Final Report for Natural Community Conservation Planning Local Assistance Grant

Grant Agreement #Q1986005

Development of a strategic conservation and management plan for burrowing owls in western Riverside County

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In collaboration with:

California Department of Fish and Wildlife

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Photo on preceding page: A Burrowing owl in a photo from a wildlife camera at an artificial burrow.

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Executive Summary

Riverside County is one of the largest and fastest growing counties in the United States and loss of habitat from development is a primary threat to the western burrowing owl (*Athene cunicularia hypugaea*) within the Western Riverside County Multiple Species Habitat Conservation Plan. Although a great deal of effort has gone into management actions in support of burrowing owl conservation, the breeding population in western Riverside County remains low. Possible management actions to bolster burrowing owl populations in the area include site restoration via specific improvements that include vegetation management and recruitment of ecosystem engineers – California ground squirrels – and conservation translocations of BUOW. The first step, however, is to identify the best sites for targeted management action. In an effort to develop a deeper understanding of the habitat suitability for BUOW regionally, as well as site-specific suitability of conserved lands in western Riverside County, we focused on the following four objectives:

1. Gather existing burrowing owl locations and associated geospatial data in the region to form the basis of a habitat suitability model;
2. Build a habitat suitability model to identify key areas that will best support burrowing owls;
3. Identify the most suitable sites for burrowing owl conservation and recovery by conducting rapid assessments using field surveys; and
4. Synthesize the information into a strategic plan to guide future conservation and management efforts.

We compiled a dataset of 724 burrowing owl occurrences in southern California from county, state, and federal data sources and spatially matched these occurrences with physiographic, climatic, and biotic variables thought to be important predictors of BUOW occupancy. We then used a Mahalanobis D^2 partition model, a niche modeling approach focused on identifying environmental factors that are consistently associated with species presence, to generate a burrowing owl habitat suitability model for the region.

In spring of 2021, we met with partners to review the model results in western Riverside County. Together, we examined conserved lands and public/quasi-public conserved lands within the Western Riverside County Multiple Species Habitat Conservation Plan boundary that intersected with areas of high predicted suitability for burrowing owls in our model. After discussing the strengths and weaknesses of various sites, we identified 15 sites of interest. We conducted further site visits with partners and refined our list to 11 priority sites for targeted on the ground rapid assessment for burrowing owl and California ground squirrel suitability.

We conducted rapid assessments at 140 plots across 11 priority sites. Plot locations were randomly selected from an evenly spaced grid of points within BUOW habitat at each site. We collected data on prey availability (small mammals, including California ground squirrels), predator pressure (raptors, corvids, and coyotes), vegetation height and composition, and soil composition to inform burrowing owl conservation potential for each site. Soil composition, prey availability and vegetation structure and composition are among the most important factors predicting CAGS and BUOW establishment and use of a site. Across sites, average soil composition varied from sandy loam to clay loam, with Lake Perris, French Valley, Johnson Ranch, and Anheuser Busch sites having the greatest overall proportion of sand, which facilitates burrowing and is associated with California ground squirrel use and persistence. Sites with high sand content and lower vegetation height, such as Lake Perris and French Valley, had among the highest levels of ground squirrel activity. Small mammal burrowing activity varied markedly among plots and across sites, with much less activity observed at Lake Mathews, El Sol, and the single site assessed at Skunk Hollow. Predator pressure from corvids (crows and ravens) was highest at Lake Mathews and McElhinney-Stimmel parcels, whereas raptors were detected more frequently at French Valley, Johnson Ranch, Skunk Hollow, and San Jacinto Wildlife Area. Larger mammalian predators such as coyotes and bobcats were detected regularly via scats across sites, with the highest scat density observed at Lake Perris.

We maintained an active collaboration with partners during the planning, implementation, and discussion of findings throughout this project and partner feedback and discussion has been invaluable. We summarized our rapid assessment findings in a BUOW conservation and management plan shared with partners as a living document to guide future discussions and conservation actions for BUOW within the WRMSHCP. We also developed a Web Mapping Application in ArcGIS Online to share and visualize our data with partners as well as serve as a planning tool for prioritizing sites for BUOW and CAGS management.

Permits

Fieldwork was conducted under the California Department of Fish and Wildlife (CDFW) Entity Scientific Collecting Permit SC-11839. This project was approved by SDZWA's Internal Animal Care and Use Committee (IACUC) and operates in accordance with all IACUC provisions under Project #20-007.

Introduction

The western burrowing owl (*Athene cunicularia hypugaea*; hereafter BUOW) is a California Species of Special Concern and is a covered species under the Western Riverside County Multiple Species Habitat Conservation Plan/Natural Community Conservation Plan (Western Riverside County Multiple Species Habitat Conservation Plan 2003; hereafter WRCMSHCP). The species is experiencing declining populations range wide (Conway 2018), as well as locally low numbers and limited distributions. Riverside County is one of the largest and fastest growing counties in the United States (WRCMSHCP Implementing Agreement, Volume III, Section 2.0) and loss of habitat from development is one of the primary threats to this species within the WRCMSHCP. While much effort has been expended on BUOW mitigation and monitoring since the WRCMSHCP was established in 2004, the total breeding population in the Core Areas of the WRCMSHCP has still failed to meet WRCMSHCP Objective 2 which states that "the Core Areas should support a combined total breeding population of approximately 120 BUOW with no fewer than five pairs in any one Core Area" (WRCMSHCP 2003). However, breeding BUOW are currently absent in a number of areas with apparently suitable habitat they might reasonably be expected to occupy. Even with multiple translocation attempts across multiple sites and years, BUOW have not persisted. Based on pair count surveys conducted since 2015, the Core Areas supported a maximum of 18 pairs (in 2018), with only one Core Area (Lake Skinner/Diamond Valley Lake) having more than five pairs in all years but one (2019; WRCMSHCP 2015, 2016, 2017, 2018, 2019, 2020).

Translocation of BUOW is being used as a mitigation strategy for locations identified for imminent development, but recent research comparing passive and active relocations has shown that the effectiveness of this strategy depends on multiple factors, highlighting the need for careful planning (Hennessy et al. 2022). Better long-term outcomes will require an understanding of the habitat suitability of receiver sites and the distribution of suitable habitat Plan-wide. Because future BUOW mitigation-driven relocations are expected to continue with the pace of development within the WRCMSHCP area, a strategic plan to identify and prioritize conservation and management needs and actions for BUOW is critical to facilitate species recovery in the region.

The aim of this project was to fill a critical information gap for the WRCMSHCP through the development of a conservation and management plan to assist in species recovery and meet the WRCMSHCP's seven species-specific objectives for BUOW. For example, habitat suitability modeling can assist with identifying key habitat and help meet Objective 1 of having at least 27,470 acres of suitable primary habitat within the MSHCP Conservation Area. Habitat suitability modeling will also assist in the identification of core areas and interconnecting linkages (Objective 2), and the identification of at least 22,120 acres of suitable secondary habitat for BUOW (Objective 3). In addition, conducting rapid assessments and Strengths, Weaknesses, Opportunities, Threats (SWOT; White et al. 2015) analysis will help with prioritizing sites for the establishment of new colonies (Objective 7). Both habitat suitability modeling and SWOT analysis may assist with addressing critical information needs on nesting habitat, which will also contribute to meeting Objective 4: “include within the MSHCP Conservation Area the known nesting locations of BUOW…”. This report and accompanying management plan will incorporate the strategies between the WRCMSHCP and the contiguous NCCPs located in San Diego County (e.g., San Diego Multiple Species Conservation Program), thus facilitating a more coordinated, landscape scale effort to address the numerous threats to BUOW. The conservation and management plan, and underlying methodology, may also serve as a model for other NCCPs.

To develop a strategic conservation and management plan for BUOW in Western Riverside County with a goal to assist in species recovery through focused land acquisition and land management actions specific to the species, we focused on four main objectives:

1. Gather existing BUOW occurrences and associated geospatial data in the region to form the basis of a habitat suitability model;
2. Build a habitat suitability model to identify key areas that will best support BUOW;
3. Identify the most suitable sites for BUOW conservation and recovery by conducting rapid assessments using field surveys; and
4. Synthesize the information into a strategic plan to guide future conservation and management efforts.

Objectives 1 & 2. Data Compilation and Regional BUOW Habitat Suitability Model Development

BUOW occurrences were compiled from all known data sources, including databases administered by California Department of Fish and Wildlife (CDFW, 2020), U.S. Fish and Wildlife Service (USFWS, 2019), and Western Riverside County Regional Conservation Authority (WRCRCA, 2019). The model includes occurrences from 1998-2020 from Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura Counties. Desert valley occurrences in Coachella Valley and Imperial County were excluded due to differences in vegetation community type. Therefore, the scope of inference for the resulting suitability model was for non-desert areas in the above counties. We evaluated the quality of all points, based on provided data about point dates, spatial precision, and evidence of BUOW occupancy at each point. Occurrence records that met data quality standards were subsequently thinned by a 150 m grid cell in order to control spatial autocorrelation. For points with more than one occurrence record, the most recent occurrence record was retained per occupied grid cell. Following these criteria, 724 spatially independent BUOW occurrence locations were included in the final dataset (Figure 1).

Environmental factors thought to be important predictors of BUOW occupancy considered for our habitat suitability model are represented as a point grid at 150 m scale for the entire area of interest, compiled by San Diego Monitoring and Management Program (SDMMP) and used with permission (SDMMP 2015). Each point on the grid is populated with data for a suite of environmental variables at that location (Table 1). We spatially joined the final set of 724 BUOW occurrence points (Figure 1) to the environmental grid, however many of these occurrences were spatially clustered which tends to elevate the influence of these areas in the model.

Previous habitat suitability models in southern California have reported significant model improvement from utilizing a subsampling approach on regional data (Barr et al. 2015). Subsampling accounts for spatial clustering of records from BUOW localities with many survey records relative to incidental sightings. It also balances the representation of habitat differences along environmental gradients (i.e. coastal vs. inland grasslands). For this project, we defined eight regions of spatially clustered data (Table 2), and selected random samples of 20 observations per sub-region for each of 1000 model iterations, in order to ensure the model represented the characteristics of each region evenly.

We used the Mahalanobis D^2 partition model, a niche modeling approach focused on identifying environmental factors that are consistently associated with species presence (Preston et al. 2008), to generate a BUOW habitat suitability model for the region. Model results are interpreted as a minimum set of basic habitat requirements for species presence, and these minimum habitat requirements can be thought of as limiting factors rather than optimal habitat conditions for a species. For a given set of environmental variables included in a model, the Mahalanobis distance (Mahalanobis D^2) is the standardized distance between the multivariate mean for environmental variables calculated at a set of species occurrences and each grid point in the landscape (Rotenberry et al. 2002, 2006). Habitat suitability at each grid point increases with similarity in environmental conditions to the multivariate mean for the species occurrence dataset. Principal components analysis (PCA) can be applied to divide the Mahalanobis D^2 into components or partitions representing independent relationships between species occurrences and the set of selected environmental variables (Dunn & Duncan 2000; Rotenberry et al. 2002). In PCA, the number of variables in the model determines the total number of partitions; partitions are orthogonal and additive; summing all partitions equals the full model and provides the original D^2 value. Smaller partitions with lower variance identify a set of environmental conditions consistently associated with species occurrences and represent limiting conditions. In contrast, partitions with high variance are less informative of habitat requirements. Partitioning by identifying essential habitat relationships is especially useful for modeling habitat suitability in changing landscapes and under novel environmental conditions.

A comparative model selection approach was used to identify the most predictive set of environmental variables, with evaluation based on a random validation sample of 35% (253 occurrences) of the BUOW occurrence records. We tested 12 models with and without inclusion of physiographic factors, soils, and land use variables, starting with a simple two-factor abiotic model that included only physiographic features: slope and elevation. Forward stepwise refinement tested whether addition of single factors improved the performance of diagnostic metrics, including precipitation, temperature, soil texture, vegetation and land use.

The variable set was chosen for its ability to predict high habitat similarity for occurrence locations and for strong concurrence between sets of calibration and validation occurrence records.

Within the selected variable set, one partition was selected to represent the model. Selecting a single orthogonal PCA partition to predict species occurrence controls for the multicollinearity common in multivariate grids of climate and topographic variables and improves model performance (Rotenberry et al. 2002). The ideal partition is one that identifies habitat characteristics that remain relatively stable across the range of presence locations, which are more likely associated with species occupation than highly variable habitat characteristics (Rotenberry et al. 2002).

Finally, the eigenvector of the selected partition was used to calculate a score for every location across the spatial grid. To calculate the Habitat Similarity Index (HSI), the score was rescaled based on the X^2-distribution to range from 0 to 1. On this scale, 1 represents habitat that perfectly matches the environmental characteristics of known occupied habitat, and zero represents areas with no suitability. All modeling was conducted in SAS software™, version 7 (SAS 1991). A threshold HSI value was determined using the maximum sensitivity+specificity criterion using the SDMTools package in R (Fielding & Bell 1997; Liu et al. 2016; VanDerWal et al. 2019; R Core Team 2021). To evaluate the area of habitat predicted to be suitable that falls within the footprint of urbanized lands, we obtained a publicly available spatial dataset of developed lands in San Diego County (San Diego Association of Governments 2016). We evaluated the spatial overlap of urban and developed areas with the extent of lands determined to have an HSI value greater than the threshold value.

Table 1. Set of climate, topography, and vegetation community variables assigned to each individual point in the spatially explicit grid of points.

