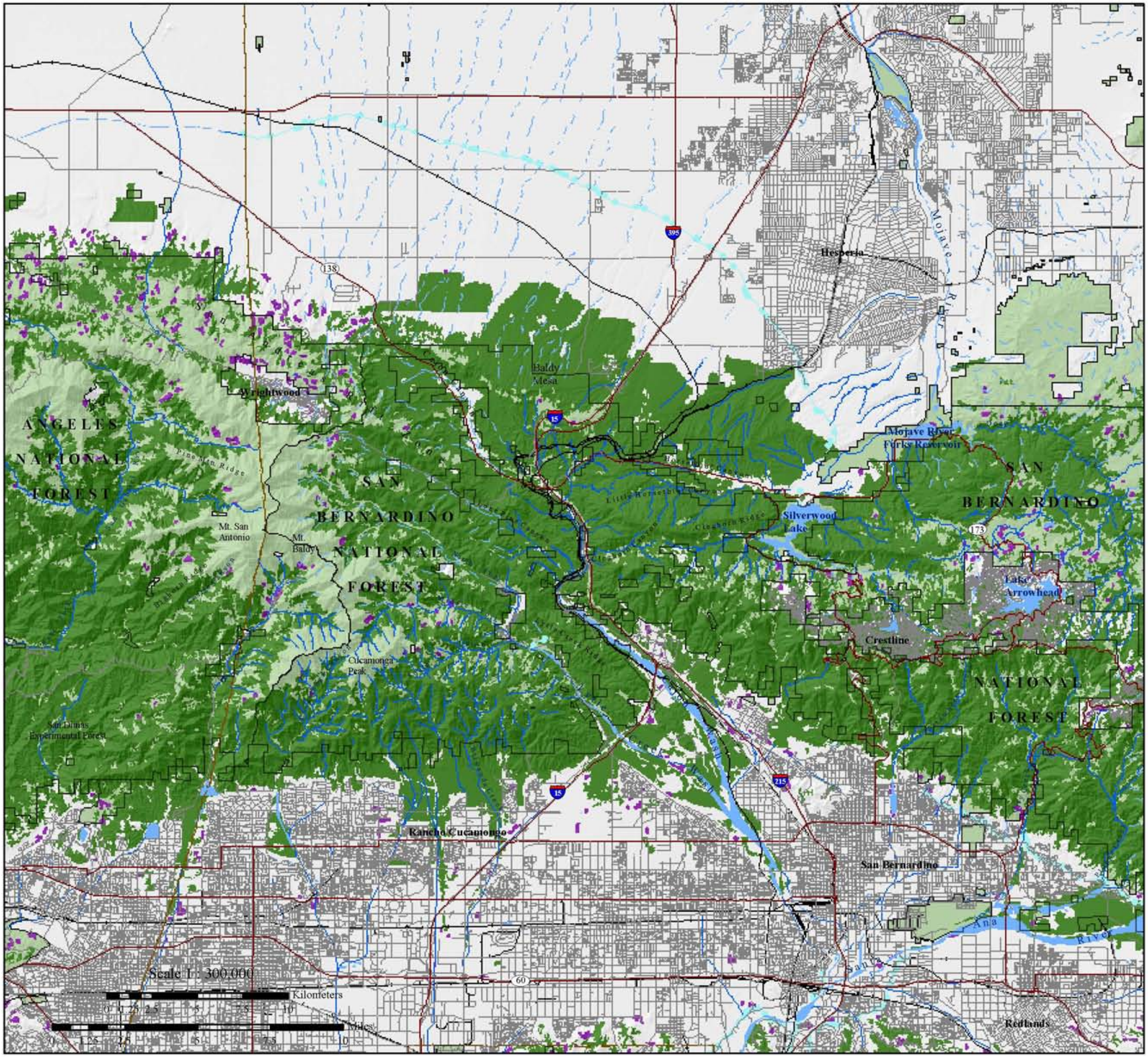
Figure 25.
Potential Cores & Patches
for
Dusky-footed Woodrat
(Neotoma fuscipes macrotis)



Legend

- Core
- Patch
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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San Bernardino Kangaroo Rat (*Dipodomys merriami parvus*)


Courtesy of NPS

Justification for Selection: The San Bernardino kangaroo rat is an orthogonal species that is sensitive to barriers, artificial light pollution, and dense stands of non-native annual grasses. Natural hydrological and geomorphological processes are necessary to sustain the alluvial scrub vegetation this species depends upon for its survival (USFWS 1998).

Distribution & Status: The San Bernardino kangaroo rat is one of 19 known subspecies of Merriam's kangaroo rat; a widespread species distributed throughout arid regions of the western United States and northwestern Mexico (Hall and Kelson 1959, Williams et al. 1993, USFWS 1998). Three subspecies occur in southern California *D. merriami merriami*, *D. m. collinus*, and *D. m. parvus*. Historically, the San Bernardino kangaroo rat ranged from the San Bernardino Valley in San Bernardino County to the Menifee Valley in Riverside County (Hall and Kelson 1959, Lidicker 1960, USFWS 1998). Once considered a common species, about 95 percent of their historical habitat has been lost. By 1997, the species was known to occupy 1,299 ha (3,247 ac) divided unequally among 7 locations (McKernan 1997, USFWS 1998, USFWS 2001). Four of these sites support small remnant populations including City Creek, Etiwanda, Reche Canyon, and South Bloomington; three sites support higher density populations, located in the Santa Ana River, Lytle and Cajon washes, and San Jacinto River (USFWS 2001). Populations along lower Lytle Creek and Cajon Wash may extend into the San Bernardino National Forest (McKernan 1997).

Factors that threaten the survival of this species include habitat loss, degradation, and fragmentation due to disruptions of the natural hydrologic regimes, sand and gravel mining, flood control projects, groundwater recharge activities, urbanization, predation by domestic cats, off-road vehicles, and vandalism (USFWS 1998, Stephenson and Calcarone 1999, USFWS 2001). The species was emergency listed as federally endangered in 1998 (62 FR 51005) and critical habitat was designated in 2002 (67 FR 19811). The USFWS has not yet developed a recovery plan for this species.

Habitat Associations: The San Bernardino kangaroo rat prefers well-drained sandy soils in alluvial fan sage scrub (McKernan 1997). They can also be found in coastal sage scrub and even chaparral vegetation types where soils are suitable (McKernan 2000). They inhabit relatively flat or gently sloping alluvial fans, flood plains, and washes, as well as adjacent upland habitats (McKernan 1997). Though they prefer open habitats (McKernan 1997), they will also use areas with dense vegetation (Braden and McKernan 2000). Early and intermediate stages of alluvial scrub are fairly open and typically support higher population densities (McKernan 1997, USFWS 1998). However, the mature terraces and upland areas provide important refugia during flood events and are believed to be essential to the long-term survival of the species (USFWS 1998). San Bernardino kangaroo rats are also known from atypical habitats, including non-native grassland, margins of agricultural fields up to 50 m (150 ft) from adjacent suitable habitat, and areas at the wildland/urban interface within flood plains and terraces that are contiguous to occupied habitat (McKernan in litt. 2000, USFWS 1998).

Spatial Patterns: Not much is known about San Bernardino kangaroo rat's movement ecology or spatial requirements. However, population density estimates (Braden and McKernan 2000) showed considerable annual variability, ranging from 2 to 26 individuals per hectare (2.47 ac; USFWS 1998). Additional spatial information for San Bernardino kangaroo rat is lacking, Merriam's kangaroo rat, a related species, has been well researched. In the Palm Springs area, Merriam's kangaroo rat home range size averaged 0.33 ha (0.8 ac) for males and 0.31 ha (0.77 ac) for females (Behrends et al. 1986). Much large home range sizes were documented for this species in New Mexico (Blair 1943), where home range size averaged 1.7 ha (4.1 ac) for males and 1.6 ha (3.8 ac) for females (USFWS 1998). Adults are territorial, defending areas surrounding their burrows (Jones 1993). Male and female home ranges overlap extensively but females home ranges rarely overlap (Jones 1993, USFWS 1998). Dispersal distances of up to 384 m (1260 ft) have been recorded (Zeng and Brown 1987).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. San Bernardino kangaroo rat prefers alluvial fan sage scrub habitat, but may also utilize coastal sage scrub, chaparral, and non-native grassland to varying degrees if soils are appropriate. Within these habitats, they occupy flat and gently sloping terrain. The northern extent of the species remaining distribution is near Lytle and Cajon Creeks, roughly below 914 m in elevation. Patch size was defined as $\geq$ 0.62 ha and < 42.5 ha. Core areas were defined as $\geq$ 42.5 ha. Dispersal distance was defined as 768 m, twice the recorded distance for Merriam's kangaroo rat.

Results & Discussion: San Bernardino kangaroo rat is an orthogonal species with very little suitable habitat within protected core areas. The largest patches of high quality habitat occur in Cable and Lytle Creeks, Cajon Wash, San Sevaine, Morse, Etiwanda, Day and Deer creeks, and the Santa Ana River (Figure 26), the majority of which was captured in the southern branch of the Least Cost Union. These areas largely coincide with designated critical habitat areas (Units 1-Santa Ana River and Unit 2-Lytle and Cajon Creeks) and areas that were proposed but not designated in the final rule (Unit 4-Etiwanda Fan). These areas were also identified as core areas for San Bernardino kangaroo rat (Figure 27). The linkage is likely to serve the needs of this species if additional habitat is added to the Union in Lytle Creek, Cajon Wash, and Day, Deer, and Etiwanda Creeks, allowing the opportunity for movement between Cajon Wash, Lytle Creek, and the population in the Etiwanda fan area. Each of these areas was identified as essential to the conservation of this critically endangered species (USFWS 1998). These areas are adjacent to extensive wildland that provides upland habitat, buffers from development, and functioning hydrological processes to maintain alluvial fan sage scrub habitat (USFWS 1998). Distances among all core areas and patches are within the dispersal distance of this species, with the exception of potential habitat identified below State Route 60, although barriers to movement may exist between suitable habitat patches.

Many small mammals are reluctant to cross roads (Merriam et al. 1989, Diffendorfer et al. 1995, Brehm 2003). To restore and protect connectivity for the San Bernardino kangaroo rat, we recommend that:

Figure 26.
Potential Habitat
for
San Bernardino Kangaroo Rat
(Dipodomys merriami parvus)

Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurrence
- Railroads
- Paved Roads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

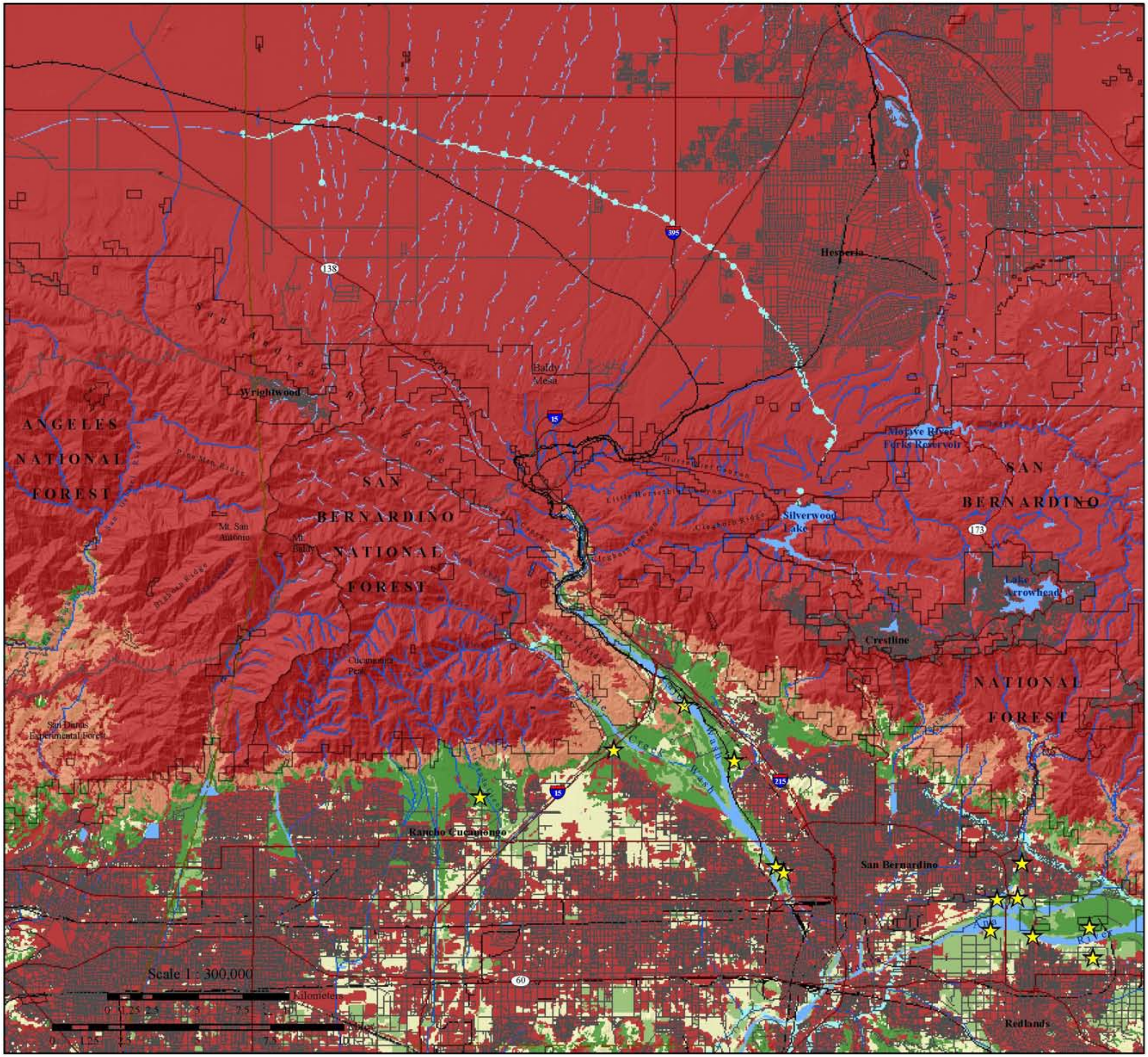

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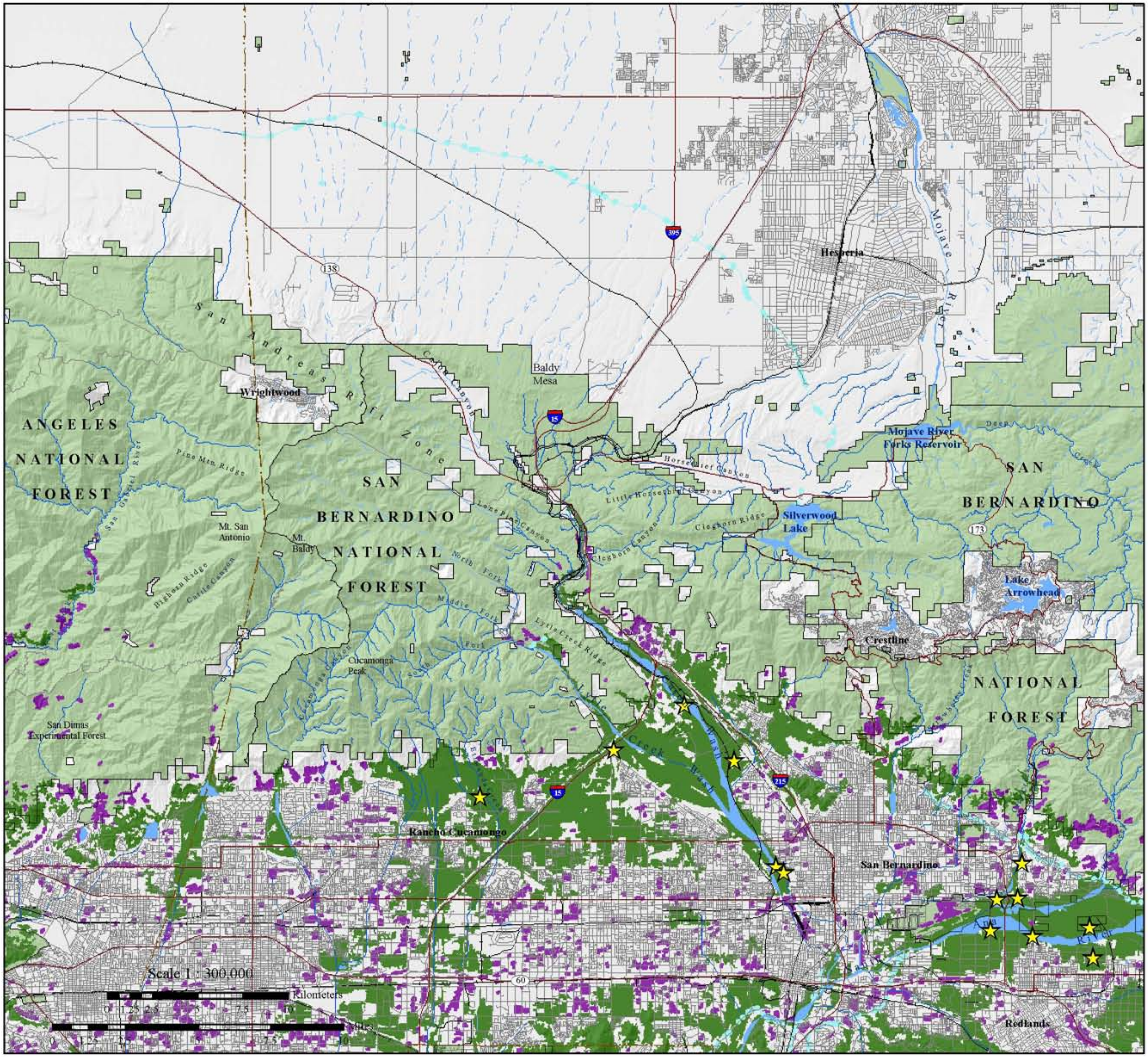
Figure 27.
Potential Cores & Patches
for
San Bernardino Kangaroo Rat
(Dipodomys merriami parvus)

Legend

- Core
- Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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- Habitat not included in the Least Cost Union in Lytle Creek, Cajon Wash, Day, Deer, and Etiwanda Creeks are added to support the needs of this species;

- Riparian buffers extend at least 1 km (0.62 mi) into upland habitat on either side of aquatic habitat be added to the Union, where feasible.

- Watershed educational programs, such as Think River, are offered to local schools in the vicinity;

- Hydro-geomorphological (e.g., flood/scour/deposition) processes are maintained; a natural flow regime is essential for conserving this species (USFWS 1998);

- Existing road density be maintained or reduced;

- Crossing structures for small mammals be placed fairly frequently to facilitate movement across major transportation routes (e.g., I-15) and reduce travel distance (Jackson and Griffin 2000, McDonald and St. Clair 2004);

- Short retaining walls be installed in conjunction with crossing structures along paved roads in the Linkage Design to deter small mammals, amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000);

- Rock collecting in creeks and washes be discouraged, due to resulting changes in habitat structure and the crushing of burrows (USFWS 2001);

- Off-road vehicles be excluded from occupied and historic habitat; closures should be enforced;

- Lighting is directed away from the linkage and crossing structures;

- Local residents are informed about the proper use of rodenticides and pesticides to reduce the likelihood of ingestion of these lethal substances on small mammals indigenous to the area;

- Land is protected through conservation easement, fee title, or other means; and

- Receptive landowners work with US Fish and Wildlife Service Partners for Fish & Wildlife Program to acquire funds and technical assistance to restore and enhance alluvial fan sage habitat on their land to benefit the San Bernardino kangaroo rat and other endangered species.

Pacific Kangaroo Rat (*Dipodomys agilis*)

Distribution & Status: The Pacific kangaroo rat was recently split into 2 species, D. agilis and D. simulans (Dulzura kangaroo rat); both have the potential to occur within the planning area. The distribution of these species extends from the coastal mountains of Baja California and southern California to the Santa Barbara-San Luis Obispo county line and inland to the Tehachapi and Piute Mountains, as far north as the South Fork of the Kern River (Best 1983, Sullivan and Best 1997, CDFG 1990). They occur at elevations up to about 2133 m (7,000 feet) in scrub and chaparral habitats (W. Spencer pers. comm.) but have been found as high as 2250 m (7400 ft) (CDFG 1990). The Pacific kangaroo rat isn't afforded any special status.

Habitat Association: This species is a habitat generalist, occurring in a variety of open habitats with scattered vegetation including coastal sage scrub, chaparral, oak woodland, pinyon-juniper woodland, desert scrub, and annual grassland (Bleich and Price 1995, W. Spencer pers. comm.). They've also been recorded in alluvial fan sage scrub (Price et al. 1991) and montane coniferous forests (Sullivan and Best 1997). However, their distribution is somewhat limited by the presence of water (Carpenter 1966, Christopher 1973, CDFG 1990) and they also require friable soils in which to burrow (CDFG 1990). This species may be associated with Atriplex and chenopodium scrubs (W. Spencer pers. comm.) as well as *Croton californicus*, *Cryptantha clevelandi*, and *Corethrogyne filaginifolia* (Meserve 1986). Goldingay and Price (1997) found them to be particularly abundant in ecotonal habitats. They frequent open chaparral and coastal sage scrub vegetation (M'Closkey 1976, Meserve 1976, Price and Kramer 1984, Keeley and Keeley 1988, Price et al. 1991) and increases in abundance following fires that create openings in the vegetation (Price and Waser 1984, Price et al. 1991, W. Spencer pers. comm.). Quinn (1990) believes *D. agilis* to be most abundant in early succession communities that occur 2 to 5 years after fire, but smaller numbers of individuals can be found scattered in more limited openings in chaparral. Thus, fire may be an important factor in maintaining long-term linkage occupancy (W. Spencer pers. comm.).

Spatial Patterns: MacMillen (1964) estimated home range size of Pacific kangaroo rat from 0.1 to 0.6 ha (0.4 to 1.5 ac) with a mean of 0.3 ha (0.8 ac). Although fairly widespread and common, they seem to occur at somewhat lower densities than other kangaroo rats, perhaps due to the more patchy nature of their habitat (sparse or open areas within scrub and chaparral, versus more homogeneous desert or grassland habitats), which may be the result of chaparral and scrub habitats providing less food (seeds from annual forbs and grasses) than grasslands and deserts (W. Spencer pers. comm.). Christopher (1973) measured population densities of the Pacific kangaroo rat that ranged from 0.9 to 10.8 per ha (2.22-26.7 ac).

Most information on movements and ecology are very similar to Merriam's kangaroo rat, although with less supporting literature (W. Spencer pers. comm.). Merriam's kangaroo rat typically remains within 1-2 territories (100 m [328 ft] or so) of their birthplace, but the species is capable of longer dispersal (Jones 1989). Behrends et al. 1986 found movements of about 10 to 29 m (33-95 ft) between successive hourly radio fixes, although they are capable of very rapid movements. For example, Daly et al. (1992) observed individuals moving as much as 100 m in a few minutes to obtain and cache experimentally offered seeds. Zeng and Brown (1987) recorded long-distance movements up to 384 m (1260 ft) in adults, concluding that these kangaroo rats are opportunistic in moving into newly available territory areas. However, unlike Merriam's kangaroo rat, the Pacific kangaroo rat may not be a strictly "orthogonal" linkage species. Because they occupy montane chaparral habitats, they may actually disperse between adjacent mountain ranges via linkages, at least over multiple generations (W. Spencer pers. comm.).

Conceptual Basis for Model Development: Movement between protected core areas in the linkage is multigenerational. This species prefers open vegetative communities including coastal sage scrub, alluvial fan sage scrub, chaparral, desert scrub, annual grassland, oak woodland, pinyon-juniper woodland, and montane coniferous forests. They are primarily found below 2250 meters in elevation. Patch size was defined as $\geq$ 0.5 ha and < 8 ha. Core areas were defined as $\geq$ 8 ha. Dispersal distance for these species hasn't been measured, so twice the dispersal distance for Merriam's kangaroo rat (768 m) was used.

Results & Discussion: The most highly suitable habitat for Pacific kangaroo rat occurs in the coastal sage and alluvial fan habitats in the foothills (Figure 28). Though, extensive core habitat for this species occurs throughout the planning area (Figure 29). The most southerly branch of the Union captured the most highly suitable habitat for this species in the planning area. All patches are within the dispersal distance for this species, although numerous barriers to movement may exist between suitable habitat patches. We conclude that the Least-Cost Union meets the needs of this species for movement among populations in the protected core areas. However, many small mammals are reluctant to cross roads (Merriam et al. 1989, Diffendorfer et al. 1995). To restore and protect connectivity for the Pacific kangaroo rat, we recommend that:

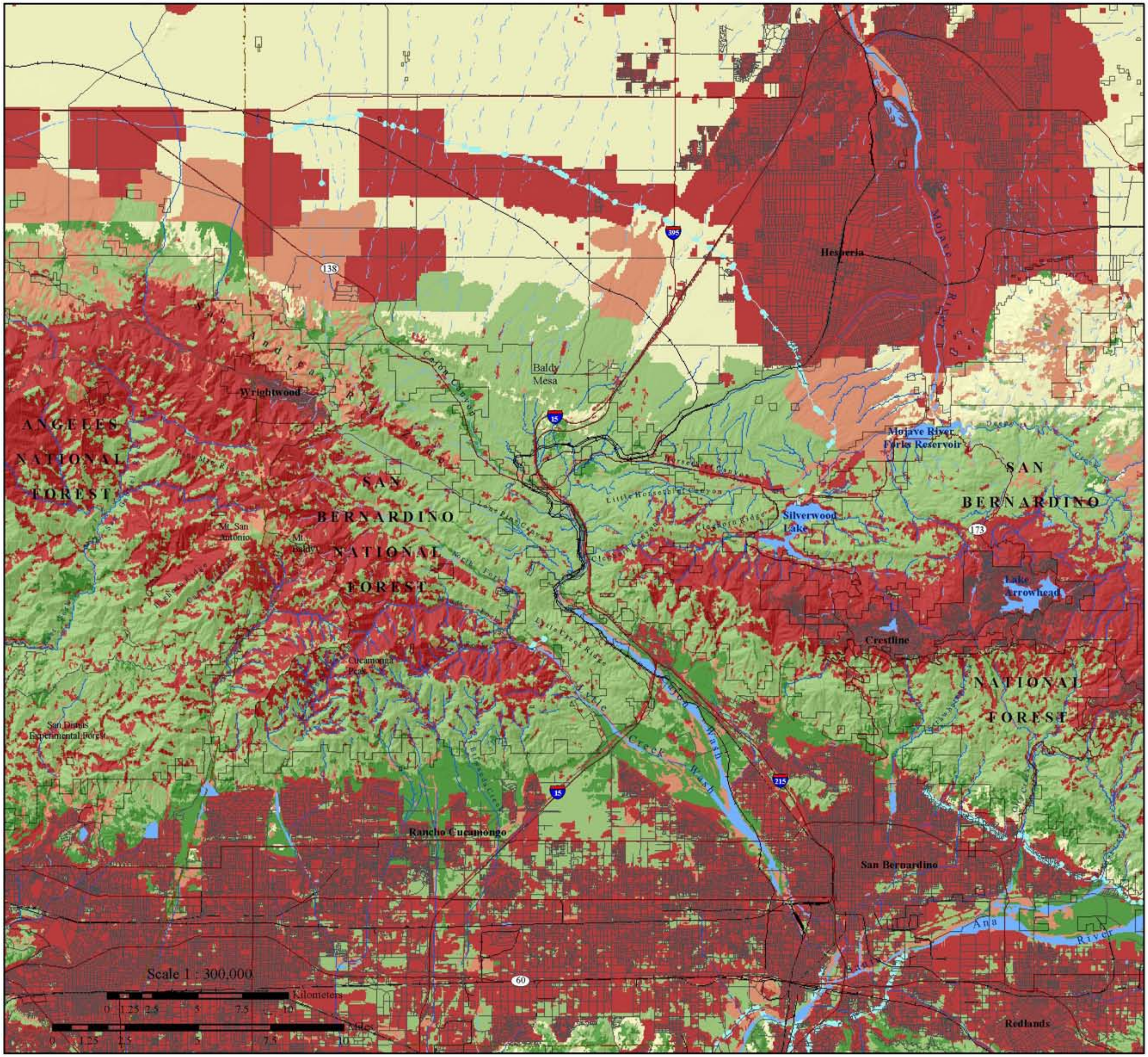
- Crossing structures for small mammals be placed fairly frequently to facilitate movement across major transportation routes (i.e., I-15, I-215) and reduce travel distance (Jackson and Griffin 2000, McDonald and St. Clair 2004);

- Short retaining walls, or other forms of barrier fencing, be installed in conjunction with crossing structures along paved roads in the Linkage Design to deter small mammals, amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000);

- Lighting is directed away from the linkage and crossing structures; and

- Local residents are informed about the proper use of rodenticides and pesticides to reduce the likelihood of ingestion of these lethal substances by small mammals indigenous to the area.

Figure 28.
Potential Habitat
for
Pacific Kangaroo Rat
(Dipodomys agilis)



Legend

Degree of Suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

N

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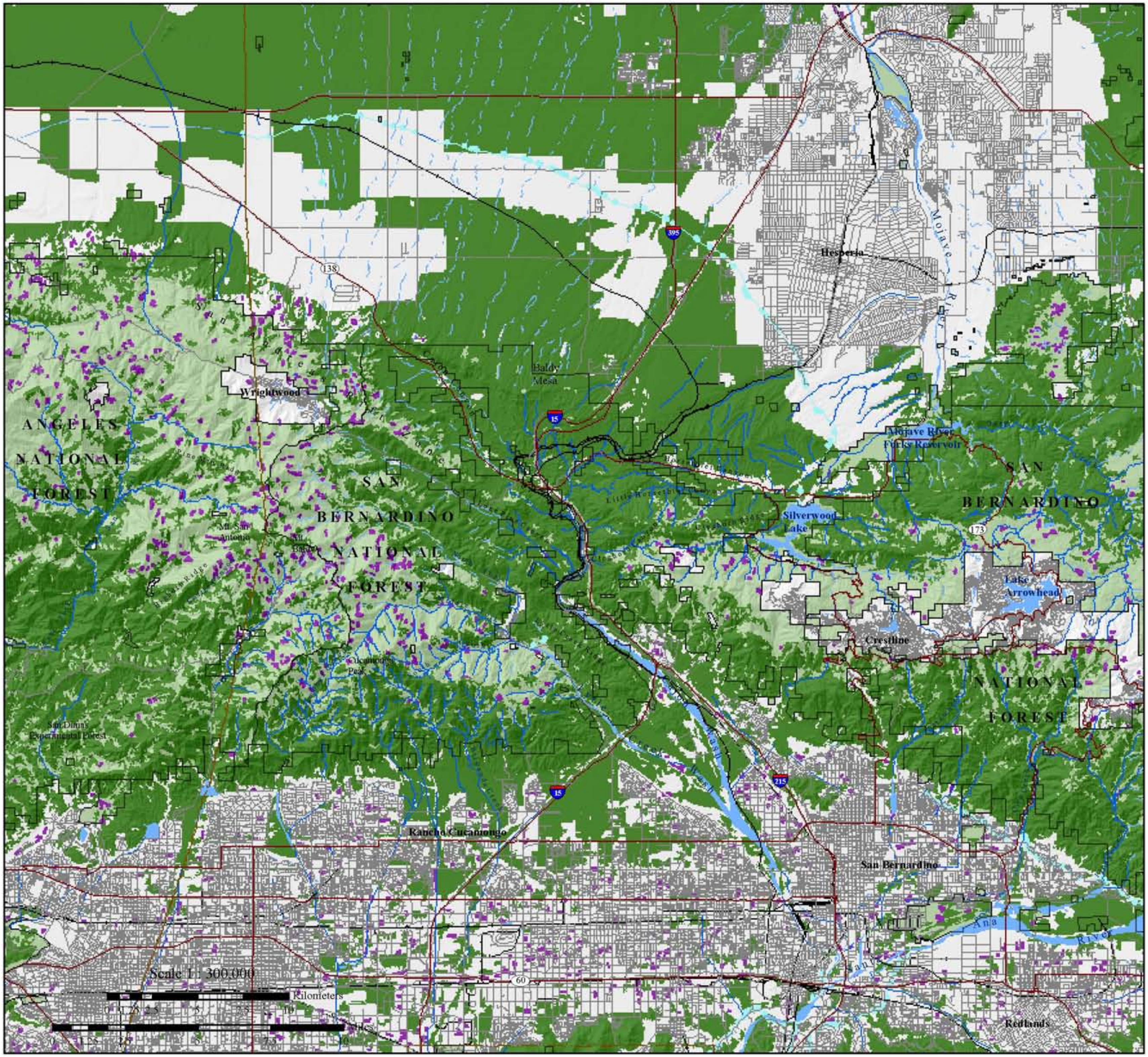
Figure 29.
Potential Cores & Patches for Pacific Kangaroo Rat
(Dipodomys agilis)

Legend

- Core
- Patch
- < Patch
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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California Spotted Owl (*Strix occidentalis occidentalis*)

Justification for Selection: The California spotted owl depends on extensive blocks of mature and old growth forests. Owl demography is strongly affected by forest fragmentation because successful juvenile dispersal depends on the proportion of the landscape that is forested (Harrison et al. 1993). Habitat fragmentation by roads has been shown to cause physiological stress in the northern subspecies (Wasser et a. 1997).

Distribution & Status: The California spotted owl is one of three subspecies, and the only one that inhabits the Sierra Nevada and southern California Coastal, Transverse, and Peninsular ranges (Remsen 1978, LaHaye et al. 1997). Their elevational range extends from lower than 305 m (1000 ft) to as high as 2591 m (8500 ft). Southern California populations are believed to function as a metapopulation, connected by infrequent but persistent interchange of individual owls among populations (LaHaye et al. 1994, Stephenson and Calcarone 1999). The largest subpopulation is the 200 plus territories in the San Bernardino and San Gabriel Mountains. Although Cajon Pass separates these two mountain ranges, there is not a major habitat discontinuity and only 6 miles separate the easternmost San Gabriel territory from the westernmost San Bernardino terriroty (Stephenson and Calcarone 1999). It is designated as a Federal and State Species of Special Concern (CDFG 2001), a Forest Service Sensitive Species, and was recently proposed for listing under the federal Endangered Species Act.

Habitat Associations: This species is associated with structurally complex mature or old growth hardwood, riparian-hardwood, hardwood-conifer, mixed and pure conifer habitats with substantial canopy cover (>70%) and majestic long-standing trees and snags (Verner et al. 1992, Gutiérrez et al. 1992, LaHaye et al. 1994, Moen and Gutiérrez 1997). Nest trees are typically the largest in the stand (Gutiérrez et al. 1992), which usually contains an accumulation of down woody debris with a well-developed soil layer (Verner et al. 1992). Foraging habitat for this subspecies can be more variable than its northern relative, sometimes hunting in chaparral, relatively open terrain for this species (Gutiérrez et al. 1992).

Spatial Patterns: This subspecies incorporates large tracts of mature and old growth forests into its home range (LaHaye et al. 1997), requiring extensive blocks of habitat between 40-240 ha (100-600 ac), that contain suitable nesting and roosting habitat, as well as available water (Forsman1976, CDFG 1990). In the mature Douglas-fir/hemlock forests of Oregon, Forsman et al. (1977) found home range to vary between 120-240 ha (300-600 ac), and similar home range sizes have been recorded in the Sierra Nevada (Gould 1974, CDFG 1990). Home ranges are generally spaced 1.6 to 3.2 km (1-2 mi) apart in appropriate habitat (Marshall 1942, Gould 1974, CDFG 1990). The distribution of prey has been found to strongly influence the size of an owl's home range (Carey et al. 1992, Zabel et al. 1995, Smith et al. 1999), and habitat use patterns (Carey et al.

1992, Carey and Peeler 1995, Zabel et al. 1995, Ward et al. 1998, Smith et al. 1999). Lower elevation habitats may be more productive due to higher prey densities in surrounding vegetative communities. Occupied habitat at lower elevations is typically dense, mature forest on north-facing slopes and deep canyons (Stephenson and Calcarone 1999).

Metapopulation analyses have estimated dispersal distances of 7-60 km (4.3-37.2 mi; LaHaye et al. 1994). However, shorter dispersal distances have been recorded. In the San Bernardino Mountain population, 67 males and 62 females dispersed 2.3-36.4 km (1.4-22.6 mi) and 0.4 –35.7 km (0.25-22.2 mi) respectively (LaHaye et al. 2001). Dispersal distances for spotted owls in other populations range from 5.8 km (3.6 mi; Ganey et al. 1998) to 56 km (35 mi; Gutiérrez et al. 1996). Several radio telemetry studies have been conducted (Miller et al. 1997, Ganey et al. 1998, Willey and van Riper 2000) that recorded even greater distances, up to 72.1 km (44 mi; *in* LaHaye et al. 2001).

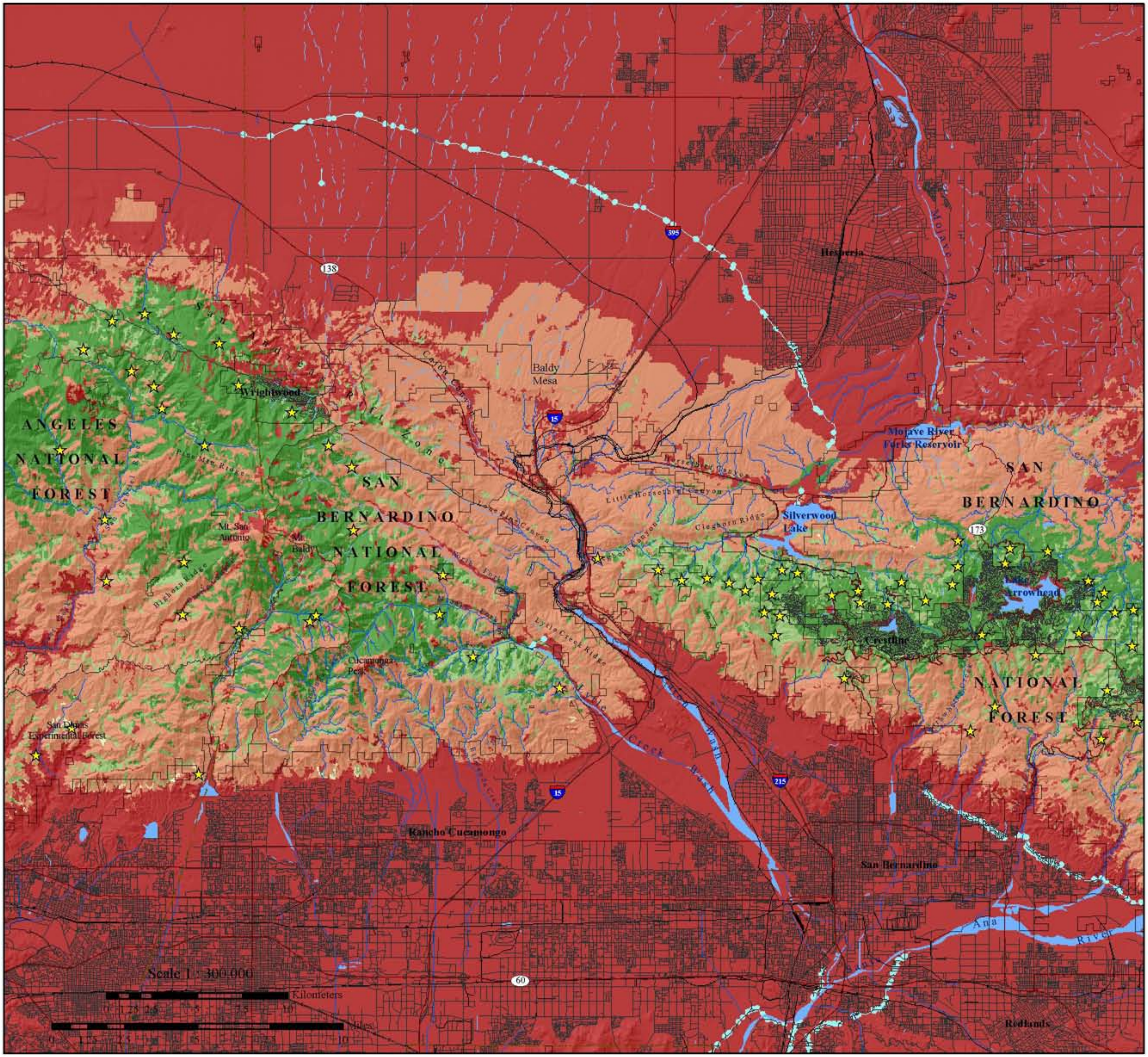
Conceptual Basis for Model Development: This species prefers structurally complex mature or old growth hardwood, riparian-hardwood, hardwood-conifer, mixed and pure conifer habitats. Home range sizes have been recorded from 40-240 ha. Patch size was classified as $\geq$ 240 ha but < 4,000 ha. Core areas potentially supporting 50 or more individuals was defined as $\geq$ 4,000 ha. Dispersal distance was defined as 144 km.

