Project Report 2016

An adaptive management approach to recovering burrowing owl populations and restoring a grassland ecosystem in San Diego County

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EXECUTIVE SUMMARY

We report on the sixth year's progress in a multi-year program with the goal of developing a strategy to support the recovery of Western burrowing owls (BUOW; *Athene cunicularia hypugaea*) and their grassland ecosystem in San Diego County. Current BUOW management is dependent on continued human intervention and may not be self-sustaining. Because the California ground squirrel (*Otospermophilus beecheyi*) is a keystone species that helps engineer California grassland ecosystems and provides critical resources for BUOW, re-establishment of this species is a crucial component of any sustainable recovery plan for BUOW and the larger ecosystem.

The main components of the program in 2016 consisted of work on both BUOW and California ground squirrel. For squirrels, we continued monitoring two previously established studies: (1) the experimental manipulation of grassland habitat structure and squirrel translocation to better support the persistence of ground squirrels, and (2) a pilot manipulation of natural squirrel dispersal into newly grazed pasture, using the addition of cover piles to attract squirrels into unoccupied habitat. In 2016, BUOW efforts continued to focus on understanding the ecological drivers and anthropogenic threats influencing BUOW population performance in San Diego County, as well as development of a county-wide Conservation and Management Plan for Burrowing Owl in San Diego County. These efforts were conducted collaboratively with California Department of Fish and Wildlife, San Diego Management and Monitoring Program, and other agency partners.

Replicated experimental squirrel translocations and vegetation structure management. The re-establishment of ground squirrel populations on potential recovery sites for BUOW was the focus of our first three years of management by science, and reported on in detail previously. Previously, we implemented a squirrel translocation program employing soft-release protocols that address ecological needs and species life-history characteristics, and manipulated vegetation structure at three sites: Rancho Jamul Ecological Reserve, the Sweetwater parcel of the San Diego National Wildlife Refuge, and Lonestar Ridge West Mitigation parcel on Otay Mesa.

The results have consistently shown that the combination of squirrel translocation and vegetation treatment together supports higher levels of squirrel activity than the use of either management strategy alone. The implementation of widespread vegetation management at Jamul in the fourth year of the experiment provided an opportunity to observe the trajectory of vegetation management and squirrel persistence on a longer time scale than the experiment originally planned. In terms of the plots established in 2011 at Jamul, one of three 2011 release plots (JE) is persisting, with observations of both squirrels and recent burrowing activity. Both 2012 release plots are persisting, and at JC, both increased numbers of squirrels and burrow numbers were recorded relative to the 2015 surveys.

Although 2016 proved to be another drought year, scattered winter rains fueled rapid growth of annual grasses in the plots, and there was a time lag between grass growth and the grazing treatment. The squirrels showed resiliency to these dramatic changes in vegetation structure, and their persistence five years post-experiment supports the continued use of grazing at Jamul.

The current management goal for the reintroduced squirrels is continued persistence with the expectation that breeding burrowing owls will be onsite within a few years. We currently recommend the addition of new cover piles in the occupied plots to enhance refugia habitat, as the original cover piles have degraded, as well as additional piles outside the plot boundaries. This habitat enhancement would occur as a management task, outside the experimental framework, and would fulfill a critical current habitat need.

Pilot study for encouraging natural squirrel dispersal. Following the implementation of grazing and woodpile installation at Rancho Jamul, we monitored the creation of burrows on the periphery of a large squirrel colony. Baseline conditions were characterized by thick invasive grasses not favored by squirrels, which were opened up by grazing. In the third season of monitoring, a total of 145 ground squirrel burrows were recorded, compared to a pre-manipulation baseline of 2 inactive burrows. Higher numbers of burrows were recorded in the woodpile transects than controls along with a greater concentration of burrows on the southern end of the BOHMA. The presence of woodpiles was statistically significant at all distances ($p<0.01$). For the first time, a notable number of burrows were recorded at the 150m distance. For burrows 150m from the source population, the number of years into the experiment was also significant, affirming that the footprint of squirrel occupancy is expanding through time. The results also indicated that colony expansion was strongly driven by juveniles dispersing in late spring and early summer and settling around cover piles prior to the fall surveys. In 2017, the experiment will be adaptively refined to reduce the distance between cover piles, with the goal of supporting more rapid colonization by squirrels.

Monitoring of BUOW population dynamics to inform management strategies for San Diego County. Since 2013, we have implemented monitoring and research of BUOW nesting and population ecology using a variety of tools such as camera traps, microclimate data loggers, GPS data loggers, and color banding. Our on-going banding effort has allowed us to document movements, site fidelity, recruitment, survival, and other facets of BUOW population dynamics and natural history.

In 2016, we monitored 38 nesting attempts, and found that fledging success was high across our three main study sites (Brown Field, Lonestar, and Johnson Canyon). The Lonestar habitat continues to improve, and reproductive success was strikingly higher at Lonestar in 2016 than in 2013-2015. Modeled juvenile survival estimates were also higher in 2016 and these updated parameter estimates will be used to update the population viability analysis for this region. The downward trend in population performance during the period of 2013-2015 was likely due to drought conditions. The higher number of chicks that survived to fledging is probably due to synergistic effects of a number of factors such as weather, density, habitat quality, and prey.

Artificial burrow design and nest microclimate. We tested three different artificial burrow designs (standard, Y, and curvy) and found that the Y design buffered the best against outside extremes in humidity and had the most stable humidity of the different burrows. Humidity in the Y burrows was close to what we observed in the natural burrows on Otay Mesa in 2014 and 2015.

To assess the potential relationship between burrow microclimate and productivity, we placed iButtons inside artificial burrows with nests in 2016. We found that for wood burrows, the inside humidity was significantly higher; the coefficient of variation of inside humidity was significantly lower (humidity was more stable); and the daily difference between inside and outside humidity was marginally significantly higher (better buffering). The inside temperature was also more stable in wood burrows but was not statistically significant. One interesting outcome of this study was that the inside humidity metrics were bimodal for wood burrows. Upon further examination of the data, we found this result could be accounted for by the number of entrances—in a number of the wooden burrows, one tunnel was blocked making them functionally one-entrance burrows.

We found statistically significant differences between natural and artificial burrows in the maximum numbers of chicks and fledglings in 2016, a result driven by lower reproductive success at plastic artificial burrows. Interestingly, we have documented increased productivity in wood burrows at Lonestar (compared to plastic burrows) which has implications for burrow design. Based on all of these results, we offer an optimized design and make recommendations concerning design and materials for artificial burrows.

Development of a rapid assessment protocol for BUOW. In 2016, we developed protocols for field-based evaluation of sites being considered for BUOW management. The rapid assessments include standardized fine-scale field surveys of prey (small mammal) availability, predator pressure, vegetation, and soil texture. Implementation of the rapid assessment involves an initial GIS analysis to generate randomized sampling points, and data collection occurs in 3-4 site visits over a 10-day period. Rapid assessments were carried out at 9 sites in 2016, and full results are reported in the draft Burrowing Owl Habitat Conservation and Management Plan.

Draft Burrowing Owl Habitat Conservation and Management Plan. The development of a conservation strategy and research plan is essential to address the complex and numerous threats to BUOW and provide an integrative tactical solution to achieve a stable and viable BUOW population in this region. In 2016, the Burrowing Owl Habitat Conservation and Management Plan in San Diego County was drafted and taken through a major revision based on agency input. The plan includes population viability estimates, key factors for establishing new breeding sites, optimal relocation techniques for both ground squirrels and BUOW, and other relevant management strategies. It also applies the habitat suitability model and rapid assessment results to identify critical areas within the county needed for protection. Management recommendations are also presented for the focal areas.

Trial of BUOW conspecific cues. In 2016, we began trialing techniques to encourage settlement and breeding of overwintering birds at Rancho Jamul. We used white latex paint at artificial burrow entrances to mimic BUOW droppings. Testing these management actions will help prepare RJER, as well as other locations, become viable BUOW recovery nodes and mark the first step towards BUOW recovery in San Diego County. For BUOW, incorporating the use of pellets, whitewash, and/or acoustic callbacks into existing translocation protocols may increase the probability of settlement for newly released BUOW. In the future, we plan to use (and continue testing) conspecific cueing methods for active translocations of BUOW that occur in the county.

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INTRODUCTION

The native grasslands of the western United States, and California in particular, are among the most endangered ecosystems in the temperate world (Samson & Knopf 1996). In California approximately 90% of species listed in the Inventory of Rare and Endangered Species can be found in grasslands (Barry et al. 2006). Grasslands support both high wildlife abundance and diversity and are one of the signature ecosystems of the West. In California, 86% of grasslands are held in private ownership because they are so favorable for human uses such as grazing, agriculture and housing developments (Davis et al. 1998). It is not surprising then that the remaining grasslands support a number of species of conservation concern. One of California's more notable grassland species is the charismatic and highly visible western burrowing owl (*BUOW, Athene cunicularia hypugaea*). Another prominent grassland species, the California ground squirrel (*Otospermophilus beecheyi)*, is abundant and common, but generally undervalued even though it is an integral component of this ecosystem and is known to exert a strong positive interaction on BUOW.

Because the California ground squirrel is a "keystone" species that helps engineer California grassland ecosystems and provides critical resources for BUOW, re-establishment of this species is a crucial component of any recovery plan for BUOW and the larger ecosystem. Ground dwelling squirrels influence the structure and composition of the grassland ecosystem, both directly as prey and indirectly through burrowing and foraging activities, suggesting a high level of interaction (Kotliar et al. 2006).

In 2011, the San Diego Zoo Institute for Conservation Research (ICR) and the Institute for Ecological Modeling and Management (IEMM) initiated a program to assist in the recovery of BUOW and their grassland ecosystem in San Diego County. Using an adaptive management approach (Walters 1986; Schreiber et al. 2004; Nichols & Williams 2006), ICR/IEMM collaboratively launched a multi-year study to restore ecological function to grassland communities in San Diego County by re-establishing ground squirrels and, ultimately, BUOW.

Project goals

The overarching objective of this project is to facilitate the re-establishment of ecosystem processes in order that the ecosystem in which the BUOW is found is less reliant on repeated human intervention. Our aim is to create suitable BUOW habitat through the ecosystem engineering activity of ground squirrels that will be self-sustaining.

Results from year one of this multi-year program were mixed and indicated that modifications to the translocation protocol were necessary to improve release success of relocated squirrels (Swaisgood & Lenihan 2012). Our results also highlighted the need to understand how soil characteristics affect squirrel establishment and retention. In year two (2012), we modified the protocols developed for ground squirrel translocation in 2011 and initiated data collection for a ground squirrel habitat suitability model. Although work was focused on refining the ground squirrel translocation methodology, we opportunistically monitored BUOW and continued pilot work using camera traps at owl nest burrows. In year three (2013), we expanded our research on BUOW, monitoring their nesting and foraging ecology at artificial and natural burrows, through the use of camera traps, direct observations, and habitat surveys. We also initiated a capture and banding effort to allow for identification of individuals. In year four (2014), we continued to monitor squirrel translocation outcomes and began a pilot project examining ways to encourage natural ground squirrel dispersal. We also continued our research efforts on BUOW, focusing on potential factors that may affect their reproduction and survival. This included GPS tracking of owl foraging movements during the breeding season to gain a better understanding of their habitat use and spatial movement patterns. By obtaining a better understanding of the factors regulating population dynamics of BUOW, in terms of reproduction, survival, recruitment, and movement patterns, we were able to use the results from this research to help inform an effective long-term management plan for BUOW in San Diego County. Year five (2015) included a continuation of our research from 2014 and development of both a habitat suitability model for BUOW and a strategic management plan to help conserve BUOW in the region. In 2016, we continued our monitoring of squirrels and owls, tested alternative designs for artificial burrows, designed and implemented a rapid assessment protocol to evaluate potential recovery nodes, revised the strategic management plan incorporating agency input, and began a field trial using mock whitewash to test the use of conspecific cues for attracting and/or retaining BUOW at a site.

The goals for 2016 were to:

1. Continue monitoring of squirrel translocation outcomes from 2011 & 2012 translocations;
2. Monitor natural ground squirrel dispersal into managed habitat at Rancho Jamul Ecological Reserve;
3. Examine BUOW population dynamics and nesting ecology by:
    - Banding and collecting genetic material from owls,
    - Using camera traps to monitor nest success, offspring survival, predation pressure, and mortality at both natural and artificial burrows,
    - Monitoring condition of artificial burrows;
4. Assess artificial burrows by:
    - Evaluating differences in microclimate in artificial and natural burrows to help inform artificial burrow design,
    - Monitoring reproductive output at both natural and artificial burrows;
5. Evaluate potential burrowing owl recovery sites by:
    - Developing a rapid assessment tool for fine-scale site selection,
    - Surveying and ground-truthing sites identified by spatial models for suitability,
    - Prioritizing sites for management and recovery of BUOW;
6. Continue to build and update the strategic management plan with new data, including:
    - Evaluating and categorizing the condition of artificial burrows in MSP MU3,

- Developing an implementation schedule for maintenance of artificial burrows;

7. Trial the use of conspecific cues to attract/retain BUOW.

Personnel

Principal Investigators:
Lisa Nordstrom, Ph.D., Debra Shier, Ph.D., Ron Swaisgood, Ph.D.