Variable	Source	Year
Soil texture		
Percent sand, clay	USDA Soil Viewer ArcMap extension	-
Percent land cover		
Bare ground	USGS Global 30m Land Cover	2010
Vegetation community		
(coastal sage scrub,	Western San Diego	2012
chaparral, grassland,	Southern OC	2013
riparian, agricultural, oak	Northern OC	2013
forest, and urban)	Western Riverside	2014
	Miramar	2012-14
	Fallbrook	2010
	Camp Pendleton	2003
	Fire Resource Assessment Program (all gaps)	2006
Topography		
Elevation	USGS (DEM)	2013
Slope	DEM-derived	2013
Climate		
Precip-monthly averages	PRISM	1981-2010
Precip-annual averages	PRISM	1981-2010
Winter precip (Oct-Jan)	PRISM	1981-2010
Spring precip (Feb-May	PRISM	1981-2010
Temp-min monthly avg	PRISM	1981-2010
Temp-max monthly avg	PRISM	1981-2010

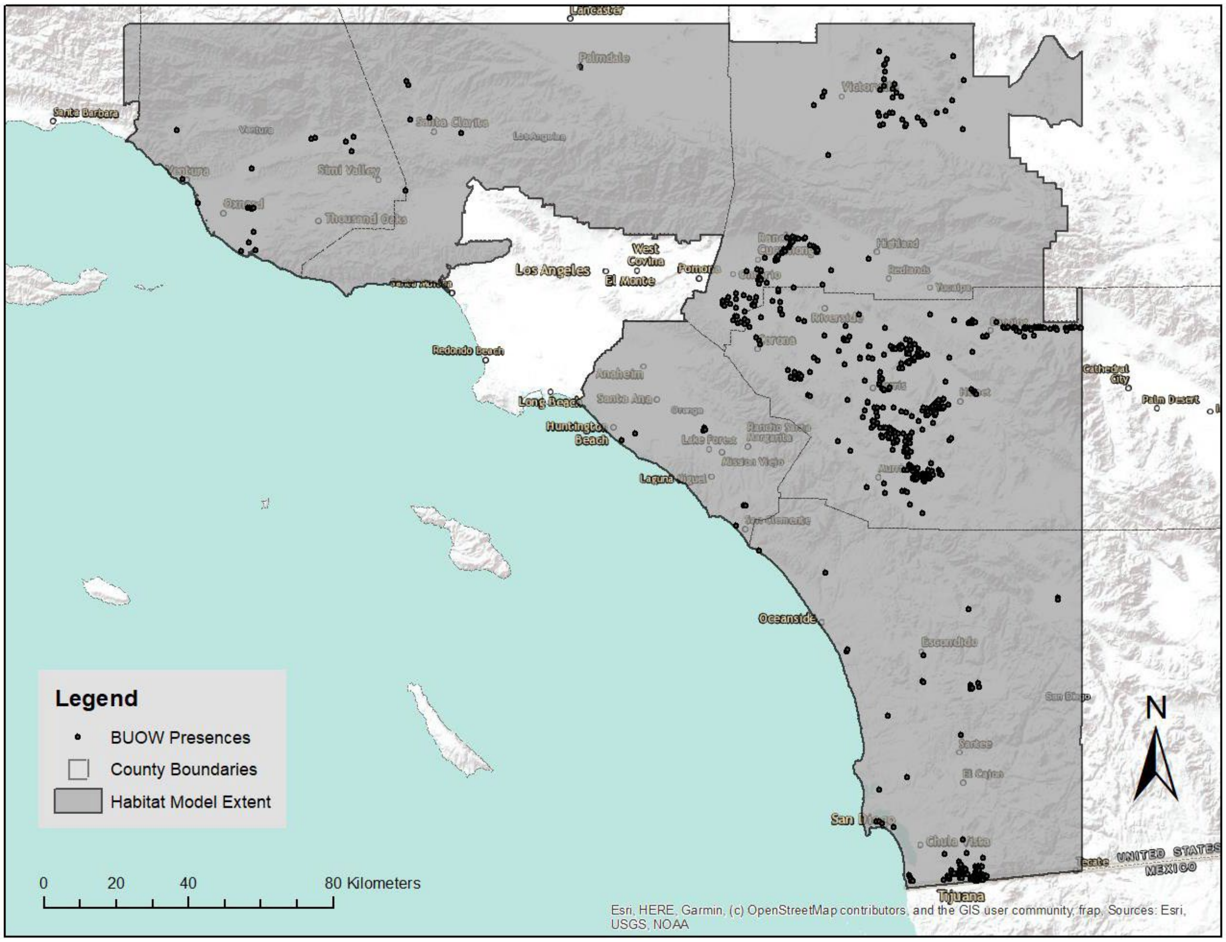


Figure 1. Extent of regional dataset for BUOW habitat suitability for years 1998-2020 along with BUOW occurrence records. The eastern extent is delineated to limit the amount of desert habitats included in the analysis, and the city of Los Angeles is excluded due to the absence of undeveloped lands during the sampling period.

Table 2. Eight regions of spatially clustered BUOW occurrence points defined during model development.

Region	Subsample size (n)
Ventura	23
Apple Valley	36
San Bernardino	113
Banning Pass	58
North Riverside	115
South Riverside	243
San Diego	43
Otay	93

Habitat Suitability Modeling Results

The selected model (Figures 2 & 3) includes both abiotic factors (minimum spring temperature, annual precipitation, elevation, slope) and land cover variables (urban, coastal sage scrub, chaparral, grassland, riparian, and agricultural) at 150 m scale. The fifth principal component was selected to represent habitat suitability, with an Area Under the Receiver Operating Characteristics (AUROC) of 0.98. For the selected model, median calibration habitat suitability index (HSI) was 0.89 and median validation HSI was 0.90. The threshold selection rule of maximum of sensitivity+specificity indicates an appropriate threshold HSI value of 0.27. Six categories of habitat quality represent the range of suitability values from relatively low (HSI=0.3-0.6) to high habitat quality (HSI≥0.9, Figures 2 & 3).

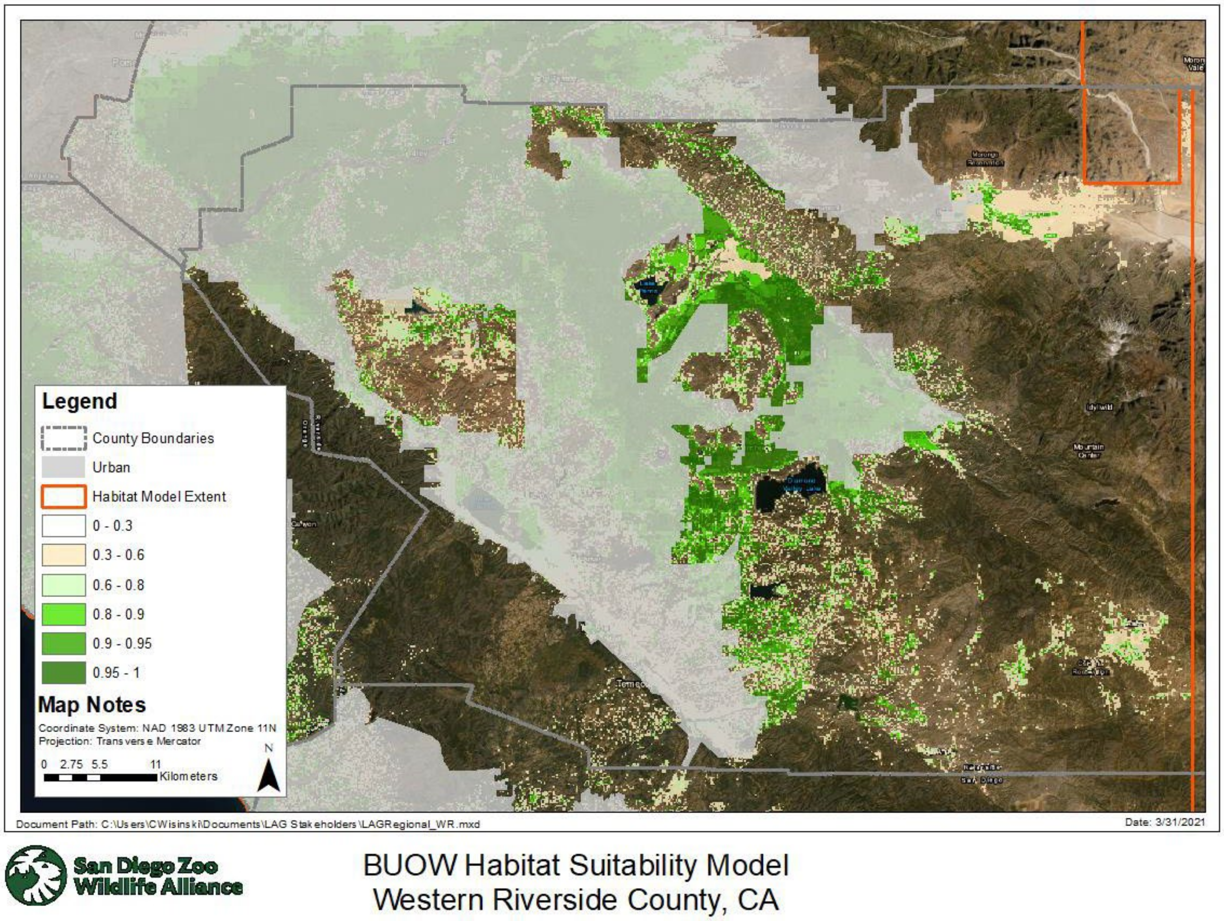


Figure 2. Western Riverside County BUOW habitat suitability model with urban areas masked. The habitat suitability index (HSI) is the eigenvalue rescaled on the X^2-distribution to range from 0 to 1. On this scale, 1 represents habitat that perfectly matches the environmental characteristics of known occupied habitat, and 0 represents habitat with no suitability for BUOW. Urban areas are excluded from the map (but not analysis).

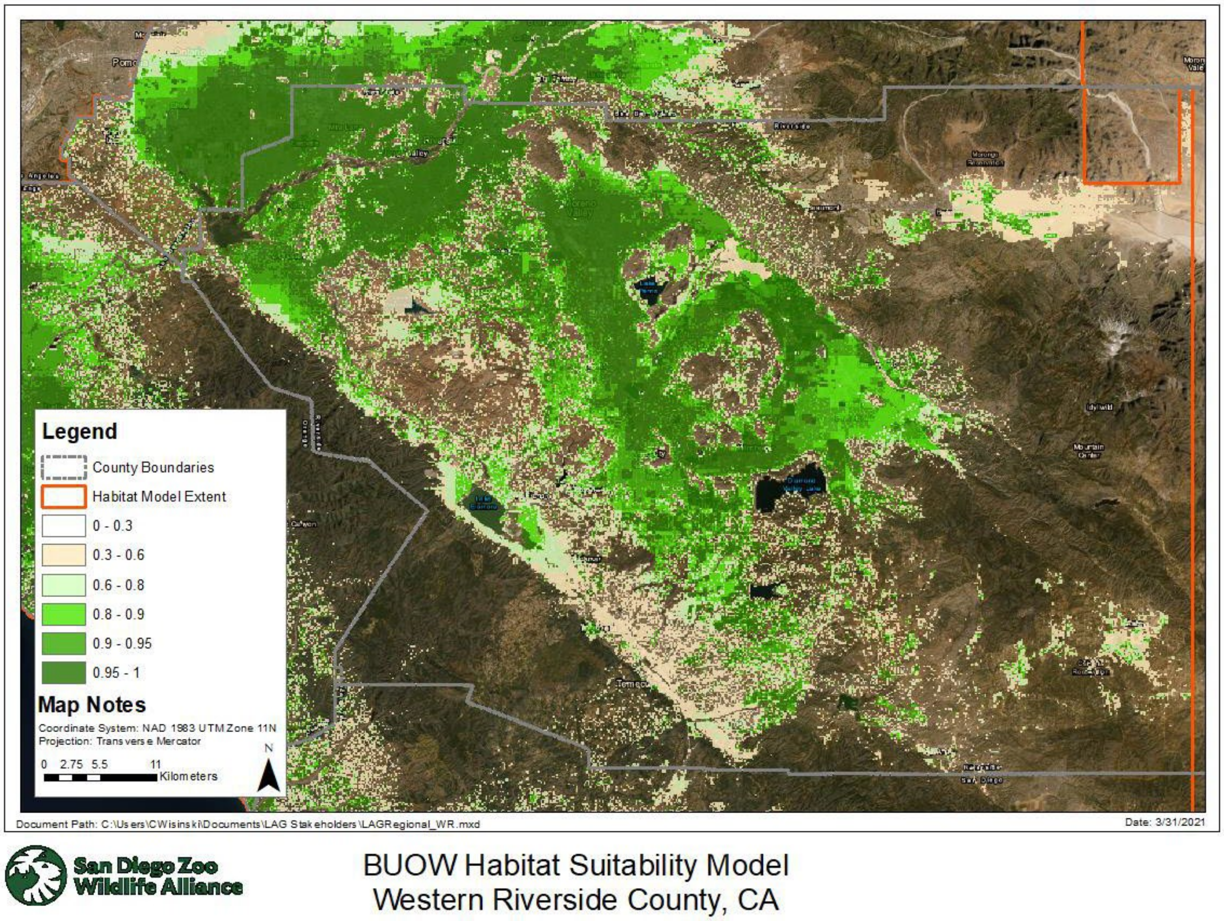


Figure 3. Western Riverside County BUOW habitat suitability model with urban areas shown. The habitat suitability index (HSI) is the eigenvalue rescaled on the X^2-distribution to range from 0 to 1. On this scale, 1 represents habitat that perfectly matches the environmental characteristics of known occupied habitat, and 0 represents habitat with no suitability for BUOW. Urban areas are shown here for comparison.

The abiotic variables most strongly correlated with the BUOW habitat suitability index were slope (r = -0.55) and annual precipitation (r = -0.51, Table 3). Among the land-use factors, shrub- and tree-dominated classification categories (chaparral, coastal sage scrub, riparian) were negatively correlated with BUOW presence. Land use currently classified as urban (r = 0.53) was strongly correlated with historic burrowing owl presence, owing to the fact that burrowing owls select sites that are most suitable for human development. The habitat suitability model calculates an HSI value for each cell across the landscape, including lands known to be within the footprint of urbanization. We evaluated the spatial overlap of developed areas (delineated as 'Urban' in Figure 2) and lands with an HSI value greater than the threshold value (HSI>0.27). This comparison identified the extent of lands predicted to be potentially suitable due to environmental factors, but which are likely unavailable due to urbanization. Over the landscape extent of potentially suitable habitat area (947,131.9 ha), 67.4% is likely unavailable due to urbanization (638,545.7 ha). These lands are masked by the extent of urban lands (Figure 2).

Another way to identify the variables that characterize burrowing owl habitat suitability is to compare the descriptive statistics for the occurrence points to the statistics for the entire landscape. Owls were recorded in lower elevation sites with flatter slopes, less annual precipitation and warmer spring conditions relative to the modeled area of interest (AOI, Table 3). The measure of variability (standard deviation) for each of these factors is smaller for BUOW-occupied sites relative to the entire modeled AOI, indicating the potential for limiting habitat relationships between BUOW and these factors.

Table 3. Descriptive statistics for burrowing owl presence points only compared to all points contained in the landscape extent, with correlation (*r*) of each variable with HSI.