Results & Discussion: The results of the habitat suitability analysis correspond well with recorded spotted owl territories in montane hardwood and conifer habitats in both the San Gabriel and San Bernardino protected core areas (Figure 30). Two major core areas were identified by the patch size analysis (Figure 31). The central branch of the union is likely to accommodate spotted owl movement between these ranges. All suitable habitat patches are well within the maximum dispersal distance of 72.1 km. We conclude that the Least-Cost Union can sustain movement needs among populations of owls, serving a critical function of preserving this top predator. They are known to prey on woodrats in chaparral habitats, thus the linkage likely provides prime hunting habitat.

Research shows that northern spotted owls (*S. o. caurina*) living in close proximity to roads experienced higher levels of physiological stress than owls living in areas without roads (Wasser et a. 1997). To maintain and protect landscape level connectivity for California spotted owl between the San Gabriel and San Bernardino protected core areas, we recommend that:

- Existing road density be maintained or reduced; no new roads in the Linkage Design;
- Lighting is directed away from the linkage to provide a dark zone for nocturnally active species. Species sensitive to human disturbance avoid areas that are artificially lit (Beier 1995, Longcore 2000);
- Local residents are informed about the proper use of rodenticides and pesticides to reduce the likelihood of ingestion of these lethal substances by the natural predators of rodent species.

Figure 30.
Potential Habitat
for
California Spotted Owl
(Strix occidentalis occidentalis)



Legend

Degree of Suitability

- High
- Medium to High
- Medium
- Low to Medium
- Low
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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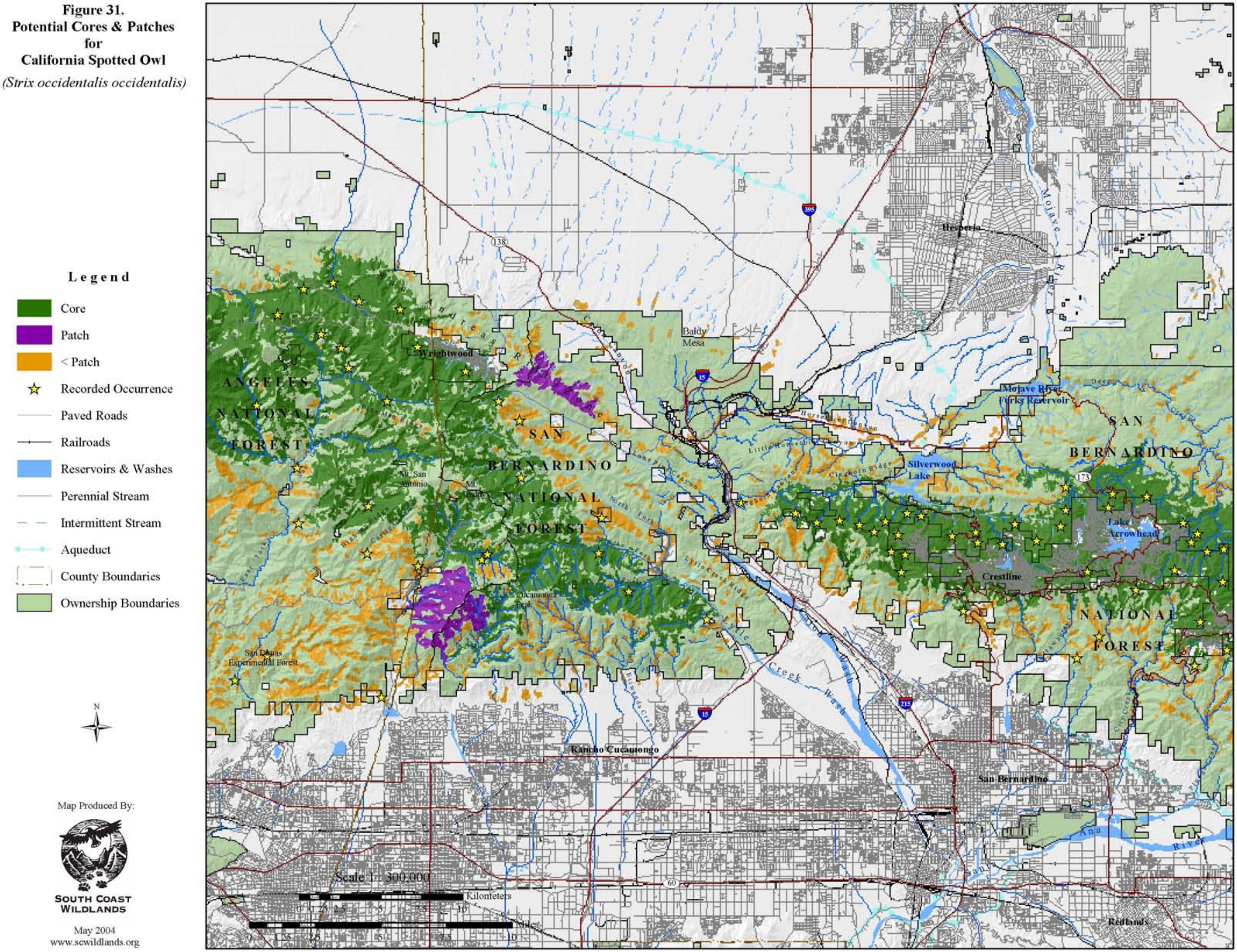
Figure 31.
Potential Cores & Patches for California Spotted Owl
(Strix occidentalis occidentalis)



Mountain Quail (*Oreortyx pictus eremophilus*)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Justification for Selection: Mountain quail require a mosaic of expansive habitats to persist. Habitat fragmentation adversely affects this species by making them more vulnerable to predation (Winter 2003). Quail are also weak flyers, either flying low to the ground, running, or walking.

Distribution & Status: Mountain quail are distributed from Washington and western Idaho south through Nevada and California to Baja California (Guitierrez and Delehanty 1999, USFS 2002). *O.p. eremophilus* is one of five recognized subspecies; they occur in the southern Sierra Nevada and central Coast Ranges, south through the Peninsular, Coast and Transverse Ranges to the Mexican border (USFS 2002). The distribution of Mountain quail and California quail (Callipepla californica) overlap in parts of their range, but they have distinct habitat requirements (Stephenson and Calcarone 1999). Mountain quail are typically found between 610-2743 m (2000-9000 ft) in elevation (Garrett and Dunn 1981, Stephenson and Calcarone 1999, USFS 2002). Prime habitat for mountain quail is extensive in both the San Gabriel and San Bernardino protected core areas (Stephenson and Calcarone 1999).

Over the last century, there has been a considerable decline of Mountain quail in the inter-mountain West. Populations have declined in Washington, Oregon, and Nevada due to livestock grazing, water development and fire exclusion. In southern California, low elevation habitats are being lost to urbanization (Gutierrez and Delehanty 1999, USFS 2002). This species has no special status; they are designated as a California Harvest Species (Winter 2003).

Habitat Associations: Mountain quail are associated with densely vegetated habitat, on steep slopes in rugged terrain (Leopold et al. 1981, Brennan et al. 1987, Stephenson and Calcarone 1999, Gutierrez and Delehanty 1999, USFS 2002). They inhabit shrub-dominated and forested habitat that is structurally complex, including pinyon-juniper-yucca associations, dense chaparral dominated by Ceanothus spp., manzanita, and scrub oak, desert scrub, mixed conifer/hardwood forests, foothill woodlands, riparian and oak woodlands (Garret and Dunn 1981, Zeiner et al. 1990, Gutierrez and Delehanty 1999). Within these plant communities, they forage on plant material and invertebrates (Gutierrez and Delehanty 1999, USFS 2002).

Spatial Patterns: Mountain quail are never far from water and escape cover (Brennan et al. 1987, Gutierrez and Delehanty 1999, USFS 2002, RCIP 2003). In addition to using dense vegetation for cover, they may also use rocks, boulders, and logs (Gutierrez and Delehanty 1999, USFS 2002). Brennan et al. (1987) found the average distance to cover was 0.83 m (2.72 ft) and to water was 131 m (430 ft). In summer, broods of young are typically no more than 0.8 km (0.5 mi) from water (Zeiner et al. 1990).

Mountain quail migrate between breeding habitat at higher elevations and wintering habitat at lower elevations (Gutierrez and Delehanty 1999, USFS 2002). Outside of the breeding season, Mountain quail form coveys that consist of family groups, multiple families, or nonbreeding adults (Gutierrez and Delehanty 1999, USFS 2002). Mountain quail coveys are relatively small, typically consisting of fewer than 15 birds (Leopold et al. 1981, Stephenson and Calcarone 1999). Densities in northern California ranged from 9 to 30 birds per 100 ha (247 ac; Brennan et al. 1997, RCIP 2003). In California, a breeding pair occupied 2-20 ha (5-50 ac; Johnsgard 1973). While in Idaho, home range averaged about 260 ha (642 ac) in a sedentary population (Ormiston 1966, RCIP 2003). Isolated fragments less than 1 km^2 (247 ac) usually lack quail populations (Crooks and Soulé 1999, Crooks et al. 2001, Crooks et al. 2004).

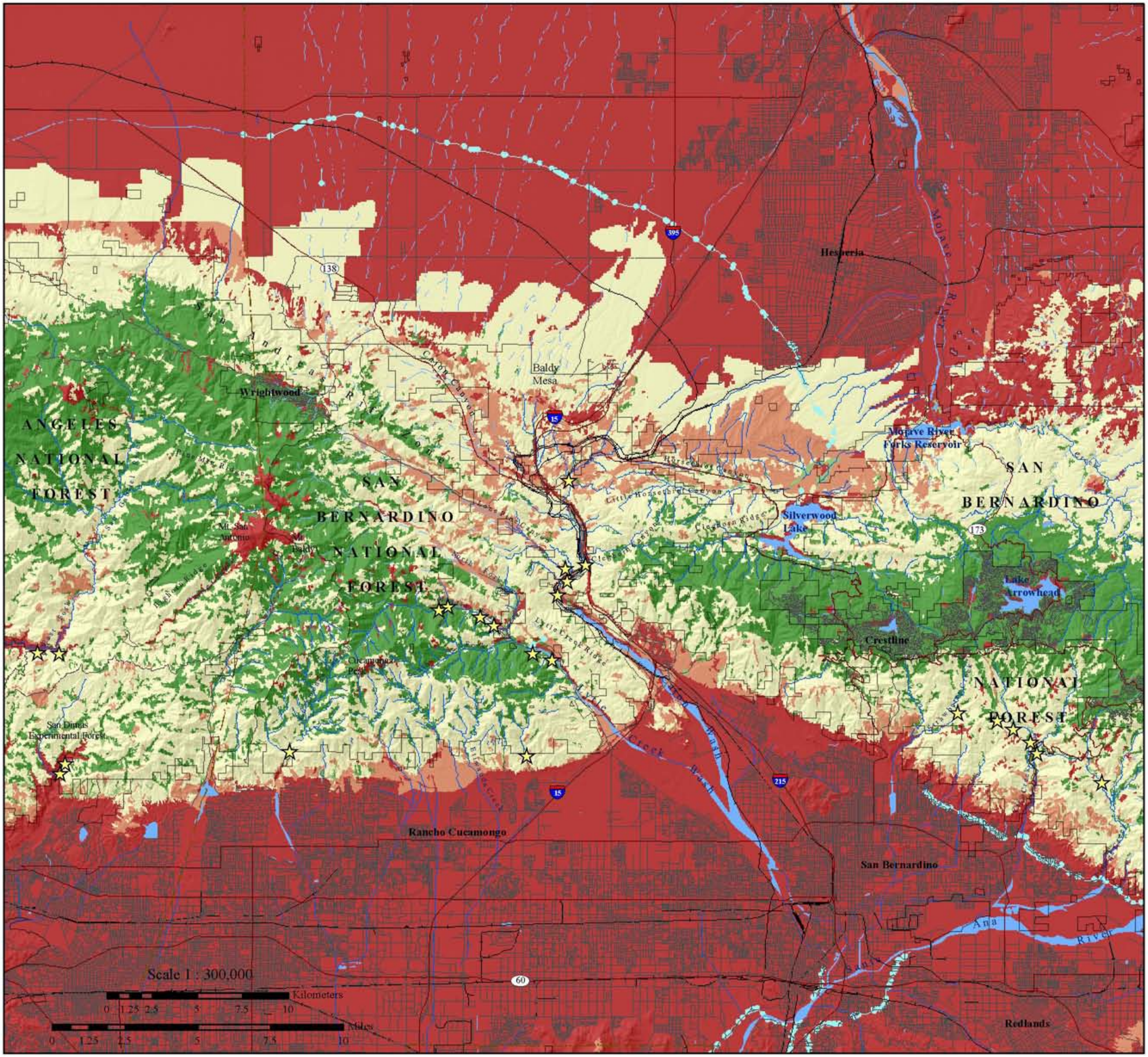
Research hasn't been conducted on natal and postbreeding dispersal of Mountain quail (Gutierrez and Delehanty 1999, USFS 2002). Pope and Crawford (1998) radio-collared both resident and translocated birds. One resident bird moved 3.7 km (2.3 mi). The longest recorded movement was of a translocated bird that traveled 30 km (19 mi), while another moved 25 km (16 mi), evidently crossing long stretches of rugged and unsuitable habitat to get to appropriate nesting habitat (Pope and Crawford 1998). Mountain quail seasonally migrate, covering even greater distances up to 32 km (20 miles; Zeiner et al. 1990, Gutierrez and Delehanty 1999, USFS 2002, RCIP 2003). Preferred travel routes include ravines and valleys during fall migration, and ridgetops during spring migration (Miller 1950, Gutierrez and Delehanty 1999).

Conceptual Basis for Model Development: Mountain quail inhabit pinyon-juniper-yucca associations, dense chaparral dominated by Ceanothus spp., manzanita, and scrub oak, desert scrub, mixed conifer/hardwood forests, foothill woodlands, riparian and oak woodland habitats, between 610-2743 m in elevation. Core areas were defined as $\geq$ 500 ha. Patch size was defined as $\geq$ 4 ha but less than 500 ha. Dispersal distance was defined as 64 km.

Results & Discussion: The most highly suitable habitat for Mountain quail was identified in the higher elevation montane hardwood, mixed conifer, and chaparral habitats (Figure 32). Extensive core habitat exists in both ranges (Figure 33). The central branch of the Least Cost Union likely facilitates movement of Mountain quail between the San Gabriel and San Bernardino Ranges, with several recorded occurrences in the vicinity of Cleghorn Canyon. Habitat added for other species in Horsethief Canyon will also benefit this species. To protect and restore connectivity for Mountain quail, we recommend that:

- Inholdings that could fragment habitat and introduce non-native predators (e.g., dogs, cats; Winter 2003) be conserved through conservation easements, fee title agreements, acquisition, or other means;
- Crossing structures are modified to facilitate quail movement; and
- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland (Winter 2003).

Figure 32.
Potential Habitat
for
Mountain Quail
(Oreortyx pictus eremophilus)



Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurrence
- Railroads
- Paved Roads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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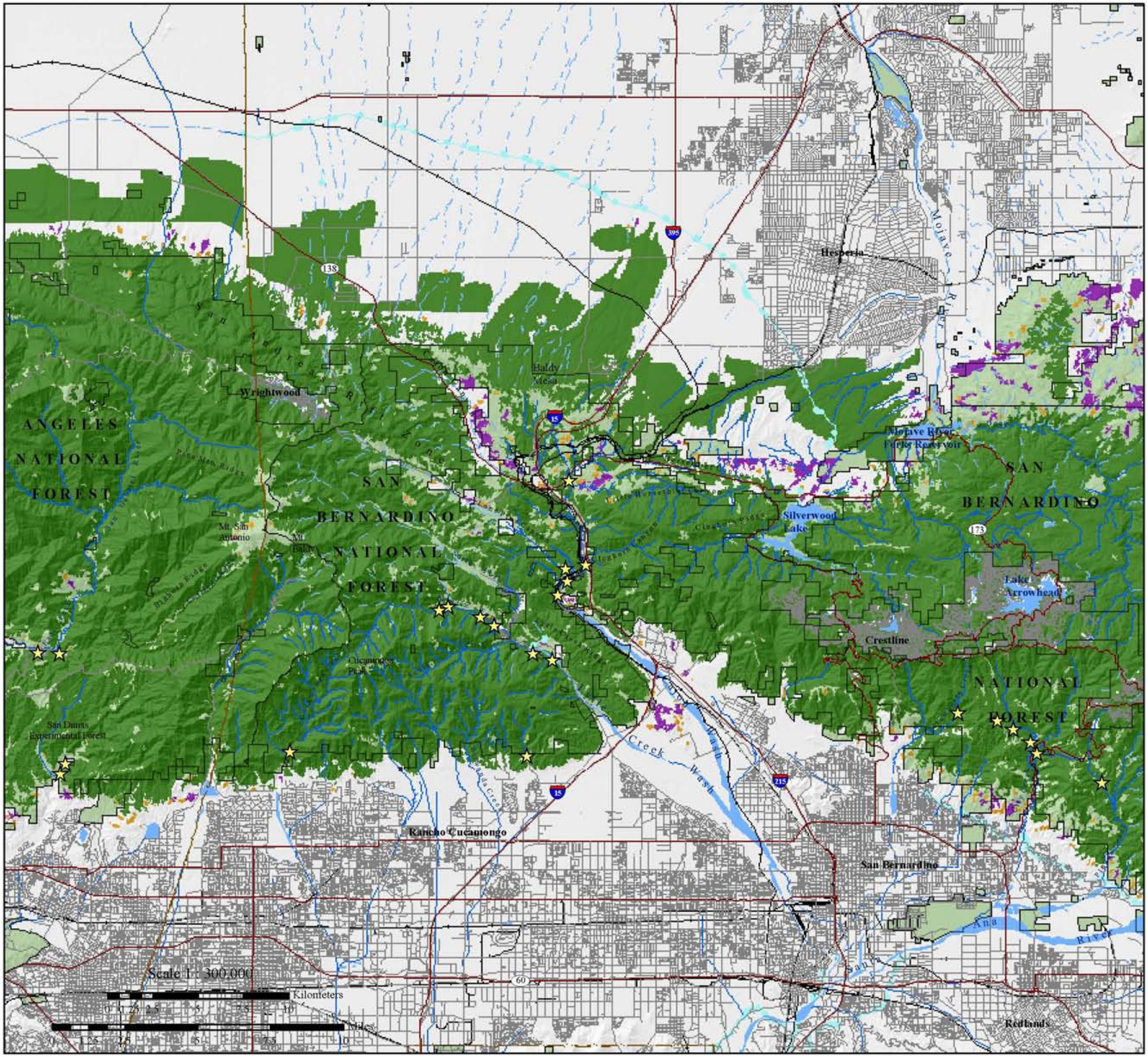
Figure 33.
Potential Cores & Patches for Mountain Quail
(Oreortyx pictus eremophilus)



Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

N

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Pygmy nuthatch (*Sitta pygmaea melanotis*)

Justification for Selection: As a cavity nester dependent on large snags, the Pygmy nuthatch serves as an indicator species for mature ponderosa pine forests (Ghalambor 2003). Pygmy nuthatches have limited dispersal abilities and therefore need greater connectivity between suitable habitat patches to promote genetic exchange among subpopulations (Ghalambor 2003).

Distribution & Status: *S. p. melanotis* is one of six recognized subspecies. *S. p. melanotis* has the largest and most discontinuous range of all the subspecies, occurring from southern British Columbia east to the Black Hills of South Dakota, to southern California and northern Mexico (Ghalambor 2003), up to elevations of 3050 m (10000 ft; Shuford and Metropulos 1996, Ghalambor 2003). Their distribution largely follows the scattered distribution of ponderosa and other yellow pines. They are found throughout the mountain ranges of southern California, including the San Gabriel and San Bernardino Mountains (Garret and Dunn 1981, Ghalambor 2003). The Pygmy nuthatch has no special conservation status.

Habitat Associations: Pygmy nuthatches are residents of western yellow pine forests, preferring those dominated by ponderosa pine (*Pinus ponderosa*). In California, they favor mature stands of ponderosa and Jeffrey pines (*P. jeffreyi*), but may also be found in mixed conifer, eastside pine, and pinyon-juniper habitats (Gaines 1988, Zeiner et al. 1990, Ghalambor 2003). They've also been recorded in open stands of large lodgepole pine (*P. murrayana*) in the White Mountains (Shuford and Metropulos 1996, Ghalambor 2003). They forage on and cache pine seeds within these habitats, but also prey upon insects and spiders during the breeding season (Bent 1948).

Pygmy nuthatches are highly communal, sociable species that breed cooperatively, which is unusual for North American songbirds (Norris 1958, Ghalambor 2003). They excavate cavities in snags for nesting and roosting, relying on cavities throughout the year. The locations of communal roost cavities are largely determined by the weather, with groups changing cavities seasonally for protection from outside temperatures (Hay 1983, Ghalambor 2003).

Spatial Patterns: With such a dependence on snags, it's not surprising that Pygmy nuthatches reach their highest densities in mature pine forests with plenty of snags (Ghalambor 2003). Norris (1958) evaluated 7 studies from California, Colorado and Mexico and found an average density of 19.5 males per 40 ha (100 ac), with a range between 5.3 and 33 males per 40 ha. Territory size may fluctuate depending on the density of pines, cavity availability, and the presence or absence of helpers (Norris 1958, Ghalambor 2003). Estimates of territory size vary by habitat type, ranging from 0.54 to 8.15 ha (1.33-20.1 ac; Norris 1958, Balda 1967, Storer 1977, Ghalambor 2003). In Marin County, territory size ranged from 0.8 to 1.3 ha (1.9 –3.3 ac), with an average of 1.1 ha (2.7 ac; Norris 1958). Each pair occupies a foraging territory year-round. Territories may overlap, but are defended during the breeding season (Bock 1969, Ghalambor 2003).

Norris (1958) evaluated natal dispersal in Pygmy nuthatches and found one male established a territory 165 m from his place of birth. Natal dispersal in females wasn't evaluated but it is expected to be further than males. First year birds established breeding sites over 4 times further from their birthplaces than the typical distance adults travel between breeding territories, with young birds moving an average of 286.5 m (940 ft) with a range of 0.6-533 m (2-1749 ft) (Norris 1958, Ghalambor 2003).

However, more significant movements can occur during post-breeding dispersal and winter wandering, when individuals may be observed in atypical habitats (Bent 1948, Garrett and Dunn 1981, Ghalambor 2003). Pygmy nuthatches have been recorded in coastal Santa Barbara County (Lehman 1994, Ghalambor 2003), and San Diego County (Unitt 1984).

Conceptual Basis for Model Development: Pygmy nuthatch movement in the linkage is likely multigenerational. This species prefers high elevation mature yellow pine forests, dominated by Ponderosa or Jeffrey pines, but will also utilize mixed conifer habitats. Core areas were define as $\geq$ 28 ha. Patch size was classified as $\geq$ 2 ha, but less than 28 ha. Dispersal distance was defined as 1066 m, twice the longest recorded movement.

Results & Discussion: The most highly suitable habitat for pygmy nuthatch was identified in the high elevation coniferous habitats (Figure 34). Large core areas were identified in both ranges (Figure 35), with small patches of habitat leading down Cleghorn Canyon. However, the patch configuration analysis suggests that populations in the San Gabriel and San Bernardino Mountains may be functionally isolated from one another, separated by distances to great for the species to traverse (Figure 36). Though they've been recorded away from coniferous mountain habitats, so movement through chaparral habitats between core areas may still be possible (Unitt 1984, Lehman 1994, Ghalambor 2003). This species has very limited dispersal capabilities, limiting opportunities for genetic exchange among populations (Ghalambor 2003). Where timber harvesting has reduced the number of snags, the number of breeding pairs declines (McEllin 1979a, Brawn 1987, Brawn and Balda 1988 a, Bock and Fleck 1995, Ghalambor 2003). To protect and restore habitat for Pygmy nuthatch, we recommend that:

- Snags are retained, at a range of between 5 to 12 per hectare (Balda 1975, Scott 1979, Diem and Zeveloff 1980, Clark et al. 1989, Ghalambor 2003). Clark et al (1989) proposed snags should be relatively large in diameter;

- The natural fire regime is restored or mimicked to benefit this species, since fire is essential in creating snags (Covington and Moore 1994, Arno et al. 1995, Fule and Covington 1995, Ghalambor 2003); and

- Special efforts should be made to restore and maintain Bigcone Douglas fir stands in Cajon Pass and adjacent canyons.

Figure 34.
Potential Habitat
for
Pygmy Nuthatch
(Sitta pygmaea melanotis)

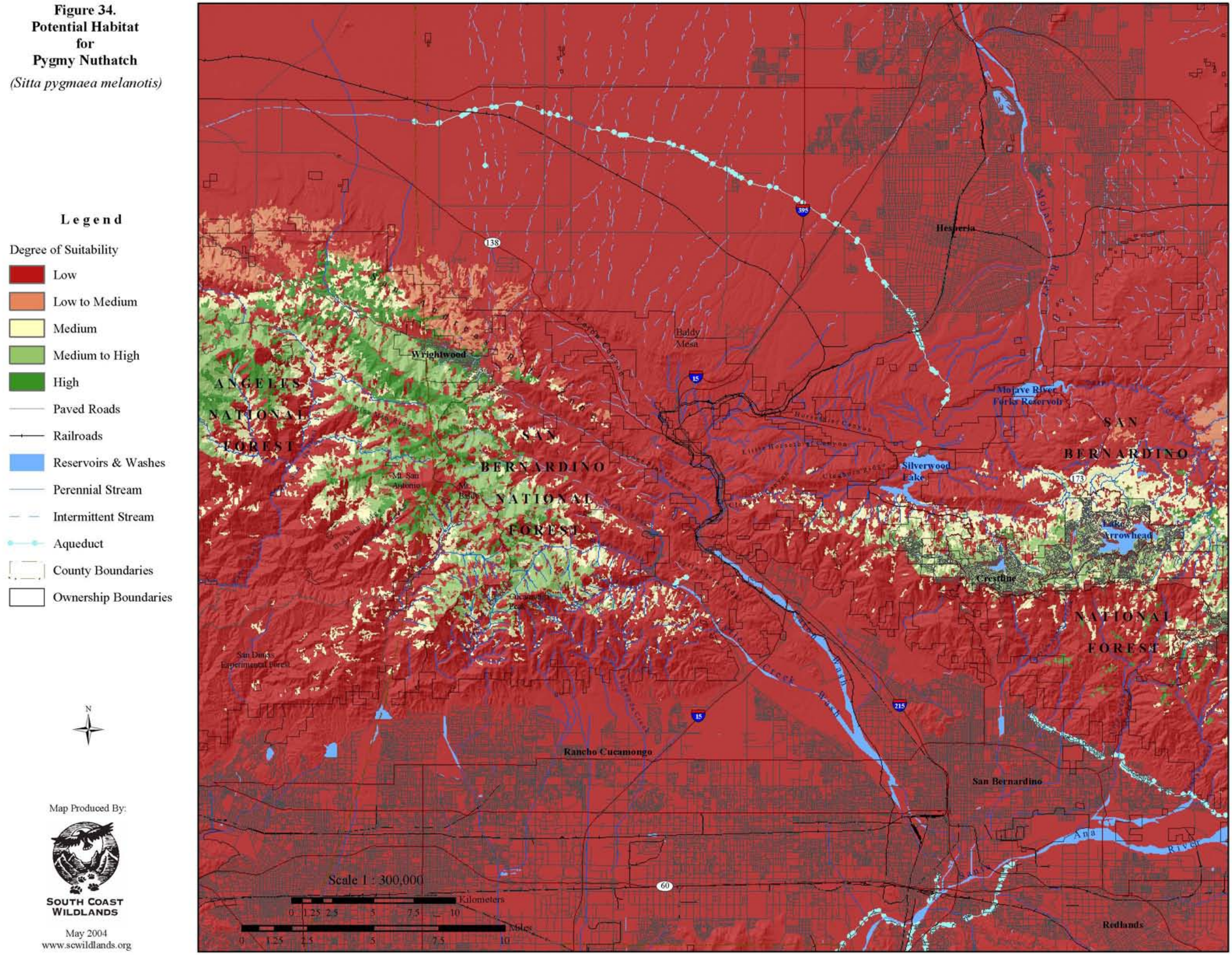

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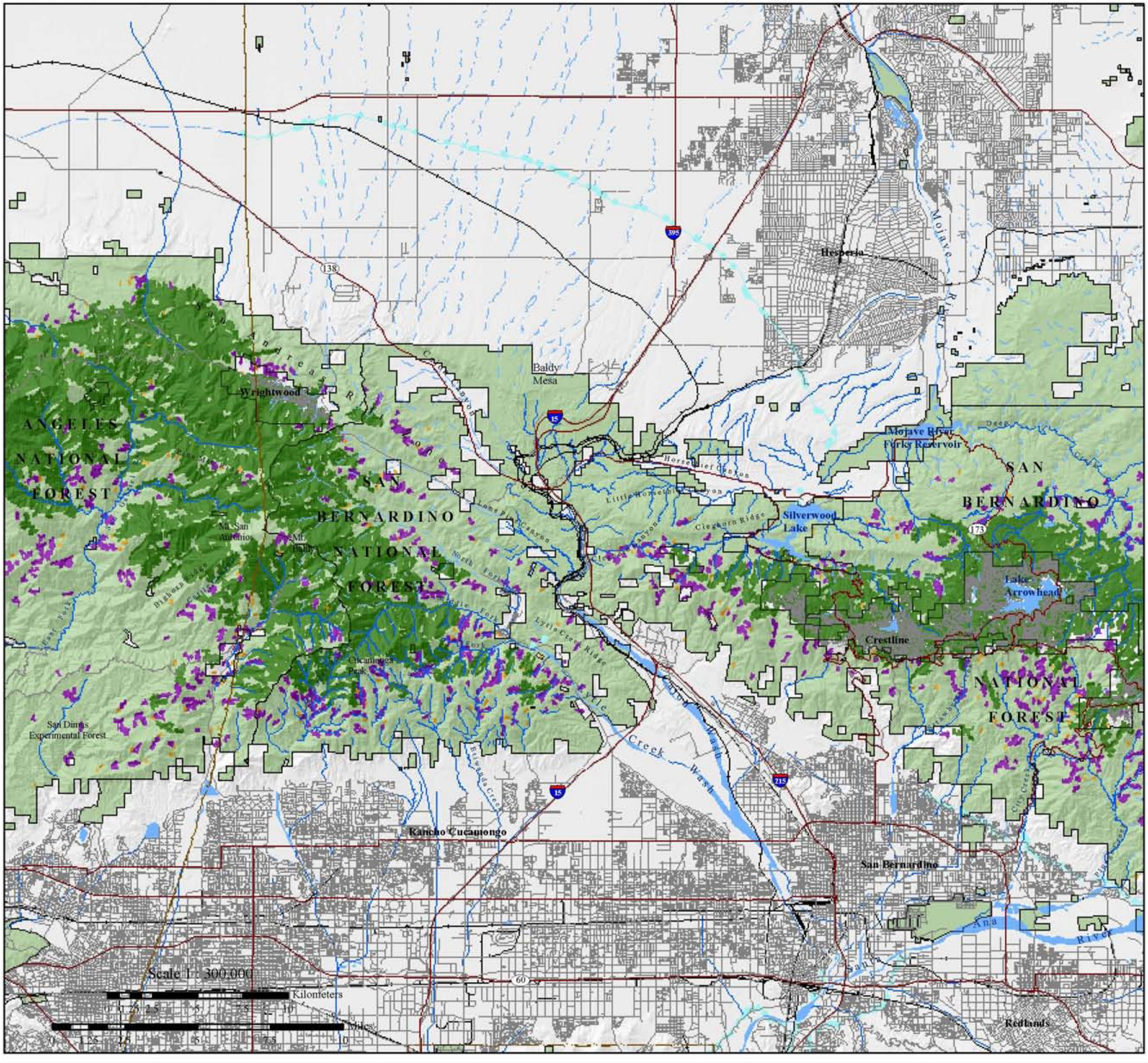
Figure 35.
Potential Cores & Patches
for
Pygmy Nuthatch
(Sitta pygmaea melanotis)



Legend

- Core
- Patch
- < Patch
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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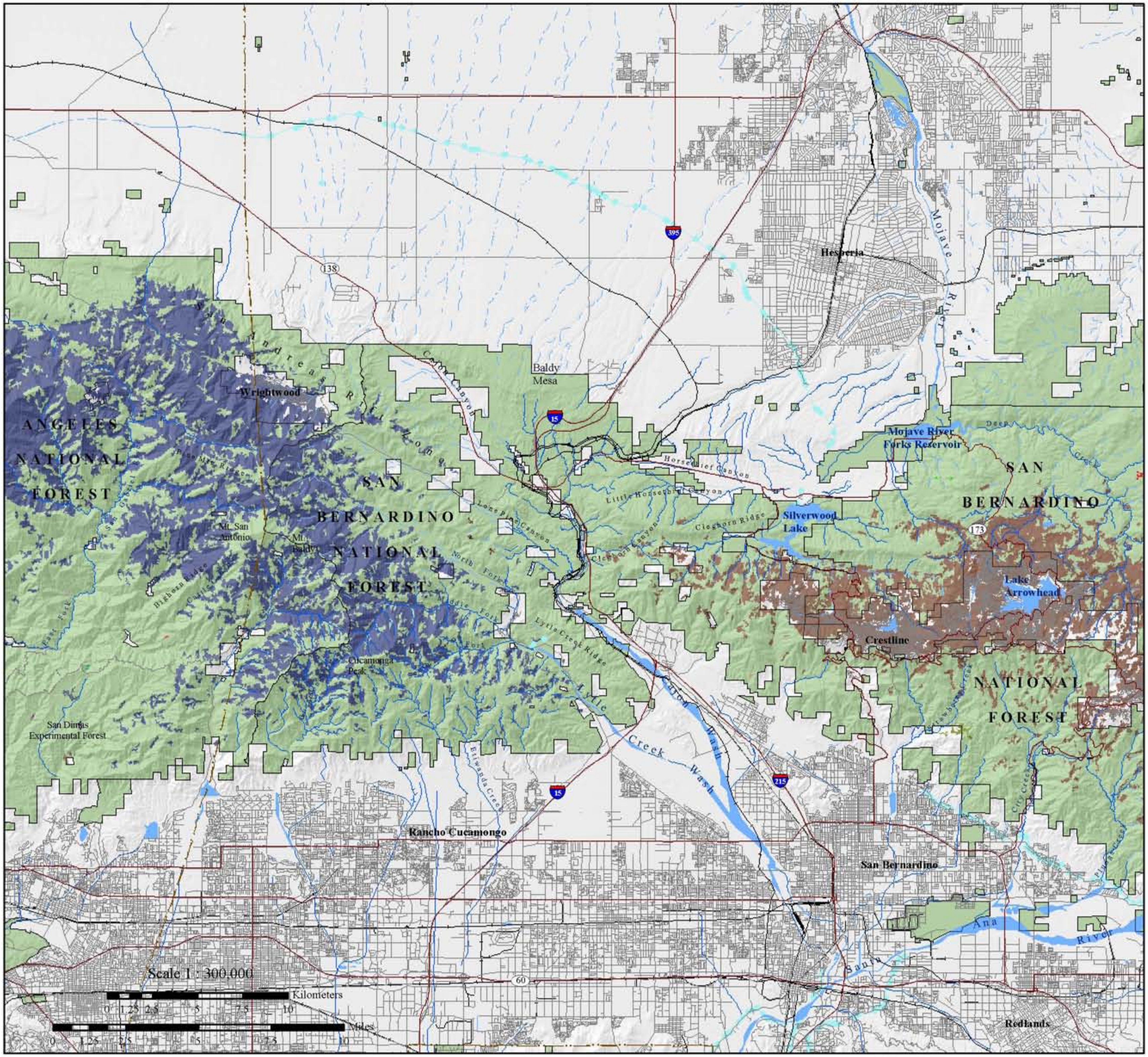
Figure 36.
Potential Cores & Patches
for
Pygmy Nuthatch
(Sitta pygmaea melanotis)

Legend

- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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Rock Wren (*Salpinctes obsoletus*)

Justification for Selection: The Rock wren is considered a habitat specialist because of their reliance upon environments that are very patchily distributed in the landscape. They are also believed to have limited dispersal abilities.

Distribution & Status: Rock wrens have a vast geographic distribution, ranging from British Columbia to Central America and from the Pacific Coast eastward to the Great Plains (American Ornithologist Union 1998, Oppenheimer and Morton 2000). In southern California, they occur in the coastal lowlands, from northern San Luis Obispo County south to San Diego County (Small 1994). Rock wren have one of the broadest altitudinal ranges of any North American bird (Small 1994); nests have been discovered at 75 m (246 ft) below sea level in Death Valley and as high as 4267 m (14000 ft) in the Sierra Nevada and White Mountains (Grinnell and Miller 1944, Small 1994, Oppenheimer and Morton 2000). The Rock wren has no special status.

Habitat Associations: Although their range encompasses a huge area, they occupy a very specialized niche (Small 1994, Oppenheimer and Morton 2000). Rock wrens may be found in a variety of open habitats, including Great Basin scrub, desert scrub, chaparral, deep-cut arroyos, dry gravelly washes, and perennial grassland (Grinnell and Miller 1944, Bent 1948, DeSante and Ainley 1980, Small 1994, Zeiner et al. 1990), as well as pinyon juniper woodland and the Bristlecone-Limber Pine Zone (Morrison et al. 1993). Within these habitats, they are restricted to rocky outcrops, talus slopes, cliffs, and earthen banks, which provide refuge, foraging and breeding sites (Grinnell and Miller 1944, Bent 1948, DeSante and Ainley 1980, Zeiner et al. 1990, Oppenheimer and Morton 2000). They may also utilize small mammal burrows (Small 1994).

Spatial Patterns: No information on home range or territory size was available in the literature, though several density estimates exist (Zeiner et al. 1990). In eastern Oregon, Anderson et al. (1972) found 25 breeding males per 40 ha (100 ac) in juniper-sage habitat. In Montana, Walcheck (1970) recorded 5 pairs per 40 ha (100 ac) in pine-juniper woodland. While in Arizona, Hensley (1954) observed 5-8 pairs of Rock wrens per 40 ha (100 ac) in the Sonoran Desert.

Research on the movement ecology of this species is also lacking. Populations at higher elevations apparently move downslope in winter, while populations further north may migrate southward (Grinnell and Miller 1944, DeSante and Ainley 1980, Zeiner et al. 1990).

Conceptual Basis for Model Development: Rock wren movement in the linkage is likely multigenerational. They may utilize a variety of open habitats, including Great

Basin scrub, desert scrub, pinyon juniper woodland, deep-cut arroyos, dry gravelly washes, perennial grassland, as well as, rocky outcrops and barren areas within chaparral, montane hardwood conifer and mixed coniferous forests. Core areas were defined as $\geq$ 240 ha. Patch size was classified as $\geq$ 3.2 ha but less than 240 ha. Dispersal distance was not estimated for this species.

