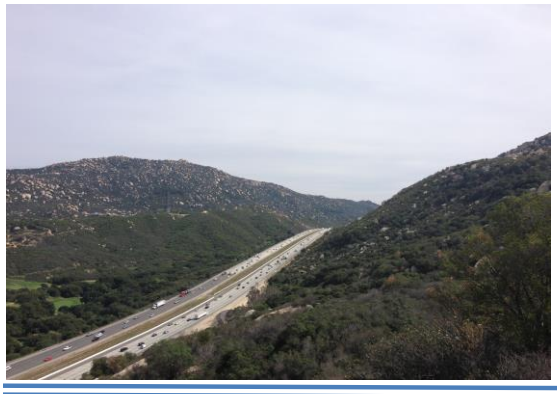


Assessment of Wildlife Crossing Sites for the Interstate 15 and Highway 101 Freeways in Southern California

March 2018

Prepared by (in alphabetical order):

Seth P. D. Riley, Ph.D., National Park Service
Trish Smith, The Nature Conservancy
T. Winston Vickers, Ph.D., UC Davis Wildlife Health Center

TABLE OF CONTENTS

Appendices

List of Tables

Page

List of Figures

Page

EXECUTIVE SUMMARY

Roads can cause significant mortality for wildlife, but large roads like freeways can also form major barriers to wildlife movement and gene flow. Freeways are ubiquitous in southern California, and two freeways, Interstate 15 and U.S. 101, have been found to be barriers to wildlife passage and gene exchange, especially for mountain lions, between the Santa Ana Mountains and the Palomar Mountains and other mountains to the east (separated by Interstate 15), and between the Santa Monica Mountains and the Simi Hills, Santa Susana Mountains, and others to the north (separated by the 101 Freeway). We used two sources of information with the goal of bridging the gap between connectivity science and conservation practice. In early 2015 we engaged an independent panel of connectivity experts to evaluate possible locations and concepts for wildlife crossings along stretches of both freeways. We also developed and implemented an evaluation tool based on landscape characteristics and wildlife data to help prioritize locations for wildlife crossing infrastructure. The experts were asked to evaluate stretches of each freeway where wildlife studies have indicated that some connectivity potential remains due to the presence of natural habitat on both sides of the road, but where new or enhanced structures are likely required to restore lost connectivity. Multiple specific sites were examined along these stretches of each freeway. For I-15, both the Landscape and Expert scoring indicated that retention and enhancement of function under the Temecula Creek Bridge, and construction of a new under or overpass south of the bridge, were both likely needed for long term connectivity. For the 101 Freeway, the Landscape and Expert scoring both strongly concluded that West Liberty Canyon is the best location for a new wildlife crossing structure, with several other locations being sites where enhancements or new construction could serve the role of providing secondary crossings. The experts indicated that an overpass, over both 101 and the parallel Agoura Rd, was the best option here to provide connectivity for a range of species. The experts agreed that accompanying measures, such as effective wildlife fencing to funnel animals to crossing points and appropriate vegetative cover on and near structures were also important. They also recommended that, over the long term, more than one crossing structure should be enhanced or created for each linkage to assure sufficient movement of wildlife to accomplish gene exchange between populations in entire mountain ranges. Increasing connectivity across both freeways is critical for the long-term viability of local wildlife populations, especially for wide-ranging species such as mountain lions, and this analysis provides a concrete way forward.

1. INTRODUCTION

The protection of habitat connectivity is arguably one of the most salient global conservation problems of our day – how to keep from fragmenting intact natural landscapes with areas of intense human land use, and how to halt and reverse the cascading impacts of habitat fragmentation resulting from past land use decisions.

The threat of habitat fragmentation to biodiversity is well recognized in southern California. Here, coastal, montane, and desert ecosystems intersect to create an area renowned for its unique and diverse biota (Myers et al. 2000). It also is an area of intense human development with a growing population of nearly 24 million that threatens the persistence of the region's natural habitats and species (State of California, Dept. of Finance 2017). Despite large expenditures of funds and effort to preserve biodiversity and conserve threatened or endangered species in the region, substantial challenges remain for persistence of some species.

The Santa Ana Mountains and Santa Monica Mountains are two of several large southern California landscapes (Figure 1) that, despite conservation investments in the hundreds of millions of dollars, remain at risk of isolation and fragmentation by roads and urban development (Riley et al. 2014, Ernest et al. 2014). Wildlife research studies have identified that major highways and associated development have severed connectivity between these coastal ranges and larger inland protected lands that are considered critical to protecting plant and animal species against climate change and other threats. Specifically, Interstate 15 (hereafter referred to as "I-15") in western Riverside County has seriously reduced connectivity between the Santa Ana Mountains and the inland eastern Peninsular Ranges (with the Palomar Mountains being the most proximate portion of the Peninsular Ranges to I-15), and US Highway 101 (hereafter referred to as the "101 Freeway") in northern Los Angeles County and Ventura County has seriously reduced connectivity between the Santa Monica Mountains and inland Santa Susanna and Sierra Madre Mountains to the north (Riley et al. 2014, Ernest et al. 2014). These concerns have been amplified by the findings of recent genetic analyses relating to both the Santa Ana Mountains' and Santa Monica Mountains' mountain lion *(Puma concolor)* populations, indicating significant genetic restriction and minimal evidence of migration into these populations in recent years. These studies indicate that genetic diversity for Santa Ana and Santa Monica mountain lions is very low (Riley et al. 2014, Ernest et al. 2014), lower than has been measured anywhere else in the west. Only in endangered Florida panthers, where severe genetic defects were present throughout the population before a genetic introgression program, has lower genetic diversity been found (Gustafson et al. 2017).

Both linkages have been prioritized for protection by the South Coast Missing Linkages Project, an effort to identify important landscape linkages throughout the State of California (Penrod et al. 2001). Subsequently, detailed linkage designs, including recommendations for highway crossing structures for the 101 and I-15 freeways, were developed (Penrod et al. 2006, South Coast Wildlands 2008). Both linkages were also identified as important in the California Essential Habitat Connectivity Project (2010), commissioned by Caltrans and the California Department of Fish and Wildlife.

Significant research and planning efforts have been conducted for both linkages to help address connectivity needs, which range from strategic land acquisition for conservation to the identification of locations and concepts for wildlife crossing structures for both freeways. Because of the rate and extent of past urbanization throughout southern California, opportunities for securing connectivity across

major freeways in both linkages are limited. Each of these areas presents unique challenges to accomplishing improved connectivity, with many improvements that have been proposed likely requiring significant financial investment, for both wildlife crossing structures and land protection, and significant political and public support.

As stated in the Wildlife Crossing Structure Handbook (2011): “There is currently an urgent need to provide transportation and other stakeholder agencies with technical guidance and best management practices on the planning and design of wildlife crossing mitigation measures. The siting of wildlife crossing structures is equally as important as their design. Identifying the proper location of crossing structures is critical for designing effective mitigation of the barrier effect caused by roads."

Given the challenges and level of financial investment required to secure connectivity for the Santa Ana to Palomar Mountains Linkage (Figure 2), and the Santa Monica to Sierra Madre Mountains Linkage (Figure 3), the National Park Service, The Nature Conservancy, and the UC Davis Karen C. Drayer Wildlife Health Center felt that both linkages would benefit from a collaborative effort to help bridge the gap between science and practice by: 1) engaging an independent panel of connectivity experts to evaluate possible wildlife crossing site locations and concepts for the I-15 and 101 Freeways; and 2) developing and implementing an evaluation tool based on landscape characteristics and wildlife knowledge to help prioritize locations for the siting of wildlife crossing infrastructure.

Figure 1. Regional map of the Santa Ana to Palomar Mountains Linkage and Santa Monica to Sierra Madre Linkage and other priority linkages in Southern California

Figure 2. Location map of Santa Ana to Palomar Mountains Linkage, including the area along I-15 evaluated for wildlife crossings.