	Correlation	**Presence only (n=724)**		**All points (n=1,352,115)**	
	(r)	**Mean**	***SD***	**Mean**	***SD***
Climatic					
minimum temperature (April, ˚C)	*0.41*	8.5	*1.2*	7.0	*2.8*
maximum temperature (August, ˚C)	*0.07*	34.1	*3.8*	32.0	*3.5*
annual precipitation (cm)	*-0.51*	30.4	*6.7*	44.3	*19.7*
spring precipitation (Feb-May, cm)	*-0.49*	15.5	*3.5*	22.1	*10.2*
winter precipitation (Oct-Jan, cm)	*-0.50*	13.8	*3.2*	20.3	*9.1*
Topography					
Elevation (m)	*-0.43*	401.0	*198.4*	750.7	*554.4*
Slope (percent)	*-0.55*	3.1	*5.0*	13.8	*12.8*
Soils					
Clay (percent)	*0.12*	20.8	*14.7*	15.1	*10.3*
Sand (percent)	*0.04*	50.5	*24.6*	54.6	*24.0*
Percent land use within 150 km					
urban	*0.53*	27.7	*40.8*	22.9	*39.5*
coastal sage scrub	*-0.15*	8.0	*21.6*	12.2	*21.8*
chaparral	*-0.44*	1.1	*8.4*	26.6	*40.2*
grassland	*0.12*	30.2	*40.9*	5.6	*19.2*
riparian	*-0.10*	0.8	*6.1*	1.3	*8.1*
agricultural	*0.20*	19.4	*35.8*	5.8	*22.8*

Objective 3. Rapid Assessment Planning and Implementation

We shared the top BUOW habitat suitability model as a Geographic Information Systems (GIS) layer file with partners from California Department of Fish and Wildlife (CDFW), U.S. Fish and Wildlife Service (USFWS), and Western Riverside County Regional Conservation Authority (WRCRCA) in April 2021. On 7 April 2021, we convened a meeting of key partners from CDFW, USFWS, and WRCRCA to discuss the suitability model and identify key areas where high suitability intersected with lands currently under conservation. As a result of this meeting, our partners considered the strengths and weaknesses of sites predicted to have high suitability by our model that are also under conservation in western Riverside County. Together, we identified 15 sites of interest for rapid assessment. Of the identified sites, we proceeded with securing access agreements and acquired access for 11 sites (Figure 4) and prepared for data collection under our rapid assessment protocol.

Rapid assessments were conducted on lands expected to be managed for conservation value in perpetuity, to analyze site-level potential as receiver sites for translocated burrowing owls or for establishing new burrowing owl population breeding nodes. The assessments were conducted from early June to late early November of 2021, a time period covering the mid- to late-breeding season and post-breeding season for BUOW.

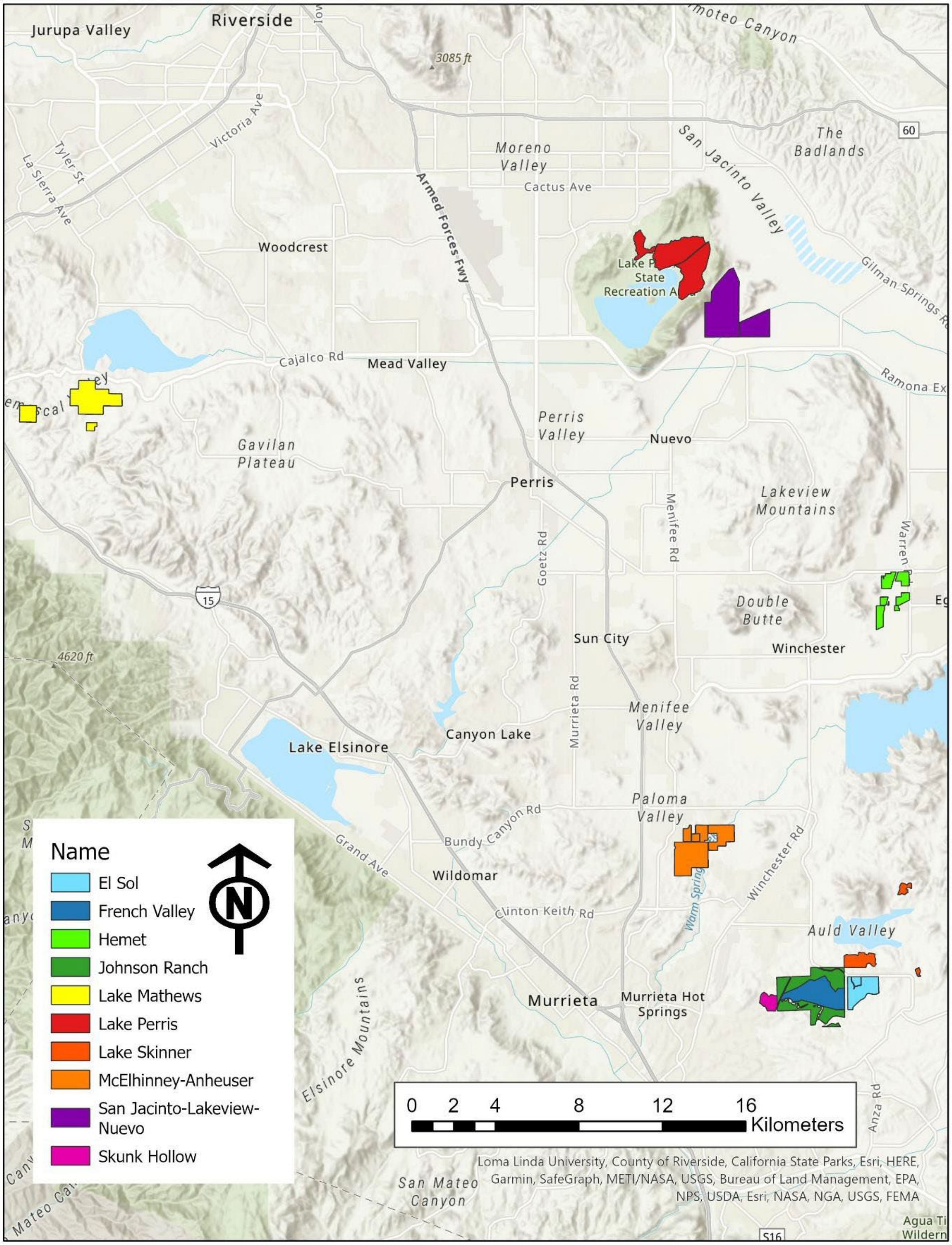
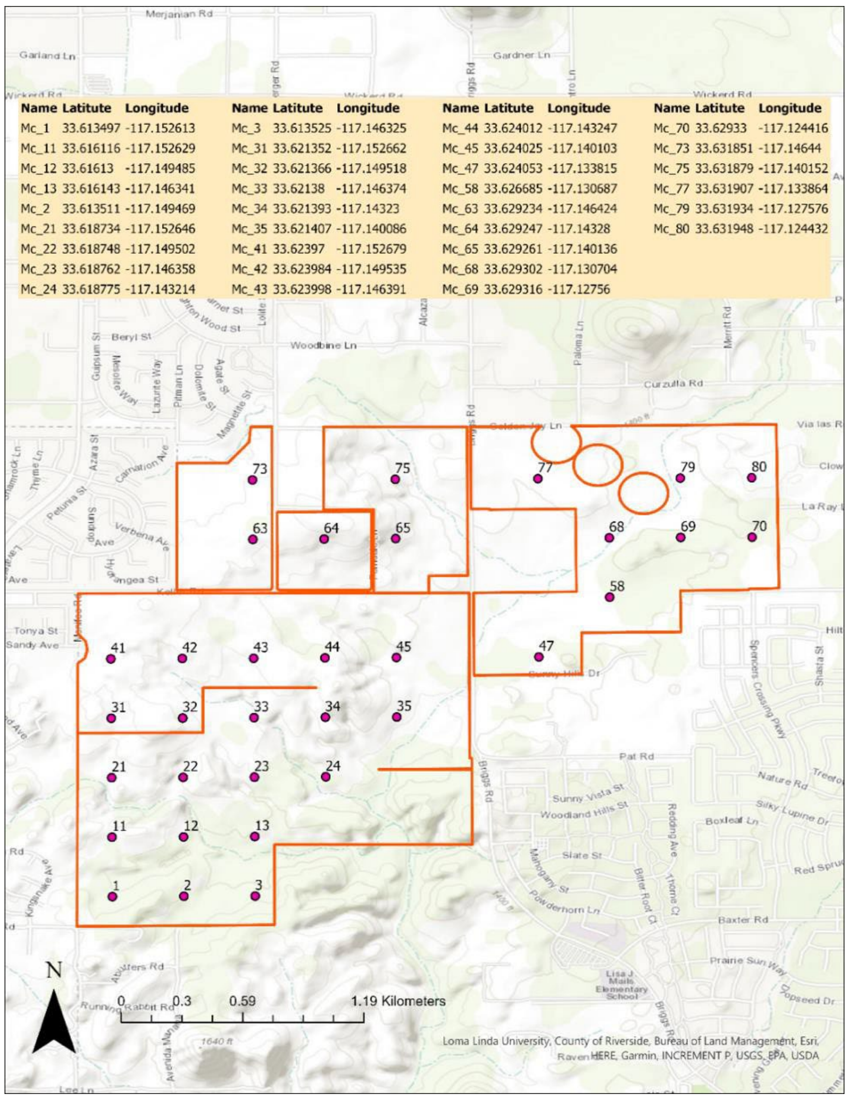


Figure 4. Sites in western Riverside County evaluated for BUOW suitability with rapid assessment methods in 2021. Note the McElhinney-Stimmel and Anheuser Busch sites are combined here.

Rapid assessment planning for priority sites

For each priority site, we generated random sampling locations for rapid assessment in a manner that facilitated maximum spatial coverage of the area under consideration. We first merged interior parcels into one outer boundary polygon. We then created a grid for each site with 350 m x 350 m (1 hectare) cells and saved the centroid of each grid cell as a point in order to evenly distribute the potential survey points throughout the parcel. We masked from consideration grid cells and point centroids that fell upon areas within 100 meters of an active burrow, slope > 15%, waterways, roads, and vegetation community types not dominated by grassland, barren, or agricultural land. Using a random number generator, we assigned each centroid point a random number and then sorted the random numbers from highest to lowest and selected the top 50% of locations to receive rapid assessment (Figures 5 & 6).



Name	Latitute	Longitude	Name	Latitute	Longitude	Name	Latitute	Longitude	Name	Latitute	Longitude
Mc_1	33.613497	-117.152613	Mc_3	33.613525	-117.146325	Mc_44	33.624012	-117.143247	Mc_70	33.62933	-117.124416
Mc_11	33.616116	-117.152629	Mc_31	33.621352	-117.152662	Mc_45	33.624025	-117.140103	Mc_73	33.631851	-117.14644
Mc_12	33.61613	-117.149485	Mc_32	33.621366	-117.149518	Mc_47	33.624053	-117.133815	Mc_75	33.631879	-117.140152
Mc_13	33.616143	-117.146341	Mc_33	33.62138	-117.146374	Mc_58	33.626685	-117.130687	Mc_77	33.631907	-117.133864
Mc_2	33.613511	-117.149469	Mc_34	33.621393	-117.14323	Mc_63	33.629234	-117.146424	Mc_79	33.631934	-117.127576
Mc_21	33.618734	-117.152646	Mc_35	33.621407	-117.140086	Mc_64	33.629247	-117.14328	Mc_80	33.631948	-117.124432
Mc_22	33.618748	-117.149502	Mc_41	33.62397	-117.152679	Mc_65	33.629261	-117.140136			
Mc_23	33.618762	-117.146358	Mc_42	33.623984	-117.149535	Mc_68	33.629302	-117.130704			
Mc_24	33.618775	-117.143214	Mc_43	33.623998	-117.146391	Mc_69	33.629316	-117.12756			

Figure 5. The initial stage of rapid assessment point selection at the McElhinney-Stimmel and Anheuser Busch areas in western Riverside County, CA. Potential survey locations (pink circles), derived from 1-hectare grid centroids, are shown. A random draw from these available locations resulted in the actual surveyed locations shown in Figure 6. Active BUOW burrows at McElhinney-Stimmel were buffered by 100 m prior to random point generation.

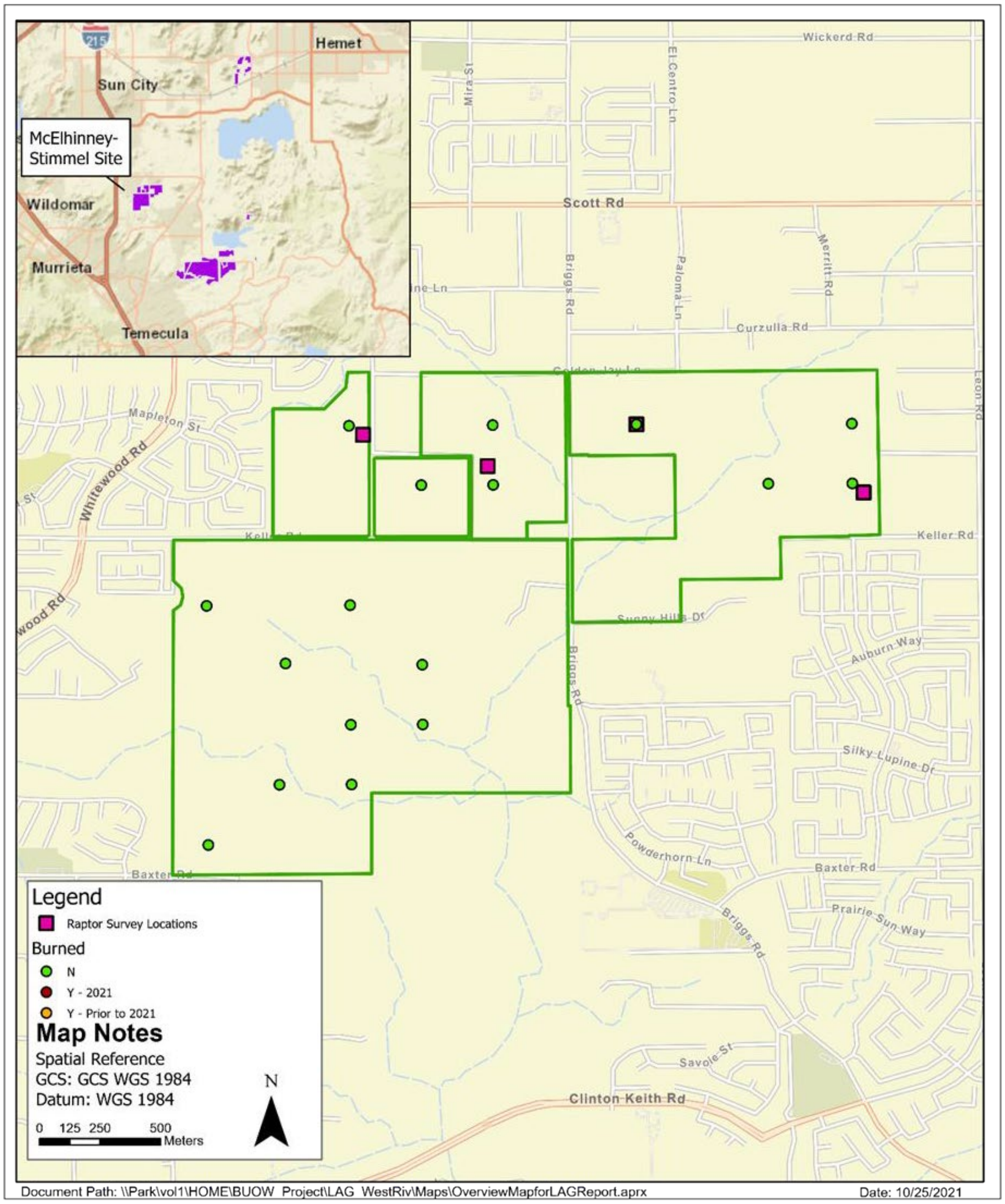


Figure 6. Map of McElhinney-Stimmel and Anheuser Busch parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares). Active BUOW burrows at McElhinney-Stimmel were buffered by 100 m prior to random point generation.

