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Project Title: Santa Ana Mountains to eastern Peninsular Range Conservation Connectivity Infrastructure Planning Project for Interstate 15 and Closely Associated Roadways

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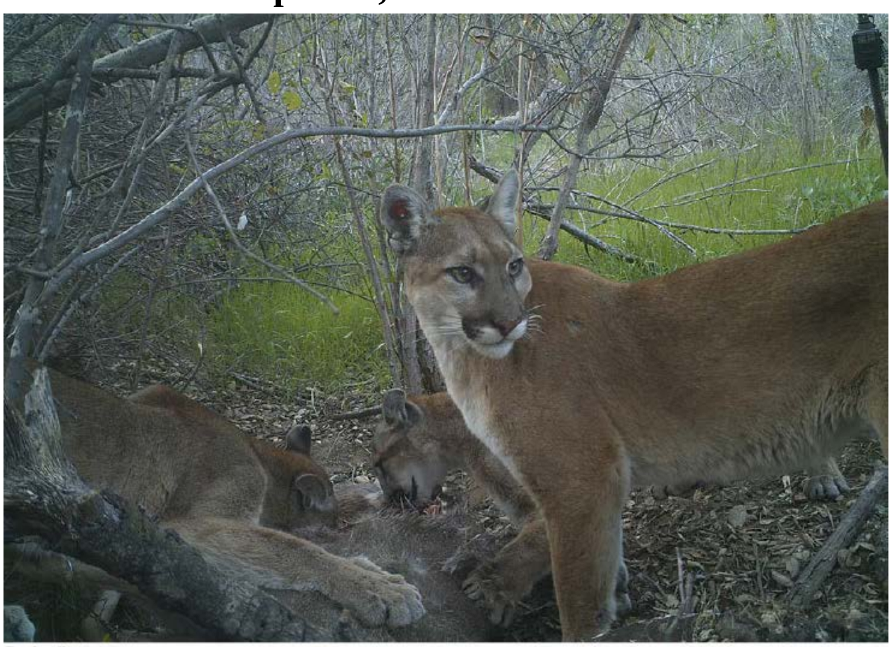


Female mountain lion F92 and female offspring F121 and F122 – daughter and granddaughters of M86 (Gustafson et al. 2017)

All are genetically important individuals for the Santa Anas mountain lion population, but illustrative of the inbreeding in the population there.

Table of Contents

List of Appendices

List of Tables and Figures

Tables:

Figures:

Pictures:

Acknowledgements

We would like to acknowledge our funders for this Project, the San Diego County Association of Governments and the Natural Communities Conservation Plan Local Assistance Grants program administered by the California Department of Fish and Wildlife. We would also like to thank our administrative staff at the UC Davis Karen C. Drayer Wildlife Health Center, and other UC Davis administrative staff, for their assistance in managing the funding grants. We would like to thank our collaborators in data analysis, Dr. Kathy Zeller, Dr. Justin Dellinger, for their willingness to share data and expertise, and Dr. Jessica Sanchez for her willingness to provide data analysis and graphical expertise. Finally we want to give a huge thanks to our field crew, Jamie Bourdon and Rich Codington, for the hard work and long hours spent documenting conditions on the ground at potential crossing sites that were evaluated, as well as placing and monitoring cameras and maintaining databases. We also thank the people at Wildnote, Inc.©, who helped us set up and use their software to document all of our site evaluations and without whose software this project would have been immensely more difficult.

Executive summary

Highways across the southern California region are major barriers and sources of mortality for mountain lions *(Puma concolor;* puma, cougar*)*, and are contributing in a major way to genetic restriction and the threat of extirpation for the Santa Ana Mountains puma population. Due to their large territories, mountain lions must regularly cross highways in this region, or be turned back by them thus suffering barrier effects. These barrier effects, especially those exerted by Interstate 15 (I-15) and associated development have resulted in significant genetic restriction in the Santa Ana Mountains puma population. This genetic restriction combined with high mortality from vehicle collisions, depredation permits, and other causes has put that population at elevated risk of extirpation (Benson et al. 2019). This risk of extirpation of the Santa Anas population has driven a need to identify areas of key connectivity for mountain lions across the region, and to develop suggestions for highway agencies to mitigate the negative effects currently being exerted on the region's mountain lion population (and potentially other wildlife species) by highways.

Mountain lion research has been conducted by researchers from UCD in southern California since 2001. The lead researcher and director of UCD mountain lion research in southern California is Dr. Winston Vickers, and he is the overall lead on this project team. Trish Smith and Brian Cohen are the

primary collaborators at The Nature Conservancy. Three faculty from the California Polytechnic University - Pomona Civil Engineering Department - Chair Xudong Jia, and faculty members Wen Cheng, and Lourdes Abellara, and three senior student teams completed the engineering portion of the project that focused on I-15. The combined UCD, CPP, and TNC collaborators are hereafter referred to as the Project Team in this report.

The title of this Project is “Santa Ana Mountains to eastern Peninsular Range Conservation Connectivity Infrastructure Planning Project for Interstate 15 and Closely Associated Roadways” (funded through this Agreement by the Natural Community Conservation Planning (NCCP) Local Assistance Grant (LAG) Program) and has been conducted coincident with the Project titled “Mountain Lion Linkage Assessment along SR’s 76,78, and 79, and testing of Hazing Devices in Western San Diego County (funded by the San Diego County Association of Governments), and The Nature Conservancy (TNC). In-kind support was provided by San Diego State University’s Santa Margarita River Ecological Reserve (SMER), the Western Riverside County Regional Conservation Authority (RCA), and California Department of Transportation (Caltrans). The lead entity on the project was the Karen C. Drayer Wildlife Health Center at the University of California, Davis (UCD), with collaborators from the California Polytechnic University, Pomona (CPP) and TNC (collectively the Project Team).

The goal of this project was for the Project Team to help define a connectivity “roadmap” for mountain lions across the region by better characterizing the sections and specific sites along area highways where mountain lions are likely to approach for crossing, define where safe crossings can occur, where barrier effects are present, and to suggest mitigation measures where appropriate. The information developed can allow Caltrans, County highway agencies, regional conservation agencies, non-profit conservation groups, and State and Federal wildlife agencies to develop the most practical approaches to improving connectivity and reducing vehicle-wildlife collisions in key highway crossing areas. Engineering collaborators from CPP joined this project to provide input into feasibility of different proposed connectivity improvements such as directional fencing, culvert or bridge modifications, sound buffering concepts, and new crossing structure construction along I-15 especially.

In addition, collaborators from the UCD Road Ecology Center and the University of Southern California have added important information on the effects that sound and light from highways and development may be having on mountain lion crossing potential - especially along I-15. Further study of those effects is ongoing as part of wider Caltrans-funded studies by that group across California. All of the information developed by the Project Team will allow better prioritization of crossing locations and infrastructure modifications that should be considered as most likely to significantly contribute to mountain lion and other wildlife connectivity, and reduce wildlife-vehicle collisions and consequent risks to humans.

We report here on the examination and characterization of sections of Interstate 15 (I-15) and multiple regional highways in the area (SR's 76, 78, and 79, Rainbow Canyon Rd., Pala-Temecula Rd., Valley Center Rd., and old Hwy 395), as well as185 individual locations along those highways that were identified by previous published studies and recent unpublished data as having the highest potential for mountain lion approach and crossing attempts to occur. Sections of highway and these individual sites were characterized and scored based on multiple criteria in order to suggest which potential sections of highway or individual sites might be regarded as highest priority for improvements by highway agencies in the future.

Our analysis process involved grading and scoring of points generated via GIS at 100 meter intervals along the full length of each of the named roadways in the study area (n=4,378 points defining approximately 272 miles of roadway). Scoring was performed based on multiple parameters and data sources. These included two different measures of habitat quality, measures of mountain lion movement likelihood and actual activity from GPS collar data, where actual crossings or attempted crossings (roadkill sites) were known to have occurred, and percentage of conserved land within the vicinity of that point. Scoring was scaled at 100, 500, and 1,500 meter radii around each point. This allowed scoring of the entire length of the roadways that lay within the confines of the study areas, and not just the locations where likely crossing sites were pre-identified. This scoring process also allowed us to identify entire sections of roadway that had higher overall potential for mountain lion crossing attempts, and adds to information that may be used by highway agencies in the future to enhance connectivity for mountain lions and other wildlife across the region.

For the possible crossing sites that had been pre-identified, the scores from the nearest 100 meter point was combined with scoring of the infrastructure present (if any) at that site, and other characteristics of the site gleaned from on-the-ground examinations in order to give each site a total score for prioritization purposes. This allowed us to characterize the areas where adequate structures were present for crossing as well as potential problem areas where mitigation should be considered. Factoring in the levels of conservation of land in the vicinity of crossing sites also allowed us to pinpoint where further efforts in land conservation would be most indicated. All crossing structures along each highway were not examined due to the desire to focus on those areas indicated by our previous data and analyses to be the sites along roads that were most likely to be used for crossing. We also examined sites that had been identified by other reports and publications such as South Coast Missing Linkages (2008) that specified road crossing locations that are important for general wildlife connectivity in the region.

Previous analyses of 51 GPS collared mountain lions in the study area indicated that those individuals crossed the major highways over 1,500 times while their collars were active, and that 6 were struck by vehicles. Other mountain lions were also involved in vehicle collisions in the area during that same period. Our results in this study indicate that the majority of the known or most likely locations for crossing do not have adequate infrastructure (bridges or larger culverts) present to accommodate safe crossing, and where adequate infrastructure does exist, fencing to funnel animals to those structures was rarely present. Some sites were found to have adequately sized infrastructure but have constraints such as excessive sedimentation, erosion, vegetation overgrowth, or excessive human presence, thus some sites could be improved with maintenance measures or measures to reduce human trespass.

Of the 185 sites we examined, 64 were sites where known mountain lion crossings had occurred based on data from GPS-collared mountain lions and trail cameras, or were sites of mountain lion-vehicle collisions. Of the 64 sites where mountain lions were confirmed to have crossed or attempted to cross, only 16 sites had culverts or bridges suitable in size for mountain lion passage. We found that 33 bridges across the regional highway network were suitable for mountain lion use, but only 22 were at sites where known crossing had occurred or where there were high levels of mountain lion activity or movement based on our analyses. However, the other 11 bridges we examined would still be and likely to support the movement of deer and other wildlife, as well as mountain lions on a more occasional basis. Of the other sites examined that did not have bridges present, we found only 17 culverts that were both of adequate size to support mountain lion movement across the roads and also unconstrained by other factors such as erosion, overgrown vegetation, etc.

Our findings suggest overall that mountain lions commonly approach highways at locations where no suitable crossing structure is present and cross the highway at grade (or not at all in the case of I-15), putting the animals and human drivers at risk. Fencing to direct mountain lions and other wildlife to safe crossing sites where they exist can solve the roadkill issue and increase human safety as well. However we found that virtually none of the examined sites or sections of highway had fencing that was adequate to direct mountain lions to functional crossings, so fencing should be a high priority for certain high risk locations. It is notable that as this report is being completed as a new directional fencing project is beginning along the seven mile section of I-15 south of Temecula. This team has been in consultation with Caltrans on that project. Corrective measures could also be taken at certain sites we examined where infrastructure existed but its function constrained in some way. Taking steps such as cleaning out sediment, reducing brush around culvert entrances, and reducing driver speeds (and the resultant negative impacts of excess sound and light) could improve function of these structures.

Infrastructure construction or improvement could improve the situation across the region for long term mountain lion and other wildlife connectivity. However, infrastructure investment for wildlife connectivity is typically only justified if the land is conserved around the crossing site. Our study found that the percentage of land conservation in the immediate vicinity (within a 500 meter radius) of the highway crossing sites studied was only significant (over 50%) at 11% of the sites studied. This percentage of land conserved near the highways is substantially lower than the percentage of land conserved across the region in general. This lack of land conservation near the highways suggests that due to steady development of private lands, that connectivity where adequate infrastructure currently exists may diminish.

For I-15 specifically, our teams at UC Davis and The Nature Conservancy worked with teams of senior civil engineering students and three Civil Engineering faculty members from Cal Poly Pomona's College of Engineering to generate conceptual plans and preliminary cost estimates for specific infrastructure improvements along I-15 south of Temecula. Their project was titled "Safe Wildlife Crossings Design for the I-15 Freeway" is included in this report as Appendix G. This valuable work, combined with our just-described highway analyses and camera data, established that there are locations along I-15 south of Temecula where new crossing structure construction is feasible, and those locations coincide with areas of significant current mountain lion activity. Thus, any new crossing structures constructed at those locations would be expected to have use by mountain lions, and provide badly needed connectivity for the genetically restricted population in the Santa Ana Mountains. It is expected that this work will provide a framework for infrastructure projects in that area in the future that will enhance mountain lion connectivity between the Santa Ana and eastern Peninsular Mountain Ranges.

Collaborators from the UC Davis Road Ecology Center and the University of Southern California have also evaluated light and sound levels along certain sections of the highways studied, especially I-15, to help guide placement of new infrastructure or improvement of existing infrastructure – especially the Temecula Creek Bridge. Preliminary findings suggest that in Temecula Creek under the bridge structure that sound levels are as high as those measured standing right beside the freeway. This means that animals approaching that bridge in what otherwise is a good wildlife travel corridor will perceive high decibels of sound just as if they were approaching the freeway at highway level. This finding, combined with variable levels of human trespass under the bridge, reinforce the need to modify that crossing to reduce both factors that can turn wildlife away or reduce use. Additionally, light measurements from space along I-15 suggest that the area identified by this study and our CPP collaborators as most suitable for a new crossing structure (just north of the border check station) is also the area with lowest light levels by that measurement. Light measurements at freeway level and on approaches to that area are ongoing and will also inform placement and design of any new structure.

On balance, we have found that there are adequate structures present in enough locations to allow adequate connectivity for mountain lions across all the highways in the region except I-15 for now. This conclusion is supported by genetic evidence from our other studies and those of collaborators. However, risks to mountain lions from both direct mortality on roads and while crossing unconserved lands near roads will only increase over time in the absence of additional conservation effort and infrastructure like directional fencing or new culverts being put in place.

We feel that in the short to medium term I-15 should and will be the focus of any modifications or new construction that is outside other highway projects due to the immediacy of the threat to the Santa Anas mountain lions. However, we hope that the extensive information generated here can guide future conservation and highway modifications across the region as highway projects are planned and implemented that can make the highways safer for animals and people, and also enhance connectivity for mountain lions and other wildlife in the long run.

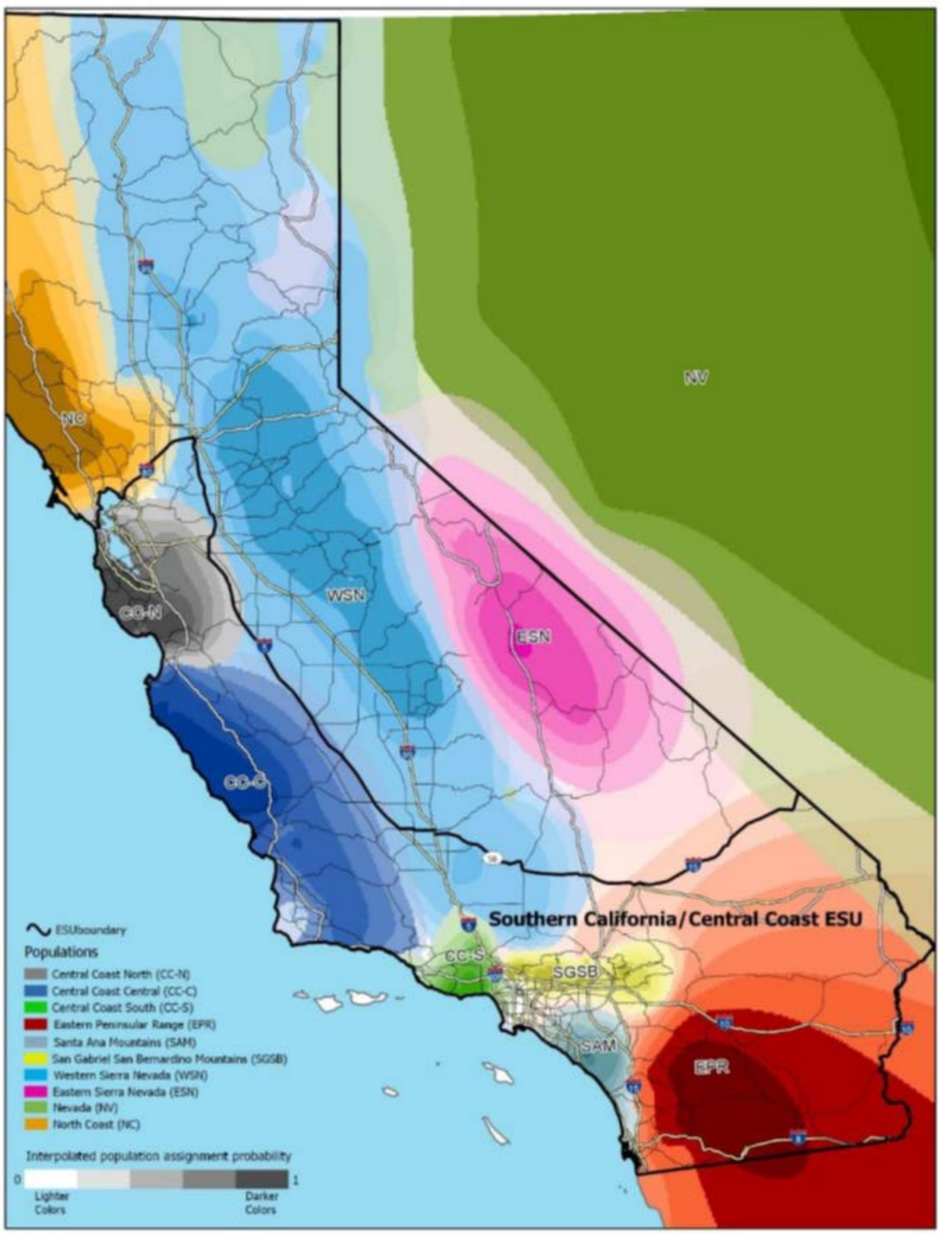
Introduction

Roads can cause significant mortality for wildlife, but large roads like freeways, major thoroughfares, and other busy highways can also form major barriers to wildlife movement and gene flow via development along the roadway due to inadequate land conservation, traffic, noise and light effects on approach to highway crossing structures, lack of crossing structures, and inadequate fencing to keep animals off the roadway and funnel them to crossing structures. Mountain lion populations in California have been shown to be divided into 10 distinct subpopulations (Gustafson et al. 2018; Map 1) with highways and human development appearing to be the major factors that separate most of the subpopulations from each other. This fragmentation of populations has resulted in six of the coastal subpopulations being petitioned for listing under the California Endangered Species Act as Threatened or Endangered (CESA Petition to the California Fish and Game Commission, 2019).

Highways are ubiquitous in Orange, Riverside, and San Diego Counties and are a significant source of mountain lion mortality (Vickers et al. 2015), but Interstate 15 (I-15) and associated development are especially notable as a barrier to the movement of mountain lions and other wildlife between the Santa Ana Mountain Range west of I-15 and the eastern Peninsular Range east of I-15. Gene flow restriction and high mortality threaten the mountain lion population west of I-15 with inbreeding depression and potential extirpation (Benson et al. 2019), and various busy highways and other sources of mortality threaten the mountain lion population east of I-15, itself isolated from other populations to the north, east, and south by I-10, the eastern deserts, and border security measures respectively (Gustafson et al. 2018).

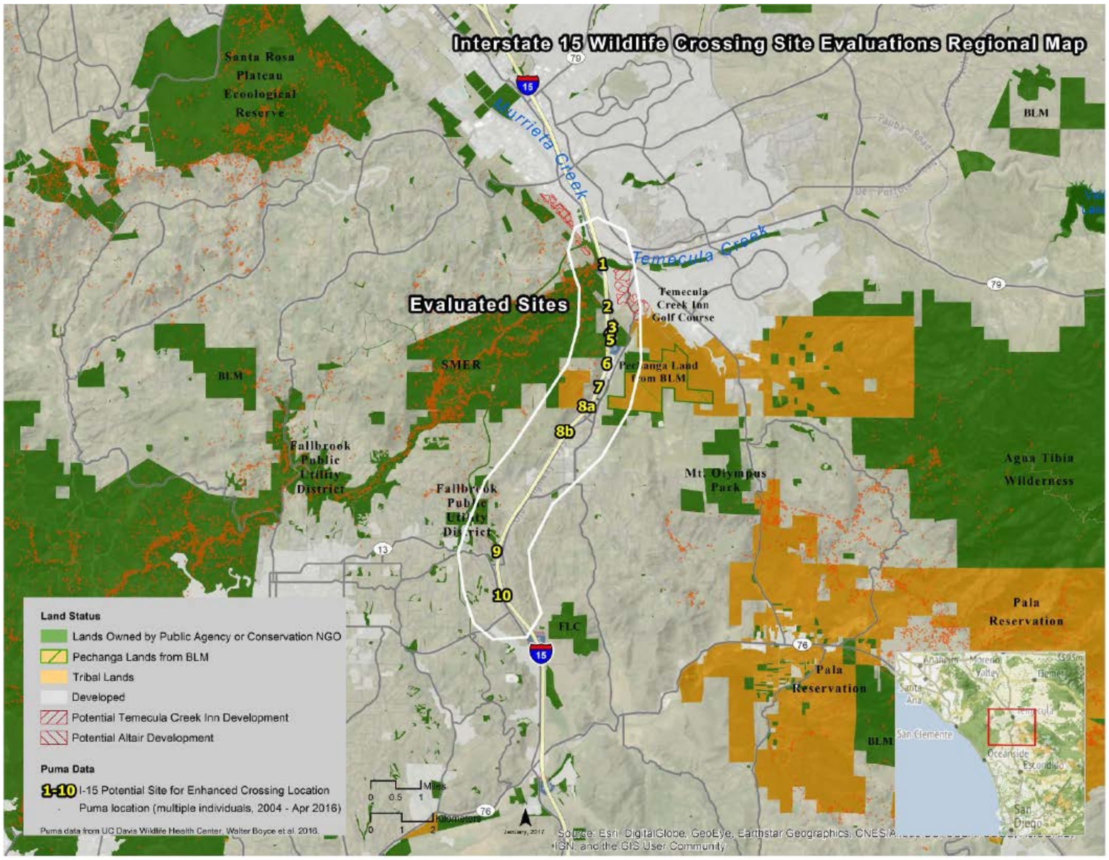
Recognizing the significance of I-15, especially the approximately 7 mile stretch south of Temecula as critical to mountain lion connectivity between the Santa Ana Range and the eastern Peninsular Range, our UC Davis mountain lion study team, The Nature Conservancy, and partners at the National Park Service convened a Connectivity Experts Workshop in 2015 to attempt to answer the question of how to enhance connectivity in that area (Maps 2, 3; Riley et al. 2018-Attached to this report as Appendix A).