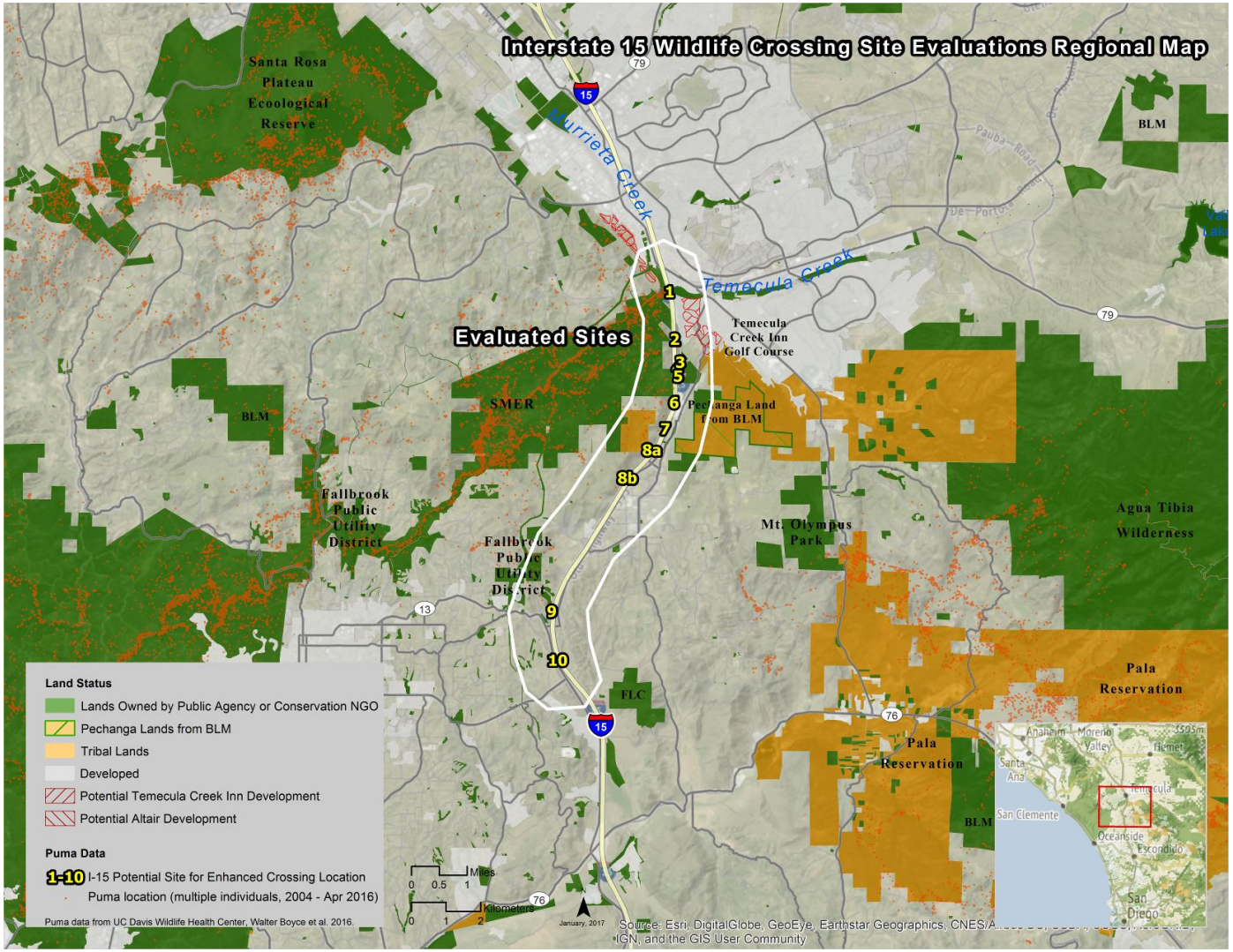
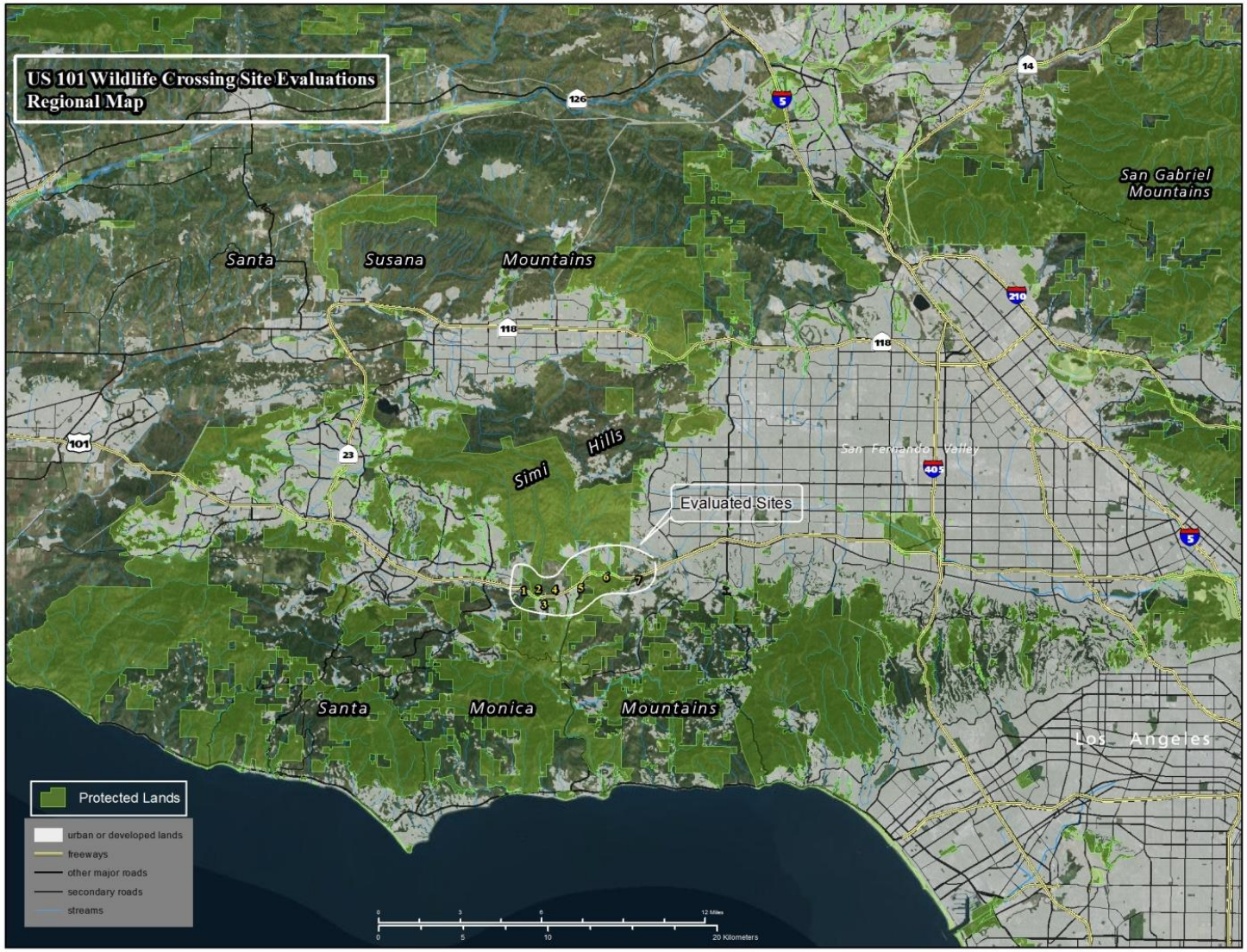


Figure 3. Location map of Santa Monica Mountains to Sierra Madre Mountains Linkage, including the area along 101 evaluated for wildlife crossings, and the intervening natural areas of the Simi Hills and Santa Susana Mountains.



Project Objective: The overall objective of this effort was to provide critical information to stakeholders involved in the development of new or improved wildlife crossing structures across the I-15 and 101 Freeways. Stakeholders that are expected to use this information include conservation agencies and organizations (governmental and non-governmental), highway agencies, local jurisdictions involved with land use decisions, wildlife agencies, and others in the region in their efforts to increase connectivity for wildlife.

Given the likelihood that these freeways negatively impact or block free exchange of genes for many wildlife species (documented for the 101 and I-15 Freeways for mountain lions, and for the 101 Freeway for bobcats, coyotes [Riley et al. 2006], and smaller vertebrates [Delaney et al. 2010]) and full use of available habitat by other wild species, assessment of potential crossing locations included the goal of providing potential movement pathways for large and medium-sized carnivores, mule deer, reptiles, amphibians, small mammals, and fish.

In relation to mountain lions specifically, the aim of crossing structure modification or new construction is to enhance the likelihood that juvenile mountain lions can move out of larger populations to the east of the Santa Ana Mountains and to the north of the Santa Monica Mountains, into the coastal mountain ranges. Without this in-migration of dispersing animals, including territory establishment and breeding, genetic diversity in these populations will continue to decline. Out-migration of animals from the Santa Ana Mountains and Santa Monica Mountains would also assure that overall genetic exchange between these populations was adequate for the health of both populations. In the Santa Monica Mountains, there have been repeated instances of close inbreeding between fathers and daughters, as well as extensive mortality from intraspecific fighting (Riley et al. 2014), both of which could likely be reduced by increasing migration out of the Santa Monicas.

This report presents background on both linkages, methods on how wildlife crossing points for each freeway were evaluated and scored through an expert review process and landscape evaluation, and summary results for each crossing point that was evaluated.

2. METHODS

The general areas of evaluation for the potential placement of wildlife crossing infrastructure for the I-15 and 101 Freeways were based on the local landscape configuration and detailed linkage assessments completed by South Coast Wildlands (Penrod et al. 2006, South Coast Wildlands 2008), and were further informed by wildlife movement studies and modelling efforts (Gibbons 2008, Tracey and Crooks 2011, Zeller et al 2015, Zeller et al. 2017a, Zeller et al. 2017b, Huber unpublished data).
Specific sites that were evaluated for the placement of wildlife crossing infrastructure along both freeways were identified using several parameters that indicate likely or at least potential use by wildlife if adequate crossing structures were present.

Parameters utilized for initial identification of potential crossing points for evaluation were:

1. Current presence of suitable habitat or pathways that could be restored to wild habitat on both sides of the potential crossing;
2. Evidence from GPS or radio tracking, camera traps, or other methods, of close approaches of mountain lions or other carnivores (e.g., bobcats and coyotes) to the freeway at that location;

3. Indication in movement or corridor models that mountain lions and other wildlife are likely to approach or cross the roadway at that point;
4. Documented crossing by mountain lions or other wildlife at that location previously (either through existing structures or at grade);
5. Occurrence of mountain lion mortalities from roadkill at that location.

Scoring of each location for ranking purposes was accomplished by use of two methods, with equal weight in final rankings assigned to each method.

Method 1: Expert Opinion

The following connectivity experts were assembled in January 2015 for a three-day workshop aimed at discussing, evaluating, and ranking locations and designs for infrastructure to improve connectivity (undercrossings, overcrossings, fencing, etc.) for the I-15 and 101 Freeways.

- Dr. Paul Beier, with Northern Arizona University, is a professor of wildlife biology who is widely recognized as one of the nation's leading experts on habitat connectivity and the design of wildlife corridors. He has studied the movements of mountain lions in southern California, has published numerous journal articles on designing, conserving, and managing functional corridors in urbanizing areas, and is the founder of CorridorDesign.org.
- Dr. Anthony Clevenger is a senior research scientist at the Western Transportation Institute, Montana State University who has been studying road effects on wildlife populations in Banff and the surrounding national and provincial parks in the Canadian Rocky Mountains since 1996. During his 20+ years of research, Dr. Clevenger's interests have been broad and ecologically based, but have been weighted towards the ecological effects of roads and the conservation of small remnant populations of carnivores.
- Dr. Patricia Cramer is a Research Assistant Professor at Utah State University. Her research focuses on transportation ecology, wildlife connectivity, and carnivore and ungulate movement. She is nationally renowned advocate for wildlife crossings, and has conducted extensive evaluation of wildlife crossing structures throughout North America and developed recommendations for their construction.
- Julia Kintsch is an ecologist specializing in conservation planning, road ecology, large landscape conservation, and collaborative problem-solving. She is recognized across North America as an expert in wildlife crossing siting and design, offering a unique understanding of the features that influence successful passage for species ranging from salamanders to deer to the elusive Canada lynx. Following an active career working for non-profit organizations such as the Nature Conservancy, Southern Rockies Ecosystem Project, and Freedom to Roam, she launched ECO-resolutions LLC in 2008.
- Dr. Patrick Huber is a Project Scientist with the Information Center for the Environment at the University of California, Davis. He earned a Ph.D. in geography at UC Davis and wrote his dissertation on spatial scale and conservation planning. His work focuses on conservation planning, landscape connectivity, and reserve design primarily in California.
- Kathy Zeller earned a PhD in Environmental Conservation at the University of Massachusetts. Her research is focused on designing wildlife corridors, modeled across a resistance-to-movement surface where the landscape is quantified in terms of the difficulty different landscape features pose to a moving organism. Her work includes methodological comparisons

for estimating resistance to movement and modeling corridors, using data from mountain lions in southern California and black bears in northern Idaho.

