U.C. Davis – Southern and Northeastern California Cougar Projects - 2019 Annual Report
January 31, 2021

Introduction / overview

This cougar (*Puma concolor*; puma, mountain lion) study is headed by Dr. Winston Vickers of the Wildlife Health Center at UC Davis. Dave Garcelon leads the northeastern California part of the study. Dr. Vickers prepared this report.

Since 2001, this study has been conducted in Orange, Riverside, and San Diego Counties in southern California south of Los Angeles, and incorporates mountainous areas including the Santa Ana Mountains portion of the Peninsular Ranges (west of I-15) and the eastern Peninsular Mountain Ranges east of I-15 (Figure 1). In late 2015, an amendment to our SCP was submitted to allow expansion of the study scope and region to study of cougar ecology and interactions with pronghorn antelope in the northeastern corner of California (Modoc, Lassen, and Siskiyou Counties) (Figure 2). This second part of our study is being conducted in collaboration with, and with the support of, Dave Garcelon and the Institute for Wildlife Studies (IWS). The SCP amendment was approved in January 2016 and trail camera monitoring and puma capture and GPS collaring activities, along with feeding site investigations, have been conducted since that time.

This current phase of our ongoing study of southern, and now northeastern, California cougars began on January 25, 2013 when we received a new 2-year Scientific Collecting Permit (SCP) from CDFW, which was renewed for 3 years in February of 2015, and renewed again for 3 years in late 2018. It is a follow-on to the first two phases of our study which ran from late 2000 to mid-2012.

In this current phase of the study, the most significant focus has been on connectivity, genetics, survival and sources of mortality, and methods of mortality prevention and connectivity improvement for cougars in southern California. In the northeastern California study area, overall predator-prey dynamics and interactions with pronghorn antelope have been the focus, along with habitat use, genetics, denning behavior, and contributing data to statewide analyses of survival and habitat selection.

Over the course of this long term study, cougars were captured, sampled, and GPS collared in Orange, Riverside, San Diego, Modoc, and Lassen Counties. In the southern CA study, capture activities had stopped in 2016, but resumed in the spring of 2020 in collaboration with Justin Dellinger of CDFW. The first cougar captured and collared in the NE CA study area was in February of 2016 and capture activities have continued yearly since then.

Our current Scientific Collecting Permit from CDFW also allows for capture and sampling activities in Imperial, San Bernardino, and Siskiyou Counties, however for that group of counties, only collection of DNA samples from deceased cougars from San Bernardino County has occurred to date.

*Goals of the study***:**

Geographic areas focused on in 2020 were:

- Northern and Western San Diego County, and southern Riverside County with special focus on the area along I-15 that is part of the primary wildlife movement corridor between the Eastern

Peninsular Range (Palomar Mountains) to Santa Ana Mountains

- The Santa Ana Mountains as whole
- The eastern Peninsular Range especially around the Volcan and Cuyamaca Mountains
- Northeastern California, with special focus on Modoc and Lassen Counties

Methods

In 2020, cougar use and movement areas were detected via scouting / tracking and placement of trail cameras in Modoc and Lassen Counties (joint UCD-IWS project), and in San Diego County (joint CDFW-UCD project). These data were used to define areas that were most promising for potential cougar capture activities.

As per our SCP, road-killed deer were collected and stored frozen for later use at bait sites. When regular cougar use of an area was detected, road-killed deer were placed at bait sites and checked daily. If cougar feeding was detected at a bait site, cage traps were set and monitored continuously via radio-transmitters affixed to the trap doors. Cameras that could transmit images from the site via cell systems were also used at trap sites if possible. Cage traps were used for the majority of captures in 2020, however hounds were used for some. Traps were checked as quickly as possible (within half an hour in almost all cases) after detection of signals indicating a cage door had closed and / or receipt of pictures indicating a cougar had entered a trap. This assured that no animal was left within a trap unattended for lengthy periods of time, minimizing the potential for self-inflicted injury within the trap.

Anesthesia drugs and dosages listed in our SCP were administered by jabstick syringe, hand syringe, or dart rifle (in the case of hound captures). Capture methods were approved by the UC Davis Institutional Animal Use and Care Committee (IACUC Permit #17233).

A wildlife veterinarian, co-PI Dave Garcelon, or Justin Dellinger or other trained CDFW biologists were present at all cougar captures, and administered or directly oversaw administration of all anesthesia, conducted and oversaw anesthetic monitoring, conducted all physical exams and sampling, and fitted all GPS-collars. Various students and wildlife biologists had opportunities to participate in captures as data recorders or other roles. We have been complimented on our attention to the well-being of the animals by the UC Davis Institutional Animal Care and Use Committee, and we feel that we have helped to set the standards of “best practices” for mountain lion captures and research.

Each animal captured had blood samples taken for assessment of exposure to infectious disease or toxins, and genetic analysis. Nasal, pharyngeal, and rectal swabs were taken in some cases for additional assessment of disease presence, especially viral entities such as influenza, and microbiome analysis. Fecal samples were taken for assessment of intestinal parasites if possible, and a whisker was taken from most animals for other analyses.

Animals were examined, measured, weighed, ear tagged, and tattooed with their individual study ID number in one ear (unless anesthetic considerations dictated not completing one or more of these items). GPS-collars were applied if body weights exceeded 50 pounds, though in the case of some young males

above that weight collars were not placed because of an absence of available 6 month drop-off units. Cougars were released at the site of capture after recovery from anesthesia.

All data acquired to date from GPS–collared cougars in southern California is being curated by Brian Cohen, GIS specialist at The Nature Conservancy office in San Diego, and in the case of 2020 data, also by CDFW. Data from cougars collared in northeastern California is being curated by IWS personnel. CDFW regional biologists Randy Botta, Kevin Brennan, Richard Shinn, Richard Callas, and / or assistant chief Rebecca Hartman, and other CDFW personnel were notified of all capture attempts prior to their initiation and invited to observe, depending on the area. Randy Botta has been given data directly when requested, and he has been given free access to all the data from the project that is archived at The Nature Conservancy. All data has also been provided to SANDAG, and other entities whose use of the data could help inform conservation action.

Aliquots of sera samples from all live-captured cougars were stored frozen for later forwarding to CDFW veterinarian Dr. Deana Clifford, and remaining blood, serum, etc is now stored at the University of California South Coast Research and Extension station in Irvine CA. at the IWS facility in Arcata, CA. All deceased cougars recovered in the study areas by the study teams were necropsied at the CDFW Wildlife Investigations Lab in Rancho Cordova, CA or the California Animal Health and Food Safety Lab in San Bernardino. Data on causes of death and locations will be added to our overall mortality databases and analyses that are ongoing.

DNA samples from all live-captured cougars, or deceased cougars from the project area, were taken, processed, maintained, and analyzed or stored for later analysis at the genetics laboratory of Dr. Holly Ernest at the University of Wyoming. Capture reports were forwarded to CDFW supervisors Justin Dellinger, Dr. Deana Clifford, and regional biologists. Some blood samples were also sent to the viral and genetics lab of Dr. Sue Van deWoude at Colorado State University.

Deer used as bait were monitored for signs of disease in cooperation with CDFW veterinarian Dr. Brandon Munk. A summary table of deer collected and examined for disease by IWS biologists is attached to this report as Appendix A. Samples of lymph nodes were provided to Dr. Munk.

Results over entire study period

The first mountain lion enrolled in the overall study was captured and GPS radiocollared in 2001. Individual animals captured totaled 146 as of December 31, 2020. Two additional new animals were captured in January 2021 (NE California study), bringing the overall total number of individuals captured since study inception (as of January 31, 2021) to 148.

Approximately half of all animals originally captured have been recaptured at some point, with some being recaptured several times with no evidence of ill effects from previous capture or GPS-collar placement (significant weight or condition change) being noted.