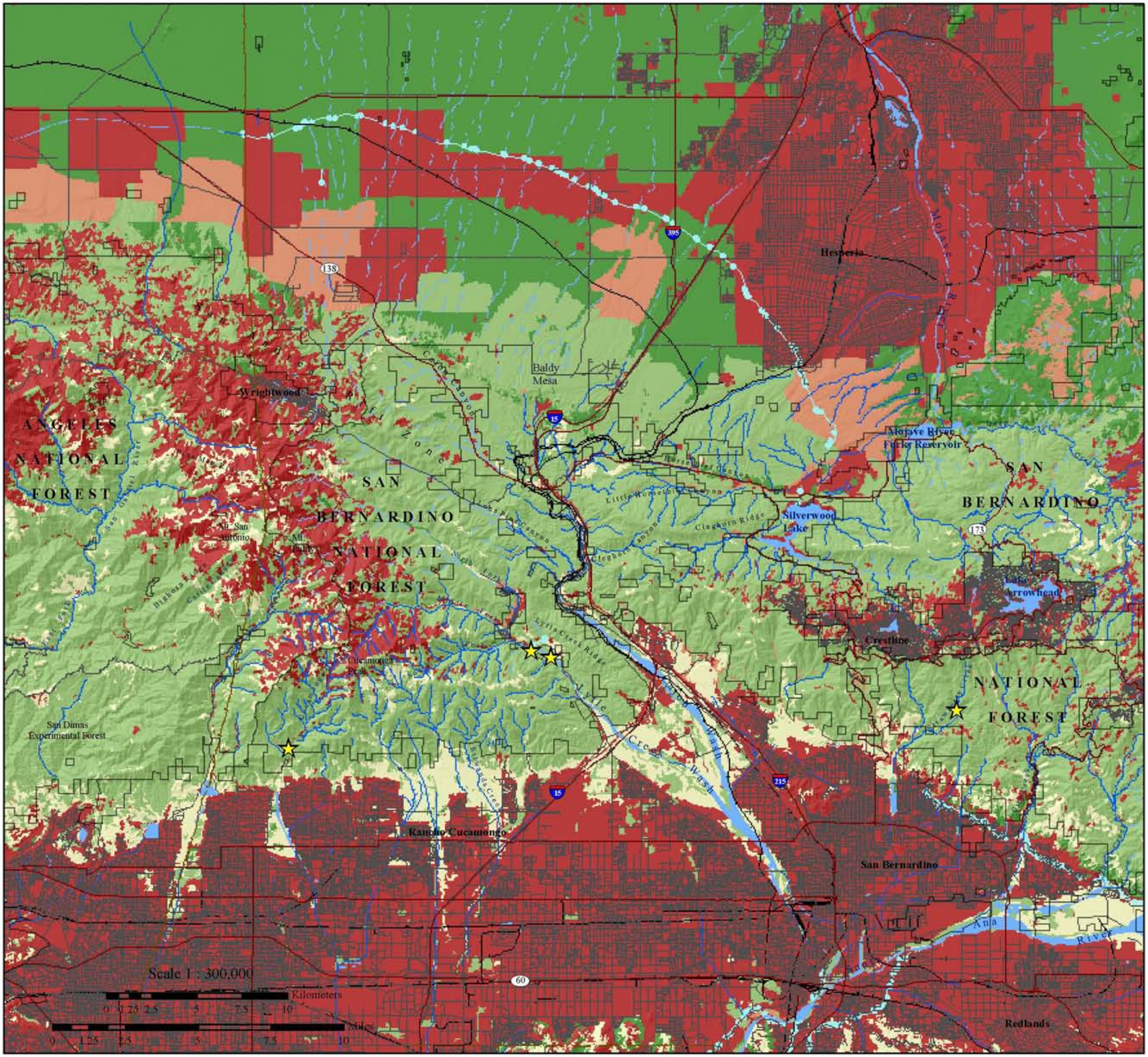
Results & Discussion: The habitat suitability analysis likely overestimates the amount of highly suitable habitat for Rock wren (Figure 37), since the scale of the data isn't fine enough to capture this species specialized niche. However, the rocky outcrops preferred by this species can be found in a number of communities that occur within the Least Cost Union (Figure 38). We conclude that the Least Cost Union is likely to serve the needs of this species. Though habitats added to support the needs of other focal species would also benefit this species. To protect and maintain habitat for Rock wren, we recommend that:

- Inholdings that could fragment habitat and introduce non-native predators (e.g., dogs, cats; Winter 2003) be conserved through conservation easements, fee title agreements, acquisition, or other means;

- Riparian and upland buffers at least 2 km wide are imposed throughout the linkage, where feasible; and

- Rock collecting in creeks and washes is discouraged, due to resulting changes in habitat structure and possible disruption of nests.

Figure 37.
Potential Habitat
for
Rock Wren
(Salpinctes obsoletus)



Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurrence
- Railroads
- Paved Roads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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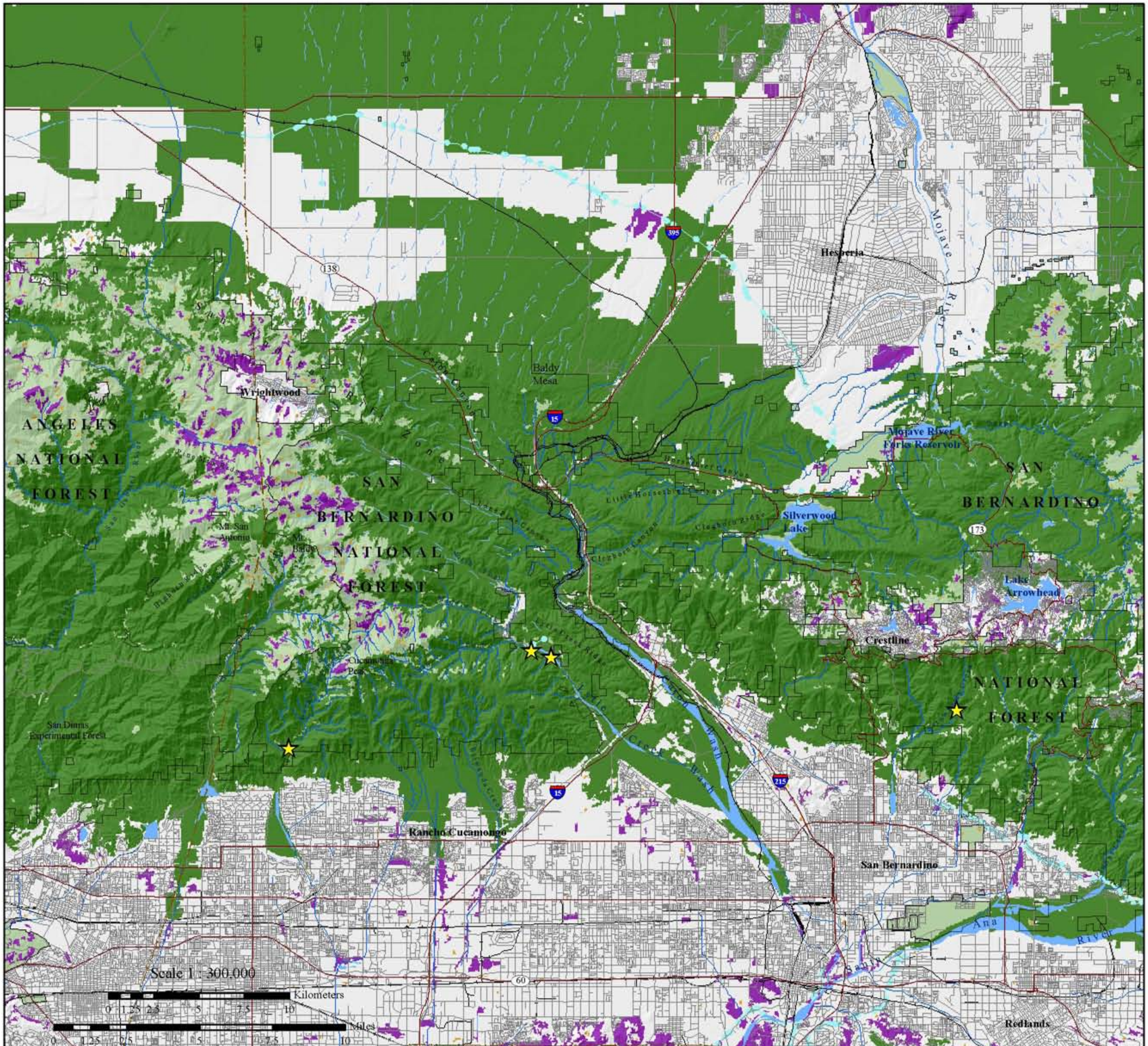
Figure 38.
Potential Cores & Patches for Rock Wren
(Salpinctes obsoletus)



Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Railroads
- Paved Roads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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Wrentit (Chamaea fasciata *henshawi*)

Justification for Selection: The Wrentit has been identified as an indicator species for Mediterranean scrub habitats, which are extremely threatened in southern California (Soulé et al. 1988, Chase et al. 2000, Crooks et al. 2001). They are highly sensitive to habitat fragmentation and are reluctant to cross roads, trails and firebreaks since they rarely venture far from cover (Small 1994). Wrentits require core habitat to persist (Crooks et al. 2001, Crooks et al. 2004).


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Distribution & Status: The Wrentit is virtually a California endemic, though it occurs from near the Oregon state line to the Mexican border. They are generally distributed west of the Cascades, the Sierra Nevada crest and the desert (Small 1994, Barhoum and Burns 2002). This species is not closely related to any other New World species (Barhoum and Burns 2002). Seven subspecies have been described, *C.f. henshawi* occurs within the study area (Geupel and Ballard 2002. Geupel et al. 2002). Wrentits typically breeds from sea level to near 2300 m (7546 ft; Geupel et al. 2002), but it has been found postbreeding up to 2500 m (8200 feet) in the San Jacinto Mountains (Garrett and Dunn 1981, Small 1994).

Extensive habitat has been lost to urbanization in coastal southern California, less than 10% of the native coastal sage scrub habitat remains (Jensen et al. 1990). Habitat loss and fragmentation have isolated remaining habitat patches, limiting opportunities for dispersal and re-colonization, and increasing opportunties for the Wrentit's predators (Geupel et al. 2002). The Wrentit isn't afforded any special status.

Habitat Associations: The Wrentit is strongly associated with scrub habitats and is recognized as the voice of the chaparral. They inhabit lowland hard and montane chaparral, coastal sage scrub, northern coastal scrub, or other habitats with a dense, structurally complex understory (Grinnell and Miller 1944, Zeiner et al. 1990, Small 1994, Geupel et al. 2002). They may also be encountered in well-developed riparian habitats that contain oaks (*Quercus* sp.), willow (*Salix* sp.) scrub, Coyote bush (*Baccahris* sp.), poison oak (*Toxicodendron* sp.), and blackberry (*Rubus* sp.) thickets (Small 1994, Geupel et al. 2002). They may also utilize shrubby understories in some coniferous habitats (Grinnell and Miller 1944, Geupel et al. 2002).

Spatial Patterns: Home range size is believed to be the same as territory size (Zeiner et al. 1990). Territories are typically smaller in denser scrub communities (Erickson 1938, Geupel et al. 2002). A recent study in coastal California (Geupel et al. 2002), studied territories of 105 pairs that averaged 0.62 ha (1.53 ac), with a range from 0.24 to 2.15 (0.59 to 5.31 ac). Cogswell (1962) evaluated 361 pairs and reported smaller territories in Los Angeles County that averaged 0.5 ha (1.3 ac), with a range of 0.2 to 1.2 ha (0.5 to

3.0 ac). Other studies in Los Angeles County reported similar results (Mans 1961, Kingery 1962). Nevertheless, Wrentits are likely to extirpated from habitat fragments smaller than 10 ha (24.7 ac) in size (Soulé et al 1988, Crooks et al. 2001, Crooks et al. 2004).

Natal dispersal distances of Wrentits average less than 400 m (1,312 ft) (Baker et al. 1995, Geupel et al. 2002). They typically stay within their territories, though outside of the breeding season off-territory movements less than 500 m (1,640 ft) may occur (Geupel et al. 2002). In moutainous regions, juveniles may move upslope after the breeding season (Garrett and Dunn 1981, Small 1994).
.

Conceptual Basis for Model Development: Movement in the linkage is likely multigenerational. The Wrentit requires dense habitats with plenty of cover. They prefer chaparral and coastal sage scrub, but may also be found in other habitats with dense cover. Core areas were defined as 14 ha, while patch size was classified between $\geq$ 1 ha but less than 14 ha. Dispersal distance was defined as 1 km.

Results & Discussion: The most highly suitable habitat for Wrentit occurs along the foothills and up through the pass to Baldy Mesa (Figure 39), the majority of which was identified as core habitat for this species (Figure 40). All three branches of the Least Cost Union contain suitable habitat for this species, though the central branch is most likely to serve this species as it captured the most contiguous block of highly suitable habitat and contains the majority of recorded occurrences.

Habitat loss and fragmentation is an issue for this species throughout much of their range. They are largely absent from smaller habitat patches (Soulé et al 1988, Crooks et al. 2001). To protect and restore habitat connectivity for Wrentits, we recommend that:

- Inholdings that could fragment habitat and introduce non-native predators (e.g., dogs, cats; Winter 2003) be conserved through conservation easements, fee title agreements, acquisition, or other means;

- Minimum width of 2 km buffer be imposed throughout the linkage design in chaparral and scrub habitats;

- Fire frequency be controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland (Winter 2003); and

- Crossing structures be expansive enough to allow scrub vegetation to grow through the structure, where feasible.

Figure 39.
Potential Habitat
for
Wrenttit
(Chamaea fasciata henshawi)

Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurence
- Railroads
- Paved Roads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

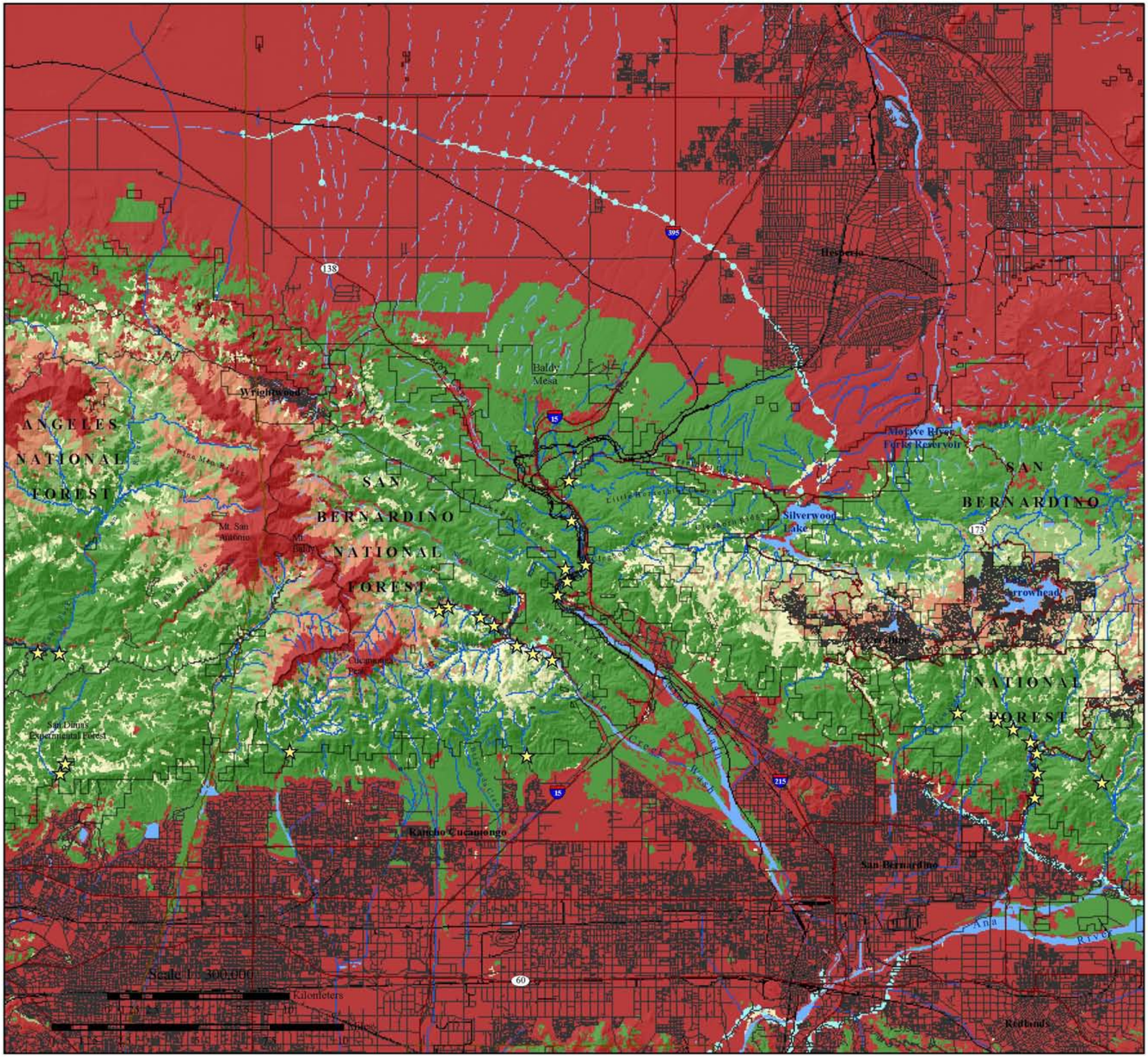

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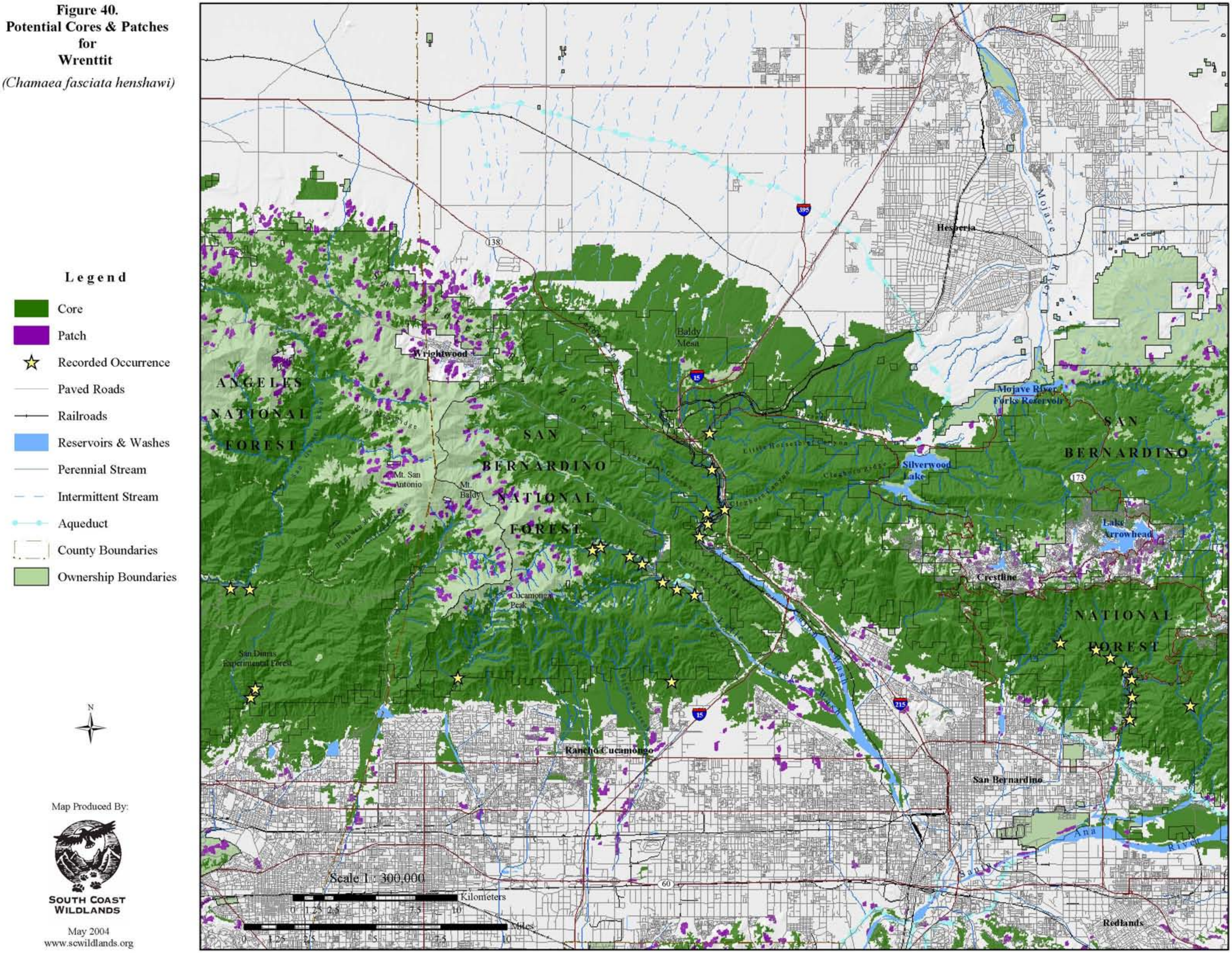
Figure 40.
Potential Cores & Patches for Wrenttit
(Chamaea fasciata henshawi)



California Treefrog (*Hyla cadaverina*)

Justification for Selection: California treefrogs are habitat specialists with low capacity to leave moist streamside environments.

Distribution: California treefrogs are patchily distributed from central San Luis Obispo County south to the Mexican border (Morey 1988b) and can occur at elevations up to 1690 m (5500 ft)(Stebbins 1985).

Habitat Associations: Adults occur in deeply cut canyons with stream boulders and large, slow pools (Kay 1989). They summer under rocks, or in rock cracks at the water's edge, and spend late fall and winter inactive in deep moist crevices (Harris 1975). They breed in quiet waters of rivers and creeks, and tadpoles require standing water up to 2.5 months (Stebbins 1954).

Spatial Patterns: Frogs in the Los Angeles County living along an ephemeral stream made daily movements up to 200 m (656 ft), although 83% of all movements measured were less than 25 m (82 ft; Kay 1989). Home ranges of individuals overlap.

Long-distance movements are restricted to streamside areas and vary between 34 and 506 m (112-1660 ft; Kay 1989). Two of nine frogs displaced 300 m (980 ft) from the point of capture were recaptured at their capture location (Kay 1989). Frogs rarely move from the streamside with winter observations occurring up to 12 m (39 ft) from streams (Harris 1975).

Conceptual Basis for Model Development: Treefrog movement in the linkage is likely multigenerational. Suitable habitat was identified as riparian obligate vegetation types (i.e., riparian forests, woodlands, and scrubs). Because habitat quantity is a poor predictor of population density in treefrogs, we did not designate a minimum patch size, and included all suitable habitat as potential core habitat.

Results and Discussion: Treefrog habitat occurs in both the San Gabriel and San Bernardino Mountain core areas (Figure 41). In the vicinity of the connection, potential habitat was identified in Lower Lone Pine Canyon, Cajon Canyon, Horsethief and Little Horsethief Canyons, Grass Valley and the West Fork of the Mojave River, and in Cable Creek. While individuals may be relatively mobile along drainages with suitable habitat, distances among suitable habitat may be too great to allow movements between these ranges. The best possibilities for movement may be along Cajon Canyon, with potential connections via Cleghorn and Lone Pine Canyons. To restore and protect habitat connections for treefrogs between the San Gabriel and San Bernardino Mountains, we recommend that:

- Areas of suitable habitat along Horsethief Canyon, Grass Valley, Cajon Wash, and upper Cable Creek are added to the Least-Cost Union, with a 1 km buffer to either side of the stream (see Figure 15);

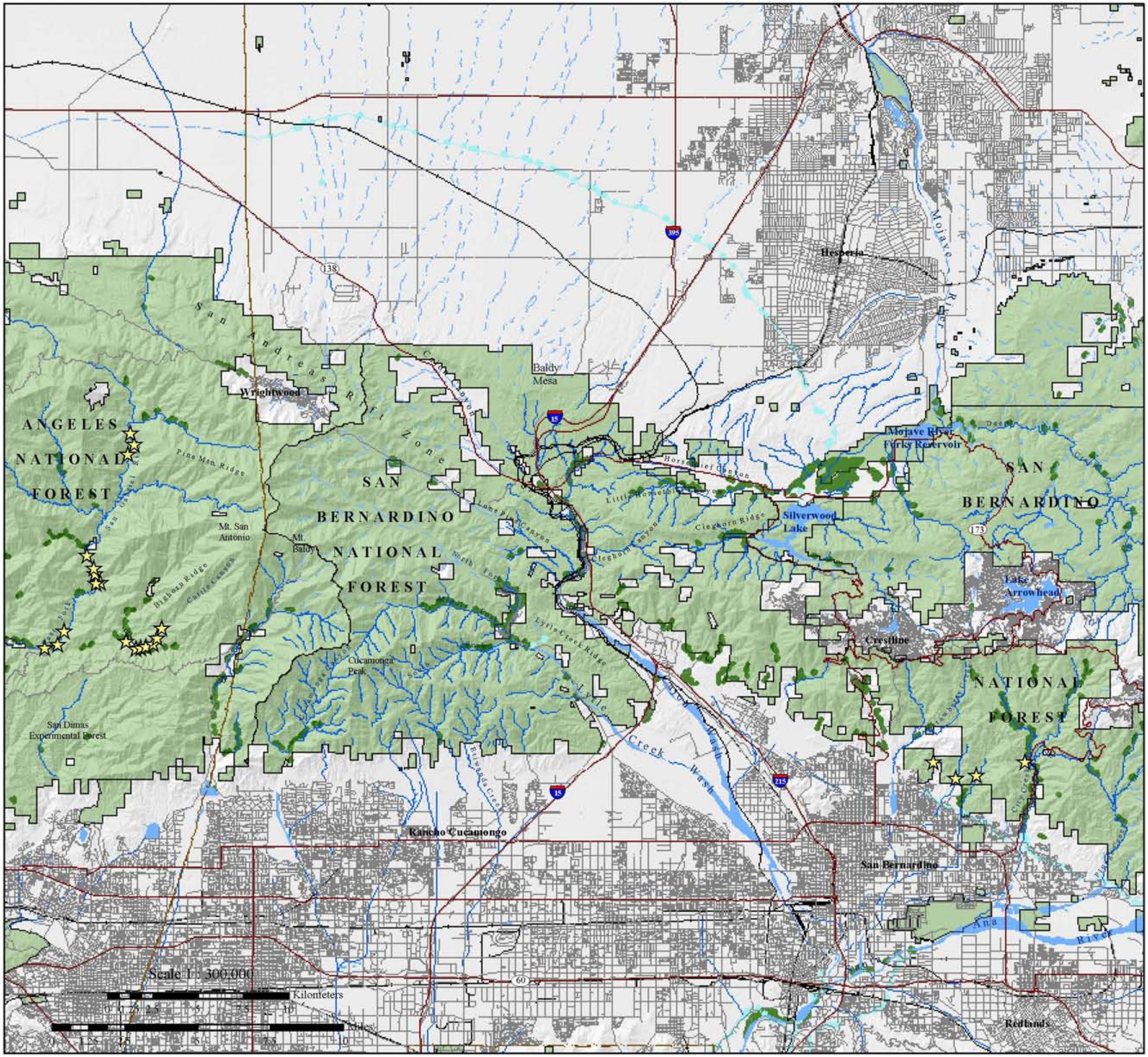
- Riparian habitats needed for breeding and movement be restored;

- Invasive species be eradicated that destroy treefrog habitat (e.g., giant reed) and prey on tadpoles (e.g., bullfrogs and fish);

- Road barriers be modified, where necessary, to allow amphibians to move along water corridors; and

- Water quality that is compromised by runoff be restored.

Figure 41.
Potential Habitat
for
California Tree Frog
(Hyla cadaverina)



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San Diego horned lizard (*Phrynosoma coronatum blainvillii)*

Justification for Selection: The San Diego horned lizard is highly sensitive to habitat loss and fragmentation. They need expansive roadless wildland to persist.

Distribution & Status: This California endemic has 2 subspecies whose ranges overlap; the San Diego horned lizard occurs in the planning area (Stephenson and Calcarone 1999). The known elevational range for this species is from near sea level to 1980 m (6496 ft; Jennings and Hayes 1994).

The San Diego horned lizard has been extirpated from nearly 45% of its former range (Jennings and Hayes 1994). Agriculture, flood control, and urbanization are cited as the main reasons for its decline (Jennings and Hayes 1994). These activities promote biological invasions by Argentine ants that eliminate native ant colonies, which the horned lizard is highly dependent on for sustenance (Pianka and Parker 1975, Montanucci 1989, Suarez et al. 2000, Suarez and Case 2002, Fisher et al. 2002). Domestic cats can also penetrate considerable distances into otherwise suitable habitat, eliminating horned lizards within a several km^2 radius (Jennings and Hayes 1994). This species is identified as Sensitive by the federal government and is considered a California Species of Special Concern.

Habitat Associations: The horned lizard frequents several vegetative communities, including inland dunes, alluvial fans, open coastal scrub and chaparral, annual grassland with scattered perennial seepweed or saltbush, and clearings in coniferous forests, broadleaf woodlands, riparian woodlands, and pine-cypress forests. However, they prefer the gravelly-sandy substrate of alluvial fans and flats dominated by alkali plants such as iodine bush (Stebbins 1985, CDFG 1988, Jennings and Hayes 1994). Essential habitat characteristics are loose, fine sandy soils, an abundance of native ants or other invertebrates, open areas for basking, and scattered low shrubs for cover and refuge (Stebbins 1985, Fisher et al. 2002). This species may utilize small mammal burrows, or tunnel into loose soils during periods of inactivity or hibernation (Jennings and Hayes 1994).

Spatial Patterns: Not much is known about home range size (CDFG 1988) or dispersal distance for this species. A recent study in 2002 however, estimated home ranges size of about $0.1 km^2$ (10 ha or 25 ac; Fisher et al.). Males of an associated species, P. solare, moved further than females, maximum distance for males was 30 m (98 ft), while females moved a maximum distance of 15 m (49 ft; CDFG 1988).

Conceptual Basis for Model Development: Movement between Core Areas in the linkage is multigenerational. They may utilize several habitat types including alluvial fans, alkali flats, dunes, open coastal scrub and chaparral, annual grassland, and clearings in coniferous forests, broadleaf woodlands, and riparian woodlands. They avoid urban and agricultural developments and areas of high road density. Patch size was defined as 2 home ranges (20 ha), using the smallest recorded range (10 ha x 2). Patch size was classified as ≥ 20 ha but < 250 ha. Core areas potentially supporting 25 pairs are ≥ 250 ha (10 ha x 25). Dispersal distance was defined as 60 m, using twice the recorded distance.

Results & Discussion: Vast amounts of highly suitable habitat were identified for this species within the planning area (Figure 42), largely following the distribution of alluvial fan, coastal sage and chaparral habitats. These habitats are all fairly contiguous in the planning area, and thus were identified as potential core areas (Figure 43). The spatial configuration of suitable habitat within the Least Cost Union and protected areas are within the species movement abilities, even with a limited dispersal distance of only 60 m. This species needs appear to be well accommodated by the Least Cost Union. Although habitat added to the Union for other focal species in Lytle and Cajon washes and the Santa Ana River will also benefit the horned lizard.

Research indicates this species is more likely to persist in larger habitat patches because of its dependence on native ants, which only occur in undisturbed habitats (Suarez and Case 2002, Fisher et al. 2002). They need large patches of suitable habitat that are in close proximity to one another (Fisher et al. 2002). To protect and restore habitat connectivity for horned lizard, we recommend that:

- Crossing structures be placed fairly frequently to facilitate movement across major transportation routes (i.e., I-15, I-215, SR-138) and reduce travel distance (Jackson and Griffin 2000, McDonald and St. Clair 2004);

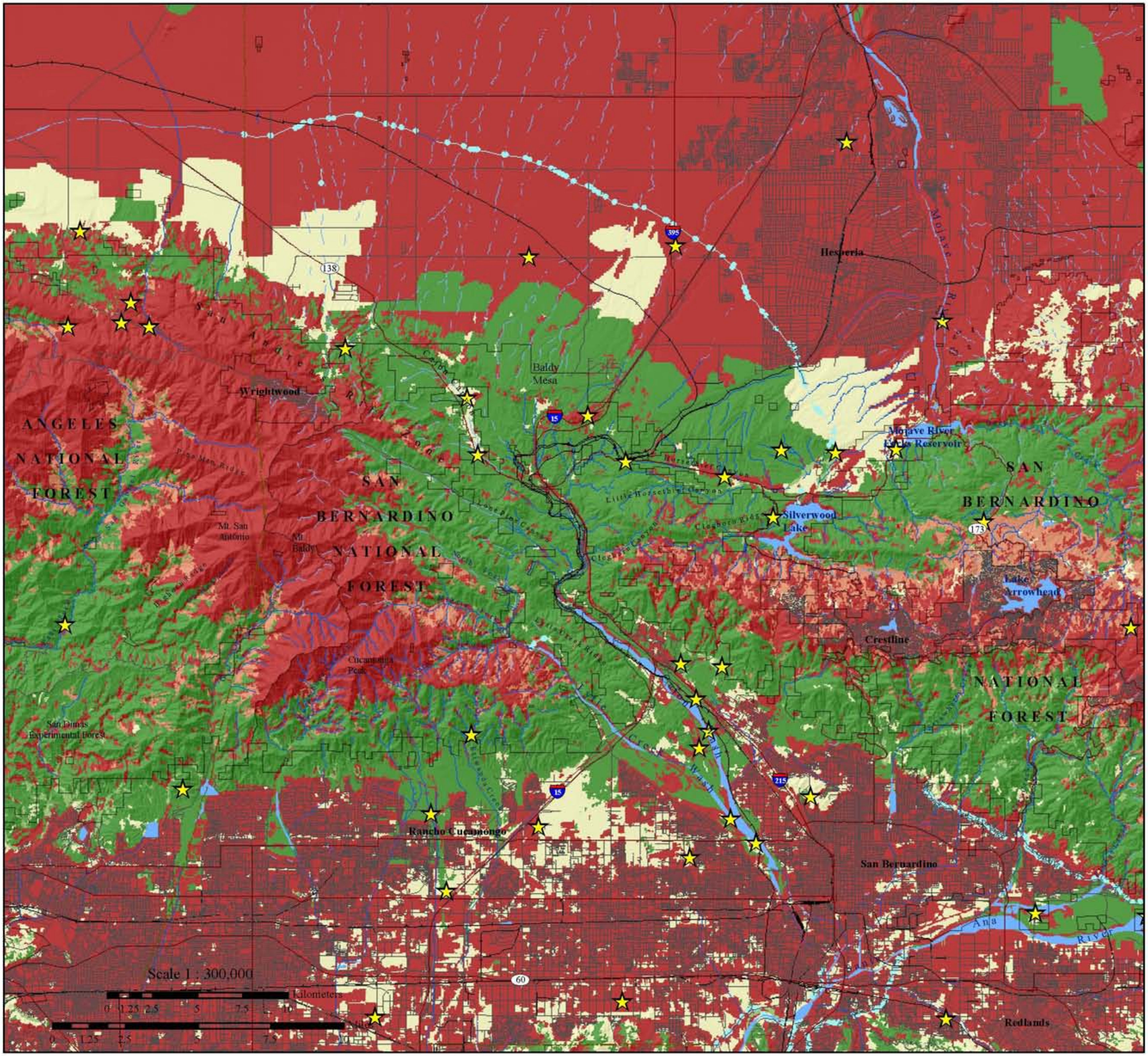
- Short retaining walls be installed in conjunction with crossing structures along paved roads in the Linkage Design to deter horned lizards from accessing roadways (Jackson and Griffin 2000);

- Riparian and upland buffers at least 2 km wide are imposed throughout the linkage, where feasible.

- Fire frequency be controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland; and

- Inholdings that could fragment habitat and introduce non-native ants be conserved through conservation easements, fee title agreements, acquisition, or other means.

**Figure 42.
Potential Habitat
for
San Diego horned lizard**
(Phrynosoma coronatum blainvillii)



Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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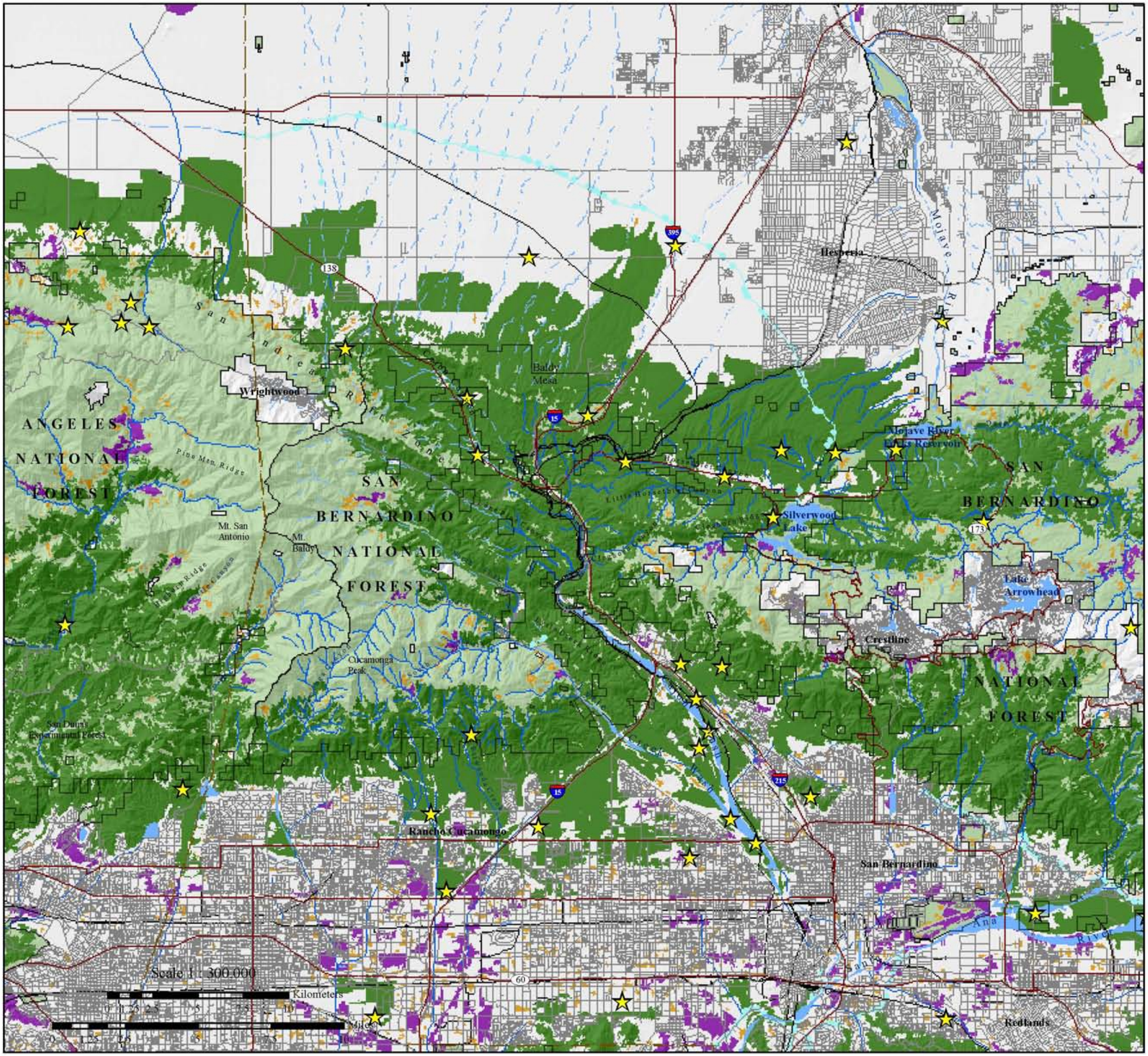
Figure 43.
Potential Cores & Patches for San Diego Horned Lizard
(Phrynosoma coronatum blainvillii)



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Chaparral whipsnake (Masticophis lateralis lateralis)

Justification for Selection: The Chaparral whipsnake, or striped racer, is particularly sensitive to habitat fragmentation. Patten and Bolger (2003) found this species to be most common in large core areas and largely absent from smaller habitat fragments. Their research showed that the probability of occurrence declined steadily across the fragmentation gradient (Patten and Bolger 2003).

Distribution & Status: The Chaparral whipsnake is one of two subspecies of the California whipsnake (*Masticophis lateralis*); the other is the endangered Alameda whipsnake (*M. l. euryxanthus*). The range of the Chaparral whipsnake extends from northern California, west of the Sierran crest and desert, to central Baja California, largely coinciding with the distribution of chaparral habitats (Hammerson 1979, Jennings 1983, Stebbins 1985, USFWS 2000). The species may be found from sea level to 1835 m (6020 ft) in elevation (Zeiner et al. 1988).

Habitat loss and fragmentation of terrestrial and aquatic habitats are cited as the primary threats to the whipsnake (USFWS 2000, Patten and Bolger 2003). Habitat conversion and alteration, including water diversions and groundwater pumping, are likely barriers to dispersal (USFWS 2000). The Chaparral whipsnake isn't afforded any special conservation status.

Habitat Associations: The Chaparral whipsnake, as its name implies, prefers mixed chaparral and chamise-redshank chaparral habitats (Zeiner et al. 1988, Swaim 1994, USFWS 2000). Although, this species may also be encountered in valley foothill riparian, valley foothill hardwood, hardwood conifer, and various coniferous forests (Zeiner et al. 1988), as well as coastal sage scrub and coyote bush scrub habitats (Swaim 1994, USFWS 2000). Furthermore, radio-telemetry studies indicate that whipsnakes regularly journey into grassland, oak savanna, and occasionally oak-bay woodland habitats (Swaim 1994, USFWS 2000). Evidently, grassland habitats are particularly important to females for egg-laying sites (Swaim 1994, USFWS 2000).