- Kelsey Stricker earned her Master's degree studying road impacts on wildlife along I-15 by utilizing remote camera arrays. She lives in the area and is the lead biologist for the Pechanga Tribe, a major landowner in the vicinity of the Santa Ana to Palomar Mountains Linkage.

The panel of experts was provided with available information relating to both linkage areas (aerial photos, maps, adjacent land conservation status, existing locations of culverts and bridges, data on crossing point use, modeling results, wildlife movement data) and participated in day-long field tours of each linkage area to evaluate various sites for the potential placement of connectivity structures. Field tours were then followed on the third day by an all-day workshop to discuss and rank sites and options for connectivity structures for each linkage. At this workshop, the experts were joined by transportation planners, wildlife agency representatives, and various local connectivity experts who have been involved in past assessments of wildlife connectivity status and options at these locations.

During the all-day workshop, the invited experts were asked to rank the crossing point locations, and in many cases expressed their opinions relating to the likely best types of structures that could be utilized at those locations. These expert opinions are noted in the report, however determining the most feasible or best type of structure that could be utilized at any crossing point was beyond the level of engineering expertise that was present at the workshop. Thus, this report is primarily focused on relating the ranking of crossing point locations and the type of structure, with specific structure feasibility assessments to occur in the future.

Rankings were converted into a point system that assigned a point score of 3 to each expert's first choice, a score of 2 to their second choice, and a score of 1 to their third choice. For the Santa Ana to Palomar Mountains I-15 Linkage crossing point assessments, some experts ranked more than one crossing point identically. In that case, both crossing points were given the same point score. Expert scores were then rescaled to a maximum score of 5 before combination with the Landscape scores (also scaled to 5).

Method 2: Assessment of Landscape Characteristics and Wildlife Use

In this method, points were assigned to each wildlife crossing location based on important characteristics that were scored categorically (Table 1). Possible points for each characteristic ranged from 0-1 based on the strength of that characteristic at the site. In some instances, fractional scores were given to reflect partial satisfaction of the listed condition (e.g., for Landscape pattern - broad scale, if connectivity was present in 3 of 4 directions, this would generate a score of 0.75). The maximum number of points attainable by any individual site was 5. Rankings from each method were then added together for a composite total score (maximum score of 10) which were used to determine overall rankings.

Table 1. Attributes used for Landscape scoring of crossing points in both linkage areas.

Attribute	**Score Guide**
1. Evidence of mountain lion use	
Confirmed crossing or roadkill, or close approach both sides	1
Approach within 100 meters (close approach) - either side	0.66
Approach within 500 meters (medium approach) - either side	0.33
No known approaches	0
2. Landscape pattern - broad scale *What is the overall landscape connectivity like, i.e., can animals effectively reach the vicinity of the crossing point?*	
Both sides have good connectivity	1
One side has good connectivity	0.50
Neither side has good connectivity	0
3. Landscape pattern - fine scale *Is the landscape in the immediate vicinity of the crossing conducive to wildlife movement - all the way to the crossing structure or freeway edge itself?*	
Both sides conducive to animals getting to and through the crossing	1
One side conducive to animals getting to and through the crossing	0.50
Neither side conducive	0
4. Land securement - broad scale *Is land generally continuously protected in larger blocks within 1 km of site?*	
Both sides protected	1
One side protected	0.50
Neither side protected	0
5. Land securement - fine scale *Is land protected leading to the crossing point from larger blocks of habitat, and at the crossing?*	
Both sides protected	1
One side protected	0.50
Neither side protected	0

3. RESULTS

Results are presented separately for each linkage. Background information on each linkage is followed by assessments of each crossing point, briefly in this section and then in more detail in the Appendices (Appendix A for Santa Ana to Palomar Mountains Interstate 15 Linkage, and Appendix B for Santa Monica to Sierra Madre Mountains 101 Freeway Linkage). Assessments for each crossing point include a summary of existing conditions related to habitat, conservation status, documented wildlife use, threats, and existing crossing structures. Assessments are then followed by a summary of the overall results based on the combination of the Expert and Landscape scores.

Note: Statements in this report regarding the potential for constructing various types of structures at each site are based on previous publications and discussions with wildlife agency personnel, other stakeholders and experts, and, in the case of the 101 Freeway crossings, preliminary engineering studies. To the authors' knowledge, no detailed engineering studies have been conducted relating to the I-15 sites to ascertain viability or costs of any options mentioned.

There are some general characteristics of successful wildlife crossings (Clevenger and Huijser, 2011; Vickers unpublished data) that have helped to inform the recommendations in this report:

1. Undercrossings that are intended to accommodate mule deer movement are generally larger than those required for most other wild species. Frequently crossings intended or with the potential for wildlife use may be judged on their "openness," which refers to the size of the opening relative to the length of the crossing, and specifically by the "openness ratio", arrived at by multiplying width times height in meters, and dividing by length in meters [(Height s x Width) / Length]. For ungulates in general, and mule deer specifically, the shorter and wider the structure the more likely mule deer are to use it. Although there is certainly variability between sites, between species, and even within species, previous research has indicated that an openness ratio of 0.6 m or greater is preferred; however, landscape character, adaptations to the highway, width relative to height, and other factors may be more important (Kitsch and Cramer 2011). This generally requires a bridge-type structure to carry the highway above the crossing, or a large arch culvert. Mule deer have been documented using arch-type culverts with lower openness ratios (0.25 – 0.3m) in situations where the terrain favors extensive deer use of the approaches to the structure (Vickers unpublished data), thus terrain modification near the crossing end points might allow for a somewhat smaller structure. In a study of 15 freeway crossings in the Santa Monica Mountains area (Ng et al. 2004), the two crossings with significant deer use were wide bridges with openness ratios of 5.2 (15 crossings) and 4.1 (9 crossings); one tunnel with a ratio of 0.37 but good natural vegetation on both sides had two crossings.

   Some proposals for enhancing connectivity have proposed a 4m round "jack and bore" culvert as the solution for the need for new crossings. For the 101 Freeway, tunnel length would likely be close to 100m, resulting in an openness ratio of 0.13m for a 4m diameter opening, less than 1/4 of the recommended value, making it not suitable for mule deer. Tunnel length for I-15 would vary depending on the site.

2. As in almost all effective wildlife crossing structures, animals must be able to see through the structure to the opposite end and the habitat cover at both ends needs to promote wildlife movement by the full range of species expected to use the structure. Arch culverts also allow for

the placement of internal structural components such as rocks, shelves, or water features that can effectively promote the movement of small rodents, reptiles, amphibians, etc. through the structure.

3. Mountain lions and other wildlife have been documented using round culvert structures that are smaller (~4 meters in diameter) than that required by mule deer (Clevenger and Waltho 2005, Kintsch and Cramer 2011, W. Vickers unpublished data). Thus, discussions of undercrossing designs and costs need to take these two different parameters into account, and the determination should be made early in the process whether connectivity for mule deer and other smaller species with more specific needs should be assured for any new or modified crossing structure to be judged successful.

4. In general, overcrossings for wildlife have several characteristics that are expected to enhance their use by a wider range of species than culverts. They are typically wide (50m or more), contain vegetation and natural substrates, have vegetation structure that accommodates the movement tendencies of multiple species, have structural elements that block sound and light from the roadway below, and incorporate modifications to the landscape and vegetation on the approaches that assist in funneling wildlife to the structure entrances.

5. In addition, high fencing (preferably 3- to 3.7-meter (10 – 12 ft.) high chain-link, buried to prevent animals digging underneath, and with barbed-wire outriggers) should be installed for long distances (up to a mile or more) in both directions along both sides of the roadway to funnel wildlife to any new or improved crossing structure (Huijser et al. 2016). This design is expected to minimize the likelihood of mountain lions, mule deer, and most of the smaller carnivores entering the roadway. Fencing of different designs and as low as 2.4 meter (8 ft.), such as "webwire" fencing without outriggers or burial, would be expected to restrict mule deer entrance to the highway but not mountain lions, smaller carnivores, or other wildlife.

Santa Ana to Palomar Mountains Linkage: Assessments of Interstate 15 Crossing Points

The Santa Ana to Palomar Mountains Linkage connects the Santa Ana Mountains and adjoining coastal lowlands with the Palomar Mountains and other inland portions of the Peninsular ranges primarily in San Diego County. The Santa Ana Mountains include over 120,000 hectares of protected chaparral, coastal sage scrub, grasslands, vernal pools, and oak and riparian woodlands. Lands that are protected as wildlife habitat are owned or managed by various public agencies including the National Forest Service, Department of Defense, California State Parks, the Counties of Orange, Riverside, and San Diego, San Diego State University, California Department of Fish and Wildlife, and a variety of water districts, non-profit entities, and others. The linkage has been studied by wildlife biologists for over 25 years and is widely recognized as critical for maintaining biodiversity in the Santa Ana Mountains, as it is the last option for securing connectivity between this coastal range and larger intact natural lands to the east (Figure 2). The linkage is necessary to maintain ecological processes and genetic diversity in the Santa Ana Mountains as they become more degraded and fragmented by development.