As of December 31, 2020, 125 individual animals have been VHF or GPS collared (1 with VHF collar only, the remainder with GPS collars), with one additional new animal being collared in January 2021. This brings the overall total since study inception to 126.

Total handling events (including recaptures) numbered 232. Of those, no animals were recorded as having significant injuries that were capture related except for one mortality. We feel the one mortality was preventable and have taken steps to assure that it does not happen again in the future. Despite the one mortality, we feel that our safety record during captures is consistent with or better than most other studies.

Samples for genetics and / or infectious disease or toxin assessment have been taken from a total of more than 250 live-captured or deceased mountain lions from both study areas to date.

Additionally, some data has been acquired from 3 cougars captured in a USGS study conducted in the northern Santa Ana Mountains, and those data have been incorporated in our analyses.

Over the course of the long term study (since early 2001), GPS data points collected from cougars in the southern CA study area have indicated that they have utilized lands as far north as the Highway 91 and 241 Toll Road junction in the northern Santa Ana Mountains in Orange Co, and as far south as the Parque Nacional Constitución de 1857 located approximately 50 miles south of the border in Mexico. They have ranged from the Pacific shore in the west to the San Jacinto and Peninsular mountain ranges in the east (Figure 3). In the Modoc/Lassen Co. study area GPS collared animals have ranged as far north as into Oregon, and east into Nevada.

2020 & January 2021 Results

Seventeen new individuals were captured in 2020 (8 in the NE CA study and 9 in So Cal). Two additional new animals were captured in January 2021 in the NE California study, bringing the total number of new animals captured in 2020 and January 2021 to 19.

Fourteen animals (11 new individuals and 3 recaptures) had GPS collars placed / replaced during captures (SoCal n=9, NE CA n=5). Eight animals in the NE CA study were not collared due to being young kittens (n=5) or juvenile males (n=3) that were not collared due to unavailability of 6 month drop-off units.

NE CA study capture detail:

From 1 January 2020 through 27 January 2021, 13 mountain lions were handled on the NE CA project (Table1). Five were adults (3 males, 2 females), three were juveniles (all males) and five were kittens (all males) handled at two den sites. The 5 adults were all GPS collared or re-collared. The 3 juvenile males were not collared due to unavailability of 6 month drop-off mechanisms for the collars. Three of the adult lions were recaptures: M205, an 8-year-old male whose collar had prematurely failed was recaptured in February; F180, a 6-year-old female was captured in March; and F163, a female a 5+-year-old female last captured four years previous was captured in January 2021. All captures went without incident.

Two collared females gave birth in 2020; F180 ~26 July and F204 ~24 August. We visited the den sites of both females when the kittens were approximately 2 weeks of age, obtained genetic samples via ear punch, and placed an ear tag in each kitten. We believe this was F204's first litter, and based on her

movements believe she lost them around early November. As of 15 December 2020, F180 still has all three of her kittens based on trail camera monitoring.

CDFW biologists and wardens have attended and assisted in a number of these captures.

Table 1a. Statistics on mountain lions captured during reporting period in Modoc and Lassen counties, California.

ID	DATE	Method	SEX	AGE	Ear Tag	Tattoo
M205*	2/25/2020	Cage Trap	M	96 mo.	205-L-Org	205-R-Blk
F180*	3/7/2020	Cage Trap	F	71 mo.	180-R-Org	180-L-Blk
M208	3/21/2020	Cage Trap	M	10.5 mo.	208-L-Org	208-R-Blk
M209	3/21/2020	Cage Trap	M	10.8 mo.	209-L-Org	None
M210	3/24/2020	Cage Trap	M	55 mo.	210-L-Org	210-R-Blk
M211	8/19/2020	Den Site	M	25 days	3-L-White	None
M212	8/19/2020	Den Site	M	25 days	4-L-White	None
M213	8/19/2020	Den Site	M	25 days	5-L-White	None
M214	9/20/2020	Den Site	M	26 days	8 -L-White	None
M215	9/20/2020	Den Site	M	26 days	0-L-White	None
F163*	1/4/2021	Cage Trap	F	59 mo.	163-R-Org	163-L-Blk
M216	1/4/2021	Cage Trap	M	40.8 mo.	216-L-Org	216-R-Blk
M271	1/23/2021	Cage Trap	M	16 mo.	217-L-Org	None

*Indicates a recaptured mountain lion.

Table 1b. Locations of captures and animal disposition/Transmitter frequencies

ID	Gen'l locale	County	UTM zone	UTM Easting	UTM Northing	Injuries	Mort date	Mortality cause	Trans.freq
M205*	Pine Creek	Modoc	10	715870	4589479	None	1/14/2021	Necr results pending	173.625
F180*	Happy Camp Mtn	Modoc	10	656784	4589479	None	N/A	N/A	173.675
M208	Rail Mountain	Modoc	10	669698.86	4604072.72	None	N/A	N/A	N/A
M209	Rail Mountain	Modoc	10	669698.86	4604072.72	None	N/A	N/A	N/A
M210	Boles Creek	Modoc	10	666318.25	4633556.19	None	N/A	N/A	173.600
M211	Rattle Snake Ridge	Modoc	10	658749	4578223	None	N/A	N/A	N/A
M212	Rattle Snake Ridge	Modoc	10	658749	4578223	None	N/A	N/A	N/A
M213	Rattle Snake Ridge	Modoc	10	658749	4578223	None	N/A	N/A	N/A
M214	Poison Flat	Modoc	10	729610	4570244	None	N/A	N/A	N/A
M215	Poison Flat	Modoc	10	729610	4570244	None	N/A	N/A	N/A
F163*	Pine Creek Cyn	Modoc	10	713748	4589283	None	N/A	N/A	173.425
M216	West Vly Reservoir	Modoc	10	716984	4566809	None	N/A	N/A	173.475
M271	Timbered Mtn	Modoc	10	686684	4623789	None	N/A	N/A	N/A

*Indicates a recaptured mountain lion.

We had a collar failure on an adult male (M210) on 9/26/20. It had been placed originally in March 2020. This lion had a home range that included northern California and southern Oregon.

We only had one mortality of a collared lion during the reporting period. M205, an adult male recaptured in February 2020, died on the east side of the Warner Mountains on 14 January 2021. The carcass was intact with no obvious trauma. After consultation with Dr. Jaime Rudd at the Wildlife

Investigations Laboratory, the carcass was bagged, iced and transported by IWS staff to the WIL the following day. The full necropsy results are pending. This lion had a very large home range, encompassing almost all of the Warner Mountain Range.

Southern CA study capture detail:

In the southern CA study, 9 individuals (subadults and adults) were captured, sampled, and GPS-collared (Table 2). All 9 were new individuals to the study. There were no recaptures. All were captured in collaboration with CDFW and their captures and collaring data will be also reported by CDFW. UCD ID numbers are noted in the table along with CDFW ID numbers to avoid confusion.

Unfortunately, of the 9 pumas collared in the SoCal project area in 2020, 5 are known deceased, 1 collar stopped transmitting data and the lion's status is unknown, and 3 are still transmitting data. Two of the deceased collared animals died of disease, specifically leptospirosis, 1 was killed by another puma, 1 was struck by a vehicle, and 1 cause of death was unknown due to level of deterioration of the body before it was found.