Rock outcrops are an essential habitat component because they provide refuge and support lizard populations, the whipsnakes primary prey (Stebbins 1985, Swaim 1994, USFWS 2000). The species is known to bask in the sun prior to morning activities but avoids the direct sun at midday by retreating to cover under large rocks or fallen logs or in crevices of rock outcrops (Hammerson 1979, Zeiner et al. 1988).

Spatial Patterns: Although the home range size of the Chaparral whipsnake is unknown, it is considered to be extensive for this energetic species (Zeiner et al. 1988). Male home ranges of the Alameda whipsnake, a closely related subspecies, have been recorded to range from 1.9 to 8.7 ha (4.7-21.5 ac), with 5.5 ha (13.6 ac) noted as the average size (Swaim 1994, USFWS 2000). Research indicates that shrub communities are the focal point of home ranges, though whipsnakes make frequent excursions into adjacent habitats (Swaim 1994, USFWS 2000). Radio-telemetry data suggests most whipsnakes are within 50 m (170 ft) of scrub habitat, though distances further than 150 m (500 ft) have been recorded (Swaim 1994, USFWS 2000).

The whipsnake is a swift moving snake (Hammerson 1979). The striped whipsnake (*M. t. taeniatus*), an allied species, moved 3.6 km (2.24 mi) after emerging from hibernaculum (Hirth et al. 1969), and it is likely that the whipsnake is capable of similar long distance movements (USFWS 2000).

Conceptual Basis for Model Development: The Chaparral whipsnake preferentially moves through mixed chaparral and chamise-redshank chaparral habitats, though they may also be encountered in valley foothill riparian, valley foothill hardwood, hardwood conifer, coniferous forests, coastal sage scrub, coyote bush scrub, grassland, oak savanna, and oak-bay woodland habitats below 1835 m.

Core areas were identified as ≥137.5 ha, using 25 times the average recorded home range size. Patch size was defined as ≥ 3.8 ha, but less than 137.5 ha, using twice the minimum recorded home range. Dispersal distance was estimated at 7.2 km, or twice the longest distance recorded for an associated species.

Results & Discussion: Highly suitable habitat for the Chaparral whipsnake largely follows the distribution of chaparral habitats in the planning area (Figure 44). The spatial configuration of suitable habitat is fairly contiguous; thus the majority was identified as potential core areas for this species (Figure 45). The needs of the Chaparral whipsnake appear to be well served by the Least Cost Union, with the central branch providing the most contiguous suitable habitat between protected areas. To protect and maintain habitat connectivity between these ranges for the whipsnake, we recommend that:

- Crossing structures be placed fairly frequently to facilitate movement across major transportation routes (i.e., I-15, I-215, SR-138) and reduce travel distance (Jackson and Griffin 2000, McDonald and St. Clair 2004);
- Riparian and upland buffers at least 2 km wide are imposed throughout the linkage, where feasible; and
- Fire frequency is controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland.

Figure 44.
Potential Habitat
for
Chaparral Whipsnake
(Masticophis lateralis lateralis)

Legend

Degree of Suitability

- Low
- Low to Medium
- Medium
- Medium to High
- High
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

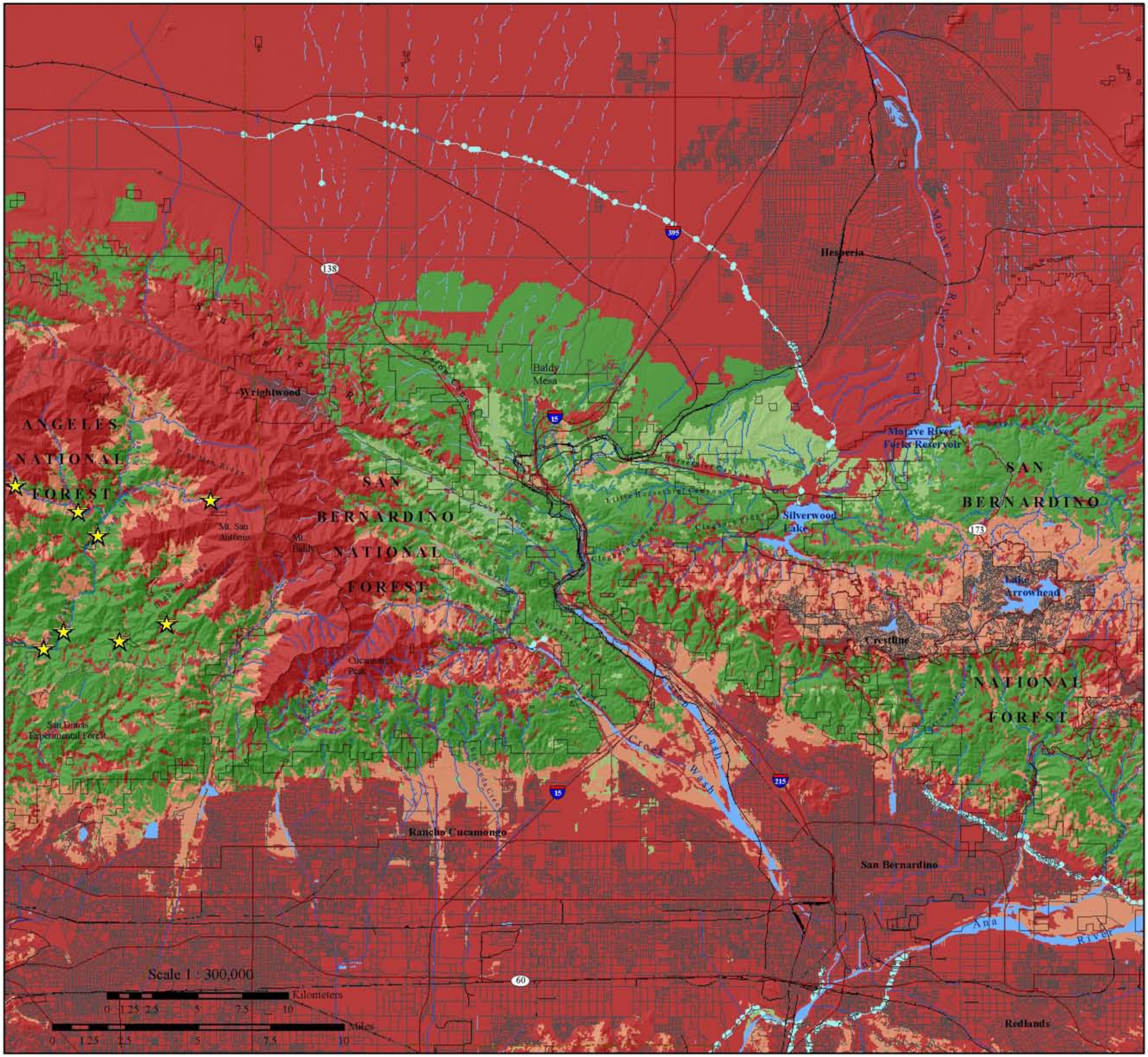

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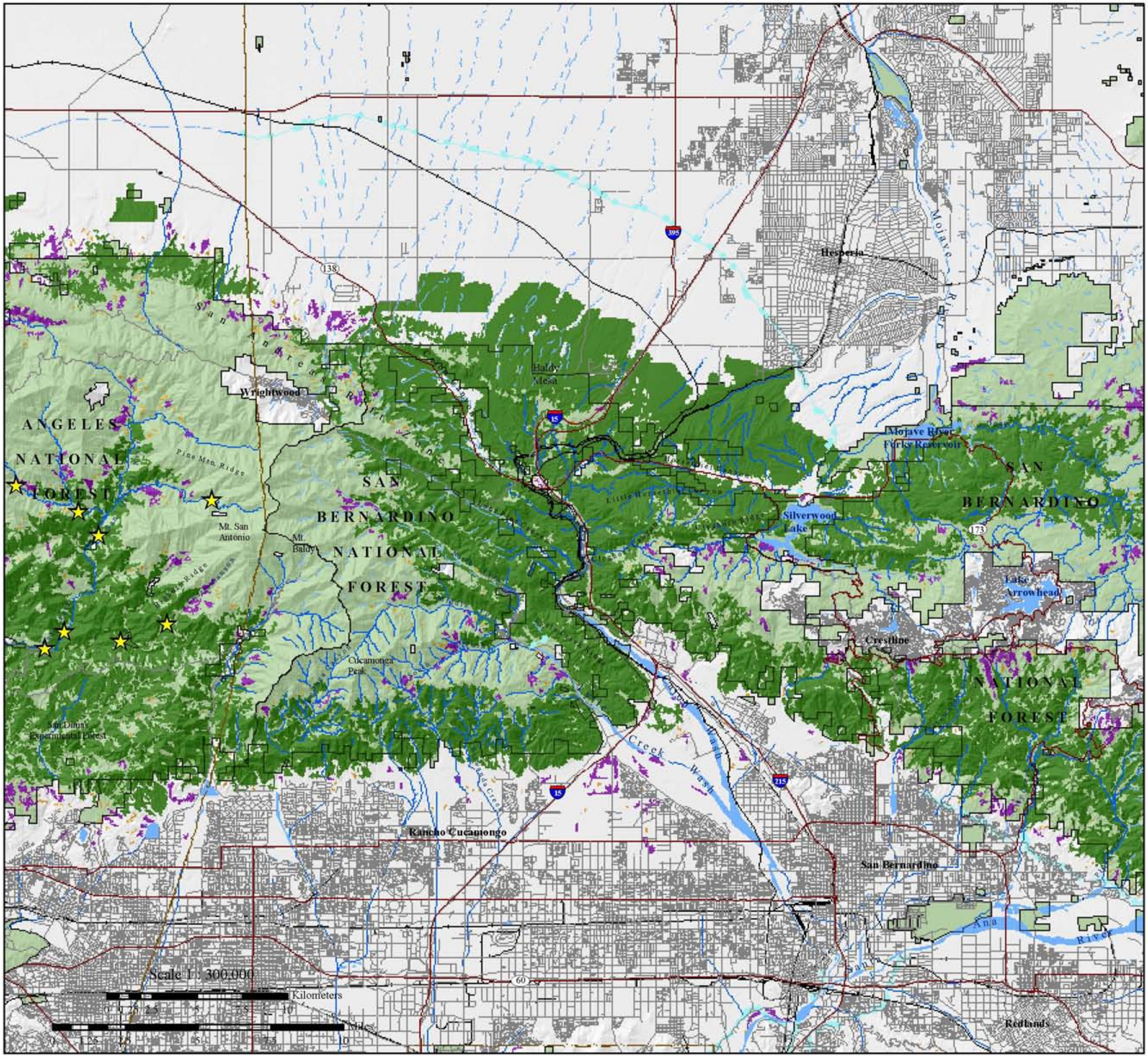
Figure 45.
Potential Cores & Patches
for
Chaparral Whipsnake
(Masticophis lateralis lateralis)

Legend

- Core
- Patch
- < Patch
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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Santa Ana Speckled Dace (*Rhinichthys osculus*)

Justification for Selection: The Santa Ana speckled dace was chosen as a habitat quality indicator because of their dependence on clear, well-oxygenated water in perennial streams that are free of exotic species.

Distribution & Status: Historically, the Santa Ana speckled dace was distributed throughout the upland portions of the Santa Ana, San Gabriel, and Los Angeles river systems of southern California, though it was always rare in the lowlands (Swift et al. 1993). Today, this species is restricted to the headwaters of the Santa Ana and San Gabriel rivers (Moyle et al. 1995). The largest remaining population is within the Angeles National Forest on lower reaches of the east, north and west forks of the San Gabriel River (Swift et al. 1993). In the planning area, small speckled dace populations have been documented in Cattle Canyon, Fish Canyon, Lytle Creek, Cajon Wash, Lone Pine Canyon, Strawberry Creek, Plunge Creek, and City Creek (Swift et al. 1993, Moyle et al. 1995, S. Loe, SBNF, pers. comm., Stephenson and Calcarone 1999). The severe flooding on Christmas day of 2003 potentially resulted in the loss of dace in Strawberry and City Creeks. There are plans to reestablish them if they have been extirpated from these creeks.

The Santa Ana speckled dace is one of the rarest native fish in coastal southern California, occupying only remnants of their former range due to habitat loss and degradation attributed to water diversions, urbanization of watersheds, and introduction of nonnative species (Swift et al. 1993, Moyle et al. 1995). They require year-round surface flows to be sustained (Moyle et al. 1989). In 1994, this species was petitioned for listing under the Endangered Species Act but was denied conservation status because the subspecies hadn't been formally described (USFS 2002), though Cornelius (1969) concluded that it is worthy of subspecies status. The Santa Ana speckled dace is considered a Forest Service Region 5 Sensitive Species and a California Species of Special Concern (Swift et al. 1993, USFS 2002), though it has been acknowledged that they are in danger of extinction (Moyle et al. 1995).

Habitat Associations: The Santa Ana speckled dace utilizes small springs, brooks, and pools in perennial streams and rivers. The dace requires abundant cover and well-oxygenated clear water with summer temperatures of 17-20 degrees centigrade (63-69^{0}F), flowing over shallow cobble and gravel riffles (Wells et al. 1975, Stephenson and Calcarone 1999, Moyle 2002). Overhanging riparian plants provide stream shading and cover for fish (Moyle et al. 1995). Spawning occurs over rocks and gravel where larvae stay until emerging and relocating to warm shallow water (Moyle 1976, USFS 2002). They forage on small benthic invertebrates (Moyle 2002, USFS 2002).

Spatial Patterns: Dispersal is facilitated during flooding events (Moyle 1976). Perennial flows contribute to dispersal of the species downstream (Riverside County Integrated Project 2000, USFS 2002). However, during high flows downstream occupants are also capable of moving miles upstream rather quickly.

Conceptual Basis for Model Development: Fine scale data on gravel and riffle habitat in the planning area was not available for the analysis. Therefore, perennial streams where the species is known to occur or where they were historically present were selected and identified as potential habitat.

Results & Discussion: Speckled dace are known to occur, or were historically present, in the San Gabriel and San Bernardino Mountains: in the lower reaches of the east, north and west forks of the San Gabriel River, in Cattle Canyon, Fish Canyon, North Fork of Lytle Creek, Cajon Wash, Lone Pine Canyon, Strawberry Creek, Plunge Creek, and City Creek (Figure 46). The Least-Cost Union includes known locations in Cajon Canyon, Lone Pine Canyon and the North Fork of Lytle Creek. To restore and protect habitat connections for speckled dace between the San Gabriel and San Bernardino Mountains, we recommend that:

- Additional core areas of suitable habitat along Lytle Creek, Cajon Canyon and Strawberry Creek where dace are known to occur or were historically present be added to the Least-Cost Union (see Figure 15);

- Riparian buffers be added to the Union that extend at least 1 km (0.62 mi) into upland habitat on either side of aquatic habitat. Contaminants, sediments, and nutrients can reach streams from even longer distances (Maret and MacCoy 2002, Scott 2002, Naicker et al. 2003), 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, Wilson and Dorcas 2003);

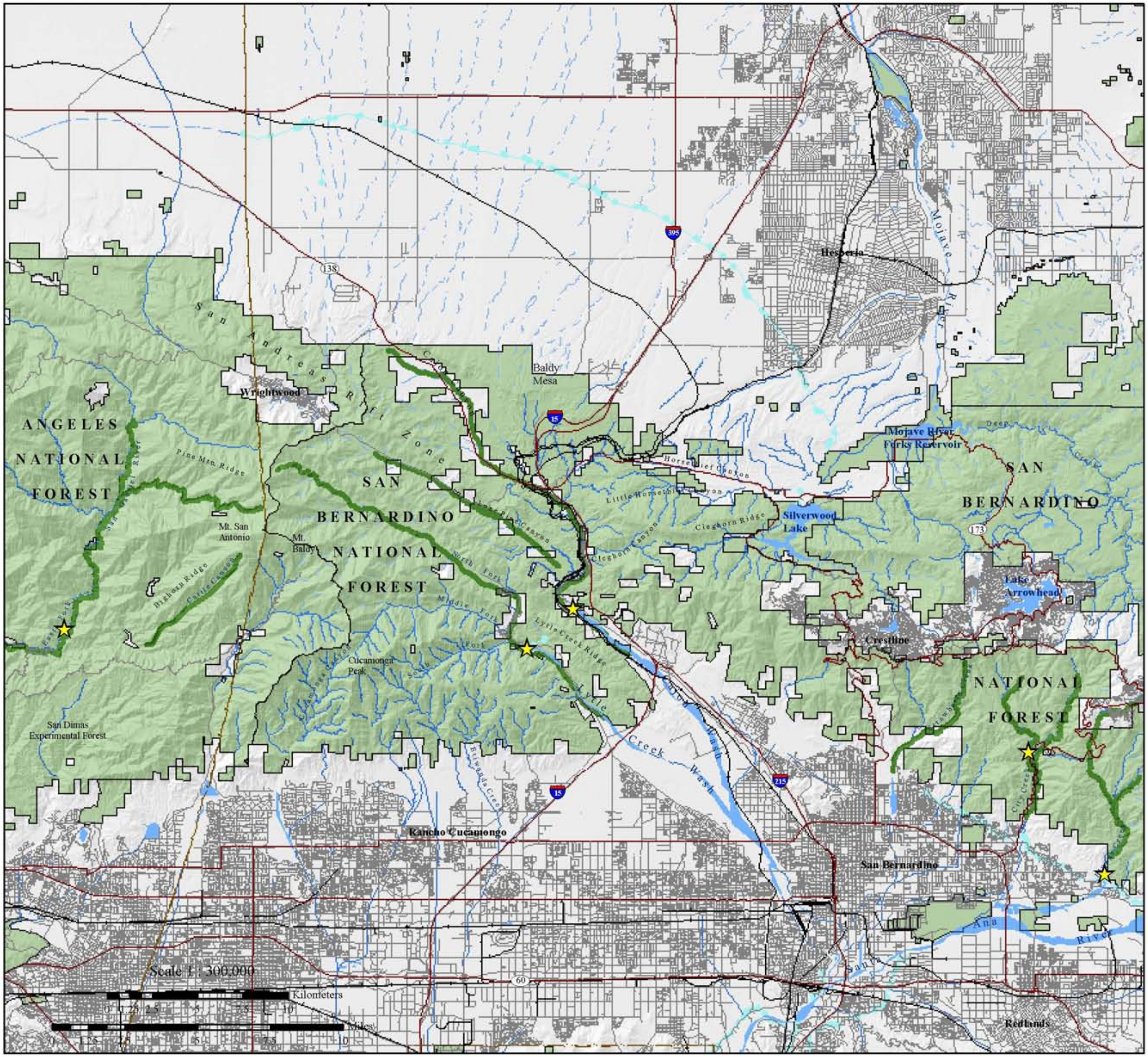
- Hydrological regimes, water quality, and riparian vegetation be maintained or restored in and among core areas of suitable habitat;

- Restore habitat connectivity and aquatic habitat integrity to all of the major streams in the upper Santa Ana Watershed;

- Artificial aquatic barriers be modified to allow for dace movement; and

- Exotic species be eradicated that degrade or eliminate dace habitat (e.g., giant reed and tamarisk) or prey on dace (e.g., exotic fish such as largemouth bass, redeye bass, lack bullheads, green sunfish and mosquitofish).

Figure 46.
Potential Habitat
for
Santa Ana Speckled Dace
(Rhinichthys osculus)



Legend

- Potential Habitat
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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Tarantula Hawk (*Pepsis* ssp.)

Justification for Selection: The Tarantula hawk was chosen because of their sensitivity to changes in habitat and highways as impediments to movement (Pratt and Ballmer, pers. comm.).

Distribution & Status: *Pepsis* is a New World genus with 15 species in the United States. *Pepsis formosa* and *P. thisbe* are the most common species in the southwest (Williams undated mat.). The Tarantula hawks distribution is strongly tied to the availability of their primary prey, tarantulas (Hogue 1974, Williams undated mat., Pratt and Ballmer, pers. comm.). They may be found at elevations up to 2286 m (7500 ft), but are typically encountered at lower elevations (Pratt and Ballmer, pers. comm.)

Habitat Associations: This species prefers coastal sage habitats (Vincent 2000), but may be found in other communities where milkweed and other nectar sources are available for adults, and host tarantulas are present (Pratt and Ballmer, pers. comm.). They may be encountered in alluvial fan scrub, montane chaparral and high desert scrub habitats. Adults are vegetarian, using nectar from a variety of flowers, while the larvae are carnivores that feed on tarantulas (Vincent 2000). Male tarantula hawks engage in a behavior known as hilltopping, where they stake out territories to find mates (Alcock and Bailey 1997, Williams undated mat.).

Spatial Patterns: This species has a fairly lengthy flight season (Alcock 1981, Alcock and Carey 1988, Alcock and Bailey 1997). Males are territorial, defending tall shrubs or small trees growing along ridges and hilltops (Alcock and Bailey 1997). Territorial defense is exhibited during the mating season. Typically there is only one resident per plant and sites are well spaced (Alcock 1981). Home range has been estimated at 3.8 km^2 (1.5 mi^2; Pratt and Ballmer, pers. comm.).

Conceptual Basis for Model Development This species prefers coastal sage scrub, but may be found in other habitats that offer nectar sources. The following vegetation communities were queried in the GIS: coastal sage scrub, alluvial fan scrub, Basin Sagebrush, Birchleaf Mountain Mahogany, Buckwheat and White Sage scrub, California Sagebrush scrub, Montane Chaparral, Mixed Soft Scrub Chaparral, and Scalebroom scrub. Access to hilltopping habitat is critically important for population persistence, thus we queried all ridges within 1.5 miles of potential habitat.

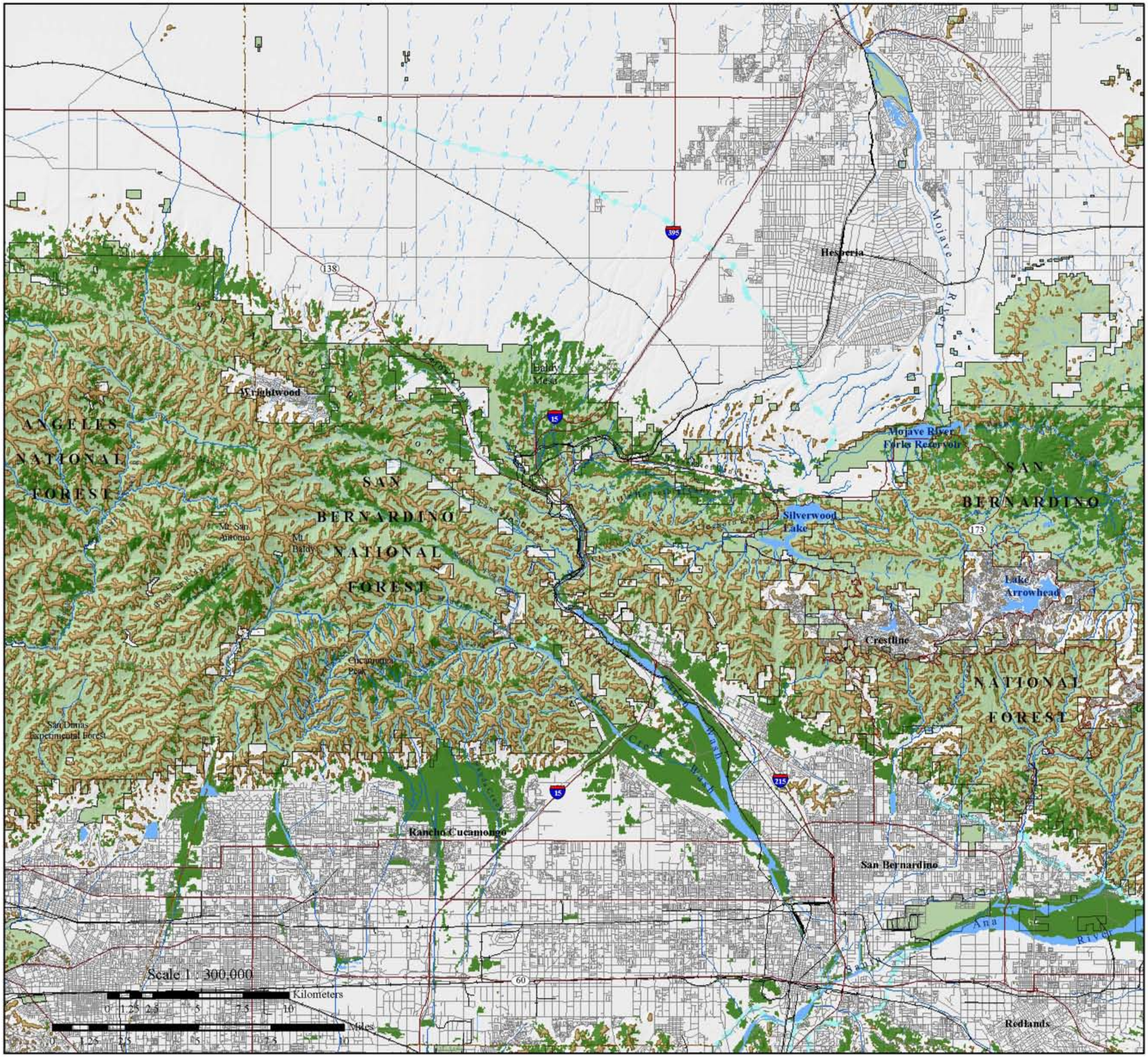
Results & Discussion: Large patches of potentially suitable habitat occurs along the alluvial fans emanating from the foothills of the San Gabriel and San Bernardino Mountains, as well as along the northern edge of the ranges in the high desert, from upper Cajon Canyon, to Baldy Mesa and The Pinnacles area, with hilltopping habitat available throughout the protected areas (Figure 47). All three branches of the Least

Figure 47.
Potential Habitat
for
Tarantula Hawk

(Pepsis spp.)

Legend

- Potential Habitat
- Hilltopping Habitat
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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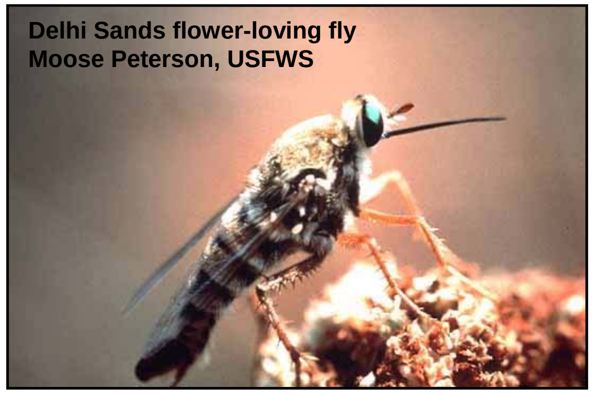
Cost Union appear to serve the needs of this species. Although habitats added to support other focal species will also benefit the Tarantula hawk. To restore and protect habitat connectivity for this species, we recommend that:

- Fire frequency be controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland;

- Land in the linkage and protected core areas is managed to sustain the natural dynamics of sand transport in order to maintain habitat for this species (USFWS 1997); and

- Potentially suitable habitat along the foothills of the San Gabriel and San Bernardino Mountains (i.e., the southern branch of the Least Cost Union) is protected through conservation easements or acquisition from willing landowners.

Giant flower-loving fly (*Rhaphiomidas acton*)



Justification for Selection: Habitat loss and fragmentation has fatally impacted species in this genus in many regions (Rogers and Mattoni 1993). The Giant flower-loving fly was chosen due to its reliance on habitats that are maintained by the natural dynamics of sand transport.

Distribution & Status: The genus *Rhaphiomidas* consists of the largest flies in North America, hence the name Giant flower-loving fly (Rogers and Mattoni 1993). These flies are restricted to arid regions of California, southern Nevada, Arizona, New Mexico, western Texas, Baja California, and northwestern Mexico (Rogers and Mattoni 1993). Cazier (1985) listed 17 species and five subspecies in the genus (Rogers and Mattoni 1993, USFWS 1997). *R. acton* is the most widespread species of the genus with 3 subspecies, whose distributions broadly overlap: *acton*, *maculates*, and *maehleri* (Rogers and Mattoni 1993). The range of *R. a. acton* encompasses Mono, Inyo, Kern, Los Angeles (Mojave Desert areas), San Bernardino, and Riverside counties (Rogers and Mattoni 1993). In the study area, populations are known from Cajon Wash and the Mojave Desert (Pratt and Ballmer, pers. comm.). They are typically found below 1219 m (4000 ft) in elevation (Pratt and Ballmer, pers. comm.).

A related species, the Delhi Sands flower-loving fly (*R. terminatus abdominalis*), was listed as an endangered species in 1993 (58 Federal Register 49881). Threats to this species include urban and agricultural development, sand and gravel mining, exotic species invasions, dumping of manure and trash, off-road vehicles, and collecting (USFWS 1997). It is likely that the Giant flower-loving fly is also impacted by these activities, though it is not afforded any special conservation status.

Habitat Associations: The Giant flower-loving fly is a habitat specialist that is strongly associated with sandy substrates (Rogers and Mattoni 1993). They require sand for oviposition (i.e. egg laying); eggs are typically deposited in loose soil under shrubs (USFWS 1997, Pratt and Ballmer, pers. comm.). Vegetative cover is always sparse, typically ranging from 10-20% cover, but the fly may be found in habitats with up to 50% cover (Rogers and Mattoni 1993, USFWS 1997). They are restricted to habitats that are patchily distributed in the landscape. They may be found on or near sand dunes, dry rocky washes with sandy areas nearby (Rogers and Mattoni 1993), and scrub habitats and alluvial fans with appropriate soils (Pratt and Ballmer, pers. comm.). Suitable habitat must contain conditions for all life stages, from the early stages dependent on subterranean environments, to adult feeding, breeding and perching areas, as well as nectar sources (USFWS 1997).

The Giant flower-loving fly has a long tubular proboscis (i.e., mouthparts) that they use to extract nectar from flowers (USFWS 1997). They utilize a wide variety of nectar sources, including Mohave sage (*Salvia mohavensis*), California buckwheat (*Eriogonum fasciculatum*), Eriastrum spp., Desert willow (*Chilopsis linearis*), Desert marigold

(*Baileya multiradiata*) (Rogers and Mattoni 1993). The fly is also an important pollinator of a listed endangered plant, the Santa Ana River woolly star (*Eriastrum densifolium sanctorum*) (Rogers and Mattoni 1993, Steinberg et al. 1998, Pratt and Ballmer, pers. comm., Atallah and Jones 2003), though it's not a habitat requirement (Pratt and Ballmer, pers. comm.). In fact, hummingbirds and the Giant flower-loving fly are the most common pollinators of this endangered plant species (Atallah and Jones 2003).

Spatial Patterns: They are known to hover while taking nectar at flowers and are considered strong flyers capable of rapid movements (Rogers and Mattoni 1993, USFWS 1997). They may disperse up to 1 mile (Pratt and Ballmer, pers. comm.). They are also well adapted for traveling over sand using false legs protruding from their underside (Rogers and Mattoni 1993). They have short flight periods (Rogers and Mattoni 1993), typically 3 days for males and 1 week for females, a short lifespan for such a large insect (Pratt and Ballmer, pers. comm.).

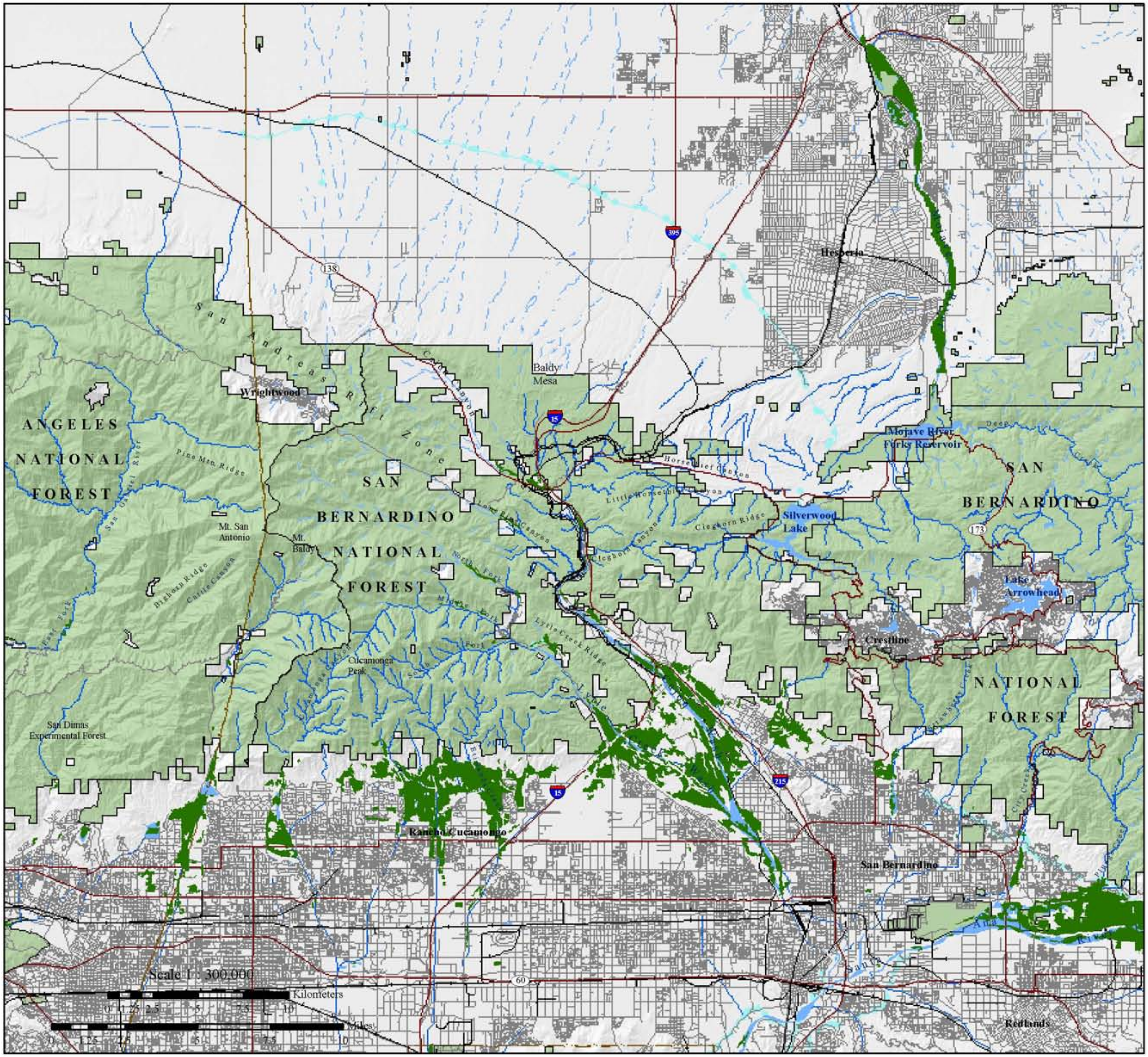
Home range has been estimated at 2.6km^2 (1mi^2) (Pratt and Ballmer, pers. comm.). Species of *Rhaphiomidas* studied in desert scrub communities have densities of 500 adults per acre (1,200 per hectare) (R. Mattoni, R. Rogers, and J. George, UCLA, unpublished data, USFWS 1997). A population of *R. acton machleri* in San Bernardino County had an average of 10 adults on each California buckwheat and Mohave sage shrub (Rogers and Mattoni 1993). While Steinberg et al. (1998) observed fewer than 25 R. acton individuals per acre. Populations may fluctuate drastically due to climatic conditions, sometimes not appearing at all (Rogers and Mattoni 1993).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. The Giant flower-loving fly may inhabit sand dunes, dry rocky washes, alluvial fans, and scrub habitats. Their nectar sources (e.g., California buckwheat, Eriastrum) may be found on dry slopes, flats, washes and gently sloping hillsides (Hickman 1993). Vegetation communities (i.e., alluvial fan sage scrub, coastal scrub, scalebroom, and barren) were queried and then areas below 1219 m in elevation were delineated as potentially suitable habitat.

Based on the literature, it was determined that patch size is a poor indicator of population density, and thus we didn't conduct patch size analysis for this species. Dispersal distance was defined as 3.2 km (2 mi) for the patch configuration analysis to evaluate whether the species may be capable of traveling between areas of potentially suitable habitat.

Results & Discussion: Habitat for this species isn't well represented within the protected core areas. Potentially suitable habitat primarily occurs within the southern part of the linkage near lower Lytle Creek and Cajon Wash, along the alluvial fans emanating from the foothills of the San Gabriel and San Bernardino Mountains, as well as along the Mojave River in the northern part of the planning area (Figure 48). All habitat patches along the base of the San Gabriel and San Bernardino Mountains are within this species dispersal distance, though barriers to movement may exist between suitable habitat patches. It appears that populations in this area are isolated from potentially suitable habitat along the Santa Ana and Mojave Rivers (Figure 49). The southern branch of the Least Cost Union appears to serve the needs of this species, though habitat added for other focal species will also benefit the fly.

Figure 48.
Potential Habitat
for
Giant Flower-loving Fly
(Rhaphiomidas acton)



Legend

- Potential Habitat
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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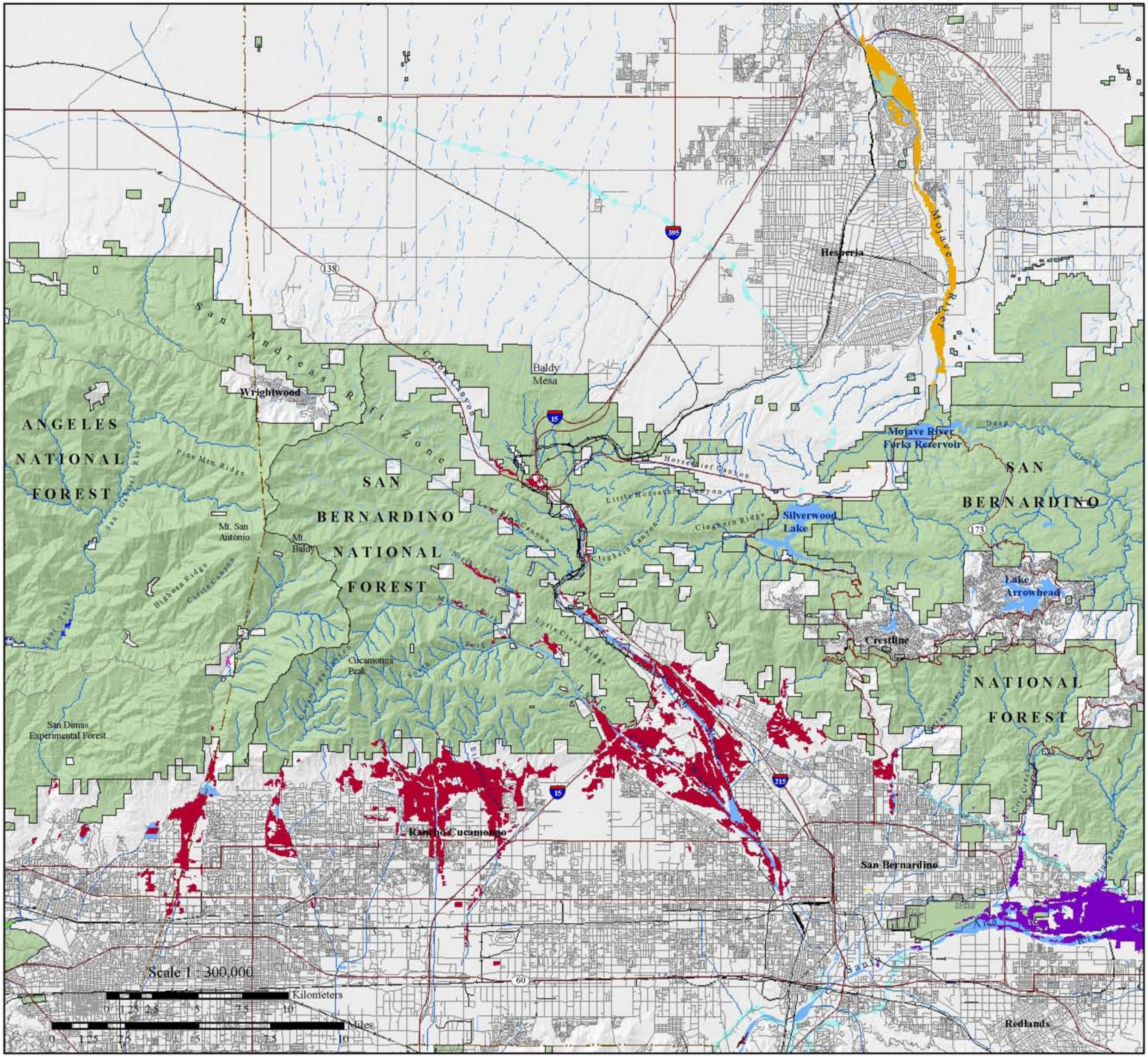
Figure 49.
Patch Configuration
for
Giant Flower-loving Fly
(Rhaphiomidas acton)

Legend

- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

Colors signify patches of suitable habitat that are within twice the dispersal distance from its neighbor.