In practical terms, urban, rural, and agricultural development have limited the potential I-15 crossing area to an approximately 10-kilometer-long (6-mile) stretch of I-15 south of Temecula where wildlands and agricultural lands are present on both sides of the freeway (Figure 2; Luke et al 2004). The only

exception to this generalization is that, further south, the bridge over the San Luis Rey River provides safe passage for wildlife under I-15, but for mountain lions, an east to west crossing at that location requires that they follow the San Luis Rey River west through the cities of Fallbrook, Bonsall, San Luis Rey, Oceanside, and developed portions of Marine Base Camp Pendleton before reaching wild areas of the Santa Ana Mountains to the north of Oceanside. Thus, this pathway is not one that is expected to support regular movement of mountain lions in and out of the Santa Ana Mountains.

Urban and rural development remain a threat to what remains of the linkage, and I-15 and associated development, as well as secondary roads, have formed an apparent partial or complete barrier to east-west movement for wildlife and plants. One secondary road of concern is Rainbow Canyon Rd (Old Hwy 395), which runs parallel to the I-15 Freeway and is a lesser but likely significant barrier to wildlife movement that needs to be addressed as part of linkage planning.

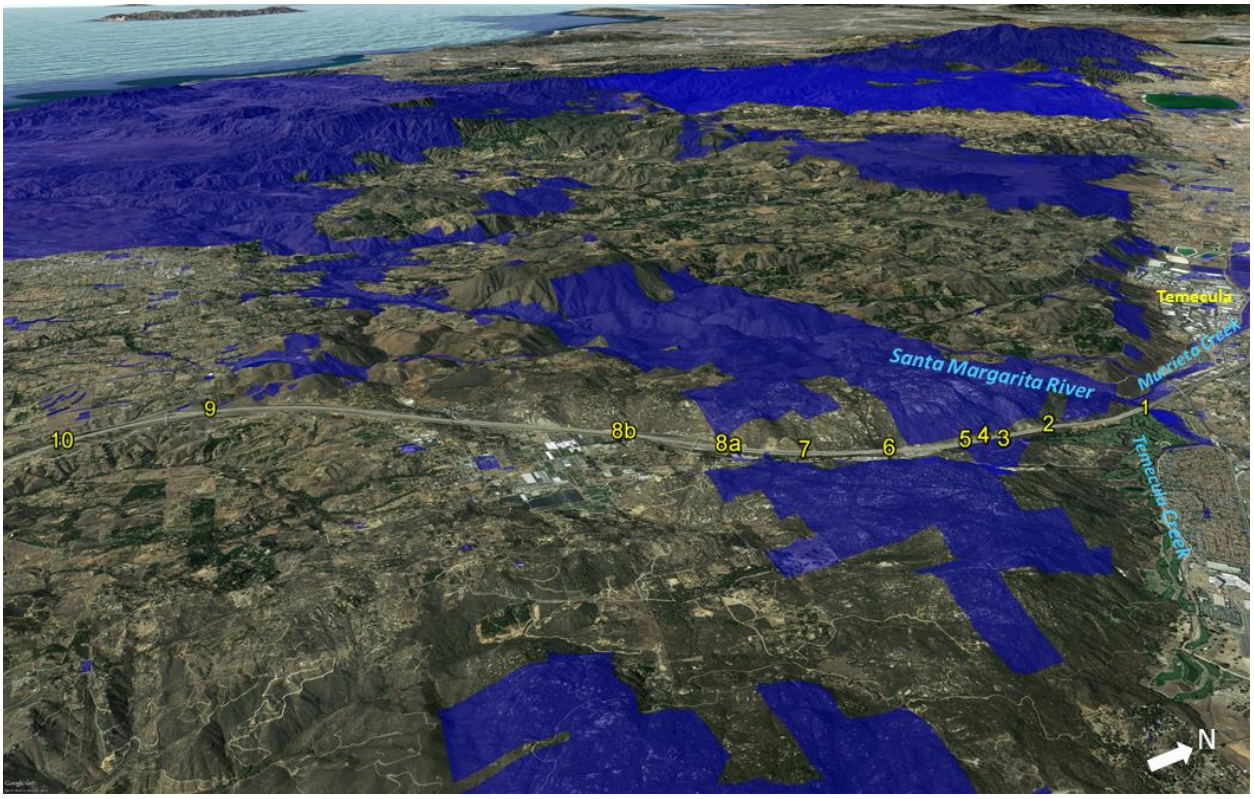
Two extensive mountain lion studies have been conducted in the region, both of which included multiple radio-collared and GPS-collared animals circulating in the Santa Ana to Palomar Mountains Linkage (Beier and Barrett 1993, Vickers et al. 2015). Mountain lion GPS points from the Vickers et al. (2015) study are depicted in Figure 2. In the Beier and Barrett study period, only two mountain lions were documented to have crossed I-15 (both west to east). In the Vickers, et al. (2015) study, only one GPS-collared animal was documented to have crossed the freeway (west to east. Based on that genetic analysis (Ernest et al. 2014), that animal (M86) did reproduce, potentially enhancing the gene pool in the Santa Ana Mountains lion population; however, few of his probable offspring have survived as of late 2016 in the population, and M86 was killed by a vehicle strike (Vickers and Boyce unpublished data). Genetic analyses from 146 sampled pumas indicate that seven pumas crossed I-15 over the last 15 years, including four males from west to east, and three males from east to west (Gustafson et al. 2017). Vickers et al. (2015) demonstrated that survival rates in the Santa Ana Mountains are lower than in most other mountain lion populations throughout the west, compounding the threat posed to the Santa Ana Mountain's population by genetic isolation.

At least five separate modelling efforts have been performed using available data (landscape and vegetation characteristics, existing culvert and bridge locations, and mountain lion movement data) to determine the best locations for wildlife crossing structures in the approximately 10-kilometer section of I-15 south of Temecula (Tracey and Crooks 2001, Gibbons 2008, Zeller et al. 2015, Zeller et al. 2017b, Huber unpublished data). These modelling efforts have indicated that several different locations have potential as sites for new or improved wildlife crossing structures. However, no consensus crossing point locations have emerged from these models, or from discussions between local wildlife agency personnel, county conservation agency personnel, other governmental representatives, and conservationists.

Crossing Point Assessments – Santa Ana to Palomar Mountains I-15 Linkage

A total of eleven potential crossings points along the roughly 10-kilometer (6-mile) segment of I-15 south of Temecula were evaluated as part of this project (Figure 3). Four of the eleven sites (Sites 8a, 8b, 9 and 10) were determined to be too highly constrained by existing development to be considered during the evaluation process. These four sites all received Landscape Scores (Table 3), but none were ranked by the experts as first, second, or third choices, possibly because of the extensive agricultural and human development on both sides of the freeway at those sites. Thus, those sites' scores were lower than any of the first seven sites described, and they are not described in depth in Appendix A, though more detailed maps of these sites are included there.

Figure 4. Eleven potential wildlife crossing points (1-8a,8b-10) along a 10-km (6-mile) stretch of I-15 in the Santa Ana to Palomar Mountains. Conserved lands are depicted in dark blue. View depicted is looking from the Palomar Mountains northwest to the Santa Ana Range with the Pacific Ocean to the west in the upper left corner.



Appendix A contains detailed information about each of the evaluated crossing points for the Santa Ana to Palomar Mountains I-15 Linkage, including: 1) a summary of existing conditions related to habitat, conservation status, documented wildlife use, threats, and existing crossing structures, if present, 2) Landscape Scores for the crossing based on available information about landscape structure and wildlife use, and 3) Expert Scores based on the experts' rankings of the location as a crossing.

Brief Crossing Point Site Descriptions and Scoring Results – Santa Ana to Palomar Mountains Interstate 15 Linkage

Site 1: Temecula Creek Bridge: This site is at the northern end of the linkage and consists of two separate span bridges for the north and south-bound traffic lanes of I-15. The bridge crosses over Temecula Creek, and each span is roughly 22 meters wide with a 15-meter separation between spans (60 meters total width). The bridge length is approximately 75 meters and the height is approximately 15 meters. Protected open space is located on either side of the bridge; however, proposed development threatens both the west and east side of this crossing. Residential uses and a civic use are proposed on a 76-hectare site just north of the west side of the bridge. In its current state, Site 1 received a Landscape Score of 4.25 out of 5 and an Experts' Score of 2.78, and ranked as the second highest priority crossing point location.

Note: Sites 2 through 4 all have steep up-slopes on the west side of the highway and downslopes on the east. All culverts noted as pre-existing are steeply sloped on their eastern ends making them unsuitable currently for regular wildlife use. It was beyond the expertise level of the group in this workshop to evaluate engineering factors that would determine whether any type of undercrossing could be constructed at these sites that would be adequately horizontal to allow for wildlife use.

Site 2: This site is the location of an existing 2m diameter culvert that drains from the west side of I-15 to the east. Intact but unprotected chaparral habitat is found on the west side of the freeway, while oak woodland and golf course development are found on the east side of the freeway at the base of the lightly vegetated downslope. Site 2 received a Landscape Score of 2.91 and an Experts' Score of 0.37 and ranked seventh overall.

Site 3: This site currently has a 2m culvert that drains west to east with intact chaparral habitat on both sides of the freeway. The property on the west side of the crossing point is currently being pursued for conservation, while the property on the east side of the culvert has been recently acquired for conservation. Site 3 received a Landscape Score of 3.33 and an Experts' Score of 1.67 and ranked fourth overall.

Site 4: This site has a 1.5m diameter culvert that drains from west to east across I-15. The west side is composed of an oak-lined drainage that is part of the Santa Margarita Ecological Reserve, while the east side of the culvert drains into intact chaparral habitat that was recently acquired for conservation. Site 4 received a Landscape Score of 3.83 and an Experts' Score of 2.59 and ranked third overall.

Site 5: This site is composed of a steep up-slope of varying height (approximately 15 - 30 meters) on both sides of the highway. The west side of the highway is protected habitat that is part of the Santa Margarita Ecological Reserve and supports rock outcrops and chaparral habitat. The east side is intact chaparral habitat that was recently acquired for conservation. Site 5 received a Landscape score of 5.0 and an Experts' score of 4.07 and was ranked as the highest priority location for a crossing structure, with the assumption by the experts that a wildlife bridge was the only type of structure that could be feasibly placed at that location.