Table 2a. Statistics on mountain lions captured during reporting period in southern CA study area

UCD ID	CDFW ID	Date	Method	Sex	Age	Ear Tag	Tattoo	Status
M250	P250	01/12/20	Cage	M	12.00	Wh 130 R	None	Mortality
M251	P251	01/12/20	Cage	M	52.00	Wh 136 L	None	Active
M252	P252	01/14/20	Cage	M	12.00	Red 6 L	None	Mortality
F253	P253	02/03/20	Hounds	F	18.00	Red 6 R	None	Mortality
M254	P254	02/08/20	Cage	M	60.00	Red 5 R	None	Active
F255	P255	02/17/20	Cage	F	14.00	Wh 32 R	255 L	Lost
F256	P256	03/25/20	Cage	F	18.00	Gr 256 L	None	Mortality
F257	P257	04/01/20	Cage	F	54.00	Gr 257 L	None	Active
F258	P258	05/17/20	Cage	F	15.00	CDFW record	CDFW record	Mortality

Table 2b. *Locations of captures and animal disposition/Transmitter frequencies*

UCD ID	CDFW ID	Gen'l locale	County	UTM zone	UTM Easting	UTM Northing	Injuries	Mort date	Mortality cause	Trans.freq
M250	P250	Milk Ranch Rd.	San Diego	11	537152.91	3647795.16	None	5/22/2020	Leptospirosis	159.050
M251	P251	Engineer's Rd	San Diego	11	537007	3652532	None	N/A	N/A	159.180
M252	P252	Milk Ranch Rd.	San Diego	11	537152.91	3647795.16	None	7/10/2020	Vehicle strike	159.160
F253	P253	San Felipe Valley	San Diego	11	CDFW record	CDFW record	None	6/5/2020	Leptospirosis	159.059
M254	P254	Engineer's Rd	San Diego	11	537007	3652532	None	N/A	N/A	159.200
F255	P255	Volcan Mountain, Juli	San Diego	11	538145.64	3667023.54	None	N/A	N/A	159.070
F256	P256	Volcan Mountain, Juli	San Diego	11	CDFW record	CDFW record	None	5/5/2020	Likely killed by lion	159.120
F257	P257	San Felipe Valley	San Diego	11	CDFW record	CDFW record	None	N/A	N/A	159.140
F258	P258	San Felipe Valley	San Diego	11	542346.13	3663003.55	None	Est ~ 10/30/20	known - Carcass decompo	159.120

Overall mortalities in the study area:

In 2020 and January 2021, the causes of death of all known (both collared and uncollared; n=15 total) deceased pumas in the SoCal study area were:

Vehicle - 5
Depredation - 3
Disease – Leptospirosis – 2
Unknown - 2
Another lion – 1
Public Safety – 1
Fire – 1 – (F121 - only confirmed remaining offspring of M86)

In December 2020, one previously collared female in the SoCal study area, F121, was found dead from emaciation and burns suffered in the Bond Fire in Orange County. She had been documented in trail camera video in October 2020 with a male lion, so was potentially pregnant when she died. She was the only known surviving offspring of M86, the only male we have documented to have entered the Santa Anas from the east and reproduced during our study period. Necropsy is pending.

Also in December 2020, a 40 pound male was hit by a vehicle on SR241 at Los Alisos Parkway but not killed – it is currently recovering at Serrano Animal and Bird Hospital and will be staying in captivity. It suffered a head injury and broken pelvis so would have certainly been added to the mortality figures had it not been transported for veterinary care.

In January 2021, a female 3 yr old puma was struck and killed in Orange County on Antonio Parkway a relatively short distance from where the young male cougar was struck in December 2020. Another puma (gender not yet known) was also reported as being struck and killed in Orange County on Ortega Highway in Casper's Wilderness Park, likely around January 28, 2021. We will attempt to determine if any of these animals are related in a later pedigree analysis.

Other uncollared cougars may have been killed on depredation permits in the southern CA study area that we were not made aware of.

The status of collared cougars whose collars dropped off or stopped transmitting prior to recapture, and captured kittens that were never recaptured for GPS-collaring, is generally unknown. Some of those previously captured and / or collared cougars whose status is unknown are also likely deceased given the mortality rates for collared cougars in the study. Trail cameras have captured photos of some of these animals after their collars dropped off, and they were positively identified by their ear tags. Dates of these confirmations of live status are also recorded in our survival database. Mortalities of some of these individuals have been detected due to their ear tags or tattoos being noted in CDFW reports on depredations, vehicle strikes, or other mortality detections.

Pumas and Roads:

Except for SR 241 in Orange County, Los Patrones Parkway in Orange County, portions of SR 76 west of I-15, and along I-15 south of Temecula (a 7 mile stretch where fencing construction is in progress),

no major highways in the region have adequate fencing to prevent cougar intrusion onto roads and funnel them to safe crossing structures.

In 2019 and 2020 our team worked under a grant and contracts from the San Diego County Association of Governments (SANDAG), and the NCCP Local Assistance Grant (LAG) program administered by CDFW, to study these high volume / high risk highway crossing areas further and to recommend infrastructure improvements to enhance wildlife connectivity across regional roads, especially I-15, and enhance human safety (Figures 3-5). Our team initiated work on this study in March of 2018, and that work was completed and report submitted in March of 2020 to CDFW and SANDAG (Vickers et al. 2020). Nearly 200 sites where known mountain lion crossings had occurred (based on high frequency GPS data, cameras, and roadkill), least cost path modeling indicated likely crossing points (Zeller et al 2017,2018), or expert opinion indicated likely crossings, were examined in depth and all findings documented. Analyses were done of conservation levels in the vicinity of crossings and habitat use likelihoods at those sites based on analyses by Zeller et al. (2017,2018) and Dellinger et al. (2019).

Major findings of the study included that most puma crossing points did not have adequate infrastructure present to allow safe passage, most crossing points had less than 50% of the land within a 500 meter radius conserved, and at most crossing points where adequate infrastructure was present, the land was not conserved at one or both ends of the structure (Vickers et al. 2020). The lack of conservation at existing adequate structures was of special concern because of the potential for functional loss of some of the adequate structures due to development. Another major concern was that the majority of crossings were occurring at grade where no infrastructure existed, either crossing structures or exclusion fencing, and thus both mountain lions and drivers were being put at risk. The fact that vehicle strikes were the top cause of death for collared mountain lions in our study emphasizes this.

As part of that same study we worked with Cal Poly Pomona civil engineering faculty and students and others to develop specific engineering plans for enhancing current crossings across I-15 or create new ones (Vickers et al. 2020; Figures 4,5). These plans have formed the basis for further engineering studies for new and enhanced crossing structures for I-15 that are being undertaken by Caltrans, as well as helping The Nature Conservancy secure a grant for planning of improvements to the Temecula Creek Bridge.

In 2018, TNC secured ownership of a key parcel adjacent to the east side of I-15 in the area deemed to be most important for construction of any new wildlife crossing of that highway. UCD has been monitoring culverts along I-15 between Temecula Creek and the San Diego County Line, the Temecula Creek Bridge crossing, and the TNC property for mountain lion activity. In 2019 and 2020 mountain lions have been detected on camera along that stretch of freeway on both sides 14 times (Figure 6; Pictures A-C). This indicates that if additional suitable crossing structures are built in that stretch, it is likely that mountain lions will use them at some point.

As an adjunct to that study, we have been collaborating with other researchers at UC Davis (Dr.'s Fraser Shilling and Amy Collins) and at UCLA (Dr. Travis Longcore) to assess sound and light levels at various types of road crossings, including some of those in the I-15 study area, to help guide Caltrans engineers in site choices for any new crossing. We are also collaborating with TNC and our UCD and UCLA partners to develop recommendations for reduction in impacts of sound and light in the Temecula Creek Bridge linkage in order to improve the likelihood of mountain lion movement through

that area.

Genetics, Disease, Mortality, and Toxins:

We continued to collect tissue samples with CDFW of deceased cougars in the study area, and record the locations and causes of death. We also have every mountain lion necropsied. This will assist in assessment of health, disease, toxin exposure, and genetics of live and deceased cougars in the study area, as well as mortality patterns.

Our study's previous findings (Vickers et al. 2015) suggested that annual survival rates of collared pumas in our southern CA study area (mean=56%) are lower than in many heavily hunted populations, and deaths due to vehicle collisions and secondary to depredation permits are the first and second most common causes of death. Vehicles appear to affect males and females approximately equally, but depredation permits are more likely to involve males.