Map 1. Map of genetically distinct mountain lion populations and major roadways in California based on data collected from 1992-2016 (the division and status of these populations could change over time and with further research). The black lines show the proposed Southern California/Central Coast ESU boundary. Derived from Gustafson et al. (2018). Genetics data source: Kyle Gustafson, PhD, Department of Biology and Environmental Health, Missouri Southern State University, and Holly Ernest, DVM, PhD, Department of Veterinary Sciences, Program in Ecology, University of Wyoming, Laramie. Roads data source: ESRI. Source "A Petition to List the Southern California/Central Coast Evolutionarily Significant Unit (ESU) of Mountain Lions as Threatened under the California Endangered Species Act (CESA)", Center for Biological Diversity and The Mountain Lion Foundation.



Map 2. Connectivity overview for southern California (Riley et al. 2018-Appendix A)

Map 3. Section of I-15 examined in Riley et al. 2018.



The experts were asked to evaluate this section of freeway where wildlife studies have indicated that some connectivity potential remains due to the presence of natural habitat on both sides of the interstate, but where new or enhanced structures are likely required to restore lost connectivity. In addition to expert opinion we also developed and implemented an evaluation tool based on landscape characteristics and wildlife data to further help prioritize locations for wildlife crossing infrastructure. Multiple specific sites were examined and both 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 and gene exchange for mountain lions and other wildlife. The experts also 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.

It is also expected that over time several larger local and state highways in the region that currently only partially impede movement of mountain lions, but are still sources of mortality, will become both busier and may likely undergo widening in order to accommodate growing human populations. This may result in other absolute barriers to movement of mountain lions and other wildlife unless proper planning assures that key highway crossing points identified are maintained and/or enhanced over time. As such it has been recognized by multiple agencies and stakeholders in the area that it is important to determine where the most important highway sections and crossing locations are for retention or improvement of connectivity for mountain lions and other wildlife.

The results of the I-15 workshop and additional subsequent analyses and modeling of mountain lion movement conducted by our project team for I-15 and other local and state highways in the region were augmented by additional field studies in 2018-2019, and the accumulated findings guided the initiation of this current project.

Project Tasks as defined in the funding grants were:

Task 1 (NCCP-LAG): Conduct wildlife crossing infrastructure assessments for the approximately 7-mile portion of I-15 in the SA-ePR linkage region south of and inclusive of Temecula Creek (study area).

Task 1 (SANDAG):

Conduct Highway Crossing Assessments and create Wildlife Crossing Improvement Plans for portions of I-15, SR's 76, 78, and 79, as well as other major highways in MU's 5,8,9, and 10 that have been identified by previous research as having high wildlife crossing potential

Task 2 (NCCP- LAG): Collaborate with Cal Poly Pomona engineering faculty and students, and other highway engineers, to assess feasibility of infrastructure changes being considered, prioritize the proposed changes, and develop conceptual design and placement specifications for any modifications.

Task 3 (NCCP-LAG): Coordinate and consult with stakeholders on findings and create maps and other tools to illustrate findings.

Picture 1. Uncollared mountain lion in Orange County crossing road on lands conserved by the Orange County Transportation Authority.

Photo courtesy Orange County Transportation Authority

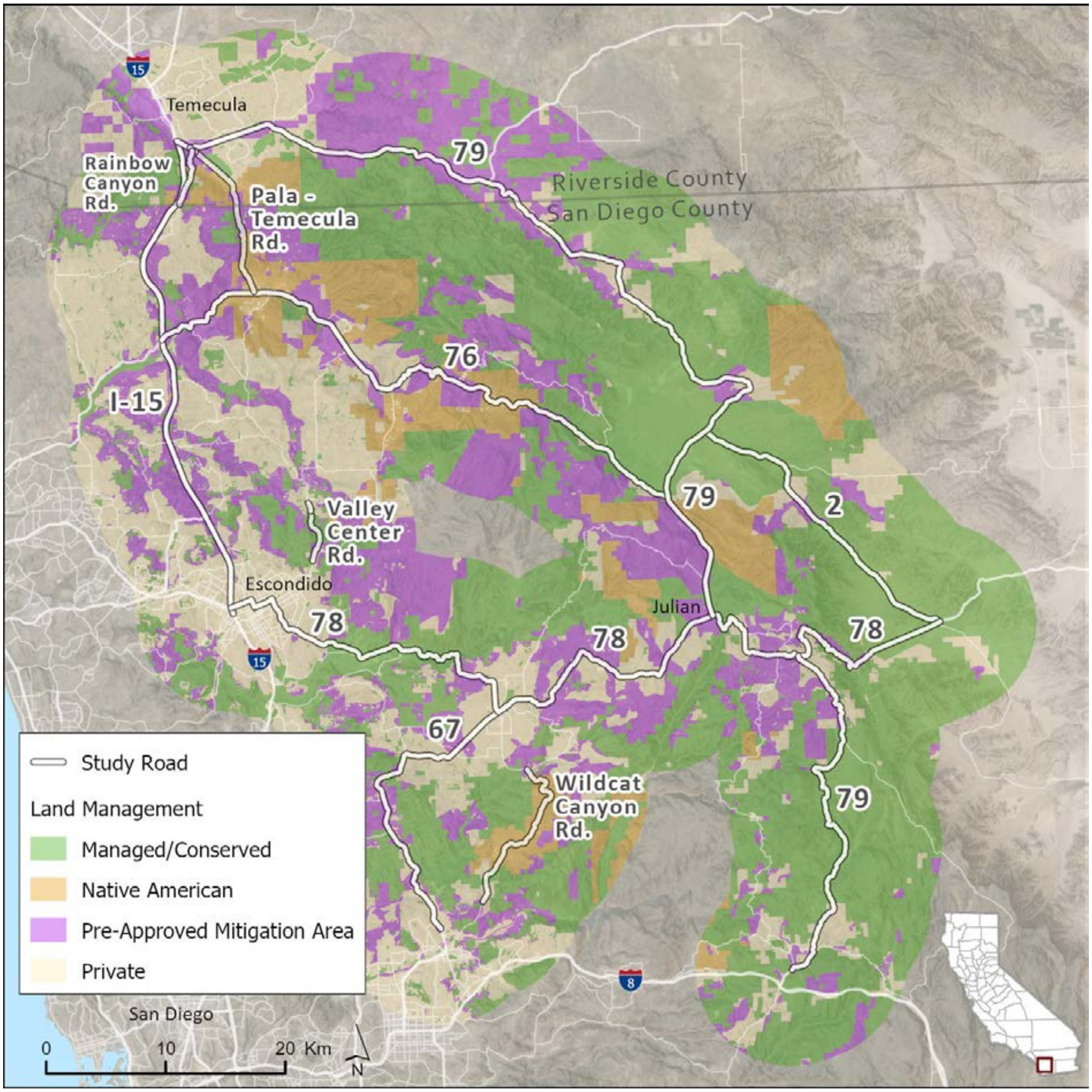
Methods:

Task 1 (NCCP-LAG and SANDAG:

Study Area and Data Sets Used

The U.C. Davis team's mountain lion study region includes San Diego, Riverside, and Orange Counties. The area of this project focused on the sections of highways in southwestern Riverside and northern San Diego Counties that are most likely to intersect mountain lion movement and migration pathways that were identified in detailed linkage assessments completed by South Coast Wildlands (South Coast Wildlands 2008), other wildlife movement studies and modelling efforts (Zeller et al. 2014, Zeller et al. 2015, Vickers et al. 2017, Zeller et al. 2017, 2018, and Huber unpublished data), as well as GPS collar and mortality data and previous crossing site evaluations (Vickers et al. 2015, Riley et al. 2018, W. Vickers and CDFW unpublished data, A. Collins and F. Shilling unpublished data; Map 4).

Map 4. Study area with Conserved, Native American, and Pre-Approved Mitigation Area lands (inclusive of Riverside County MSHCP lands – hereafter referred to collectively as PAMA lands), along with Private lands outside of PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Quantification of roadway characteristics important to mountain lion and other wildlife crossing:

In order to quantify characteristics that the Project Team felt were most pertinent to wildlife approaches to roadways, specific points were identified at 100 meter intervals along the examined roadways in the study area. This resulted in 4,378 total points along ~232 miles of the highways that were the focus of this study (I-15, SR's 79, 78, 76, Pala-Temecula Rd, Rainbow Canyon Rd.)

The Project Team, with assistance from Dr. Kathy Zeller and Dr. Justin Dellinger who had developed some of the models utilized in the analysis, developed a quantification system for important characteristics at each point that allowed comparison of the points with each other more effectively. Characteristics that were quantified within 100 meter, 500 meter, and 1,500 meter radii of each point included: 1) conservation status; 2) habitat suitability (from habitat modeling in Vickers et al. 2017- Attached to this report as Appendix B, Zeller et al. 2017,2018); 3) resource availability (from Dellinger et al. 2019); 4) mountain lion activity (from GPS collar data – calculated from lines of movement between datapoints, broken into 10 meter segments and quantified); and 5) movement likelihood (from movement modeling in Vickers et. al 2017-Appendix B and Zeller et al. 2017, 2018). Each point was given a numerical score for each component of the assessment at each scale and values were normalized or log transformed to a range of scores from 0 - 10 (Table 1). After initial data exploration it was decided by the Project Team to use the 500 meter scale scores in the rest of the analyses. It was felt that this scale captured not only the immediate roadway environment, but also factors somewhat further from the roadway that still are likely to influence mountain lion movement to and across the roadway or not.

Caveats:

Using data from some of the models and GPS collars created certain biases that could not be avoided because none of the data used was collected or created specifically for the purposes it was put to here. For instance, mountain lion GPS collar data was more concentrated in some areas versus others due to collaring being geographically based, mountain lion use of the landscape not being uniform, and data points being collected at variable times in some locations versus others. However, because the information from collars is so specific to the species of concern and the high frequency (5 and 15 minute interval between data points) was so useful for pinpointing actual highway crossing points, it was data that proved invaluable for that purpose, but its collection bias resulted in substantially more known crossing points being identified along SR76 than the other highways, even though many crossings of the other highways (especially SR79) by GPS-collared mountain lions have occurred.

Table 1. Criteria for scoring and score ranges

Title	Criteria	Scoring
Conservation score	Percentage of land within 100, 500, and 1,500 meters of a road point or examined site that is conserved	0 - 10
Habitat score	Quality of habitat for mountain lions within 100, 500 and 1,500 meters of a road point or examined site per K. Zeller habitat modeling	0 - 10
Resource score	Quality of resources for mountain lions within 100, 500 and 1,500 meters of a road point or examined site based on J. Dellinger resource modeling	0 - 10
Activity score	Numbers of mountain lion pathway 10 meter segments (based on GPS-Collar data) that lie within 100, 500, and 1,500 meters of a road point or examined site	0 - 10
Movement score	Likelihood of mountain lion movement within 100, 500, and 1,500 meters of a road point or examined site based on K. Zeller movement modeling	0 - 10
Observational score	Total of scores for crossing structure type (0-3); Lack of constraints on structures (0-3); Landscape structure / wildlife evidence (0-2), and confirmed crossing this location (0-2) based on on-the-ground road crossing site surveys	0 - 10
	Summary value for all scores	0 - 60

These scores were used for comparison between sites based on each characteristic that was scored, as well as cumulative scores. Scores for points that were closest to sites pre-identified as high likelihood crossing sites (as detailed below) were combined with scores from on-the-ground examinations (Observational scores described below) to inform overall ranking of crossing sites and highway sections.

Pre-Identification of Potential Road Crossing Locations for Examination

Prior to field examination, the UCD team identified 191 locations along I-15, State Routes 79, 78, 76, and smaller state highways Rainbow Canyon Rd, and Pala Temecula Road that had a higher likelihood of mountain lions attempting to cross based on the various publications and sources listed above. Data used to identify these sites included the results of least cost path modeling, habitat use and movement modeling, based on GPS collar data, gene flow modeling, documentation of actual crossing by mountain lions using high frequency (5 minute and 15 minute interval) data acquisition, documentation of crossing using trail cameras, expert opinion and previous modeling, GPS or camera data at and near the roadway, and documentation of mountain lion collisions with vehicles occurring at known locations (South Coast Wildlands. 2008, Vickers et al 2015, Vickers et al. 2017, Riley et al. 2018, Zeller et al. 2017, 2018, Dellinger et al. 2019, W. Vickers and California Department of Fish and

Wildlife unpublished data). U.C. Davis Team members conducted filed examinations of the 191 identified potential wildlife crossing locations along the highways in the study area. Due to incomplete information, 6 sites were excluded from the analysis, yielding a final group of 185 sites that were analyzed and reported on here.

Sites that were examined in the field were designated with the following naming convention. Survey sites are depicted by type on Map 5 below and listed with their characteristics in Appendices C and D:

- A and a number = Sites where crossings by mountain lions have been confirmed based on GPS collar data using only GPS points spaced in time at 5 or 15 minute intervals occurred on opposite sides of a highway at that location (n=41)

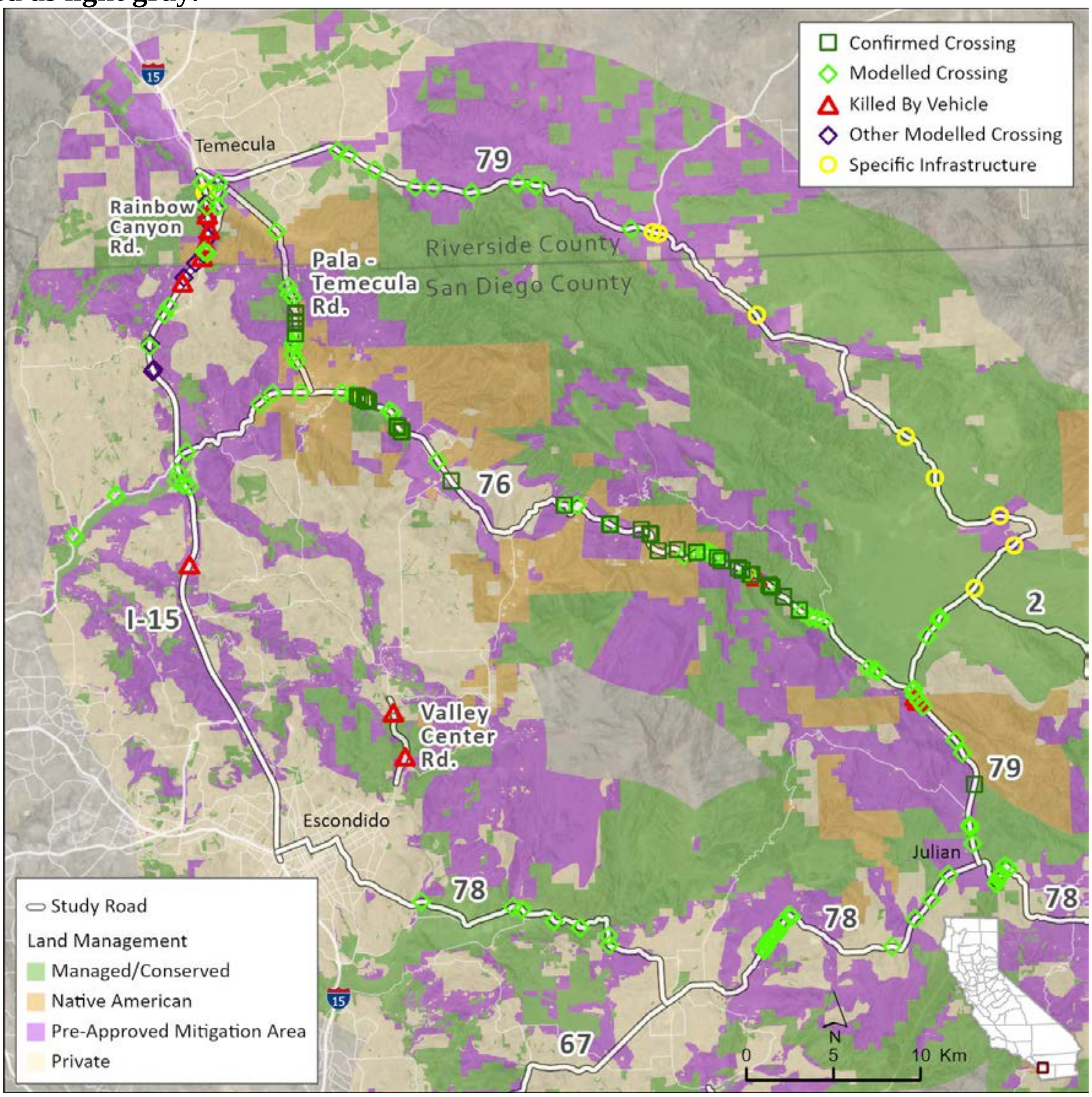
- P and a number = Sites identified by least cost path modeling (Vickers et al. 2017, Zeller et al. 2017, 2018) as likely locations for mountain lion road crossing to occur (n=109 with one site occurring at same location as an A site)

- M, F, or U and a number = sites where mountain lions were killed by vehicles while attempting to cross (n=11)

- WS and a letter or number = sites identified by other modeling as potential crossing locations along I-15 (n=11)

- Locations with a name = specific river or creek bridges that were not identified with one of the other parameters, but were identified by other studies as potentially important for connectivity (n=14).\

Map 5. Individual sites (n=186) that were examined on-the-ground and included in the analysis. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Sites where mountain lions are confirmed to have crossed or attempted to cross the different roadways in the study (Sites with A, M, F, or U designations) were identified by utilizing high frequency (5 and 15 minute temporally spaced) GPS collar locations and mountain lion vehicle collision mortality sites. These sites were regarded by the study team as the "gold standard" of the 185 crossing sites studied in terms of understanding characteristics of the landscape where successful crossings as well as road mortalities were most likely to occur (Map 5). Most of the sites identified by GPS locations were along SR76 due to the particular programming of GPS collars in that area, but the characteristics of those sites did assist the Project Team in understanding characteristics of the other highways that would be most predictive of crossing attempts occurring on those highways.

Each survey site was evaluated in the field for its potential as a highway crossing point for mountain lions and other wildlife within a conceptual regional network of crossings that could ensure mountain lion genetic and physical connectivity across the region. Each location was examined in depth in the field, photographed, and characterized. Forty parameters were potentially recorded at each site using Wildnote software (© 2018 Wildnote Inc.), and photos taken at the site were also recorded by the software into a complete database. Photos were imprinted with the GPS location where the photo was taken, and direction that the camera was pointed via the Hunter NavCamera App (© 2014-2020 Hunter Research and Technology LLC) on iPhones (® Apple Computer, Inc.). All characteristics that were recorded in ground surveys of the 185 sites examined and characterized are listed in Table 2.

Table 2. Information recorded during on-the-ground examinations of all surveyed sites.

Information recorded at surveyed sites	
Survey ID	Structure type
Survey Date	Culvert distance below road
Highway name	Height
Highway number if not listed	Width
Location	Length
NEW Location?	Structure floor material
Drop Point (Lat/Long) (latitude)	Able to see through culvert
Drop Point (Lat/Long) (longitude)	Water?
Drop Point (Lat/Long) (speed)	Human presence likely at night?
Drop Point (Lat/Long) (direction)	Describe human presence potential
Drop Point (Lat/Long) (altitude)	Constraints
Drop Point (Lat/Long) (accuracy)	Describe constraint
Surveyor	Evidence of other animals?
Road type	Describe evidence of other animals present
Estimated width of road from one pavement edge to the other	Fencing present?
Landscape character suggestive of likely crossing point	Describe fencing type and height
Describe reason landscape character not conducive to crossing	Consider for camera?
Landscape and veg structure suggest corridor	Camera suggestions
Describe limitation of landscape and veg and which side of road	Comments
Other species observed	Management recommendations

Scoring of each site based on the on-the-ground exams was done using a similar but more extensive scoring system than the one previously used in the 2015 Connectivity Experts Workshop focused on I-15 (Riley et al. 2018-Appendix A). Various characteristics related to the physical infrastructure (or lack thereof) that were recorded in on-the-ground surveys were scored, including whether crossings by mountain lions had been previously documented at the site, whether crossing structures were present and their size, type and whether there were constraints to their use, and whether landscape characteristics appeared to favor wildlife movement to and from the site (whether there was evidence of wildlife use of the crossing site, whether there was evidence of human presence at the site, how the landscape structure such as canyons and vegetation would tend to favor crossing at that location or not; Table 3). Final infrastructure scores were the sum of these scores on a scale of 0-10).

Table 3 – Observational scoring protocol

Structure Grade - 0= no structure, 1=culvert <3 ft, 2 = culvert 3 ft or more, 3 = bridge
Constraint/Plus Factor Score: 3 if can see through and trails, tracks, other evidence of use of structure by wildlife (ideal); 2 if can see through but no evidence of use, or if evidence of use but can't see through; 1 if can't see through and no evidence of use; 0 if full time water, accessibility compromised, or likely human presence at night.
Landscape score: 2 if suggests likely crossing point; 1 if minor contraints of landscape; 0 if significant landscape negatives
Confirmed crossing this location: 2 if yes; 0 if no

Documentation of all sites that were examined on the ground included recommendations that were recorded on-site for infrastructure changes that would be most impactful for assuring long term functional connectivity at that location. Measures that were considered for possible recommendation included new crossing structure construction (under or over-crossings), modifying of existing structures, placement of fencing for funneling animals to safe structures at that location or nearby, fencing or other measures to reduce human presence, placement of new vegetation-berms-walls to reduce negative sound and light impacts and structure avoidance even when adequate structures are present, and maintenance measures to increase wildlife crossing function, such as removal of ponding, vegetation clearing to improve visibility of and/or through the crossing structure, and other measures.

In addition, the UCD Team collaborated with PhD student Amy Collins and Dr. Fraser Shilling from the UC Davis Road Ecology Center, and Dr. Travis Longcore of the University of Southern California, to conduct light and sound measurements at some of the likely highway crossing sites identified in the study with a special focus on I-15. The purpose of this work was to assist in prioritizing sites for potential mitigation of negative light and sound effects on wildlife movement through existing crossings, as well as to assist in prioritizing of sites along I-15 that are being considered for new crossing structure construction.

Task 2 (NCCP-LAG):

For I-15 specifically, additional information was available from the previously mentioned 2015 Connectivity Experts Workshop (Riley et al. 2018-Appendix A). This information, along with more current data (Vickers et al 2017-Appendix B, Zeller et al 2017, 2018, W. Vickers and CDFW unpublished data), was utilized by the CPP faculty members and three teams of junior and senior civil engineering students who worked with the UCD and TNC Teams to conduct their project design effort with the title "Safe Wildlife Crossings Design for I-15 Freeway". The CPP teams evaluated the feasibility of new structure construction or modification of existing structures at the potential crossing locations along I-15 that had been given priority by both experts and landscape scoring processes previously described.

The CPP teams focused on three tasks in order to generate a technical report of their findings as a guidance document for future planning and engineering of potential crossing improvements or new construction along I-15:

1. Plan feasible improvements to the Temecula Creek Bridge and its environment to promote more wildlife use, and specifically to mitigate factors that currently negatively impact the potential for mountain lion and other wildlife use.
2. Examine potential crossing sites south of the Temecula Creek Bridge to determine the most feasible site for an undercrossing structure such as a large culvert (ability to build based on landscape characteristics and costs).
3. Examine potential crossing sites south of the Temecula Creek Bridge to determine the most feasible site for an overcrossing structure such as a wildlife bridge (ability to build based on landscape characteristics and costs).