Site 6: On the west side of I-15 at this site there are several small gullies with intact but unprotected chaparral, rock outcrops, and small oak trees. The east side includes a lightly vegetated down-slope that extends below the highway edge, and an adjoining open lot containing mixed native and non-native vegetation that is approximately 100 x 120 meters in size and bordered by commercial lots to the north and south and Rainbow Canyon Road to the east. The U.S. Border Patrol has a check station with off-ramp just north of the site where extensive light and human activity are present 24 hours a day. Site 6 received a Landscape Score of 2.33 and an Experts' Score of 0.74 and ranked sixth overall.

Site 7: The west side of I-15 at this location is a steep rocky up-slope adjoining a small canyon with intact chaparral, rock outcrops, and small oak trees. The east side includes a sparsely vegetated down-slope that extends below the highway edge and adjoins an open lot that is approximately 150 x 150 meters in size with scattered small buildings at the edge. This lot is bordered by commercial lots to the north and south and Rainbow Canyon Road to the east. Site 7 received a Landscape Score of 3.25 and an Experts' Score of 0.74 and ranked fifth overall.

Sites 8a, 8b, 9, and 10: These sites are all located along I-15 south of Site 7. All sites received Landscape Scores (Table 3), but none were ranked by the experts as first, second, or third choices because of the

extensive agricultural and human development on both sides of the freeway at these sites. Thus, the scores for these three sites were lower than any of the first seven sites described, and they are not described in depth in Appendix A, though more detailed maps of these sites are included there.

Table 2. Expert scores by crossing point in the Santa Ana to Palomar Mountains I-15 Linkage

Expert	**Expert Scores by Site**										
	Site1	**Site2**	**Site3**	**Site4**	**Site5**	**Site6**	**Site7**	**Site 8a**	**Site 8b**	**Site9**	**Site 10**
Paul Beier	1		2	2	3						
Patty Cramer	3		2	2	2	1	1				
Kathy Zeller	1		3	2	2						
Patrick Huber	2				3						
Julia Kintsch	1		2	2	3						
Tony Clevenger	2				3						
Kelsey Stricker	1	2				3	3				
Seth Riley	2			3	3						
Christy Brigham	2			3	3						
Cumulative scores unweighted	15	2	9	14	22	4	4	0	0	0	0
Cumulative scores normalized to scale of 0-5	2.78	0.37	1.67	2.59	4.07	0.74	0.74	0	0	0	0

Table 3. Landscape and Combined Expert-Landscape scores by crossing point in the Santa Ana to Palomar Mountains I-15 Linkage

Scoring components	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8a	Site 8b	Site 9	Site 10
1. Evidence of mountain lion or other wildlife use	1	0.66	0.33	0.33	1	1	1	1.0	1	0.33	0
2. Landscape pattern - broad scale	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.50	0.50	0.75	0.75
3. Landscape pattern - fine scale	0.75	0.75	1	1	1	0.50	0.75	0.50	0.50	0.75	0.75
4. Land securement - broad scale	0.75	0.75	0.75	0.75	0.75	0.75	0.75	.75.	0.50	0	0
5. Land securement - fine scale	1	0	0.50	1.0	1.0	0	0	0.50	0.50	0	0
Total landscape scores (0-5)	4.25	2.91	3.33	3.83	4.50	3.00	3.25	3.25	3.00	1.83	1.50
Expert Scores (from Table 2)	2.78	0.37	1.67	2.59	4.07	0.74	0.74	0	0	0	0
Total score (expert plus landscape, 0-10)	7.03	3.28	5.0	6.42	8.57	3.74	3.99	3.25	3.00	1.83	1.5
Overall rank	**2**	**7**	**4**	**3**	**1**	**6**	**5**	**8**	**9**	**10**	**11**

Summary of Results – Santa Ana to Palomar Mountains Interstate 15 Linkage

Site 5 ranked highest in the expert scoring with 6 out of 9 experts selecting it as the highest priority, and a wildlife bridge structure at this site was considered by the experts to be the most functional for the widest array of wildlife and plant species, including mountain lions and deer. Both the location and wildlife bridge concept are consistent with previous studies (Beier and Barrett 1993, Fisher and Crooks 2001, Luke et al. 2004). This site ranked first in the landscape scoring. The exact location where a bridge structure would be placed in the stretch of the freeway encompassed by Site 5 would be dependent on engineering feasibility studies.

All experts ranked Site 1, Temecula Creek Bridge, as one of the top three crossing point locations; however, eight of the nine experts ranked this site as second or third priority, with only one expert ranking it as the highest priority location. Experts pointed to the fact that this site currently has the highest existing potential for wildlife movement, but has significant challenges to its proper function due to road noise and human presence. They felt that road noise and human disturbances could be sufficiently mitigated to increase this location's functionality for species such as mountain lions and deer. Recommended improvements include substantial reduction of sound and light pollution from traffic crossing the bridge, removal of lighting at the pump station on the west side of the bridge, prohibition of human presence under the bridge and in the creek bed at night, prohibition of further human development and nighttime activity on the Temecula Creek golf course and near the confluence of Temecula and Murrieta creeks and the Santa Margarita River on the west side of the bridge. In addition, experts agreed that increased native vegetative cover should be established on the golf course to promote the use of the site by deer and other wildlife. Even if the proposed residential development moves forward, the experts felt that this crossing could still function for medium-sized carnivores, smaller wildlife and plants, but its function for mountain lions and mule deer would be further degraded.

Site 4 ranked third overall in the cumulative Landscape and Experts' score; however, like Site 5, making this crossing site functional would necessitate construction of a new structure. The experts were equally divided on whether the crossing structure for this location should be an overpass or an underpass.

Site 3, previously suggested by some county staff and wildlife agency personnel as a possible location for an underpass to accommodate mountain lions and medium-sized carnivores, ranked fourth overall, and was a second or third priority for four of the nine experts.

Sites 2, 6, and 7 ranked similarly low in the expert scoring, each only receiving one vote as a first, second or third priority, though site 7 ranked fifth overall due to the occurrence of two puma roadkills at that location, confirming as at some other sites that pumas would potentially use a crossing if constructed at that location.

Sites 8a, 8b, 9, and 10 did not receive any support from the experts, although 8a and 8b both had puma roadkill occur very near their locations. Due to the lack of support from the experts, the cumulative score for each of these crossing points were very low.

Discussion – Santa Ana to Palomar Mountains Interstate 15 Linkage

Overall, when combined, the Expert and Landscape scores for the Santa Ana to Palomar Mountains I-15 Linkage support Site 5 as the highest priority location for the placement of a ***new wildlife crossing structure***.

However, Site 1, Temecula Creek Bridge, received the second highest Landscape Score ***in its current state*** based on existing landscape structure and evidence of use by many species including those requiring water for connectivity, and it placed second in overall scoring. It was also recognized as the only site of the 11 evaluated that currently functions for any significant wildlife movement, and that function is threatened by a development proposal recently approved by the City of Temecula. It was also the site that the experts felt had the most economic viability with regards to near term improvement.

Sites 4 and 3 were the next highest ranked crossing sites, but like Site 5, both ***would require construction of a new crossing structure*** (either over or under crossing) to become viable wildlife crossings. It is notable that sites 3, 4, and 5 all lie within a short (~0.3 mi) section of I-15 and have similar vegetation structure on either side of the freeway, and similar large-scale connectivity potential. Because landscape structure does not favor one over the other enough to rule either of the others out, if funding for a new structure becomes feasible, the ultimate choice between these three may rest most strongly on engineering factors and whether the land is conserved where any new crossing structure would have its end points.

The expert consensus was that ***more than one structure should be constructed or enhanced*** to provide the best potential for improved connectivity for a variety of wildlife species. Relying on only one highway crossing structure to provide adequate connectivity, especially for a wide range of species, between two entire mountain ranges, was regarded by the experts as risky and likely to fail. Thus, ***retention and enhancement of function of the Temecula Bridge is indicated even if a new wildlife structure may someday be built at Site 3, 4, or 5.***

Additional measures recommended by the experts for any new or improved wildlife crossing structures include: 1) wildlife fencing along both sides of I-15 to help funnel wildlife to the crossing structures (Huijser et al. 2016), 2) habitat modification of dense chaparral slopes on either side of the roadway, such as the construction of wildlife trails, to facilitate wildlife movement through the habitat to a new or improved structure, and 3) construction of an additional wildlife crossing structure across Rainbow Canyon Road, a busy secondary road to the east of I-15.

The crossing point rankings and the recommendation for more than one crossing structure are consistent with the findings of local experts who have evaluated crossing options over the last 25 years. In the last five years, local agencies and experts have prioritized a wildlife undercrossing structure at Site 3, and a wildlife overpass at Site 5. Although a wildlife overpass is viewed by local experts as the best option to serve the widest variety of species, local government agencies have generally expressed greater interest in an undercrossing due to a lower perceived expense. However, relative expense levels have not yet been determined via engineering studies, and we urge that such studies be done in order that informed decisions may be made on this question.

Santa Monica to Sierra Madre Mountains Linkage: Assessments of Crossing Points for the 101 Freeway

Santa Monica Mountains National Recreation Area (SMMNRA) is the largest urban national park in the country. Its 150,000 acres of mountains and coastline in Los Angeles and Ventura counties are a network of local, state, and federal parks interspersed with private lands and communities. SMMNRA is part of a globally rare Mediterranean ecosystem that is exceptionally biodiverse, with more than 450 animal species and 84 distinct plant alliances.

The Santa Monica Mountains, which run east-west to the north of Malibu, to the west of the Los Angeles Basin, and to the south of the San Fernando and Conejo Valleys, are substantially cut off from other large natural areas to the north by the 101 Freeway. This freeway is 8-10 lanes and receives very heavy traffic: it is one of the busiest freeways in the world, and in fact the 101-405 Freeway interchange (about 19 kilometers, or 12 miles to the East of the study area) is the second most trafficked in the entire country. As a national park in the Los Angeles area, at Santa Monica Mountains National Recreation Area the National Park Service has always been interested in and concerned about the effects of urbanization and habitat fragmentation on natural resources, including wildlife populations, particularly for wide-ranging species such as mammalian carnivores.