We continued to work with our genetics and disease collaborators to better understand the interplay between genetics and disease and how contact patterns between individual pumas contribute to disease transfer, as well as gene exchange. Genetic analysis of 35 samples from the Santa Anas and eastern Peninsular Range were sent to the Holly Ernest lab at the University of Wyoming in 2020 for analysis and pedigree construction, and addition to our existing pedigree for the SoCal study are mountain lions (Gustafson et al. 2017). Those analyses will be completed in 2021.

We are collaborating with Colorado State University post doc Erick Gagne on analysis of gene flow based on landscape characteristics (in review) and with statewide researchers on genome analyses that will give much more detail into the different genetic characteristics of the lion subpopulations across the state.

We have also given input to CDFW in relation to the petition to list 6 California puma populations as threatened under the California Endangered Species Act. This petition is currently in review.

We worked with CDFW and other researchers to complete a statewide habitat analysis that was published in 2019 (Dellinger et al.), and contributed our data to statewide survival and fire-effects analyses that are in progress, as well as national and international analyses of habitat use and road mortalities.

Education and depredation prevention:

We continued to educate and inform the general public, livestock and pet owners, agency personnel and managers, and others about mountain lions and how to most successfully coexist with them in the southern California landscape via prevention of depredation events.

Dr. Vickers has initiated a collaboration with the Mountain Lion Foundation, UC Extension, and UC Davis Veterinary School Extension to develop training materials for 4-H and FFA members, as well as adults, in proper methods for protecting their livestock from predators like mountain lions. This resulted in release of a peer-reviewed curriculum for use by 4-H clubs to teach students how to prevent depredation (Cheung et al. 2019). Our team is also working to assess the effectiveness of different

hazing and deterrent devices on cougars and is collaborating with other mountain lion researchers and CDFW in that effort.

Additionally, CDFW policy toward issuing of depredation permits has changed over time to a policy that requires non-lethal measures to be employed twice and have failed before a lethal take permit may be issued. These include placing deterrent devices and taking other deterrent measures, and improving livestock husbandry and removing cover near livestock pens. The work of our team and others highlighting the risk to these populations was strongly considered in the policy change. Unfortunately, despite this change in policy, 3 pumas were killed in our So Cal study area in 2020 as a result of depredation.

We have created a series of short documentary films and one full length film about mountain lions in California that are intended as educational tools for use by various entities in the state such as CDFW, Parks Departments, and non-profits that interact with the public on the subject of mountain lions. They have been viewed over 400,000 times online and elsewhere.

Developing and comparing population monitoring methods for the Santa Ana Mountains.

In an attempt to assess various methods for monitoring the Santa Anas population with the goal of capturing any population decline before the population advances to extirpation, we have initiated a project with CDFW-LAG, SANDAG, and TNC funding to test non-invasive methods for population estimation. The project is a collaboration with Dr. Jeff Manning of Washington State University. The primary method to be tested is via hair snare collection of DNA and mark-recapture analytic techniques (See Appendices B, C). Field work and preparatory analyses began in 2020 and are in progress, with project completion planned for 2022.

We are also collaborating with USGS on testing the use of photos from the hair snare sites to potentially identify individual mountain lions.

Additionally, a collaboration with Panthera may result in camera distribution across the Santa Ana Range with a second method of population estimation using photos with time-to-event and space-to-event analytics applied for population estimation. This would be aimed at assessing the use of cameras alone for adequate population monitoring.

Another monitoring method, estimation of population based on DNA from scat is planned for the Santa Anas if funding can be obtained. CDFW conducted scat dog collections (n=~200 samples) in the eastern Peninsular Range in Nov-Dec 2020 which will allow testing of the technique in part of the study area, but not the Santa Anas as yet.

Analysis of population viability in the Santa Ana Mountains:

A population viability analyses published in 2019 (Benson et al.) suggests that increased connectivity and movement of mountain lions from the adjacent areas into the Santa Anas appears to be key to the viability of mountain lions in the Santa Anas in terms of reducing probability of extinction due to both demographic and genetic factors.

With immigration at a low level consistent with what has been documented during the last 15 years (3 males; Gustafson et al. 2017), the likelihood of extirpation of the population over the next 50 years is uncomfortably high (1 in 5 or 6 chance). At the current or lower levels of immigration, genetic diversity (heterozygosity) is predicted to decline substantially in the next 50 years raising concerns about inbreeding depression. If inbreeding depression develops then extirpation in a much shorter time frame (<15 yrs) becomes very likely without intervention.

Initial results of semen quality analysis in 2020 from two male lions in the study area that died (one from the Santa Anas and one from the eastern Peninsula Range population) by Audra Huffmeyer of UCLA have raised the level of concern about inbreeding depression due to teratospermia. However, the low sample size precludes making any firm statements about either population as a whole. Further analyses will be done as opportunities for sampling arise. Similar assessments are ongoing in the Santa Monica Mountains population.

This highlights the importance of slowing the rate of loss of genetic diversity to avoid the potential for compromised demographic performance due to inbreeding depression. Dr. Benson's results suggest that movement of individuals into the Santa Ana's needs to occur at a higher rate than we have documented to date in order to avoid the projected further loss of genetic diversity. So this again highlights the importance of maintaining and increasing linkages that allow mountain lions to move from adjacent areas into the Santa Anas.

NE CA Project Research Detail:

Five of the adult and juvenile lions that were captured in 2020 were tested for FIV and FeLV using the Witness Antibody Test Kits (Zoetis Inc.) and all were negative. Two additional juvenile lions were tested for FIV alone and tested negative.

From our 2019 analysis, we found that home range size of lions in Modoc and Lassen counties vary considerably even within sexes. The average 85% fixed kernel home range for adult females was 258 km2 (range 100 - 512 km2), while that of adult males averaged 541 km2 (range 223 - 1046 km2). The larger female home ranges were associated with a seasonal shifts in the areas used. One adult male residing in the Modoc National Forest, that has preyed primarily on wild horses, had a home range of 1,360 km2 (95% fixed kernel).

Also in 2018-19 (2020 data pending) investigations of mountain lion diet in the NE California study area has generally followed what has been reported elsewhere for the species, with deer being the primary prey item. Deer made up the primary prey items found at clusters (54%), but coyotes (16%), pronghorn (10%), horses (10%), and elk calves (2%) were also recorded. Other small prey items such as beaver, rabbits and squirrels were also observed at kill sites. One adult male lion appears to specialize in wild horses as his main prey, with all but a few of his investigated kills being horses.

How Data from the NE CA study is being collected and used for mountain lion conservation throughout California:

-Contributed to paper on habitat selection of mountain lions in California (Dellinger et al. 2019)

-Contributed data to current work on a paper on mountain lion survival in California (J. Benson et al. in prep)

-Collected whiskers for current work being done by CDFW to use stable isotope analysis in mountain lions

-Collaborating on proposed project to compare disease exposure of mountain lions across California in relation to human population density

-Currently working on a paper examining kill site habitat selection by mountain lions in Modoc and Lassen counties (supported this graduate student research); (Ewanyk et al. in review)

-Currently working on a paper examining denning behavior of mountain lions in Modoc and Lassen counties (Brinkman et al. in prep)

-Currently working on paper examining pronghorn demographics in northeastern California which includes impacts of mountain lion predation (Garcelon et al. in prep)

-Currently working on a project to examine familial/pedigree analysis of mountain lions in northeastern California using genetic samples (Analyses pending)

Discusssion

Low annual survival rates of pumas in southern California, combined with restricted genetics and connectivity are a major concern especially for the population in the Santa Ana Mountains which is estimated to number between 16 and 21 adults (Beier et al. 1993, Benson et al. 2019).

These findings suggest that with projected increases in human population size in the region and the attendant loss of habitat and increased traffic and roads, that cougars in this mountain range are under increasing threat. The population east of I-15, though larger and potentially more robust, also faces the same array of increasing threats.