Field Team—Squirrel monitoring:
Field Organizer: JP Montagne, M.S. (ICR in-kind contribution)
Volunteers: Sara Alhawi, Tandora Grant, Brenda Jackson, Jim Marsh, Shanda McDonald, Susan Naibkhyl, Lowry Pierich Jr. ; <u>73 total hours.</u>

Field Team—BUOW monitoring:
Field Organizer: Colleen Wisinski, M.S.
Expert Advisors: Jeff Lincer, Ph.D. (BUOW), Mathias Tobler, Ph.D. (software, data management; ICR in-kind contribution)
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Volunteers from San Diego Zoo Global (ICR in-kind contribution): Kathleen Esra, Carina Graham, Karin Kupka, Kate Lambert, Gloria Marselas; ~700 total hours
Genetic Analyses (ICR in-kind contribution): Heidi Davis, Tram Nguyen

Habitat Rapid Assessments:
Field Organizer and Data Analysis: Sarah McCullough Hennessy, Ph.D.
Field Technicians: Susanne Marczak, Michael Stevens, Jacob Hargis
Volunteers from Point Loma Nazarene University: Mike Mooring, Kirra Connolly, Tanner Mathews
Volunteers from San Diego Zoo Global (ICR in-kind contribution): Miguel Kaminsky

Permits

Fieldwork was conducted under the California Department of Fish and Wildlife (CDFW) Scientific Collecting Permits of Colleen Wisinski (SC-11839), Jeff Lincer (SC-1606), and JP Montagne (SC-11422). BUOW banding and bleeding were conducted under the Federal Bird Banding Permit of Jeff Lincer (20242) with Colleen Wisinski (20242-A) as a subpermitee. This project was approved by SDZG's Internal Animal Care and Use Committee (IACUC) and operates in accordance with all IACUC provisions under Projects #11-017, #12-002 and, #14-009.

TASK A: LONG-TERM MONITORING OF CALIFORNIA GROUND SQUIRREL TRANSLOCATIONS

Introduction

As a means to improve grassland habitat for BUOW and other species of concern, in 2011 we initiated the development of a scientific, ecologically relevant strategy for relocating California ground squirrels. Long-term success is contingent upon our ability to translocate California ground squirrels to the restoration sites in numbers sufficient for a population to establish itself at an ecologically functioning threshold where squirrels serve as ecosystem engineers (Kotliar et al. 2006; Soule et al. 2003). Many translocation programs are unsuccessful or marginally successful because of high mortality (O'Bryan & McCullough 1985, Jones & Witham 1990) and post-release dispersal away from the release site (review in Stamps & Swaisgood 2007). Salmon & Marsh (1981) noted, "Our experience has been that California ground squirrels released into an area will rarely stay." In one translocation study, 83% of California ground squirrels relocated in a hard release without acclimation immediately abandoned the release site (Van Vuren et al. 1997). Post-release monitoring, attention to release group composition, and ecologically relevant modifications to the post-release habitat and social environment can have profound effects on the success of translocation programs (Stamps & Swaisgood 2007; Swaisgood 2010). These factors were incorporated into our own translocation project, which met with mixed success. However, we increased squirrel persistence by making carefully documented and controlled alterations to the release strategy, following adaptive management procedures.

Detailed reports on outcomes and methodologies of translocations as part of this project can be found in previous annual reports, and the resulting recommended protocols can be found in Shier et al. (2016). In 2016, we monitored persistence of squirrels at six experimental plots in two release sites to continue our assessment of minimum survival and retention at two plots established in 2012 and record colony persistence at four plots established in 2011. We also monitored the persistence of squirrel ecosystem engineering effects at the same plots as another indicator of squirrel persistence and to track current burrow availability for both squirrels and owls.

Methods

Plot size and layout

Pairs of circular plots were established based on similar vegetation community, soil type, slope, and aspect as well as proximity. Each circular plot was 100 m in diameter, with an area of 7854 m^2 (1.94 acres). Each plot was divided evenly into three equal wedge-shaped subplots. The subplots received one of three treatments: control, mowing, and mowing plus augering. Squirrels were translocated into one plot from each pair (Figure 1-1). This design allowed us to separate the direct effects of vegetation manipulation from the ecosystem engineering effects of ground squirrels.

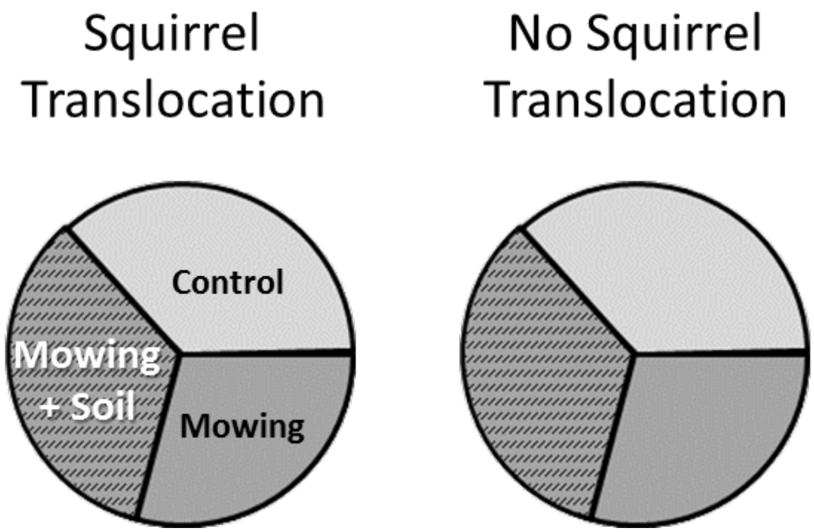


Figure 1-1. Paired design of the habitat enhancement/squirrel translocation experiment.

Treatment methods

Treatment 1: Mowing and thatch removal. Mowing and thatch removal was conducted without motorized equipment to minimize soil compaction and surface disturbance. Vegetation treatments occurred in May, at the end of the growing season for annual grasses but before grasses were dried out. Vegetation was mowed to a height of 7.5 – 15 cm using handheld weed-whackers, and the resulting thatch was raked and removed from the site. There was no evidence of soil disturbance from mowing or thatch removal.

Treatment 2: Mowing and thatch removal plus soil decompaction. Soil decompaction was implemented by augering 20 holes per subplot to produce a density of one hole every 10 m^2. Holes were drilled to ~0.3 m depth on a 45 degree angle with a one-person handheld auger fit with a 6 in. auger bit.

Squirrel translocation procedures

California ground squirrels were captured for relocation from source sites at North Island Naval Base Coronado (NBC) and at local ranches in Pine Valley and Jamul. The target number was 30-50 squirrels released per plot. The target release group for one pie comprised a minimum of three adult males and six adult females, plus their weaned pups, and attempts were made to maintain familiar social groups of individuals.

ICR biologists performed a health check and recorded age, sex, weight and reproductive condition for each squirrel. Individuals were marked with standard ear tags, radio-frequency identification (RFID) tags, and unique dye markings for individual identification. A subset of adult squirrels was equipped with VHF radio-collars to allow tracking and monitoring of individual squirrels post-release.

When squirrels were transferred to the acclimation burrows, the experimental plots in 2011 were surrounded with a battery-powered electric-tape fence to deter predation attempts by coyotes. Squirrels were provided with food and water bottles. After one week, acclimation cages were removed, and the squirrels were monitored with observations, radio-tracking, re-trapping, and camera traps to measure squirrel retention on site, movements off site and survivorship.

A second year of translocations was conducted to supplement the initial squirrel populations. The supplemental translocations occurred in August (in contrast to the June timing of the 1st year translocations). In the second year, woody debris piles were added to the plots to provide additional cover.

Study sites and plot locations

Study sites

The study was planned for three sites in southern San Diego County: Rancho Jamul Ecological Reserve, the Lonestar Ridge West parcel on Otay Mesa, and the San Diego-Sweetwater National Wildlife Refuge. After the first year of the study, the Lonestar site was discontinued and additional pairs of plots were added at Rancho Jamul.

Plot nomenclature and location data

Site codes were assigned to denote whether plots were located at Rancho Jamul (RJER), or Sweetwater (SWTR). The plots are labeled with a unique name, plus a letter denoting which of the paired plots was the control (C, "Control") or the squirrel translocation (G, "Ground squirrel") plot (See Table 1-1 for GPS locations).

Table 1-1. Final plot locations (UTM coordinates reported in projected coordinate system NAD1983 Zone 11N).

Site	Plot	Elevation (m)	Easting	Northing
Rancho Jamul	RJER JE-C	832	512823.5110	3617500.8735
	RJER JE-G	834	512740.9191	3617655.3768
	RJER JW-C	870	512169.7722	3617351.9940
	RJER JW-G	843	512149.1849	3617576.5499
	RJER JS-C	771	512546.2182	3616321.7555
	RJER JS-G	760	512614.0000	3616179.2598
	RJER JC-C	842	512385.5666	3617027.1563
	RJER JC-G	834	512263.0544	3616527.6144
	RJER JB-C	759	512579.1138	3615943.9042
	RJER JB-G	736	512541.3664	3615716.0390
Sweetwater	SWTR SE-C	676	503004.8305	3617329.0047
	SWTR SE-G	616	503047.2489	3617443.9296

Assessment methods

Long-term post-release monitoring — 2011 and 2012 plots

We monitored persistence of squirrel colonies in Rancho Jamul at five release plots: Jamul South (JS), Jamul West (JW), and Jamul East (JE) which were established in 2011, and Jamul Baja (JB) and Jamul Central (JC), established in 2012. These plots received no translocations or habitat manipulation since 2012 and 2013 respectively. We observed each release plot three consecutive days for three hours between 8AM and 12PM. We did not monitor the Sweetwater East plot (SE) since the 2015 monitoring found no squirrels present.

Burrowing activity

Observers walked a grid pattern through each subplot and recorded California ground squirrel activity. Burrows with an opening of at least 7 cm at the point of maximum diameter were recorded as probable California ground squirrel burrows. The size and shape of both the burrow entrance and the burrow apron were recorded. If scat was found around the burrow or on the apron, it was identified to species and recorded. The condition of the burrow entrance (i.e. clear, cobwebbed, collapsed) was recorded, as well as other field notes about burrow condition and use.

Statistical analysis

Squirrel monitoring results were not statistically analyzed. For burrowing activity, a repeated measures analysis was conducted utilizing all six pairs of plots. Since four pairs were begun in 2011 and two pairs were begun in 2012, the variable representing time in the repeated measures model is a categorical variable representing the number of years into the experiment (Years 1- 5). The structure of the repeated measures model takes into account the additional variance from initiation of plots in two different years by use of a categorical variable representing each set of paired plots. This variable accounts for pair-level variance from both the site and year the plot was initiated.

Results

Minimum long-term persistence — 2011 plots

We monitored colony persistence on the four 2011 plots between May 18th and June 4th. After four years without active management, we detected six squirrels at JE (Table 1-2; Figure 1-2). At JW and JS, no squirrels were detected and examination of burrows revealed no recent activity.

Minimum long-term persistence — 2012 plots

We monitored colony persistence on the two 2012 plots between May 18th through June 4th. After three years without active management, we detected 28 squirrels, with 13 at JB and 15 at JC (Table 1-2; Figure 1-2).

Table 1-2. Total number of squirrels captured during long-term monitoring. The first and second years followed initial and supplemental translocations. We used the same trapping protocol for the third year, while the fourth and fifth years were monitored using an observational scan method. Additional evening trapping is separated and in italics.

Time of capture	Type of release	JB	JC	JS	JE	JW	SE	Total
Morning	1st Year (Initial)	0	8	7	6	5	5	**32**
	2nd Year (Supplemental)	15	10	5	14	11	7	**62**
	3rd Year (Retention)	40	13	0	1	2	3	**58**
	4th Year (Observation)	13	15	0	9	6	0	**43**
	5th Year (Observation)	-	-	0	6	0	-	**6**
Evening	*1st Year (Initial)*	*0*	*2*	-	-	-	-	***2***
	2nd Year (Supplemental)	*1*	*3*	*7*	*9*	*0*	*2*	***22***
	3rd Year (Retention)	*11*	*0*	*0*	*0*	*0*	*0*	***11***

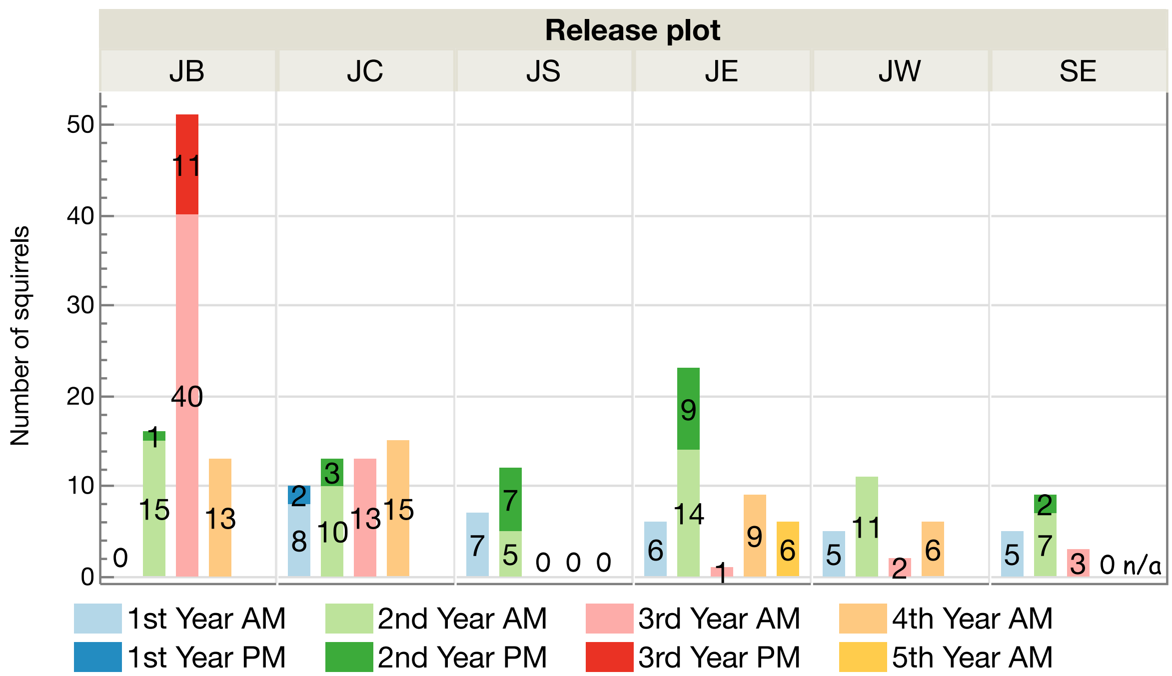


Figure 1-2. Summary of the number of squirrels captured on each plot. These numbers include translocated individuals, their progeny and immigrants from local populations through trapping during the first three years and observational scans starting with year four. After 2011, we increased sampling by adding an evening trapping session, therefore there are no values for Year 1 PM for SE, JW, SE and JS. All long-term monitoring was scheduled in June to maximize capture probability of juveniles prior to dispersal; therefore trapping took place twelve months after initial translocation (1st Year), and nine months after the supplemental translocation (2nd Year).