Task 3 (NCCP-LAG):

Stakeholder involvement was solicited via organizing meetings and workshops involving stakeholders and wildlife crossing experts, distribution of information about the project and its goals, presentation of preliminary results, and soliciting feedback from participants. In addition, TNC led the development of a Steering Committee with has formed a Santa Ana to Palomar Mountain Linkage Coalition to support conservations, funding, and connectivity efforts.

Results

Task 1 (NCCP-LAG and SANDAG):

Scoring of Movement and Activity:

As noted above, movement scores were derived from mountain lion movement models developed by Dr. Kathy Zeller from extensive GPS data (nearly 350,000 individual mountain lion locations) generated across the region during the course of the UC Davis mountain lion study (Vickers et al. 2017-Appendix B, Zeller et al. 2017,2018). Due to a slightly more limited geographic focus of the previous study where those models were developed, they did not include some sections of SR79 that are in the current study area. As a result, movement scores were not available for some examined sites. Likewise, activity scores derived from mountain lion movement pathways near the highway crossing sites were not present at all sites due to the tendency for clustering of movement pathways to occur in some sections of highways versus others due to vagaries of individual mountain lions.

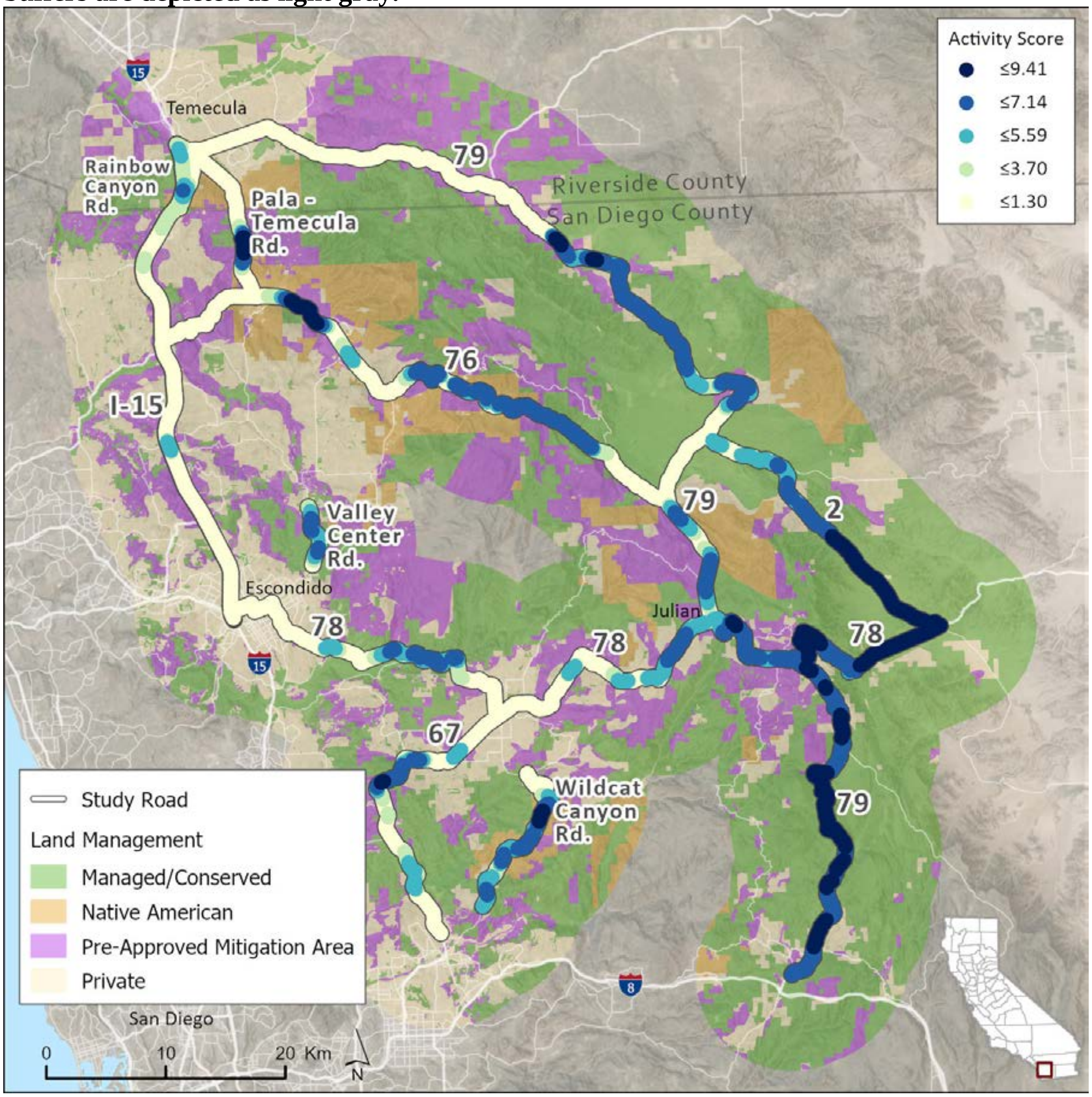
Regression analysis of the site scores (apart from Observational Scores) as continuous variables suggested that the scores most directly related to mountain lions approaching and crossing roads (Activity and Movement scores) were correlated most strongly with Habitat and Resource scores, and that Conservation scores were not closely correlated with any of the other scores, likely because of the low percentages of conserved lands near the highway crossing sites generally, a somewhat surprising finding that we address further in the following results section and discussion.

Activity and movement scores for regional highway segments:

Because Activity and Movement scores were calculated based on different data analysis methods, they were not highly correlated in the analysis of surveyed sites generally. Activity scores had a wider range of values and variation across the different highway survey sites versus Movement scores that reflected modeling of likely movement of mountain lions across the entire landscape. The net effect of the Movement modeling scoring was a “smoothing” of the likelihoods of approach to a highway across the different highways versus the Activity scores. Activity scores were extremely valuable in many locations however because they came directly from GPS collar data, and gave the most direct evidence of which sites were likely to be utilized for crossing with some certainty.

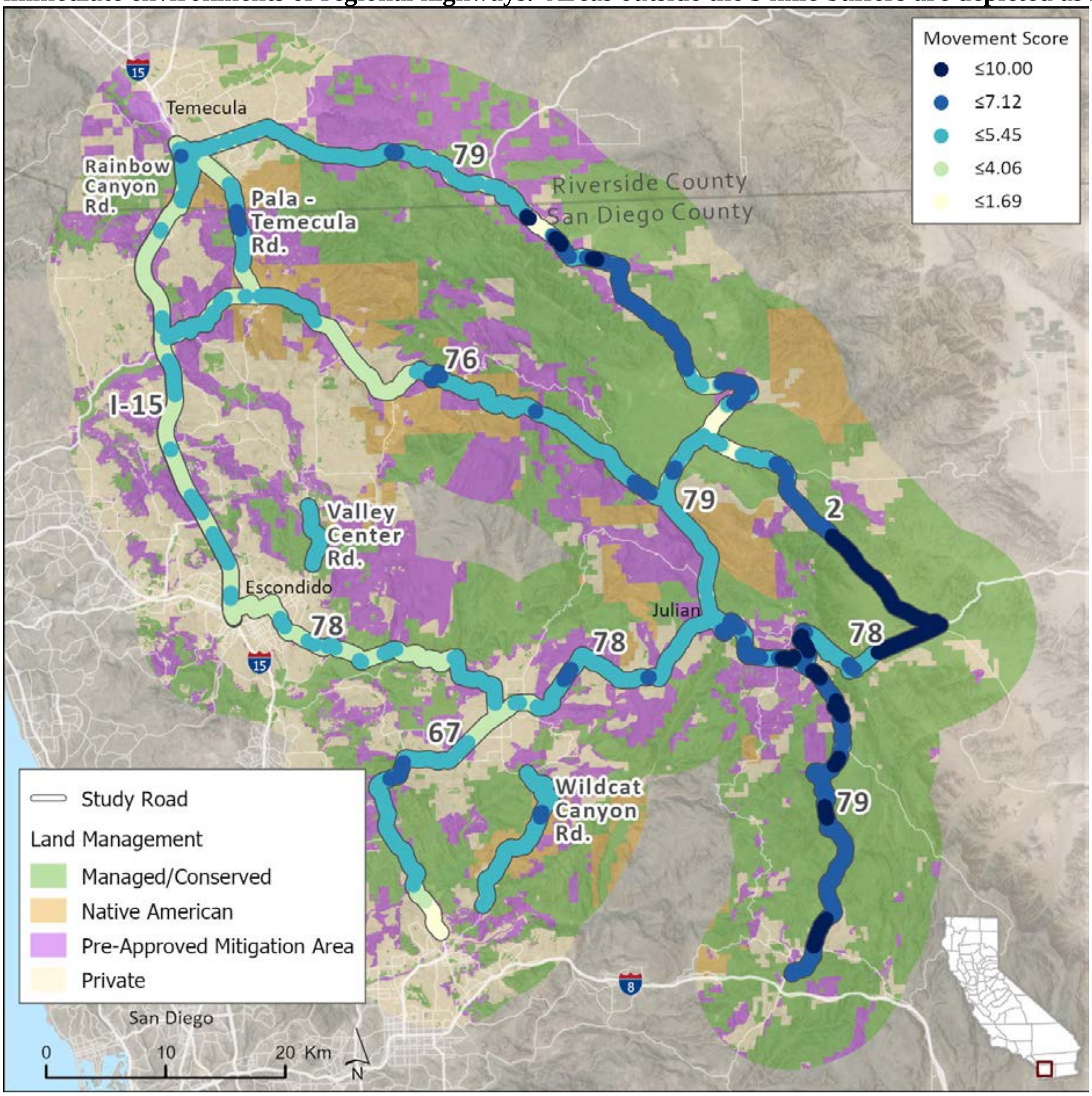
As noted earlier, points at 100 meter intervals were generated along all the highways surveyed, as well as other regional highways (Wildcat Canyon Road, SR67, S2). Display of Activity and Movement Scores for all of the 4,378 points illustrates the general sections of the regional highways where maintenance of connectivity for mountain lions is most indicated, and maintenance or creation of safe road crossing infrastructure at regular intervals is most important (Map 6). Activity scores were highest for parallel sections of SR76 and SR79 on either side of the Palomar Range, S2 in San Felipe Valley, SR78 and SR79 south and east of Julian, the section of Wildcat Canyon Rd. near and south of the Barona Casino, SR 67 west of Ramona, SR 78 east of Ramona, Pala-Temecula Rd., and I-15 at and just south of Temecula Creek (Map 6). Certain sections of SR79 and I-15 had very low or zero activity scores due to poor habitat around those sections or absence of GPS collaring activity in the past near those sections, or mountain lion use of the habitat being further from the highway than in other areas.

Map 6. Activity scores based on data from GPS-collared mountain lions for all points along the regional highways at 100 meter intervals. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Movement scores were more even across the region than activity scores but highlighted some of the same areas of regional highways that are very important for connectivity for mountain lions as Activity scores did – specifically sections of SR79 east of the Palomar Mountains, S2 in San Felipe Valley, SR78 and SR79 south and east of Julian, Pala-Temecula Rd. short segments of SR67, SR78 west of Julian, and Wildcat Canyon Rd., and I-15 at and just south of Temecula Creek. Because the most southern section of SR79 was not included in movement modeling done previously in Zeller et al. 2017, no data was available from the models for that section. In order to be able to map the overall movement potential for mountain lions across the region, collar-based activity scores were substituted where no modeling-based scores existed. This resulted in a blended dataset used to generate the combined movement and activity map below for all the datapoints along the highways in the study (Map 7).

Map 7. Blended movement and activity scores for points along the highways at 100 meter intervals. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Characteristics of individual sites that were surveyed:

Across the study area a total of 185 known or modeled sites that were determined to have high potential for mountain lion crossing of roads were examined and characterized in the field, with the distribution among the different highways detailed in Table 4, Figures 1a and b, and Map 8. The results of these examinations and analyses are expected to help guide Caltrans and other agencies in their efforts to address connectivity for mountain lions and other wildlife across the region.

Wildlife crossing infrastructure present at examined sites

All findings from the on-the-ground surveys, including photos taken at the sites, are included in this report as Appendices C and D. Of the 185 sites examined and characterized, 79 (43%) had either culverts that were large enough to allow mountain lion use (3 ft diameter or larger; n=43; 23%) or bridges (n=36; 19%) present. Smaller culverts were present at 49 sites (26%), and no culvert or bridge infrastructure was present at 56 sites (30%; Table 4; Map 8; Appendices C and D). Variations in structure types occurring across the various highways in the study area were substantial (Table 4; Figures 1a and b).

Existing bridges were the most numerous (n=36) structures that could support mountain lion movement safely across roads in this study, and have the advantage of also potentially supporting the movement of mule deer (*Odocoileus hemionus*) (Table 4; Map 8; Appendices C, D). However 3 of the bridges examined had significant constraints on their use by mountain lions and other wildlife that were related to human presence. Bridges over creeks or riverbeds are generally regarded as the most functional passageways for the largest number of species, and generally support mountain lion movement. However, some factors associated with bridges, especially when they carry large amounts of traffic such as on I-15, can be negative for mountain lion use. These factors can include noise from the roadbed and bridge structure as vehicles pass overhead that is often amplified directly underneath the bridge, light from passing cars or lighting on the bridge itself, and if a creek landscape is too open with little cover it may be less attractive to mountain lions. These challenges are especially acute for one bridge in the study that more than any other is a key to mountain lion connectivity in the region, the Temecula Creek Bridge on I-15 (site 44P). The challenges for the Temecula Creek Bridge are discussed in depth later in the report.

Of the 43 culverts that were judged to be of adequate size to allow mountain lion use, more than half (53%; n=23; Table 4) had significant constraints on their use by mountain lions - such as positioning issues relative to stream beds, lack of visibility all the way through, vegetation blocking entrances, nearby human structures, evidence of significant human presence, etc. (Appendices C, D). Thus, culverts that were of adequate size and also had no, or only partial, constraints represented only 20 out of the total of 93 culverts (22%) of all sizes that were examined. (Table 4; Appendices C, D).

Thus, over the entire 185 sites examined where mountain lions were known or projected to potentially attempt to cross the named highways, 53 sites (33 bridges, 20 culverts; 23%; Table 4; Appendix C) were found to potentially accommodate mountain lions crossing safely, with the 33 bridge sites also able to accommodate mule deer crossing. Analysis of these 53 sites in relation to mountain lion use specifically indicated that only 39 of the 53 have relatively high potential for regular use, though the other 14 may be used at times.

Table 4. Number of sites examined on each highway, with structure types and number present. For bridges and larger culverts, the number of structures with no or only partial constraints is in parenthesis.

Highway name	Bridges	Culverts 3 ft or more	Culverts less than 3 ft	No Culvert or Bridge	Total sites examined
I-15	3 (2)	14 (5)	0	8	25 (7)
I-15/Old Hwy 395 jct	0	0	0	1	1 (0)
Rainbow Canyon Rd.	1 (1)	0	1	1	3 (1)
Old Hwy 395	2 (1)	0	2	1	5 (1)
Pechanga Parkway	1 (1)	1 (0)	0	0	2 (1)
Pala-Temecula Rd	0	2 (1)	4	8	14 (1)
SR-79	13 (13)	3 (3)	8	8	32 (16)
SR-76	11 (10)	19 (9)	16	23	69 (19)
SR-78	5 (5)	3 (1)	18	6	32 (6)
Valley Center Rd	0	1 (1)	0	1	2 (1)
Total Sites Examined	**36 (33)**	**43 (20)**	**49**	**57**	**185 (53)**

Figure 1a. Distribution of potential wildlife crossing structures types by highway and structure type as recorded in ground surveys. Each color represents a structure type, each bar represents the count on that highway (X axis) of structures of the given type.

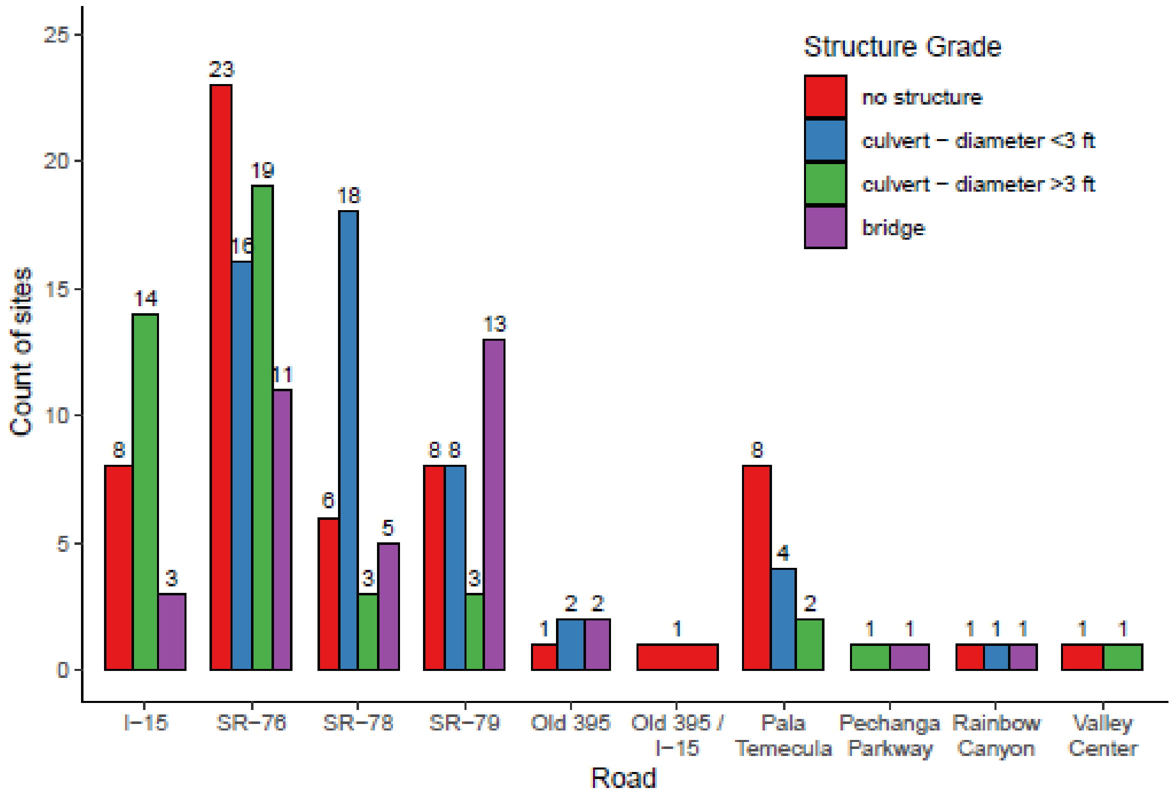
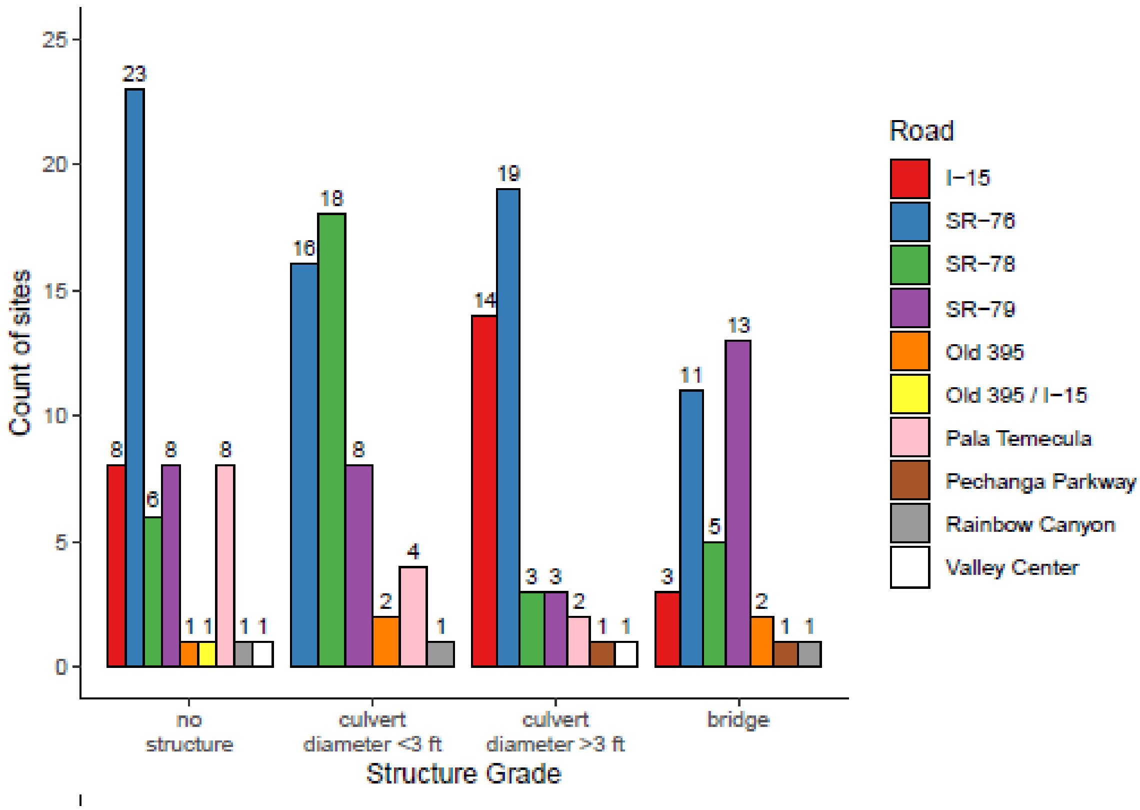
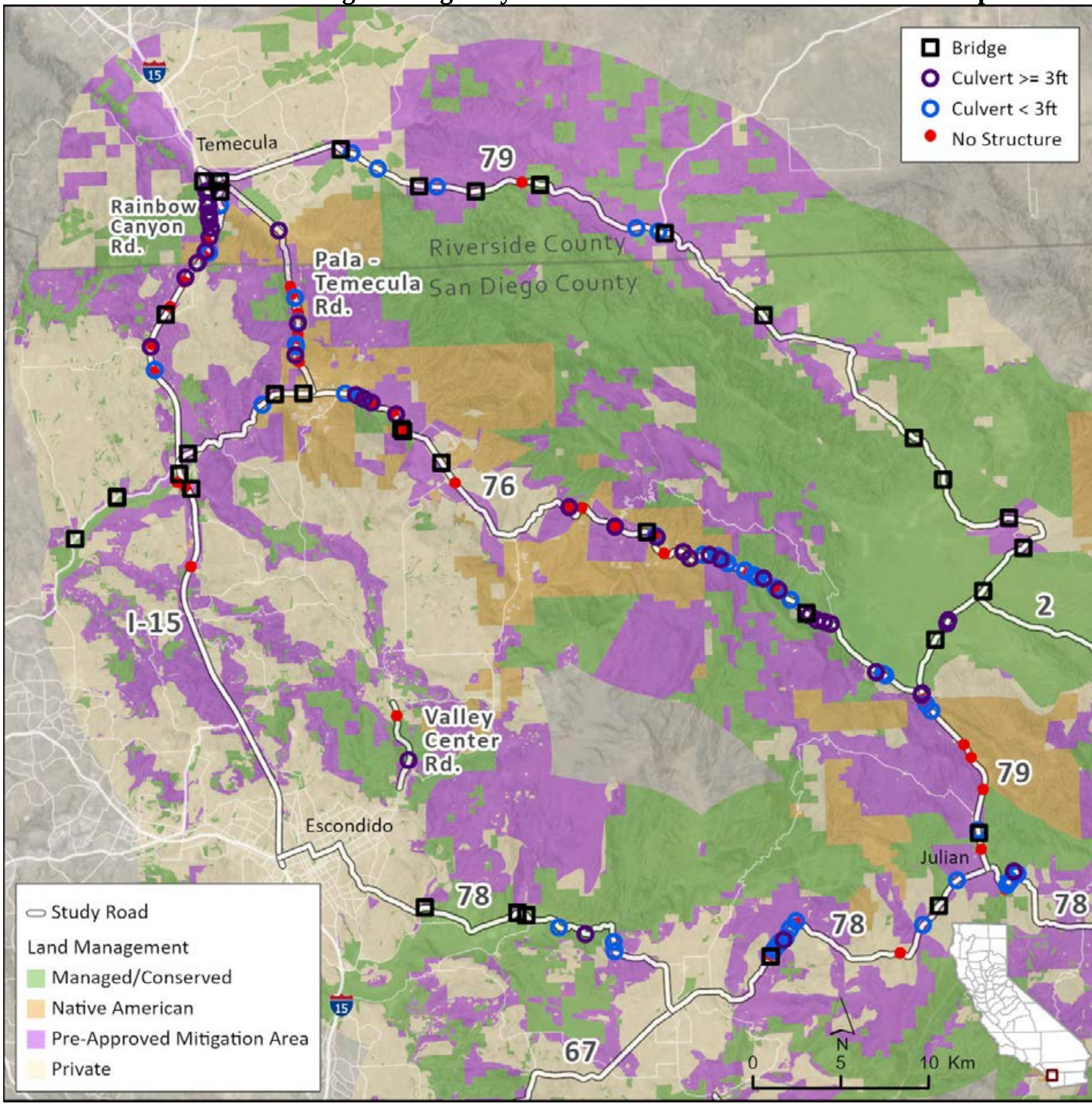


Figure 1b. Distribution of potential wildlife crossing structures types by highway and structure type as recorded in ground surveys. Each color represents a highway, each bar represents the count on that highway of structures of the given type (X axis).