For more than two decades, the park, along with other partner agencies in the region such as the Santa Monica Mountains Conservancy and California State Parks, has been concerned about habitat connectivity between the Santa Monica Mountains and other remaining natural areas in the region. These and other agencies and groups have worked hard and spent millions of dollars in land acquisition money to strategically acquire and conserve land near the 101 Freeway, especially in the Liberty Canyon area in Agoura Hills. It was easy to see from the beginning of these efforts, and it is easy to see on any current map of the region, that the Agoura Hills-Calabasas grade area, specifically from Palo Comado Canyon Rd. to Mureau Rd., is one of the last areas where wildlife connectivity would be possible across the 101 Freeway (Figure 3). This area is one of the few remaining places along the Freeway where there is natural habitat adjacent to it on both sides. Planners did not consider the connectivity needs of wildlife when it was built in this area in 1949, or in the ensuing decades, and thus there is urban development along the 101 Freeway throughout the San Fernando and Conejo Valleys. The one other place in the Santa Monica Mountains where there is remaining natural habitat on both sides of the road is in the Conejo Grade area, just east of Camarillo. This area is less desirable for a wildlife crossing primarily because north of the Freeway, connectivity to other large natural areas is seriously compromised by roads and development. This area is also at the far western end of the Santa Monica Mountains, making it less accessible to as many animals as areas in the middle of the Mountains. However, two sub-adult mountain lions did cross the 101 Freeway in the Conejo Grade area in 2015 (National Park Service, unpublished data). Multiple crossings and connectivity in multiple areas are both generally desirable, so creating a safe wildlife crossing in this area in the future would be optimal.

The consensus maps developed as part of the South Coast Wildlands Linkage Design show the 101 Freeway crossing near the Agoura Hills-Calabasas grade area as the best location for providing connectivity for multiple species (Penrod et al. 2006). Starting in 2011, multiple agencies in the region formed the Linkage Implementation Alliance (LIA) to develop and coordinate efforts to turn the linkage maps into conservation reality through land acquisition, easements, education, etc. This group continues to meet quarterly.

In 1996, the park began studies of mammalian carnivores, specifically bobcats and coyotes and later (in 2002) mountain lions as well, to better understand wildlife movement in the area and the effects of the major barrier of the 101 Freeway. These studies have found that while carnivores can and sometimes do use developed areas, they largely use remaining natural areas, subsist on natural foods, and are subject to regular mortality from anthropogenic sources such as vehicles and toxicants (Riley et al. 2003, Riley et al. 2007, Riley et al. 2010, Gehrt and Riley 2010, Beier et al. 2010). The 101 Freeway was found to be a major barrier to movement for all three species, and in fact was also found to be a barrier to gene flow, such that significant genetic differentiation was present across it (Riley et al. 2006, Riley et al. 2014, Serieys et al. 2015). For mountain lions, the barrier effects of 101, along with other freeways in the region such as 405 and 5, are particularly severe. Genetic diversity for Santa Monica mountain lions is very low (Riley et al. 2014), lower than has been measured anywhere else in the west and like that in the isolated Santa Ana Mountains population (Ernest et al. 2014). The barrier effects of the freeway are also likely contributing to close inbreeding between relatives (e.g., fathers and daughters) and potentially to increased mortality from intraspecific strife (adult males killing subadult males and females, and even an adult female) because of the severely restricted dispersal of subadults out of the Santa Monicas (Riley et al. 2014). A recent population viability model incorporating both demographic and genetic factors predicted a continued steep decline in genetic diversity, leading to likely quick extinction once inbreeding depression compounds the effects of the already small population (Benson et al. 2016). The model found that even modest increases in immigration greatly ameliorated both demographic and genetic problems. Finally, research on smaller, less mobile species has also documented the genetic effects of roads and urban development. Specifically, significant genetic differentiation related to habitat fragmentation was found for three different lizard species, western fence lizards, side-blotched lizards, and western skinks, as well as for a common chaparral bird, wrentits (Delaney et al. 2010).

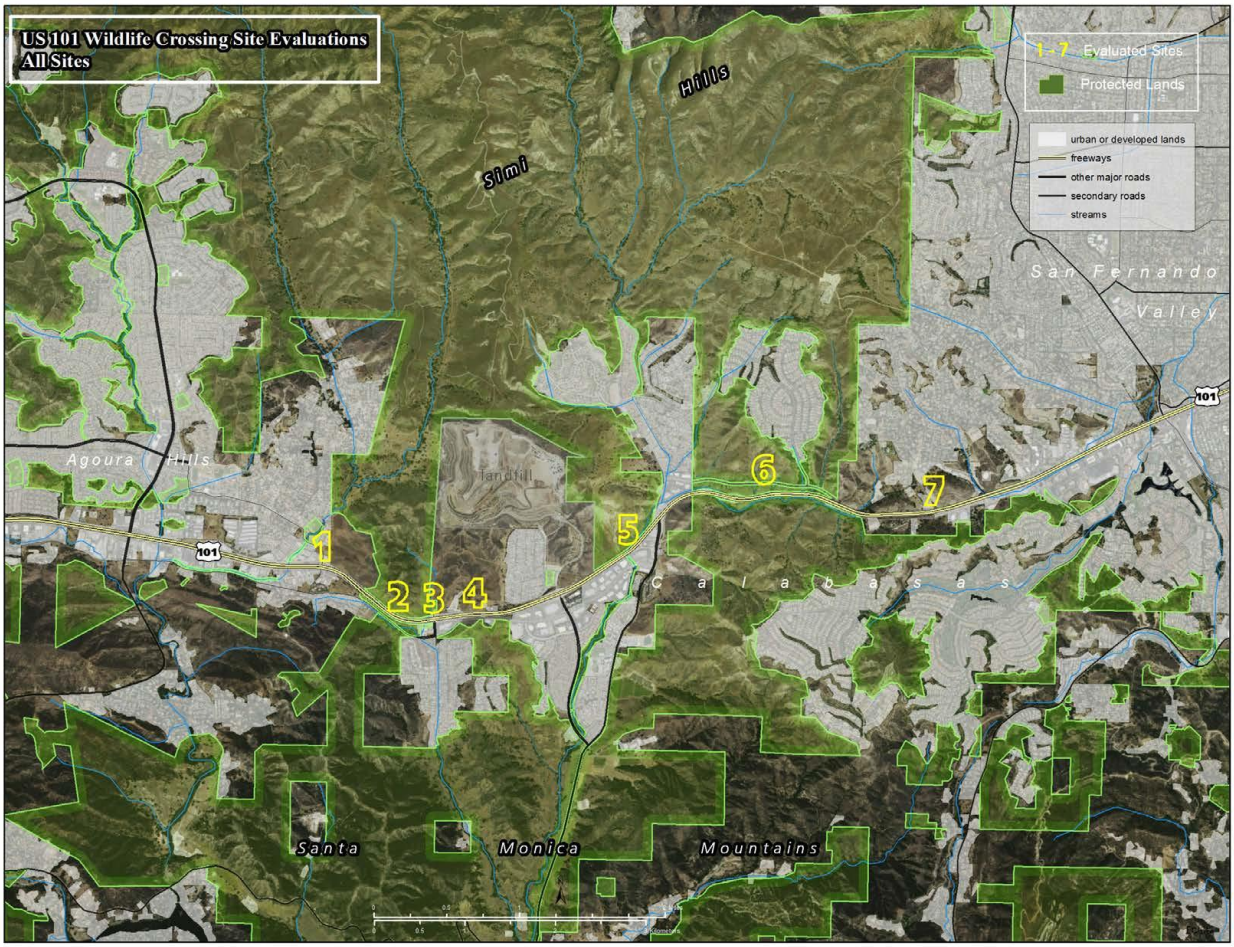
Overall, the mandate of the National Park Service, and the goal of the other open space agencies in the region, is to preserve the natural populations and communities present in the Santa Monica Mountains and the surrounding region as much as possible. The 101 Freeway, and the massive interruption in connectivity that it represents, is a significant impediment to this goal. Connectivity between natural areas is critical for all components of the natural communities, especially for wide-ranging species such as mountain lions or mule deer, but for all species of plants and animals as well. Over the long-term, we cannot hope to have naturally functioning ecosystems without increasing the effective connections between the Santa Monica Mountains and other natural areas to the north. Therefore, it has been a high priority to establish more connectivity across the 101 freeway for wild populations, particularly for wide-ranging animal species. Multiple agencies in the region, including the National Park Service, Caltrans, SMMC/MRCA, California State Parks, and others have been working towards this goal for more than two decades.

Specifically, for this workshop, the goal was to bring in experts who had experience with wildlife connectivity and road challenges around the country and the world, and to obtain their input on our situation here with the 101 Freeway and connecting the Santa Monicas to other protected areas to the north. In this report, the goal was also to integrate landscape information and current wildlife knowledge with the expert opinion to provide the fullest picture of the challenges and potential solutions.

Crossing Point Assessments – Santa Monica to Sierra Madre Mountains 101 Freeway Linkage

A total of seven potential wildlife crossing points along a 9.5-kilometer (5.9-mile) stretch of the 101 Freeway in the Agoura Hills-Calabasas area were evaluated as part of this analysis (Figure 5). A brief description of each of these potential crossing points is presented below.

Figure 5. Seven potential wildlife crossing points along a 9.5 km (5.9 mile) stretch of the 101 Freeway in the Agoura Hills-Calabasas area of the Santa Monica to Sierra Madre Mountains Linkage.



Appendix B provides more detailed information about each crossing location, including: 1) a summary of existing conditions related to habitat, conservation status, documented wildlife use, threats, and existing crossing structures, if present; 2) Landscape Scores for the location based on existing data related to landscape conservation status and wildlife use, particularly for mountain lions, and 3) Expert Scores based on their rankings of the crossing locations.

Brief Crossing Point Site Descriptions and Scoring Results – Santa Monica to Sierra Madre Mountains 101 Freeway Linkage

Site 1: Palo Comado Canyon Road Bridge. This farthest west site is a bridge for a two-lane paved road that receives moderate vehicle use, including entering and exiting freeway traffic. The bridge is immediately adjacent to residential development on both sides, although at the broader scale there is protected open space in three of four directions. The site received a Landscape score of 1.25 (6th) and a 0 from the experts, for a total score of 1.25 out of 10 (sixth overall).