All locations were uploaded to hand-held GPS units as well as to a map within ArcGIS Field Maps. Researchers in the field had the agency to select a substitute random location should one of the selected points fall within an area that is not suitable for BUOW (e.g. coastal sage scrub, rock outcrop, wetland). The order in which we completed sites was determined by timing of right of entry agreements and logistics (e.g. proximity to other parcels to be assessed). Once our first right of entry agreement was in-hand, rapid assessment field work was initiated on 25 June 2021 and completed on 3 November 2021 (Table 4; Figure 7).

Table 4. List of sites selected for rapid assessment for burrowing owl suitability in western Riverside County, CA. Survey timeframe and sampling effort at each site is also indicated.

Site Name	Land Management	Survey dates	Sites assessed
The Playa/Hemet	Regional Conservation Authority (RCA)	25 June - 20 July 2021	13
McElhinney-Stimmel	Regional Conservation Authority (RCA)	8-26 July 2021	8
Anheuser Busch	Regional Conservation Authority (RCA)	14 July - 6 August 2021	10
El Sol	Regional Conservation Authority (RCA)	29 July - 11 August 2021	7
Lake Skinner/MSR - Multi Species Reserve	Riverside County Parks	10-23 August 2021	7
Lake Mathews	Riverside County Habitat Conservation Agency (RCHCA)	17-30 August 2021	14
Lake Perris	California State Parks	31 August- 20 September 2021	28
San Jacinto Wildlife Area/Lakeview Nuevo	California Department of Fish and Wildlife (CDFW) and Regional Conservation Authority (RCA)	21 September - 19 October 2021	23
Skunk Hollow	Center for Natural Lands Management (CNLM)	11 October - 3 November 2021	1
French Valley	California Department of Fish and Wildlife (CDFW)	11 October - 3 November 2021	20
Johnson Ranch	Riverside County Parks/CNLM	11 October - 3 November 2021	9
Total			**140**

Figure 7. Daniel Banyai-Becker (L) and Timothy Gaffney (R) set up a wildlife camera to detect small mammal presence at a plot center for burrowing owl suitability rapid assessment, Hemet Playa, western Riverside County, CA, 2021.

Rapid Assessment Implementation

Rapid assessments are designed to rapidly collect accurate data on several metrics of interest. As such, there is an inherent tradeoff between the number of metrics included and the intensity of data collection. The strength of the rapid assessment approach is in the ability to efficiently evaluate multiple sites via a consistent, objective framework thereby providing useful information to land managers for future conservation planning. The data provide a snapshot of current conditions, and enable qualitative comparisons of the relative levels of multiple habitat metrics across sets of sites. Conversely, the intensity of data collection in the rapid assessments may not be sufficient for statistical analysis. In addition, measures of abundance from rapid assessments should not be interpreted as absolute measures, as would be captured by longer term or higher intensity sampling. For the purpose of quickly filling in knowledge gaps, however, rapid assessments are useful.

We collected data on prey availability (small mammals such as gophers, kangaroo rats, and pocket mice), predator pressure (raptors, corvids, and coyotes), vegetation height and composition, and soil composition to inform burrowing owl conservation potential for each site. Sampling was randomized in order to support inference. Implementation of the rapid assessment involves an initial GIS analysis to generate randomized sampling points, as described above, and data collection, which occurs in three or four site visits over a 10-day period.

At each site, we established rapid assessment plots centered upon the randomly selected grid centroid as outlined above. All sampling with the exception of the predator transects occurred at these points (i.e., small mammal prey availability, California ground squirrel presence, soil and vegetation composition and structure). Raptor and corvid point count stations were established at locations that provided the best visibility for the entire site. At times the raptor and corvid point count stations were the same as the plot center for rapid assessment, but in other cases they were separate locations. Sampling was focused on the most suitable grassland areas of each site, rather than all lands within preserve boundaries. A consistent level of survey effort was maintained across sites of varying sizes by holding the sample point density constant at a mean density of 1 point per 25 hectares.

For each site, data collection occurred over multiple site visits. Wildlife cameras at sampling stations ran for a minimum of 10 nights. The general sampling schedule was as follows, but may vary depending on the size of a site:

- Visit 1 (day 1): camera set-up (at each sampling station), raptor/corvid point counts visit 1 (at designated stations, not necessarily at camera station plot centers)
- Visit 2 (day 5): camera maintenance, vegetation/burrow surveys, and soil sample at each sampling station, raptor/corvid point counts visit 2
- Visit 3 (day 10): collect cameras, large mammal predator transects (walking cattle trails, roads, or other paths through or adjacent to a site), wrap up vegetation/burrow surveys if any points left, raptor/corvid point counts visit 3

- Possible 4th visit if there were any camera issues

For each plot, we initiated the rapid assessment protocol in the following order:

1. Set up camera station at plot center to record small mammal occupancy. Deploy camera & set out sterilized millet (if using it).
2. Establish a North-South transect centered upon the plot center, such that the transect extends 50 m in both directions.
3. Record vegetation height and composition via point intercept every 1 m along the North-South transect (Figure 8).
4. Record small mammal burrow density and extent of soil disturbance within 2 m on either side of a 25 m subset of the longer 50 m North-South transect (Figure 9). Do the same in the East-West direction by repositioning one 50 m meter tape.
5. Collect a soil sample at the plot center.

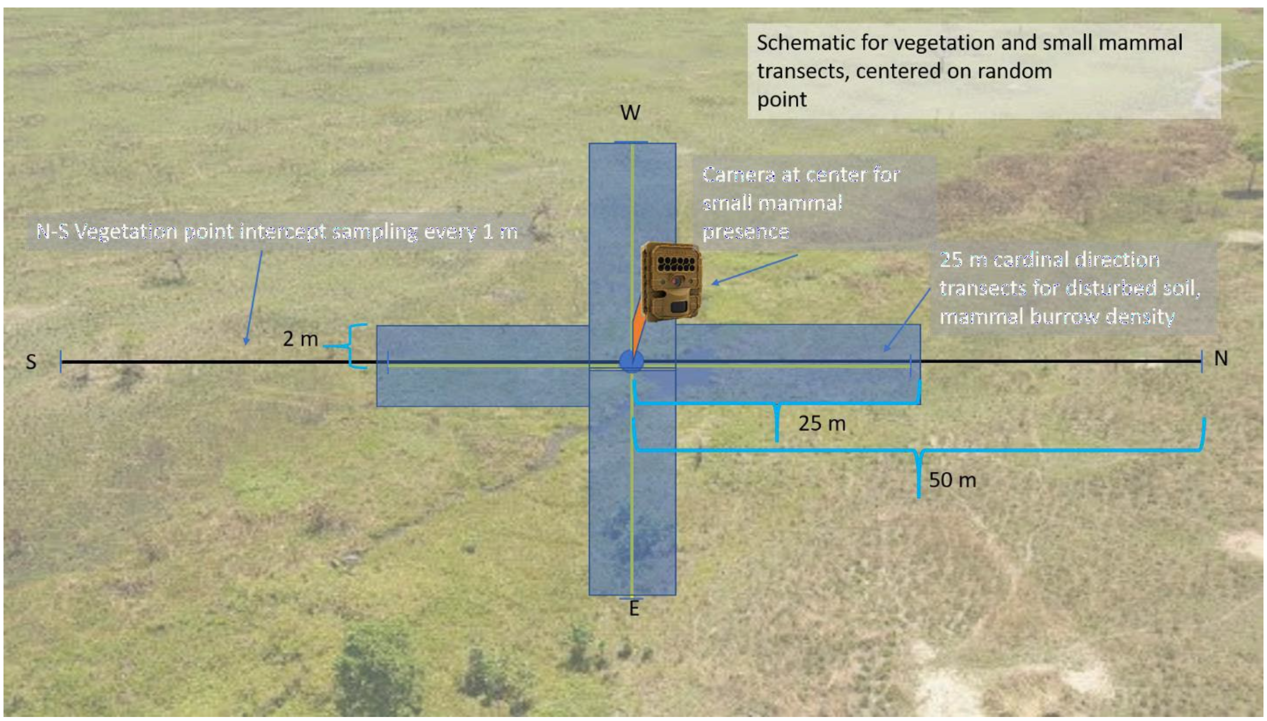


Figure 8. Overview of rapid assessment plot and transect configuration, which consists of a 100 m North-South transect and 4 shorter, 25 m transects in each cardinal direction. A wildlife camera was established at the plot center, and a soil sample was collected at the plot center.

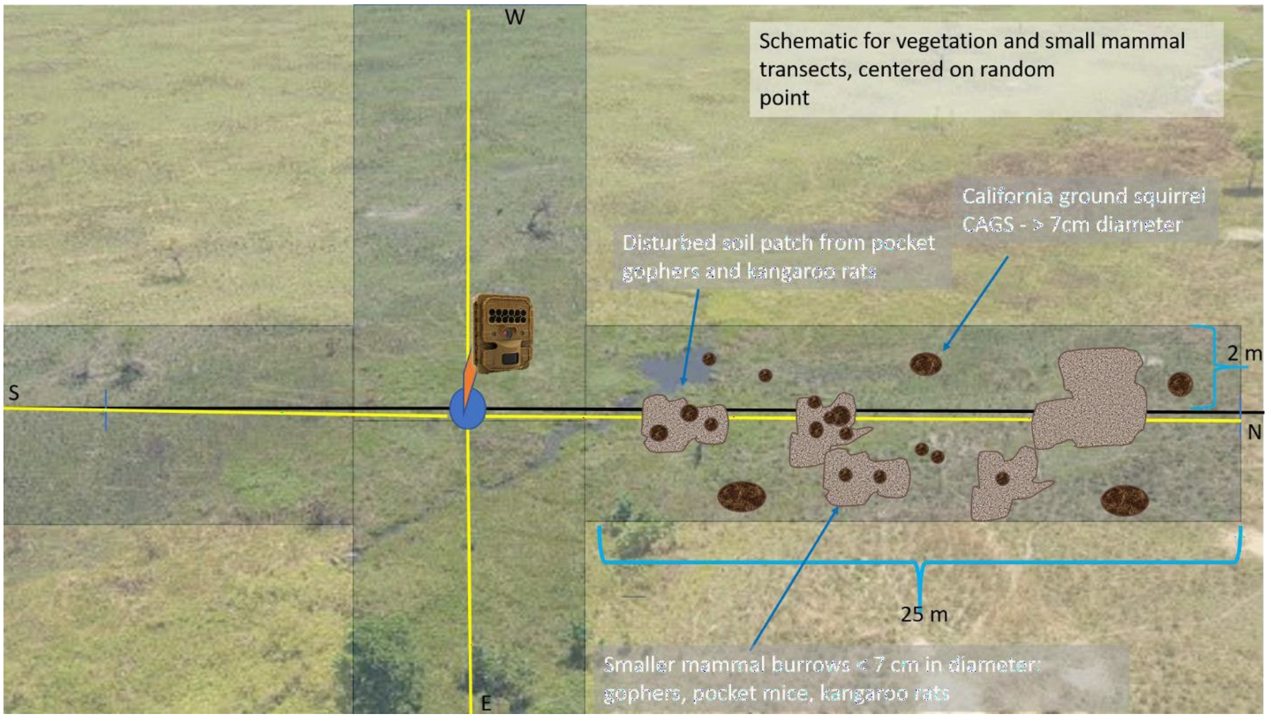


Figure 9. Overview of California ground squirrel and other small mammal burrow density and soil disturbance quantification along each of 4, 25 m transects established from the plot center.

Vegetation structure and composition

To assess the current composition and structure of the plant communities within the delineated grassland areas of suitability described above, we sampled vegetation height and composition at each plot. We sampled vegetation characteristics along a 100 m North-South transect, centered on the sampling point (Figure 8). Grassland structure varies significantly throughout the growing season with respect to vegetative height and percent cover, thus our assessments are meant to serve as a snapshot for comparison among sites.

We used a hand-held GPS unit to navigate to each sampling point then anchored a 50 m tape at the plot center oriented to the North and South (0° and 180°, respectively) using a compass. We recorded whether or not the 100 m North-South transect crossed either natural or anthropogenic boundaries (roads, field edges, ecotones). We used the point-intercept method to characterize vegetation composition and structure along the transect (Figures 8, 9, and 10). Every 1 m from 0-100 m we recorded the presence of all functional cover types intercepting the point, not just the tallest layer of vegetation, and recorded the height of the tallest functional cover type at each intercept. Vegetative functional groups include exotic/native forb, exotic/native grass, crop, shrub, bare ground, litter, rock, road, coarse woody debris, and tree. Next we recorded the height of each functional group to the nearest cm using a collapsible meter stick. Finally, for each transect we compiled the relative proportion of cover (counts per 100 m) and the height (min., mean, max $\pm$ SD) of each functional cover type.