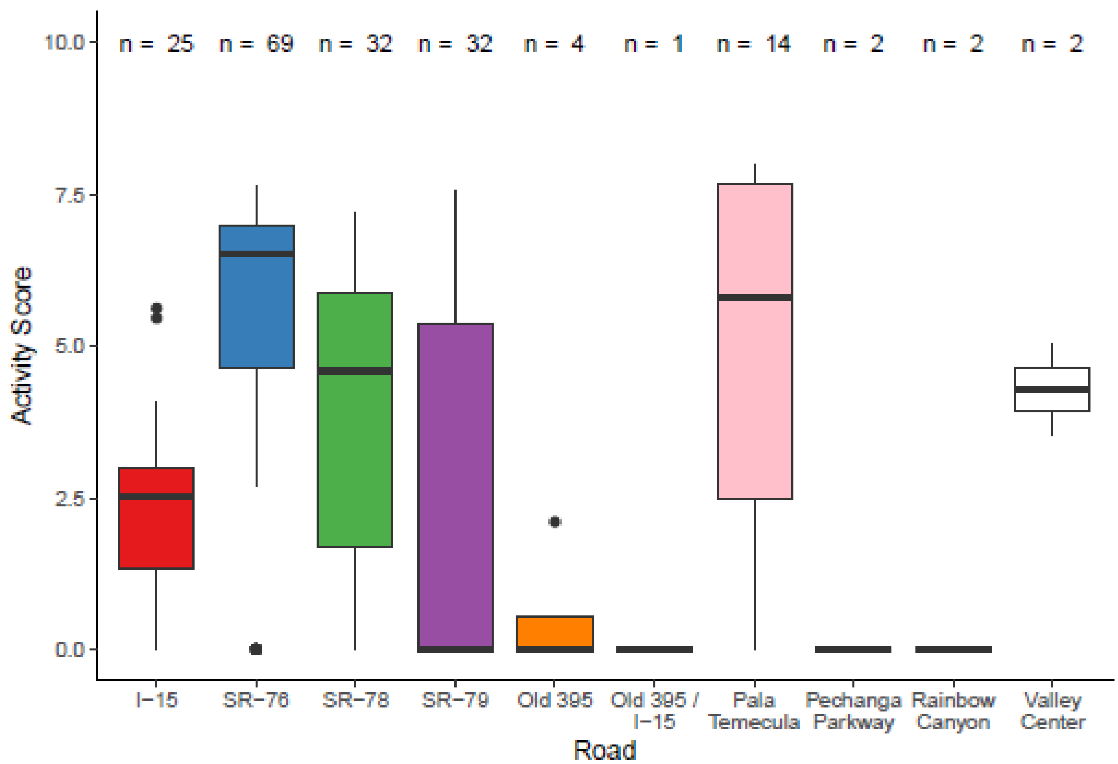
Map 8. Sites examined with structure type denoted. Structure scores are: Bridge (3), Culvert over 3 ft. diameter (2), Culvert less than 3 ft diameter (1), No structure (0) Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Characterizing Sites by Activity and Movement Scores:

Boxplots of Activity and Movement Scores of the different highway survey sites illustrate the differences between the two methods of assessing movement potential across the highways, specifically at the crossing sites surveyed (Figures 2,3). These charts illustrate that Activity scoring based on specific mountain lion GPS collars are much more variable than Movement scores when assessed by highway. Median Activity scores were highest at the surveyed sites along SR76, and median Movement scores were highest along SR78. Sites surveyed with color coding of the sites by Activity score are illustrated in Map 9 below.

Figure 2. Activity scores of surveyed sites by highway.



Map 9. Activity Scores across the regional highway sites surveyed. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.

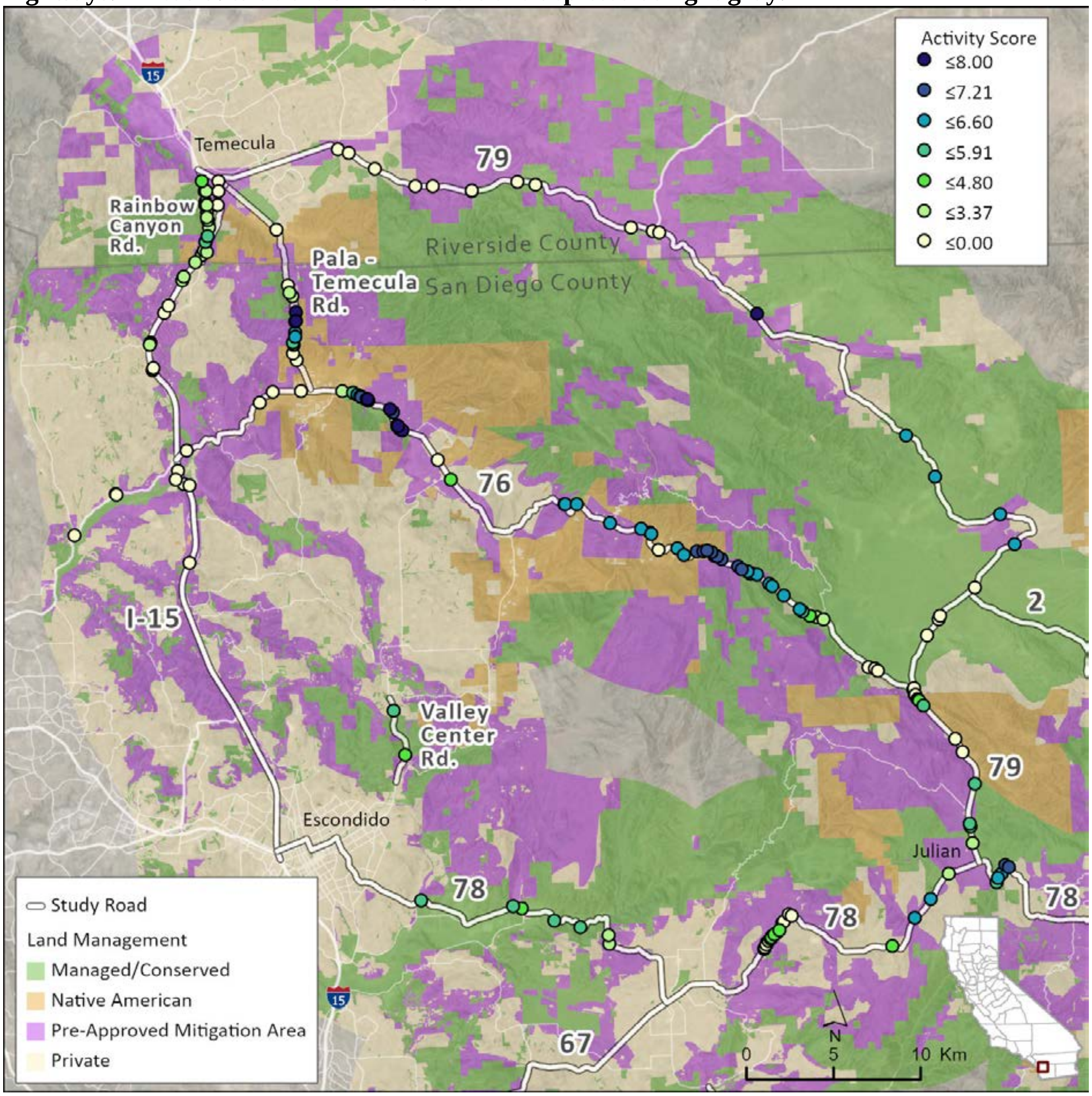
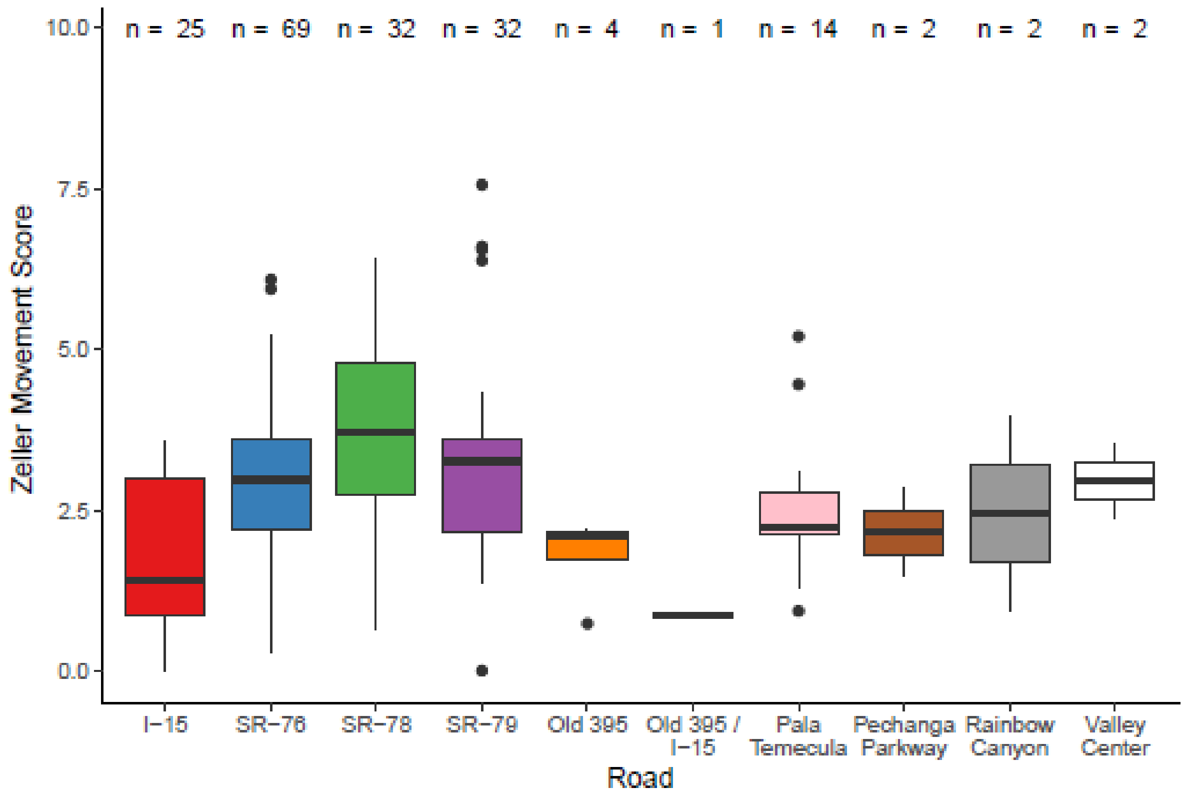
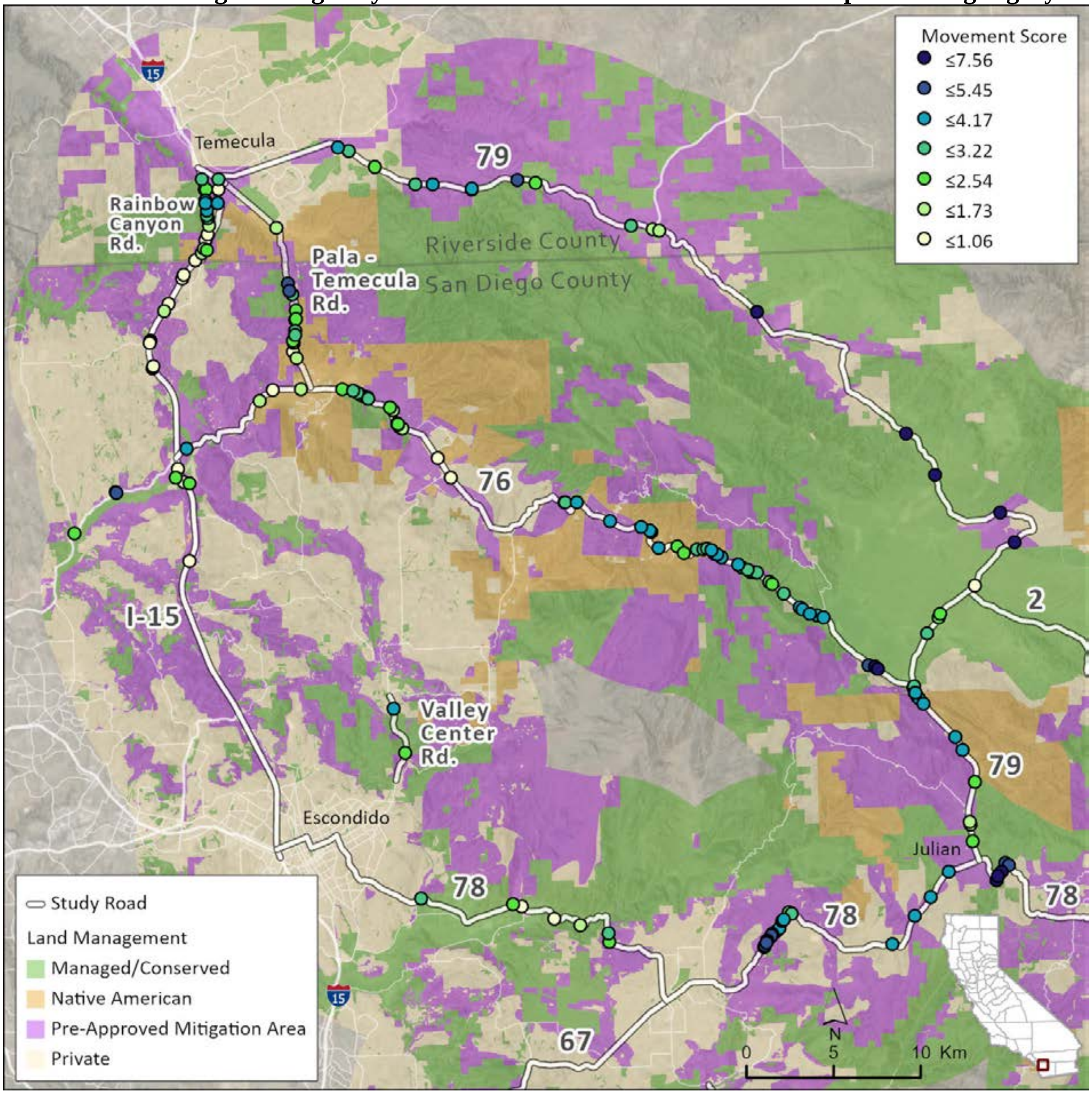


Figure 3. Movement scores of surveyed sites by highway.



Both scores afford different ways to assess and prioritize sites in general. Sites with high scores by either measure were considered by the Project Team to be priority locations, but sites with high scores on both measures were considered to be especially notable. As noted above, for certain short highway segments no Movment data was available, and in some areas no Activity data was available due to vagaries of where mountain lions were captured and collared. In those areas, scores from the other data set were subsituted to produce a blended picture of all known likelihood of mountain lion use of specific sites for crossing the roads. Map 10 illustrates the individual surveyed sites that had the highest scores by the blended scoring system. Zoomed in maps for each highway with sites named are attached to this report as Appendix E.

Map 10. Blended movement and activity scores for the regional highway sites surveyed. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.

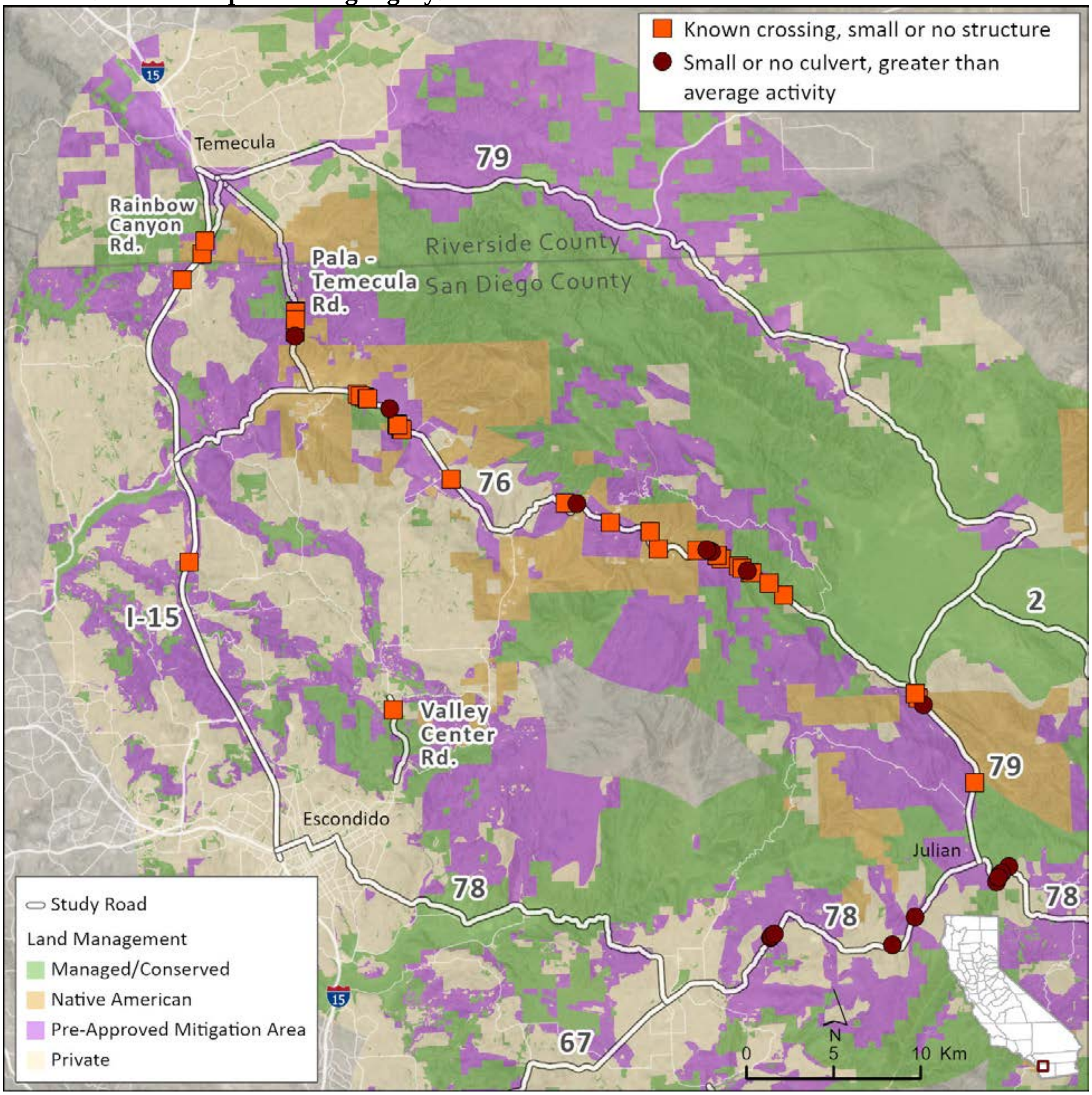


Descriptions and scores for confirmed mountain lion crossing sites and sites with higher than average mountain lion Activity based on collar data:

Of the sites where mountain lions were confirmed to have crossed roads successfully or been killed in the attempt (n=64 sites), 32 (50%) had no infrastructure present and 12 (19%) had only small culverts (Appendices C, D; Map 11). Of these known crossing locations, bridges were present at 6 sites (10%) and larger culverts were present at 14 sites (21%), however 4 of the 14 larger culverts were constrained in some way as noted above. Thus, over two-thirds (69%) of sites where crossings or attempted crossings occurred had no adequate structures. This necessitated animals crossing at grade, and suggests a need for infrastructure improvement at those locations – either fencing to funnel animals to nearby locations with adequate crossing structures or new structure construction if adequate land conservation is present at the sites. We take that into account in prioritization of sites detailed later in the results.

It is notable that based on our ground surveys, nearly all surveyed sites, including those where mountain lions crossed, did not have roadside fencing adequate to prevent mountain lion or other wildlife entry to the roadway, or to funnel them to the infrastructure present in cases where it was adequate.