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Roads are barriers to movement for several invertebrates (Mader 1984, Thomas Reid Associates 1984, USFWS 1997). Adult Delhi Sands flower-loving flies have been observed to avoid paved roads (R. Rogers, pers. obs.), though it is believed that at least some individuals may disperse across these barriers (USFWS 1997). To protect and restore habitat connectivity for the Giant flower-loving fly, we recommend that:

- Potentially suitable habitat along the foothills of the San Gabriel and San Bernardino Mountains (i.e., the southern branch of the Least Cost Union) is protected through conservation easements or acquisition from willing landowners;

- Land in the linkage and protected core areas is managed to sustain the natural dynamics of sand transport in order to maintain habitat for this species (USFWS 1997); and

- Research is conducted to identify dispersal distances and habitat characteristics of movement corridors to determine what is necessary to facilitate genetic exchange between populations (USFWS 1997).

Metalmark Butterfly (Apodemia mormo)

Justification for Selection: The Metalmark butterfly was selected due to their limited dispersal capabilities and vulnerability to roadkill; roads are significant barriers (Pratt and Ballmer pers.com).

Distribution & Status: There are 9 species in the genus *Apodemia* (Powell 1975). Although the species *A. mormo* is distributed throughout the western United States and south into Baja California Mexico (Orsak 1977, Scott 1986, Struttman & Opler undated mat.), the subspecies *A. m. virgulti* occurs only in southern California and south into neighboring Mexico (Orsak 1977). The Metalmark butterfly may occur from sea level up to 1254 m (5000 ft) in elevation (Orsak 1977, Pratt and Ballmer pers.com).

Habitat Associations: This butterfly inhabits arid habitats, such as dry, rocky slopes in desert scrub or xeric chaparral-covered hills, but may also be found in grassland, open woodland, and dune habitats (Scott 1986, Prchal and Brock 1999, Struttman & Opler undated mat.), as well as coastal sage scrub (Pratt and Ballmer pers.com). Larval hostplants include Wright's buckwheat (*Eriogonum wrightii*), Heerman's buckwheat (*E. heermannii*) (Pratt and Ballmer 1991, Prchal and Brock 1999), and California buckwheat (*E. fasciculatum*) (Orsak 1977). Young caterpillars feed on leaves, while older caterpillars consume both leaves and stems (Scott 1986, Struttman & Opler undated mat.). Each caterpillar undergoes five stages of growth (i.e., instars), prior to transforming into a butterfly (Ballmer and Pratt 1988). Adult nectar sources include many species of buckwheat, as well as other plants, such as Ragwort (*Senecio* sp.) and Rabbitbrush (*Chrysothamnus* sp.) (Struttman & Opler undated mat.).

Spatial Patterns: The Metalmark flight season is from March to October (Scott 1986, Struttman & Opler undated mat.), with a peak in late March (Orsak 1977). They live for a little over a week; the average lifespan for males is about 9 days, 11 days for females (Scott 1986). During this time, they must feed and mate, and females have to locate a host buckwheat plant to deposit their eggs before they perish (The Essig Museum, undated mat.). Most of their activities take place in the open; they prefer full sun (Scott 1986). Although density estimates are lacking, Metalmarks can be quite abundant in inland areas, particularly in undisturbed foothill habitats (Orsak 1977). Home range has been estimated at 100 m^2 (1076 ft^2; Pratt and Ballmer pers.com).

Typically, Metalmarks make very limited movements during their life spans, averaging 49 m (161 ft) for males and 64 m (210 ft) for females. The longest recorded movement was 617 m (2024 ft; Scott 1986).

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. The Metalmark butterfly prefers dry, rocky slopes in desert scrub or chaparral, but may also be found in coastal sage scrub, grassland, open woodland, and dune habitats. Within these communities, they may be found from sea level up 1254 m in elevation.

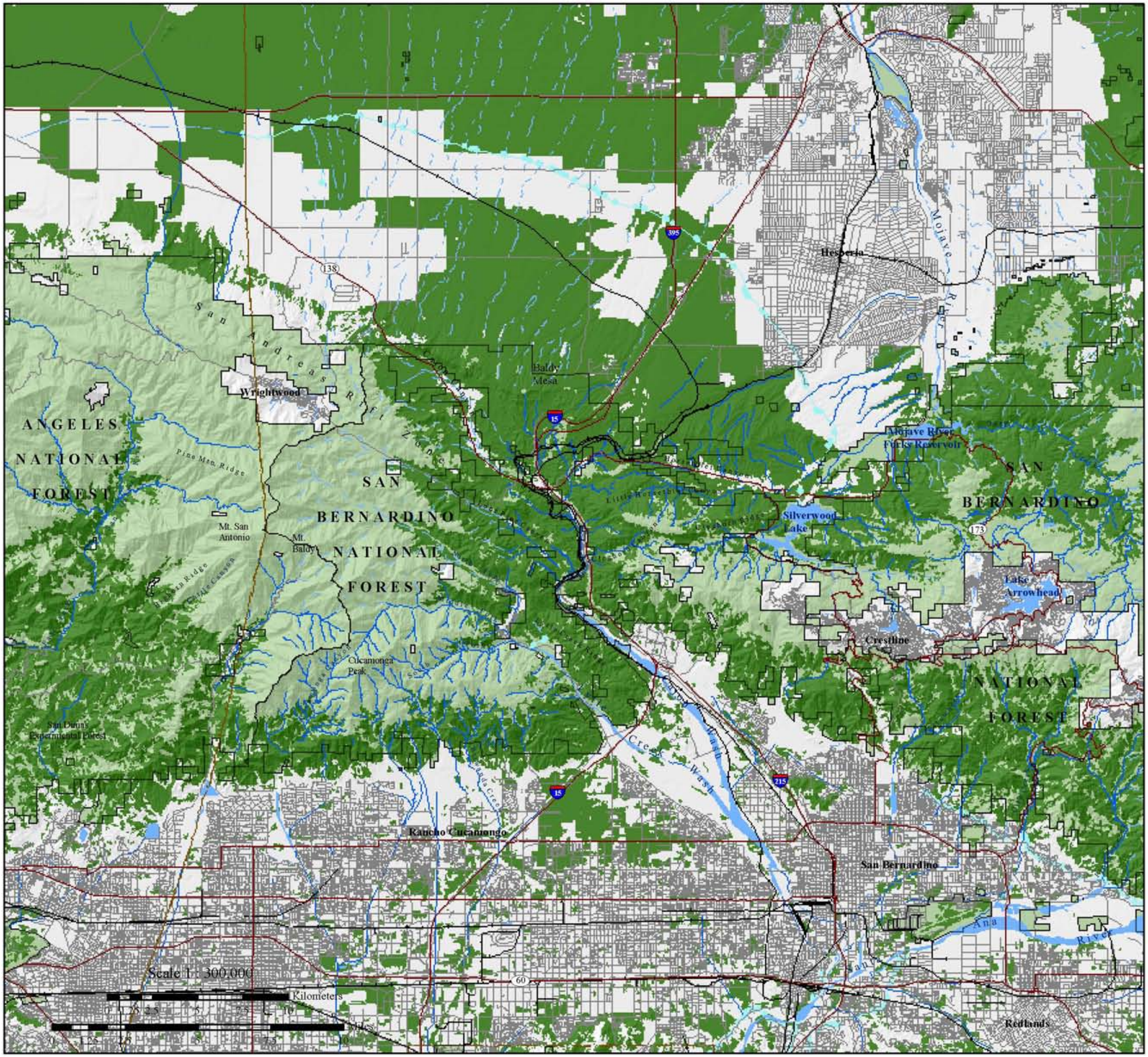
Results & Discussion: Highly suitable habitat for the Metalmark butterfly is fairly widespread in the planning area (Figure 50), largely following the distribution of scrub habitats that support *Eriogonum* species, their host plants. Fairly contiguous blocks of potentially suitable habitat were captured in all three branches of the Least Cost Union. All suitable habitat within the San Gabriel and San Bernardino Mountains and the Union are within the dispersal distance of this species (Figure not shown), though barriers to movement may exist between suitable habitat patches. We conclude that the linkage will likely serve the needs of this species. To protect and restore habitat connectivity for the Metalmark butterfly, we recommend that:

- Fire frequency be controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland;
- Riparian and upland buffers at least 2 km wide are imposed throughout the linkage, where feasible; and
- Crossing structures are large enough to allow for the development of vegetation (i.e., *Eriogonum* species) through the passage.

Figure 50.
Potential Habitat
for
Metalmark Butterfly
(Apodemia mormo)

Legend

- Potential Habitat
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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Green hairstreak butterfly (*Callophrys affinis perplexa*)

Justification for Selection: The Green hairstreak butterfly was chosen as a habitat quality indicator, a good species for monitoring habitat health in the linkage (Pratt and Ballmer pers.com).

Distribution & Status: There are 4 recognized subspecies; *C. a. perplexa* occurs from lowland California to western Oregon, Carson Range of Nevada, and Puget Sound in Washington (Scott 1986). They are typically found below 1254 m (5000 ft) in elevation (Pratt and Ballmer pers.com).

Habitat Associations: The Green hairstreak butterfly prefers open habitats such as coastal sage and desert scrub, and are considered an indicator species for coastal sage scrub (Pratt and Ballmer pers.com). They may also be encountered in woodland, chaparral, and sagebrush habitats if the canopy is sparse (Scott 1986). Larval hostplants may include several buckwheats (*Eriogonum* sp.), Deerweed (*Lotus scoparius*) and other species in the Lotus genus, as well as wild lilacs (*Ceanothus* spp.; Orsak 1977, Scott 1986, Heath 2004). Adult primarily use buckwheat plants as nectar sources (Heath 2004).

The larvae of this species have a symbiotic relationship with ants. Ants protect butterfly larvae and pupae from predators, even carrying them to ant nests for shelter, where they may pupate in peace (Downey 1961, Orsak 1977). In return, the larvae exude a honey like fluid that is consumed by the tending ants (Downey 1961, Orsak 1977).

Spatial Patterns: The flight season for the Green hairstreak butterfly is in spring, usually from late February to April, though populations at higher elevations may have a later season (Scott 1986, Pratt and Ballmer pers.com). Individuals may live up to 19 days in nature (Scott 1986). The hairstreak is territorial, with an average home range size of 100 m^2 (1076 ft^2; Pratt and Ballmer pers.com).

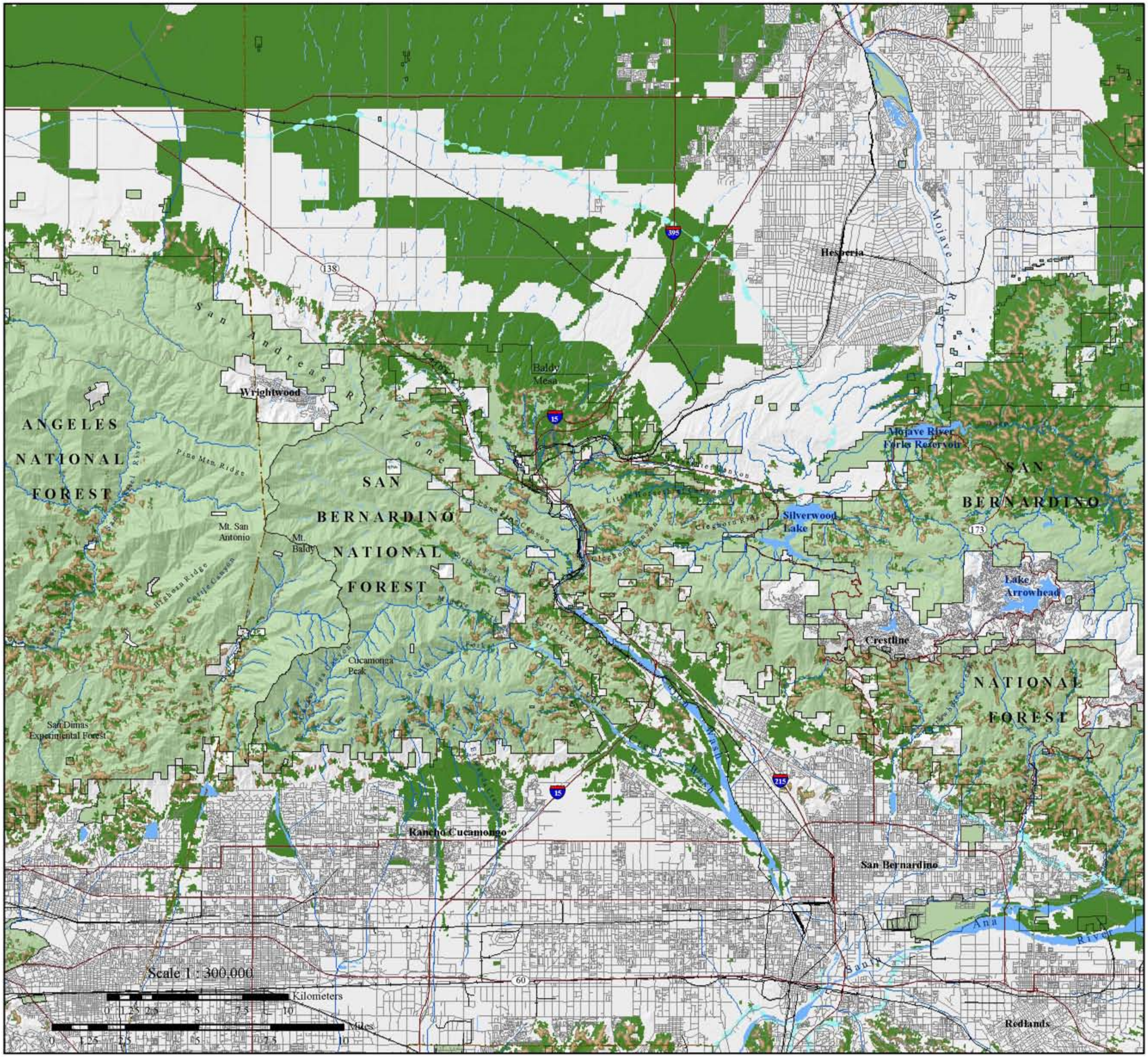
This species isn't considered a good disperser, but they will fly to high points where they engage in a behavior known as hilltopping to search for mates (Scott 1986, Pratt and Ballmer pers.com). They may travel along ridgetops and dry streams (Santa Barbara Museum of Natural History, undated mat.). Orsack (1977) typically encountered them along foothill ridges. While Emmel and Emmel (1973) found males perching on overhanging branches along washes and openings in chaparral.

Conceptual Basis for Model Development: Movement in the linkage is multigenerational. This species is an indicator for coastal sage scrub but may also be encountered in desert scrub, sagebrush, and open woodland and chaparral habitats below 1254 m in elevation. Access to hilltopping habitat is critically important for population persistence, thus we queried all ridges within 100 m of potential habitat.

Results & Discussion: The majority of potential habitat for this species was identified in the coastal sage habitat along the foothills and the scrub communities of the desert (Figure 51). All three branches of the Least Cost Union provide either potentially suitable habitat or hilltopping habitat for this species. Fairly good size blocks of habitat were identified on Baldy Mesa, The Pinnacles, and along the foothills, while hilltopping habitat occurs in scattered patches throughout the protected areas and Least Cost Union. We conclude that the linkage would likely serve the needs of the Green hairstreak butterfly. Though habitat additions included to support other focal species would also benefit this species. To protect habitat connectivity for this species, we recommend that:

- Fire frequency be controlled to prevent type conversion of chaparral and scrub habitats to nonnative annual grassland;
- Riparian and upland buffers at least 2 km wide are imposed throughout the linkage, where feasible; and
- Crossing structures are large enough to allow for the development of vegetation (i.e., *Eriogonum* species, Deerweed) through the passage.

Figure 51.
Potential Habitat
for
Green Haristreak Butterfly
(Callophrys perplexa)



Legend

- Potential Habitat
- Hilltopping Habitat
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

N

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Slender-horned spineflower (*Dodecahema leptoceras*)

Justification for Selection: The Slender-horned spineflower was chosen to represent alluvial fan scrub habitats between the San Gabriel and San Bernardino Mountains. This species is reliant upon natural hydrologic regimes to sustain their habitat (USFWS 2001, T. Krantz, pers. comm.).

Distribution & Status: The spineflower is an endemic species restricted to alluvial fans on the coastal side of the Transverse and Peninsular Ranges in Los Angeles, Riverside and San Bernardino counties. In the planning area, extant populations exist along the southern margins of the San Gabriel and San Bernardino Mountains (Munz 1974, Croft 1989, USFWS 2001, USFS 2002, T. Krantz, pers. comm.). Historically, this species occurred up to Blue Cut in the Cajon Pass (T. Krantz, pers. comm.).

The Slender-horned spineflower has the distinction of being the most critically endangered plant species in southern California (Croft 1989). The species is threatened by development encroaching into the floodplain, sand and gravel mining, domestic livestock grazing, and invasion of exotic plants (USFWS 1987), as well as, flood control projects, trash dumping, trampling, and off-road vehicles (Krantz 1984, USFWS 1987, Croft 1989, Hickman 1993, Stephenson and Calcarone 1999, California Native Plant Society 2001, USFWS 2001, USFS 2002). It is believed to be vulnerable to extirpation throughout its range (California Native Plant Society 2001, USFS 2002). Even on public land, such as the San Bernardino National Forest, populations are declining (Stephenson and Calcarone 1999, USFS 2002). The spineflower was listed as a federally endangered species in 1987, and is also state listed as endangered (USFWS 1987, Croft 1989, CDFG 2003).

Habitat Associations: This species prefers alluvial fan scrub vegetation on mature sandy benches or floodplain terraces with sandy to gravelly soils surrounded by chaparral, cismontane woodland, and coastal sage scrub at elevations between 200-760 m (650-2,500 ft) (Munz 1974, Croft 1989, Hickman 1993, California Native Plant Society 2001, USFS 2002). Nearly all occurrences for this species are associated with well-established alluvial scrub habitats, usually dominated by scrub oak (*Quercus berberidifolia*), coast live oak (*Q. agrifolia*), chamise (*Adenostoma fasciculatum*), and buckwheat (*Eriogonum fasciculatum*) (Croft 1989, Gordon-Reedy 1997, USFS 2002). It has also been found in association with mountain mahogany (*Cercocarpus betuloides*) and yerba santa (*Eriodictyon trichocalyx*), in addition to juniper (Reveal and Krantz 1979, Krantz 1984, USFWS 1987). They've also been observed in remnant riparian forests with sycamore (*Platanus racemosa*) and cottonwood (*Populus fremontii*) (Croft 1989). Neel and Brown (1987) recorded this species in chaparral dominated by juniper (*Juniperus californica*), white sage (*Salvia apiana*), and Croton (*Croton californicus*) (Croft 1989). Within all of these community associations, the spineflower is restricted to sparsely vegetated areas lacking canopy cover (Croft 1989), typically with undisturbed cryptogamic crusts (Reveal and Krantz 1979, Krantz 1984, USFWS 1987). The spineflower hasn't been documented on recently deposited alluvial or disturbed soil, nor is it found in areas with dense exotic annual grasses (Croft 1989, USFWS 2001, USFS 2002, T. Krantz, pers. comm.).

Spatial Patterns: The Slender-horned spineflower is an annual herb that blooms from April to June (Munz 1974, Hickman 1993, California Native Plant Society 2001). As such, annual variation in the amount and timing of precipitation can greatly affect population abundance (USFWS 2001, USFS 2002). Whether seeds can remain dormant for extended periods of time and still viable is unknown, though some believe the seed bank to be long lived (Reveal pers. com. *in* Croft1989). Dispersal mechanisms are also a mystery (Croft 1989), though it has been hypothesized that hairy mammals (e.g., coyote) may be dispersal agents or major floods may transport seeds over unknown distances (T. Krantz, pers. comm.).

Conceptual Basis for Model Development: Vegetation communities (i.e., alluvial fan sage scrub, coastal sage scrub, and barren) were queried in the GIS and then patches falling between 200-760 m were delineated as potentially suitable habitat.

Results & Discussion: The results of the habitat suitability model correspond well with recorded occurrences for this species (Figure 52). The southern branch of the Least Cost Union captured potentially suitable habitat for this species on the alluvial fans emanating from the San Gabriel and San Bernardino Mountains, while the central branch encompasses habitat in Cajon Wash up to Blue Cut. The linkage is likely to serve the needs of this species if additional habitat is added to the Union. To protect and restore habitat for the Slender-horned spineflower, we recommend that:

- Suitable habitat not captured by the Least Cost Union along the base of the San Gabriel Mountains in Deer, Day, Etiwanda, and San Sevaine Canyons, Lytle and Canyon Washes are added to support the needs of this species;

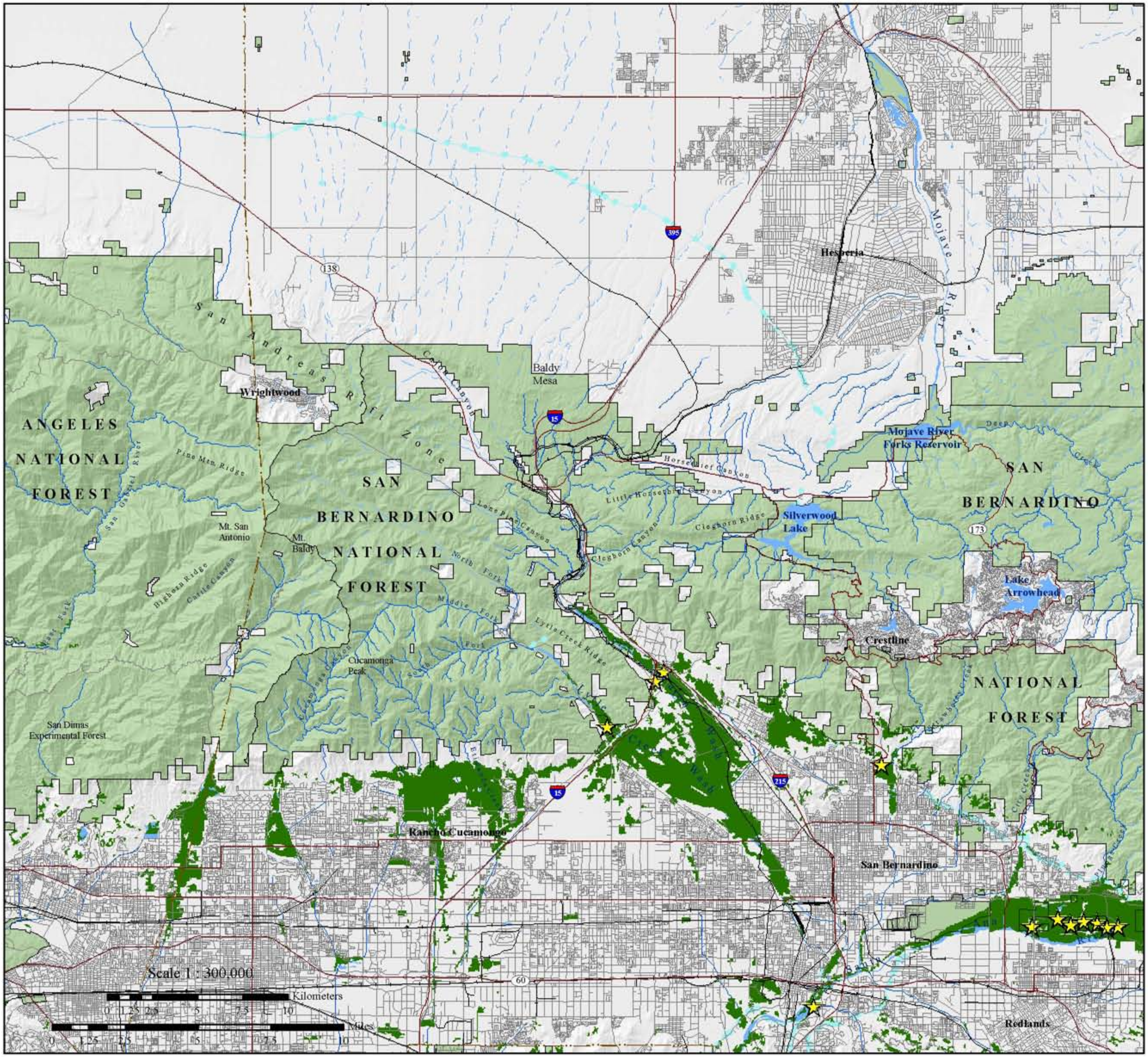
- Natural hydrological and fluvial geomorphological processes be protected and restored (USFWS et al. 1997, USFS 2002) throughout entire drainages with occupied or suitable habitat (Croft 1989);

- Research is conducted to determine dispersal mechanisms and habitat requirements for germination and establishment (Croft 1989);

- Historical, existing, and potential habitat is protected through conservation easements and acquisitions with willing landowners to protect existing populations and sites for reintroduction (Croft 1989). The federal Endangered Species Act as amended (16 U.S.C. 1534) authorizes USFWS to acquire land for the conservation of endangered plants with Land and Water Fund Act appropriations; and

- Receptive landowners work with US Fish and Wildlife Service Partners for Fish & Wildlife Program to acquire funds and technical assistance to restore and enhance alluvial fan sage habitat on their land to benefit the Slender-horned spineflower and other wildlife.

Figure 52.
Potential Habitat
for
Slender-horned Spineflower
(Dodecahema leptoceras)



Legend

- Potential Habitat
- Recorded Occurrence
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

N

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California Sagebrush (*Artemisia californica*)

Justification for Selection: California sagebrush is declining rapidly throughout its range and was chosen as a keystone species to represent sage scrub habitat linking the San Gabriel and San Bernardino Mountains (T. Krantz, pers. comm.). Habitat fragmentation and loss of sagebrush (Artemisia spp.) habitats have imperiled these native habitats and species that depend upon them, including the coastal California gnatcatcher (Knick et al. 2003).

Distribution & Status: California sagebrush is distributed from South Coast Ranges to cismontane southern California and Baja California Norte (Munz 1963, Hickman 1993), extending as far inland as Cajon and San Gorgonio passes (Holland 1986). Sagebrush occurs in a fairly contiguous narrow band along the coastal base of the San Gabriel and San Bernardino foothills. It is primarily found below 762 m (2500 ft) in elevation (Munz 1963).

Historically, sagebrush habitats covered nearly 63 million ha in the west (Knick et al. 2003). Urbanization, agriculture, mining, oil and gas development, and the never-ending road network have fragmented and eliminated expansive areas once dominated by sagebrush (Schmida and Barbour 1982, Howard 1993, Noss et al. 1995, Hann et al. 1997, Knick et al. 2003). Sagebrush habitats are one of the most imperiled ecosystems in North America (Noss and Peters 1995, Mac et al. 1998, Knick et al. 2003). *Artemisia california* is the dominant plant in several designated sensitive plant communities (Holland 1986, CDFG 2003), including Riversidean sage scrub, which occurs in the planning area.

Habitat Associations: California sagebrush is a dominant plant in coastal sage scrub, and is often found in association with White sage (*Salvia apiana*), Black sage (*S. mellifera*), California buckwheat (*Eriogonum fasciculatum*), Deerweed (*Lotus scoparius*), and Our lord's candle (*Yucca whipplei*) (Munz 1963, Hickman 1986). It prefers dry steep slopes and alluvial fans and is typically found on dry rocky or gravelly slopes below the chaparral (Munz 1963), though it intergrades with chaparral at slightly higher elevations (Holland 1986, Hickman 1993).

Spatial Patterns: Sweet smelling California sagebrush blooms from August to December on steep xeric slopes (Munz 1963, Holland 1986). The seeds are lightweight and believed to be wind dispersed and capable of long distance movements (Minnich 1980). During fire-free intervals, seed germination is moderate to high; crown sprouts after fires (Zedler 1981).

Conceptual Basis for Model Development: Vegetation communities (i.e., California sagebrush, ceanothus mixed chaparral, lower montane mixed chaparral, scrub oak, encelia, buckwheat, sumac, and mixed soft scrub chaparral) were queried in the GIS and then patches falling below 762 m were delineated as potentially suitable habitat.

Results & Discussion: Potential habitat for Sagebrush was identified along the base of the San Gabriel and San Bernardino Mountains (Figure 53). Though the model likely underestimated the amount of suitable habitat, as this species intergrades with chaparral at slightly higher elevations. The southern branch of the Least Cost Union is likely to accommodate this species, though habitat added for other focal species will also benefit California sagebrush.

Sagebrush habitats have been severely fragmented, altering vegetation dynamics, disturbance regimes, and facilitating the spread of nonnative invasive species (Braun 1998, Brooks and Pyke 2001, Gelbard and Belnap 2003, Knick et al. 2003). To protect and restore habitat for this species, we recommend that:

- Suitable habitat not captured by the Least Cost Union along the base of the San Gabriel Mountains in Deer, Day, Etiwanda, and San Sevaine Canyons, Lytle and Canyon Washes, and upper Cable Canyon is added to support the needs of this species;

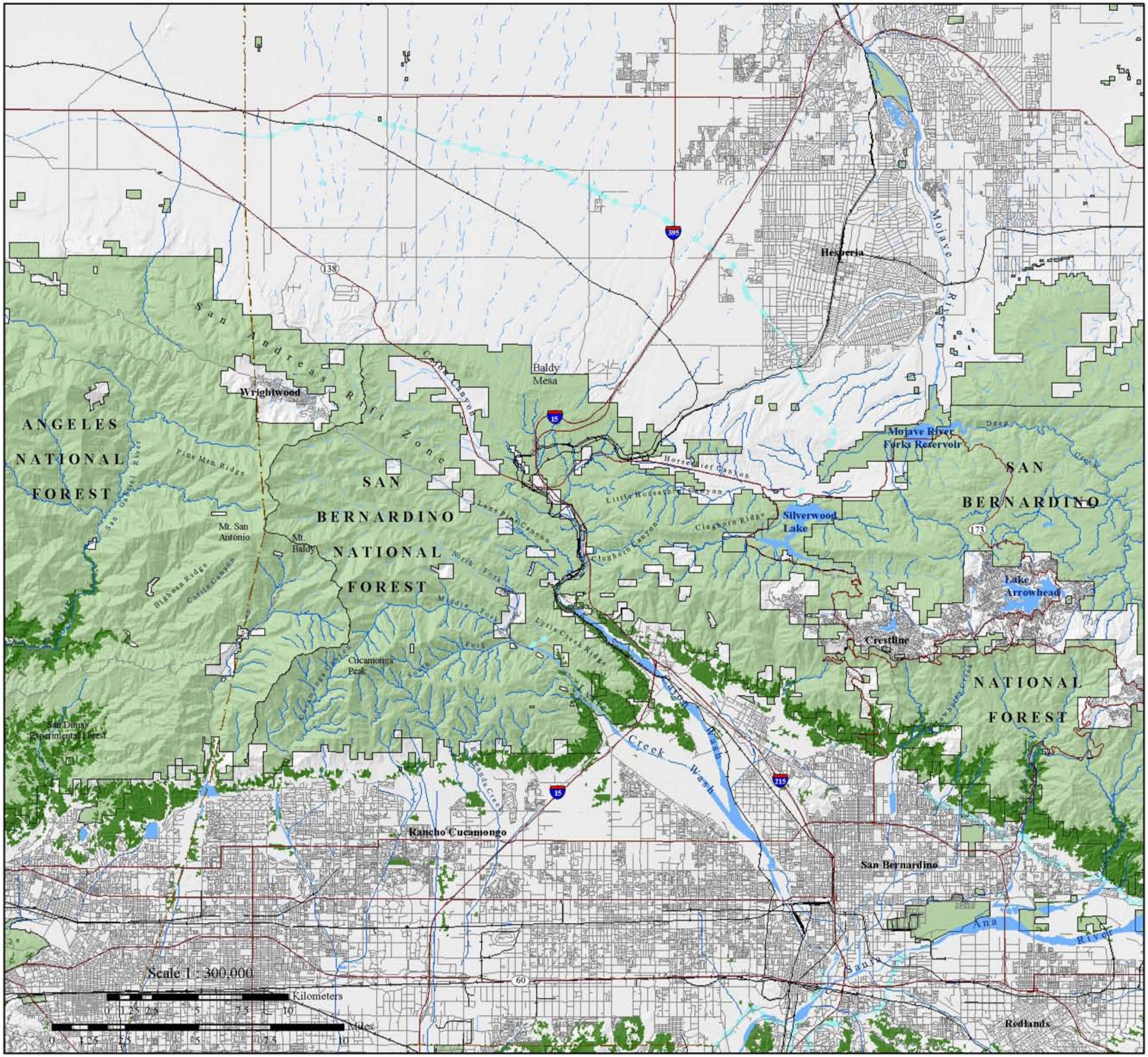
- Fire frequency be controlled to prevent type conversion of sagebrush habitats to nonnative annual grassland;

- Acquire private land to add to the reserve lands; and

- Receptive landowners work with US Fish and Wildlife Service Partners for Fish & Wildlife Program to acquire funds and technical assistance to restore and enhance sagebrush and alluvial fan habitats on their land to benefit the Slender-horned spineflower and other wildlife, such as the coastal California gnatcatcher.

Figure 53. Potential Habitat for California Sagebrush

(Artemisia californica)



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White Alder (Alnus rhombifolia)

Justification for Selection: White alder was selected as a focal species to link riparian habitats between the San Gabriel and San Bernardino Mountains. White alder contributes to structural diversity in riparian woodlands, an important habitat requirement of many bird species that breed in riparian systems (Sands 1979, Gaines 1980, Gray and Greaves 1984, Uchytil 1989).

Distribution & Status: White alder is distributed from the Pacific coast of Baja California, north to southern British Columbia, reaching its eastern limits in Idaho (Johnson 1968, Uchytil 1989). In California, it is found in the Coast, Transverse, and Peninsular Ranges (Holland 1986), from sea level to over 2438 m (8000 ft) in elevation (Griffin and Critchfield 1972).

Riparian woodlands in California are being lost at a staggering rate, due to urbanization, stream channelization and flood control projects (Wheeler and Fancher 1984, Uchytil 1989). Many riparian communities, including those dominated by White alder, are designated as sensitive natural communities (Holland 1986, CDFG 2003).

Habitat Associations White alder is restricted to riparian woodland communities along perennial streams (Arno and Hammerly 1977, Conard et al. 1980, McBride and Strahan 1984, Holstein 1984, Shanfield 1984, Brothers 1985, Uchytil 1989), but may also extend along major streams into other habitats (Johnson 1968, Uchytil 1989). In these communities, it is associated with Fremont cottonwood (Populus fremontii), California sycamore (Platanus racemosa), willows (Salix spp.), ash (Fraxinus spp.), California live oak (Quercus agrifolia), valley oak (Q. lobata), and Douglas-fir (Pseudotsuga menziesii) Vogl 1976, Roberts et al. 1980, Roberts 1984, Barbour 1987, Uchytil 1989). White alder is often a dominant species in deciduous riparian forests (Holstein 1984, Roberts et al. 1980, Uchytil 1989).

Spatial Patterns: White alders are wind pollinated. Female catkins develop into woody cones, containing numerous seeds (Schopmeyer 1974, Uchytil 1989), the majority of which are viable (Schopmeyer 1974, Uchytil 1989). The seeds are transported both up and downstream by wind and water to suitable germination sites on moist sites (Brothers 1985, Uchytil 1989, D. Woodward, pers. com.). Seeds are important for colonization of new sites but established alders also regenerate from root or trunk sprouting (Sampson and Jespersen 1963, Shanfield 1984, Uchytil 1989). Alder seeds are also consumed by birds, which may act as dispersal agents (U.S.D.A. Forest Service 1937, Uchytil 1989, D. Woodward, pers. com.).

Conceptual Basis for Model Development: Riparian vegetation communities (i.e., White alder riparian forest, California sycamore, Fremont Cottonwood, mixed riparian woodlands) along perennial streams were queried in the GIS and then patches falling below 2438 m were delineated as potentially suitable habitat.

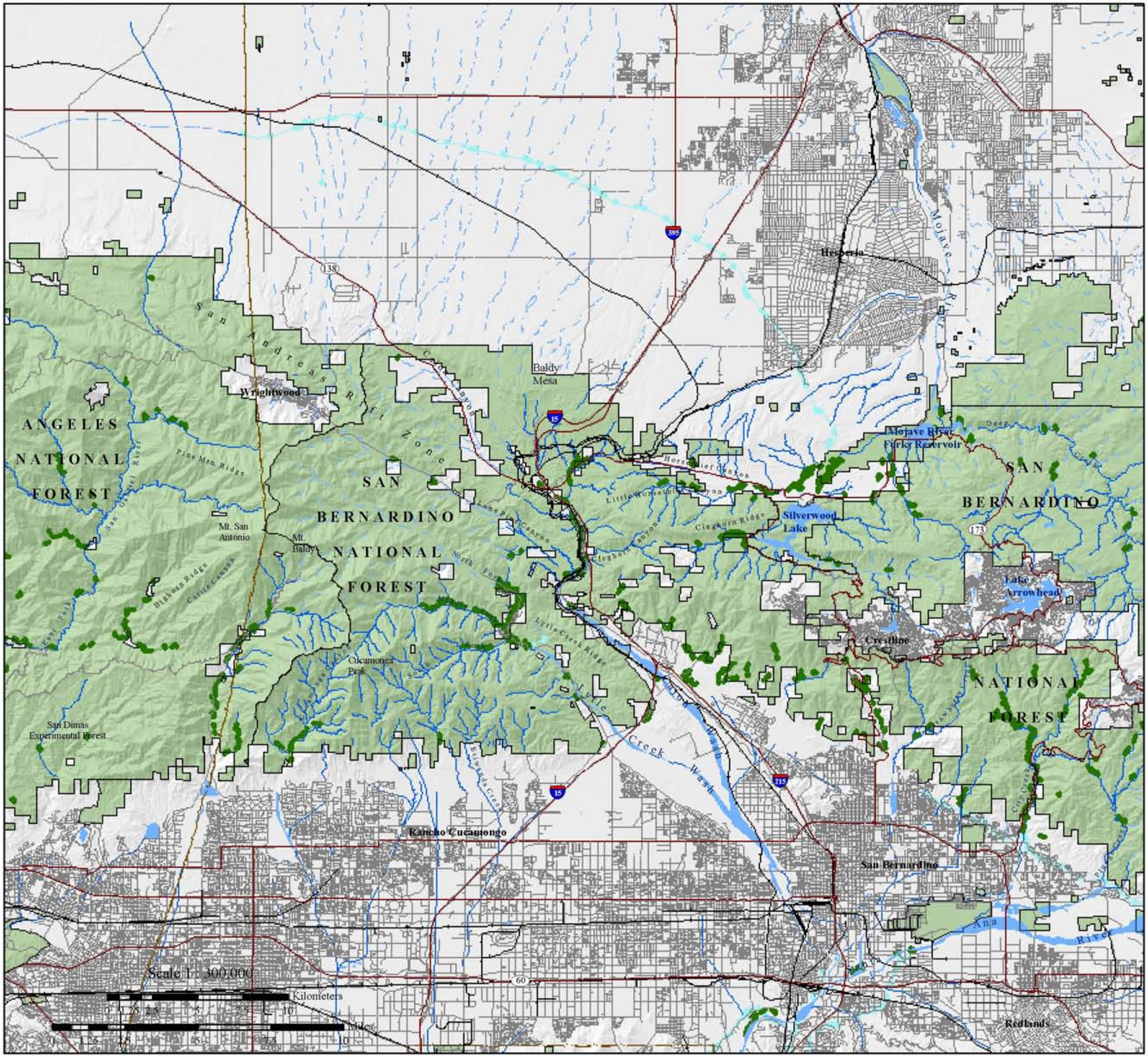
Results & Discussion: Scattered patches of potential habitat for White alder were identified in both the San Gabriel and San Bernardino Mountains (Figure 54). The northern and central branches of the Least Cost Union are likely to accommodate this species, if additional habitat is added to the Union. Riparian communities are being lost at an alarming rate in the South Coast Ecoregion. To protect and restore habitat for this species, we recommend that:

- Suitable habitat not captured by the Least Cost Union in Horsethief and Little Horsethief Canyons, Grass Valley, West Fork of the Mojave River, Strawberry and City creeks, and upper Cable Creek is added to support this species;
- Riparian buffers at least 2 km wide are imposed throughout the linkage, where feasible;
- Natural flood dynamics are protected, maintained, and restored;
- Acquire private land private land to add to reserves; and
- Receptive landowners work with US Fish and Wildlife Service Partners for Fish & Wildlife Program to acquire funds and technical assistance to restore and enhance riparian habitat on their land to benefit the many species dependent on aquatic habitats.