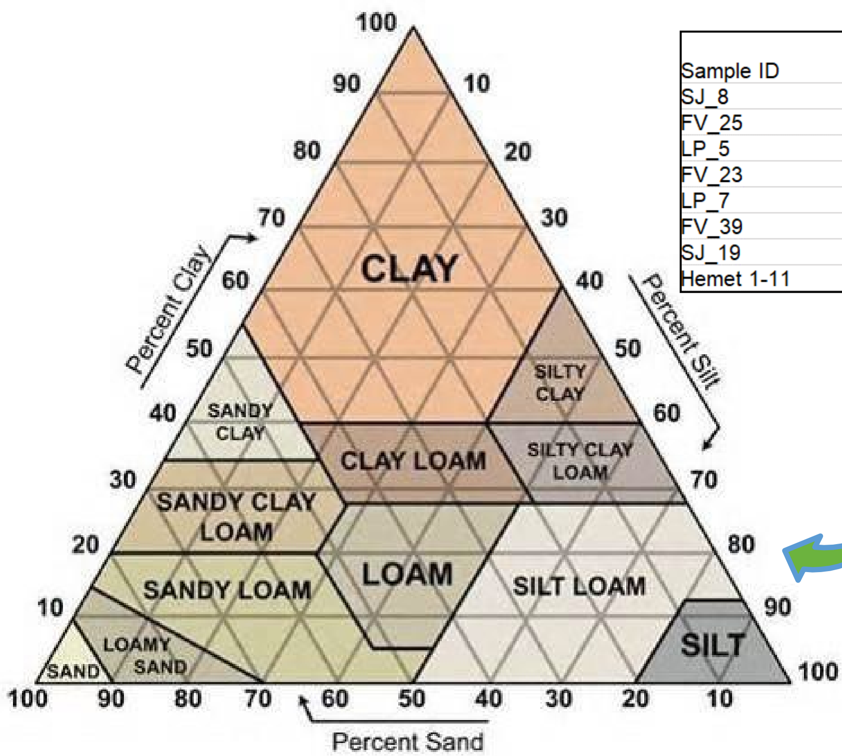
Figure 10. Vegetation sampling using the point-intercept method along 50 m North-South transects

Soil composition

To assess suitability of soils for squirrel burrowing activity, we collected a soil sample at each plot center. We used a trowel to collect approximately 100 g from the top 8 cm of soil and assessed for soil texture and gravel content. We then processed each soil sample using the soil texture hydrometer method of mechanical analysis (https://lter.kbs.msu.edu/protocols/108) at the US Fish and Wildlife Service Laboratory in Carlsbad, CA. The hydrometer method determines the percentage of sand, silt, and clay in the inorganic fraction of soil via the sedimentation rate of particles suspended in water. After mixing the soil sample well, including breaking it up with a mortar and pestle, we weighed 40-50 g of the sample and mixed it with distilled water and a 5% solution of sodium hexametaphosphate (dispersing agent solution). We then transferred the mixture to a large graduated cylinder and added distilled water to the 1000 ml mark (Figure 11). A separate cylinder with just distilled water and the dispersing agent solution is used as a control. We took hydrometer readings of each cylinder within the first minute following transfer to the large cylinder and recorded the temperature. We then let the cylinders stand undisturbed for 3 hours. After the settling period, we again took the temperature of each sample cylinder and the control cylinder as well as a final hydrometer reading from both the control and sample cylinders. Soil texture is reported as percent clay, percent sand, and percent silt. Sand (g/L) is derived by subtracting the 40 second hydrometer reading from the initial sample mass. Clay (g/L) is derived by subtracting the 3-hour hydrometer reading from the initial sample mass. Percent sand is ((sand g/l)/sample mass) x 100. Percent clay is ((clay g/l)/sample mass) x 100. Percent silt is the difference (100-(%sand+%clay)).

Finally, we determined the soil texture class (e.g. loam, clay, sandy loam) of each sample by entering the % sand and % clay values into an online soil texture calculator (https://nowlin.css.msu.edu/software/triangle_form.html; Figure 12).

Figure 11. Soil samples from plot centers at each rapid assessment site in western Riverside County, CA (L) and soil texture analysis using the hydrometer method of mechanical analysis (R).



Sample ID	% Sand	% Clay	% Silt
SJ_8	5.49	48.16	46.35
FV_25	71.94	10.92	17.14
LP_5	72.16	8.88	18.95
FV_23	73.43	5.42	21.16
LP_7	70.47	5.11	24.42
FV_39	76.09	5.10	18.80
SJ_19	36.72	22.09	41.19
Hemet 1-11	31.42	23.44	45.14

Figure 12. Example of soil texture analysis. The table in the upper right is an example of the % sand, % clay, and % silt values generated from the hydrometer method of mechanical analysis. These values were then entered into the soil texture class calculator, which generates the soil texture class, represented by the USDA soil textural triangle on the left.

Prey availability

We estimated metrics of prey availability with wildlife cameras and belt transect sampling focused on small mammals rather than invertebrate prey (Figure 9). Field data collected in 2013-2015 indicate that local prey/productivity relationships rely on small mammal prey to support higher BUOW productivity (Wisinski et al. 2016). Gophers are an important prey item for BUOW in southern California, and BUOW also opportunistically prey on a variety of mice and kangaroo rat species. Conversely, data from 2014-2015 indicated a significant negative relationship between productivity (i.e., maximum number of chicks and number fledged) and the proportion of invertebrates delivered to the breeding burrow. Both findings are consistent with an approach to prey availability sampling that focuses on small mammal species – both relative abundance and sign (soil disturbance and burrows). We also estimated a relative abundance measure for CAGS due to the obligate relationship between owls and squirrels in this region.

Small mammal occupancy

We established camera stations at the center of each randomly selected point. At each plot center, we used zip ties to mount a Reconyx HP2X camera (https://www.reconyx.com) and lock box on a wooden stake approximately 20 cm above the ground, with the camera facing North (Figure 8, Figure 9). We ensured that the top of the stake was not more than 2’ (0.61 m) above the ground to reduce potential for perching by raptors and corvids. The cameras were set to high sensitivity, and recorded both 10 second videos and photos, with a 1-minute quiet period between camera triggers. Cameras were set to night only mode with an ISO/Shutter speed setting at 1/30th and 1600, respectively, or set to “Optimized” for newer models.

We hand-pulled vegetation from an area approximately 2 meters in front of the camera and placed a handful of sterilized millet if possible, depending upon land-manager preferences, at a bait station 1.5 m in front of the camera. We sterilized the millet in a microwave for 4 minutes, stirring every 1-2 minutes to avoid burning the seeds. Cameras were deployed for a minimum of 10 nights. The resulting images and video data were processed using Adobe Bridge, and occupancy estimates were calculated in the software program Presence, using a simple single-season model. Occupancy estimates represent a measure of the proportion of sampling points occupied by a species. In this context, the occupancy values can be interpreted as a relative index of abundance of small mammals among sites. Concerns that baited stations may skew abundance measures upwards by attracting individuals from greater distances apply when the objective is to estimate population levels. However, baited stations may be used for relative measures of abundance, as long as the stations are implemented consistently across sites. At the request of land managers, we did not bait cameras with sterilized millet at Johnson Ranch, French Valley, Skunk Hollow, and Lake Mathews.

Small mammal disturbance and burrow density

At each plot center, we set out four 25 m transects along each cardinal direction, making sure to avoid large obstructions. We used a line-intercept method to measure areas of disturbed ground resulting from gopher and other small mammal activity, with additional notation for recent digging activity (Figure 9). As we walked each 25 m transect, we recorded the point (in cm) where the tape first intersected soil disturbance from digging, burrow creation, and back-filled burrow entrances, and the point where the contiguous section of disturbance ended (in cm). Our goal was not to record each individual instance of raised soil around a small mammal burrow entrance, but to capture contiguous patches of disturbed ground. Gaps in disturbed soil > 10 cm (i.e. vegetated patches) warranted the beginning of a new disturbance patch. Individual segments of bare ground began when the transect first intercepted bare ground, and were ended when the transect intercepted vegetation, so that measurements were limited to bare ground. The segment lengths were totaled and used to calculate a percentage of the overall combined transect lengths (100 m) that intercepted areas disturbed by small mammal activity. The percentage of small mammal-disturbed ground was averaged by site to produce mean and standard error estimates which indicated intensity of small mammal activity by site.

We also counted the number of small mammal burrows within a 2 m wide belt on either side of each 25 m transect (2 m on either side of the centerline). We considered burrows with openings smaller than 7 cm to be created by small mammals including pocket gophers, kangaroo rats, pocket mice, and other small mammal species (Figure 13).

Figure 13. Small mammal burrow entrances (< 7 cm in diameter), back-filled burrows, and associated mounds of disturbed soil used to quantify relative extent of disturbed soil and relative density of small mammal burrows for each plot and each site in western Riverside County, CA.

California ground squirrel presence and burrow density

In addition to small mammal soil disturbance and burrow density, we also quantified CAGS burrow density along each of the aforementioned 25 m transects. CAGS burrows were generally large and conspicuous with burrow openings ≥ 7 cm (about the length of your index finger) in diameter with an apron of disturbed soil around it (Figure 14). CAGS tracks were larger, and there were usually larger squirrel-sized scats (about the size of a Tic Tac) around the burrow in the loose dirt. Latrines, small depressions filled with feces, were often observed near burrow entrances. Squirrel burrows falling within the belt were tallied to indicate presence and relative abundance of CAGS at each plot and for each site.

Figure 14. California ground squirrel burrow entrances (≥ 7 cm in diameter) and associated "aprons" of disturbed soil used to quantify relative density of California ground squirrel burrows for each plot and each site in western Riverside County, CA

Predator pressure

We included both aerial predators (raptors and corvids) and larger mammalian ground predators (coyotes and bobcats) in our rapid assessments of predator pressure. Wildlife cameras at BUOW nest burrows in San Diego County often record predation events, and show that the predators listed above are the most significant predators of BUOW in this region. Great horned owls and barn owls are also known predators that should be included in the assessment if feasible, but were not included in this study.

Raptor and corvid surveys

For our aerial predator surveys, we defined corvids as crows and ravens and raptors as any raptor species that could reasonably be expected to prey on BUOW, including hawks, falcons, and eagles. Turkey vultures and BUOW were excluded from the raptor counts. Surveys were conducted on three separate occasions at each point count station – generally on days 1, 5, and 10. Aerial predator surveys were 10 min in duration and timed to fall between the morning hour when raptors began catching thermals (roughly three hours after sunrise) and noon, when activity declined due to heat (surveys were conducted when temperatures were < 85 °F). Aerial predator point counts were established to encompass the largest view of the site possible. We selected point count stations on ridges or small rises within BUOW habitat at each site. The number of point count stations established for a site depended upon site topography and amount of visual obstruction. Some rapid assessment plot centers had good site visibility and were used as point count locations, but in many cases, we established point count stations that were separate from rapid assessment plot centers, and the new point count stations were recorded with a hand-held GPS unit. If the entire site could be viewed from one aerial predator point count station, then one station was sufficient for that particular site.

Upon arriving at a point count station, we recorded environmental conditions with a Kestrel 3000 weather meter (https://kestrelinstruments.com) including ambient temperature and mean wind speed. Once an observation session had been initiated by starting a 10-minute timer, an observer began systematically scanning the air, horizon, and all visible perches with binoculars while a second observer (data recorder) also scanned without binoculars. For each point count observation session, we recorded the avian species and number of each species observed, including unknowns. The 10-minute observation period was long enough to detect the raptors in the viewshed, and short enough to limit accidental double counting as individuals move around. We summarized the data across point count stations to produce relative abundance estimate for each species by site.

Large mammalian predator transects

We assessed the presence of larger mammalian ground predators by walking or driving a linear transect within or adjacent to each site and documenting scats and their general contents. We identified potential transects via aerial imagery (e.g. Google Maps) or in situ and selected linear features that were between 500 and 1500 m in length (e.g. Figure 15). Transects could be dirt roads, two-tracks, railroad rights of way, cattle trails, or established trails that intersected BUOW habitat within a site or were directly adjacent to the site. The start and end points of each transect were mapped as waypoints in a hand-held GPS unit and the actual length of each track recorded as the distance between the two waypoints. For each transect, we walked the transect at a pace of approximately 2 mph and recorded the number of coyote and bobcat scats and examined the contents of each. Fresh scat was noted (based on moisture level) and scats were classified by content (fur and bone, seeds and vegetation, or both categories present). We could not distinguish domestic dog from coyote tracks and therefore all canid scats were classified as coyote. We considered scats within 0.3 m of one another as the same scat, unless there was a difference in age or composition. These counts were summarized as scats/km for each site and provide a relative index of mammalian predator activity levels at each site.

Figure 15. An example of a mammalian predator scat transect within or adjacent to a rapid assessment site for BUOW suitability in western Riverside County, CA.

Rapid Assessment Results and Discussion

Vegetation structure and composition

Soil composition and texture are key variables in determining habitat for ground squirrels and other small mammals, as friable soils promote digging and burrow creation. While soil composition cannot be changed by management actions, grassland vegetation management is a key means for promoting persistence of both California ground squirrels and BUOW (Hennessy et al. 2018). In a recent study to assess habitat characteristics associated with California ground squirrel occurrence and persistence, continued squirrel presence and maintenance of active burrows declined with increasing vegetation cover and thatch (litter) (Hennessy et al. 2018).

Grasses and litter (thatch) were among the most abundant vegetative functional groups across all sites visited (Table 5). Because exotic grasses and exotic forbs were dominant, we grouped non-native and native grasses and forbs into two general categories: grass and forbs (Table 5). Vegetation height was lowest on average at French Valley, El Sol, and Lake Perris, and active grazing and other vegetation management activities coincided with our sampling efforts. A sudden ground fire burned several plots at the Hemet Playa complex on 29 June 2021, and we modified our survey protocol omitting vegetation and small mammal camera trials at these plots as all vegetation was completely burned.

Habitat suitability index (HSI) values were calculated at each plot and averaged across plots within each site. Consistently high BUOW suitability was observed at Hemet, French Valley, Lake Skinner, and Johnson Ranch with low within-site variability in HSI values (smaller range and standard deviation). Lower suitability and high variability in HSI values were observed at Anheuser Busch, McElhinney-Stimmel, Lake Mathews, and San Jacinto Wildlife Area (Table 5; Figures 16-22). Only one plot was surveyed at Skunk Hollow due to there being active burrows and vernal pool habitat that limited our ability to sample much of the parcel. The single plot that fell outside of active burrows and sensitive habitats fell within an area of less suitability compared to the majority of the parcel. Overall, Skunk Hollow is associated with high predicted BUOW suitability.