Map 11 – Known mountain lion crossing sites, and sites with greater than average Activity scores, but <u>without</u> adequate crossing structures present. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



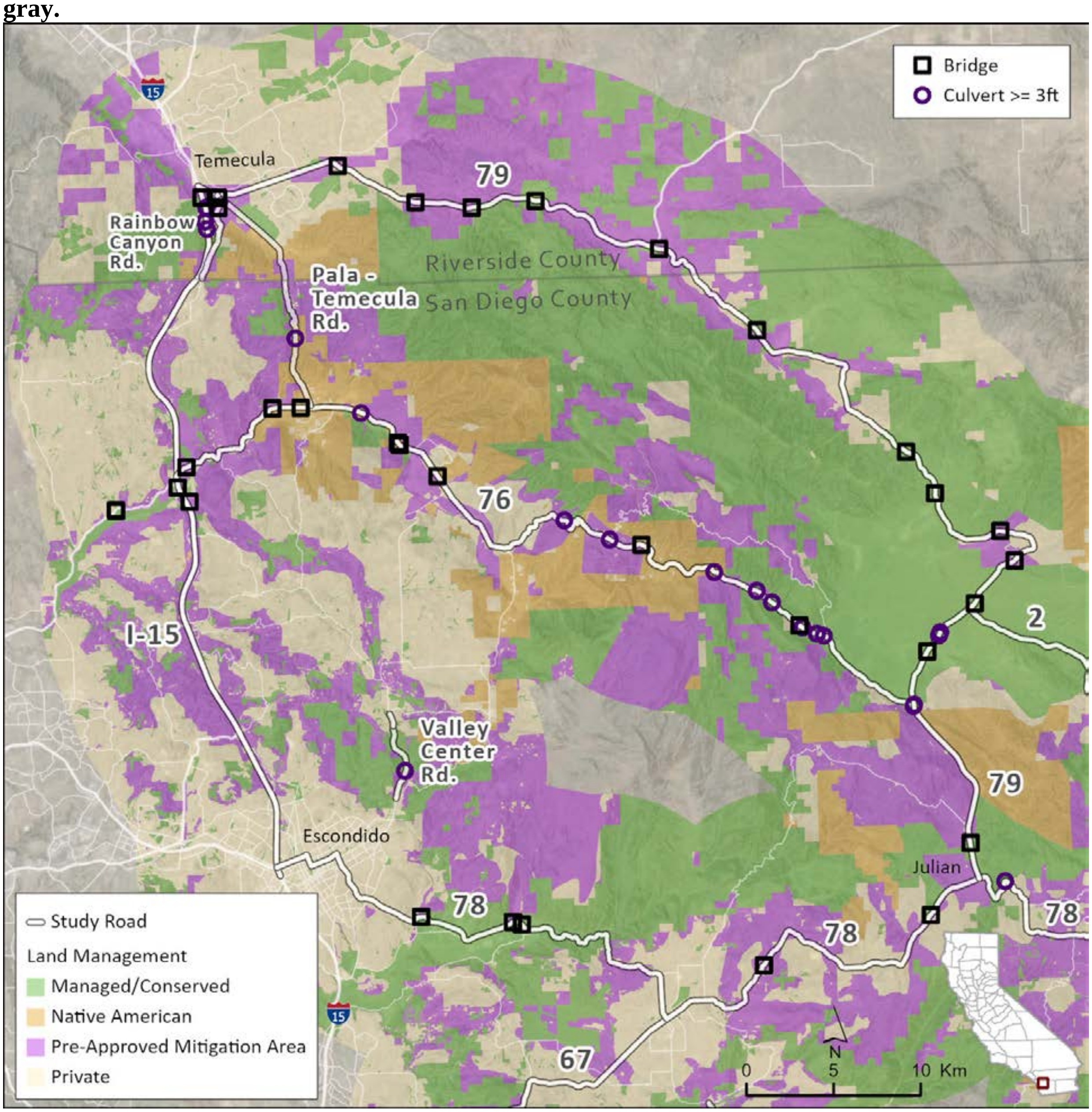
Characterization of crossing structures combined with mountain lion Crossing, Activity, and Movement levels:

Culverts greater than 3 feet in diameter that were unconstrained, and bridges that were unconstrained, were present at 53 of the 185 sites examined (29%; Table 5; Map 12). Mountain lions were known to have crossed the road at 13 of these sites, and 23 of the sites had higher than average activity and / or movement levels. Three of the sites were mountain lion mortality sites from vehicle collisions despite adequate infrastructure for safe crossing being present. Thus 39 of the 185 sites investigated have both adequate infrastructure to support long term connectivity and a high potential for mountain lion use of the sites as those areas now exist (Table 5, Map 13).

Table 5. Number of sites with adequate infrastructure present with road mortality, and known crossings, Activity and Movement levels above or below average.

Highway name	**Total sites with adequate infrastructure**	**Number of adequate sites where roadkill has occurred**	**Number of adequate sites with confirmed crossings**	**Number of adequate sites with no known crossings but above average activity or movement scores**	**Number of adequate sites no known crossings and below average activity or movement scores**
I-15	7	1	0	4	2
I-15/Old Hwy 395 jct	0	0	0	0	0
Rainbow Canyon Rd.	1	0	0	0	1
Old Hwy 395	1	0	0	0	1
Pechanga Parkway	1	0	0	0	1
Pala-Temecula Rd	1	0	1	0	0
SR-79	16	0	1	9	6
SR-76	19	1	9	6	3
SR-78	6	0	2	4	0
Valley Center Rd	1	1	0	0	0
Total Sites	**53**	**3**	**13**	**23**	**14**

Map 12 – Sites where existing infrastructure is of adequate size to support mountain lion movement across highways. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.

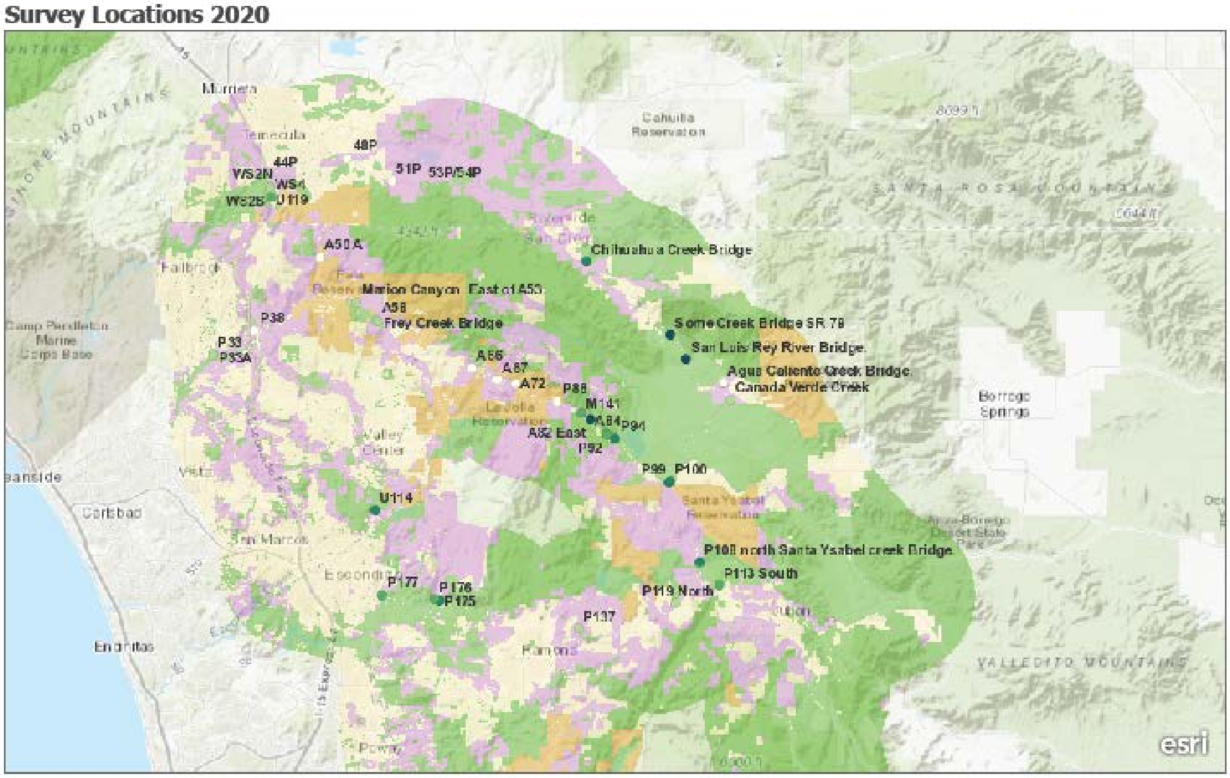


We regard these 39 sites as highest priority for maintaining their current function for mountain lion connectivity (Appendix C, D). This means maintaining them as free as possible from debris and other obstructions, as well as preventing excessive human presence especially at night. The primary infrastructure change to consider for these sites is fencing to funnel animals to them from other nearby sites where crossing at grade may occur, and to reduce human incursion from the roadway into the area of the crossing structure which would reduce its function for wildlife.

Map 13. Sites (n=39) where mountain lions have crossed the road or with high Activity and Movement Scores with adequate infrastructure present. Site symbols are colored by Conservation score.

4/13/2020 ArcGIS - Survey Locations 2020

Survey Locations 2020



Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

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Conservation scoring for all potential crossing sites that were examined:

In order to determine if these 39 sites have adequate conservation in their area to assure long term viability, we assessed the conservation status of the lands surrounding these specific sites. Conservation scores for all examined and scored sites (n = 183, two examined sites were not scored on this parameter) ranged from zero (meaning no conserved lands were within a 500 meter radius of the site; or in a 1 km diameter circle with the site at the center) to 9.54 (meaning that nearly 100% of the land within that circle was conserved).

The average conservation percentage within the 500 meter radius of all sites that were examined was 17.2 % conserved (score of 1.72) but the median percentage was only 7.8% (score of 0.78), with a score of zero at 48 sites (26% of sites). Scores indicated that 116 sites (63% of sites) had conservation percentages between 1% - 50% conserved (Conservation score 0.01-5.0), and only 21 sites had over 50% of the land in the 500 meter radius around the site (Conservation score > 5.0). Thus the vast majority of sites where mountain lions might approach the regional highways have minimal conserved lands in the immediate vicinity of the crossings (Appendix C; Figures 4, 5; Map 14). This contrasts with the 50-60% of overall lands that are projected to be mountain lion habitat in the study region that were classified in previous research as conserved (Vickers et al. 2017-Appendix B, Zeller et al 2017, Dellinger et al. 2019).

Figure 4. Distribution of Conservation Scores across all surveyed sites.
0 = 0% conserved, 10 = 100 % conserved

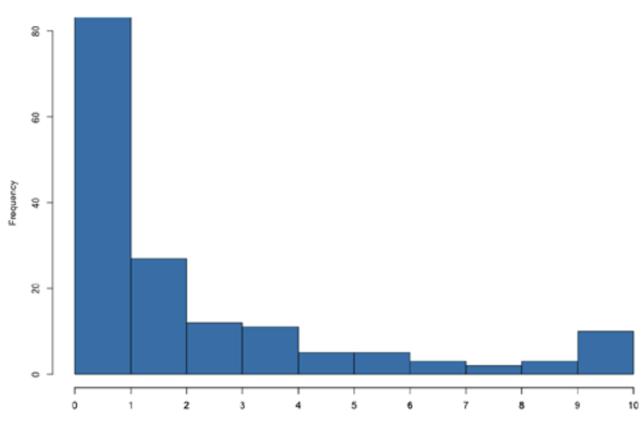
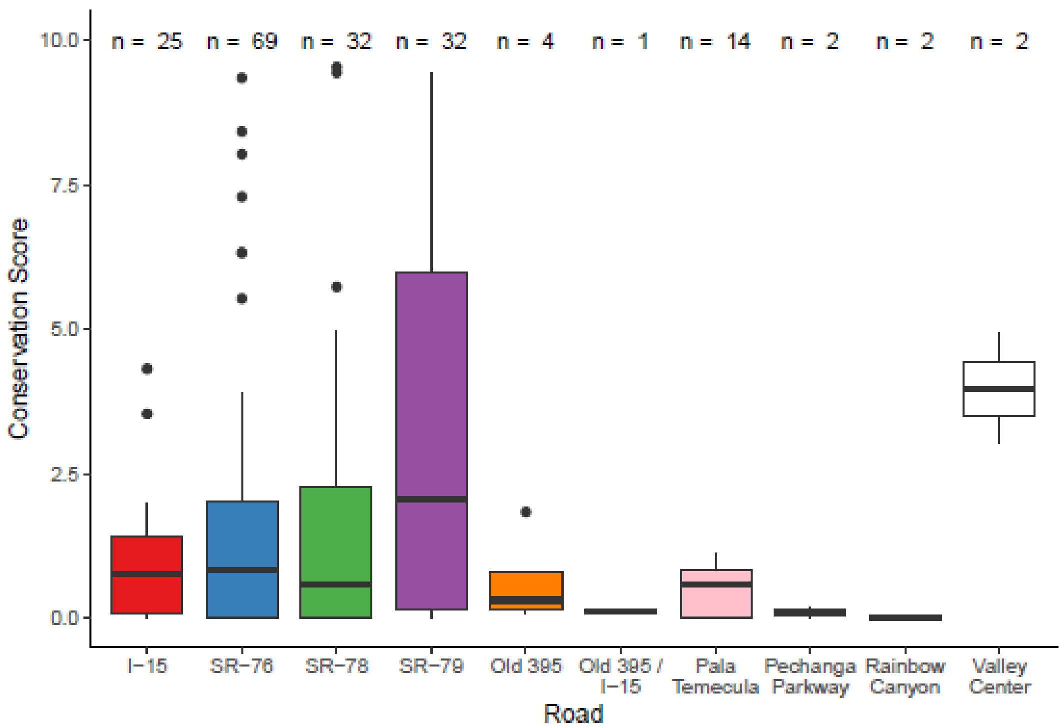
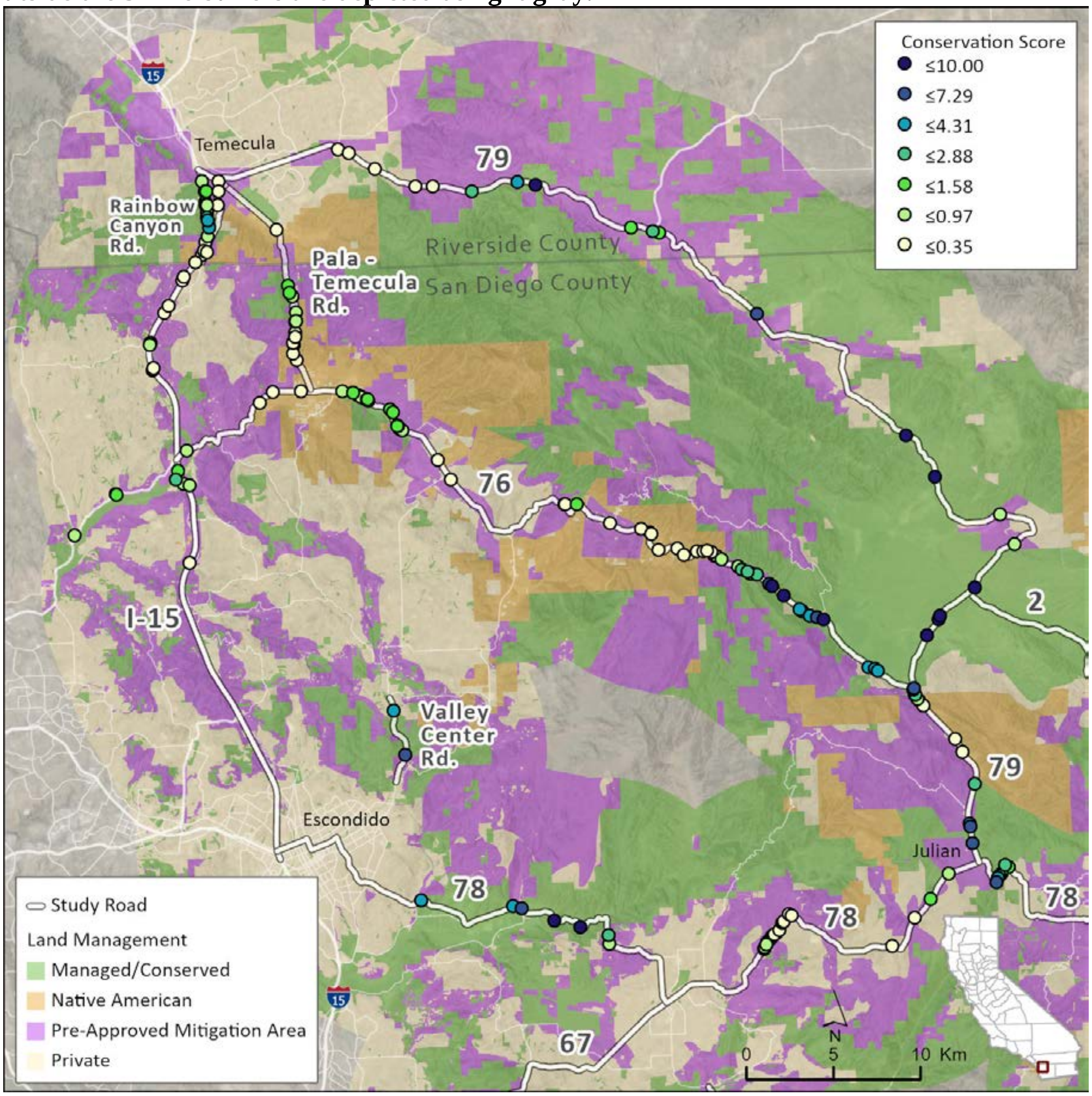


Figure 5. Boxplots of Conservation Scores by highway. Each box represents the middle 50% of scores for examined sites along that highway. The median score is represented by the horizontal line in the box, with the quartiles above and below the median above and below the line. The upper and lower quartiles are represented by the "whiskers" above and below the box. Individual dots represent significant outliers. Numbers of sites documented for each highway are noted above each boxplot.



Map 14 - Surveyed sites with Conservation Scores – scores are based on the percentage of land that is conserved that is within a 500 meter radius of each survey site. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Higher conservation scores imply a lower risk of mortality for mountain lions in the vicinity of that crossing (Burdett et al. 2010, Dellinger et al. 2019), and would be expected to reduce the likelihood of development blocking access to the highway at any given point

For the 64 sites where mountain lion crossings or attempted crossings were known to occur, conservation scores ranged from 0.0 at 15 sites (23.4% of sites), to 84.2 % conserved as the maximum. Unfortunately, only 5 sites of the 64 (7.8% of sites) where mountain lions were confirmed to have crossed or attempted to cross had over 50% of the land conserved.

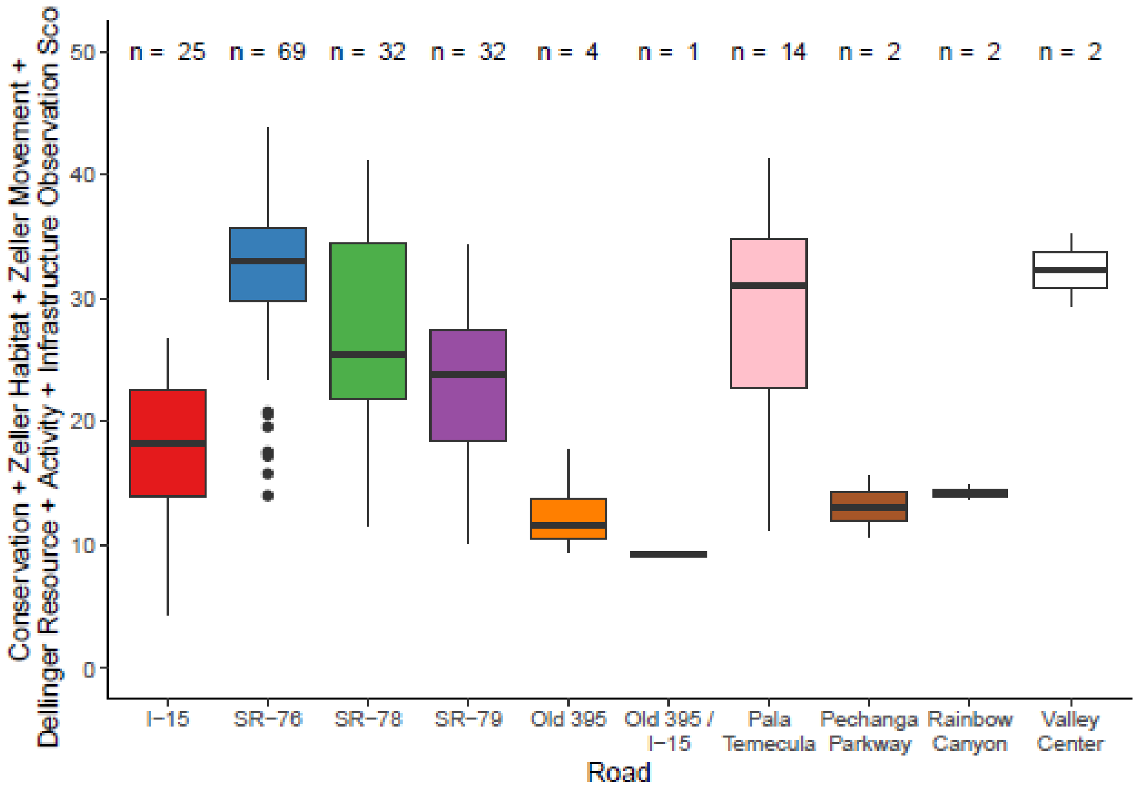
For the 39 highest priority sites (adequate infrastructure sites that had known crossings or high Activity and Movement scores; Appendix C), conservation levels were over 50% at 22 of the 39 sites (56.4% of sites), and ranged from a high of 95% conserved to a low of 21%. Though these values were somewhat better on average than values for the assessed sites as a whole, in order for these key sites to be maintained over the long run as viable crossings for mountain lion connectivity, additional conservation effort is needed.

Total Scores derived from all scores combined:

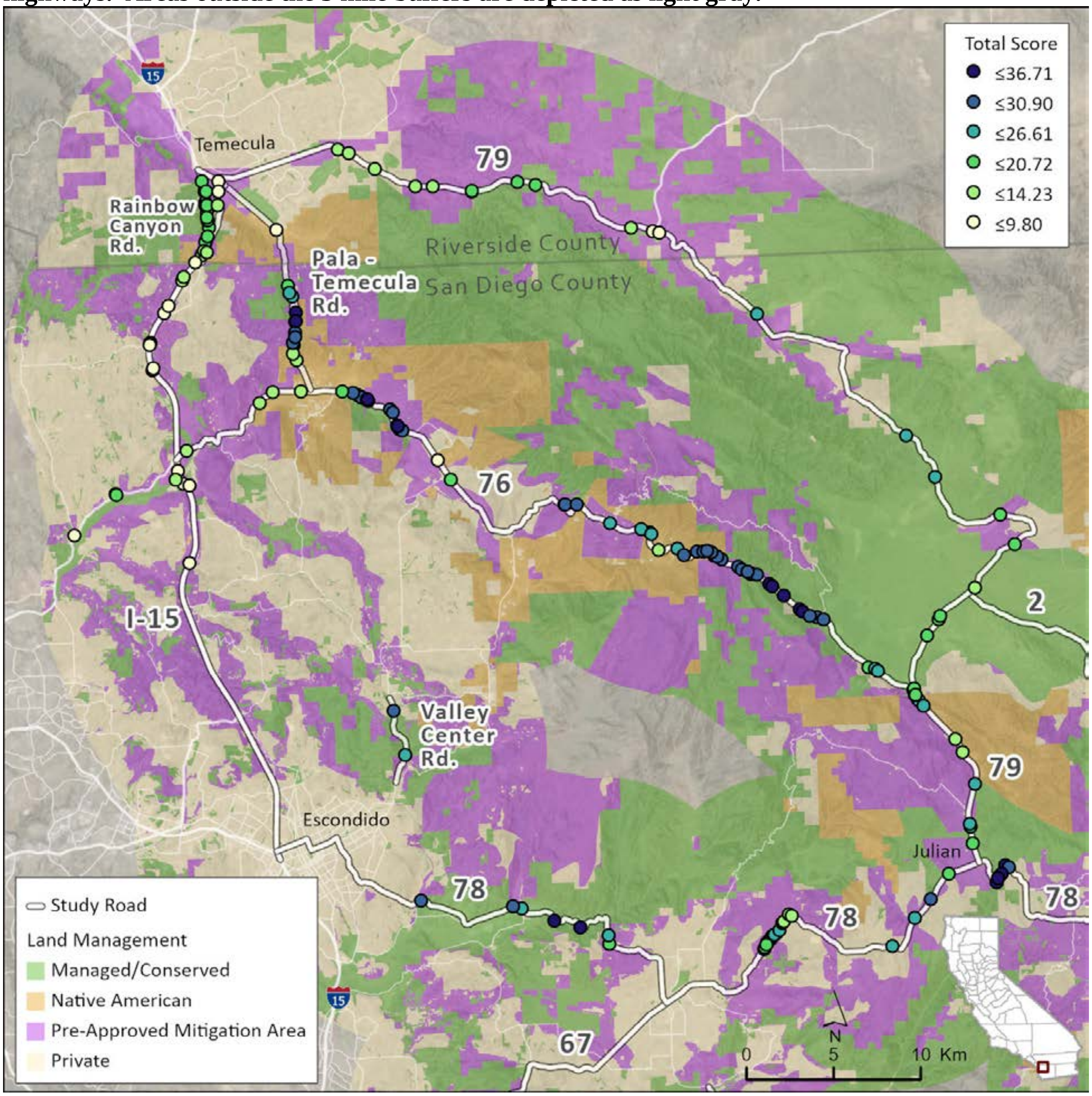
As shown by the statistical analyses done on the individual scores for both highway points and surveyed sites, various scores were correlated with each other at a variety of levels. The Project Team explored an additive method of creating a total score from individual scores as one method for taking in the totality of a site's characteristics for comparisons between them.