Even under current conditions of immigration into the Santa Ana's, the likelihood of extirpation of the population over the next 50 years is uncomfortably high (1 in 5 or 6 chance), and if inbreeding depression develops then extirpation in a much shorter time frame (<15 years) becomes much more likely without intervention (Benson et al. 2019).

Thus the key to keeping robust populations of mountain lions in southern CA is to assure and improve connectivity, and reduce mortality rates. Our team has been involved with extensive communication and collaboration with the three counties in the region, transportation agencies, non-profits such as The Nature Conservancy, and wildlife agencies, and others in 2020 in an attempt to accomplish these goals.

We feel that it is critical that education, investment in proper road crossings and fencing, habitat conservation, prevention of habitat fragmentation, and proper domestic animal husbandry all be employed to improve the potential for puma population persistence in the region, especially the Santa Ana Mountains population. These mitigation measures are under human control, but require increased financial and political support in order to accomplish real reductions in current rates of mortality. In light of the bias toward males in the known-mortality statistics for San Diego County, and the need for greater movement of males across I-15 into the Santa Anas, reducing mortalities of males (especially young males) east of the freeway should be a major priority. We are exploring other potential programs and pathways that might also be utilized to reduce threats to these populations.

Plans for 2021:

We will continue collaborations with most of the mountain lion researchers in CA and CDFW to conduct further genetic and disease research, connectivity and roads research, and research into deterrence devices to help protect livestock from predation. We are also actively collaborating with TNC, SANDAG, Caltrans, and others on roads improvements. The UCD team and CDFW will continue to collect data from the 3 remaining collared cougars in the eastern Peninsular Range and potentially test deterrent devices and strategies on those animals, as well as utilizing data from all 9 animals collared in 2020 to help define areas for deterrent testing and other analyses.

We will complete the study of non-invasive methods of population for the Santa Anas, with potential application to other study populations.

We plan a new collaboration between IWS and the Audubon Canyon Ranch Living with Lions Project in Sonoma-Napa-Mendocino Counties. This collaboration will allow comparison studies between the three areas relating to disease and toxin exposure, habitat utilization at fine scales, prey studies, and others.

In the NE CA study area specifically, IWS will also focus on:
-Determining mountain lion kitten survival through non-invasive photo monitoring.
-Continuing to investigate the diet of lions in northeastern California through visiting GPS clusters to identify kill sites.
-Determining mountain lion habitat use, density and range overlap to better understand changes in landscape use patters if/when wolves establish in the study area.
-Developing further peer reviewed publications via another MS graduate student that IWS has taken on to work on mountain lion biology in the study area.

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- San Diego County Association of Governments
- The Foothill East Transportation Corridor Agency
- The Nature Conservancy
- California Department of Fish and Wildlife
- Orange County Natural Communities Coalition
- South Coast UC Research and Extension Station
- Caltrans
- San Diego State University Santa Margarita River Ecological Reserve
- Individual donors, with special appreciation to Vicki Long for her consistent significant support over the years

We also thank the following entities for their cooperation and permissions for access to managed conserved lands at various times during the study period, without which the study would not have been possible:

- California Dept. of Fish and Wildlife
- US Forest Service
- US Bureau of Land Management
- US Fish and Wildlife Service
- Orange, San Diego, and Riverside Counties and County Parks Departments
- The Irvine Ranch Conservancy
- City of San Diego Water District, Parks, and Environmental Services Departments
- Caltrans
- Foothill East Transportation Corridor Agency
- The Nature Conservancy
- San Diego State University
- Western Riverside County Conservation Authority
- Fallbrook Water District and others
- Wildlands Conservancy
- Conservation Fund

We appreciate all those persons who have participated in project field or lab activities, data analyses and interpretation, scientific collaboration, or consultation with the project in 2020. We are especially appreciative of our current primary southern California field personnel - Jamie Bourdon, Rich Codington, Armand Avery, and Lina Vu and our northeast California field personnel – Jon Ewanyk, Colton Wise, Matt Brinkman, John Randolph, and other IWS biologists for their dedication and willingness to put in long hours and much hard work to assure the success of the project and enhance puma conservation. We also acknowledge our primary lab scientist Magdalena Plancarte who has been instrumental in assuring the integrity of our samples, and key UCD collaborators Dr.'s Jessica Sanchez, Walter Boyce, Fraser Shilling, and Amy Collins along with Dr. Travis Longcore of UCLA. We also appreciate the collaboration and assistance of personnel at the South Coast Research and Extension Station, especially Chris Martinez and Dr. Niamh Quinn.

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Vickers, W., T. Smith, B. Cohen. Final report re NCCP-Local Assistance Grant # P1750301 from California Dept. of Fish and Wildlife and SANDAG – UCD agreement #A37682/MOU #5005298 Awarded to the University of California, Davis Wildlife Health Center. Project Title: Santa Ana Mountains to eastern Peninsular Range Conservation Connectivity Infrastructure Planning Project for Interstate 15 and Closely Associated Roadways. May 2020.

Vickers, W. and J. Manning. Estimation of the Population of Mountain Lions in the Santa Ana Mountains and Comparison of Techniques for Population Estimation and DNA Collection, Wildlife Photo Technology Development, and Development of a Long-term Monitoring Plan and Collaborations for Mountain Lion Populations in Regional NCCP. Interim Reports October 2020 and January 2021.

2020 Abstracts / Posters

McDowell, S., A. Oke, A. Bass, S. Mavandad, D. Waetjen, C. Stephens, T. Longcore, W. Vickers, F. Shilling. Wildlife crossing design to reduce noise and light disturbance. Transportation Research Board Annual Conference. January 2021.

Figure 1 – UCD Wildlife Health Center Cougar Project Study Area – Santa Ana Mtns and eastern Peninsular Range