Figure 54.
Potential Habitat
for
White Alder
(Alnus rhombifolia)

Legend

- Potential Habitat
- Paved Roads
- Railroads
- Reservoirs & Washes
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries



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This chapter is the heart of the report. In it, we summarize the goals of the Linkage Design, present a map of the final design (Figure 55), and describe the land included in it. However, conserving a linkage is more complex than circumscribing the important acres on a map. While developing the Linkage Design, we conducted fieldwork to identify barriers to movement or land use practices that may prevent species from moving through the linkage. The bulk of this chapter is a description of the existing barriers and prescriptions for actions needed to ensure that the Linkage Design is effective.

Goals of the Linkage Design

To accommodate the range of species and ecosystem functions it is intended to serve, the Linkage Design attempts to: 1) provide live-in and move-through habitat for multiple species; 2) support metapopulations of smaller species; 3) ensure the availability of key resources; 4) buffer against edge effects; 5) reduce contaminants in streams; 6) allow natural processes to operate with minimal constraints from adjacent urban areas; and 7) allow species and natural communities to respond to climatic changes. We elaborate on these seven goals in the following paragraphs.

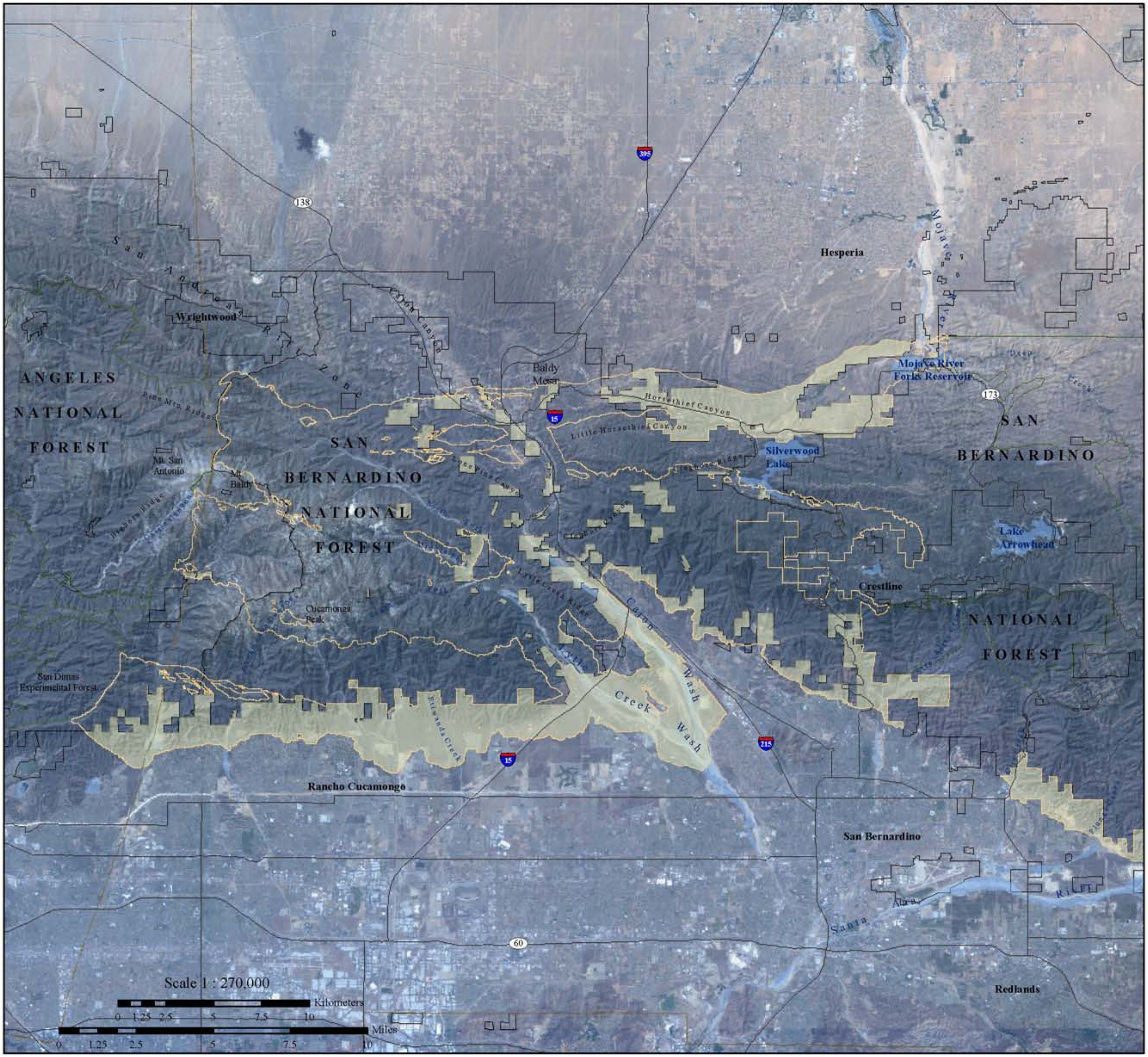
The Linkage Design must be wide enough to provide live-in habitat for species with dispersal distances too short to allow movement through the entire length of the linkage. Harrison (1992) proposed a minimum corridor width for a species living in a linkage as the width of one individual's territory (assuming territory width is half its length). Thus, our minimum corridor width of 2 km should accommodate species with home ranges of up to 8 km^2 (3 mi^2). This would accommodate all focal species except mountain lion, as well as larger non-focal species such as bobcats.

The Linkage Design must support metapopulations of less vagile species. Many small animals, such as horned lizards, treefrogs, and many invertebrates, require dozens of generations to move between core areas. These species need a linkage wide enough to support a constellation of metapopulations, with movements among subpopulations, over decades.

The Linkage Design is expected to ensure the availability of key resources, including host plants (e.g., for butterflies), pollinators, nesting and roosting sites, and other essential elements. For example, many species commonly found in riparian areas depend on upland habitats during some portion of their cycle. These species include butterflies that use larval host plants in upland areas and drink from water sources as adults, western pond turtles that live most of their lives in water but lay their eggs in sandy upland habitats, and fish, such as the Santa Ana speckled dace, that feed on the aquatic larvae of insects, many of which depend on terrestrial habitats as adults.

The Linkage was designed to buffer against edge effects. Human activities in neighboring areas can have undesirable effects on protected areas. These "edge effects" include artificial night lighting, predation by species supported by human activities (e.g., pets, released pets, and native predators such as raccoons that reach

Figure 55.
Linkage Design



Legend

- Linkage Design Boundary
- Unprotected Area
- Roadless Areas
- Interstate/Highways
- Ownership Boundaries
- County Boundaries

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high density due to availability of garbage), elevated soil moisture and stream flow from irrigation, pesticides & pollutants, noise, hobby animals that increase risk of interactions with native predators, and removal of natural vegetation. Edge effects (Murcia 1995) 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) 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 ant populations due to the invasion of argentine ants up to 200 m (650 ft) from irrigated areas (Suarez et al. 1998), and predation by pet cats which decimate small vertebrate populations (Churcher and Lawton 1987, Hall et al. 2000) 100 m (300 ft) from the edge (K. Crooks, unpublished data). Although, 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). In addition, homeowners may clear vegetation up to 61 m (200 ft) around their homes to reduce fire risk and meet insurance requirements at the wildland-urban interface (Longcore 2000).

In areas of the Linkage with streams, upland habitat protection is needed to prevent the degradation of aquatic habitat quality. Contaminants, sediments, and nutrients can reach streams from distances greater than 1 km (0.6 mi) (Maret and MacCoy 2002, Scott 2002, Naicker et al. 2003), 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).

The Linkage Design must allow natural processes of disturbance and subsequent recruitment to operate with minimal constraints from adjacent urban areas. Linkage width should be sufficient such that the temporary devastation caused by fires, floods and other natural processes does not affect all habitats in the linkage simultaneously. Fire as a natural process is especially challenging to sustain in a relatively small linkage area. Large fires, such as those occurring under Santa Ana wind conditions, could easily burn all habitats in the linkage. Before human occupation, naturally occurring fires (due to lightning strikes) were relatively rare in the coastal ranges of southern California (Radtke 1983). As populations in the region soared, fire frequency has also increased dramatically (Keeley and Fotheringham 2000). Homeowners at the wildland-urban interface, alarmed by the devastation of these wildland fires are further promoting the use of prescribed burns to reduce fuels in surrounding natural areas. Although fire has been shown to reduce the occurrence of exotic species in native grasslands (Teresa and Pace 1996), in shrublands it can have the opposite effect (Giessow and Zedler 1996), encouraging the invasion of non-native plants, especially when fires are too frequent. While the pattern of disturbance caused by this altered fire regime is unpredictable, wider linkages with broader natural communities may be more robust to these disturbances.

The Linkage Design must also allow species to respond to climate change. Over the past century, the earth's warming rate has increased four-fold, and predictions for changes in California's weather include warmer winters with increases in flooding and fire (Field et al. 1999). Plant and animal distributions are predicted to change with the climate, expanding and contracting and rising and falling in elevation (Field et al. 1999).

The Linkage must be broad enough to allow for these wholesale movements in natural communities, and should encompass a diversity of microhabitats (e.g., slopes, aspects, elevations, and soil types) that allow species to colonize new areas.

Description of the Linkage Design

At first glance, the linkage between the San Bernardino and San Gabriel Mountain Ranges seems simply to be a matter of getting plants and animals across Interstate 15. Indeed, for most species, the freeway is the most obvious barrier between core population centers, and National Forest land abuts both sides of the freeway for several miles. However, a Linkage Design that simply maintained and improved permeability along I-15's frontage with Forest Service land would fail to provide connectivity for lowland species along the southern foothills, and could result in Baldy Mesa becoming an island or peninsula of habitat, hemmed in by urban and agricultural land on the north, increasingly dense ranchette development in upper Cajon Canyon on the south and west, and I-15 on the south and east. Therefore, the Linkage Design has three roughly parallel routes to accommodate diverse species and ecosystem functions (Figure 55). The central branch is relatively short (with length equal to the width of the freeway, frontage road, and adjacent rail lines) and largely in public ownership; but the northern and southern branches are roughly 39 km (24 mi) long and include substantial private lands.

The northern branch offers a high desert connection dominated by xeric chaparral communities, with patches of desert scrub, juniper and Joshua tree woodlands, grassland, and riparian habitats, serving species such as the badger, rock wren, horned lizard, and metalmark butterfly. It extends from the Upper North Fork of Lytle Creek, across Stockton Flat, down into Lone Pine Canyon, across Cajon Pass to Horsethief Canyon, up into Summit Valley and then on to the West Fork of the Mojave River. The central branch links a series of higher elevation forest and shrubland habitats serving numerous species, including puma, mule deer, spotted owl, mountain quail, and wrentit. This branch also offers the best potential connection for bighorn sheep, pygmy nuthatch, treefrog, whipsnake, and speckled dace. It encompasses the majority of land between Upper Lytle Creek Ridge, lower Lone Pine Canyon, Crowder and Cleghorn Canyons in the north and Cucamonga and Arrowhead Peaks in the south. The southern branch encompasses coastal and alluvial fan scrub habitats from San Antonio, Cucamonga, Deer, Day, Etiwanda, Morse, and San Sevaine creeks, to Lytle Creek and Cajon Wash, serving the movement needs of the endangered San Bernardino kangaroo rat and slender-horned spineflower, as well as the Pacific kangaroo rat, tarantula hawk, giant flower-loving fly, and California sagebrush.

As expected given the marked elevational gradient and the transition from cismontane scrub and woodland communities in the south to the transmontane Mohave desert in the north, the Linkage Design encompasses a diversity of natural communities, including 33 different major vegetation types (Table 3). Although natural vegetation comprises most of the Linkage Design, urban and agricultural development covers roughly 1.8% of its area. Habitats within the linkage are similar to those found in the two core areas, with chaparral, woodland, and conifer communities dominating. Chaparral is by far the most common vegetation community, covering the steep rugged slopes of Cajon Pass, and extending into the desert and coastal foothills at mid-elevations.

Table 3. Approximate Vegetation and Land Cover in the Linkage Design

Vegetation Type	Area (ha)	Area (acres)
Pinyon-Juniper	1.08	2.67
Alkali Desert Scrub	16.02	39.59
Closed-Cone Pine-Cypress	18.09	44.70
Agriculture	23.31	57.60
Eucalyptus	38.52	95.19
Desert Riparian	40.77	100.74
Water	43.51	107.52
White Fir	49.68	122.76
Desert Wash	51.48	127.21
Ponderosa Pine	64.62	159.68
Coastal Oak Woodland	72.63	179.47
Montane Riparian	92.62	228.88
Eastside Pine	160.20	395.86
Wet Meadow	164.97	407.65
Subalpine Conifer	192.78	476.37
Alpine-Dwarf Shrub	223.62	552.57
Sagebrush	350.93	867.18
Desert Scrub	451.41	1,115.45
Jeffrey Pine	457.38	1,130.21
Valley Foothill Riparian	595.36	1,471.17
Juniper	748.59	1,849.82
Urban	907.60	2,242.72
Montane Chaparral	1,146.96	2,834.20
Annual Grassland	1,174.56	2,902.41
Barren	1,709.51	4,224.30
Chamise-Redshank Chaparral	3,434.55	8,486.95
Montane Hardwood-Conifer	3,831.52	9,467.89
Mixed Conifer	4,516.56	11,160.67
Montane Hardwood	5,513.31	13,623.70
Coastal & Alluvial Scrub	6,117.67	15,117.09
Mixed Chaparral	20,359.25	50,308.81
TOTAL	52,569.06	129,901.03

A diversity of riparian forests, woodlands, and scrubs occur throughout the linkage and core areas. Cajon Wash meanders along I-15 through the entire linkage, with Lone Pine, and two unnamed tributaries flowing into Cajon Wash from the San Gabriels, and Crowder, Cleghorn, and Pitman Canyons and two unnamed tributaries flowing into Cajon Wash from the San Bernardino Mountains. These riparian areas of the Linkage

Design provide the most direct connections between these ranges for semi-aquatic species (e.g., California treefrog). Other significant riparian routes are the North, Middle and South Forks of Lytle Creek that join Cajon Wash in the southern part of the linkage, and Horsethief and Little Horsethief Creeks that flow into the West Fork of the Mojave River. While other riparian drainages in the Linkage Design (i.e. Deer, Day, Etiwanda, San Sevaine, Strawberry, City and Plunge creeks), also provide important habitat for upland, aquatic and semi-aquatic species, though don't provide a continuous connection between ranges. Despite the relatively low amount of acreage encompassed by riparian communities (about 1.6%), these habitats support a disproportionately large number of species and are key movement areas for most aquatic and terrestrial organisms.

Approximately 66% of the Linkage Design currently enjoys some level of conservation protection, mostly in National Forest land, whose management policies do not allow conversion to urban or agricultural use. The Bureau of Land Management, California State Parks, and California Department of Fish and Game also administer land in the linkage. Other major landholders include the San Manuel Tribe in the foothills of the San Bernardino Mountains east of the Linkage Design, and the Army Corp of Engineer lands along the Mojave River.

Removing and Mitigating Barriers to Movement

Five types of features impede species movements through the Linkage: roads, railroads, impediments to stream flow, industrial operations, and residential development. This section describes these impediments and suggests where and how their effects may be mitigated to improve linkage function.

This discussion focuses on structures to facilitate movement of terrestrial species across roads, and on structures to facilitate stream flow under roads. Although in some parts of the linkage, these structures are almost synonymous with "corridors" or "linkages," these terms properly apply to the entire area needed to facilitate movement between large protected core areas, and crossing structures represent only choke points within the linkage. Although I-15 is by far the most important barrier in this particular linkage, it is not the only one, and specific crossing structures must be integrated with other essential components of the linkage. Thus it is essential to keep the larger landscape context in mind when discussing existing or proposed structures to cross movement barriers. This broader context also allows awareness of a wider variety of restoration options for maintaining functional linkages. Despite the necessary emphasis on crossing structures in this section, we urge the reader keep sight of the primary goal of conserving landscape linkages to promote movement between core areas over broad spatial and temporal scales.

Roads as Barriers to Upland Movement: Wildland fragmentation by roads is increasingly recognized as one of the greatest threats to biodiversity (Noss 1983, Harris 1984, Wilcox and Murphy 1985, Wilcove et al. 1986, Noss 1987, Reijnen et al. 1997, Jones et al. 2000, Trombulak and Frissell 2000, Forman and Deblinger 2000, Forman et al. 2003). Roads cause fragmentation by killing animals in vehicle collisions, by creating discontinuities in natural vegetation (the road itself and induced urbanization), by altering animal behavior (noise, artificial light, human activity), by promoting invasion of exotic species, and by degrading the chemical environment (Lyon 1983, Noss and Cooperrider 1994, Forman 1998). Roads present semi-permeable to impermeable barriers for nonflying animals (e.g., insects, fish, amphibians, reptiles, and mammals) and even some flying species (e.g., butterflies and low-flying birds). The genetic isolation of populations caused by roads is an increasing cause of concern. For example, Ernest (2003) documented little flow of mountain lion genes between the Santa Ana and Palomar ranges (where I-15 is the most obvious barrier), and between the Sierra Madre and Sierra Nevada (where I-5, and urbanization along SR-58, are the most obvious barriers). Fragmentation by roads increases inbreeding and genetic drift, potentially contributing to extinction of local populations.

The impact of a road on animal movement varies with species (e.g., the same freeway would have different impact on ground beetles, coyotes, or birds), context (vegetation and topography near the road), and road type and level of traffic (Clevenger 2001). For example, a road on a stream terrace can cause significant population declines in slow-moving amphibians approaching breeding ponds (Stephenson and Calcarone 1999), but a similar road on a ridgeline would have negligible impact on the population. Virtually all documented impacts on animal movement concern paved roads; dirt roads are of less concern and may even facilitate movement of some species, such as mountain lion (Dickson et al. 2004).

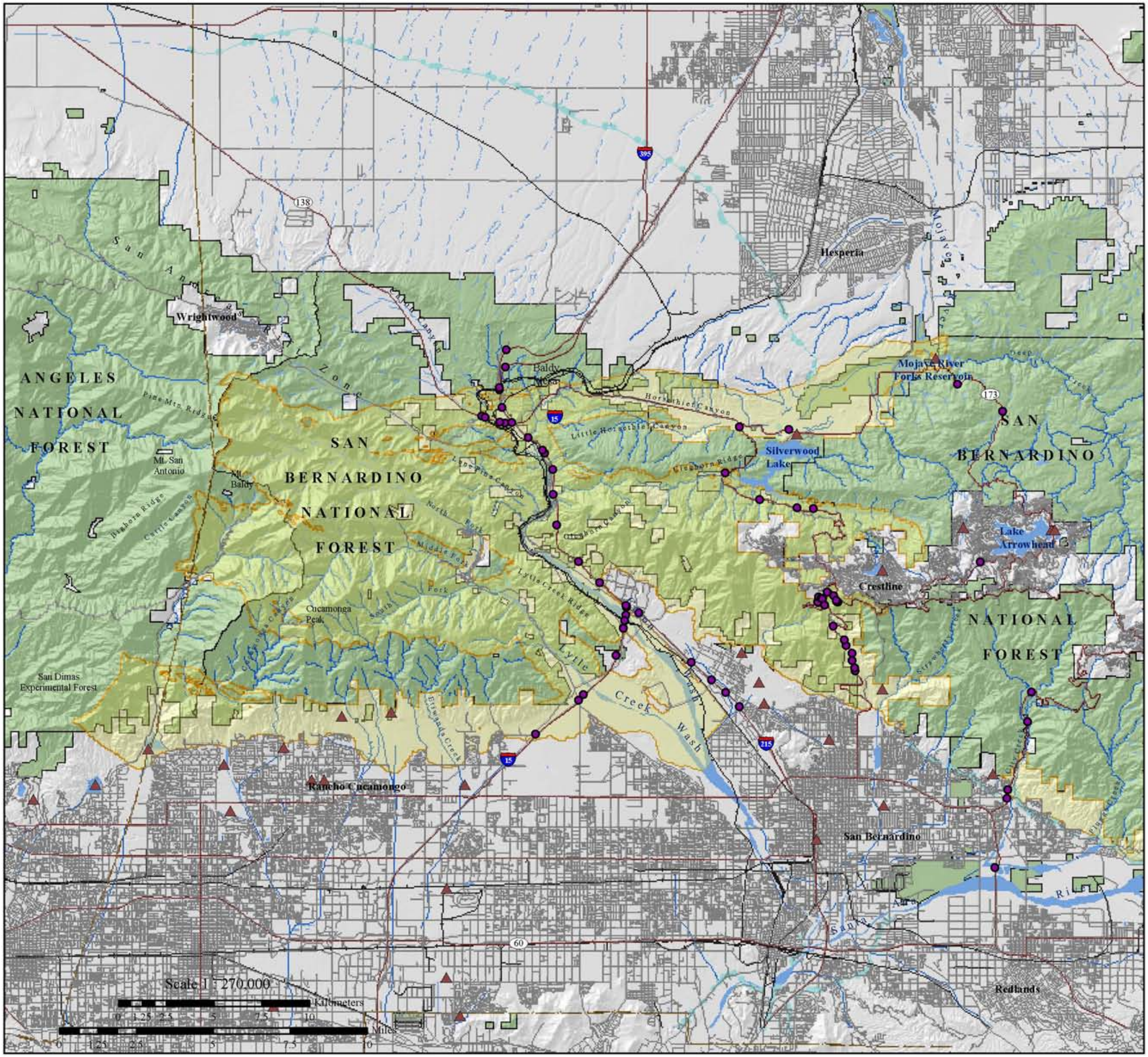
Roads in the Linkage Design: At the time of this report, there are 249 km (154.77 mi) of paved roads in the Linkage Design area (Table 4). Two of these roads, Interstate 15 and State Route 138, are major transportation routes and pose the most substantial barriers to movement (Figure 56). Interstate 15 is by far the most severe impediment, bisecting the linkage for a distance of roughly 27 km (17 mi), with 46 million vehicles a year traveling through the pass (USDA Forest Service 2004). A survey of these roads found a variety of bridges, culverts and drainage pipes that might be useful for implementing road mitigation projects (Figure 56).

Table 4. Major transportation routes in the Linkage Design.

Road Name	Length (km)	Length (mi)
Interstate 15	27.04	16.80
State Highway 138	33.39	20.75
State Highway 18	17.16	10.66
State Highway 173	11.83	7.35
Neighborhood roads	159.66	99.21
Total Length of Paved Roads	**249.08**	**154.77**

Types of Mitigation for Roads: Forman et al. (2003) suggest several ways to mitigate the ecological impact of roads on landscape linkages by creating wildlife crossing structures and reducing traffic noise and light, especially at entrances to crossing structures. Wildlife crossing structures have been successful both in the United States and in other countries, and include underpasses, culverts, bridges, and bridged overcrossings. Most structures were initially built to accommodate streamflow, but have been documented to be useful for wildlife movement. Research and monitoring have confirmed the value of these structures in facilitating wildlife movement. The main types of structures, from most to least effective, are vegetated land-bridges, bridges, underpasses, and culverts.

Figure 56.
Existing Infrastructure in the Planning Area



Legend

- LinkageDesign
- Potential Crossing Structures
- Dams
- Interstate/Highways
- Paved Roads
- Railroads
- Perennial Stream
- Intermittent Stream
- Aqueduct
- County Boundaries
- Ownership Boundaries

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There are approximately 50 wildlife overpasses, or vegetated land bridges (Figure 57) in Europe, Canada, Florida, Hawaii, New Jersey, and Utah (Evink 2002, Forman et al. 2003). They range in width from 50 m (164 ft) to more than 200 m wide (656 ft) (Forman et al. 2003). Soil depth ranges from 0.5 to 2 m, allowing for the development of herbaceous, shrub and tree cover (Jackson and Griffin 2000). Wildlife fencing is necessary to funnel animals towards passageways and away from roads (Falk et al. 1978, Ludwig and Bremicker 1983, Feldhammer et al. 1986, Forman et al. 2003). Earthen one-way ramps can allow animals that wander into the right of way to escape over the fence (Bekker et al. 1995, Rosell Papes and Velasco Rivas 1999, Forman et al. 2003). Habitat connectivity can be enhanced for some small ground-dwelling animals by ensuring there is contiguous vegetation, or by placing branches, logs, and other cover along the overpass (Forman et al. 2003). Overpasses maintain ambient conditions of rainfall, temperature, light, vegetation, and cover, and are quieter than underpasses (Jackson and Griffin 2000). In Banff, large mammals preferred overpasses to other crossing structures (Forman et al. 2003). Similarly, birds associated with woodland habitats used overpasses significantly more than they did open areas without an overpass. Other research indicates overpasses may encourage birds and butterflies to cross roads (Forman et al. 2003).

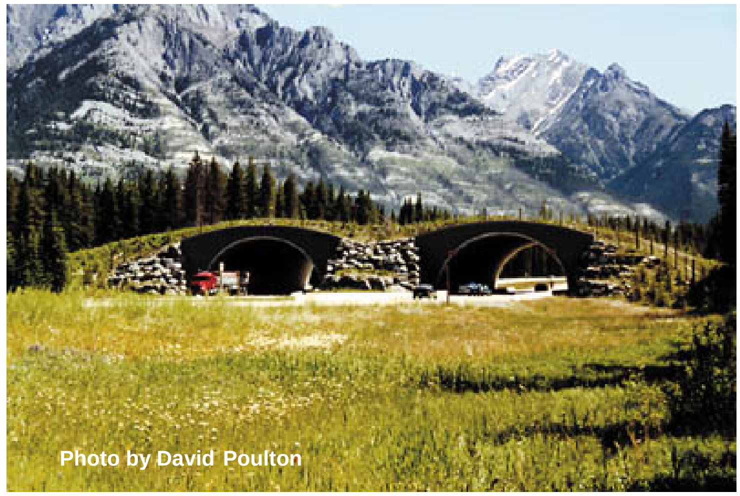

Figure 57. An example of a vegetated land bridge built to enhance movement of wildlife populations.

Bridges over waterways should be wide enough to permit growth of both riparian and upland vegetation along both stream banks (Jackson and Griffin 2000, Evink 2002, Forman et al. 2003). The extended bridge is the most successful and cost-effective means of providing connectivity (Evink 2002). Bridges with greater openness ratios are generally more successful than low bridges and culverts (Veenbaas and Brandjes 1999, Jackson and Griffin 2000). The best bridges, sometimes termed viaducts (Figure 58), are elevated roadways that span entire

Figure 58. A viaduct in Slovenia built to accommodate wildlife, hydrology, and human connectivity.

wetlands, valleys, or gorges (Jackson and Griffin 2000), but are cost-effective only where the topographic relief is sufficient to accommodate the structure (Evink 2002).

Figure 59. Arched culvert on German highway, with rail for amphibians and fence for larger animals.

Although inferior to bridges for most species, culverts are also effective (Jackson and Griffin 2000). For carnivores and other large mammals, large culverts (Figure 59) are most effective, and natural earthen substrate flooring is preferable to concrete or metal (Evink 2002). Gloyne and Clevenger (2001) suggest that underpasses for ungulates should be at least 4.27 m in height and 8 m wide, with an openness ratio of 0.9 (openness ratio=height x width/length). Noise, artificial night lighting, and other human activity can deter animal use of a passageway (Yanes et al. 1995, Pfister et al. 1997, Clevenger and Waltho 2000, Forman et al. 2003), and noise can deter animal passage (Forman et al. 2003). Shrub or tree cover should occur near the entrance to the crossing structure (Evink 2002). Existing structures can be substantially improved with little investment by installing wildlife fencing, earthen berms, and vegetation to direct animals to passageways (Forman et al. 2003).

For rodents, pipe culverts (Figure 60), about 1 ft in diameter without standing water are superior to large, hard-bottomed culverts, apparently because the overhead cover makes them feel secure against predators (Forman et al. 2003, Clevenger 2001). In places where a bridged, vegetated undercrossing or overcrossing is not feasible, placing pipe culverts alongside box culverts can help serve movement needs of both small and large animals. Special crossing structures that allow light and water to enter the structure have been designed to accommodate amphibians (Figure 61). Short retaining walls should be installed, where necessary, along paved roads to deter small mammals,

Figure 60. Pipe culvert designed to accommodate small mammals.

Figure 61. Amphibian tunnels allow light and moisture into the structure.

amphibians, and reptiles from accessing roadways (Jackson and Griffin 2000). Concrete retaining walls are relatively maintenance free, and a great deal better than wire mesh, which must be buried and regularly maintained.

Recommended Crossing Structures on Interstate 15: Interstate 15 is the most substantial impediment to movement within the Linkage Design. Historic Route 66 and several major rail lines run alongside the freeway in many areas, adding to the barrier effect. Following standard practice where a road bisects a major wildland, we recommend crossing structures at intervals of 1.5 to 2 km (0.9 to 1.25 miles) (Clevenger and Wierzchowski in press). Thus, we propose a total of 10 bridged undercrossings or wildlife overpasses along the 19 km (12 mi) of Interstate 15 through the San Bernardino National Forest. We also recommend two crossing structures outside of National Forest lands, one north of Cajon Pass, and one south of Devore Heights. Three crossing structures adequate to accommodate wildlife movement currently exist.

The precise location of the additional crossing structures can be dictated by cost, feasibility, and other factors, and construction can be delayed until the next lane addition, ramp remodeling, or other significant project on each mile of the freeway. Although the timing and the precise locations are not critical, it is important that (a) the average interval between structures must be less than 1.25 miles, and the largest interval must not exceed 1.75 miles, (b) each new or improved crossing structure should be a vegetated overpass or bridge (none should be culverts), sited along natural travel routes, and (c) the entire right-of-way should be fenced to funnel animals toward the crossing structures. Excellent examples of roads retrofitted with large crossing structures at similar intervals include State Route 260 between Payson and Forest Lakes, Arizona, State Route 87 south of Rye, Arizona, the Trans-Canada Highway in Banff National Park, Canada, Interstate 75 through the Everglades in Florida, and Interstate 4 near Daytona Beach, Florida.

Currently 3 bridges along I-15 accommodate animal movement; all occur within a 1.5-mile long section of highway south of the Cajon interchange (Figure 62 and 63). We recommend maintaining these structures, protecting adjacent land from development, and ensuring that future road projects do not degrade the crossing structure. By far the best of these is the bridge at Cleghorn Canyon (Figure 62). In addition to being an excellent high bridge, the Least Cost Corridors for puma, mule deer, and bighorn sheep cross I-15 at Cleghorn Canyon, and there is a perennial spring in the upper canyon that draws animals into the drainage. Until new or upgraded crossing structures are available, it is critical that this structure be maintained and that the private and public lands near it are protected from urban development. The private parcel(s) at Cozy Dell (about 200 acres) should be targeted for conservation easement, purchase, or other action to maintain its wild character.

The other two bridged crossings lie north of Cleghorn Canyon and south of the site of old Cajon (Figure 63). Compared to Cleghorn, these bridges have shorter spans, less clearance above the wash, and the canyons drain much smaller watersheds (100 to 300 acres, compared to about 1500 acres for Cleghorn). They may be expected to serve focal species, such as the Pacific kangaroo rat, San Diego horned lizard, Chaparral whipsnake, or the Metalmark butterfly.

Figure 62. View westward down Cleghorn Canyon under I-15. This photograph was taken about 3 weeks after a fire burned most of the vegetation in the canyon. The right bank is private property.

Figure 63. Two bridged crossings of I-15 north of Cleghorn Canyon, looking east from historic Route 66. The bridge at left is about 0.7 miles north of Cleghorn Canyon; the bridge at right is about 400 yards south of the Cajon interchange.

There are also two sets of culverts on I-15 that probably accommodate some level of animal movement. A large box culvert about ½ mile south of the SR-138 interchange serves Crowder Canyon and the Pacific Crest Trail (Figure 64). Crowder Canyon serves a large watershed, lies on the Least Cost Corridor for Badger, and carries water much of the year. This should be one of the best locations for a crossing structure in the entire linkage. We strongly recommend replacing this structure with a bridged crossing. Conserving the 300-acre private parcel along SR-138, about 1 mile upstream in Crowder Canyon, and the two 160-acre parcels that straddle the freeway near the culvert would also enhance the integrity of the linkage.

Figure 64. Left: Looking west down Crowder Canyon into the box culvert under I-15. The Pacific Crest Trail also uses this culvert. Right: Inside the central area of the culvert, showing water covering much of the floor and indirect light at the opening.

The other set of culverts under I-15 were built to allow one-lane Forest Road 3N21 to cross the freeway about 1.5 miles southwest of Cajon Summit, in an area where the northbound and southbound lanes are about a half-mile apart (Figure 65). Motorcycles, off-road vehicles, and other recreationists regularly use the dirt road. Although small and not located on a major drainage, these culverts may be used by some animals.


Figure 65. The culverts for 1-lane Forest Road 3N21 as photographed from a small hill in the wide median of I-15 lanes. Left: the culvert under the southbound lanes. Right: the culvert for the northbound lanes (same size as the other culvert) is under the tractor-

trailer in the center of the photo. The bridge in the background carries a railroad over a small canyon and FR-3N21.

Recommendations for SR-138 (Rim of the World Road): Currently, this 2-lane road receives light tourist traffic, though substantial increases in traffic and upgrading of the highway is planned. The USFS is working with the Department of Transportation to design adequate linkages that will include 1 or more bridges and other large crossing structures to accommodate wildlife movement. In this section, we recommend maintaining current conditions, and conservation agreements to preclude development of a 300-acre private inholding in Crowder Canyon (as reference above with respect to the Pacific Crest Trail crossing site).

West of I-15, SR-138 serves an increasing number of homes in the Cajon Canyon inholdings. Of the 8 miles of SR-138 within the San Bernardino National Forest west of I-15, 6 miles lie in a stairstep swath of private property about ½ to 2 miles wide. There are many 1-10 acre ranchettes in this area, but several large undeveloped tracts could be in large parcels of several hundred acres (Figure 66). Except on the smaller housing lots, most of the private land is in natural vegetation. Although this western portion of SR-138 is not an impermeable barrier, especially at night, in the long term, permeability for most species is likely to be lost if further subdivision and home-building occurs here. If coupled with development along SR-138 outside the Forest, this will contribute to the isolation of the 10,000-acre Baldy Mesa from the rest of San Bernardino National Forest.

Figure 66. About 6 of the 8 miles of SR-138 west of I-15 are in private property, some of which (left) is developed, and some of which (right) is predominantly native vegetation without development.

In upper Cajon Canyon along SR-138, we recommend maintaining the rural character of the landscape, with appropriate measures to confine light and noise pollution to homesites. We urge purchase of conservation opportunities for any large parcels that could provide permeability between Baldy Mesa and the rest of San Bernardino National Forest along at least ¼ mile of undeveloped road frontage. If major improvements are made to SR-138, we recommend bridged undercrossings, or vegetated land bridges with native vegetation within the crossing structure at points where land on both sides provide unobstructed path linking National Forest land. There are currently 2 areas where NF land lies on both sides of the road: (1) a mile-wide swath of National Forest land about a mile west of I-15 near the Mormon Rocks recreational site (2) a half-mile stretch of

National Forest land just before SR-138 exits the Forest near Mountain Top Junction. However, the best potential linkage location in the upper end of Cajon Canyon lies just north of the Forest Service boundary, where topography is well suited for large mammal movement. Again, we emphasize that these improvements are not needed until significant road improvements (wide shoulders, realignment, or additional lanes) are undertaken.

Recommendations for Lytle Creek Road: This 2-lane paved road crosses Lytle Creek once, and serves the small communities of Scotland and Lytle Creek. These 2 communities probably prevent most wildlife movement into upper Lytle Creek. However, the Middle Fork and South Fork of Lytle Creek may permit some riparian connection along the Lytle Creek drainage. Lytle Creek is home to several listed and sensitive aquatic and semi aquatic species, including the Santa Ana speckled dace and San Gabriel slender salamander (*Batrachoseps gabrieli*), as well as species dependent on upland habitats, such as Nelson's bighorn sheep. We recommend conservation measures to maintain rural character of the 2 large private parcels in lower Lytle Creek (about 120 and 160 acres) as well as 2 smaller parcels, and attention to wildlife connectivity during any upgrading of Lytle Creek Road.

Other Recommendations Regarding Paved Roads Within the Linkage Area:

- Consider existing crossing structure as indicators of the approximate location of freeway crossings, not as fixed elements of a Linkage Design.

- Transportation agencies should use each road improvement project as an opportunity to replace fill slopes and pipe culverts with bridges (large enough to allow vegetation to grow). Promote the use of earthen substrate flooring. In locations where a bridge is not feasible and only a culvert can be provided, install a pipe culvert (designed to remain free of water) parallel to the box culvert to provide for passage of small mammals, amphibians, and reptiles.

- Encourage woody vegetation leading up to both sides of crossing structures to provide cover for wildlife and to direct their movement toward the crossing structure. Work with the U.S. Forest Service, California Native Plant Society, local Resource Conservation District or other non-profit organization active in restoration efforts in the area to restore riparian communities and vegetative cover at passageways.

- Install appropriate wildlife fencing along the freeway to guide animals to crossing structures and keep them off the highway. Install escape structures, such as earthen ramps, to allow animals to escape if they get trapped on the freeway.

- Use retaining walls or fine mesh fencing to guide amphibians and reptiles to crossing structures.

- On both freeways and other paved roads, minimize artificial night lighting, and direct the light onto the roadway and away from adjacent wildland.

Roads as Ephemeral Barriers: Structures designed for wildlife movement are increasingly common. In southern California, 26 wildlife crossing structures were installed along 22-miles of State Route 58 in the Mohave Desert specifically for desert tortoise movement (Evink 2002). In the South Coast Ecoregion, the Coal Canyon interchange on State Route 91 is now being converted, through a partnership with CalTrans, California State Parks, and Hills for Everyone, from a vehicle interchange into a wildlife underpass to facilitate movement between the Chino Hills and the Santa Ana Mountains. About 8 wildlife underpass bridges and viaducts were installed along State Route 241 in Orange County, although urbanization near this toll road has compromised their utility (Evink 2002). Elsewhere, several crossing structures, including 3 vegetated overpasses, have been built to accommodate movement across the Trans-Canada Highway in Banff National Park (Clevenger 2001). In south Florida, 24 underpasses specifically designed for wildlife were constructed along 64km of Interstate 75 in south Florida in about 1985. The structures are readily used by endangered Florida panthers and bears, and have reduced panther and bear roadkill to zero on that route. Smaller wildlife crossings on State Route 29 in south Florida are as readily used by wildlife (Lotz et al. 1996), but mortality continues because the right of way is not fenced.

Almost all of these structures were designed specifically for wildlife movement along existing highways and were not part of the original road design. This fact demonstrates that the existing low permeability across a freeway section should not be accepted as irreversible. Most importantly, the current lack of permeability should not be used as an excuse to develop lands adjacent to the freeway on the grounds that the freeway is a permanent and absolute barrier. Indeed, at least 2 pumas crossed bustling Interstate-15 near Temecula in the early 1990's (Beier 1996, and unpublished data), and another crossed SR-118 near Simi Valley several times since 2002 (Ray Sauvajot, National Park Service, unpublished data). In contrast to a road, an urban development creates a barrier that cannot be corrected by building crossing structures. Urban and suburban areas make particularly inappropriate landscapes for movement of all large carnivores, most reptiles and amphibians, and many nocturnal small mammals. Thus development along freeways creates significant new and more permanent obstacles to landscape connectivity, above and beyond that presented by a freeway alone.

Representatives from CalTrans have attended each of the four workshops of the South Coast Missing Linkages effort, and the agency is eager to spend its mitigation dollars in the most important linkage areas. For example, CalTrans recently proposed building a wildlife overpass over SR-118, and in February 2003 CalTrans started removing pavement from the Coal Canyon interchange in Orange County and transferred the property to California State Parks expressly to allow wildlife movement between Cleveland National Forest and Chino Hills State Park. In the case of I-15, improvements may not occur during the next 10-20 years, during which time gene flow will continue to be disrupted. However, once connectivity is restored, genomes of all affected species should rapidly recover.

Rail Line Barriers to Movement

Like highways, railroads also can impede plant and animal movement (Messenger 1968, Niemi 1969, Klein 1971, Stapleton and Kiviat 1979, Muehlenbach 1979, Lienenbecker and Raabe 1981, Forman et al. 1995), though there are some differences. Railroads tend to follow straighter lines than roads, trigger more and larger fires, and scatter deleterious particles widely over the land bordering the rail line (Forman and Boerner 1981, Forman et al. 2003). Roadkill rates are likely a great deal lower per train than per vehicle on roads, though trains have been derailed from collisions with large mammals. Grain spilled from trains can attract deer and bears to feed on the rail line; such events have caused significant mortality to grizzly bears in Montana (Federal Register Feb 11 2004. 69: 6683-6685; C. Servheen, University of Montana, personal communication). Freight trains transporting cargo also disperse non-native seeds, insects, and perhaps mammals along railroad networks (Thomson 1940, Stapleton and Kiviat 1979, Forman et al. 2003).