Descriptively, total site scores (all criteria scores totaled together) for the 185 sites had a very wide range from 6.63 to 38.23 on a scale of 0 – 60, with considerable variation in scores by individual highways (Figure 6; Map 15; Appendix C). Median Total Scores as well as the ranges of scores varied widely across the set of highways examined. The mean Total Score across all sites was 23.3, and median score was 24.05, however mean and median scores varied widely between highways, with I-15 having the lowest median score and SR 76 the highest. All surveyed site scores by characteristic, as well as total scores, are included in Appendix C.

Figure 6. Box plots of Total Scores (all six scores combined for all 183 examined sites – two sites were not scored on all parameters) for each road in the study. Each box represents the middle 50% of scores for examined sites along that highway. The median score is represented by the horizontal line in the box, with the quartiles above and below the median above and below the line. The upper and lower quartiles are represented by the "whiskers" above and below the box. Individual dots represent significant outliers. Numbers of sites documented for each highway are noted above each boxplot.



Map 15. All potential crossing sites that were examined by Total Score (Conservation+Habitat+Resource+Movement+Activity+Observation scores). Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Prioritization of sites across the region for maintenance or improvement of mountain lion connectivity:

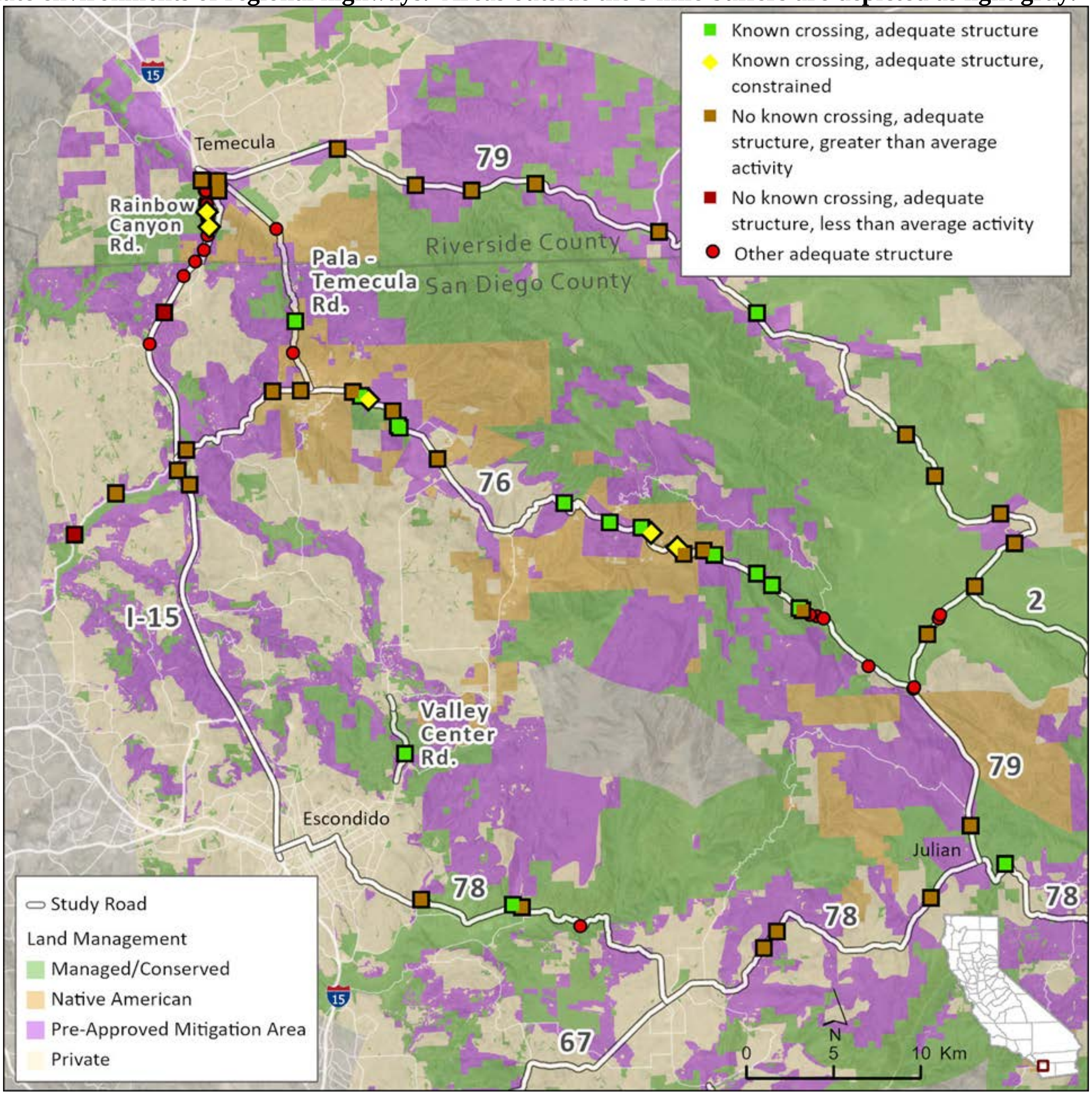
After analysis and consideration of all of the data and efforts to date, the Project Team's prioritization of sites for potential modifications by highway agencies is broken into two areas of focus. One focus area is I-15, and the most likely sites for improvement via infrastructure change are well documented in Riley et al. 2018-Appendix A and the CPP Team report (Appendix G), and are reinforced by the Activity and Movement Scores detailed earlier in this report.

Sites and sections of highways to consider for prioritization for improvement / modifications are across the broader region may be considered in a variety of ways due to the amount of data available. The UCD-TNC teams looked at prioritization in numerous ways and we list two different prioritization schemes below with broad recommendations. However, with Appendix C to this report, made up of an Excel workbook containing all the data and a variety of characterizations, any highway or other Agency personnel may parse the data in whatever way they find most appropriate for their particular interests or goals.

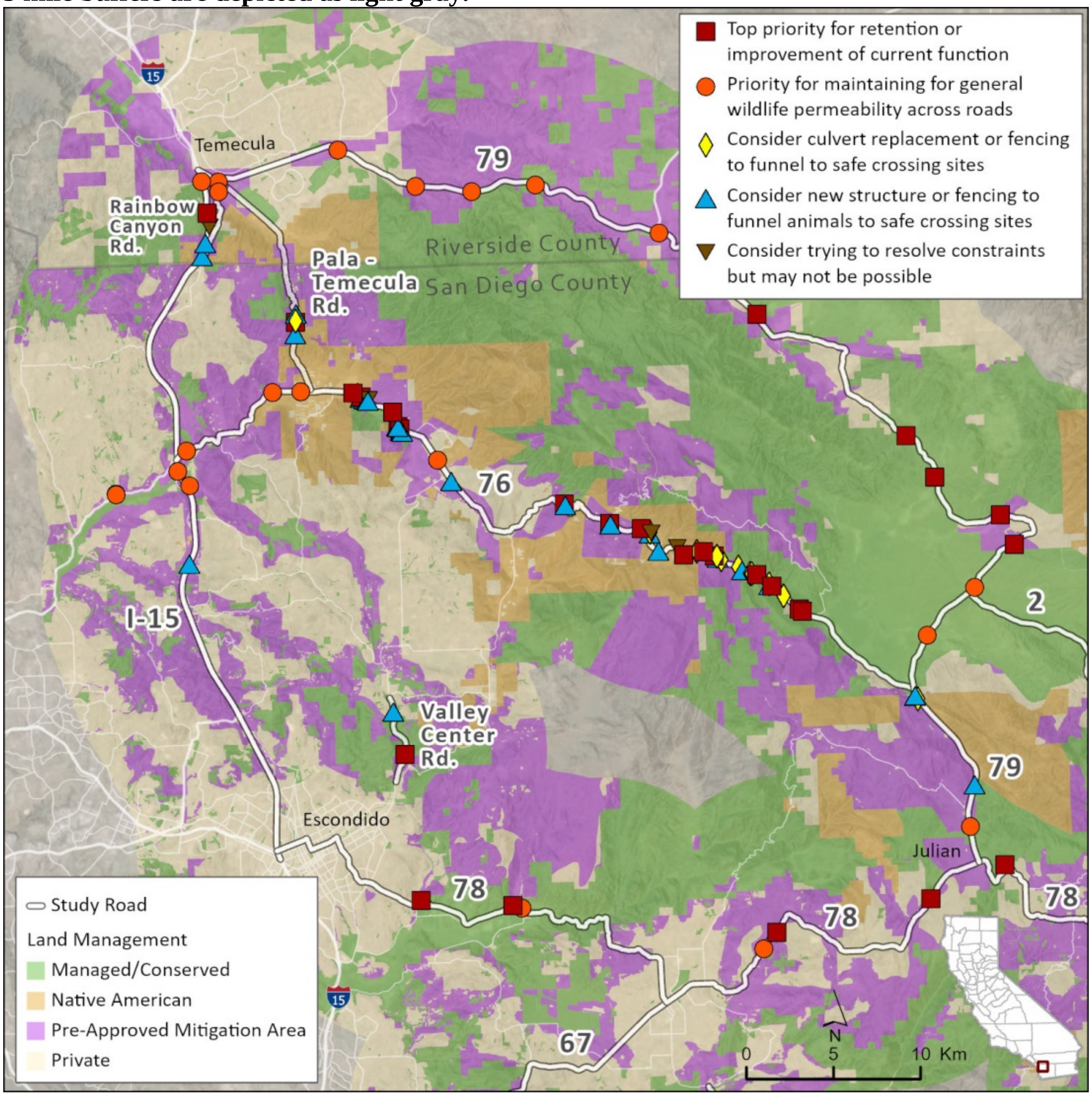
Our first method for characterizing the sites overall as to most important to long term mountain lion connectivity focused first on where mountain lions had crossed roads or had high Activity and Movement scores, and eliminated sites that had no known crossings and lower than average scores. This left 98 sites to prioritize, broken into four groups as listed below (Maps 16, 17; Table 6).

1. Sites where mountain lions are known to have crossed or attempted to cross highways, adequately sized crossing infrastructure is present and maintenance activities or fencing can improve function (n = 17).
2. Sites where mountain lions have not been documented as crossing or attempting to cross, but adequate infrastructure is present and activity and movement scores are above the average score of sites where crossings had occurred (n = 12).
3. Sites where bridges are present but activity and movement scores are below the average for sites where crossings have occurred (n = 21).
4. Sites where mountain lions are known to have crossed or attempted to cross highways, and adequate crossing infrastructure is NOT present or is too small (n = 48). New infrastructure should be considered at these sites as culvert or highway projects are planned, and fencing is indicated to funnel mountain lions and other wildlife to those structures.

Map 16 – Sites where known crossings and high crossing potential exists with infrastructure noted. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



Map 17 – Recommendations for actions at different sites. Conserved, Native American, and PAMA lands, along with Private lands outside PAMA's, and larger regional highways depicted. Five mile buffers were created around each highway to better define the immediate environments of regional highways. Areas outside the 5 mile buffers are depicted as light gray.



A second method of characterization of the sites relative to long term mountain lion connectivity across the region utilized all 183 sites that had scores on all parameters. This method focused on types of infrastructure, with known crossings, and Activity and Movement scores then factored in. This method is meant to focus a bit more on infrastructure status to assist highway agencies in assessing the types of measures to consider over time by highway, and breaks the sites into 6 groups (Table 7; Appendix C, “Priority based on structure and crossing-Activity-Movement scores” – Column D; Map 18).

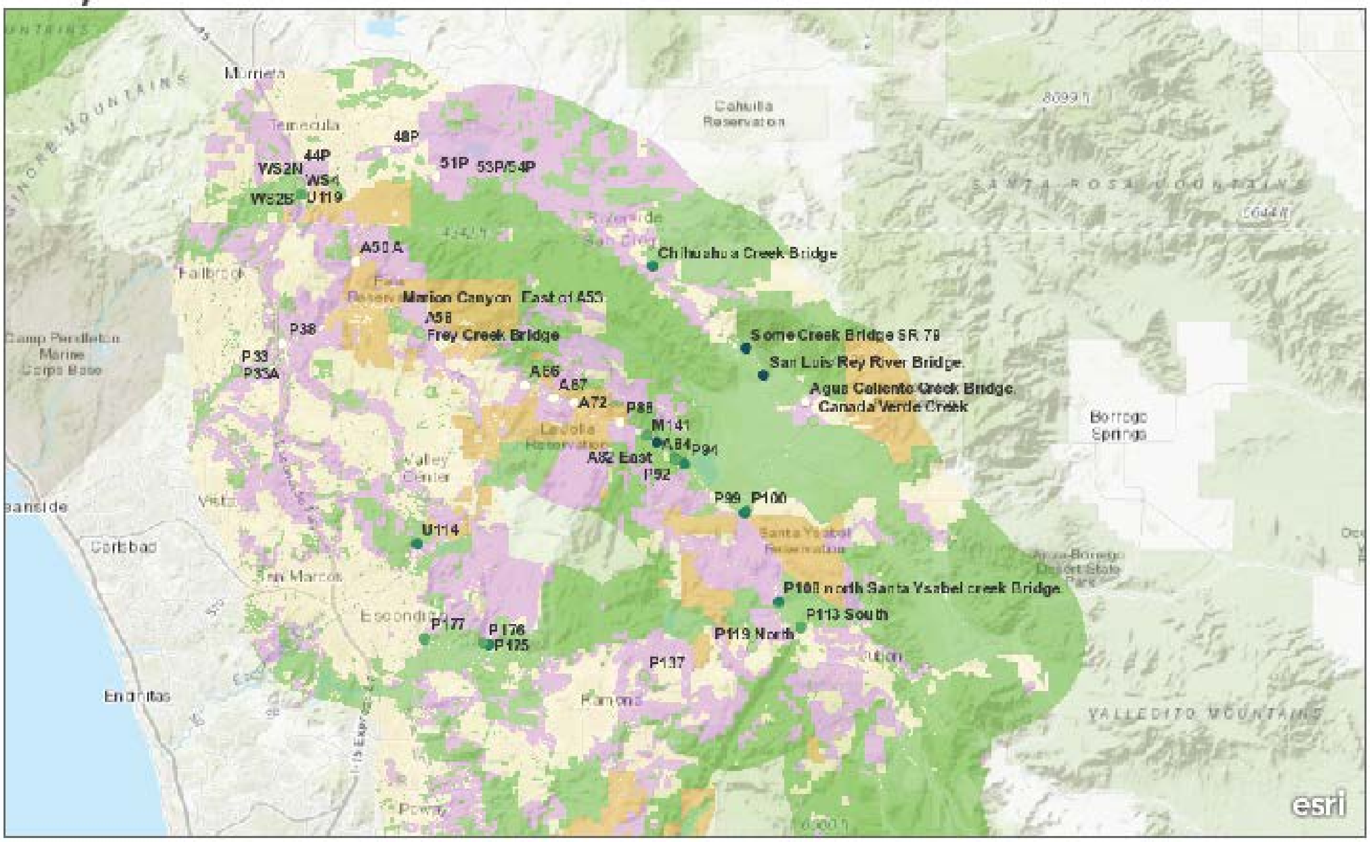
1. Sites with adequate infrastructure for mountain lion crossing and known crossings or Activity and / or movement scores indicate likely use of those sites in the future (n=39) – First priority for fence construction, driver slowing, and enhancement of culvert size where needed (sites on I-15 especially) – prioritize sites with high conservation scores and increase conservation where indicated to maintain long term connectivity (Map 18).
2. Sites where adequate structures exist but mountain lion activity is lower (n=14) – Increase conservation where indicated to sustain connectivity for other wildlife and occasional mountain lion use long term, second priority for fencing if known crossing sites or high Activity or Movement sites nearby.
3. Known mountain lion crossing sites but small culverts or constrained large culverts present – Improve or replace culverts with larger structure, or add fencing if adequate crossings nearby (n = 16) – prioritize sites by conservation levels. Alternatively other steps to slow and warn drivers. Prioritize by conservation level. Increase conservation where indicated.
4. Known mountain lion crossing or high activity but no culvert present (n=48) – Install culvert or add fencing if adequate crossings nearby – prioritize sites by conservation levels. Alternatively other steps to slow and warn drivers. Increase conservation where indicated.
5. Higher than average mt lion activity with constrained large or small culverts (n = 37) – Install culvert or add fencing if adequate crossings nearby – prioritize sites by conservation levels. Alternatively other steps to slow and warn drivers. Increase conservation where indicated.
6. Low mountain lion activity and no infrastructure present (n = 31) – no infrastructure additions needed, but conservation where indicated by habitat and resource use scores.

As noted above, within these groups, any consideration of infrastructure expenditures should be guided by the conservation status of the site, and sites with high conservation scores, conserved lands adjacent to the highway on both sides, and positions within wildlife movement corridors should have highest priority. Map 18 below illustrates Group 1 above (Table 8). Maps denoting the other groups and closer views of the highways and sites are included in this report as Appendix H.

Map 18. Group 1 priority sites. Adequate infrastructure is present (bridges or larger culverts that are unconstrained) and either known crossings occurred at those sites or they have high Activity and / or Movement scores

4/13/2020 ArcGIS - Survey Locations 2020

Survey Locations 2020



Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

https://www.arcgis.com/home/webmap/print.html 1/1

As examples of the different methods for site prioritization that may be utilized, and the value of Appendix C for sorting and exploring the data, the highest priority sites by each method listed above were generated to create Tables 6 and 7 below with some of the site characteristics and Team recommendations. Other characteristics can be chosen and recommendations are general as examples. The Appendix C database can be sorted as desired by the user. For the purposes of prioritization for actual highway infrastructure improvement, we want to again emphasize that the Conservation scores are key to determining which site improvements can be expected to provide the greatest bang for the buck in the long term, as well as the positioning of the site relative to larger blocks of conserved lands and wildlife movement corridors (Appendix B).

Table 6. Site prioritization. Method 1 – Crossings focused (n=99; Maps 16, 17) . Sites are ordered by highway and site name.

Site class	Recommendations	Road	Location ID	Latitude	Longitude
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	15	44P	33.47461538	-117.1388515
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	15	M186/M178	33.43657533	-117.1399229
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	15	M188/M181	33.44322561	-117.1377883
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	15	P33	33.31416249	-117.1973889
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	15	P33A	33.31384046	-117.1972822
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	15	P35	33.3173684	-117.15186
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	15	P36	33.3249777	-117.1589307
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	15	U088	33.2774253	-117.1535162
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	15	U119	33.45824154	-117.1360886
Known cross, adeq culvert size but constrained	Consider trying to resolve constraints but may not be possible	15	U148	33.45049524	-117.1349769
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A52	33.361588	-117.04683
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A53	33.360732	-117.045048
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A54	33.359834	-117.042557
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A55	33.359279	-117.041036
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A56	33.359057	-117.040518
Known cross, adeq culvert size but constrained	Consider trying to resolve constraints but may not be possible	76	A57	33.35863515	-117.0401269
Known cross good bridge	Top priority for retention or improvement of current function	76	A58	33.3446497	-117.0225002
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A59	33.345436	-117.023
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A60	33.3450154	-117.022768
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A61	33.344969	-117.022844
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A62	33.342892	-117.020801
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A63	33.34278	-117.02059
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A64	33.342425	-117.019944
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A65	33.316105	-116.990787
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	A66	33.30179	-116.921578
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	A67	33.291041	-116.894036
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A68	33.291057	-116.893708
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A69	33.285747	-116.869431
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A70	33.285713	-116.869582
Known cross, adeq culvert size but constrained	Consider trying to resolve constraints but may not be possible	76	A71	33.284891	-116.868786
Known cross good bridge	Top priority for retention or improvement of current function	76	A72	33.287803	-116.874689
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A73	33.276507	-116.864621
Known cross, adeq culvert size but constrained	Consider trying to resolve constraints but may not be possible	76	A74	33.276917	-116.852956
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A75	33.275064	-116.84103
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A76	33.272024	-116.828399
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A77	33.270357	-116.826143
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A78	33.266302	-116.815741
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A79	33.265059	-116.813624
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A80	33.262711	-116.808646
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A81	33.262551	-116.807641
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	A82	33.25689	-116.79712
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	A82 East	33.25576	-116.795534
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	A83	33.250568	-116.788538
Known cross good bridge	Top priority for retention or improvement of current function	76	A84	33.24342099	-116.7791528
Known cross good bridge	Top priority for retention or improvement of current function	76	A84	33.243361	-116.779148
Known cross good bridge	Top priority for retention or improvement of current function	76	Frey Creek Bri	33.34350716	-117.0214014
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	M141	33.262022	-116.804604
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	Marion Canyo	33.36060079	-117.0446941
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	76	P38	33.33540286	-117.15317

Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	76	P73	33.36436884	-117.0990536
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	76	P74	33.36429222	-117.0816852
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	76	P76	33.362792	-117.049602
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	76	P77 east Alice	33.35218993	-117.0254305
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	P78	33.345021	-117.022491
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	76	P79	33.326685	-116.998726
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	P80	33.301803	-116.921047
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	76	P82	33.291083	-116.893642
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	P83	33.275064	-116.84103
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	76	P84	33.273493	-116.849138
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	76	P85	33.274884	-116.836912
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	76	P88	33.272454	-116.830402
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	P89	33.272196	-116.82876
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	76	P91	33.256998	-116.797222
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	76	P92	33.242231	-116.777276
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	78	P113 South	33.107356	-116.658182
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	78	P119 North	33.091138	-116.704499
Adeq size culv, min constr, > avge activity + mov score bas	Top priority for retention or improvement of current function	78	P128	33.076401	-116.799703
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	78	P137	33.068118	-116.808019
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	78	P175	33.093358	-116.955672
Known cross good bridge	Top priority for retention or improvement of current function	78	P176	33.094772	-116.961148
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	78	P177	33.098957	-117.017383
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	48P	33.48877543	-117.0542287
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	51P	33.4687247	-117.0069906
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	53P/54P	33.46509961	-116.9724787
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	56P	33.46747349	-116.9330188
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	79S single spa	33.440525	-116.857791
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	79	A85	33.150022	-116.675134
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	79	Agua Caliente	33.288643	-116.65354
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	Buena Vista C	33.25153	-116.67086
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	79	Canada Verde	33.273062	-116.645476
Known cross good bridge	Top priority for retention or improvement of current function	79	Chihuahua Cr	33.396817	-116.799079
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	79	P101	33.197068	-116.70989
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	P103	33.227626	-116.70104
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	79	P108 north Sa	33.127801	-116.67859
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	79	San Luis Rey R	33.30939	-116.69296
Bridge no kno cross min constraints, >avg mov+act scores	Top priority for retention or improvement of current function	79	Some Creek B	33.331278	-116.709868
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	79	U079	33.19484	-116.708119
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	79	U149	33.197209	-116.709724
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	PalaTemecula	A47	33.40533568	-117.083278
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	PalaTemecula	A48	33.40540311	-117.0832459
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	PalaTemecula	A49	33.4052667	-117.0833208
Known cross culvert too small	Consider culvert replacement or fencing to funnel to safe crossing sites	PalaTemecula	A50	33.40096049	-117.0834998
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	PalaTemecula	A50 A	33.40032217	-117.0836798
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	PalaTemecula	A51	33.39474167	-117.0839644
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	PalaTemecula	P45	33.47418178	-117.1285781
Bridge no kno cross min constraints <avg mov+act scores	Priority for maintaining for general wildlife permeability across roads	RainbowCyn	P46	33.46907138	-117.128621
Known cross - no culvert or bridge	Consider new structure or fencing to funnel animals to safe crossing sites	alley_Center_F	U108	33.197709	-117.030833
Known cross adeq culvert size no constr	Top priority for retention or improvement of current function	alley_Center_F	U114	33.174792	-117.024467

Table 7: Site Prioritization Method 2 – Infrastructure focused - Category 1 (n=39; Map 18). Other Categories can be retrieved from Appendix C, Column D "Priority based on structure and crossing-Activity-Movement scores". Sites in this table are ordered by highway and conservation score.