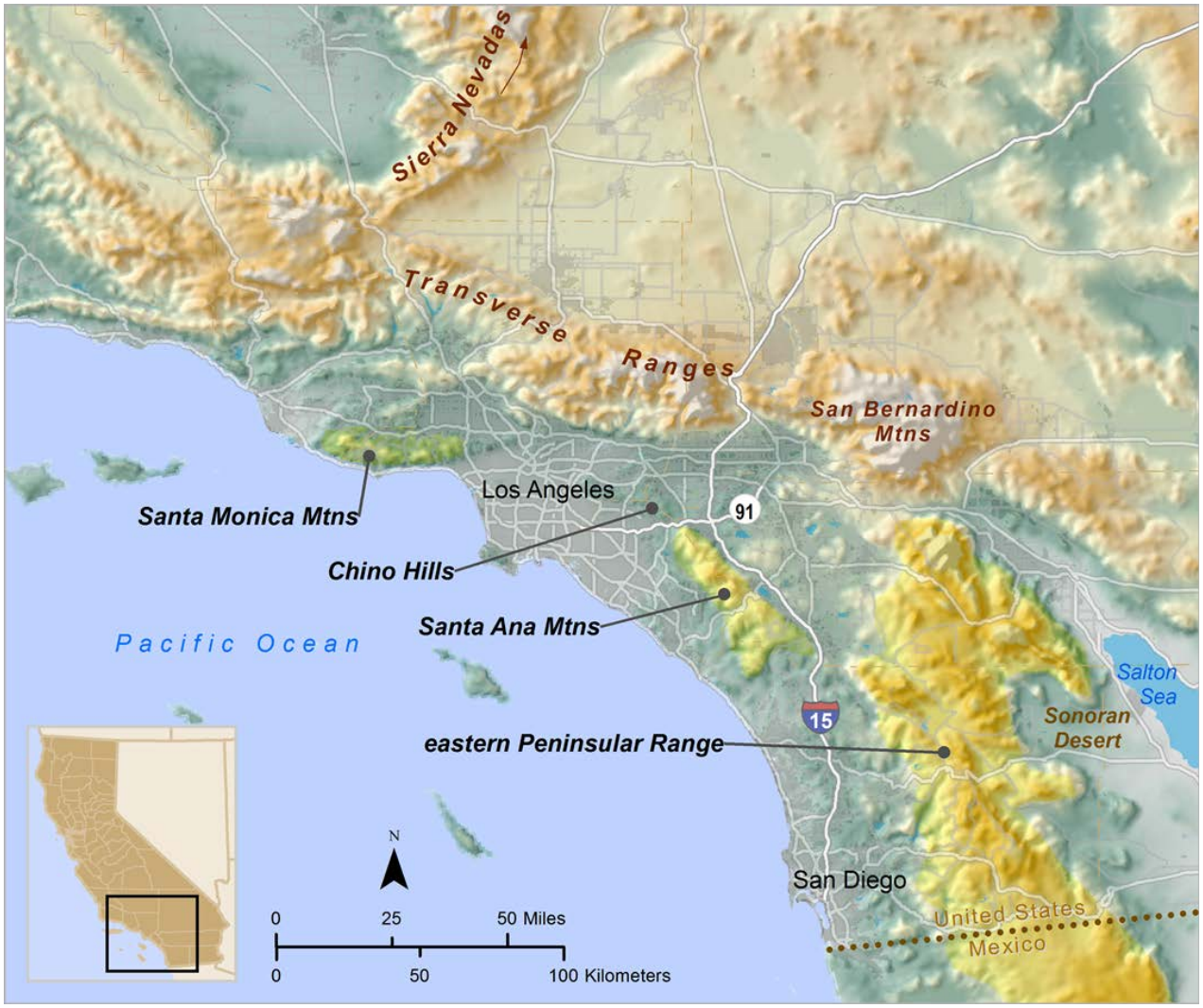


Figure 2. Modoc and County, CA

Figure 3. North San Diego, SW Riverside, and Southern Orange County Connectivity Study and and North San Diego County Multi-species Conservation Plan (NCMSCP) area, and mountain lion datapoints from the southern California study to date.

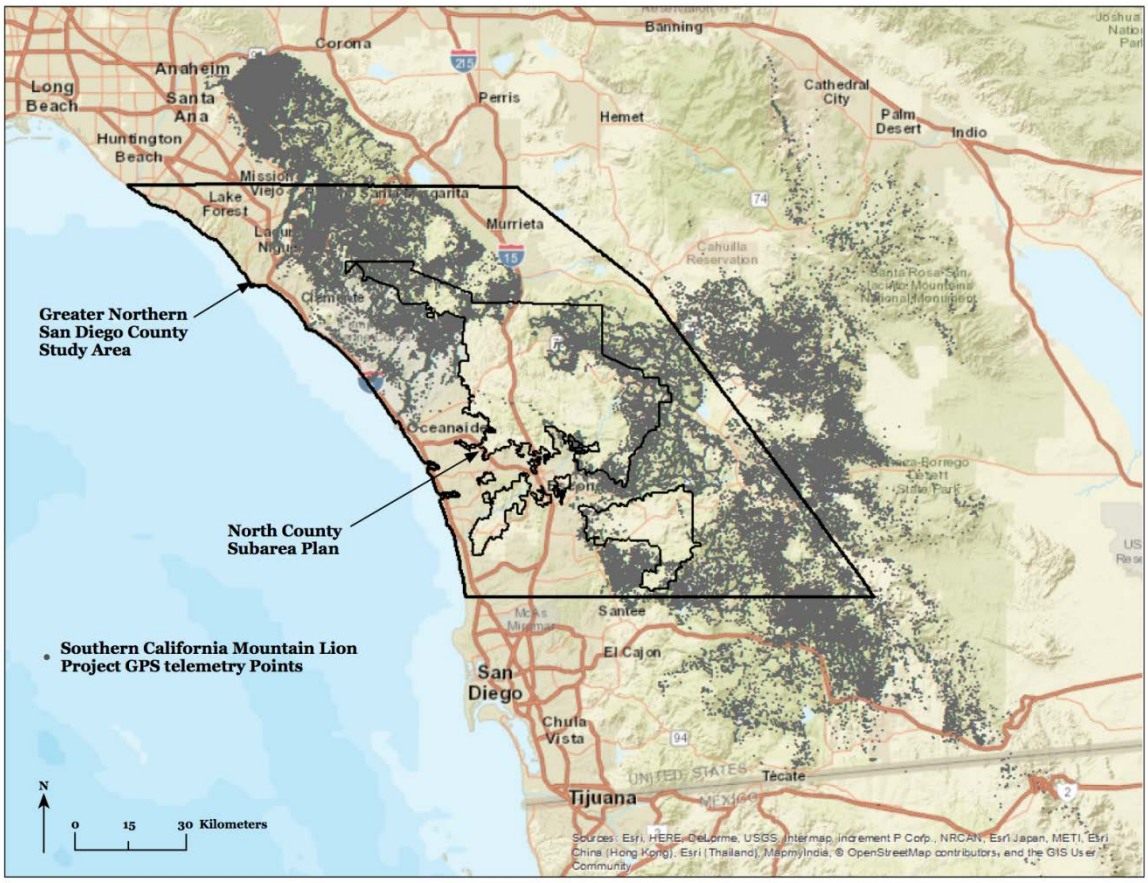


Figure 4. Location map of Santa Ana to Palomar Mountains' Linkage, including the area along I-15 evaluated for wildlife crossings with mountain lion GPS data points displayed.