Squirrel burrowing activity

The spring 2016 time point represents an interval of 30 months since final 2013 supplemental translocation for JC and JB plots. For the remaining pairs of plots, the 2016 spring sample represents activity 42 months after final 2012 supplemental translocation. In spring 2016, squirrel activity was almost exclusively found in the plots that received squirrel translocation (Figure 1-3). The number of burrows in each plot continued to generally decrease, with the exception of JC, where the number of burrows increased by 17% over the 2015 burrow count.

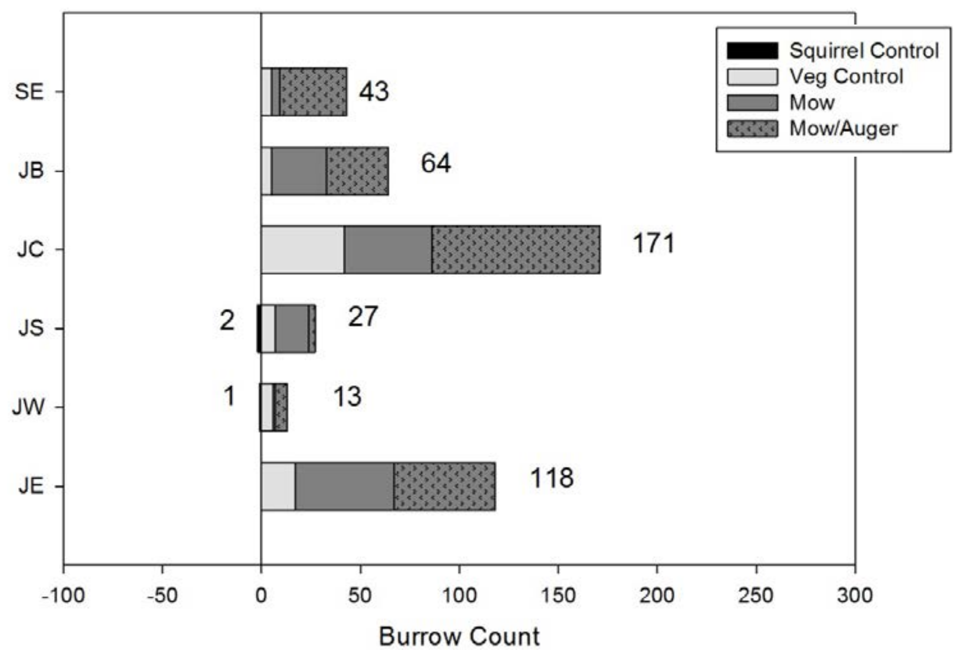


Figure 1-3. 2016 squirrel activity by plot pair, measured as the number of burrows equal to or greater than 7 cm diameter. For JC and JB, the March 2016 sample represents activity levels 30 months after final 2013 supplemental translocation. For the remaining pairs of plots, the March 2016 sample represents activity 42 months after final 2012 supplemental translocation.

The proportion of squirrel burrows continued to be higher in the subplots receiving vegetation treatments than the control subplot (Figure 1-3). Quantifying the total area of ground surface disturbance, derived from the apron areas measured at each burrow, is another useful metric of squirrel activity. Summing the individual apron areas within each treatment subplot gives one number per subplot that can be used as a proxy for squirrel activity within each subplot. Before creating this proxy measurement, we assessed the distribution of individual apron areas in all subplots. Out of 437 burrows, 238 burrows included an apron. The distribution exhibits right (positive) skew due to the relatively low proportion of burrows with large aprons. The creation of a large apron requires time and effort, and not all burrows are developed to this extent. In response to the observed skewness, the proxy estimate of squirrel activity was treated with a square root transformation for all analyses.

The results from the repeated measures model indicate that the interaction of squirrel translocation and vegetation treatment continued to be highly significant through the spring of year 5 ($p<0.01$, Table 1-3). The combination of both mowing and squirrel translocation are supporting squirrel activity levels. There still exists some separation in activity level between the subplots with mowing only and with the addition of augering, but the variability, shown by the degree of overlap in the standard error bars, has also increased as squirrels have persisted in some plots but not others.(Figure 1-4).

Table 1-3. Generalized linear repeated measures model results from burrowing activity, measured as apron area, sampled during 2011-2016 (n=6). The data were square root transformed. Analysis includes time points for year 1 post –translocation, year 2 pre- and post-supplemental translocation, and year 3, 4, and 5 spring timepoints. All interactions were modeled.

Treatment	Apron area			
Effect	df	ΔR^2	F	P
Between Subjects				
Squirrel	1	0.88	66.79	<0.01
Pair	5	0.05	0.78	0.60
Error	5	0.07		
Within Subjects				
Time	5	0.29	6.03	<0.01
Time x Squirrel	5	0.20	4.08	<0.01
Time x Pair	25	0.27	1.10	0.40
Error	25	0.24		
Veg	2	0.47	29.36	<0.01
Veg x Squirrel	2	0.38	23.96	<0.01
Veg x Pair	10	0.07	0.93	0.55
Error	10	0.08		
Veg x Time	10	0.14	1.99	0.06
Time x Veg x Squirrel	10	0.09	1.23	0.30
Time x Veg x Pair	50	0.42	1.19	0.27
Error	50	0.35		

The interaction between time and squirrel translocation observed at previous timepoints also continued to be significant ($p<0.01$). The time variable represents the repeated annual fall and spring measurements conducted in each subplot since the initiation of the experiment. The variable incorporates both variation across year and across seasons, treating the passage of time as a linear, nonhierarchical effect. Thus the interaction found includes such patterns as the staggered initiation of plots in 2011 and 2012, and the seasonal timing of translocations across the two year treatment plan.

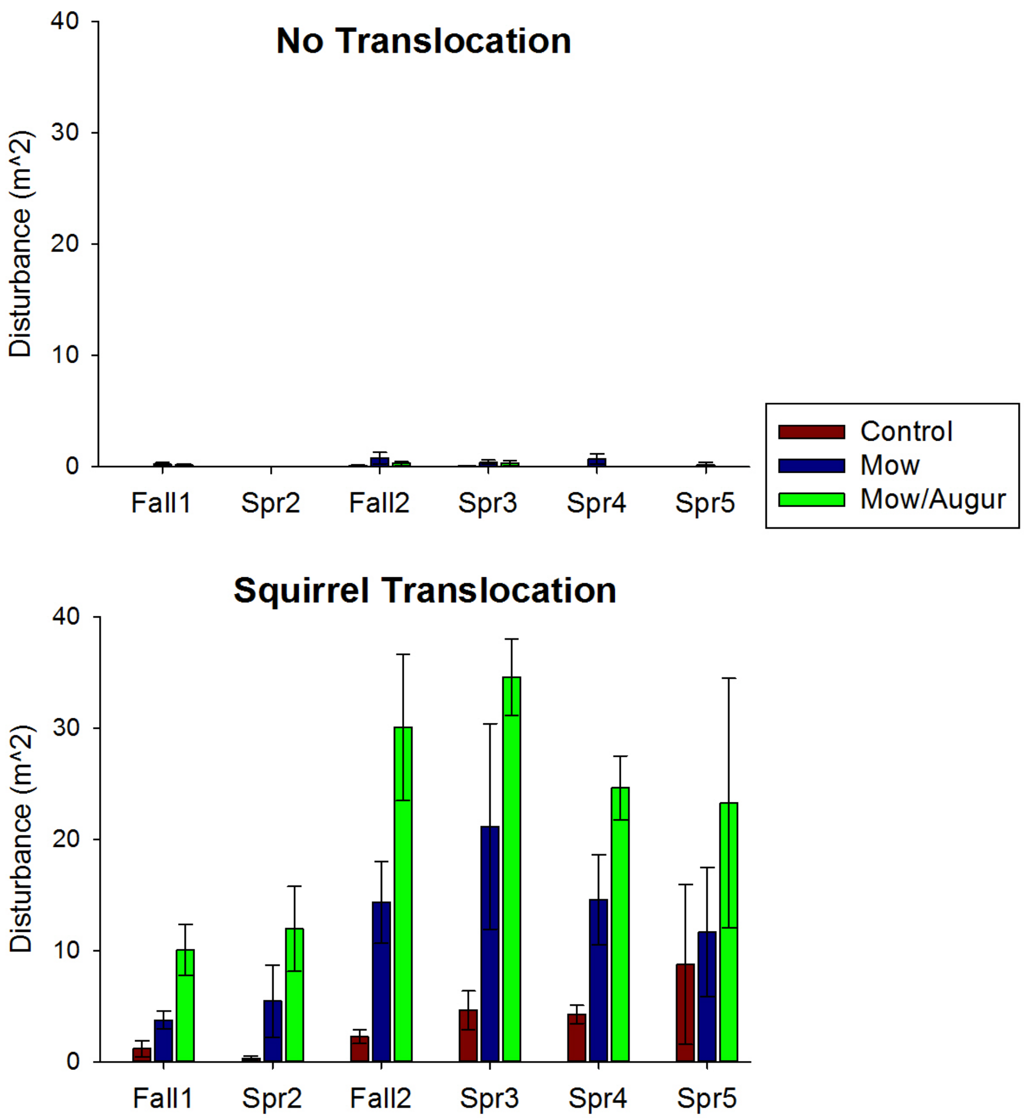


Figure 1-4. Overall ground surface disturbance (derived from the apron areas measured at each burrow) as a proxy for squirrel activity during 2011-2016 (n=6). Activity levels at both translocation and control plots are presented.

Discussion

Population status at experimental plots

The primary monitoring objective for 2016 was to determine the continued persistence of squirrel colonies at the release sites after 30 or 42 months without additional translocations. In terms of the plots established in 2011 at Jamul, one of three 2011 release plots (JE) is persisting, and the burrows on the plot showed signs of recent digging activity. Both 2012 release plots are persisting, and at JC, both increased numbers of squirrels and burrow numbers were recorded relative to the 2015 surveys. At JB, the spike in squirrel numbers observed in 2015 was not sustained. Ground searches found only a few scattered burrows in the vicinity of JB, indicating squirrel dispersal beyond the riparian zone.
In the plots with squirrels still present, we continue to see the general activity patterns observed during the experiment, with greater numbers of burrows in the original mowing areas compared to the control areas.

The initial establishment of squirrels in the mowed areas is likely driving their continued activity in these areas. We have not documented significant patterns of colony expansion beyond the plot boundaries. Either the surrounding habitat may be unsuitable, or more likely, squirrel densities could be too low to cause juveniles to seek new territories. Determining the best conditions for squirrel dispersal and developing management techniques for encouraging natural dispersal by squirrels into desired areas are now the focus of our current squirrel research.

Reintroduction of an ecosystem engineer

The main finding of the experiment was that both vegetation management and squirrel re-introduction were necessary for significant burrow habitat creation. The implementation of widespread vegetation management at Jamul in the fourth year of the experiment provided an opportunity to observe the trajectory of vegetation management and squirrel persistence on a longer time scale than the experiment originally planned.

Although 2016 proved to be another drought year, scattered winter rains fueled rapid growth of annual grasses in the plots, and there was a time lag between grass growth and the grazing treatment. The squirrels showed resiliency to these dramatic changes in vegetation structure, and their persistence five years post-experiment supports the continued use of grazing at Jamul.

The current management goal for the reintroduced squirrels is continued persistence with the expectation that breeding burrowing owls will be onsite within a few years. Therefore, the immediate objective is strategic implementation of limited management activities to support continued squirrel persistence. We currently recommend the addition of new cover piles in the occupied plots to enhance refugia habitat, as the original cover piles have degraded. The addition of new piles outside the plot boundaries also would provide a corridor for squirrel movement in between plots and potentially enable population expansion through settlement of additional territories. This habitat enhancement would occur as a management task, outside the experimental framework, and would fulfill a critical current habitat need.