Road	Location ID	Latitude WGS	Lontitude WG	nservationSco	Structure type	Crossing-Activity-Movement	Recommendation
15	WS4	33.45433826	-117.1359322	3.53	Culvert - unconstrained	Movement > Avg	Priority for possible new structure
15	WS2N	33.46350232	-117.1370035	0.86	Culvert - unconstrained	Movement > Avg	Priority for possible new structure
15	U119	33.45824154	-117.1360886	0.84	Culvert - unconstrained	Known cross - Movement > Avg	Priority for possible new structure
15	WS2S	33.46211314	-117.1371078	0.83	Culvert - unconstrained	Movement > Avg	Priority for possible new structure
15	44P	33.47461538	-117.1388515	0.75	Bridge - unconstrained	Activity > avg	Priority for improvement
76	A82 East	33.25576	-116.795534	8.03	Culvert - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
76	P94	33.238765	-116.768593	7.29	Culvert - unconstrained	Movement > Avg	Consider for fencing, driver slowing
76	P99	33.199658	-116.710655	5.53	Culvert - unconstrained	Movement > Avg	Consider for fencing, driver slowing
76	A84	33.243361	-116.779148	3.9	Bridge - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
76	P92	33.242231	-116.777276	2.88	Culvert - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
76	M141	33.262022	-116.804604	2.62	Culvert - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
76	P33A	33.31384046	-117.1972822	1.51	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
76	P33	33.31416249	-117.1973889	1.34	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
76	A58	33.3446497	-117.0225002	0.93	Bridge - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
76	Frey Creek Bri	33.34350716	-117.0214014	0.78	Bridge - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
76	Marion Canyo	33.36060079	-117.0446941	0.67	Culvert - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
76	P38	33.33540286	-117.15317	0.47	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
76	A66	33.30179	-116.921578	0.13	Culvert - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
76	A72	33.287803	-116.874689	0	Bridge - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
76	A67	33.291041	-116.894036	0	Culvert - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
76	P88	33.272454	-116.830402	0	Culvert - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
78	P175	33.093358	-116.955672	4.96	Bridge - unconstrained	Activity > avg	Consider for fencing, driver slowing
78	P177	33.098957	-117.017383	4.02	Bridge - unconstrained	Activity > avg	Consider for fencing, driver slowing
78	P176	33.094772	-116.961148	3.71	Bridge - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
78	P113 South	33.107356	-116.658182	2.24	Culvert - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
78	P119 North	33.091138	-116.704499	1.44	Bridge - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
78	P137	33.068118	-116.808019	0.94	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
79	San Luis Rey R	33.30939	-116.69296	9.42	Bridge - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
79	Some Creek B	33.331278	-116.709868	9.28	Bridge - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
79	P100	33.200403	-116.710356	5.98	Culvert - unconstrained	Movement > Avg	Consider for fencing, driver slowing
79	P108 north Sa	33.127801	-116.67859	5.34	Bridge - unconstrained	Activity > avg	Consider for fencing, driver slowing
79	Chihuahua Cr	33.396817	-116.799079	5.3	Bridge - unconstrained	Known cross - Activity and Movement > Avg	Consider for fencing, driver slowing
79	53P/54P	33.46509961	-116.9724787	1.99	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
79	Canada Verde	33.273062	-116.645476	0.63	Bridge - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
79	Agua Caliente	33.288643	-116.65354	0.48	Bridge - unconstrained	Activity and Movement > avg	Consider for fencing, driver slowing
79	48P	33.48877543	-117.0542287	0.06	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
79	51P	33.4687247	-117.0069906	0	Bridge - unconstrained	Movement > Avg	Consider for fencing, driver slowing
PalaTemecula	A50 A	33.40032217	-117.0836798	0.58	Culvert - unconstrained	Known cross - Activity > Avg	Consider for fencing, driver slowing
alley_Center_I	U114	33.174792	-117.024467	4.92	Culvert - unconstrained	Known cross but Activity and Movement < Av	Consider for fencing, driver slowing

I-15 Camera and Engineering Assessment:

The part of the overall study that was focused specifically on I-15 was in addition to the site exams described above. The I-15 portion of the study was focused on the section of I-15 between Temecula and the intersection with Mission Road. This section of highway, especially the section in Riverside County from Temecula to the border with San Diego County, has been the focus of study for many years in relation to possible infrastructure improvement or new construction for wildlife. Recent information suggestion that the genetic restriction of mountain lions on the west side of I-15 in the Santa Ana Mountains puts that population at risk of extirpation has given new urgency to these assessments.

To that end all potential crossing sites along the approximately 7 mile stretch of the freeway from the Temecula Creek Bridge to the intersection with Mission Road were examined and characterized (n = 31) with the same scoring system as was utilized for other sites, but in addition camera studies were conducted at all the sites, and an extensive effort was undertaken with the Cal Poly Pomona Civil Engineering Department to assess feasibility from an engineering perspective of infrastructure change or new construction in that section.

Monitoring of the existing large culverts under I-15 and adjacent drainages and conserved lands, as well as the Temecula Creek Bridge area, with trail cameras (n = 41 locations) for a total of 7,568 camera nights was also done during the study, and cameras confirmed periodic mountain lion activity at 7 camera locations on 10 occasions (Table 8; Appendix F). Camera sites that recorded mountain lion activity included ones near the Temecula Creek Bridge (west side), within meters of the roadway at several locations on either side of the freeway between the Temecula Creek Bridge and the Border Patrol Check Station just north of the County Line, and on conserved lands (TNC's Rainbow Property) abutting the freeway on the east side (Table 8, Map 19, Appendix F). Pictures 2 and 3 below are example pictures from the cameras.

In addition, a young male mountain lion was killed by a car in late December 2018 during the study period very near several of the potential crossing points and locations where cameras had recorded mountain lions earlier in the same month (Table 8, Map 19). That individual was designated M233 for study purposes and has had DNA sampling done to determine whether his genetic origin was from the population east or west of I-15. That information will be known late in 2020.

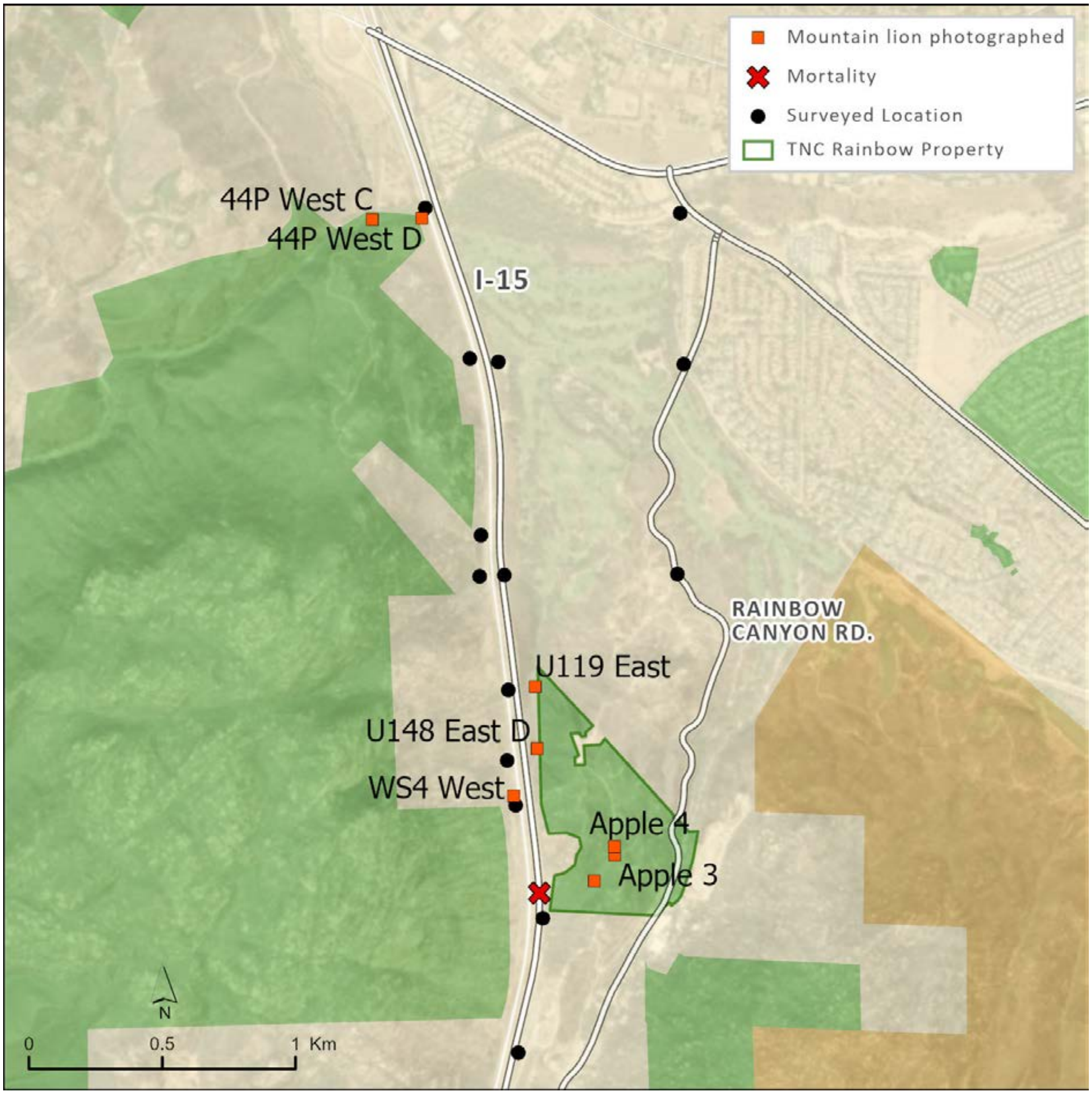
Picture 2. Mountain lion looking into I-15 culvert at site WS4 from the west side

Picture 3. Mountain lion on the TNC Rainbow Property adjacent to the east side of I-15

Table 8 – Sites where mountain lions were photographed along I-15

Site Name	General area	Latitude	Longitude	Number of mountain lion events	East or West Side of Highway
44P West C	SMER Gate	33.47428	-117.14068	1	West
44P West D	South trail closest to bridge	33.47427	-117.13932	1	West
WS4 West	I-15 West culvert	33.45466	-117.13611	1	West
U148 East D	Creek bed	33.45624	-117.13495	1	East
U119 East	East Creek bed/Culvert	33.45833	-117.135	1	East
Apple 3	TNC Rainbow Property along road	33.45256	-117.13515	4	East
Apple 4	TNC Rainbow Property along road	33.45284	-117.13204	1	East
M233 mortality site Dec 2018	I-15 near WS4	33.45141	-117.13520	1	
Apple 5	TNC Rainbow Property in Ravine	33.45172	-117.13281	1	East

Map 19 – Locations where mountain lions were photographed along I-15 between December 2018 and March 2020, and location of the December 2018 mountain lion mortality (M233). The TNC Rainbow Property that was purchased in order to have conserved land on both sides of I-15 at a viable location for a potential new crossing structure is outlined in green on the east side of the freeway. Several of the mountain lion photos have been taken on that property.



Cameras also recorded the presence of numerous other wild mammal species at the monitored locations (striped skunk *(Mephitis mephitis*), spotted skunk (*Spilogale gracilis),* bobcat *(Lynx rufus),* coyote *(Canis latrans),* grey fox *(Urocyon cinereoargenteus),* raccoon *(Procyon lotor),* ringtail (*Bassariscus astutus),* cottontail rabbits (*Sylvilagus audubonii*), various rodents and birds, and one beaver

(*Castor canadensis*) near existing culverts or the Temecula Creek Bridge in over 700 photos (Appenidx F). Striped skunks, bobcats, and gray foxes were especially common at those locations.

Interestingly, no mule deer were recorded on any of the cameras, including those in Temecula Creek under the bridge and elsewhere along the creek bed. Very few of the wild animals photographed at culvert mouths along I-15 were photographed moving into or through the culvert. At some culverts the numbers of photos of certain species were substantial and dramatically different at the west and east end of the culverts. In the vicinity of the Temecula Creek Golf Course, for instance, photos of bobcats and coyotes were common at the east end of the culverts, but much less common at the west ends. In the same area, pictures of gray foxes were much more common at the west end of those culverts versus the east end.

Nearly all culverts along I-15 in the study area are either sharply slanted at some point in their course or deviate in some other way from a straight through alignment. Thus, the ability to see through to the other end, generally a necessary prerequisite for culvert use by wildlife, is rarely present. However, our cameras did record a number of instances where smaller animals appeared to move through the culverts despite their limitations. Raccoons were the most common species to seem to move completely through a culvert, perhaps because of their inquisitive and relatively bold nature.

Occasional anecdotal reports of roadkill of species like coyotes on I-15 in the study area were received by the study team during the study period but Caltrans does not keep data related to that at this time, so we were unable to confirm frequency of roadkill events involving species other than mountain lions.

Humans were detected on camera (both during the day and the night). The majority of the photos of humans were in Temecula Creek in the Bridge area (moving along the creek on either side of the bridge or under the bridge structures). Some of these humans were legitimate in their presence at these locations (Caltrans workers, researchers, etc. during the day) but many represented trespassers that would be expected to reduce wildlife activity in those crossings due to their presence at all times of the day and night. The human presence at night would especially be expected to reduce wildlife use of that crossing point. Human presence in the crossing area under the Temecula Creek Bridge has diminished over the time of the study due to concerted efforts by personnel from multiple agencies and entities to reduce trespass in that area.

Cameras deployed on the other highways in the study at larger crossings were operated for shorter periods due to the number of study sites, and were focused on the largest and most likely crossing points for the largest array of species (bridges and very large culverts). Those cameras captured pictures of mountain lion, bobcat, coyote, grey fox, other mesocarnivores, and deer using crossing structures (Appendix F). As with the I-15 cameras, humans were detected on camera (both during the day and the night) at times, with some presence in the middle of the night. As with the Temecula Creek Bridge, some of these humans were legitimate in their presence at these locations (Caltrans workers, researchers, etc. during the day) but many represented trespassers that would be expected to reduce wildlife activity in those crossings due to their presence.

California Polytechnic University – Pomona Project Findings:

The CPP portion of the project was undertaken in concert with the UCD and TNC teams, and their report was completed by CPP students and faculty in May of 2019. It is included here as Appendix G. A presentation of the work by the students involved can be seen here:

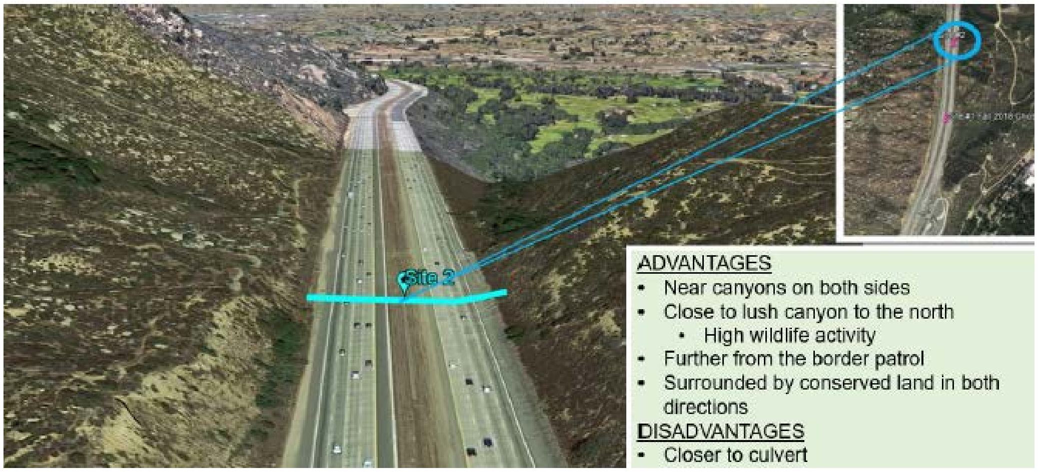
https://streaming.cpp.edu/media/0_nxln5xps

The website the students created for the project can be seen here:

and https://i15wildlifecrossing.wixsite.com/calpolypomona

The CPP teams found that new crossing structures (a large culvert or a wildlife bridge) were technically feasible for construction just north of the Border Patrol check station near the Riverside-San Diego County Line (Figures 7 – 10). The most feasible locations for construction of either an overcrossing or undercrossing structure are at or very near the WS3, WS4, WS5-Center, and U148 sites. These location choices are also supported by the GPS and photo evidence of mountain lion activity in that area. (Appendix G; Table 8; Map 18) and light measurements (Map 19). Additionally, specific modifications of Temecula Creek and the Temecula Creek Bridge, including sound dampening measures that were indicated by Dr. Collins's work (Figure 11; Table 7) were proposed by the CPP teams to improve function of that passageway. Detailed descriptions of the CPP Team's proposed new structures and bridge modifications, as well as preliminary cost estimates, are included in the full CPP technical report that is incorporated here as Appendix G.

Figure 7. Site projected by the CPP team to be the best site for a new wildlife overcrossing. View is looking north – the Temecula Creek Golf Course is visible on the right side of the Freeway upper portion of the Figure (east side of the Freeway)



Figures 8 and 9. Preferred designs for an overcrossing structure

Figure 10 – Preferred alternative for a new undercrossing structure type – a 12x12 ft concrete box structure to be installed just to the north of the proposed site of an overcrossing.

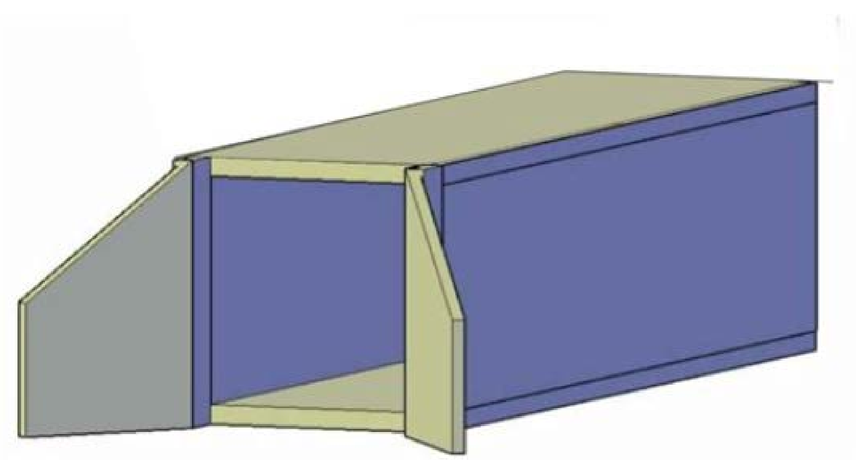


Figure 6.2. *Concrete Box Culvert Design.*

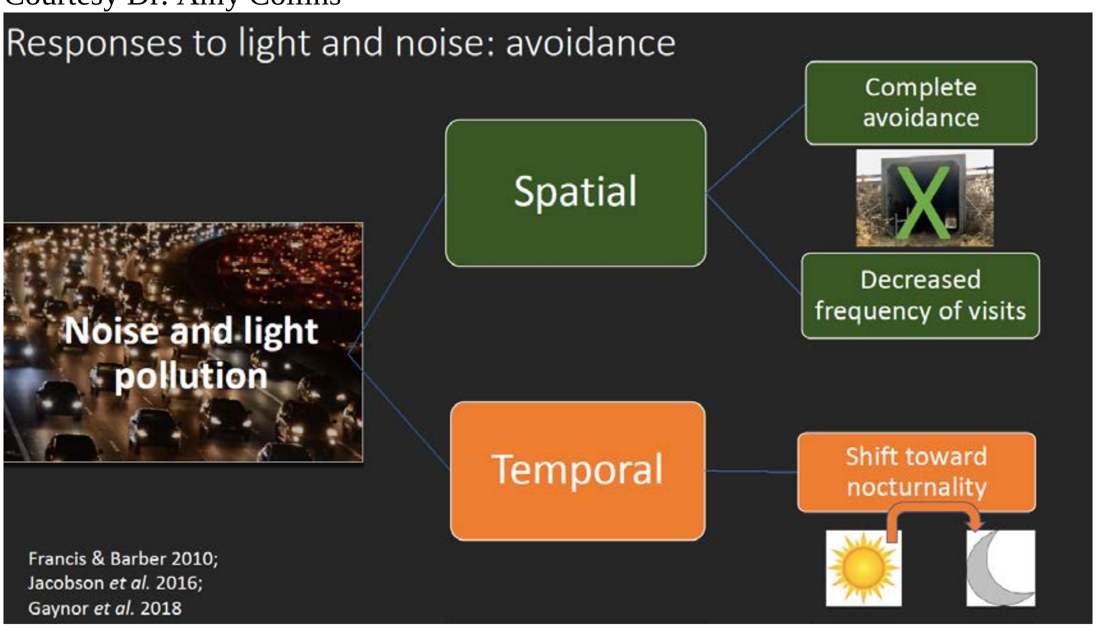
Discussions are ongoing with Caltrans and other entities exploring options (further engineering, funding, etc.) for construction of a new crossing structure at one of the sites identified by the CPP Team

The CPP Team's recommendations and those of others have been incorporated into a proposal by the TNC team that has been funded to complete plans, specifications, and associated environmental permitting for modifications of the Temecula Creek Bridge, habitat restoration in Temecula Creek, and construction of new fencing. That project will start in July 2020.