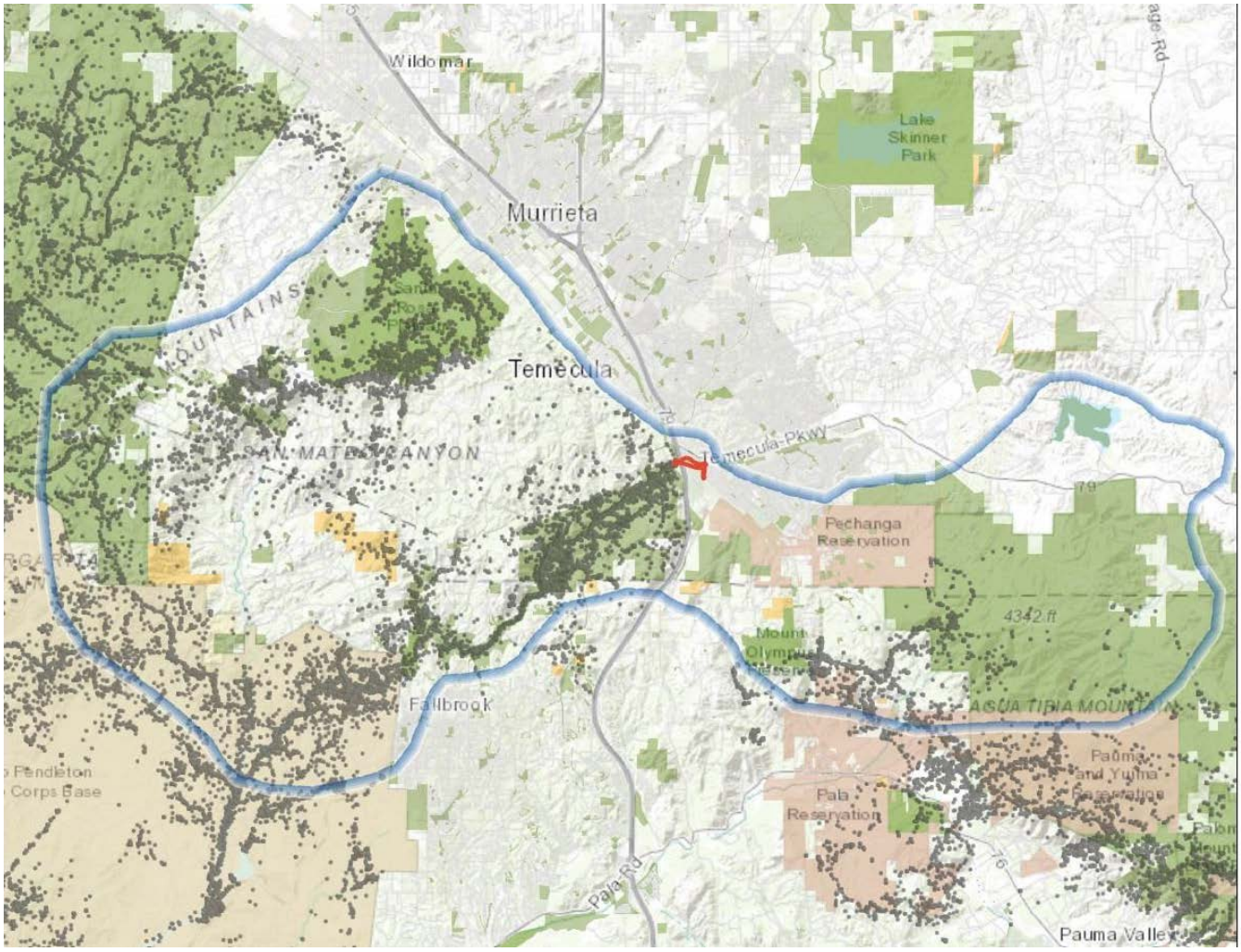


Figure 5 – Current and potential wildlife crossing sites examined for road crossing study (Vickers et al. 2020)

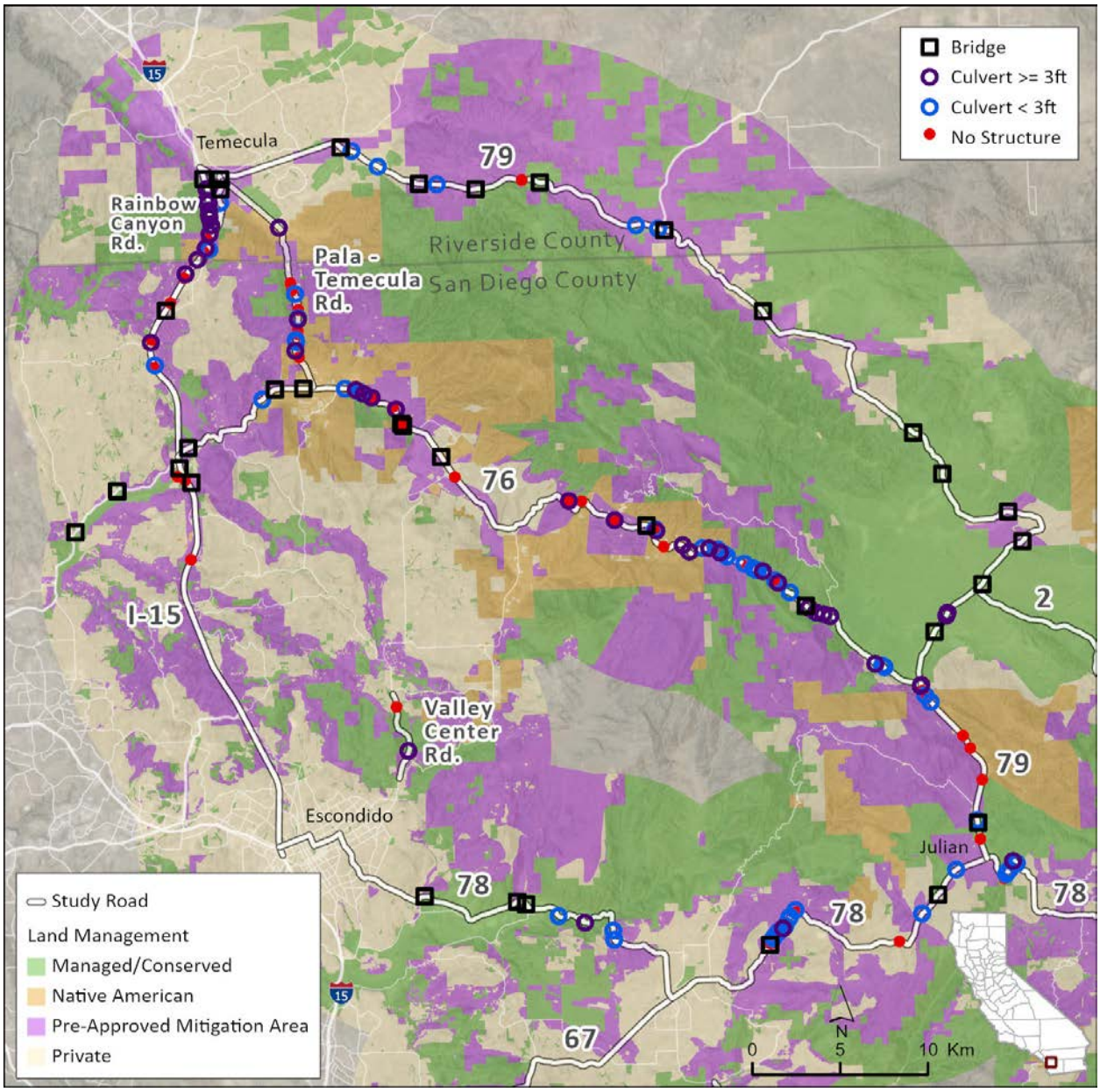
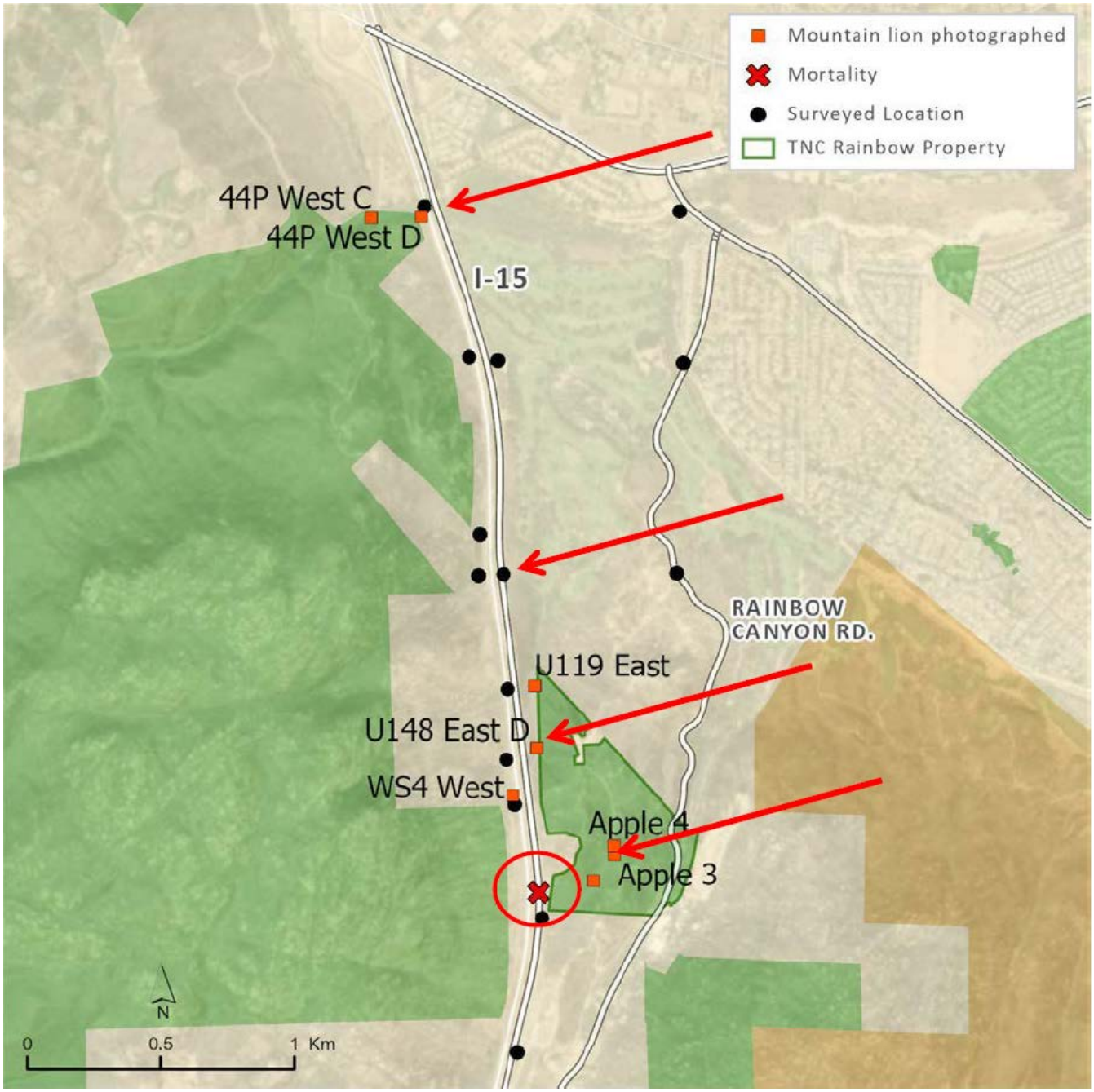