Existing Rail Lines in the Linkage Design Area: Three major rail lines run through Cajon Pass, roughly parallel to I-15. The two Burlington Northern Santa Fe (BNSF) Railroad lines run close together along a single raised bed in lower Cajon Wash, but have separate beds up to ½ mile apart above old Cajon. The Southern Pacific (SP) Railroad line lies about 200-400 m west of the western BNSF track. In most of the linkage area, the 3 rail lines run on the west bank of Cajon Wash, while I-15 runs on the east bank. Near Cajon Junction (SR-138 junction with I-15), the tracks cross over Cajon Wash and under I-15 and from there northward the rail lines are east of the freeway. In the central part of the linkage area, from approximately Blue Cut to Cajon Junction, the 3 rail lines, old Route 66, and the freeway form a ¼-mile-wide band of 5 parallel impediments to animal movement between the San Bernardino and San Gabriel Mountains. For about a mile near old Cajon, the tracks lie directly in Cajon Wash, decreasing its value as a travel corridor. In other narrow parts of the canyon, it was necessary to create steep cut and fill slopes to accommodate these transportation corridors (Figure 67).

Figure 67. Near the mouth of Cleghorn Canyon, the BNSF rail lines hug Cajon Wash. The SP rail line (above the train) has steep cut banks (center of photo) and fill slopes (right side of photo).

 

Figure 68. Two views of the SP rail line crossing Lone Pine Canyon (a major east-west animal movement area) near the confluence of Pine Canyon and Cajon Wash. Left: In most of Pine Canyon, the rails lie on a bed of gently-sloping gravel. For some small mammals, amphibians, and reptiles, the rails and expanse of gravel probably are moderate impediments. Right: Lone Pine Canyon wash is funneled through a 5-ft culvert under a 16-ft fill slope supporting the rail line.

Recommendations to Mitigate the Effects of Rail Lines in the Linkage Design Area: We believe that the existing rail lines from Blue Cut to Cajon Junction present a significant impediment to movement of small mammals, reptiles, and amphibians. Although the lines are probably not a complete barrier, in concert with nearby I-15 and Route 66, the railroads contribute to reduced connectivity in the linkage area.

Figure 69. Railroad bridges built for SPRR (foreground) and BNSFRR (narrower span in background) over FR-3N21 and an unnamed wash, about 1.5 miles north of the I-15/SR-138 interchange.

We recommend a policy of using any railroad realignment as an opportunity not simply to mitigate loss of wildland connectivity, but to improve it. Ameliorating the adverse affects of railroads is similar to that for roads, providing viaducts, bridged underpasses, and tunnels (Reed and Schwarzmeier 1978, Borowske and Heitlinger 1981, Forman et al. 1995). We recommend that crossing structures should be (a) built every 1.5 to 2 km, (b) aligned among the 3 rail lines, and aligned with crossing structures on I-15, (c) integrated with sound walls to reduce noise pollution, and (d) integrated with fences where beneficial to guide small animals toward crossing structures. Fencing can be permeable to humans and larger animals, and would not be needed where steep cut and fill slopes already divert animals from the road. Figure 69 illustrates two railroad bridges within the linkage area.

Implementing these recommendations will take cooperation among the rail line operators and transportation agencies. We urge them to work together to develop a long-term coordinated plan to ensure that wildlife-crossing structures are aligned in a way that maximizes their utility to animals. We recognize that it is unrealistic to expect the crossing structures to be built at the same time. However, an overall plan will ensure that, for instance, a planned crossing structure on I-15 does not abut an impermeable section of railroad for which no crossing structure is planned.

Impediments to Streams

Wetland and riparian habitats occupy less than 1% of the total land area in the western U.S., yet are used by up to 80% of terrestrial vertebrate species (Kreuper 1992). The ninth annual report of the U.S. Council on Environmental Quality (1978) states, “no ecosystem is more essential than the riparian system to the survival of the nation’s fish and wildlife” (Horwitz 1978, Faber et al. 1989). Despite their importance to biological communities, over 90% of the historic wetland and riparian vegetation in Southern California has been eliminated or severely altered by urban and agricultural activities (Peters and Noss 1995). Coastal watersheds, in particular, have suffered due to dams, diversions, channelization, development, livestock grazing, and land disturbance (Dennis et al. 1984, Bell 1997). This extensive loss of habitat has resulted in declines in wildlife and plant populations that depend wholly or in part on riparian systems (Faber et al. 1989).

Terrestrial organisms moving through rugged landscapes often use riparian areas as travel routes. Some invertebrates, such as butterflies, preferentially move through streamside areas (USGS 2002, Orsack 1977). Some species of frogs are restricted to streamside movements (Kay 1989). Although southwestern pond turtles are capable of overland movements of up to 0.5 km (0.3 mi)(Holland 1991), they preferentially move along stream courses (Bury 1972). Even large, mobile vertebrates, such as mountain lions, have shown preferences for moving through riparian corridors (Beier 1995, Dickson et al. 2004).

For plants and animals associated with streams or riparian areas, impediments are presented by dry stretches due to water diversions and extractions, road crossings, exotic species, water recharge basins, farming in streambeds, gravel mining, and concrete structures that stabilize stream banks and streambeds. Increased runoff can also create permanent streams in areas that were formerly ephemeral; permanent waters can support aggressive invasive species, such as bullfrogs and exotic fish that prey on native aquatic species, and giant reed that supplants native plant communities (Fisher and Crooks 2001).

Impediments to streams in the Linkage Design: The Linkage Design encompasses several connections for semi-aquatic and riparian species. Though, no one tributary provides a direct riparian connection between the two core areas. Cajon Wash meanders from north to south through the entire linkage west of I-15. Lone Pine Canyon and two unnamed tributaries flow into Cajon Wash from the San Gabriel Mountains, while Crowder, Cleghorn, Pitman, and two unnamed tributaries between Crowder and Cleghorn flow into Cajon Wash from the San Bernardino Mountains. In times of high surface flows, these tributaries may provide an avenue along which aquatic and semi aquatic species journey between the San Gabriel and San Bernardino Mountains. Other significant riparian routes in the Linkage Design include the North, Middle, and South Forks of Lytle Creek, Horsethief and Little Horsethief Canyons, and the West Fork of the Mojave River. Today, riparian forests are significantly reduced in some places due to a combination of factors, including dams, water diversions, ground and surface water extraction, the effects of which are exacerbated by drought.

There are a number of dams in the vicinity. In the southern branch of the Linkage Design, San Antonio Dam is operated by the Army Corps of Engineers, while the dams on Deer Canyon and Day Creek are managed by SB County Flood Control District. Further west in the foothills of the San Gabriel Mountains, 4 other dams occur, including San Dimas, Big Dalton, Morris, and Cogswell dams. Big Bear Dam was the first built in the San Bernardino Mountains, followed by Lake Arrowhead Dam built in 1922 on Little Bear Creek. The County of San Bernardino erected New Lake Arrowhead Dam in 1976, also on Little Bear Creek. San Bernardino County Regional Parks Division manages Lake Gregory Dam, built in 1938 on Houston Creek. In 1971, two dams were built on the West Fork of the Mojave River in the northern branch of the linkage; Cedar Springs Dam operated by the State Department of Water Resources, and the Mojave Forks Dam administered by the Army Corps of Engineers. The Campus Crusade for Christ International built the Mineral Hot Springs Dam in 1967 on East Twin Creek. Finally, the Seven Oaks Dam at the Forest boundary now dams the Santa Ana River for flood control purposes; Mill Creek and City Creek are other major drainages.

Surface and groundwater extraction is also a concern in all of the rural communities within the Forest Service boundaries. For instance, in Lake Arrowhead groundwater extraction on private land is making streams on National Forest lands run dry. While the lower reaches of Lytle Creek are impacted by surface and groundwater extraction for hydropower and municipal uses, administrative withdrawals for campgrounds and picnic areas, and unauthorized withdrawals (USDA Forest Service 2004). The upper reaches of Lytle Creek still support an incredible diversity of species, including a Speckled dace population, but withdrawals in the lower reaches are affecting downstream species and their habitats (CDFG 2003, USDA Forest Service 2004).

Water quality has also been impaired. Big Bear Lake and several reaches of Mill Creek and Lytle Creek were listed as impaired under Section 303(d) of the Clean Water Act (USEPA 2003; http://www.swrcb.ca.gov/tmdl/docs/2002reg8303dlist.pdf). Big Bear Lake is impacted by medium to high concentrations of copper, mercury, metals, and sedimentation due to excessive resource extraction and development, while Mill and Lytle Creeks are impacted by pathogens from an unknown source. These listings make these riparian stretches eligible for the development of intensive management plans called Total Maximum Daily Load (TMDL) plans. TMDLs are implemented by the Regional Water Quality Control Board, which evaluates the cause of water quality deterioration and then enacts an implementation plan to return water quality to targeted values.

Riparian areas are crucial for sustaining populations of water-dependent species (e.g., Santa Ana speckled dace, California treefrog) in the Linkage Design area, and may function as steppingstones that allow movement by semiaquatic species. The pond turtle, for instance, is known to make overland movements among drainages (Holland unpubl.). They can also provide travel routes for terrestrial organisms, such as mountain lion, which are known to move along riparian corridors (Spotwart and Samson 1986, Beier and Barrett 1993, Dickson et al. 2004).

Examples of Mitigation for Stream Barriers: The primary goal of many restoration projects has been to restore habitat for targeted species; however, few restoration projects have focused on the natural dynamics of the systems on which these species depend (Bell 1997). In riparian systems, annual floods are a major component of ecosystem function. Many riparian plants are considered pioneer species, and have developed adaptations such as rhizomes, stolons, and wind- and water-disseminated seeds, that allow seedlings to become quickly established on newly deposited soils (Ohmart 1994). Because of the adaptation and resilience of riparian plants to high-disturbance regimes such as floods, revegetation can be a natural process if threats (i.e. invasive species) are removed from the system and physical processes are restored (e.g., dams and diversions are mitigated or removed, natural flow regimes restored).

Continuity between upland and riparian vegetation types is also a key component of viable riparian ecosystems. Many species commonly found in riparian areas depend on upland habitats during some portion of their cycle. These species include butterflies that use larval host plants in upland habitat and drink as adults, western pond turtles that lay their eggs in sandy upland habitats, and western toads that summer in upland burrows. Most fish feed on the aquatic larvae of insects that depend on terrestrial habitats as adults. While the width of upland habitats needed beyond the streams edge has rarely been estimated for these species, information on the western pond turtle suggests that a 1-km (0.6-mi) upland buffer (i.e., 0.5 km to either side of the stream) (Holland 1991) is needed to sustain populations of this species.

Conservation measures to minimize the impacts of development on aquatic habitats primarily focus on the use of riparian buffer zones. Regulations exist to limit development along or near streams and rivers (Barton et al. 1985, Allan 1995, Wilson and Dorcas 2003). However, although these buffers are intended to prevent erosion and filter runoff of contaminants (U.S. Environmental Protection Agency), research suggests that current regulations are inadequate to protect populations of semiaquatic reptiles and amphibians. A functional buffer must encompass a sufficient amount of upland habitat to maintain water-quality and habitat characteristics essential to the survival of many aquatic and semiaquatic organisms (Brosofske et al.1997, Wilson and Dorcas 2003). However, maintaining riparian buffers will not suffice for some species, for instance, to preserve salamander populations in headwater streams, land use must be considered at the watershed level (Wilson and Dorcas 2003).

Recommendations to Mitigate the Effects of Streams Barriers in the Linkage Design Area: To enhance species use of riparian habitat and restore riparian connections through the Linkage Design area, we recommend:

- Wherever possible restore the natural historic flow regime or create a regime that provides maximum benefit for native biodiversity. Work with the U.S. Forest Service, National Marine Fisheries Service, California Department of Fish and Game, Department of Public Works, Water Districts, watershed groups and others to investigate the historic flow regimes and develop a surface and groundwater management program to restore and recover properly functioning aquatic/riparian conditions.

- Mitigate the effects of road crossings in riparian zones. Coordinate with the California Department of Transportation, National Marine Fisheries Service, U.S. Forest Service, and California Department of Fish and Game to evaluate existing stream crossings and upgrade culverts, stream crossings, bridges, and roads that impede movement (USFWS 1998). Use several strategies, including information on preferred crossings, designing new culverts, retrofitting or replacing culverts, general recommendations, post construction evaluation, maintenance and long-term assessment. Install specialized culverts and bridges in streams for improved fish passage to address outfall height, water velocities, and water depth for adequate upstream fish passage (Carey and Wagner 1996, NFMS 2000, Evink 2002).

- Restore riparian vegetation in all drainages and upland vegetation within 1 km (0.6 mi) of streams and rivers. These areas may restrict plant or animal movements and compromise water quality by increasing erosion and non-point sources of pollution. If restored, these areas would support aquatic and semi-aquatic species and enhance movement through both aquatic and riparian habitats. Discourage the construction of concrete-banked streams and other channelization projects.
- Explore opportunities to restore habitat connectivity with the Santa Ana River and its tributaries for aquatic species, such as the Santa Ana speckled dace.

- Remove exotic plants (e.g. Arundo, Tree of Heaven) and animals (e.g., bullfrogs, African clawed frogs) from streams, rivers, and lakes. Work with the Biological Resources Division at USGS, U.S. Forest Service, Bureau of Land Management and other relevant agencies to survey streams and drainages for invasive species and develop a comprehensive removal strategy.

- Enforce existing regulations protecting streams and stream vegetation from illegal diversion, alteration, manure dumping, and vegetation removal. Agencies and regulations with applicable jurisdiction include U.S. Forest Service, California Department of Fish and Game, Streambed Alteration Agreements, Army Corps of Engineers, Clean Water Act, and Native Plant Protection Act.

- In high abuse areas (e.g., Cajon Wash, Crowder Canyon, Baldy Mesa), prevent off-road vehicles from driving in the creek bottom and enforce closures. Review existing regulations relative to linkage goals and develop additional restrictions or recommend closures in sensitive areas.

- Aggressively enforce regulations restricting farming, gravel mining, suction dredging, and building in streams and floodplains.

- Increase and maintain high water quality standards. Work with the Resource Conservation District to help establish use of Best Management Practices for all rural communities in the forests. Work with Regional Water Quality Control Board and the Total Maximum Daily Load (TMDL) process to reduce nutrient levels in impaired reaches.

- Support the protection of riparian and adjacent upland habitats on private lands. Pursue cooperative programs with landowners to improve conditions in riparian and upland habitats on private land in the Linkage Design.

Other Land Uses that Impede Utility of the Linkage

Land management policies in the protected areas and the linkage can have substantial impact on habitat and movements of species through the Linkage Design area. It is essential that major land-management entities integrate the linkage plan into their policies and regulations.

Mining Operations

Mining operations harm species, habitat, and ecological systems through direct impacts from the mining operation, impacts on water and air quality, impacts due to the associated infrastructure (roads, pipeline, power lines), habitat loss and fragmentation, non-native species invasions, release of pollutants, and increased motorized access (Penrod et al. 2002). All types of mining activity, from simple prospecting to the use of sluice boxes and suction dredges, can harm aquatic species. Mining can alter habitat in a way that promotes the presence of harmful non-native species, for instance, suction dredging creates deeper pools, which provide habitat for nonnative predatory species such as sunfish and bullfrogs. Surface and groundwater quality can be degraded, and water quantity diminished through the direct use of water in the mining process. Mining can also impair air quality through the generation of fugitive dust from blasting and crushing activities, roads, pipeline corridors, and other infrastructure disturbances. Both riparian and terrestrial habitats can be heavily impacted by mining activities (USFWS 2001).

Mining in the Linkage Design Area: In the San Gabriel Range, suction dredging occurs along the San Gabriel River and Cajon Wash, and recreational gold panning also occurs in some areas. Gold mining has also occurred in Little Horsethief Canyon, where suction dredging operations and other forms of gold mining threaten special status species. A mineral withdrawal has been proposed in Little Horsethief Creek to aid in the recovery of the arroyo toad and other sensitive species.

Examples of Mitigation for Mining Operations: Mining operations can be modified with actions that reduce the affects of these industrial activities. Preventing any further mining operations in key areas of the Linkage Design through administrative withdrawals will have the greatest effect on preserving linkage function. Existing mining operations can be targeted for regulatory actions that reduce the effects of these industrial activities. These include, limiting noise from blasting, minimizing night lighting, reducing traffic in sensitive areas or constriction points, monitoring water quality and quantity, minimizing the use of harmful chemicals, and increasing enforcement of existing regulations. The California Surface Mining and Reclamation Act (1975) require that land used in mining operations be restored.

Recommendations to Mitigate the Effects of Mining in the Linkage Design Area: Agencies with regulatory oversight of mining operations include U.S. Fish and Wildlife Service, California Department of Fish and Game, Army Corps of Engineers, Regional

Water Quality Control Board, U.S. Forest Service, Bureau of Land Management and San Bernardino County. We provide the following initial recommendations regarding mining activities in the Linkage Design area:

- No new mining operations in key areas of the Linkage Design. Apply for administrative withdrawals to promote recovery of listed and sensitive species and their habitats.

- Prohibit surface occupancy within riparian zones. Mining operations should avoid disturbance of natural waterways, rare or imperiled habitat or species, wildlife movement corridors, and other biological resources.

- Placement of mine tailings, soil and overburden, and industrial waste in riparian zone should be prohibited.

- Monitor facilities and mining residue in or adjacent to riparian zones to ensure that discharges are not causing detrimental effects to listed or sensitive species or their habitat.

- Monitor mining operations for the presence of non-native aquatic species and develop eradication programs.

- Monitor compliance with all regulations, approved plan of operations, Habitat Conservation Plans, and with state and federal law.

- Monitor the off-site effects of mining activities on key physical and biological resources and downstream conditions.

- When existing mining operations are completed, reclaim under guidelines set forth by the 1975 California Surface Mining and Reclamation Act.

Urban Barriers to Movement

Urban development, unlike a road or an aqueduct creates a barrier that cannot be corrected by building crossing structures. Urban and suburban areas make particularly inappropriate landscapes for movements of most plants and animals (Marzluff and Ewing 2001). Apart from the direct loss of habitat caused by the construction of buildings and associated infrastructure, urban developments have negative effects far beyond the boundaries of the construction footprint. These edge effects can significantly reduce plant and animal populations and impede ecosystem functions in surrounding areas. Most terrestrial mammals that move at night will avoid areas that have artificial night lighting (Beier, in press). Pet cats can hunt in a 3 ha area (Hall et al. 2000) and significantly depress populations of small vertebrates (Churcher and Lawton 1987, Crooks 1999, Hall et al. 2000). Irrigation of landscapes surrounding homes can encourage the spread of argentine ant populations into natural areas, where they cause a halo of local extinctions of native ant populations extending 200 m (656 ft) into native vegetation (Suarez et al. 1998, Bolger et al. 2000). Similar affects have been documented for amphibians (Demaynadier and Hunter 1998). Habitat disturbance caused by intense human activity (e.g., off-road vehicle use, dumping, camping and gathering sites) also tends to rise in areas surrounding urban developments. Areas with habitat disturbance from human use show decreases in bird and small mammal populations (Sauvajot unpubl.).

Urban Barriers in the Linkage Design Area: Urban developments comprise 1.7 % of the Linkage Design area. The town of Devore Heights and other San Bernardino suburbs lie in and near the southern edge of the linkage, and the city of Hesperia and its suburbs border the north edge of the linkage area. In addition, there are several significant inholdings within San Bernardino National Forest that have been developed. The most massive and urbanized area of inholdings consists of about 12 square miles of residential developments surrounding Lake Arrowhead and Lake Gregory, and further east the even more expansive Big Bear in the heart of the San Bernardino Mountains. The number of residents living within the San Bernardino Forest boundary is one of the highest in the nation (USDA Forest Service 2004). The village of Wrightwood covers about 3 square miles in the San Gabriel Mountains. These areas are impermeable to wildlife movement due to high traffic volume, large numbers of pets (predators on small wildlife, prey of large carnivores), and light and noise pollution.

The other inholdings with urbanization and suburbanization are smaller and more rural in character. These include about 5 square miles on upper Cajon Canyon (along SR-138 west of I-15), and about 1.5 square miles in the villages of Scotland and Lytle Creek in Lytle Creek Canyon.

About 20 to 30 undeveloped inholdings averaging about 160 acres in size are widely scattered throughout the National Forest in the Linkage Area, including 4 parcels along I-15, 5 parcels in Lone Pine Canyon, 4 parcels on old Route 66 in lower Cajon Wash, and 1 parcel on SR-134 in upper Crowder Canyon. These 14 parcels have road access, relatively gentle terrain, and affect riparian corridors. Most have only 1 or 2 buildings on each parcel. Most of the other inholdings are on steeper slopes, and have poorer road access. Increased urbanization of currently undeveloped inholdings could seriously compromise wildland connectivity.

We recommend a public education campaign, such as the On The Edge program developed by the Mountain Lion Foundation, which encourages residents at the urban wildland interface to become active stewards of the land. Such voluntary cooperation is essential to functioning of the linkage, to limit impacts of lighting, roads, domestic livestock, pets, and traffic on wildlife movement in the Linkage Design area.

In addition, several massive development projects have been proposed that would seriously jeopardize the utility of the linkage. The largest housing development ever approved in San Bernardino County (i.e., Lytle Development Company) would impact the southern branch of the linkage in Lytle Creek, an area that was zoned for resource conservation. This project has been challenged but the fate of Lytle Creek is still uncertain. Another large-scale development has been proposed in Summit Valley that would compromise the northern branch of the linkage above Silverwood Lake, and still other projects are proposed. These types of large-scale developments are totally incompatible with maintaining habitat values in existing protected areas and the functionality of the linkage.

Examples of Mitigation for Urban Barriers: Urban developments, unlike roads, create movement barriers that cannot be readily removed, restored, or mitigated. Preventing urban developments in key areas through acquisition or conservation easements with willing landowners will have the greatest effect on preserving linkage function. Mitigation for existing urban developments focuses on designing buffers that reduce penetration of undesirable effects into natural areas (Marzluff and Ewing 2001). These buffer areas can be targeted for management actions that reduce the effects of urban activities. These include fencing in pets, reducing human traffic in sensitive areas or constriction points, limiting noise and lighting, reducing traffic speeds, minimizing use of irrigation, minimizing the use of pesticides, poisons and other harmful chemicals, and increasing enforcement of existing regulations.

Recommendations for Mitigating the Effects of Urban Barriers in the Linkage Design Area: We provide the following initial recommendations regarding urban, suburban, and rural developments in the Linkage Design area:

- Encourage land acquisition and conservation easements with willing private lands owners in the Linkage Design

- Homes abutting the linkage area should have minimal outdoor lighting, always directed toward the home and yard rather than into the linkage. Homeowners should use fences to keep dogs and domestic livestock from roaming into the linkage area. In the case of existing homes, this can best be arranged as a voluntary agreement among landowners.

- Develop a public education campaign, such as the On The Edge program developed by the Mountain Lion Foundation, which encourages residents at the urban wildland interface to become active stewards of the land by reducing penetration of undesirable effects into natural areas. Education topics should include fencing in pets, constructing predator-safe enclosures for livestock, reducing human traffic in sensitive areas or constriction points, limiting noise and lighting, reducing traffic speeds, minimizing use of irrigation, minimizing the use of pesticides, poisons and other harmful chemicals, and effective reporting of violations.

- Work with San Bernardino County on their General Plan updates to encourage zoning of rural areas of the Linkage Design to larger lot sizes (e.g., 40-80 acres).

- Work with the County to discourage major new residential or urban developments in key areas of the Linkage Design area.

- Where development of single residences does occur, we recommend restrictions that limit edge effects (above). A few estates on large lots (such as 50 acres or larger) may be compatible with the linkage. However, the total extent of any development should be limited.

- The Mountain Lion Foundation (http://www.mountainlion.org) has also worked to develop predator safe domestic livestock enclosures and works with several ranchers, farmers, and rural residents to help keep livestock and pets safe, with the ultimate goal of reducing the number of depredation permits issued for mountain lions.

- Work with the U.S. Forest Service, Fire Safe Councils and California Department of Forestry and Fire Protection to develop fire preparedness plans that do not compromise linkage function. County regulations should be revised to minimize vegetation removal in protected areas of the Linkage Design area.

Recreation

Recreational use is not inherently incompatible with wildlife movement through the Linkage Design. However, intense recreational activities have been shown to cause significant impacts to wildlife and plants (Knight and Gutzwiller 1995). Even such relatively low-impact activities as wildlife viewing, hiking, and horse back riding have been shown to displace wildlife from nutritionally important feeding areas and prime nesting sites (Anderson 1995, Knight and Cole 1995). The increased time and energy spent avoiding humans can decrease reproductive success and make species more susceptible to disease (Knight and Cole 1995). In addition, humans, horses and pets can carry seeds of invasive species into natural areas (Benninger 1989, Benninger-Traux et al. 1992), with potentially devastating effects.

Recreation in the Linkage Design Area: Areas currently available for recreation include the US Forest Service lands in the Core Areas, the Pacific Crest Trail, Silverwood Lake State Recreation Area, and Old Route 66 historic right-of-way. Forest Service lands provide a wide range of recreational opportunities, from nature-based dispersed recreational activities (e.g., hiking, bird watching) to high-density recreation in developed sites. The majority of recreational use is concentrated in developed facilities with road access. Recreational activities in the vicinity of the linkage include camping, hiking, fishing, off-road vehicle use, water-based recreation, snow skiing, and shooting areas. Designated off-road vehicle areas occur on Baldy Mesa and Cleghorn Ridge, but unauthorized road and trail creation is high on Baldy Mesa, Crowder Canyon, and Cajon Wash. In the Lytle Creek area, water-based recreational activities occur year round, and there are camping sites along the lower portions of the Middle and South Forks. Recreational dams obstruct downstream flows impacting species dependent on a consistent flow regime. These perennial streams are also popular fishing spots for trout, with the most heavily used reaches planted by the California Department of Fish and Game. There is also a shooting area in Lytle Creek (USDA Forest Service 2004).

Examples of Mitigation for Recreation: If recreational activities are effectively monitored, most negative impacts can be avoided or minimized by limiting types of use, directing recreational activities away from particular locations, sometimes only for particular seasons, and with reasonable precautions.

Recommendations to Mitigate the Effects of Recreation in the Linkage Design Area: We provide the following initial recommendations to prevent or mitigate negative effects of recreation in the Linkage Design area:

- Monitor trail development and recreational use to provide a baseline for decisions regarding levels, types, and timing of recreational use.

- Work with regional monitoring programs, such as the State's Resource Assessment Program, to collect information on special status species, species movements, and vegetation disturbance in areas of high recreational activity.

- Enforce existing regulations on types of recreational use currently established.

- Work with the Forest Service and non-governmental organizations to develop and conduct on-the-ground, multi-lingual outreach programs to river-based recreational users on how to lessen impacts in sensitive riparian areas.

- Monitor the creation of recreational dams to ensure that they don't impede flows.

- Coordinate with California Department of Fish and Game on their fish stocking activities to ensure that no fish (e.g., sport fish, mosquitofish) are being introduced to areas that support habitat for listed or sensitive aquatic species (e.g., native fish such as the speckled dace, native amphibians).

- Roads and trails that pass through known bighorn sheep lambing areas should be closed during the reproductive season (Holl and Bleich 1983, Papouchis et al. 2001, USFWS 2001).

- No off-road vehicle routes should occur within bighorn sheep habitat (USFWS 2001).

- Unauthorized off-road vehicle routes should be closed, obliterated, and restored; closures should be enforced.

- Enforce leash laws so that dogs are under restraint at all times (USFWS 2001, Holl et al. 2004).

Land Protection & Stewardship Opportunities

A variety of planning efforts addressing the conservation and use of natural resources are currently underway in the Linkage Design area. The South Coast Missing Linkages Project supports and enhances existing efforts by providing information on regional linkages critical to achieving the conservation goals of each planning effort. Since the South Coast Missing Linkages Project addresses connectivity needs for the major linkages associated with the South Coast Ecoregion, it can provide a landscape context to localized planning efforts to assist them in achieving their conservation goals. This Project is deeply committed to collaboration and coordination to achieve the vision of a wildlands network for the South Coast Ecoregion and beyond.

In this section, we provide information on planning efforts, agencies, and organizations in the region that may represent potential collaborative opportunities for conserving the San Gabriel – San Bernardino Linkage. While this list is not exhaustive, it is meant to provide a starting point for persons interested in becoming involved in preserving and restoring linkage function.

Bureau of Land Management: BLM sustains the health, diversity and productivity of the public lands for the use and enjoyment of present and future generations. BLM network of park supporters. These initiatives have helped the parks acquire more land, create more trails, restore wildlife habitat, build visitor centers, construct interpretive displays, and support family camping for underserved youth. CSPF is a partner in the South Coast Missing Linkages. For more on their exciting programs, visit www.calparks.org.

California Wilderness Coalition: The California Wilderness Coalition builds support for threatened wild places on a statewide level by coordinating efforts with community leaders, businesspeople, decision-makers, local organizations, policy-makers, and activists. CWC was also a co-sponsor of the statewide Missing Linkages effort. For more information, visit them at http://www.calwild.org.

California Wild Heritage Campaign: The mission of the California Wild Heritage Campaign is to ensure the permanent protection of California's remaining wild public lands and rivers. Congresswoman Hilda Solis has introduced the Southern California Wild Heritage Act. The bill will significantly expand the National Wild & Scenic Rivers System and the National Wilderness Preservation System on federally managed public lands in Southern and Central California. A total of 13 new Wild & Scenic Rivers are included in the bill, totaling more than 312 miles, and 47 new Wilderness Areas and Wilderness Additions totaling 1,686,393 acres. Two of the proposed Wilderness Areas are in the vicinity of the Linkage Design, the Cucamonga Wilderness Addition (13,620 ac) and the Sheep Mountain Wilderness Additions (2,400 ac). Wild and Scenic Rivers proposed in the vicinity include: Lytle Creek, San Antonio Creek, and Deep Creek. The Campaign builds support for wilderness and wild & scenic river protection by compiling a detailed citizen's inventory of California's remaining wild places; organizing local communities in support of those places; building a diverse, broad-based coalition; and educating the general public, government officials and the media about the importance of protecting California's wild heritage. For more information on the status of the Act, visit http://www.californiawild.org.

County of Los Angeles: Los Angeles County is currently engaged in a 2025 General Plan update, which will likely include proposed revisions and expansions to existing Significant Ecological Areas (SEA). SEAs that occur in the vicinity of the linkage include San Dimas Canyon, San Antonio Wash, and San Gabriel Canyon. The General Plan update also provides an opportunity to ensure zoning in the Linkage Design is conducive to conserving linkage function. For more information on the General Plan update go to http://www.planning.co.la.ca.us.

County of Los Angeles, Department of Parks and Recreation: Los Angeles County manages Devil's punchbowl County Park within the Angeles National Forest on the northern slopes of the San Gabriel Mountains. For more information, visit them at http://www.parks.co.la.ca.us.

County of San Bernardino: San Bernardino County is also in the process of a 2025 General Plan Update that consists of two phases, the first of which was completed in 2002. During Phase I, a strategic analysis of the 1989 General Plan and Environmental Impact Report (EIR) was conducted. Phase II is anticipated to be a three-year process which began in mid-2003. To find out more about the General Plan Update, go to: www.sbcountygeneralplan.net, or visit the county's website at http://www.co.san-bernardino.ca.us/.

Deep Creek Open Space Coalition: The Coalition is working to conserve Deep Creek, a scenic and recreational paradise, and one of southern California's finest wild trout streams. The Coalition was instrumental in protecting 800 acres in Deep Creek. For more info, contact Jean Frederickson at jeanf@charter.net.

Endangered Habitats League: The Endangered Habitats League is dedicated to ecosystem protection and sustainable land use. EHL participates in regional planning to curtail sprawl and preserve intact rural and agricultural landscapes. They actively support the revitalization of urban areas and the development of vibrant community centers, effective mobility and affordable housing choices. EHL is engaged in conservation activities in the Linkage Design, particularly in the Lytle Creek area. For more information, visit them at http://www.ehleague.org.

Environment Now: Environment Now is an active leader in creating measurably effective environmental programs to protect and restore California's environment. Since its inception, they have focused on the preservation of California's coasts and forests, and reduction of air pollution and urban sprawl. Environment Now uses an intelligent combination of enforcement of existing laws, and application of technology and process improvements to eliminate unsustainable practices. To find out more about their programs, visit their website at http://www.environmentnow.org

Friends of Fawnskin: The Friends of Fawnskin are working to save their rural community on the north shore of Big Bear Lake. This area also supports one of the highest concentrations of wintering Bald Eagles in southern California. The Friends goal is to maintain and protect the nature-oriented atmosphere of their historic small town of Fawnskin. To find out more, go to www.friendsoffawnskin.com.

National Park Service The purpose of the National Park Service is "...to promote and regulate the use of the...national parks...which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." NPS is a partner in the South Coast Missing Linkages Project. For more on the National Park Service, see http://www.nps.gov.

Pacific Crest Trail Association: The mission of the Association is to protect, preserve and promote the Pacific Crest National Scenic Trail so as to reflect its world-class significance for the enjoyment, education and adventure of hikers and equestrians. The Association works to: promote the Pacific Crest National Scenic Trail as a unique educational and recreation treasure; provide a communications link among users and land management agencies; and assist the U.S. Forest Service and other agencies in the maintenance and restoration of the Pacific Crest National Scenic Trail. The Pacific Crest Trail crosses through portions of the Linkage Design and may be helpful in directing federal funds to secure land in the linkage. To find our more about the Association, visit them at http://www.pcta.org.

Regional Water Quality Control Board: The State WQCB strives to preserve, enhance and restore the quality of California's water resources, and ensure their proper allocation and efficient use for the benefit of present and future generations. The RWQCB oversees waters in the Linkage Design area. For more information, visit their website at http://www.swrcb.ca.gov.

Resource Conservation Districts (RCD): The federal district has three offices with responsibilities in the Linkage Design or core areas, Antelope Valley RCD, Mojave Desert RCD, and the Inland Empire West RCD. This non-profit agency supports conservation of natural ecosystems through programs that reduce the effects of on-going land-use practices on the environment. A major portion of their effort is to advise residents on the management of soil, water, soil amendments and other resources used for agriculture and home gardening. RCDs are supported by state and local grants. They provide leadership in partnership efforts to help people conserve, maintain, and improve our natural resources and environment. Programs include Emergency Watershed Protection, Environmental Quality Incentives, Resource Conservation and Development, Soil Survey Programs, Soil and Water Conservation Assistance, Watershed Protection, River Basin, and Flood Operations, Wetlands Reserve & Wildlife Habitat Incentives. They do not enforce regulations but instead serve the interests of local residents and businesses. To find out more about their programs, go to http://www.carcd.org.

San Bernardino Land Trust: SBMLT grew out of heightened conservation concerns in the early 1990s, when the San Bernardino National Forest faced multiple threats to its ecological integrity. They have been involved in several successful land acquisition efforts specifically for conservation purposes, including the Upper Deep Creek acquisition of 800 acres. SBMLT has an advisory committee that assists in several areas of expertise, including legal, real estate, forestry, biology, journalism, and publications. Land trusts are key to implementing the Linkage Design, and the SBMLT is working diligently to keep the forest intact. For more information, see http://www.lta.org/findlandtrust/CA.htm.

San Bernardino Valley Audubon: Audubon members are dedicated to protecting birds, wildlife and our shared environment. They work with policymakers in Washington, D.C., state legislatures, and local governments across the country to restore and protect our natural legacy; secure funds for vital conservation programs; and preserve key natural areas. The San Bernardino Valley Audubon Chapter has over 1600 members in San Bernardino and Riverside Counties and is actively engaged in conservation activities in the Linkage Design and surrounding areas. For more information, go to www.sbvas.org.

San Gabriel and Lower Los Angeles Rivers and Mountains Conservancy: The Rivers and Mountains Conservancy is a state agency working to create a Parkways and Open Space Plan for the San Gabriel River and lower Los Angeles River watersheds. The RMC works to preserve open space and habitat for present and future generations. To fulfill that mission, the RMC is engaged in multiple projects that provide low-impact recreation, education, wildlife and habitat restoration, and watershed improvements. The RMC is actively engaged in conservation planning efforts in the San Gabriel Mountains. To find out more about the RMC, visit their website at http://www.rmc.ca.gov.

Santa Monica Mountains Conservancy: This state agency was created by the Legislature in 1979 and is charged with the primary responsibility for acquiring land with statewide and regional significance. Through direct action, alliances, partnerships, and joint powers authorities, the Conservancy's mission is to strategically preserve, protect, restore, and enhance treasured pieces of Southern California's natural heritage to form an interlinking system of parks, open space, trails, and wildlife habitats that are easily accessible to the general public. The Conservancy manages parkland in the San Gabriel (i.e., Santa Clarita Woodlands) protected core area. They also manage land in the surrounding ranges, in the Santa Monica Mountains, Simi Hills, and Santa Susana Mountains as part of their Rim of the Valley Trail Corridor plan. The SMMC is a partner in the South Coast Missing Linkages effort. For more information on SMMC, visit them at http://www.smmc.ca.gov.

Save our Forest Association, Inc.: The Save Our Forest Association, Inc. (SOFA) was formed to stop inappropriate land exchanges within the San Bernardino National Forest, though now they work on a variety of critical conservation issues. SOFA monitors and comments on any large development projects which effect the long term health and vitality of the forest ecosystem in the San Bernardino Mountains, including large subdivisions, water extraction, etc. They also closely monitor commercial logging, cattle grazing, and off-road vehicle use. To find out more about the association, visit their website at www.saveourforestassoc.org.

Sierra Club's Southern California Forests Campaign - Sierra Club volunteers and staff have created the Southern California Forests Campaign to encourage public involvement in the 4 southern California Forest's Resource Management Plan revision process. The goals of the campaign are to reduce the threats to our forests and to enjoy, protect and restore them. The Angeles and San Gorgonio Chapters are both very active in the Linkage Design and core areas. For more information on the Sierra Club's campaigns, go to http://www.sierraclub.org.

South Coast Wildlands: South Coast Wildlands is a non-profit group established to create a protected network of wildlands throughout the South Coast Ecoregion and is the key administrator and coordinator of the South Coast Missing Linkages Project. For all 15 priority linkages in the Ecoregion, South Coast Wildlands supports and enhances existing efforts by providing information on regional linkages critical to achieving the conservation goals of each planning effort. For more information on SCW, visit their website at http://www.scwildlands.org.

South Coast Missing Linkages Project: SCML is a coalition of agencies, organizations and universities committed to conserving 15 priority landscape linkages in the South Coast Ecoregion. The project is administered and coordinated by South Coast Wildlands. Partners in the South Coast Missing Linkages Project include but are not limited to: The Wildlands Conservancy, The Resources Agency California Legacy Project, California State Parks, California State Parks Foundation, United States Forest Service, National Park Service, Santa Monica Mountains Conservancy, Conservation Biology Institute, San Diego State University Field Station Programs, The Nature Conservancy, Environment Now, and the Zoological Society of San Diego Center for Reproduction of Endangered Species. For more information on this ambitious regional effort, go to http://www.scwildlands.org/pages/sc_missinglinks.php.

Southern California Wetlands Recovery Project: The Southern California Wetlands Recovery Project is a partnership of public agencies working cooperatively to acquire, restore, and enhance coastal wetlands and watersheds between Point Conception and the International border with Mexico. The goal of the Southern California Wetlands Recovery Project is to accelerate the pace, the extent, and the effectiveness of coastal wetland restoration in southern California through developing and implementing a regional prioritization plan for the acquisition, restoration, and enhancement of southern

California's coastal wetlands and watersheds. For more information on this exciting project, visit their website at http://www.coastalconservancy.ca.gov/scwrp.

The Nature Conservancy: TNC preserves the plants, animals and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. TNC is a partner in the South Coast Missing Linkage Project. For more information on their activities, go to http://www.tnc.org.

The Wildlands Conservancy: The Wildlands Conservancy is a non-profit, member-supported organization dedicated to land preservation, river preservation, trail development and environmental stewardship through education. Their Save the Saints Program brings together multiple land trusts and conservancies to identify key lands for acquisition within National Forest boundaries and lands contiguous with the Forests in the Santa Ana, San Gabriel, San Jacinto, and San Bernardino Mountains. TWC is a vital partner in the South Coast Missing Linkages project. For more information on TWC, please visit their website at http://www.wildlandsconservancy.org.