Light and Sound Measurements:

Light and noise have been recognized for many years as contributors to the negative effects of highways on wildlife (Figure 11).

Figure 11. Impacts of sound and light on wildlife.
Courtesy Dr. Amy Collins



Dr.'s Collins, Shilling, and Longcore are continuing to analyze and report preliminary data from their study of sound and light levels at some of the crossing sites in the study – along I-15 as well as several other highways in the region. Some preliminary findings have been reported by Dr. Collins in abstract and thesis form, and by Dr. Shilling in report form to Caltrans. Some highlights from that reporting include that in our study area as well as other portions of California, wildlife exhibit spatial and temporal avoidance of noisy underpasses, wildlife species richness declines near noisy highways, and wildlife exhibit temporal avoidance of bright underpasses.

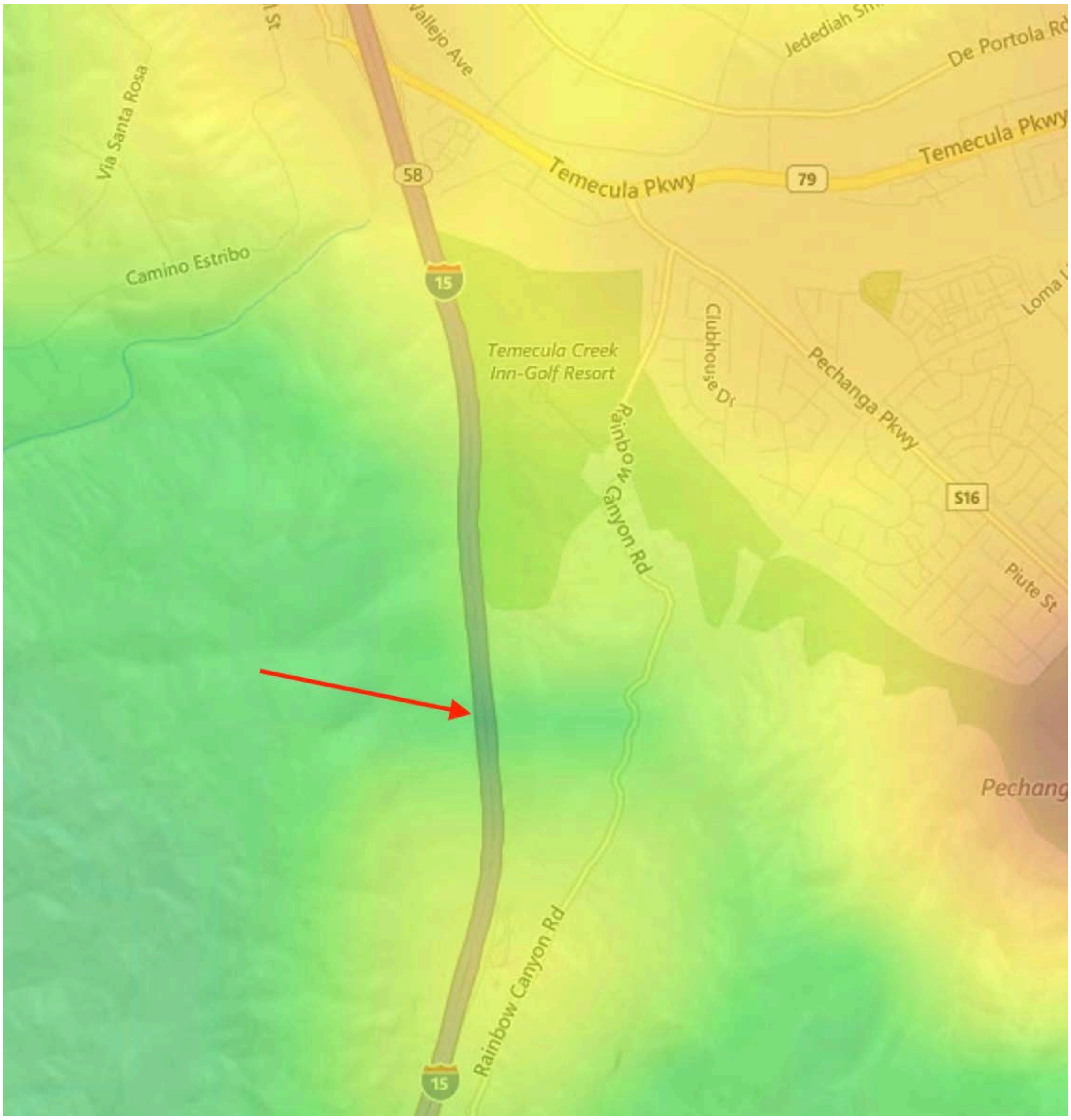
On I-15 specifically, mean and median sound levels measured under the Temecula Creek Bridge were very close to those measured level with the traffic beside the freeway itself (Table 6). Peak levels especially in the dbc range went above 90 db at times. Since measurements were taken underneath the bridge where normally some sound dampening would be expected to occur because of being below the level of the traffic, this suggests that amplification is likely occurring in that location due to the bridge structure itself. Sharp spikes in sound occur when large trucks or loud motorcycles go overhead which can startle animals away even if they have become accustomed to a loud drone of steady traffic. Sound levels measured at the mouths of existing culverts south of the bridge were generally lower since those are below the level of the road and to some degree sheltered from road sound by embankments. Sound levels were still high though on approaches to these culverts from the hillside above (Table 6)

Table 7 – Sound measurements at sites along I-15. A. Collins unpublished data.

Site	noise level	median (L50)	mean	min	max	l90	l10	l1	var
highway I-15	dba	72.4	72.601236	62.2	82.1	69.1	76.5	80.4	9.83102
temecula creek bridge	dba	68.2	68.057656	59.1	78.3	65.5	70.4	72.5	4.129617
ws2 south	dba	59.9	59.864663	56	64.2	57.7	62.1	63.725	2.875303
ws2 south approach level with road	dba	64.4	64.744804	55.7	82.1	60.7	69.08	77.128	13.451
ws3 north	dba	61.3	61.588235	54.9	78.6	58.6	65.2	70.498	7.686845
ws3 south	dba	61.6	61.682921	57.4	72.6	58.9	64.37	69.6	5.829062
ws3 south approach level with road	dba	71.2	71.016154	65.2	80.1	68.4	73.4	76.322	4.196988
highway I-15	dbc	81	81.173953	68.9	93.1	77.3	85.7	89.7	11.63755
temecula creek bridge	dbc	78.4	78.749446	67.1	91.7	74.3	83.7	87.3	13.18695
ws2 south	dbc	70.5	71.07506	65.5	81	67.9	75.3	78.8	8.144376
ws2 south approach level with road	dbc	71.65	72.071101	64.2	87.8	67.5	77.3	83.195	15.24385
ws3 north	dbc	77.7	77.8681	73.7	89.4	74.9	81.09	86.4	6.203855
ws3 south	dbc	75.6	75.676485	69.4	88.4	71.86	79.34	84.282	9.225078
ws3 south approach level with road	dbc	77.8	78.391774	72.2	95.4	74.6	82.6	89.708	11.93009

Preliminary measurements of light have been done along I-15 at some of the crossing sites we have evaluated, but additional measurements are ongoing and analyses will be completed and reported later in 2020 and 2021. Map 19 illustrates one tool for measuring light remotely and inferring potential impacts, though light level measurements at ground level are also necessary to properly evaluate the levels of light that the animal is perceiving.

Map 19 – Measurement of light along I-15 in the study area from space. Areas with the most light are the most yellow to white, and areas with less light are more green to blue. The red arrow indicates the area of lowest light along that section of freeway as seen from space. This location corresponds to the area of I-15 where new crossing structures have been proposed in the CPP report (Appendix G), as well as the portion of the highway where mountain lion activity has been confirmed by trail cameras near the highway on both sides.



Task 3 (NCCP-LAG):

Trish Smith of TNC and Winston Vickers of UCD have been coordinating and communicating with Caltrans and other stakeholders to share preliminary results of all Tasks under both LAG and SANDAG funding. Trish Smith of TNC has coordinated multiple meetings of stakeholders in relation to connectivity planning for I-15 and across the region.

In addition, Caltrans engineers and biologists, wildlife agency personnel, various experts, and local stakeholders have been invited to attend presentations and workshops where the CPP Teams presented their information at various points during the development of their I-15 Connectivity Improvement Plan. In November, 2018 TNC, with funding donated by Boeing, organized a full day workshop at Cal Poly Pomona where wildlife crossing design experts from throughout North America as well as local stakeholders received presentations from and provided input to the CPP teams on their preliminary crossing design concepts.

TNC also organized a meeting of Caltrans engineers and planners and the CPP teams in February 2019 to provide additional input, direction, and advice on crossing designs and engineering feasibility studies. The students final presentation to Caltrans was conducted at the CPP School of Engineering Open House in May 2019, where the CPP project received 2nd Place among more than 70 engineering projects presented. The CPP team also made a presentation to the Tri County Inter-Agency Working Group in April 2019 along with presentations from Dr. Vickers and Justin Dellinger with DFW, who gave an update on statewide mountain lion genetics. Dr. Vickers made an additional presentation to the Tri County Inter-Agency Working Group in November 2019.

Dr. Vickers also presented preliminary study findings to the San Diego Management and Monitoring Program meeting in August of 2019 and the SANDAG Environmental Mitigation Program Committee in September 2019. Several other presentations of findings so far have been done, including a talk to an audience at the International Conference on Ecology and Transportation in September, 2019 by all three principals in this study – Trish Smith, Winston Vickers, and CPP faculty Wen Cheng.

As part of stakeholder engagement for this project, TNC convened a Steering Committee made up of representatives of SDSU, Sierra Club and TNC to plan and organize regular meetings for a Santa Ana to Palomar Mountains Linkage Coalition. The Steering Committee developed a Charter for the coalition, identified invitees, and organized its first meeting in April 2019. The first meeting was attended by approximately 28 stakeholders representing various land management agencies, local jurisdictions, wildlife agencies, and local non-profit conservation groups. The first meeting focused on approving the draft charter, identifying other stakeholders to participate in coalition, and prioritizing actions for the next 18 months. The second Linkage Coalition meeting, held in December 2019, was attended by over 30 stakeholders which divided up into working groups to start identifying actions related to land protection, public outreach, and science and planning. A third meeting is planned for April 2020.

Education of the public at large is also critical in order to develop the public will to devote significant resources to mountain lion conservation via expensive highway improvements. To that end, all the members of the Project Team have conducted public outreach through personal talks to area groups, the CPP student teams presented their findings as a poster at the 2019 Urban Wildlife Conference in Portland, OR, at various public meetings, and at the final ceremony for all the engineering groups at CPP https://streaming.cpp.edu/media/0_nxln5xps, and created a website detailing the findings of their portion of the overall project https://i15wildlifecrossing.wixsite.com/calpolypomona.

Additionally a webpage and podcast was developed by TNC https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/a-path-for-mountain-lions/?src=e.dfg.eg.x.pod.F, and a documentary film series was developed by the UCD team that has been viewed online over 50,000 times at www.camountainlions.com.

Discussion:

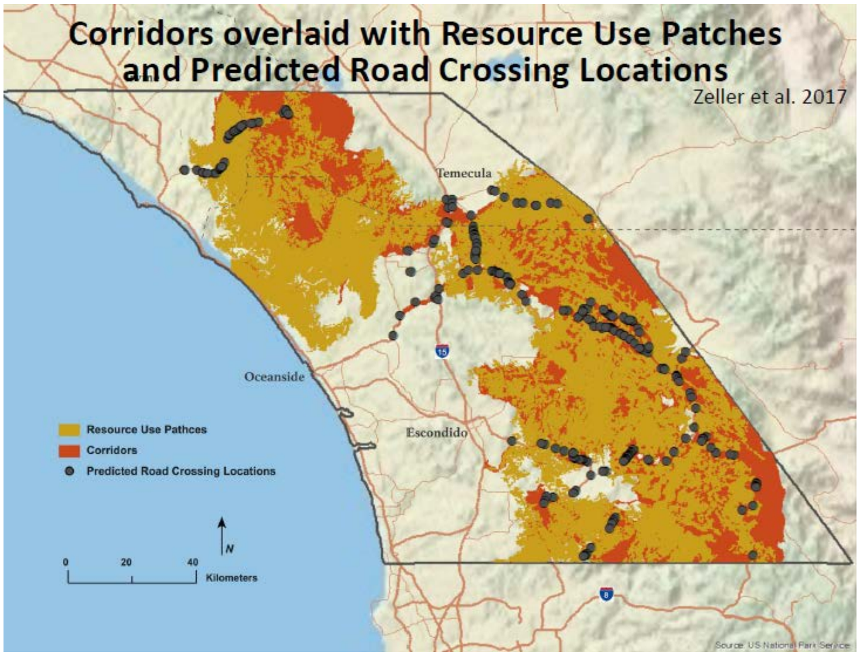
It is apparent from these findings and previous GPS collar and roadkill data that mountain lions approach I-15 from the east and the west in the corridor / linkage area relatively frequently, and that despite the high number of vehicles on that roadway, they occasionally are killed while attempting to cross at grade. Crossing structures do exist that potentially allow mountain lions to cross I-15 safely but they are constrained, in the case of the Temecula Creek Bridge by high levels of traffic noise and periodic human presence, and in the case of the larger culverts by their shapes.

The data presented here paints a clear picture that improvement is needed at the Temecula Creek Bridge and the creek environment, and that if funding could be found to create a new crossing structure north of the Border Patrol check station that it is highly likely in our opinion that mountain lions would use such a structure.

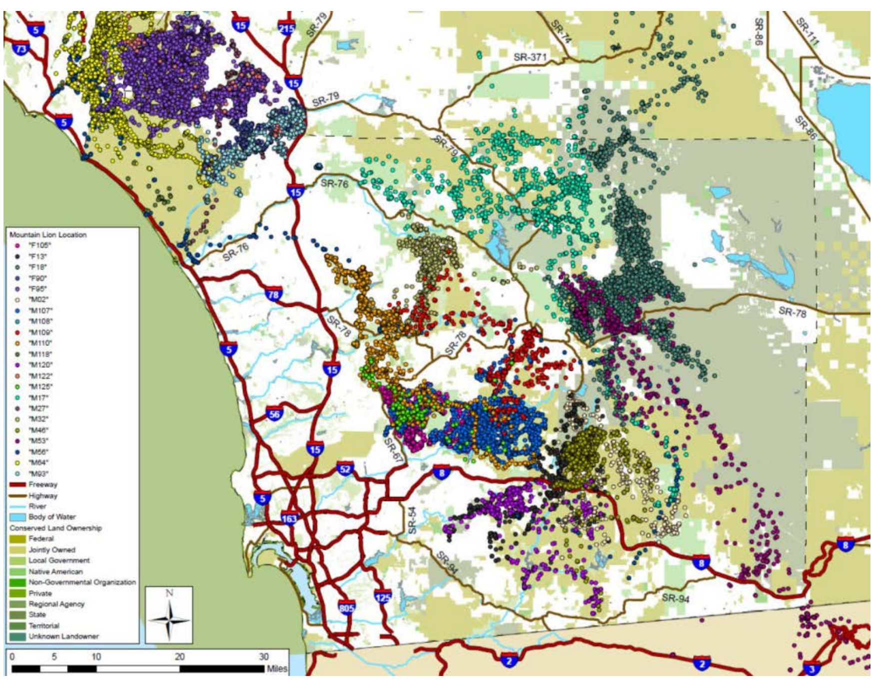
However in order for mountain lions, especially migrating young males, to reach I-15 from the east they must negotiate multiple highway barriers as detailed in this report. As is evident from this work, many crossing structures are present across the region that will accommodate safe mountain lion movement under roads, and certain sections of I-15, Pala-Temecula Rd, SR's 76, 79, and 78, and S2 are the most critical to maintain connectivity across the region for the overall movement of mountain lions between the Santa Anas and the eastern Peninsular Range. The ability for migrating young male mountain lions to move safely across the many highways in the region toward the west and I-15, as well as to the east, is essential to the potential for gene flow into and out of the Santa Anas. This gene flow is absolutely essential to the long or even medium term persistence of the Santa Anas population (Benson et al. 2019).

Map 20 below from Zeller et al. 2017 and Map 21 amply illustrate that in order for any given mountain lion to utilize the habitat and exist in this region, they must cross major highways many times each year, and take the concomitant risk each time, a risk that results in their death periodically. These risks are multiplied for dispersing young animals as they approach highways with no foreknowledge of safe crossing points. Thus the value of fencing that can help direct them to safe structures in areas where we have shown mountain lion movement across the roads to be most likely.

Map 20. Corridors and key resource use patches for mountain lions in the study area. From Zeller et al. 2917.



Map 21. Mountain lion GPS collar data and San Diego County Roads



As seen in our scoring scheme, a key in our characterization of examined sites was both the presence of adequate structures and evidence of mountain lion use or likely use based on quantified evidence (GPS collar data, camera data, roadkills, and extensive modeling based on GPS collar data). We focused on mountain lion Movement and Activity scores as the best predictors of actual road crossings occurring (as detected by high frequency GPS collar data). We found that average Movement and Activity scores were substantially higher at examined locations where crossings or attempted crossings (road kill) had occurred over time than at locations where none had been identified.

Making sure that safe crossing structures that we have identified are retained and conservation of land is increased in the area of these crossings is critical for their long term retention of function. Only 22 sites of all 183 we scored on conservation had over 50% of the land around them conserved. Conservation scores were generally low across the majority of crossing sites that we examined, with only 22 sites having more than 50% of the land around them conserved. Of the highest priority sites we identified, only 7 of 39 had over 50% conserved land around them. This suggests a need for substantially more land conservation efforts near the highway sections and sites where good crossing structures exist.

Unfortunately, land conservation takes a lot of time and investment – as well as willing sellers, and land adjacent to highways may often be more expensive to obtain for conservation purposes than land further from the roadways. These lands near highways may even be considered suboptimal for conservation efforts, but it is clear from this analysis and others that a lack of conserved lands at and near crossing sites constitutes a barrier or increased risk factor for mountain lions. As noted in the maps, many of the areas where land conservation is indicated are designated as pre-approved mitigation (PAMA) or otherwise targeted for potential conservation by Riverside and San Diego Counties. It is hoped that these findings can help with prioritization of purchases for connectivity purposes as opportunities become available.

The locations where mountain lions commonly approached highways were more likely to be at locations where no suitable crossing structures were present than where one was present, thus forcing the animals to cross the highway at grade (or not at all in the case of I-15). This increases the odds substantially that at some point a collision with a vehicle will occur, putting the animals and human drivers at risk. A recent vehicle-mountain lion collision in northern California resulted in nine human injuries, four of them serious, illustrating this point.

However, many of the locations where mountain lions had apparently crossed at grade or been killed in collisions with cars are within reasonably short distances of structures that allow safe crossing under the highway. Thus directional fencing can be beneficial for reducing the risk to both mountain lions and people, and many opportunities to use that tool exist in this study area. Fencing, when combined with some of the existing crossings, especially bridges in some areas, could diminish mortality likelihood and enhance mountain lion use of existing structures. Addition of directional fencing would be indicated to reduce roadkill potential and enhance function at virtually all of the key crossing sites, as well as discourage human presence at some sites. A six mile fencing project along SR241 in Orange County has decreased roadkill of all wildlife species by over 95%, a testament to the effectiveness of such measures if designed properly.

Due to the research and documentation that has been done in this area by our UCD Team and others, the California Department of Transportation District 8 has initiated a new wildlife exclusion fencing project to extend from the Temecula Creek Bridge to the Rainbow Canyon Road junction at the County Line with San Diego County in association with a repaving project. This project is expected to reduce wildlife-vehicle collisions in this area, as well as encourage animals to move to the Temecula Creek Bridge to cross, or possibly encourage use of the large but imperfect culverts in that section of I-15.

All evidence accumulated during this study period (camera and mortality, as well as previous mortality) suggests that any new crossing structure constructed across I-15 in the locations our UCD and CPP Teams have identified and outlined should be functional for mountain lion connectivity, and that suggested improvements to the Temecula Creek Bridge area should also enhance the likelihood of mountain lion use. To that end, funding has been secured by The Nature Conservancy from the State Wildlife Conservation Board to advance plans and specifications and associated environmental compliance required to implement riparian habitat restoration, new fencing, and sound baffling to improve wildlife movement potential under Temecula Creek Bridge. This is a good example of cooperation between the non-profit, academic, and public agencies to create better outcomes for wildlife. We applaud Caltrans for making this kind of effort that is so needed across the region.

We hope stakeholders and Agencies will use the findings of this study to help guide additional conservation activity, as well as roadway improvements, that will enhance connectivity for mountain lions and other wildlife in the region. We also hope that the start that this project has made on defining the engineering feasibility of new crossing structure construction, and the evidence that we have accumulated for its likely success if built, helps compel movement forward toward eventual construction. The planning for improvements of the Temecula Creek Bridge environment is encouraging and hopeful for eventual enhancement of its function as a safe wildlife passageway.

New/ongoing studies and efforts in the region relating to mountain lion connectivity, population stability, mortality reduction, and genetics:

Dr. Vickers and collaborators have gotten funding for a study to test and compare hair snare, camera grid, and scat dog protocols to monitor the Santa Ana Mountains puma population numbers and genetics non-invasively. This study is a collaborative effort with Dr. Jeff Manning of Washington State University, Dr. Justin Dellinger of CDFW, Dr. Mark Elbroch of Panthera, Dr. Holly Ernest and Dr. Kyle Gustafson of the University of Wyoming, Dr. Robert Fisher, Dr. Jeff Tracy, Dr. Kris Preston, and Carlton Rochester of USGS, and Trish Smith and Brian Cohen of TNC. Field work is planned for the Summer and Fall of 2020, and potentially extending into 2021. It is hoped that this collaborative effort can lead to protocols that will allow long term monitoring of the

Dr. Vickers and collaborators will also be testing behavioral responses of GPS-collared mountain lions to hazing/deterrent devices under funding from SANDAG in order to better inform owners of domestic animals how to better protect their animals. This work is in collaboration with CDFW, Dr. Manning of Washington State University, and The Mountain Lion Foundation – and is being conducted in 2020 and 2021. As part of that effort 8 mountain lions have been GPS-collared in San Diego County in the first three months of 2020.

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