The reintroduction of squirrels at Rancho Jamul is an important pilot effort to return this engineer species to targeted, protected reserve lands as a key component of restoring more functional grasslands. The restoration goal is to shift the site to a more sustainable hybrid state through reintroduction of the ecosystem engineer (Hobbs et al. 2009), a state consisting of dominant exotic grass cover, active human management of grass structure, burrowing squirrels, and breeding owls. The current year of monitoring results indicates continued progress towards this goal of a more diverse and sustainable ecological community.

TASK B: MONITORING NATURAL DISPERSAL OF CALIFORNIA GROUND SQUIRRELS INTO THE BURROWING OWL HABITAT MANAGEMENT AREA (BOHMA) AT RANCHO JAMUL ECOLOGICAL RESERVE

Introduction

Rancho Jamul Ecological Reserve has designated a Burrowing Owl Habitat Management Area (BOHMA) where BUOW have been released into artificial burrows and efforts have been made to improve the landscape to retain owls after release. The goal of this task is to continue improving the habitat by encouraging the natural dispersal of California ground squirrels from an existing adjacent colony through vegetation treatment and the addition of protective cover. In 2014, CDFW initiated grazing as a vegetation treatment in conjunction with systematic placement of woodpiles allowing us to address the following questions: (1) Does vegetation management through grazing influence natural dispersal of California ground squirrels?; (2) If natural dispersal occurs, which age cohort is dispersing?; and (3) Does the placement of cover in managed habitat expedite natural dispersal?

The BOHMA has been periodically grazed by cattle to reduce non-native grasses and forbs since early 2014. If natural dispersal of ground squirrels can be facilitated through vegetation management via grazing, information on which age cohort disperses into managed habitat will enable us to determine the ideal time of year for these vegetation treatments. Adult squirrels may disperse after breeding in early spring while juveniles disperse in early to mid-summer (Holekamp 1984). Should new burrows be documented during the spring surveys, we can assume adult ground squirrels are dispersing because there are no juveniles this time of year. However, if we document new burrows during the August/September survey, we would assume that juveniles are digging these burrows.

Furthermore, observations from ground squirrel settlement following translocation indicate that squirrels use cover while establishing new burrows. Our working hypothesis is that squirrels will be more likely to disperse and colonize if they can excavate burrows in or near cover thereby reducing predation risk during the period in which they are establishing burrows. To address this question, CDFW installed sixteen woodpiles, which functioned as cover, on the BOHMA during February 2014 (Figure 2-1).

Figure 2-1. Map of the BOHMA with transects. There are 32 transects in the BOHMA divided equally across four distances (50m, 150m, 250m, & 350m) from the source population of squirrels in the lower left section of the map. Half of the transects are centered on woodpiles used to provide cover (yellow) and half are control transects with no woodpiles (orange). CDFW added nine new woodpiles (yellow asterisk) October 2016 to reduce the distances between cover.

Methods

In 2016 CDFW continued to control non-native vegetation by grazing cattle, and we monitored squirrel dispersal with CDFW partners using the methods outlined in our 2014 report (Swaisgood et al. 2015). We conducted surveys April 12th and September 29th.

Statistical analysis

The data are highly zero-inflated since we detected no burrows in many of the transects, therefore we used nominal logistic regression to model the effects of transect type (cover [woodpile] vs. control), season (fall vs. spring) and year on the presence or absence of ground squirrel burrows. We first analyzed all transects together, but since squirrel settlement varied greatly between the four distances from the original source population, we then repeated the analyses with a subset of transects from the 50m distance and again for those at the 150m distance.

Results

Summary of 2016 surveys

We recorded a total of 145 ground squirrel burrows during our 2016 surveys, 61 located within transects and 84 burrows found in areas outside of transects (Table 2-1). Of the 145 burrows counted, 94 were newly identified in 2016, while the rest were recounts of burrows identified during previous surveys (Table 2-2). We identified 32 new burrows in the spring, and 62 new burrows in the fall. Fifteen burrows recorded in prior years were recounted in 2016, indicating long-term persistence of squirrels. We continued to document an increase in burrows at cover transects 50m from the original population border. Finally, this year we found a notable number of burrows (>40) at the 150m distance, with higher numbers in the cover transects than controls (Figure 2-2). A distribution trend towards transects five through eight and thirteen through sixteen indicates a predilection for the southern section of the BOHMA (Figure 2-3).

Presence/absence of ground squirrel burrows at all transects

When we examine all transects regardless of distance from source population, results from the nominal logistic regression model reveal season, year and the presence of cover are all significant predictors of the presence of ground squirrel burrows (Table 2-3, Figure 2-4). The odds of ground squirrel burrows being found within cover transects were 2.8 times greater than in control transects ($p<0.01$). We were also 2.8 times more likely to detect burrows in the fall compared to spring ($p<0.01$). The odds of finding burrows in transects decreased slightly from 2014 to 2015, but not significantly (odds ratio=2.7, $p=0.06$), however from 2015 to 2016, the odds increased 3.6-fold ($p=0.01$), effects likely driven by climatic variation.

Presence/absence of ground squirrel burrows 50m from original source population

Transect type was the only significant factor to predict the presence of burrows at the 50m distance based on the nominal logistic regression model (Table 2-3, Figure 2-5). We were almost eight times more likely to find burrows in cover transects than control transects ($p<0.01$).

Presence/absence of Ground squirrel burrows 150m from original source population

For transects at the 150m distance, the nominal logistic regression revealed both season and year predicted the presence of burrows (Table 2-3, Figure 2-5). The odds of detecting burrows increased 6-fold in the fall compared to spring ($p=0.01$). In 2015, we were 11 times less likely to find burrows than in 2014, but in 2016 our odds increased 39-fold compared to 2015 ($p<0.01$). Transect type was not a significant predictor because burrows were found in both cover and controls, however we did record a higher number of burrows in the cover transects, further supporting the benefits of cover placement (Figure 2-2).

Discussion

This experiment was designed to pilot test the hypothesis that we could facilitate colonization from natural squirrel dispersal, given an adequate population base. This alternative to squirrel translocation is attractive as it could be a more cost-effective solution to ecosystem engineer recruitment in some prescribed circumstances. With three years of survey data, we are able to address our original research questions. Most notably, we have shown that the placement of cover expedited natural dispersal, with immediate colonization to nearby woodpiles. Following the 2015 surveys we were concerned that the distance between rows was too great to attract squirrels further east, but 2016 proved to be a productive year for expansion of this ground squirrel colony. After two years, ground squirrels reached the next row of woodpiles. Because of the amount of time that it took for squirrels to begin to establish burrows 150m from the edge of the original resident population, we recommended a tighter configuration of 50 meters between cover piles to increase dispersal rates. Therefore, on October 27th and 28th CDFW staff added nine new woodpiles to the BOHMA splitting the difference between existing woodpiles (Figure 2-1).

Colony expansion occurs throughout the year. Nevertheless, our results indicate that colony expansion is more strongly driven by juveniles dispersing in late spring and early summer and settling around cover piles before the fall surveys. We documented a significantly higher number of burrows in the fall compared to spring surveys. In order to facilitate colony expansion, management should establish cover piles before pups are weaned in early spring in order to target juvenile dispersal into unoccupied habitat.

Other habitat factors such as vegetation openness, type and soil association may also influence squirrel colony expansion. While cattle had full access to the BOHMA they preferentially grazed the southern half of the study area, and the squirrel colony expanded into this portion of the study area as well. California ground squirrels may be selecting this region of the BOHMA due to a more open landscape created by cattle activity. Yet, it is also possible squirrels made their settlement choices based on vegetation type. The northern half of the study area is dominated by Bromus spp., while the southern half is composed of a more diverse mixture of non-native grasses and forbs. Finally, soil type may also be influencing ground squirrel settlement decisions. The geological formation of the northern section of the BOHMA is comprised of alluvial deposit and the southern section is metavolcanic rock. Results from our squirrel translocation experiment indicate that ground squirrels were more likely to remain on plots with metavolcanic rock parent layer as opposed to alluvial deposits, which generally has higher clay content. Taken together, these results suggest that squirrels prefer to establish into soil with low clay content and attempting to facilitate squirrel expansion into areas with high clay content may not be successful.

We established a second experimental replicate in October 2016 in the northern section of Rancho Jamul (Figure 2-6). We modified our design from the BOHMA configuration by reducing the distance between rows of transects to 50m and removing the fourth row. We also added twelve control transects just north of the replicate study site to better quantify the effect of cover piles on natural dispersal. Otherwise, vegetation management is unchanged. Cattle were grazed on this parcel of RJER and will continue to be used in 2017 to reduce grass biomass. Prior to placing the cover piles, CDFW manually removed grass thatch if present, and applied pre-emergent (~2oz. Surflan liquid per woodpile) and post-emergent herbicides (~2lbs Simazine granules per woodpile) within a 15ft diameter circle.

Implications for conservation and management

Overall, encouraging natural dispersal by ground squirrels may be an important part of a long-term strategy for managing protected areas for BUOW. Nevertheless, our results indicate that relying on natural squirrel dispersal takes time (two years to see early stages of expansion by 150m), even when encouraged with vegetation management and provision of cover. Given the current small population size of BUOW in San Diego County, and the population viability models indicating that this population is in jeopardy of being extirpated, more active management techniques such as squirrel translocation and artificial burrow creation will be necessary to expedite habitat improvement for BUOW at designated recovery nodes where ground squirrels are currently absent or at densities too low to serve their appropriate ecosystem function.

Table 2-1. Burrow counts for BOHMA surveys. Total number of ground squirrel burrows found within transects for each survey session. We opportunistically recorded burrows found outside of transects, with totals in parentheses. (Value changes from previous reports reflect corrections based on reassessment of burrow criteria.)

Distance	Transect	Spring 2014	Fall 2014	Spring 2015	Fall 2015	Spring 2016	Fall 2016
50m	woodpile	2	7	8 (4)	11 (8)	11 (4)	22 (8)
	control	1	1 (1)	0 (1)	2 (6)	0 (10)	0 (19)
150m	woodpile	0	2 (1)	0	1	5 (12)	12 (21)
	control	1	3	0	0	3 (1)	4 (8)
250m	woodpile	0	0	0	0	0	2 (1)
	control	0	0	0	0	0	0
350m	woodpile	0	1	0	0	1	1
	control	0	1	0	0	0	0
	Annual total	**19 (2)**		**22 (19)**		**61 (84)**	

Table 2-2. Individually identified burrows. Summary of all new burrows identified in Spring and Fall of each year, plus those identified in prior years but still present. New spring burrows that were still present in the fall of the same year are shown in parentheses and excluded from the total.

Year	ID'd Prior Year(s)	New ID Spring	*Spring ID, Fall count*	New ID Fall	Total
2014	-	4	*(0)*	17	**21**
2015	3	13	*(9)*	16	**32**
2016	15	32	*(26)*	62	**109**

Table 2-3. Wald test results for each term included in the nominal logistic models.

		All transects		50m distance		150m distance	
Term	**df**	**Chi^2**	**p**	**Chi^2**	**p**	**Chi^2**	**p**
Transect type	1	6.75	**0.009***	8.22	**0.004***	0.14	0.709
Season	1	6.75	**0.009***	1.72	0.189	5.27	**0.022***
Year	2	6.55	**0.038***	0.67	0.714	8.79	**0.012***

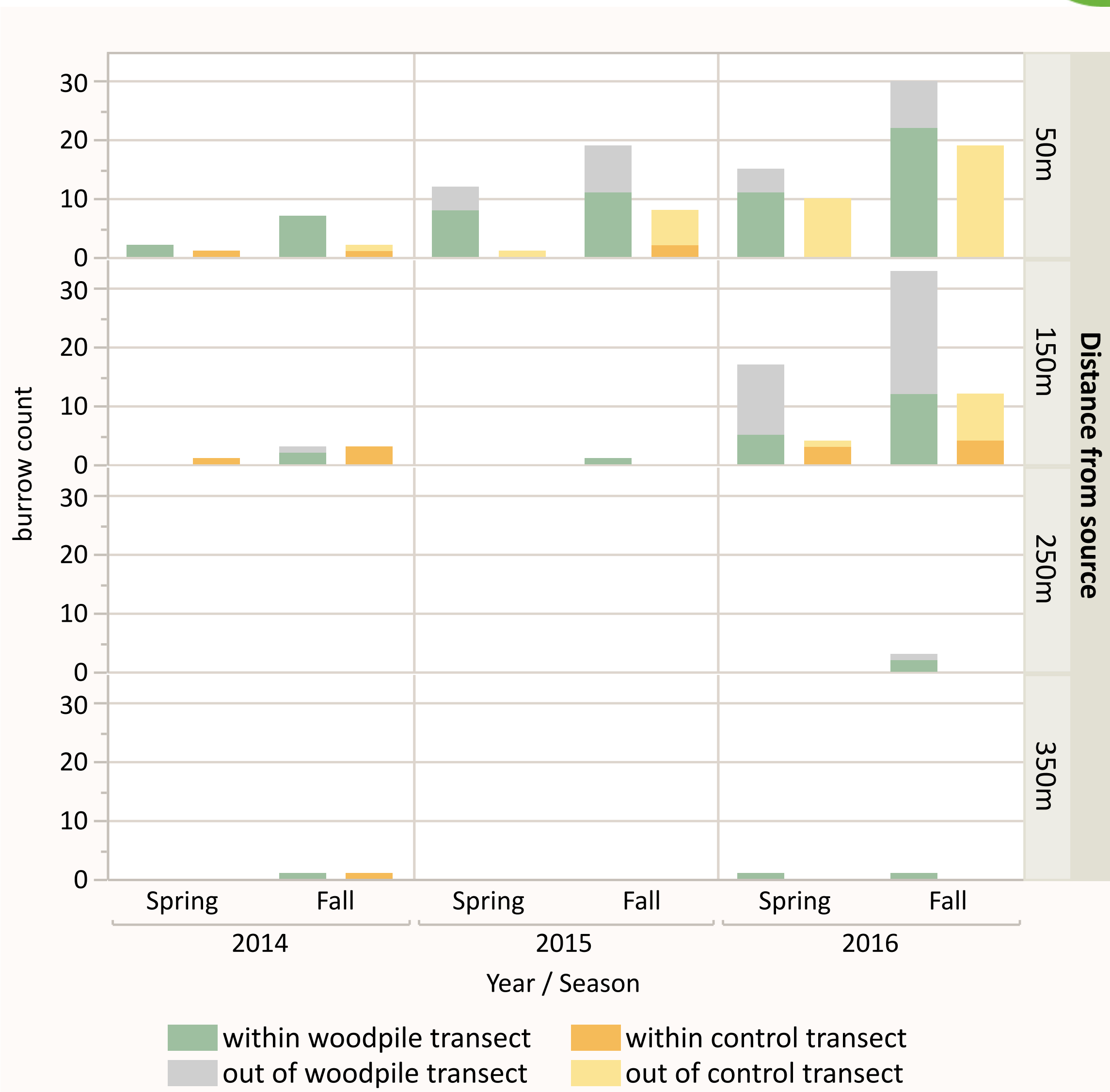


Figure 2-2. Summary of number of burrows detected for each survey. The total number of squirrel burrows found within woodpile (green) and control (orange) transects at increasing distances from the source population for the six surveys completed in the spring and fall of 2014 through 2016.