Figure 6. M233 mortality site (red X in circle) relative to sites where mountain lion photos were taken (orange squares and red arrows).



Picture A. Mountain lion on conserved property (TNC) immediately east of I-15.

Picture B. This lion photo was taken in front of the culvert on the southbound side of I15 at WS4. This culvert is at the top of a steep grade, but protected from the freeway noise and lights to a great degree by its position behind a hill. It drops off steeply from this entrance on the west side of the freeway toward the east side. You cannot see through this culvert, although there is a vertical shaft at the western edge of the freeway which allows some light to that point during the day.

Picture C. Same lion on west side entrance to culvert, departing after considering entry

It is notable that a young male mountain lion (ID number M233 in the UCD database) was struck and killed by a car on I-15 on December 26, 2018 in that vicinity of I-15, but it is unclear until genetic analyses are done whether the deceased animal came from the east or west side of the freeway. The map below shows the M233 mortality site relative to the site where photos of lions were taken in the same month (December 2018).

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Appendix A:

Summary of road-killed deer collected for use in study in 2020

Deer ID	Date(YYYY/MM/DD)	Lat	Long	Disease Checked	Previous Drug	Sex	Lymph	Collector
D1	20191218	41.50161	-120.52589	Y	N	F	Y	J. Randolph
D2	20191218A	41.10092	-120.91717	Y	N	F	Y	J. Randolph
D3	20200106	41.42674	-120.62928	Y	N	F	Y	J. Randolph
D4	20200113	41.51613	-120.52646	Y	N	F	Y	R. Shinn
D5	20200113a	41.49468	-120.577	Y	N	F	Y	J. Randolph
D6	20200123	41.51167	-120.53959	Y	Y	F	N	J. Ewanyk
D7	20200123A	41.4836	-120.54482	Y	Y	M	N	J. Ewanyk
D8	20200127	40.29197	-120.50394	Y	N	F	Y	J. Randolph
D9	20200131	41.48886	-120.66952	Y	N	M	Y	J. Randolph
D10	20200131A	41.48824	-120.54094	Y	N	M	Y	J. Randolph
D11	20200203	41.49439	-120.56418	Y	N	M	Y	J. Randolph
D12	20200203A	41.51818	-120.48011	Y	Y	M	Y	J. Randolph
D13	20200206	41.7134	-121.28606	Y	Y	F	Y	J. Randolph
D14	20200206A	41.71683	-121.28947	Y	Y	F	Y	J. Randolph
D15	20200206B	41.49444	-120.55595	Y	N	F	Y	J. Randolph
D16	20200210	41.49454	-120.55354	Y	Y	M	Y	J. Ewanyk
D17	20200202	41.52911	-120.17139	Y	Y	F	N	J. Ewanyk
D18	20200212	40.38311	-120.59769	Y	Y	F	Y	J. Randolph
D19	20200224	41.43076	-120.54804	Y	N	F	Y	J. Randolph
D20	20200224A	41.43076	-120.54804	Y	N	F	N	J. Randolph
D21	20200302	41.49495	-120.5406	Y	N	F	Y	J. Randolph
D22	20200302A	40.27067	-	Y	Y	F	Y	J. Randolph

			120.47852					
D23	20200308	41.49042	-120.704	Y	Y	F	N	J. Ewanyk
D24	20200308A	41.48888	-120.53265	Y	Y	M	Y	B. Gallagher, J. Ewanyk
D25	20200309	40.57945	-120.63998	Y	Y	M	Y	J. Randolph
D26	20200309A	40.291	-120.5022	Y	Y	F	Y	J. Randolph
D27	20200316	41.37102	-120.53903	Y	Y	F	Y	J. Randolph
D28	20200317	41.48374	-120.54664	Y	Y	F	N	B. Gallagher, J. Ewanyk
D29	20200323	41.47977	-120.55458	Y	N	M	Y	J. Randolph
D30	20200326	41.48819	-120.62376	Y	Y	F	N	J. Randolph
D31	20200326A			Y	N	M	Y	J. Ewanyk
D32	20200401	41.4885	-120.53494	Y	N	F	Y	J. Randolph
D33	20200402	40.94411	-120.50748	Y	Y	M	Y	J. Randolph
D34	20200402A	41.47904	-120.53945	Y	N	M	Y	J. Randolph
D35	20200407	41.52962	-120.15832	Y	Y	UNK	Y	J. Ewanyk
D36	20200518	41.49304	-120.53958	N	N	F	N	J. Ewanyk
D37	20200929	41.4232	-120.54559	Y	Y	F	N	J. Ewanyk
D38	20201001	41.36913	-120.56357	Y	Y	M	Y	J. Randolph
D39	20201128	41.49173	-120.61868	Y	N	M	Y	J. Randolph
D40	20201216	40.37721	-120.58458	Y	N	F	Y	A. Slear, J. Gonzalez, J. Randolph
D41	20201217	41.50308	-120.52059	Y	N	M	Y	A. Slear, J. Gonzalez
D42	20201218	41.49995	-120.53086	Y	N	F	Y	A. Slear, J. Gonzalez
D43	20201218A	41.50314	-120.5215	Y	N	F	Y	A. Slear, J. Gonzalez
D44	20201221	41.51	-120.50057	Y	N	F	Y	A. Slear, J. Gonzalez
D45	20201222	40.32256	-120.54456	Y	N	F	Y	A. Slear, J. Gonzalez
D46	20201229	41.50305	-120.52159	Y	N	F	Y	A. Slear, J. Gonzalez
D47	20201230	41.50944	-	Y	N	F	Y	A. Slear, J. Gonzalez

			120.50075					
D48	20201231	41.54364	-120.45597	Y	Y	F	N	A. Slear, J. Gonzalez
D49	20210111	41.40437	-120.92975	Y	Y	F	N	A. Slear, J. Randolph
D50	20210111A	41.50157	-120.52549	Y	N	F	N	A. Slear, J. Randolph
D51	20210111B	40.37336	-120.57854	Y	N	M	N	J. Gonzalez
D52	20210111C	40.38241	-120.59641	Y	N	F	N	J. Gonzalez
D53	20210114	41.50896	-120.50278	Y	N	M	Y	J. Gonzalez
D54	20210126	40.35462	-120.56077	Y	N	F	Y	J. Gonzalez

Note: Two additional roadkilled deer were collected from Camp Pendleton wardens for the southern California study and were sampled by them. Exact collection locations were not communicated to our team.

Appendix B – Scope of Work – Estimation of Santa Anas mountain lion population project and Appendix C – January 2021 Interim Report – Estimation of Santa Anas mountain lion population project follow