Site 2: West Liberty Canyon. This site is just west of Liberty Canyon. It has natural vegetation on both sides, connects to protected open space both immediately adjacent to and farther away from the crossing location, and has extensive known use by wildlife including mountain lions and other carnivores. This was by far the best site, based on both Landscape scores (5) and Expert evaluation (5): it received a 10 out of 10 overall, while no other site had a landscape score above 3.33 or an overall score above 5.

Site 3: Liberty Canyon Road. This is the road underpass where Liberty Canyon Road passes under the freeway. It is well connected to open space on the north side, and broadly to the south, with known wildlife use. However, there is commercial development immediately adjacent on the south side, and the underpass itself is unvegetated and open with regular traffic entering and exiting the freeway. There was some underpass use by wildlife in a study from 1999-2000, but recent monitoring has found very little, despite extensive use of nearby areas by all species, including mountain lions. The overall score was 3.70, fourth out of seven.

Site 4: Agoura Road Pass. This site is east of Liberty Canyon, where there are hills rising above the freeway on both sides which could assist with overpass construction, and a mountain lion was killed on the freeway here. However, the land is not protected immediately to the north or south, and the broader connectivity is poor to the south. This site received a Landscape score of 3 (4th of 7), but was given no priority by the experts, for an overall score of 3.

Site 5: Las Virgenes Creek. This site is where Las Virgenes Creek goes under the freeway. It is a nice wide, natural underpass, with some documented use by wildlife including deer. Although it is well connected to natural and protected areas to the north, to the south the creek passes through intensive residential and commercial development for a long stretch before it connects with natural protected lands. This was the third highest ranked site for the experts, second in Landscape Score, and third overall (4.76 out of 10).

Site 6: Mureau Road Tunnels. This site includes multiple culverts for water passage in the vicinity of Mureau Rd (north of the freeway). The site is well connected and protected immediately adjacent to the crossing points, but at a broader scale there is development in some directions on both sides. There is also generally standing water on the south side of the culverts, decreasing their effectiveness. The experts felt this site had some potential (ranking second, with 1.95 out of 5), and it was second in Landscape Score at 3.08, ranking second overall (4.98 out of 10).

Site 7: Mureau Road Bridge. This is the farthest east site, another road bridge over the freeway where Mureau Road crosses it. It is one lane each way with a sidewalk on the east side and regular traffic between Hidden Hills and Agoura Hills to the north and Calabasas to the south. It is not well-connected

on either side at the fine or the broad scale, although there is some land protection to the southwest. This was the lowest ranked site by every measure, with a 0.75 out of 10 overall score.

Summary of Results – Santa Monica to Sierra Madre Mountains 101 Freeway Linkage

Overall, the results of the crossing point assessment for the 101 Freeway were very clear in terms of the best location for a new crossing structure, with the same conclusion coming from both the Expert and the Landscape Score assessments: West Liberty Canyon is the best location for a new wildlife crossing structure. As noted in the site descriptions and as is clear from Tables 4 and 5, on both sides this site has protected, natural habitat both adjacent to the freeway and farther away, and it has had known use nearby by multiple wildlife species including mountain lions and other carnivores. This site scored 5 out of 5 on the Landscape Score assessment, and was the unanimous top choice among the seven sites for the experts.

The Mureau Road culverts, Las Virgenes Creek, and Liberty Canyon Road all scored between 3.7 and 4.98 overall, reflecting some potential, but all were far behind West Liberty Canyon because of various problems. Liberty Canyon Road is an active road with traffic coming on and off the freeway, and it is completely open and unvegetated underneath the bridge. It also has development immediately adjacent to the road on the south side, both to the southeast and southwest. Recent monitoring with remote cameras has documented no confirmed crossings by wildlife in two years (through April 2017), despite detections of many species, including mountain lions, immediately adjacent to it (National Park Service, unpublished data). Las Virgenes Creek has a natural, vegetated crossing under the freeway and good direct connections to open space immediately on the north side, but to the south there is a long stretch of thin riparian vegetation through intense urban development (Fig. 5). The Mureau Road Culverts are across a major secondary road, Mureau Road, from large areas of open space, and many of them are small, dark, and have bends, so the other side is not visible. Of the two tunnels that do have line of sight all the way across, one has a large pool of standing water on the south side which would seriously impede use from either direction. All of these locations could have some value as redundant sites, especially with improvements (see below), but again, all are far inferior to the West Liberty Canyon site.

Table 4. Expert scores by crossing point for the Santa Monica to Sierra Madre 101 Freeway Linkage

Expert (Note: Expert Kathy Zeller was not able to visit this linkage)	**Expert Scores by Site**						
	Site 1 PC Canyon Road Bridge	**Site 2** West Liberty Canyon	**Site 3** Liberty Canyon Road	**Site 4** Agoura Road Pass	**Site 5** Las Virgenes Creek	**Site 6** Mureau Road Tunnels	**Site 7** Mureau Road Bridge
Paul Beier		3			1	2	
Patty Cramer		3			2		
Patrick Huber		3			2		
Julia Kintsch		3	2			1	
Tony Clevenger		3	2			1	
Winston Vickers		3				2	
Trish Smith		3			1	2	
Cumulative scores unweighted	0	21	4	0	6	8	0
Cumulative scores normalized to scale of 0-5	**0**	**5.0**	**0.95**	**0**	**1.43**	**1.90**	**0**

Table 5. Landscape and Combined Expert-Landscape scores by crossing point in the Santa Monica to Sierra Madre Mountains 101 Freeway Linkage

	Site 1 PC Canyon Road Bridge	**Site 2** West Liberty Canyon	**Site 3** Liberty Canyon Road	**Site 4** Agoura Road Pass	**Site 5** Las Virgenes Creek	**Site 6** Mureau Road Tunnels	**Site 7** Mureau Road Bridge
1. Evidence of mountain lion or other wildlife use	0	1	1	1	0.33	0.33	0
2. Landscape pattern - broad scale	0	1	0.50	0.75	1	0.75	0
3. Landscape pattern - fine scale	0.50	1	0.75	0.50	0.50	0.50	0
4. Land securement - broad scale	0	1	0.25	0.50	1	1	0.50
5. Land securement - fine scale	0.75	1	0.25	0.25	0.50	0.50	0.25
Total landscape scores (0-5)	**1.25**	**5.0**	**2.75**	**3.00**	**3.33**	**3.08**	**0.75**
Total score (expert plus landscape, 0-10)	**1.25**	**10.0**	**3.70**	**3.00**	**4.76**	**4.98**	**0.75**
Overall rank	**6**	**1**	**4**	**5**	**3**	**2**	**7**

Discussion - Santa Monica to Sierra Madre Mountains 101 Freeway Linkage

In terms of what kind of structure would be best, the consensus of the experts was that an overpass, over both 101 and Agoura Rd., at the West Liberty Canyon site would be the best solution for the most number of taxa. The experts agreed that an overpass just over the Freeway, which based on the site characteristics would need to end right next to Agoura Rd, would not be desirable because it would endanger animals coming off the structure, they would not be delivered across the road to nearby natural habitat, and it would be a bad precedent and perception both for this and future projects. Given the quality of the site, the next most effective solution would be a tunnel also at the Liberty Canyon West Site, although the tunnel also would not convey animals across Agoura Rd, south of 101. A tunnel, regardless of size, would also not be as effective for smaller species such as small mammals, reptiles, and amphibians. Both an overpass and a large tunnel were considered to likely be functional for all the medium and large mammals considered, including mountain lions and deer, although a tunnel large enough for deer under a freeway that wide (10 lanes of pavement) would pose serious engineering and traffic challenges, and therefore come at great monetary and social and political cost.

In the long run, multiple crossing structures should be available for a wide range of species to effectively cross the 101 Freeway between the Santa Monica Mountains and areas to the north. In terms of other sites, the existing Las Virgenes Creek underpass was thought to be functional for some species, including deer, smaller vertebrates, and aquatic species such as amphibians, since it has permanent water. However, though the area north of the freeway is natural and protected, connectivity south of the freeway is limited by the thin vegetated corridor that is surrounded by development for several hundred meters. In the past, the presence of invasive aquatic species, specifically crayfish, made this crossing less ideal for native aquatic species, although recent extensive efforts to remove crayfish in Las Virgenes Creek have reduced this concern. The second-best site in terms of expert opinion and total score was the Mureau Road Tunnels. This site is well connected to protected natural habitat near the Freeway, has some connectivity farther away, and has existing tunnels that could be improved. Although these tunnels are long and relatively small, they could be valuable for carnivores, and could serve to augment an overpass at West Liberty Canyon. A disadvantage here is that Mureau Road separates the crossing area from the open space to the north, so animals would have to cross four lanes of pavement and a median. This would be a significant barrier for many smaller species, and a potential mortality source for larger ones. Experts agreed that wildlife fencing should also be constructed in association with any new or improved structures to help funnel wildlife to the crossings (Huijser et al. 2016).

4. OVERALL CONCLUSIONS

Both the Santa Ana to Palomar Mountains and the Santa Monica to Sierra Madre Mountains Linkages in southern California have been a focus of regional wildlife research and conservation planning efforts for over 25 years. These two linkages are widely recognized as critical for maintaining biodiversity in the two largest coastal southern California mountain ranges, and both these linkages represent the last local opportunity for securing connectivity with larger intact natural lands.

For both linkages, the expert consensus was that, to maximize connectivity for multiple wildlife species, a diversity of crossing structures should be enhanced or constructed. While wildlife overpasses would likely serve the broadest suite of species, experts also pointed to the opportunities provided by enhancing existing creek crossings. Temecula Creek in the Santa Ana Mountains and Las Virgenes Creek in the Santa Monica Mountains might provide the best and most economical option for improving

connectivity for smaller mammals, amphibians, and fish. These are the only potential aquatic crossings for either the I-15 or 101 Freeways; however, both Temecula and Las Virgenes Creeks have urban edge issues of noise, exotic species, light, and human activity that would require mitigation and long-term management.