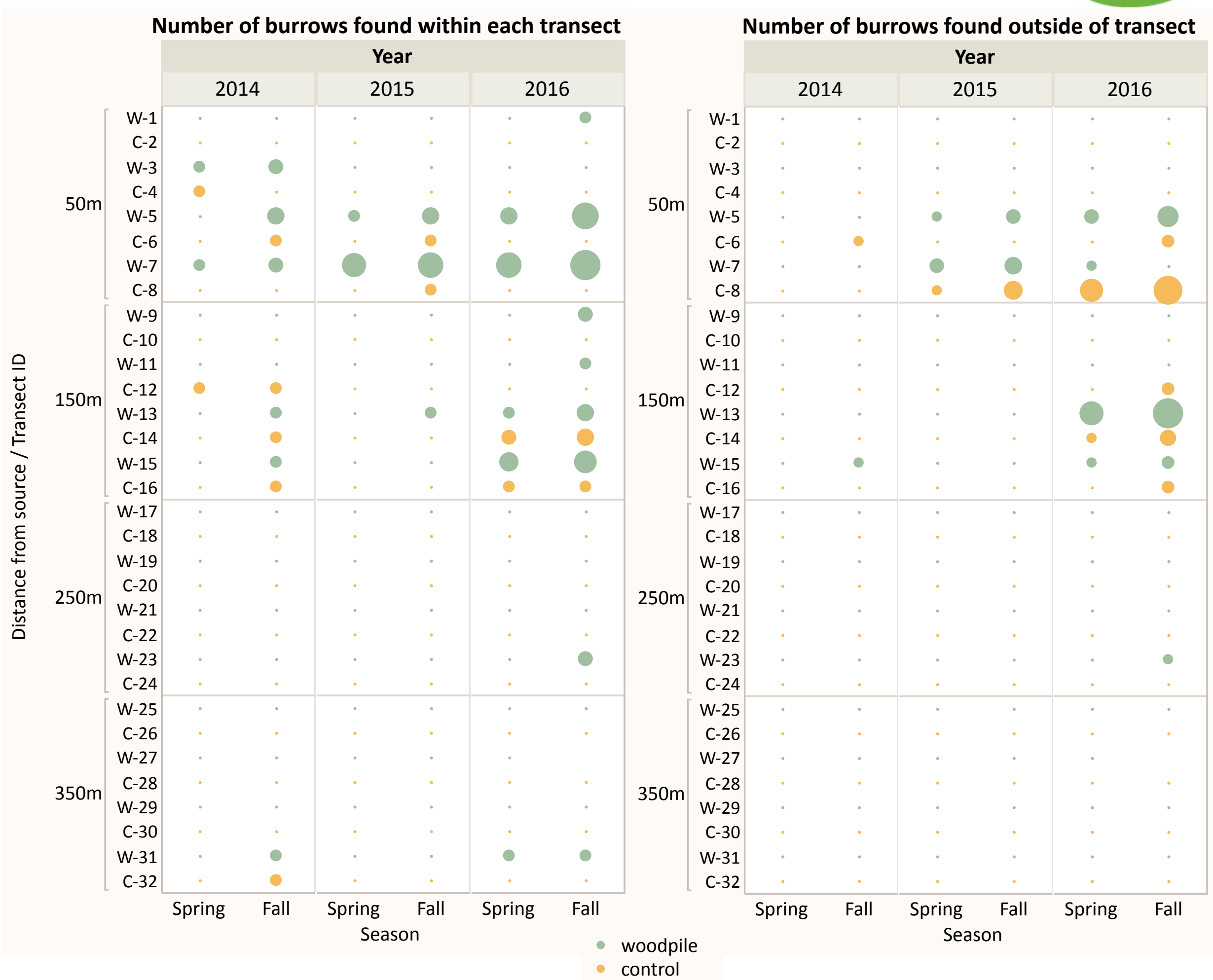


Figure 2-3. Relative quantity of burrows at each transect. The size of each circle represents the quantity of burrows recorded at each transect. The left figure displays burrows found within transects. Each transect is numbered 1 through 32 and prefaced with a "W" for woodpiles (grey) and "C" for controls (orange). We also opportunistically recorded squirrel burrows found outside of transects, shown in the figure on the right.

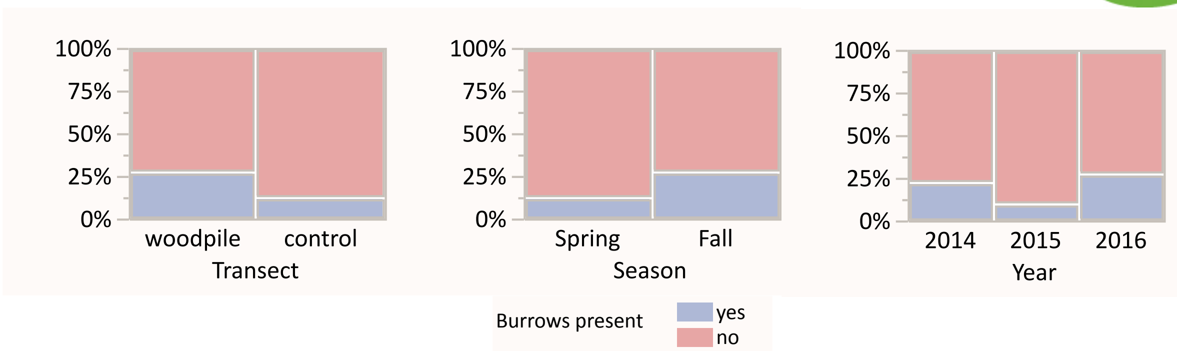


Figure 2-4. Mosaic plots for the percentage of transects with ground squirrel burrows for all transects. Overall, 28% of woodpile transects had ground squirrel burrows compared to 14% of control transects, and more transects had burrows in the fall (28%) than the spring (13%).

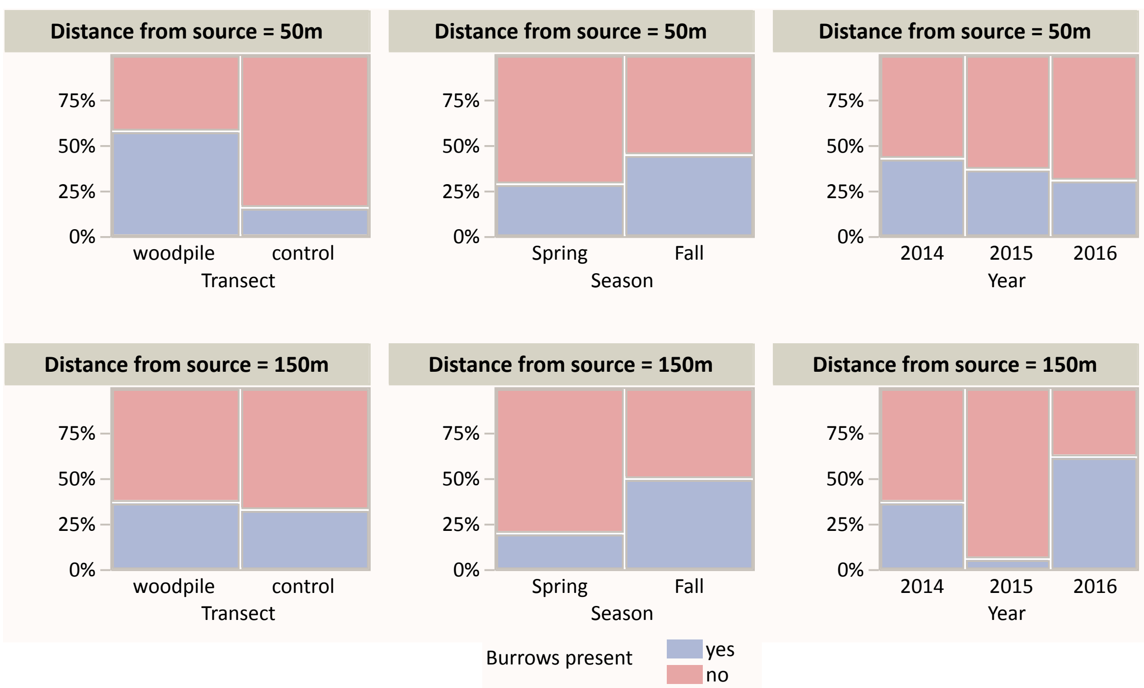


Figure 2-5. Mosaic plots for the percentage of transects with ground squirrel burrows at the 50m and 150m distances. When transects from each distance are examined separately, we see a significant difference between woodpile and control transects at the 50m distance (58% and 17% respectively), while the differences were not significant between fall and spring, nor across years. At 150m, more transects had squirrel burrows in the fall (50%) than in spring (21%), and in the first and third years of the study (38% in 2014, 6% in 2015, and 63% in 2016).

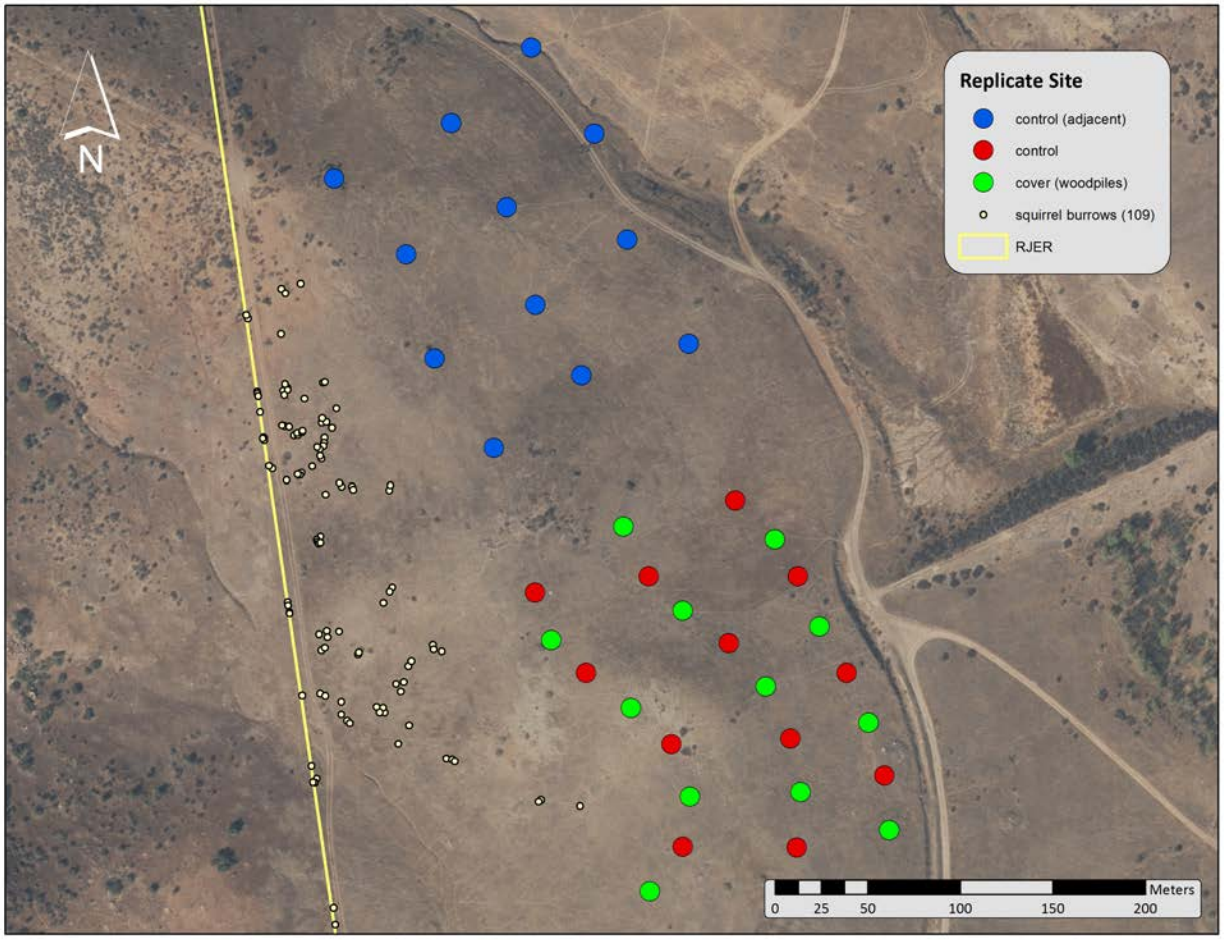


Figure 2-6. Map of the Replicate site transects and burrows. In October 2016, CDFW staff established a new replicate site in the north of RJER. We reduced the distance between cover, so that each line of transects is 50m, 100m, & 150m from the current ground squirrel colony boundary. We added an additional group of control transects adjacent to the study area (blue circles). Twelve transects are centered on woodpiles used to provide cover (light green circles) and twelve are control transects with no woodpiles (red circles). ICR staff recorded 109 burrows within RJER (yellow points), which were used to determine the colony boundary.