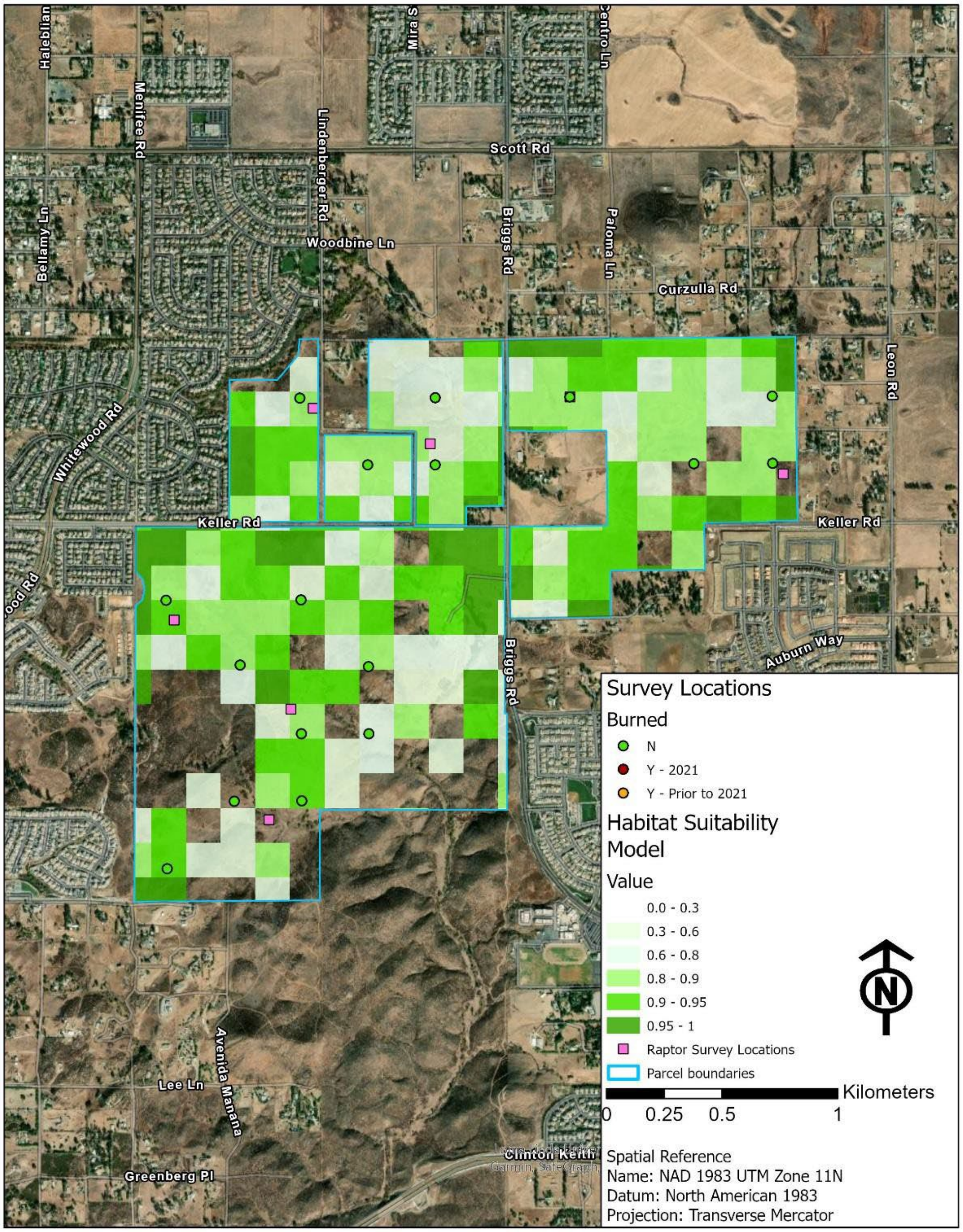


Figure 16. Map of McElhinney-Stimmel and Anheuser Busch parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability.

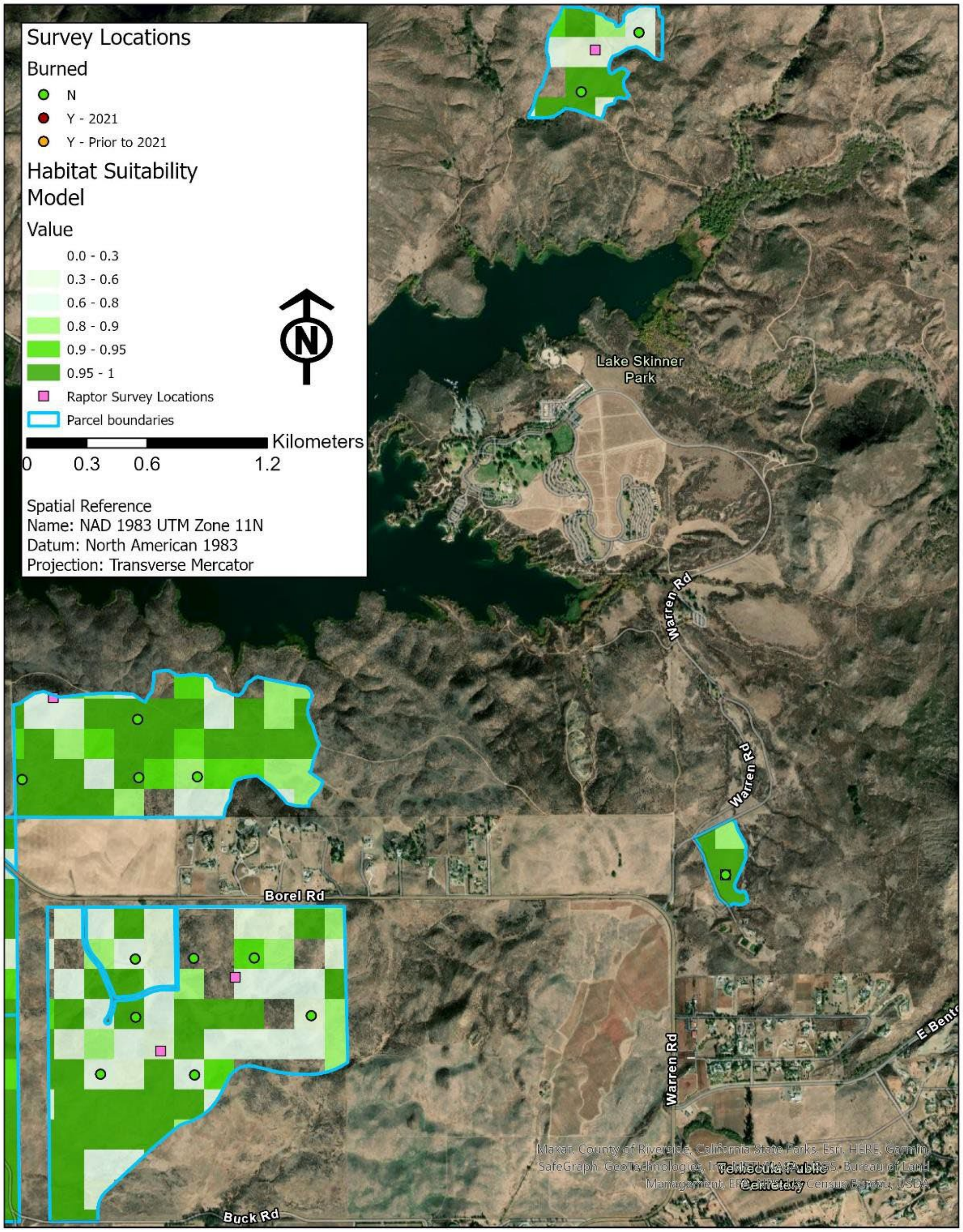


Figure 17. Map of Lake Skinner and El Sol parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability.

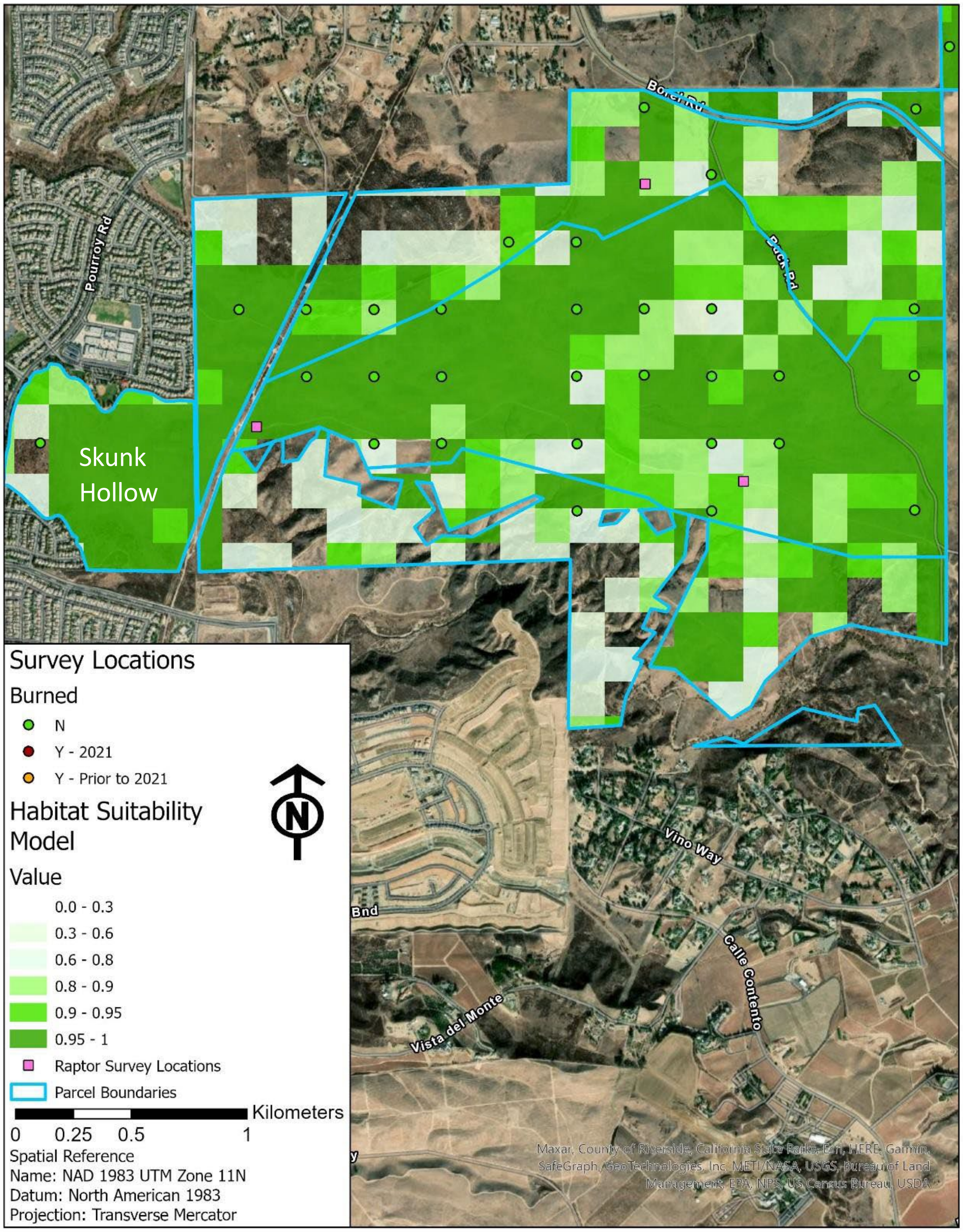


Figure 18. Map of French Valley, Johnson Ranch, and Skunk Hollow parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability. Skunk Hollow is the left-most parcel with the single sample location falling outside of what is consistently high BUOW suitability.

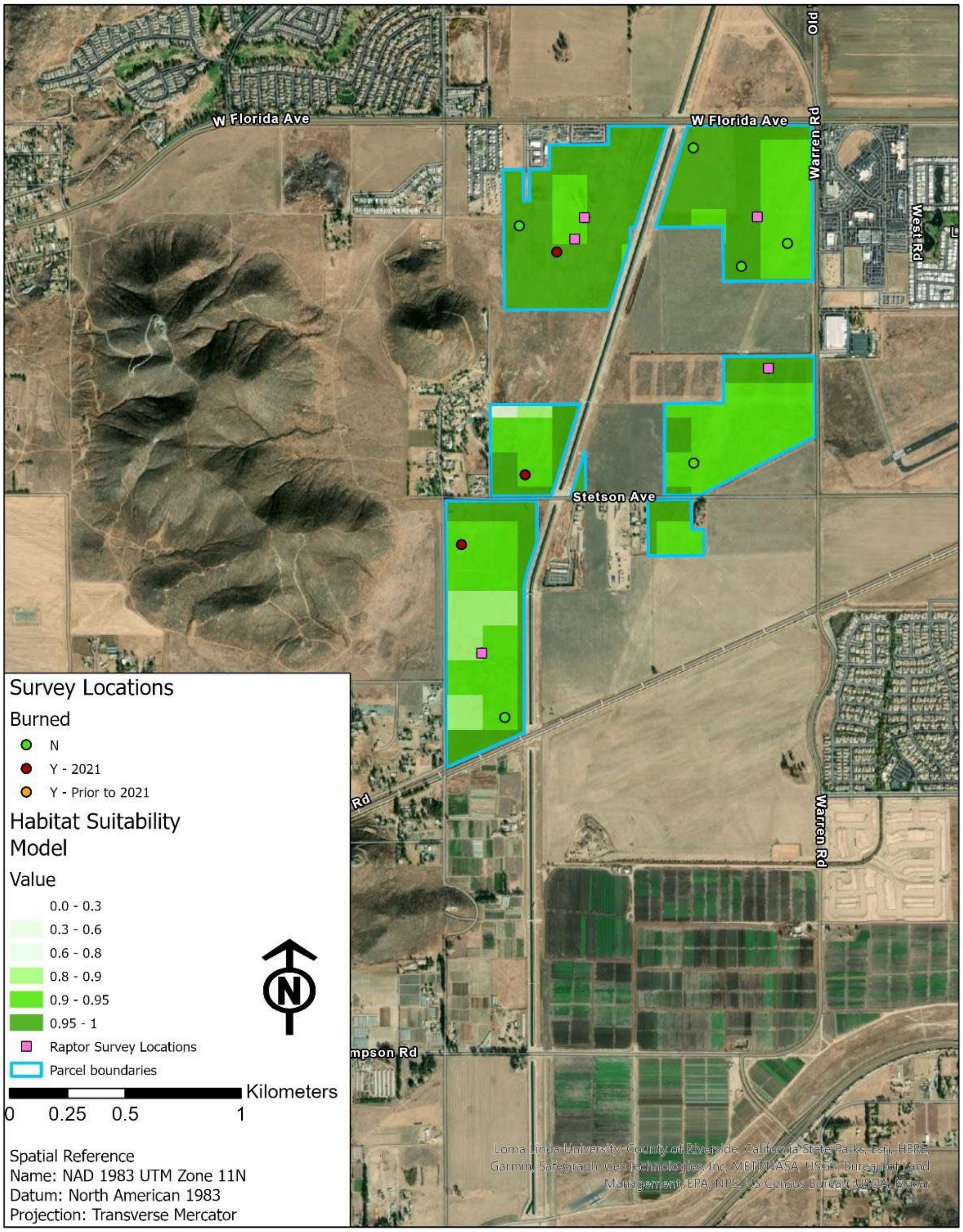


Figure 19. Map of Hemet Playa parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability. A fire burned through a large portion of the Hemet parcels in June 2021, indicated by burn status (red circles). At these locations, vegetation and small mammal occupancy data were not collected.