US Army Corps of Engineers: The mission of the ACOE is to provide quality, responsive engineering services for planning, designing, building and operating water resources and other civil works projects (Navigation, Flood Control, Environmental Protection, Disaster Response, etc.). They also are engaged in watershed planning efforts that may provide opportunities for restoration of natural water flow and riparian vegetation in the linkage. For more information, go to http://www.usace.army.mil.

US Fish and Wildlife Service: The U.S. Fish & Wildlife Service works to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. The agency can provide support for prosecuting violations to the Endangered Species Act, law enforcement, permits, and funding for research on threatened and endangered species. Several threatened or endangered species occur or have the potential to occur in the Linkage Design area, including but not limited to arroyo toad (*Bufo microscaphus*), California red-legged frog (*Rana aurora draytonii*), Yellow-legged frog (*Rana muscosa*), California gnatcatcher (*Polioptila californica californica*), southwestern willow flycatcher (*Empidonax traillii extimus*), and least Bell's vireo (*Vireo belli pusillus*). The federal Endangered Species Act as amended (16 U.S.C. 1534) authorizes USFWS to acquire lands and waters for the conservation of fish, wildlife, or plants with the Land and Water Fund Act appropriations. The added protection provided by the Endangered Species Act may also be helpful for protecting habitat in the linkage from federal projects. For more information, visit their website at http://www.fws.gov.

US Fish and Wildlife Service Partners for Fish & Wildlife Program This program supplies funds and technical assistance to landowners who want to restore and enhance wetlands, native grasslands, and other declining habitats, to benefit threatened and endangered species, migratory birds, and other wildlife. This program may be helpful in restoring habitat on private lands in the Linkage Design. For more information on this Program, please go to http://partners.fws.gov.

US Forest Service: The mission of the USDA Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. The four southern California Forests (Los Padres, administers land in the Linkage Design area. A revised Resource Management Plan is expected in the coming years that may establish acquisition priorities in the linkage. Representatives from BLM have attended each of the South Coast Missing Linkages workshops. For more information on lands administered by the BLM, visit http://www.ca.blm.gov.

Bureau of Reclamation: Reclamation's Southern California Area Office (SCAO) is responsible for water conservation, reclamation and reuse projects to enhance water management practices throughout southern California. Reclamation will also oversee the restoration of existing mining operations in the Linkage Design once operations have ceased. For more details, visit http://www.usbr.gov/lc/region/scao/sccwrrs2.htm.

California Department of Fish and Game: CDFG manages California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. Acquisition dollars for CDFG projects are authorized through the Wildlife Conservation Board as part of their Concept Area Protection Plan (CAPP) process. For more information on the Department, visit their website at http://www.dfg.ca.gov.

California Department of Transportation: CalTrans strives to achieve the best safety record in the nation, reduce traveler delays due to roadwork and incidents, deliver record levels of transportation system improvements, make transit a more practical travel option, and improve the efficiency of the transportation system. CalTrans representatives have attended each of the South Coast Missing Linkages workshops and are eager to spend their mitigation dollars on the most important linkage areas; they recently proposed building a wildlife overpass over SR-118. In February 2003, CalTrans started removing pavement from the Coal Canyon interchange on SR 91 in Orange County and transferred the property to California State Parks expressly to allow wildlife movement between the Santa Ana Mountains of the Cleveland National Forest and Chino Hills State Park. To find out more about the innovative plans being developed by Caltrans, visit their website at http://www.dot.ca.gov.

California State Parks: California State Parks provides for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources, and creating opportunities for high-quality outdoor recreation, such as those available at Silverwood Lake State Park. The Department is actively engaged in the preservation of the State’s rich biological diversity through their acquisition and restoration programs. Ensuring connections between State Park System wildlands and other protected areas is one of their highest priorities. CSP is involved in the Coal Canyon habitat connection restoration project to preserve mountain lion movement under SR 91 at the north end of the Santa Ana Mountains. CSP co-sponsored the statewide Missing Linkages conference and is a key partner in the South Coast Missing Linkages effort. For more information, visit their website at http://www.parks.ca.gov.

California State Parks Foundation: The Foundation is the only statewide organization dedicated to preserving, advocating and protecting the legacy of California's State Parks. The Foundation supports environmental education, wildlife and habitat preservation, volunteerism, and sound park policy. Since its inception, the Foundation has provided over $110 million for projects and educational programs while building a statewide

Angeles, San Bernardino, and Cleveland) are in the process of jointly revising their Resource Management Plans. The biological importance and feasibility of connecting the four forests to the existing network of protected lands in the region is being evaluated in the Draft Environmental Impact Statement. The USFS is allocated Land and Water Conservation Funds annually, which are designed to protect recreational open space, watershed integrity, and wildlife habitat and may be a source of funds for protecting land in the planning area. The Forest Service is taking a proactive role in habitat connectivity planning in the region as a key partner in the South Coast Missing Linkages Project. For more information, go to http://www.fs.fed.us/r5/scfpr.

US Geological Survey, Biological Resources Division: The Biological Resource Division (BRD) works with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources. BRD develops scientific and statistically reliable methods and protocols to assess the status and trends of the Nation's biological resources. BRD utilizes tools from the biological, physical, and social sciences to understand the causes of biological and ecological trends and to predict the ecological consequences of management practices. BRD enters into partnerships with scientific collaborators to produce high-quality scientific information and partnerships with the users of scientific information to ensure this information's relevance and application to real problems. BRD is engaged in several research projects on U.S. Forest Service land. For more information, go to http://www.biology.usgs.gov.

Wildlife Conservation Board: The Wildlife Conservation Board administers capital outlay for wildlife conservation and related public recreation for the State of California. The Wildlife Conservation Board, while a part of the California Department of Fish and Game, is a separate and independent Board with authority and funding to carry out an acquisition and development program for wildlife conservation. DFG owns and manages land in the planning area and has a strong interest in the linkage. Conceptual Area Protection Plans are internal DFG documents used to help determine acquisition priorities. For more information on WCB, go to http://www.dfg.ca.gov/wcb.

Zoological Society of San Diego: The Applied Conservation Division of the Society's Center for Reproduction of Endangered Species is working to conserve natural habitats and species in southern California, as well as other parts of the world. For example, the Applied Conservation Division supports conservation of southern California ecosystems through seed banking of endangered plant species, and ongoing studies of local birds, reptiles, and mammals and their habitats. For more information on ZSSD, go to http://www.sandiegozoo.org.

A Scientifically Sound Plan for Conservation Action

In the South Coast Ecoregion, 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 one of the world's greatest biological warehouses of species diversity.

This interaction among human development and unparalleled 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 catastrophic changes to a once intact ecosystem. The conservation plan for the San Gabriel-San Bernardino Linkage addresses these challenges by seeking to influence regional patterns of development in a manner that best preserves landscape level processes in the Ecoregion.

The prioritization of this linkage for conservation and the demarcation of lands requiring protection in the linkage are based on the best available conservation techniques and expertise of biologists working in the region. This project provides a strong biological foundation and quantifiable, repeatable conservation design approach that can be used as the basis for successful conservation action.

Next Steps

This Linkage Design Plan acts as a scientifically sound starting point for conservation implementation and evaluation. The plan can be used as a resource for regional land managers to understand their critical role in sustaining biodiversity and ecosystem processes, both locally and in the South Coast Ecoregion. Existing conservation investments in the linkage are already extensive including lands managed by the US Forest Service, Bureau of Land Management, California State Parks, California Department of Fish and Game, and other conservancy lands. Each holding lies within Core Areas or the linkage itself and serves a unique role in preserving some aspect of the connection. Incorporating relevant aspects of this plan into individual land management plans provides an opportunity to jointly implement a regional conservation strategy.

Additional conservation action will also be needed to address road, stream, urban, and industrial 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 persons interested in becoming involved in preserving and restoring linkage function. We urge the reader keep sight of the primary goal of conserving landscape linkages to promote movement between Core Areas over broad spatial and temporal scales, and to work within this framework to develop a wide variety of restoration options for maintaining linkage function. To this end, we provided a list of organizations, agencies and regional projects that provide collaborative opportunities for implementation.

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 and to generate an appreciation and support of the conservation effort. 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. The biological information, figures and tables from this plan are ready materials for interpretive programs. We have also prepared several 3D animations (Appendix C on the enclosed CD) that provide a landscape perspective of the linkage.

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 Design area. 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 remaining wildlands of the South Coast Ecoregion form a patchwork of natural open space within one of the world's largest metropolitan areas. Without further action, our existing protected lands will 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 altered 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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South Coast Missing Linkages Workshop
Wednesday August 7, 2002 at the University of Redlands

8:30	*Welcome Address* Geary Hund, California State Parks
8:40	*Where Linkage Planning and MSCPs Meet* Tom Scott, University of California Riverside
9:00	*Connectivity Planning for Plants* Tim Krantz, University of Redlands
9:20	*The Role of Arthropods in Wildlife Linkages* Greg Ballmer, Tri-County Conservation League
9:40	*Reptiles and Amphibians in the Transition and Foothill Regions of the San Bernardino Mountains* Chris Brown, U.S. Geological Survey Biological Resources Division
10:00	Break
10:15	*Ornithological Considerations for Habitat Connectivity Planning* Chet McGaugh & John Green, AMEC
10:35	*Distribution, Biology, Dispersal, and Habitat Connectivity Issues Affecting the Spotted Owl in Southern California* William S. La Haye, Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, St. Paul
10:55	*Considering Small Mammals in Linkage Planning for the South Coast Ecoregion* Wayne Spencer, Conservation Biology Institute
11:15	*Cougars, Corridors, and Conservation* Paul Beier, Northern Arizona University
11:45	*Considerations for Connectivity & Overview of Working Groups* Claudia Luke, San Diego State University Field Station Programs
12:10	Lunch – *Vouchers will be issued to all participants for use in the Commons*
1:00	Working Group Session

Taxonomic Group Leaders

Plants:	Tim Krantz
Invertebrates:	Gordon Pratt
Herps/Fish:	Chris Brown & Claudia Luke
Birds:	Bill La Haye
Mammals:	Paul Beier

4:45 *Closing Remarks* by Kristeen Penrod, South Coast Wildlands Project

5:00 Adjourn; Please join us for a Beer & Wine Social

Workshop Summary

Geary Hund, California State Parks – *Welcome*

- Missing Linkages initiative identified 232 statewide linkages; 69 are associated with the South Coast Ecoregion; 15 most crucial are focus of collaborative planning effort coordinated by South Coast Wildlands Project; this workshop will lay the biological foundation for corridor planning between the San Bernardino Mountains and surrounding ranges (San Gabriel, Granite, Little San Bernardino, and San Jacinto Mountains)
- Preservation of biodiversity in southern California will require connectivity
- Linkage between Santa Ana Mountains and Chino Hills was established across 91 freeway at Coal Canyon, where mountain lion established home range on both sides of freeway as documented by Paul Beier; private properties purchased and protected, and CalTrans will close the exit, remove pavement, and restore the underpass
- California Floristic Province is one of 25 global biodiversity hotspots; South Coast Ecoregion is considered a "hotspot within a hotspot" deserving special attention
- Scientific investigation combined with environmental advocacy can achieve landscape-level connectivity needed for nature to adapt to changes over time

Tom Scott, University of California, Riverside - *Where Linkage Planning and MSCPs Meet*

Summary: The focus of my current research is examining biologically diverse hot spots within the Riverside and Coachella Valley Multiple Species Conservation Plans (MSCPs). Some of the linkage areas we will be considering today are located within these MSCPs. My discussion will highlight some of the diverse species that occur in these linkage areas, and some considerations for habitat corridor planning in areas with high biological diversity.

Biography: Dr. Scott is an Adjunct Associate Professor in the Department of Earth Sciences at the University of California, Riverside. He received his PhD at the University of California in 1987. His research focuses on wildlife conservation in fragmented and altered landscapes, including studies of wildlife movement, habitat use, and population biology in oak woodland, sage scrub, and riparian habitats; behavioral changes and adjustments in habitat use of woodland bird species in response to human activities; the conservation and management of island bird species through captive propagation, predator control, and habitat restoration.

- Political mentality against southern California exists due to intense level of development and high representation in Congress; this is land of geologic, climatic, and human superlatives; regional single family housing is worth up to $27 billion per year
- Landscape disturbance began in 1940s with water availability; urban sprawl/suburbia expansion occurring in developed areas around the world; educated, politically active individuals living in Wildland-Urban Interface (WUI); can achieve conservation with local support (residents dislike rapid landscape change); about 38-48% of landscape will be converted; 100 km WUI edge in San Diego County, 2300 km in Riverside County

- One acre of natural habitat in southern California more valuable for global biodiversity preservation than acre of lowland tropical rainforest; tropics are diverse, but southern California's high level of endemism reveals unique suite of species at each location
- California contains 30% of entire country's endemic taxa, and has semitropical influence; endemics have narrow distributions due to range contraction or isolation
- Multiple edges of distributions (species margins) meet in southern California, which has resulted in abundance of endemic species
- High level of endemism at Baldwin Lake/ Pebble Plains, Otay Mesa, Del Mar, Vail Lake, Sierra Madre/Occidental; geologic calliope ranges from "brand new" to 9 million years old, with mountains still rising (11,000 feet but less than 2 million years old) as Pacific and North American Plates slide past each other; San Jacinto Peak is greatest vertical climb in North America (800 to 3200 m over less than seven km); incredible spatial diversity, but landscape variation is a challenge for functional linkage planning
- Multiple Species Conservation Plans (MSCPs) direct land use and resource management planning; Riverside County and Western Mojave plans are being developed, and include habitat linkages between preserves; important for biologists to get involved in MSCP process, the political solution to Endangered Species Act issues; even with plans, landscape will suffer from air pollution, recreational use, and urban drool (excess runoff often supporting harmful exotic species, such as bullfrogs)
- Linkages must be functional, with stated goals and measurable benefits

Tim Krantz, University of Redlands – *Connecting Rare Plant Communities*

Summary: People don't think of plants as migrating, but they certainly do—not as individuals, but over the span of generations. Montane plant communities migrate up and down in elevation over time between glacial and interglacial episodes, while valley species move through passes and along flood plains. Most of Southern California's rare plant communities are characterized by restricted suitable habitats and/or limited dispersal capability. Compounding those natural limitations, habitat fragmentation, flood control measures, invasive exotic species and other developments constrain the remaining opportunities to provide connections between rare plant populations and communities.

Biography: Dr. Krantz is an Assistant Professor of Environmental Studies at the University of Redlands; and is Director of the Salton Sea Database Program. He is a recognized authority on the flora of the San Bernardino, San Gabriel and San Jacinto Mountains and has worked extensively on endemic plants and plant communities of the region. He has worked for many years, first as an employee and later as a consultant to the Southern California National Forests, mapping endemic plant distributions; and served for six years on the San Bernardino County Planning Commission.

- Rare plant communities move over long-term (hundreds to thousands of years) between glacial and interglacial episodes (fossil evidence of conifer species found in Santa Ana and San Jacinto washes); usually restricted to specific ecological conditions; poor dispersal abilities, as movement away from favorable habitat would be disadvantageous
- Linkages contain montane communities (San Bernardino, San Gabriel, San Jacinto) separated by barriers/corridors (Cajon Wash, Banning Pass and Santa Ana River)
- Big Bear region has extremely diverse endemic flora; plant communities include pebble plains (relic from ice age) as "islands in a sea of conifers" restricted to dense clay soils; mapped using indicator species (Bear Valley sandwort and Kennedy's

buckwheat, an alpine plant found at 7000 ft – nearest relatives located at nearby 11,500 ft summit)

- Sub-alpine meadow: clay soil with more water; associated with several endangered plants (Big Bear checkerbloom, slender-petal mustard, California dandelion)
- Mapped extant locations of plant communities, forming network of preserves to protect best remnants of these unique communities; corridors over long-term provide genetic resources for plant communities to make necessary connections
- Another community restricted to carbonate resources/limestone soils (includes cushion berry buckwheat and Parish's daisy); nearest relatives in desert communities; concentrations of endemic species threatened by limestone mining, but less than 30% of mineral resource actually valuable for mining – great opportunity for conservation
- Linkage areas also contain southern rubber boa, spotted owl, bald eagle, unarmored three-spine stickleback, Andrew's marble butterfly; plant communities are animal communities, and so habitat connectivity will benefit both flora and fauna
- Lowland passes/washes may act as barriers for montane species
- San Jacinto slender-horned spineflower and Santa Ana River woolly star are restricted to alluvial fan sage scrub, found between mountain ranges
- Seven Oaks Dam on upper Santa Ana River currently prevents natural flood scour events that maintain dynamic ecosystem; sand/gravel mining, flood control and development are fragmenting community
- Shortest route not necessarily best route; easier for most species to cross fewer life zones between mountain ranges (San Timoteo Canyon, Wildwood Canyon, and Crafton Hills may link San Jacinto and San Bernardino Mountains better than Banning Pass)

Greg Ballmer, Tri-County Conservation League - *The Role of Arthropods in Wildlife Linkages*

Summary: Arthropods are ubiquitous in all habitats and are largely responsible for maintaining habitat quality and productivity. For arthropods, habitat fragmentation frequently leads to speciation rather than extinction. Most arthropods, by virtue of their small size, ecological specialization, high reproductive rate, and small home ranges, do not benefit directly from habitat linkages. Exceptions include arthropod species having a metapopulation structure. Also, arthropod communities benefit indirectly from habitat linkages when those linkages help to maintain populations of vertebrates, whose presence is critical to maintaining overall community structure.

Biography: Greg Ballmer earned a B.S. degree in Entomology at UCR in 1967, he then spent three years in Thailand as a Peace Corps Volunteer entomologist in the Thai National Malaria Eradication Project. Greg returned to UCR in 1971, where he completed his M.S. degree in Entomology in 1973. Currently, Greg lives in Riverside and works as a Staff Research Associate in the Entomology Department at University of California, Riverside. Although his professional experience is primarily with agricultural pest control, Greg's private interests include butterfly biology and systematics, arthropod habitat conservation, and overall preservation of native California habitats and biotic communities. In 1989 Greg Ballmer petitioned the US Fish and Wildlife Service to list *Rhaphiomidas terminatus abdominalis* (Delhi Sands Flower-loving Fly) as an Endangered Species; it received that status in 1993.

- Invertebrates are primary intermediate between plant and animal biomass, and provide vital ecosystem services (food for invertebrates and small vertebrates, breakdown of organic wastes/nutrient recycling, soil aeration, pollination, vector for seed dispersal)
- Habitat is combination of biotic and abiotic factors with which an organism interacts to support its growth and reproduction; organism is integral part of its habitat
- Linkages allow long-term gene flow which increases functional genetic diversity of population; this helps overcome stochastic events and long-term environmental changes
- Linkages allow short-term movement to escape catastrophic events, use accessory habitat and re-colonize after disturbance; arthropods occupy diversity of habitats and community types at different points in life cycles, and therefore need connectivity
- Arthropods maintain habitat quality within linkage areas; habitat loss or conversion can form serious barrier to insect movement; must link small invertebrate populations to maintain gene pool and metapopulation structure
- Certain arthropods may not need linkages (those that have high reproductive rate, occupy restricted or widely spaced geographic areas, are highly migratory or wind dispersed); rapid evolution/speciation can occur when populations are isolated
- Vernal blue butterfly subspecies – in southern California only occurs on somewhat barren ridgetop in San Bernardino Mountains with specific buckwheat host plant – linkages will not benefit such Pleistocene relics with spotty distribution – not found in nearby appropriate locations that contain the host plant
- Migratory painted lady butterfly has ephemeral populations and does not need linkages
- Delhi Sands flower-loving fly, an endemic arthropod threatened by habitat fragmentation, inhabits scattered sand patches; endemic Jerusalem cricket also utilizes sandy habitat; both are capable of re-colonizing habitat from source population after disturbance

Chris Brown, USGS Biological Resources Division - *Reptiles and Amphibians in the Transition and Foothill Regions of the San Bernardino Mountains*

Summary: The transition and foothill regions of the San Bernardino Mountains are biological hotspots in San Bernardino County, having a unique mixture of coastal, mountain and desert herpetofauna. These areas are also important connections between the Transverse Ranges. Although much of this habitat still exists, development is encroaching on the San Bernardino Mountains, weakening these linkages, and several barriers already exist in a setting that was historically wide open. We have been studying the herpetofauna of the transverse ranges since 1995 in order to better understand the distribution and needs of the sensitive reptiles and amphibians throughout this region. Successful management of the diverse herpetofauna within these historical corridors of the Transverse Ranges must take into consideration the heterogeneous and expansive nature of the transition zones and foothills that connect the San Bernardino Mountains with outlying ranges.

Biography: Chris Brown is a biologist for the US Geological Survey, Western Ecological Research Center. Since 1995, he has been studying the herpetofauna of southern California to support research needs of UC San Diego, San Diego State University, National Biological Survey and the USGS. His interests in herpetology have focused on distribution, status and natural history of the mountain and coastal herpetofauna of southern and Baja California.

- Linkage area contains wide range of habitats; linkages from San Bernardino Mountains to surrounding ranges include coastal and desert influences, transitional belt of habitat around mountains, and montane habitats, resulting in phenomenal diversity; working group must select multiple species to represent the four different linkages - horned lizard, speckled rattlesnake, and western spadefoot toad recommended as focal species
- 1 turtle, 13 lizards, 19 snakes, 4 salamanders, and 7 frogs and toads inhabit planning area; (SB = San Bernardino Mountains, SG = San Gabriel Mountains, SJ = San Jacinto Mountains, LSB = Little San Bernardino Mountains, GM = Granite Mountains)
- Salamanders demonstrate limited connectivity between these mountain ranges; garden slender salamander (south-facing coastal slopes; SB – SG, SJ); San Gabriel Mountain slender salamander (SB – SG); large blotch salamander (SB – SJ); Monterrey ensantina best example for species movement (gene flow) between all these ranges
- Frogs and toads: western toad (SB – SG, LSB); arroyo toad (SB – SG, SJ); red spotted toad (desert slopes); spadefoot toad (little known about distribution, but recently found in foothill transition zones around SB – SG, SJ); California treefrog (fairly common in all ranges); mountain yellow-legged frog (most historical habitat lost in Santa Ana wash)
- Desert tortoise on desert slopes (SB – GM, SJ); tortoises reside within linkage areas
- Fish: speckled dace (SB – SG), found in Cajon wash and Lytle Creek, but rather isolated
- Lizards: zebra-tailed lizard (SB - SJ); coast horned lizard (SB – SJ, SG, LSB); long-nosed leopard lizard (desert transition zone; SB – SJ, SG, LSB); Gilbert skink (possibly SB – GM); western whiptail (all ranges; species variety may be result of isolation)
- Snakes: glossy snake (resides within linkage areas; SB – GM, recommended focal species); ringneck snake (SB – SG); distribution largely unknown for: red racer, patch-nosed snake, lyre snake, and rosy boa (which does not like to cross even dirt roads); southwestern speckled rattlesnake (easily detectable, found throughout linkage areas, recommended as focal species, good barometer for snake movement)
- Amphibian visual encounter surveys; targeted species for San Bernardino area include arroyo toad, western toad, California treefrog, Pacific treefrog, spadefoot toad; field biologists noting movement barriers (roads and dams), impacts of recreation (ATV use and illegal dumping), development impacts (light pollution, habitat and connectivity loss)
- Herpetofauna biodiversity data (starting in 1999): pitfall trap arrays at 51 study sites throughout southern California; over 630 arrays (4400 buckets, 1800 snake traps, 28 km fencing); captured 46 species in 18 families; study sites have between 9-33 species
- Historical perspective must consider natural history of desert and coastal species, as different forms intergrade (ex – gopher snakes at Silverwood Lake); natural gene flow should be conserved; 5 different forms of red racer in California

Chet McGaugh & John Green, AMEC – *Ornithological Considerations for Habitat Connectivity*

Summary: The power of flight, and the amazing dispersal and migratory abilities of birds enable them to traverse huge expanses of unsuitable habitat. Habitat connectivity at the landscape level is not an issue for most birds. Birds resident within the linkages, or living in similar habitats adjacent to the linkages, would benefit most from the connectivity of large habitat patches. Sensitive species and ecological specialists would benefit more from conservation measures within their various habitats than from an attempt to establish linkages.

Biography: Chet McGaugh is a wildlife biologist specializing in ornithological studies. As a consultant (currently with AMEC Earth and Environmental in Riverside) and as an avid birdwatcher, he has studied the distribution and ecology of birds in this ecoregion for 25 years. He participated in the U.S. Fish and Wildlife Service's life history study of the California Gnatcatcher, and has conducted hundreds of surveys for sensitive bird species, including the Least Bell's Vireo, Southwestern Willow Flycatcher, and the California Gnatcatcher. He is the compiler of the Salton Sea – North Christmas Bird Count.

Biography: John Green is a wildlife biologist specializing in ornithological studies. As a consultant with AMEC Earth and Environmental, John specializes in the monitoring of sensitive bird populations such as the Least Bell's Vireo. John's many contributions to the ornithological community in this ecoregion include his acclaimed Southeastern California Rare Bird Alert, which is the Internet clearing-house for bird sightings in the region, and his participation in a valley-wide survey of Mountain Plovers in the Imperial Valley in 2002.

- Many bird species are capable of easily dispersing between suitable habitats
- Flightless birds and those that can only fly limited distances need connectivity; California gnatcatcher is weak flyer with poor dispersal over unsuitable habitat, and therefore is susceptible to impacts from habitat fragmentation
- Diversity in flying ability and movement patterns between species
- No need to consider water birds or migratory species for connectivity planning
- Sedentary birds and birds unlikely or unwilling to disperse over large areas of unsuitable habitat will benefit from linkages; ex – cactus wren, rock wren, scrub jay, California thrasher, wrentit, Bewick's wren, bushtit; gene flow occurs if populations are not isolated; many birds would utilize habitat available within linkage areas, but montane species have characteristics and habitat needs distinct from birds inhabiting most of the lower elevation linkage areas; unknown whether many mountain species cross washes and desert habitat to move between the ranges
- Acorn woodpecker shows seasonal movements to hospitable resource areas
- Band-tailed pigeon probably crosses between ranges, which allows gene flow
- Sensitive species that would utilize linkages include Le Conte's thrasher, sage sparrow, rufous-crowned sparrow, burrowing owl, and loggerhead shrike

Bill LaHaye, University of Minnesota, St. Paul – *Distribution, Biology, Dispersal, and habitat connectivity issues affecting the Spotted Owl in southern California.*

Summary: The Spotted Owl is a large avian predator that primarily inhabits older forests in western North America. This owl is an interior forest species whose flight adaptations have been driven by the need for maneuverability in densely wooded environments. Thus in spite of having a wingspan exceeding one meter, the Spotted Owl is a weak flyer in open terrain. This may restrict the dispersal of this owl in regions lacking contiguous forest. Here I present the pertinent results of a 12-year demographic study on this species in the San Bernardino Mountains. Information will be presented on general biology, current and historic distribution, dispersal, and metapopulation aspects of the Spotted Owl in southern California.

Biography: Bill LaHaye received a Master of Science degree from Humboldt State University in 1989 and has been studying the Spotted Owl for 20 years. While he has worked on various projects studying this species in California, Arizona and New Mexico, the majority of Bill's efforts have been in southern California. The topics of Bill's published works include natural history, diet, demography, dispersal, and metapopulation dynamics.

- Spotted owl demography research conducted in San Bernardino Mountains; owls inhabit interior forests with dense canopy and ambush prey; live in continuous forest at higher elevations, with distribution more patchy and linear at lower elevations; may have historically utilized oak woodlands; current distribution in southern California includes islands of mountaintop habitat with metapopulation becoming fragmented
- Owls studied for 12 years in San Bernardino Mountains and 6 years in San Jacinto Mountains; over 95% of encountered owls were banded; no movement between mountain ranges has been documented during this study
- About 850 owls banded in San Bernardino Mountains (over 300 adults and over 500 juveniles); researchers were surprised that no juvenile dispersal was observed

Wayne Spencer, Conservation Biology Institute - *Considering Small Mammals in Linkage Planning for the South Coast Ecoregion*

Summary: For good reasons, linkage planning between major mountain ranges tends to focus on large, wide-ranging mammals. Smaller mammals should not be ignored in these efforts, however, because they can play numerous important roles in maintaining or monitoring linkage functionality. For example, small mammals are essential prey for larger carnivores within landscape linkages, may represent ecological “keystone species,” and may be useful indicators for monitoring effects of fragmentation. Small mammals could be classified by their irreplaceability and vulnerability in assessing which may be useful indicators of linkage function, or they could be classified by their major habitat associations or ecological functions. Although a few small mammals may use inter-montane linkages to disperse from one mountain range to another, those species living completely within linkages at lower elevations may be even more important for assessing inter-montane linkages. Linkage planning should therefore consider “orthogonal linkages,” or those that follow elevational bands or drainages crossed by inter-montane linkages. For example, such rare rodents as the San Bernardino Kangaroo Rat and Palm Springs Pocket Mouse inhabit desert washes and alluvial fans that lie between adjoining montane habitats. Landscape linkages should therefore be planned to capture essential habitat for these species across their breadth while connecting between mountains on either side. Other general guidelines concerning small mammals in linkage planning include: (1) provide live-in habitat for prey species; (2) provide for natural processes like fire and erosional-depositional forces that replenish habitats; (3) provide for the full range of ecological gradients across the linkage, such as the full range of geologically sorted substrates in alluvial fans; (4) provide for upslope ecological migration in response to climate change; and (5) consider the limited dispersal tendencies of small mammals relative to dispersal barriers, such as roads and canals, and avoid creating death traps for them when designing crossings for larger species. Linkage planning should also consider ways to provide niches for habitat specialists, such as creating bat roosts in bridges or overpasses designed to accommodate wildlife movement.

Biography: Dr. Spencer is a wildlife conservation biologist who specializes in applying sound ecological science to conservation planning efforts. He has conducted numerous field studies on sensitive wildlife species, with a primary focus on rare mammals of the western U.S. Dr. Spencer has studied martens, fishers, and other carnivores in forest and taiga ecosystems, as well as rare rodent species and communities in the southwestern U.S. In the South Coast Ecoregion he has served as principal investigator for research designed to help recover the critically endangered Pacific Pocket Mouse and has worked intensively on efforts to conserve endangered Stephens' Kangaroo Rats, among other species. Dr. Spencer is currently serving as Editor in Chief for a book on mammals of San Diego County. He also serves as a scientific advisor on a variety of large-scale conservation planning efforts in California, including the San Diego MSCP/MHCP, and the eastern Merced County NCCP/HCP. He is increasingly being asked by state and federal wildlife agencies to help facilitate scientific input in conservation planning efforts, and to help train others in science-based conservation planning.

- Most linkages designed for large mammals that must move between large habitat areas to survive and reproduce; many smaller species will not use inter-montane linkages for movement, but rather will benefit from the protected habitat
- Small mammals (especially rodents and lagomorphs) are prey for larger mammals; small mammals are more dispersal limited and habitat specialized than larger mammals
- Keystone species include burrowing rodents (pocket gophers, ground squirrels and kangaroo rats) that modify soil, impact plant distribution, create habitat for other species
- Micro-habitat specialists; pocket mouse subspecies adapted to slices of vegetation community or geological substrate; genetic differentiation due to geographic isolation
- Conservation planning recognizes irreplaceability and vulnerability (incorporating and connecting habitat for rare endemic species with limited distributions)
- For most taxa (including small mammals), linkages are not designed to move individuals of various species from one mountain range to another (many have not moved between ranges for tens of thousands of years), but rather to provide for long-term genetic exchange and adaptation; species will benefit from preserved habitat in linkages
- Orthogonal linkage concept: for small mammals distributed in elevational bands in particular vegetation communities or soil strata, breadth of linkage is important; habitat located at right angle to general linkage arrows; connect both across and along linkages
- Inhabitants of pinyon juniper, oak woodland, chaparral, and other lower elevation areas of linkages may be planned for (western gray squirrel, dusky-footed woodrat, chipmunk)
- Different suite of species needed for each linkage; species that should be considered for planning: round-tailed ground squirrel, Mojave ground squirrel, western gray squirrel, chipmunk, San Bernardino kangaroo rat, little pocket mouse, long-tailed weasel, spotted skunk, ringtail, badger (fragmentation-affected grassland species), kit fox, dusky-footed woodrat, pinyon mouse, pocket gopher (keystone burrowing species, dispersal limited)
- Plans for bat roosting structures can be incorporated into bridge and overpass structures
- Linkages for large mammals must provide habitat for prey base (unless function is simply to move species across and away from roads); also, consider location of rare and endemic species to compliment linkage design
- With climate change, expect upslope migration resulting from global warming; linkages should be broad enough to accommodate natural processes (flood scour and deposition, fire); capture whole environmental gradients to protect multiple specialized species

Paul Beier, Northern Arizona University – *Cougars, Corridors, and Conservation*

Summary: Because the puma or cougar lives at low density and requires large habitat areas, it is an appropriate umbrella species for landscape connectivity in the South Coast Ecoregion. A crucial issue, however, is whether connectivity is provided by narrow corridors through urban areas (an artificial substitute for natural landscape connectivity). In particular, corridors decrease extinction risk only if they facilitate dispersal of juveniles between mountain ranges. To address this issue, we conducted fieldwork on pumas in the Santa Ana Mountain Range, a landscape containing 3 corridors (1.5, 6, and 8 km long). Each of the 3

corridors was used by 2 or more dispersing juvenile puma. Five of 9 radio-tagged dispersers successfully found and used a corridor. The corridors in this landscape were relict strips of habitat, not designed to facilitate animal movement. Puma doubtless would be even more likely to use well-designed linkages. Puma will use corridors that lie along natural travel routes, have < 1 dwelling unit per 50 acres, have ample woody cover, lack artificial outdoor lighting, and include an overpass or underpass integrated with roadside fencing at high-speed road crossings. "If we build it, they will come."

Biography: Paul Beier is Professor of Conservation Biology and Wildlife Ecology at Northern Arizona University. He has worked on how landscape pattern affects puma, northern goshawk, Mexican spotted owls, white-tailed deer, and passerine birds (the latter in both West Africa and northern Arizona). He serves on the Board of Governors for the Society for Conservation Biology. A full description of his activities is available at http://www.for.nau.edu/~pb1.

- Pumas exist at low density; functional connectivity needed for movement and dispersal
- Santa Ana Mountains study: 9 radio-collared juvenile dispersers tracked; three corridors/habitat constrictions present, but not designed for habitat connectivity:
  1. Coal Canyon (short freeway undercrossing near railroad tracks, stables, and golf course); 3 lions attempted to cross (2 successful); M6 was premier user of corridor, crossing under freeway more than 22 times in 18 months; home range included habitat on both sides of freeway; after completion of study, surrounding properties were preserved, and CalTrans agreed to close underpass to traffic, remove asphalt, and turn over to California State Parks for restoration and use as wildlife linkage
  2. Santa Ana – Palomar (longer, I15 is major impediment, patchwork of land ownership); 2 lions attempted to cross (1 successful); one lion crossed Santa Ana – Palomar linkage by walking across I15 rather than finding a safer route underneath; point of crossing was just north of border patrol/INS checkpoint; several lions were killed crossing at this same site – multiple lions are demonstrating preferred crossing site, which should be focus of planning for vegetated freeway overpass
  3. Arroyo Trabuco (protected from urban areas by tall bluffs, contains dense riparian vegetation, resident deer population, darkness, water); 3 lions attempted to cross (3 successful); comfortable corridor – lions spent 2-7 days traveling through corridor
- 5 of 9 study animals found and successfully used one of the three corridors; sites were not designed for animal movement, which explains unsuccessful attempts
- Photographic overview of potential linkage areas from field reconnaissance to demonstrate habitat opportunities; USGS map used to show the location for each photo:
  1. SB-GM linkage area: one-mile-wide band with virtually no housing – great opportunity; Grapevine Canyon has perennial water; Joshua tree woodland and creosote scrub
  2. SB-SG linkage area: Cajon Wash; I15 impediment; National Forest property on both sides; potential riparian and upland connections; old route 66, railroad tracks; bridged and culvert undercrossings for I15 at four main drainages (best bridge is at Cleghorn Creek with perennial water and direct route into Lone Pine Canyon); vegetation scorched by recent wildfire; SG-Baldy Mesa secondary linkage important
  3. SB-SJ linkage area: low elevation connection across San Gorgonio Pass; possible upland connection through badlands and San Timoteo Canyon; I10 and SR111 are impediments; Morongo Reservation includes upper San Gorgonio River; massive sand and gravel mining operation; development along I10 increasing impediment; many drainages/canyons in lower San Jacinto Mountains; The Wildlands Conservancy recently protected portion of Whitewater River; windfarms near I10

4. SB-LSB linkage area: SR62 main impediment; several drainages cut through Morongo Valley; Mission Creek – good bridges for movement – The Wildlands Conservancy owns portion; desert wash connectivity possible across freeway; possible need for crossing over highway; large band of undeveloped land; natural wetlands in Big and Little Morongo Wash

Claudia Luke, San Diego State University Field Station Programs – *Considerations for Connectivity & Overview of Working Group Session*

Summary: This presentation describes the Santa Ana – Palomar Mountains linkage to allow workshop participants to understand purposes of focal species groups, identification of critical biological issues regarding connectivity, and qualities of species that may be particularly vulnerable to losses in connectivity.

Biography: Claudia Luke received her Ph.D. in Zoology from University of California, Berkeley in 1989. She is a Reserve Director of the Santa Margarita Ecological Reserve, an SDSU Field Station, and Adjunct Professor at San Diego State University. She is on the Board of Directors for the South Coast Wildlands Project and has been the lead over the last two years in conservation planning for the Santa Ana – Palomar Mountain linkage.

- At the November 2000 Missing Linkages conference, participants determined which areas within California needed to be connected to allow species movement
- South Coast Ecoregion workgroup selected criteria to prioritize linkages and connect largest protected lands; planning efforts have progressed for the Santa Ana – Palomar Mountains linkage area - workshops have been held to select focal species
- Global linkage role: preservation of biodiversity hotspot with concentration of endemic species (formed by gradients in elevation, lack of past glaciers, soil diversity)
- Regional linkage role: maintenance of habitat connectivity to prevent extirpations, and considerations for climate change (warmer wetter winters and drier summers may cause extreme floods and wildfires, drier vegetation types may expand to higher elevations)
- Local linkage role: connect protected parcels, considering dispersal methods of focal species, and impacts to habitat specialists, endemics, edge effects, and gene flow
- Focal species approach to functional linkage planning based on Beier and Loe 1992 corridor design (choose appropriate species, evaluate movement needs, draw corridor on map, monitor); focal species are units of movement used to evaluate effectiveness of linkages; wide diversity of species necessary to maintain ecological fabric; collaborative planning effort based on biological foundation and conservation design/delivery
- Choose species sensitive to fragmentation to represent linkage areas; Crooks and Soule 1999 showed that in San Diego as fragment size decreases, mid-sized carnivores increase (mesopredator release), and multiple bird species are lost; must consider associated species in planning, including keystone species important for survival of other species (ex - *Yucca whipplei* pollinated by specific invertebrates)
- Each taxonomic working group will choose a few species, delineate movement needs, record information on natural history, distribution, habitat suitability, current land conditions, key areas for preservation and restoration; consider metapopulation dynamics so that if a species disappears due to disturbance, habitat can be re-colonized
- Focal species data will be displayed on conservation design map and used to guide planning efforts; regional approach to linkages will help project to gain visibility and leverage to work with multiple agencies and organizations

The South Coast Wildlands is in the process of producing several flyovers or 3D visualizations of the San Bernardino-San Gabriel Connection and other linkages throughout the South Coast Ecoregion as part of the South Coast Missing Linkages Project.

The 3D Visualization provides a virtual landscape perspective of the local geography and land use in the planning area. 2002 USGS LANDSAT Thematic Mapper data was used to build a natural color composite image of this study area.

INSTRUCTIONS ON VIEWING FLYOVER

The flyover provided on this CD is an .mpg file (media file) which can be viewed using most popular/default movie viewing applications on your computer (e.g. Windows Media Player, Quick Time, Real One Player, etc).

Simply download the .avi file "3D_Visualization.mpg" from the CD onto your computer's hardrive. Putting the file on your computer before viewing, rather than playing it directly from the CD, will provide you with a better viewing experience since it is a large file.

Double click on the file and your default movie viewing software will automatically play the flyover.

If you cannot view the file, your computer may not have any movie viewing software installed. You can easily visit a number of vendors (e.g. Real One Player, Window Media Player, etc.) that provide quick and easy downloads from their websites.

Please direct any comments or problems to:

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