TASK C: BURROWING OWL NESTING ECOLOGY AND POPULATION DYNAMICS

Introduction

Working with the BUOW partnership, SDSU IEMM developed a conceptual model explaining possible factors regulating BUOW population dynamics. Among the most fundamental variables identified in this model are burrows, habitat type (vegetation), prey abundance and availability, and predation. In 2011 and 2012, we conducted a pilot project to test the utility of using camera traps to document BUOW reproductive ecology and population dynamics. We found that camera traps placed at the nest burrow entrances allow us to count chicks to determine reproductive success, track prey deliveries by adult owls, and identify prey items. Due to our success with the pilot project, in 2013 we made this research the focus of much greater effort. In 2014 and 2015, we added the use of GPS telemetry to study foraging movements and iButton dataloggers to examine burrow microclimate. In 2016, we continued to monitor BUOW nesting ecology using a variety of tools, including camera traps, color banding, and iButtons.

Using camera traps at a number of natural and artificial burrows at sites with varying habitat characteristics, we have been able to monitor the relative productivity of BUOW at different locations and habitat types. These data have been especially important for assessing the viability of management actions involving establishment and maintenance of artificial burrows. Current BUOW management practices focus strongly on the installation of artificial burrows to encourage occupancy and breeding in an area. However, artificial burrows are often placed in available areas with minimal consideration of the immediate habitat characteristics or potential foraging areas. It has been hypothesized that artificial burrows may sometimes serve as an ecological trap, drawing owls in to nest in areas that do not otherwise provide sufficient resources or expose the owls to greater risk of predation. We have also documented that artificial and natural burrows differ with regard to microclimate inside the burrow, but the potential effects on nesting success and offspring viability are not well-understood. By comparing productivity and prey provisioning at artificial and natural burrows, we can gain a better understanding of how artificial burrows are functioning as a management tool for BUOW (this is explored further in the next section).

Our continued efforts with color-banding, which allows for individual recognition of the birds, is helping to increase our knowledge of survival, recruitment, and movement of BUOW through resighting via camera trap photos and on-the-ground observations. During our banding efforts, we collect genetic material, which is stored at ICR's Frozen Zoo. In 2015, we began initial genetic analyses on samples collected since 2013 to determine the sex of each individual and relatedness among individuals. We also examined the population genetics of the BUOW of San Diego County. In 2016, we continued to collect genetic samples to add to our dataset for future analyses. Furthermore, we have used our resighting data to model adult and juvenile survival since 2011.

Methods

Study sites

The study sites were all located on public lands and conservation areas in San Diego County within Management Unit 3 of the Management Strategic Plan (San Diego Management and Monitoring Program 2013). We focused on five priority sites that were identified in 2013 for monitoring BUOW nesting and foraging ecology (Figure 3-1); site selection is described in the 2013 annual report (Wisinski et al. 2014):

1. Brown Field Municipal Airport, managed by City of San Diego Airports;
2. Lonestar Ridge West Mitigation Site, managed by California Department of Transportation;
3. Johnson Canyon/Lonestar Ridge East Mitigation Site, managed by California Department of Transportation;
4. Poggi VOR, managed by Federal Aviation Administration; and
5. Lower Otay Reservoir Burrowing Owl Management Area (LORBOMA), managed by City of San Diego Public Utilities.

Brown Field Municipal Airport (Brown Field; N 32° 34’ 18.84”, W 116° 58’ 46.67”) is characterized by managed non-native grassland habitat with highly disturbed human use areas. California ground squirrels occur in relatively high numbers and create natural burrows for the owls to occupy. All nest burrows that we monitored at Brown Field were natural burrows. Lonestar Ridge West Mitigation Site (Lonestar; N 32° 34’ 43.61”, W 116° 58’ 01.85”) is a restored vernal pool and BUOW mitigation site established in 2012. The site contains 50 artificial burrows (25 plastic, 25 wood) with at least 25 additional starter holes and natural burrows onsite, particularly along the perimeters. Lonestar is characterized by tarplant (*Deinandra* spp.) and other native vegetation with some patches of native needle-grass (*Stipa* spp.). In 2015, a major effort was made to establish native grassland in the southern portion of the site with high success. The Johnson Canyon/Lonestar Ridge East Mitigation Site (Johnson Canyon; N 32° 34’ 56.48”, W 116° 57’ 15.83”) is a more established mitigation restoration site characterized by coastal sage scrub vegetation with patches of non-native grasses. The site contains 21 artificial burrows. Poggi VOR (Poggi; N 32° 36’ 37.14”, W 116° 58’ 44.80”) is characterized by managed non-native grassland habitat and contains a high number of ground squirrels and a high density of natural burrows. LORBOMA (N 32° 37’ 17.05”, W 116° 54’ 55.96”) is an artificial burrow site characterized by coastal sage scrub habitat with some areas of native and non-native grass. The site contains 23 artificial burrows.

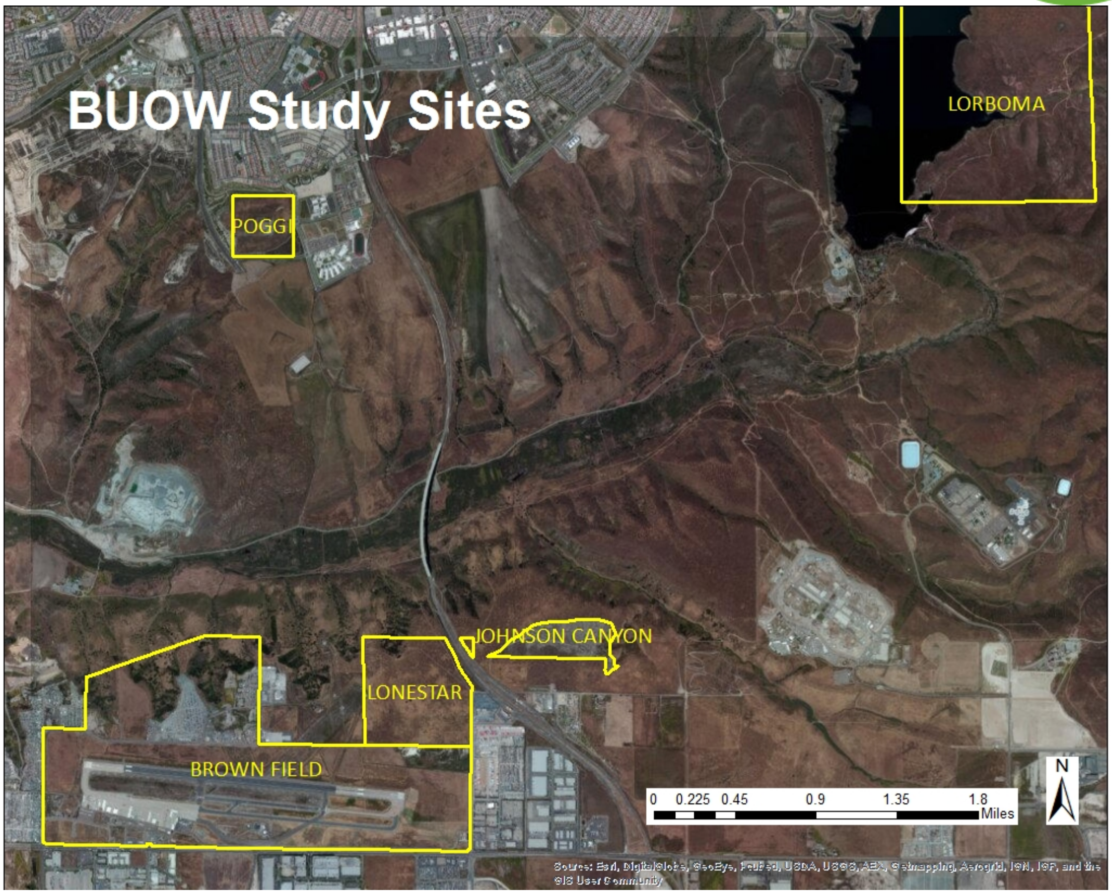


Figure 3-1. Map of the 2016 BUOW study sites.

Nest monitoring

In 2013, we compiled known natural and artificial burrow locations within Management Unit 3 from previous years' data, eBird, CNDDB, California Department of Fish and Wildlife (CDFW), and CalTrans. We surveyed all of these known locations, which included all areas with artificial burrows except the Sweetwater Authority property, to determine the status of each burrow (active, inactive, need for maintenance) and used this list to determine which burrows to monitor throughout the breeding season. We focused on burrows on public lands and obtained the necessary permissions to access these areas. Five areas were identified as priority sites for monitoring. In 2016, we focused on Brown Field, Lonestar, and Johnson Canyon due to a lack of breeding owls at Poggi or LORBOMA.

All known nest burrows at the study sites were checked weekly and were monitored using camera traps. However, Poggi and LORBOMA were checked less frequently after we determined that no owls were present at either site. The number of owls seen, sex and age class of the owls, and the presence of ground squirrels or predators were recorded for each nest visit. In addition, incidental BUOW sightings and sign at private lands in Otay Mesa and at squirrel translocation plots at Rancho Jamul Ecological Reserve were recorded throughout the study period. We opportunistically checked artificial burrows in Management Unit 3 to collect data on BUOW use and condition of the burrows. These data were added to our database and will help inform our on-going assessment of artificial burrows in San Diego County.

In late 2015, we modified a number of artificial burrows to allow for direct access to the nest chambers (see Hennessy et al. 2016 [Appendix 4] for further information). Due to these modifications, we were able to better track nesting phenology and nest contents at these burrows in 2016.

Camera trapping

We set cameras at burrow entrances (usually one for natural burrows and two for artificial burrows) when we suspected the presence of eggs or chicks (through direct observation of the nest chamber or behavior of the female). In 2016, all nest burrows at the study sites received camera traps, including two burrows that were located under the helicopter pads at Brown Field. Excessive plant growth due to the temporary closure of the helicopter pads compromised our ability to detect prey deliveries, but we were still able to collect productivity and predation data from these burrows.

We used Reconyx® PC900 remote camera systems to monitor the entrances of occupied nest burrows. We also used Bushnell® Natureview cameras with an adjustable focal length lens at a small number of the burrows. Each camera was placed 1-3 m from the burrow entrance approximately 0.5-0.75 m above the ground and focused on the entrance and apron area of the burrow. We placed the cameras at an angle (as close to perpendicular as possible) to the entrance to allow for better identification of prey items brought by the owls. We set the cameras to take 3 pictures per motion-triggered event with a 30-second rest period in between trigger events. We changed camera batteries and retrieved SD data cards once per week to coincide with the weekly nest visit. We added or moved cameras if the juveniles moved to a satellite burrow.

Camera trap data processing

All camera trap photos were organized by burrow and date. We used Adobe® Bridge to examine all of the photos and tag each photo with pertinent information such as the presence of non-BUOW visitors (including predation events and humans; see Appendix 1 for protocol with full keyword list). We recorded the maximum numbers of adults and juveniles, respectively, along with the identities of any banded owls. We re-examined all tagged photos a second time for quality control. Volunteers were recruited and trained, and completed the first tier of photo processing; quality control was completed by staff. Although it was not part of the 2016 Scope of Work, we also tagged photos with the types of prey items delivered at a subset of both natural and artificial burrows. We suspected the prey base might be different from previous years based on wetter weather conditions, and, if this was the case, we wanted to examine potential effects on productivity. We recorded each independent prey delivery, predation, or burrow visit event. Events were considered independent if 1) it was clear that the subsequent prey delivery contained a different item, or 2) more than an hour elapsed between visits by other species (e.g. rabbits). Predation events were much more discrete and easier to identify as independent.

Analysis of camera trap data

Using the daily maximum juvenile counts, we determined the maximum numbers of chicks (post-emergence to fledging) and the maximum numbers of fledglings (present after 45 days of age) at each burrow. We used 2-sample t-tests to test for differences in productivity by burrow type. Analysis of site differences was limited due to low sample sizes. We also excluded the data from any burrows where we were not able to confirm that eggs had been laid.

We examined prey deliveries from camera set-up date to fledging or failure date to account for the high variability in the duration of camera deployment (i.e. successful nests had cameras running for a much longer period of time). We calculated the total number of prey deliveries for this period and divided by the number of photo days to standardize between burrows. We also calculated the proportions of bird, herpetofauna, invertebrate, mammal, and unknown prey from the same period.