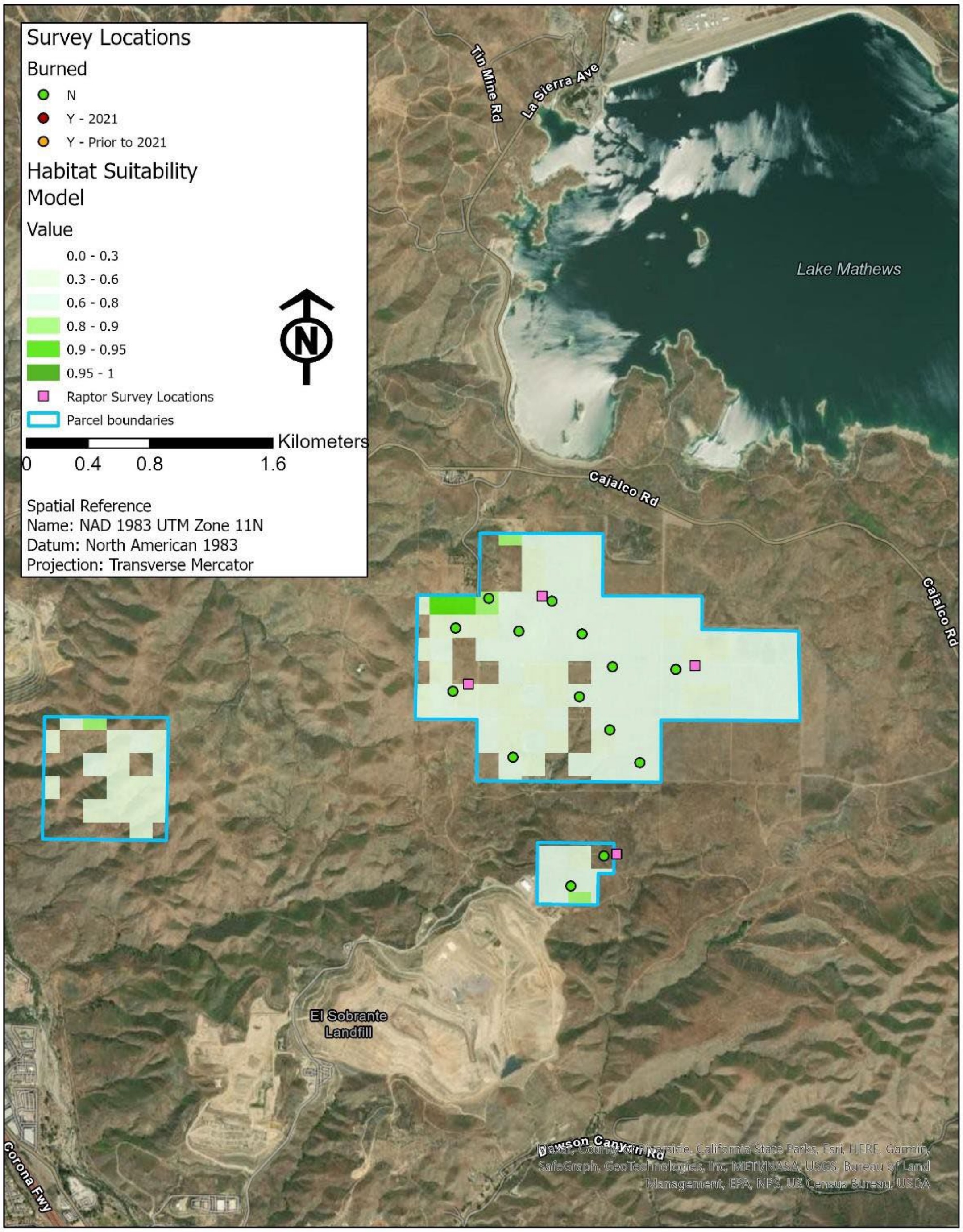


Figure 20. Map of Lake Mathews parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability.

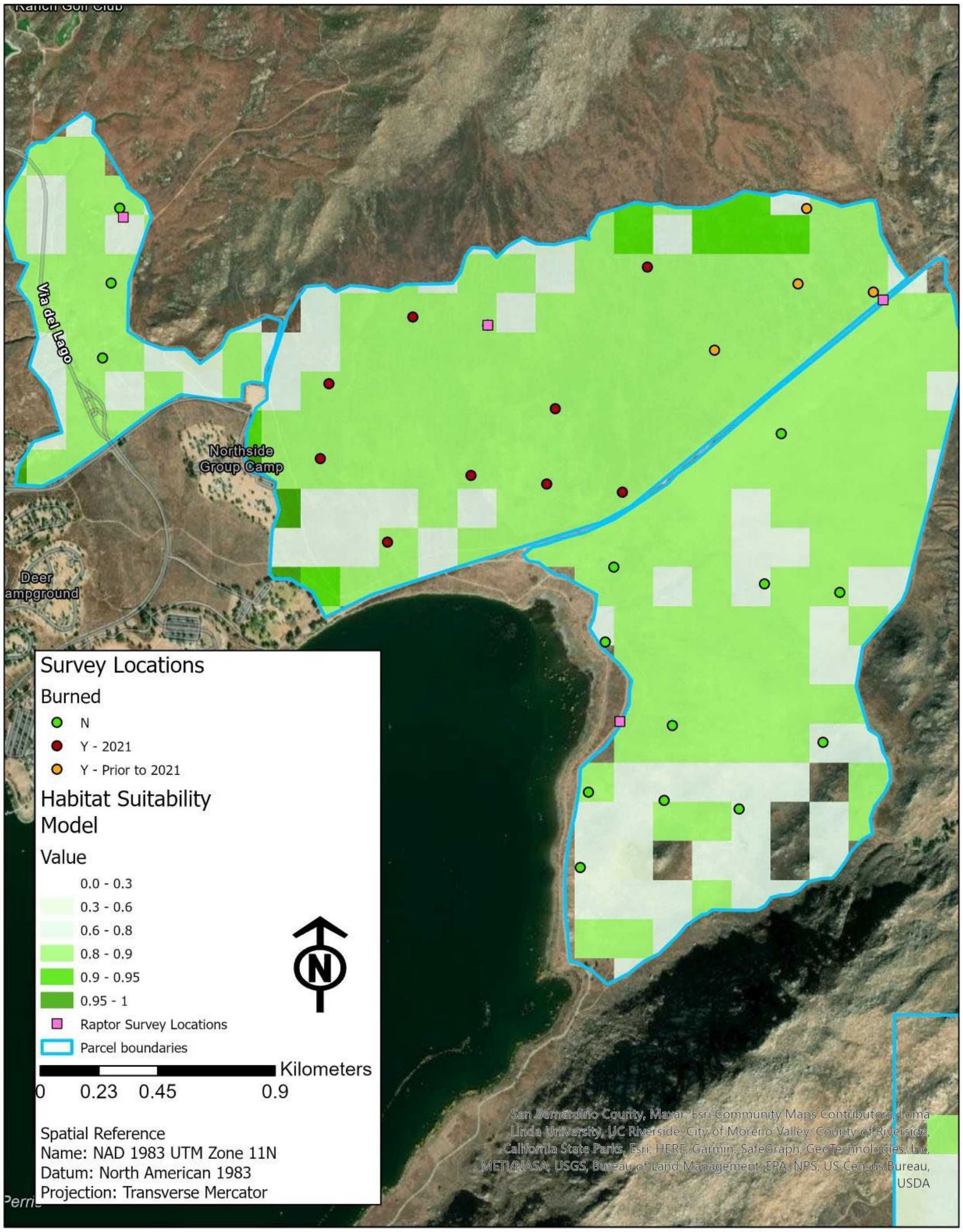


Figure 21. Map of Lake Perris parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability.

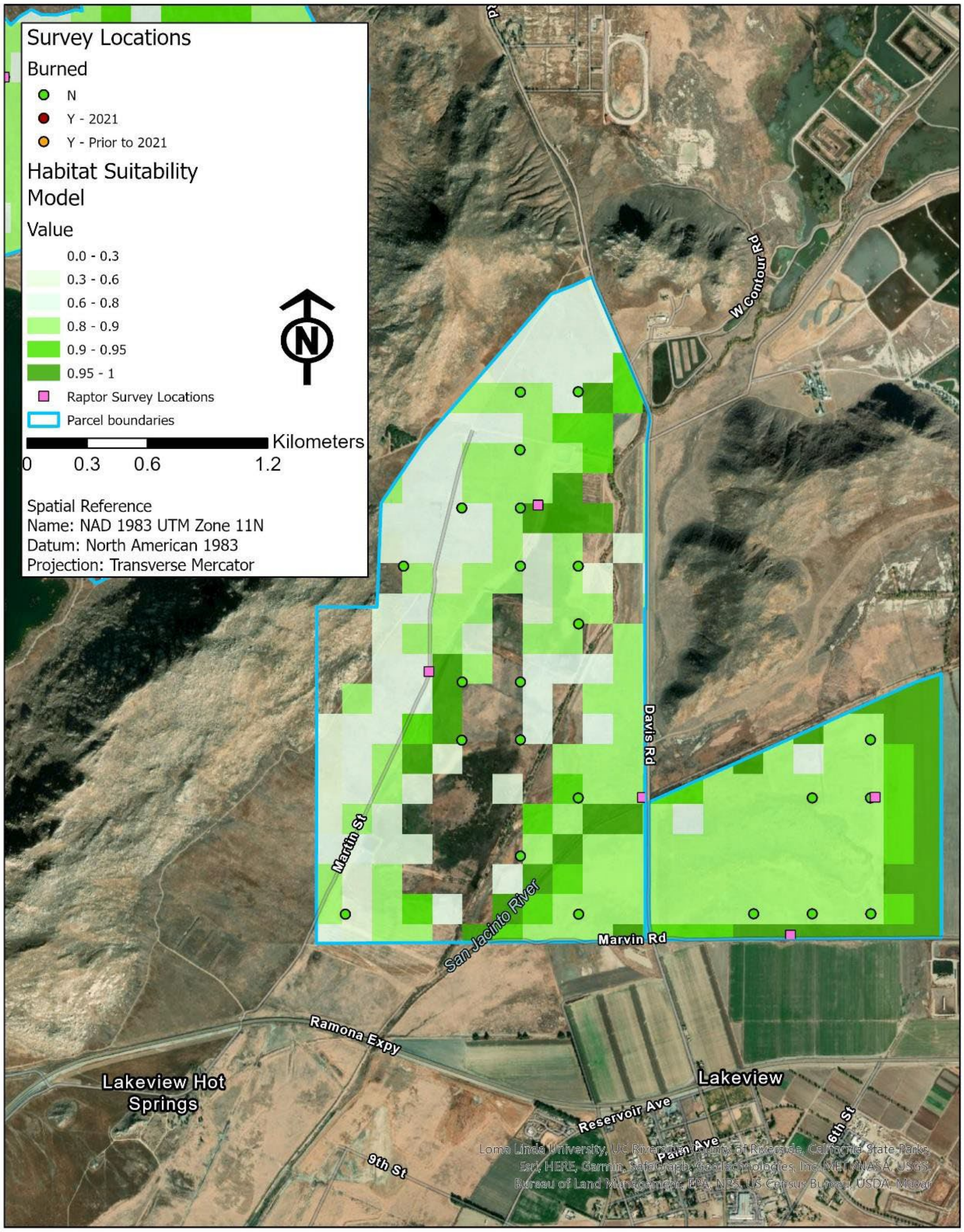


Figure 22. Map of San Jacinto Wildlife Area and Nuevo Donation parcels in western Riverside County, CA with surveyed locations (circles) shown along with random raptor point count locations (squares) and modeled habitat suitability.

Table 5. Vegetation composition at each site is shown as mean proportional representation of key functional groups in each 100 m transect. HSI scores are the mean BUOW habitat suitability pixel values across sample locations within each site. Mean dominant functional group height (cm) is shown in addition to mean percent coverage by bare ground, forbs (native and exotic), grass (native and exotic), course woody debris (CWD), and litter. Transects are averaged across all plots sampled per site in western Riverside County, CA.

Site	Mean HSI score	HSI range ± SD	Mean height (cm)	Height range ± SD	% Bare	% Forb	% Grass	% CWD	% Litter
Anheuser Busch	0.744	0.0-0.94 ±0.3	16.43	0.0-83.9 ± 17.5	10.67	15.56	36.22	3.00	19.11
El Sol	0.642	0.0-0.95 ±0.3	7.90	0.0-71.6 ± 13.2	11.71	10.00	34.00	2.00	29.57
French Valley	0.895	0.7-0.98 ±0.1	4.48	1.0-37.5 ± 6.22	14.20	11.20	37.60	3.40	30.80
Hemet	0.947	0.9-0.99 ±0.0	12.25	0.4-49.6 ± 9.2	14.44	6.00	55.89	10.22	21.00
Johnson Ranch	0.923	0.7-0.99 ±0.1	11.34	1.0-71.3 ± 14.8	10.89	12.78	34.67	3.22	21.33
Lake Mathews	0.659	0.3-0.81 ±0.1	12.40	0.1-100.4 ± 17.6	18.71	20.43	36.21	3.71	15.36
Lake Perris	0.805	0.7-0.89 ±0.1	8.43	0.0-51.5 ± 9.92	47.96	13.07	16.86	2.39	17.18
Lake Skinner	0.939	0.8-0.99 ±0.1	14.13	0.0-75.3 ± 15.0	15.57	13.00	45.71	3.14	16.14
McElhinney-Stimmel	0.694	0.2-0.89 ±0.3	18.33	0.0-93.5 ± 19.9	14.88	12.50	29.88	6.25	12.25
San Jacinto Wildlife Area	0.746	0.0-0.96 ±0.2	14.49	0.1-64.1 ± 13.2	8.45	18.55	48.55	7.45	13.32
Skunk Hollow	0.237	NA[1]	22.44	1.0-86.0 ± 22.5	19.00	14.00	25.00	5.00	4.00

[1] Only one sample plot in this parcel

Soil composition

Soil composition and texture are key for ground squirrel establishment, and ground squirrel presence, together with vegetation structure, are prerequisites for BUOW occupancy and persistence (Hennessy et al. 2018). Soil textures at sites in western Riverside County were categorized as sandy loams, loams, and clay loams based on soil composition and texture analysis. Gravel content was consistently low across all sites and ranged between 1.74-9.24 percent (Table 6).