In addition to wildlife fencing to funnel wildlife to the crossing structures, some form of habitat modification would benefit both linkages. For the I-15 linkage, which has dense chaparral on both sides of the freeway, it was recommended that wildlife trails be constructed through the chaparral to attract carnivores and deer to the crossing structures. For the 101 Freeway, the restoration of coastal sage scrub in areas currently dominated by non-native grassland would provide needed cover for wildlife approaching the crossing, such as on the north side at the West Liberty Canyon site.

Participants also stressed that secondary roads that run parallel to both freeways – such as Rainbow Canyon Road in the I-15 Linkage and Agoura Road in the 101 Freeway Linkage - can be problematic for wildlife and that both linkages need to incorporate crossing structures for these secondary roads.

The authors recognize that assuring adequate connectivity for wildlife in these two areas will require significant public investment and political will, particularly because of significant costs associated with crossing structure construction and land protection. We hope that the results of this workshop will help guide all parties to a consensus opinion relating to crossing improvements, which can then allow progress towards improving wildlife connectivity at both critical locations.

5. ACKNOWLEDGEMENTS

The authors would like to thank all who participated in the workshop and who provided feedback during the preparation of this report. Specifically, we would like to thank The National Park Service, The Nature Conservancy, and Vicki Long for providing financial support for the workshop.

6. REFERENCES

Beier, Paul, and R. Barrett. "The cougar in the Santa Ana Mountain Range, California. Final report. Orange County Cooperative Mountain Lion Study, Department of Forestry and Resource Management." *University of California, Berkeley, USA* (1993).

Beier, Paul, and B. Brost. "Use of land facets to plan for climate change: conserving the arenas, not the actors." *Conservation Biology* 24, no. 3 (2010): 701-710.

Beier, Paul, K. Penrod, C. Luke, W. Spencer, and C. Cabañero. "South Coast Missing Linkages: Restoring Connectivity to Wildlands in the Largest Metropolitan Area in the USA." *Connectivity Conservation*: 555-86.

Benson, John F., P. Mahoney, J. Sikich, L. Serieys, J. Pollinger, H. Ernest, and S. Riley. "Interactions between demography, genetics, and landscape connectivity increase extinction probability for a small population of large carnivores in a major metropolitan area." In *Proc. R. Soc. B*, vol. 283, no. 1837, p. 20160957. The Royal Society, 2016.

California Dept. of Finance. 2016. New State Population Report: California Grew by 348,000 Residents in 2015. Press Release. Available: http://www.dof.ca.gov/Forecasting/Demographics/Estimates/E-1/documents/E-1_2016PressRelease.pdf

Clevenger, Anthony P., and M. Huijser. *Wildlife crossing structure handbook: design and evaluation in North America*. No. FHWA-CFL/TD-11-003. 2011.

Clevenger, A.P., and N. Waltho. Performance indices to identify attributes of highway crossing structures facilitating movement of large mammals. Biological Conservation, 121:453-464. (2005)

Delaney, Kathleen S., S. Riley, and R. Fisher. "A Rapid, Strong, and Convergent Genetic Response to Urban Habitat Fragmentation in Four Divergent and Widespread Vertebrates." *PLoS ONE* 5, no. 9 (2010).

Ernest, Holly B., W. Vickers, S. Morrison, M. Buchalski, and W. Boyce. "Fractured Genetic Connectivity Threatens a Southern California Puma (Puma Concolor) Population." *PLoS ONE* 9, no. 10 (2014).

Fisher, Robert R., and K. Crooks. “Baseline biodiversity survey for the Tenaja corridor and southern Santa Ana Mountains. Final Report.” *U.S. Geological Survey, Sacramento, California*. 2001.

Gehrt, Stanley D., S. Riley, and B. Cypher. *Urban carnivores: ecology, conflict, and conservation*. John Hopkins University Press, 2010.

Gibbons, Philip. “Determining Suitable Wildlife Crossing Locations Across a Southern California Interstate. Final Masters’ Thesis. Department of Geography.” *San Diego State University, California, USA*. 2008.

Gustafson Kyle D., W. Vickers, W. Boyce, H. Ernest. 2017. A single migrant enhances the genetic diversity of an inbred puma population. R. Soc. open sci. 4: 170115.

Huijser, Marcel P., E. Fairbank, W. Camel-Means, J. Graham, V. Watson, P. Basting, and D. Becker. "Effectiveness of short sections of wildlife fencing and crossing structures along highways in reducing wildlife–vehicle collisions and providing safe crossing opportunities for large mammals." *Biological Conservation* 197 (2016): 61-68.

Kintsch, J. and P.C. Cramer. Permeability of existing structures for terrestrial wildlife: A passage assessment system. Research Report No. WA-RD 777.1. Washington State Department of Transportation, Olympia, WA. (2011).

Luke, Claudia, K. Penrod, C. Cabañero, P. Beier, W. Spencer, and S. Shapiro. "South coast missing linkages project: A linkage design for the Santa Ana—Palomar Mountains connection." *South Coast Wildlands* (2004).

Myers, Norman, R. Mittermeier, C. Mittermeier, G. da Fonseca, J. Kent. Biodiversity hotspots Biodiversity hotspots for conservation priorities. *Nature* 403:853–858. (2000).

Ng, Sandra J., J. Dole, R. Sauvajot, S. Riley, and T. Valone. "Use of highway undercrossings by wildlife in southern California." *Biological Conservation* 115 (2004):499-507.

Penrod, Kristeen L., R. Hunter, and M. Merrifield. "Missing linkages: restoring connectivity to the California landscape, conference proceedings." *Co-sponsored by the California Wilderness Coalition, The Nature Conservancy, US Geological Survey, Center for Reproduction of Endangered Species, and California State Parks* (2001).

Penrod, Kristeen L., C. Cabañero, P. Beier, C. Luke, W. Spencer, E. Rubin, R. Sauvajot, S. Riley, and D. Kamradt. "South coast missing linkages project: A linkage design for the Santa Monica–Sierra Madre Connection." *South Coast Wildlands and National Park Service* (2006).

Riley, Seth P.D., R. Sauvajot, T. Fuller, E. York, D. Kamradt, C. Bromley, and R. Wayne. "Effects of urbanization and habitat fragmentation on bobcats and coyotes in southern California." *Conservation Biology* 17, no. 2 (2003): 566-576.

Riley, Seth P.D., J. Pollinger, R. Sauvajot, E. York, C. Bromley, T. Fuller, and R. Wayne. "A Southern California Freeway Is a Physical and Social Barrier to Gene Flow in Carnivores." *Molecular Ecology* 15, no. 7 (2006): 1733-741.

Riley, Seth P.D., C. Bromley, R. Poppenga, F. Uzal, L. Whited, and R. Sauvajot. "Anticoagulant exposure and notoedric mange in bobcats and mountain lions in urban southern California." *Journal of Wildlife Management* 71, no. 6 (2007): 1874-1884.

Riley, Seth P.D., L. Serieys, J. Pollinger, J. Sikich, L. Dalbeck, R. Wayne, and H. Ernest. "Individual behaviors dominate the dynamics of an urban mountain lion population isolated by roads." *Current Biology* 24, no. 17 (2014): 1989-1994.

Serieys, Laurel E.K., A. Lea, J. Pollinger, S. Riley, and R. Wayne. "Disease and freeways drive genetic change in urban bobcat populations." *Evolutionary applications* 8, no. 1 (2015): 75-92.

South Coast Wildlands. "South Coast Missing Linkages: A wildland network for the south coast ecoregion." *Produced in cooperation with partners in the South Coast Missing linkages initiative. Available online: http://www. scwildlands. org. 67p* (2008).

Spencer, Wayne D., P. Beier, K. Penrod, K. Winters, C. Paulman, H. Rustigian-Romsos, J. Strittholt, M. Parisi, and A. Pettler. "California essential habitat connectivity project: a strategy for conserving a connected California." *Prepared for California Department of Transportation, California Department of Fish and Game, and Federal Highways Administration* (2010).

State of California, Department of Finance, *E-1 Population Estimates for Cities, Counties and the State with Annual Percent Change — January 1, 2016 and 2017.* Sacramento, California, May 2017.

Tracey, Jeff A., J. Zhu, and K. Crooks. 2011. "Modeling and inference of animal movement using artificial neural networks" *Environmental and ecological statistics* 18.3 (2011): 393-410.

Vickers, T. Winston, J. Sanchez, C. Johnson, S. Morrison, R. Botta, T. Smith, B. Cohen, P. Huber, H. Ernest, and W. Boyce. "Survival and mortality of pumas (Puma concolor) in a fragmented, urbanizing landscape." *PloS one* 10, no. 7 (2015): e0131490.

Wilmers, Christopher C., Y. Wang, B. Nickel, P. Houghtaling, Y. Shakeri, M. Allen, J. Kermish-Wells, V. Yovovich, and T. Williams. "Scale dependent behavioral responses to human development by a large predator, the puma." *PLoS One* 8, no. 4 (2013): e60590.

Zeller, Katherine A., K. McGarigal, P. Beier, S. Cushman, W. Vickers, and W. Boyce. "Sensitivity of landscape resistance estimates based on point selection functions to scale and behavioral state: pumas as a case study." *Landscape Ecology* 29, no. 3 (2014): 541-557.

Zeller, Katherine A., K. McGarigal, S. Cushman, P. Beier, W. Vickers, and W. Boyce. "Using step and path selection functions for estimating resistance to movement: pumas as a case study." *Landscape Ecology* (2015): 1-17.

Zeller, Katherine A., K. McGarigal, S. Cushman, P. Beier, W. Vickers, W. Boyce. "Sensitivity of resource selection and connectivity models to landscape definition." *Landscape Ecology.* DOI 10.1007/s10980-017-0489-8. (2017).

Zeller, Katherine A., W. Vickers, H. Ernest, W. Boyce. "Multi-level, multi-scale resource selection functions and resistance surfaces for conservation planning: Pumas as a case study. PLoS ONE 12(6): e0179570. https://doi.org/10.1371/journal.pone.0179570 (2017).