We examined the main and interaction effects between the different prey metrics, year, burrow type and productivity using linear regression and ANOVA, as appropriate. The response variables evaluated were maximum number of emergent chicks, nest success, and number of fledglings (productivity). Only observations of breeding pairs on their first nest attempt were included in this analysis (n=96). Mixed effects models with year or burrow type as mixed effects were run but did not account for increased amounts of variation over the parallel fixed effects models. Models for maximum number of chicks and number of fledglings were Poisson generalized linear regression with an ordinal response variable, and nest success was modeled as a binomial variable.

ANOVA was conducted in JMP 12. GLM and GLMM mixed effects models were developed in R version 3.2.1 using packages base, lme4, and lmerTest. Model selection was conducted with the package AICcmodavg, and based on AICc and Aikake weights, which are derived from a calculation of the relative likelihood of each model ($\exp(-0.5 * \Delta AIC)$.

Banding

During the nestling and fledgling stages of the breeding season, we captured, banded, and took genetic samples (blood and/or feathers) from BUOW at or near their nest burrows. We used one-way door traps at the burrow entrances as our primary capture technique for juveniles and adult females. We included the use of call/playback to more efficiently capture adult males. Bow nets were used to capture fledglings and adults late in the breeding season. Standard morphometric measurements were taken for each bird. Blood samples were taken from the brachial vein; in the case of very small nestlings, body feathers were taken. All blood, feather, and tissue samples are being stored in the Frozen Zoo® at the Beckman Center, San Diego Zoo Institute for Conservation Research. Unbanded owls received two aluminum bands: a USGS band and a green alphanumeric Acraft band.

We used mark-resight data from 2011-2016 to model and estimate apparent annual survival using a Cormack-Jolly-Seber model in Program MARK (White and Burnham 1999). Due to small sample sizes in some groups, we used a relatively simple model to allow us to estimate confidence intervals. The underlying model allowed survival (φ) to vary by age (adult vs. juvenile) and year, but held the recapture probability (p) constant throughout the study period {φ(a2−t/t)p.}. We structured the model in this way because there was not enough data to estimate the recapture and survival probabilities for each capture occasion, and the parameters of interest were age- and year-specific survival rates.

Results

Nest monitoring & Camera trapping

During the 2016 breeding season, we monitored 40 BUOW burrows weekly from mid-March through September (Table 3-1, Figure 3-2). We opportunistically checked burrows located on private land, but did not monitor them for breeding. We confirmed breeding (by presence of eggs or chicks) at 31 of the 40 burrows. We were not able to confirm breeding at the other burrows for two main reasons: (1) in most cases, we were not able to confirm the presence of eggs in natural burrows, so if a failure occurred before chick emergence, we could not confirm whether breeding had taken place; or (2) if a burrow occurred on private land, we observed it from the nearest road and only revisited it as time allowed during the rest of the season.

We observed 38 nesting attempts (21 at natural burrows and 17 at artificial burrows) using camera traps, but some had limited data due to nest failures or finding the nesting attempt late in the cycle. Camera traps ran from 18 March to 15 December for a total of 6976 camera days (including secondary cameras at satellite burrows) and collected approximately 3.5 million photos.

Table 3-1. Breeding success at all BUOW nests located in the Otay Mesa area during the 2016 breeding season.

Burrow[1]	Site	Breeding	Successful[2]	# Fledged[3]	Notes	Banded Birds[4]
1. Euc 6	Lonestar	Likely[5]	N	0	Nest depredated by skunk, female killed on 16 April	M: 72 over X F: 12 over Y
2. LS 160 (A)	Lonestar	Y	N	0	Nest abandoned by 27 April	M: 29 over Y
3. LS 132 Natural	Lonestar	Y	Y	5+[6]	05/Z from LS 142 also fledged at this burrow[6]	M: 24 over Y F: 34 over Y
4. LS 142 (A)	Lonestar	Y	Y	1[6]	05/Z fledged at LS 132 Natural[6]	M: 90 over Y F: 33 over Y
5. LS 144 (A)	Lonestar	Y	N	0	Sibling pair (hatched at LS 185 in 2015)	M: 98 over Y F: 62 over Y
6. LS 97 (A)	Lonestar	Y	Y	2+[7]	26/Z from LS 109 also fledged at this burrow[7]	M: 49 over Y
7. LS 109 (A)	Lonestar	Y	Y	3[7]	26/Z fledged at LS97[7]	M: 67 over Y F: 73 over Y
8. LS 67 (A)	Lonestar	Y	N	0	Male last seen 9 May	M: 53 over Y F: 03 over Y
9. LS 52 (A)	Lonestar	Y	Y	2		M: 04 over Y F: 57 over Y
10. LS 21 (A)	Lonestar	Y	Y	7[8]	28/Z was likely from LS 21, but was banded at LS 13[8]	M: 71 over X F: 87 over X
11. LS 13 (A)	Lonestar	Y	Y	4+[8]	28/Z likely dispersed here from LS 21[8]	F: 35 over Y[9]
12. LS 185 (A)	Lonestar	Y	Y	5		M: 73 over X F: 28 over Y
13. LS 175 (A)	Lonestar	Y	N	0		M: 00 over Y F: C over C
14. Lonestar Mound	Lonestar	Y	Y	3		M: 94 over Y F: 75 over Y
15. 8L[10]	Brown Field	Y	Y	1	Nest found late, in inaccessible area of airport	M: 31 over X
16. Gravel Lot	Brown Field	Y	Y	1	Possibly attempted a second nest, but unconfirmed	M: 27 over Y F: 07 over X
17. Tripad North	Brown Field	Likely[5]	N	0	Nest apparently flooded (see text for details)	M: 88 over X F: 30 over Y
18. Tripad South	Brown Field	Y	Y	4		M: 89 over X F: 94 over X
19. BCS	Brown Field	Y	Y	5	Sibling pair (male hatched at LMSS in 2014, female hatched at LMSS in 2015)	M: 78 over X F: 42 over Y
20. Auto World Fence	Brown Field	Y	Y	2		M: 63 over Y F: 50 over Y
21. Gorilla NN	Brown Field	Y	N	0	Nest destroyed by coyote on 18 April	M: 31 over Y F: 77 over X
22. No Outlet	Brown Field	Y	Y	4		M: 56 over Y F: 39 over Y

Table 3-1 continued.

Burrow[1]	Site	Breeding	Successful[2]	# Fledged[3]	Notes	Banded Birds[4]
24. La Media Stop Sign	Brown Field	Likely[5]	N	0	Nest apparently abandoned by 7 April	M: 68 over X F: B over E
25. JC 15 (A)	Johnson Canyon	Y	Y	3		M: 26 over Y F: 37 over Y
26. Border Pacific[10]	Private	Y	Y	5	Burrow not visited weekly	
27. Siempre Viva[10]	Private	Y	Y	1 or 2	Burrow not visited weekly	
Renests/Late Nests						
a. Euc 6 renest	Lonestar	Y	Y	3		M: 72 over X
b. LS 159 (A)--LS 160 renest	Lonestar	Y	Y	5	Possibly same female as first nest attempt	M: 29 over Y
c. LS 40 (A)	Lonestar	Y	Y	4	Nest found late, nested in burrow tunnel	
d. LS 176 (A)--LS 175 renest	Lonestar	Y	Y	2		M: 00 over Y F: C over C
e. Parking Lot Palm--TPN renest	Brown Field	Y	Y	3		M: 88 over X F: 30 over Y
f. Cabco--Gorilla NN renest	Brown Field	Likely[5]	N	0	Female possibly sick and last seen 9 May[12]	M: 31 over Y F: 77 over X
g. Pacific Coast--LMSS renest	Brown Field	Y	Y	4		M: 68 over X F: B over E
Non-breeding/Unknown						
i. LS 194 & 201 (A)	Lonestar	Y*	N	0	*1 egg seen in each burrow in mid-April, both abandoned almost immediately	M: 88 over Y
ii. OSe7 (A)	Lonestar	Likely[5]	n/a	n/a	Copulation seen, burrow apparently abandoned by early April	M: 40 over Y F: 66 over Y
iii. Pillbox	Brown Field	Unlikely	n/a	n/a	unbanded female seen at burrow early, but left by 18 March	M: 32 over Y
iv. EAA	Brown Field	Unk[11]	n/a	n/a	unbanded male, may be same male as Old Charlie	F: 62 over Y
v. Gails	Brown Field	Unk[11]	n/a	n/a	Copulation seen, but other breeding behaviors not observed	M: 20 over Y F: 46 over Y
vi. Old Charlie	Brown Field	Unlikely	n/a	n/a	unbanded male, may be same male as EAA	
vii. General Dynamics	Brown Field	Unlikely	n/a	n/a	unbanded male, 2 banded birds seen on camera only at night (bands unreadable)	

[1]Artificial burrows indicated with (A).
[2]Nests were considered successful if 1 or more juveniles fledged (reached 45 days of age).

[3]At burrows without cameras, the # fledged is a minimum based on weekly visit data. For burrows with cameras, the # fledged is the maximum number of juveniles seen on camera after the estimated fledge date (30 days after the first emergence date).
[4]All alphanumeric bands are green aluminum.
[5] Breeding likely but unconfirmed.
[6]Female (33 over Y) last seen 1 June; male (90 over Y) last seen 8 June; juveniles: 16/Z last seen 6 June, 27/Z last seen 8 June, 49/Z last seen 13 June, 27/Z & 49/Z remains found on 14 June, 05/Z moved to LS 132 Natural 15 June and fledged there on 19 June.
[7]Juvenile 26/Z moved to LS 97 on 11 June and fledged there on 21 June.
[8] Juvenile 28/Z was likely from LS 21 (needs to be confirmed with genetic analysis), but was banded at LS 13 on 26 May. It apparently moved there on or around 19 May at or near fledging.
[9]35 over Y was previously White X5.
[10]Burrows did have cameras. Estimates are based on nest visits.
[11]Breeding status unknown; not enough information to determine whether breeding was likely.
[12]Female was possibly sick and was last seen 9 May. Female 62/Y at was present at burrow 14-17 May and Female 39/Y was seen at burrow from 20 May to early June (both were seen copulating with male).

Table 3-2. Summary of prey deliveries seen in camera trap photos during the 2016 breeding season. Data were taken from a subset of breeding burrows during the focal period starting with the camera set-up date and ending with the fledging or failure date for each respective burrow.

Site	Burrow[1]	Prey/ Photo Day	Birds (%)	Inverts (%)	Herps (%)	Mammals (%)	Unknown (%)	BUOW Prey (#)
Lonestar	LS 97 (A)	22.27	<1	85	<1	6	7	0
	LS 109 (A)	14.72	<1	79	<1	9	8	0
	LS 67 (A)	10.29	<1	91	<1	1	8	0
	LS 21 (A)	17.51	<1	81	<1	5	14	0
	LS 185 (A)	23.01	<1	84	<1	2	14	0
	Euc 6 Renest	13.98	<1	87	<1	4	8	0
Brown Field	Gravel Lot	8.97	<1	66	<1	29	3	0
	BCS	11.02	<1	54	<1	39	6	0
	Gorilla NN	14.31	0	90	0	3	7	0
	No Outlet	22.26	<1	75	<1	6	19	1
	Parking Lot Palm	7.21	<1	77	<1	10	12	0
	Pacific Coast	16.69	<1	57	<1	22	21	0
Johnson Canyon	JC 15 (A)	25.29	<1	75	<1	12	13	0

[1]Artificial burrows indicated with (A).

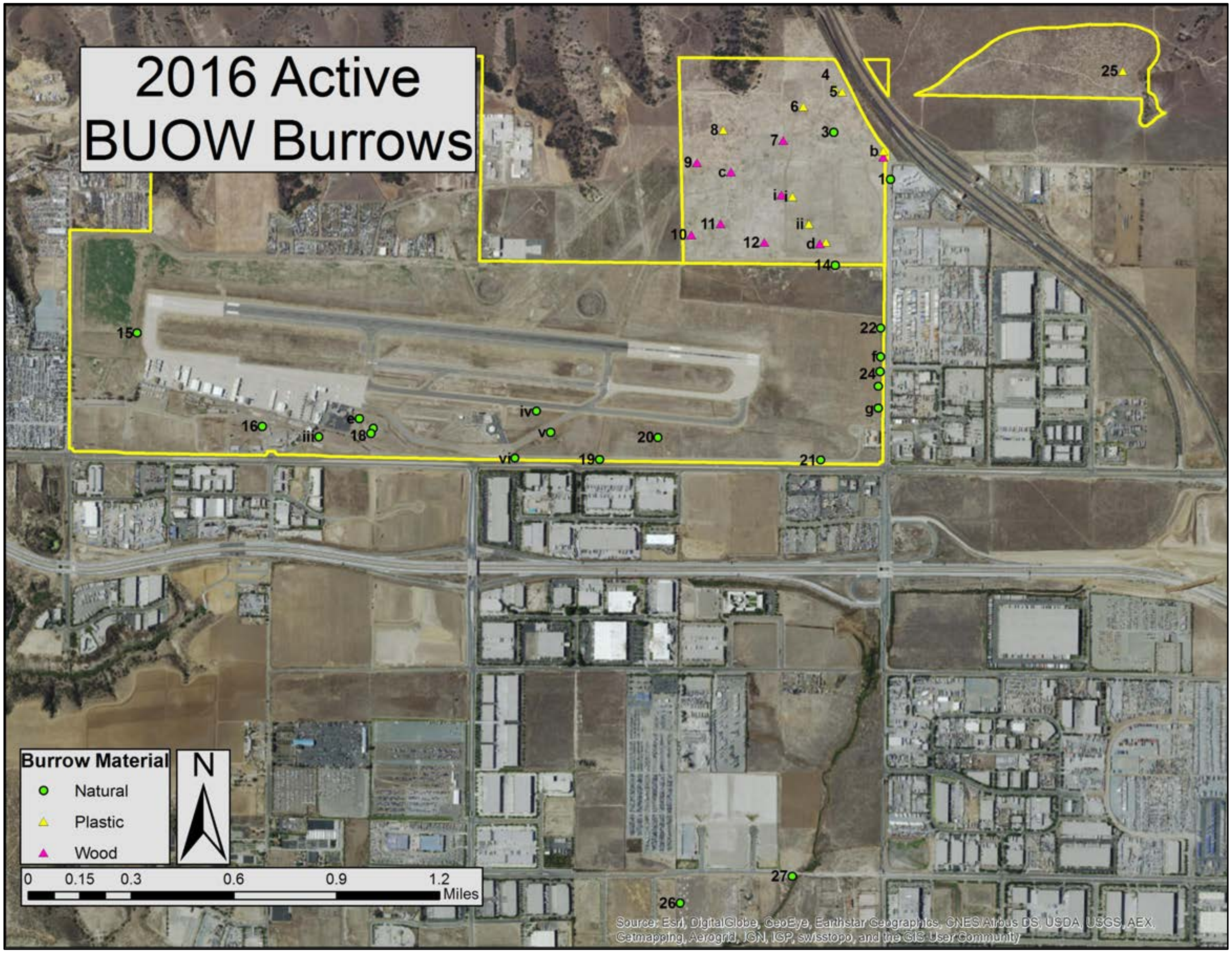


Figure 3-2a. Map of all active BUOW burrows found in 2016. Numbers refer to Table 3-1.