Previous research in southern California grassland ecosystems shows that the likelihood of California ground squirrel presence increases with more friable metavolcanic soils consisting of a higher sand and lower clay content (Swaisgood et al. 2019). Translocated California ground squirrels released on soils with higher clay content also dispersed farther from the release site (Swaisgood et al. 2019), and squirrel presence and activity at a site was associated with soils with a mean sand content of 62%, while squirrels did not use or construct burrows at sites with a mean sand content of 54% or less (Hennessy et al. 2018). For example, an earlier attempt at squirrel translocation at a parcel on Otay Mesa in San Diego County was unsuccessful in part due to heavy clay soils (samples ranged from 30-57% clay). Of all sites sampled, Lake Perris had consistent low clay, high sand soils, and the highest overall mean percentage of sand.

Prey availability and California ground squirrel presence

Gopher and other small mammal activity was detected at all areas, and occupancy was confirmed via wildlife cameras regardless of whether the plot center was baited with sterilized millet or not, with the exception of Skunk Hollow (Table 7; Figures 23-24). The number of small mammal burrows and proportion of total transect length disturbed by burrowing mammal activity provides an index of prey availability as well as a proxy for soil composition suitable for burrowing. Small mammal burrowing activity varied markedly among plots and across sites, with much less activity observed at Lake Mathews, El Sol, and Skunk Hollow (Table 7).

Presence of CAGS and active burrows indicate that soil composition (low clay, high sand) and vegetation conditions (lower mean height, increased bare ground) are suitable for supporting squirrels. Plots with higher squirrel activity can also delineate areas where squirrels can be recruited from and encouraged to disperse within a site by use of brush piles (Swaisgood et al. 2019). Notably, sites with high sand content and lower vegetation height, such as Lake Perris and French Valley, had among the highest levels of ground squirrel activity (Tables 5-7).

Table 6. Summary of soil composition and texture, as determined by hydrometer method, summarized by site in western Riverside County, CA.

	% Sand		% Clay		% Silt		% Gravel		
Site	Mean	range ± SD	Mean	range ± SD	Mean	range ± SD	Mean	range ± SD	Average texture
Anheuser Busch	54.79	34.8-64.2 ± 8.0	16.68	9.8-29.8 ± 5.7	28.54	23.0-35.5 ± 4.0	6.56	1.2-20.3 ± 6.3	Sandy Loam
El Sol	49.76	41.5-53.3 ± 4.0	8.86	6.9-11.5 ± 2.0	41.38	38.1-47.0 ± 3.1	6.32	2.5-11.9 ± 3.8	Loam
French Valley	65.53	32.9-81.6 ± 11.6	9.26	2.7-16.3 ± 3.9	25.21	15.8-54.4 ± 9.4	7.47	2.2-11.9 ± 2.6	Sandy Loam
Hemet	33.53	13.1-69.0 ± 19.4	27.90	7.8-49.3 ± 13.7	38.58	22.7-53.8 ± 9.4	1.74	0.0-10.3 ± 3.0	Clay Loam
Johnson Ranch	59.53	46.1-69.3 ± 8.1	10.78	9.3-11.8 ± 0.8	29.69	19.6-43.3 ± 8.4	8.85	2.3-23.7 ± 6.4	Sandy Loam
Lake Mathews	35.20	18.1-55.8 ± 10.1	26.20	9.1-43.3 ± 11.6	38.60	30.4-48.9 ± 4.8	9.24	0.4-20.0 ± 5.8	Loam
Lake Perris	71.63	61.7-89.0 ± 6.9	7.35	3.1-15.5 ± 2.7	21.02	7.5-28.3 ± 5.1	7.02	0.0-24.6 ± 5.4	Sandy Loam
Lake Skinner	47.96	39.8-65.1 ± 8.0	14.52	6.8-30.4 ± 7.5	37.52	24.7-46.8 ± 7.8	5.56	0.9-16.9 ± 5.5	Loam
McElhinney-Stimmel	47.64	32.5-69.2 ± 12.6	22.81	7.1-42.1 ± 11.6	29.55	23.7-36.5 ± 5.0	5.69	3.4-9.8 ± 2.7	Loam
San Jacinto Wildlife Area	34.89	5.5-84.7 ± 27.4	30.45	4.4-59.7 ± 19.0	34.66	11.0-55.5 ± 11.4	3.46	0.0-15.9 ± 4.1	Clay Loam
Skunk Hollow	52.88	NA[1]	18.68	NA[1]	28.44	NA[1]	3.86	NA[1]	Sandy Loam

[1] Only one sample plot in this parcel

Table 7. Ecosystem engineers and prey availability indicators, including small mammal (SM) occupancy index, mean small mammal burrow count across sites, and mean percent of total transect length disturbed by small mammals including gophers, pocket mice, and kangaroo rats. Mean number of California ground squirrel (CAGS) burrows across sites is also shown. Data are summarized by site in western Riverside County, CA.

	SM occupancy	CAGS burrows		SM burrows		% SM disturbance	
Site	**index of relative abundance**	**average burrow count along 100 m of transects**		**average burrow count along 100 m of transect**		**% disturbance along 100 m of transects**	
Range			**0-59**		**3-1661**		**0-89%**
		Mean	**range ± SD**	**Mean**	**range ± SD**	**Mean**	**range ± SD**
Anheuser Busch	0.400	1.7	0-11 ± 3.5	191.3	48-498 ± 150.9	13.9	2.8-37.9 ± 11.3
El Sol	0.429	0.4	0-2 ± 0.8	88.0	8-235 ± 91.9	7.4	0.0-20.0 ± 7.7
French Valley[1]	0.150	10.2	0-59 ± 15.2	802.4	125-1661 ± 439.0	40.9	3.3-81.0 ± 21.4
Hemet	0.111	0.6	0-6 ± 1.7	478.6	3-1224 ± 488.1	30.4	0.0-73.2 ± 27.2
Johnson Ranch[1]	0.110	5.8	0-25 ± 8.2	620.2	84-1212 ± 351.3	45.7	9.0-88.7 ± 25.1
Lake Mathews[1]	0.286	9.8	0-41 ± 13.0	132.9	31-223 ± 65.0	10.3	0.0-33.0 ± 9.9
Lake Perris	0.643	14.0	2-27 ± 8.8	357.8	121-773 ± 195.5	20.2	7.2-43.5 ± 9.9
Lake Skinner	0.143	0.9	0-5 ± 1.9	557.1	290-1227 ± 341.2	34.1	13.9-80.8 ± 21.6
McElhinney-Stimmel	0.250	1.6	0-5 ± 2.1	270.6	43-668 ± 200.0	12.6	0.4-26.4 ± 9.2
San Jacinto Wildlife Area	0.318	3.3	0-18 ± 5.2	276.1	6-704 ± 218.5	13.1	0.0-43.9 ± 12.5
Skunk Hollow[1]	NA[2]	0.0	NA[3]	88.0	NA[3]	2.8	NA[2]

[1] Wildlife cameras were not baited.

[2] No small mammals were detected by wildlife cameras.

[3] Only one sample plot in this parcel.

Figure 23. ***Dipodomys*** **spp. captured by Reconyx cameras at plot center documenting small mammal occupancy as part of rapid assessment for burrowing owl suitability in western Riverside County, CA.**

Figure 24. ***Peromyscus*** **spp. captured by Reconyx cameras at plot center documenting small mammal occupancy as part of rapid assessment for burrowing owl suitability in western Riverside County, CA.**

Predator pressure

The presence of avian predators varied a great deal among sites, with corvids being particularly conspicuous at Lake Mathews and McElhinney-Stimmel (Table 8). Raptors were detected more frequently at French Valley, Johnson Ranch, Skunk Hollow, and San Jacinto Wildlife Area (Table 8). Predator perches and roosting sites are abundant within and adjacent to all sites. The high number of corvid detections at the Lake Mathews site is likely due to the proximity of the parcels surveyed to the El Sobrante Landfill (Figure 20).

Larger mammalian predators such as coyotes (Figure 25) and bobcats were detected via scats regularly across sites. The density of scats (scats/km) does not necessarily equate to higher density of individual predators, however, only that predators are present and active in the area. Scat transects were established along easily traveled routes such as dirt roads, trails, and two-tracks, features that are preferred by coyotes and bobcats for travel and marking. The highest scat density was observed at Lake Perris (Table 8). Note that the French Valley, Johnson Ranch, and Skunk Hollow complex was considered as one contiguous site when selecting predator transects and point count stations, therefore reported values for predator pressure at these sites are the same.

Table 8. Summary of predation pressure metrics by site in western Riverside County, CA. Predator metrics include mean density of wild canid and felid (coyote and bobcat) scats for each site, mean corvid (crows and ravens) and raptor (Buteos, Accipiters, Falcons) abundance in point count surveys across three visits.

	Ground predators	Corvids (crows, ravens)		Raptors (Buteos, Accipiters, Falcons)	
Site	**density of coyotes, "wild" canids, and bobcats (scat/km)**	**counts averaged by sample points**		**counts averaged by sample points**	
Range	**23-134**	**0-56**		**0-9**	
	Mean	**Mean**	**range ± SD**	**Mean**	**range ± SD**
Anheuser-Busch	47	5.00	0-12 ± 3.2	1.72	0-5 ± 1.7
El Sol	23	1.00	0-5 ± 1.6	0.67	0-3 ± 1.0
French Valley	87	6.67	2-12 ± 3.6	5.11	1-8 ± 2.4
Hemet	23	9.92	3-20 ± 6.3	3.92	0-9 ± 3.0
Johnson Ranch	87	6.67	2-12 ± 3.6	5.11	1-8 ± 2.4
Lake Mathews	52	17.17	4-56 ± 14.7	0.75	0-3 ± 1.1
Lake Perris	134	5.08	0-9 ± 3.2	1.75	0-6 ± 1.7
Lake Skinner	60	1.56	0-8 ± 2.6	0.22	0-1 ± 0.4
McElhinney-Stimmel	51	14.33	3-31 ± 9.7	2.67	1-4 ± 1.0
San Jacinto Wildlife Area	56	9.33	2-27 ± 7.7	3.40	1-7 ± 1.6
Skunk Hollow	87	6.67	2-12 ± 3.6	5.11	1-8 ± 2.4

Figure 25. Subadult coyote (*Canis latrans*) with small mammal prey captured by Reconyx cameras at plot center as part of rapid assessment for burrowing owl suitability in western Riverside County, CA.

Partner Discussion and Collaboration

We met with partners throughout the performance period to discuss BUOW suitability model results, identify sites for rapid assessment, to visit sites in person and discuss site attributes, as well as to present rapid assessment results and discuss strengths and weaknesses of sites amongst the group.

We participated in annual western Riverside BUOW partner meetings and presented our work as part of this CDFW NCCP LAG grant in January 2021 and February 2022. In April 2021, we met with key partners from CDFW, USFWS, Western Riverside County Regional Conservation Authority, Riverside County Parks, and Center for Natural Lands Management to discuss the BUOW suitability model and identify priority sites for targeted rapid assessments. During May, 2021, we worked with partners to arrange site visits to the majority of priority sites previously identified as priorities for BUOW conservation and rapid assessment for BUOW suitability (Table 9; Figures 26-29). In March 2022, we met with key partners from CDFW, USFWS, Western Riverside County Regional Conservation Authority, Riverside County Parks, California State Parks, Center for Natural Lands Management, and Riverside County Habitat Conservation Agency to present rapid assessment results and discuss site specific strengths and challenges. The results of these discussions were incorporated into our working conservation and management plan for western Riverside County.

Table 9. Schedule of site visits and attendees for in person assessment and discussion of priority sites for BUOW conservation in western Riverside County, CA.

May 2021	Friday 7th	Tuesday 11th	Thursday 20th
	Menifee Area: McElhinney Stimmel, Anheuser Busch, El Sol	Perris Area: San Jacinto Wildlife Area, Lakeview, Hemet area	Johnson Ranch, Skunk Hollow, French Valley, Lake Skinner MSR
Kim Klementowski, CNLM			x
Joe Sherrock, RivCo Parks			x
Johnathan Reinig, RivCo Parks	x		
Nick Peterson, CDFW		x	x
Danielle Stewart, CDFW			x
Noelle Ronan, USFWS		x	
Betsy Dionne, RCA		x	
Colleen Wisinski, SDZWA	x	x	x
Susanne Marczak, SDZWA	x	x	
Melissa Merrick, SDZWA	x	x	x

Figure 26. Site visits with partners to Hemet parcels, western Riverside County, CA. Here partners discuss the challenges of managing vegetation for CAGS and BUOW given sensitive vernal pool plant species that occur here.

Figure 27. Site visits with partners to San Jacinto Wildlife Area, western Riverside County, CA. Here partners admire newly established mounds with rocks to encourage CAGS and subsequent BUOW use.

Figure 28. Site visits with partners to Lake Skinner Multi-Species Reserve, western Riverside County, CA. Here partners, discuss a site where artificial burrows were installed but BUOW no longer use them.

Figure 29. Site visits with partners to French Valley and Johnson Ranch parcels, western Riverside County, CA. Here partners discuss vegetation management and rubble piles that were placed to encourage CAGS into the interior of the site.

To visualize rapid assessment results and the regional burrowing owl suitability model, we created an interactive Web Mapping Application via ArcGIS online and shared this with partners. The online mapping application enables users to view rapid assessment results for variables that convey important information about suitability for both BUOW and CAGS such as soil composition, abundance of CAGS and small mammal burrows, and mean vegetation height. Our aim was this interface would serve as a collaborative tool for managers as well as a basis for ongoing discussion and collaboration.

Web mapping application:
https://sdzg.maps.arcgis.com/apps/webappviewer/index.html?id=6e725622cbb7453b920537e41ccc714c.

We summarized our rapid assessment findings in a Western Riverside County Burrowing Owl Management Plan, shared with partners as a living document to guide future discussions and conservation actions for BUOW within the WRMSHCP. The Western Riverside County Burrowing Owl Management Plan can serve as a starting point for discussions of site prioritization for future burrowing owl habitat management and improvements, mitigation translocations, and artificial burrow installation. As a living document, we envision this plan being refined with continued discussion.

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