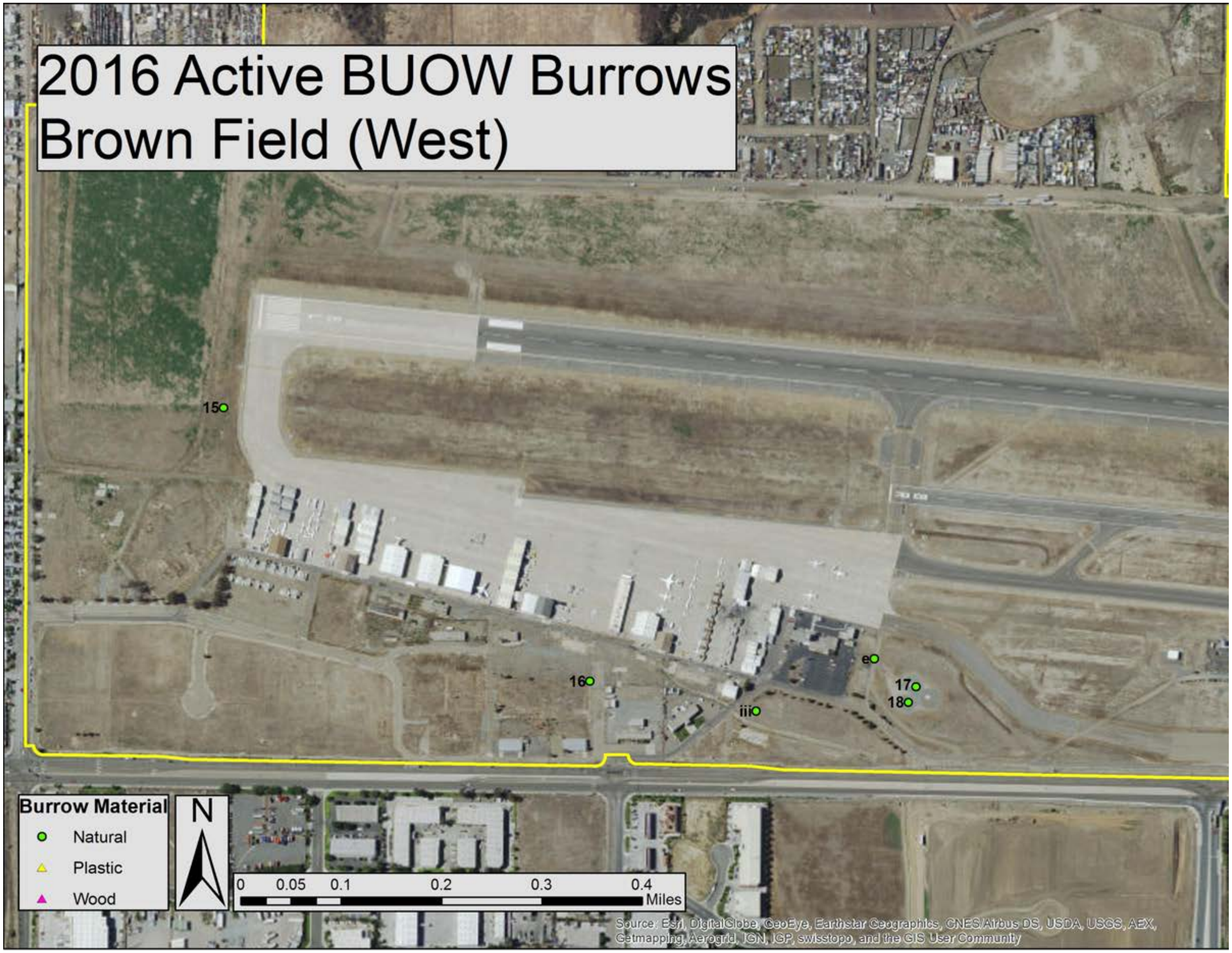


Figure 3-2b. Map of active BUOW burrows found at Brown Field (west) in 2016. Numbers refer to Table 3-1.

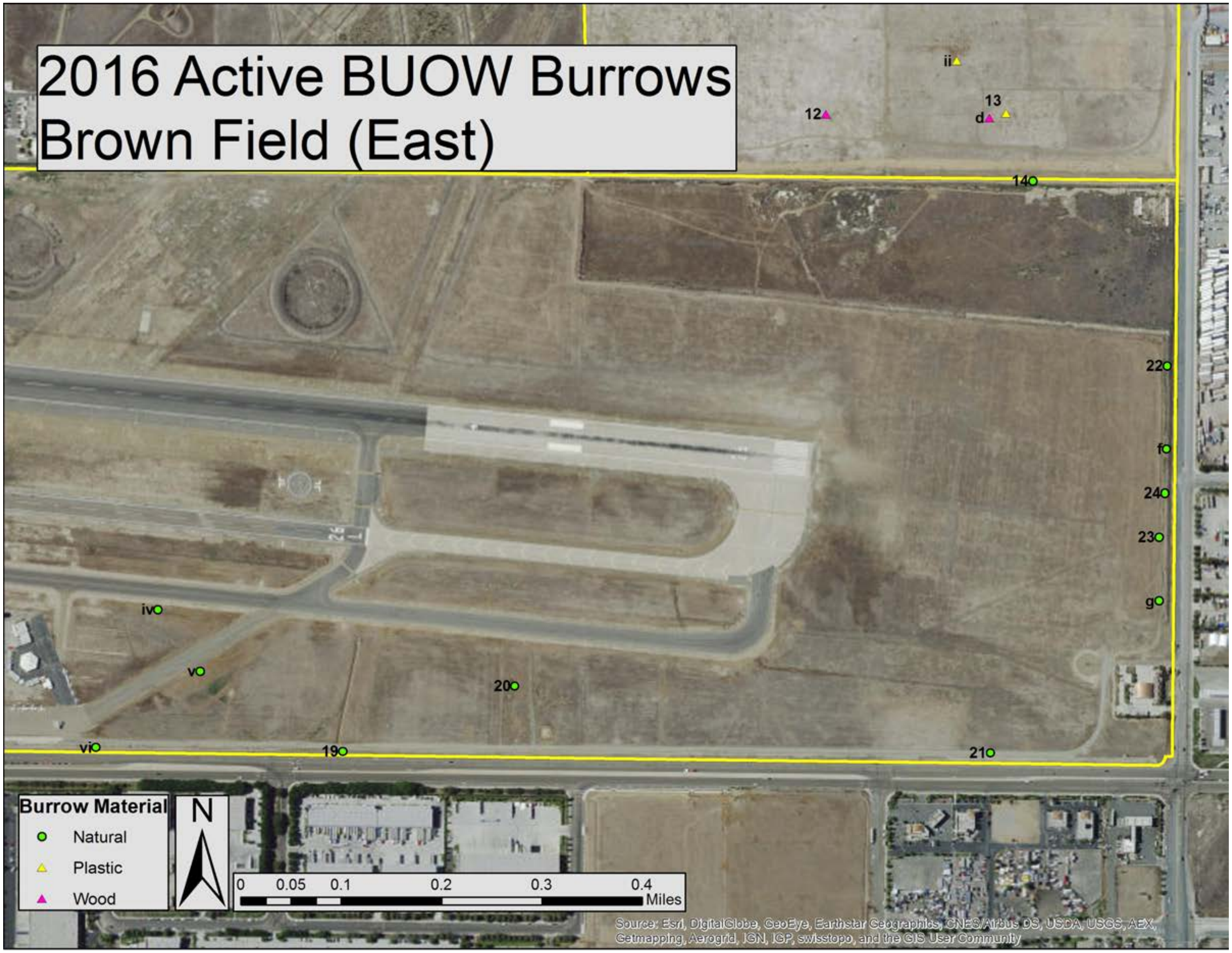


Figure 3-2c. Map of active BUOW burrows found at Brown Field (east) in 2016. Numbers refer to Table 3-1.

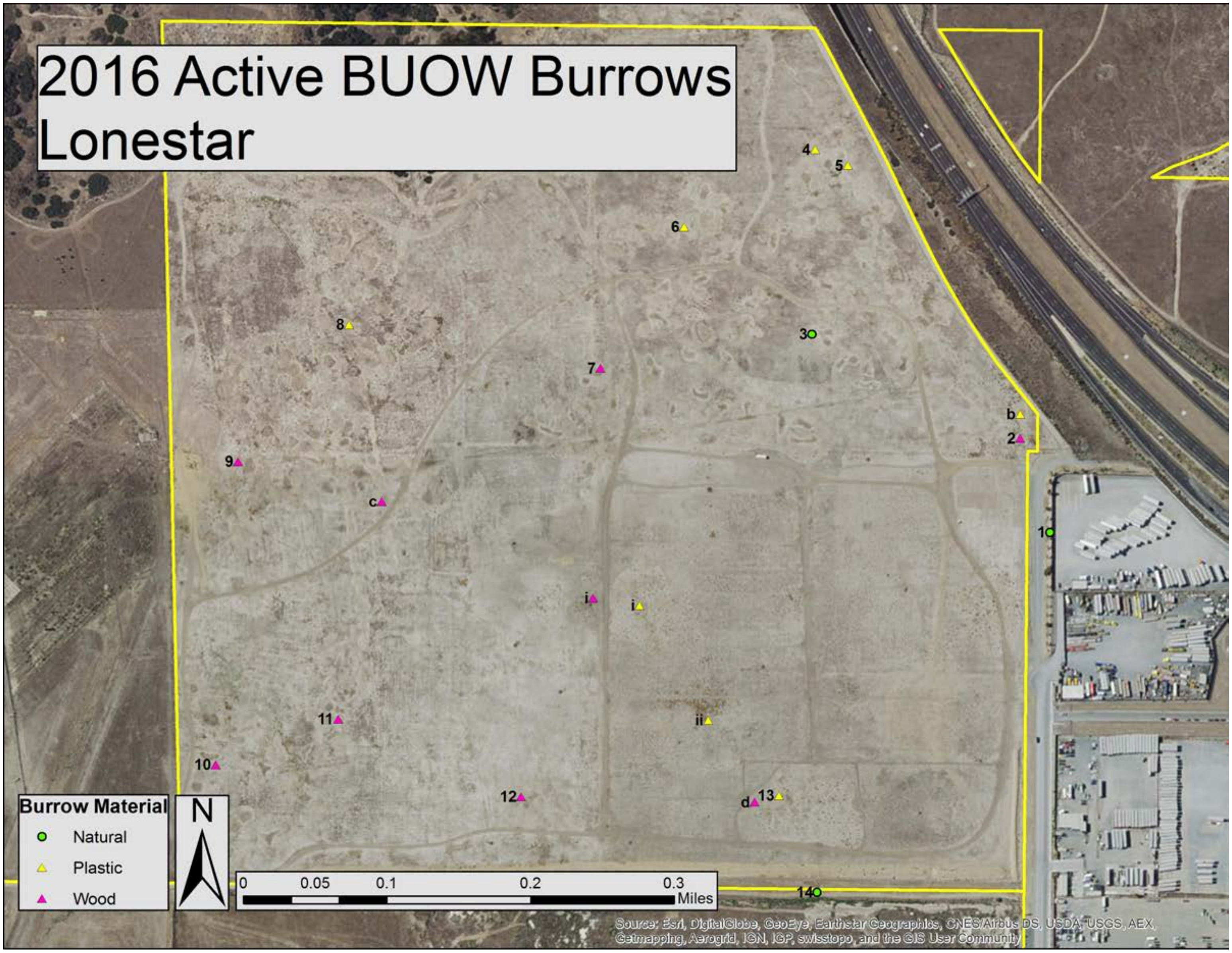


Figure 3-2d. Map of active BUOW burrows found at Lonestar in 2016. Numbers refer to Table 3-1.

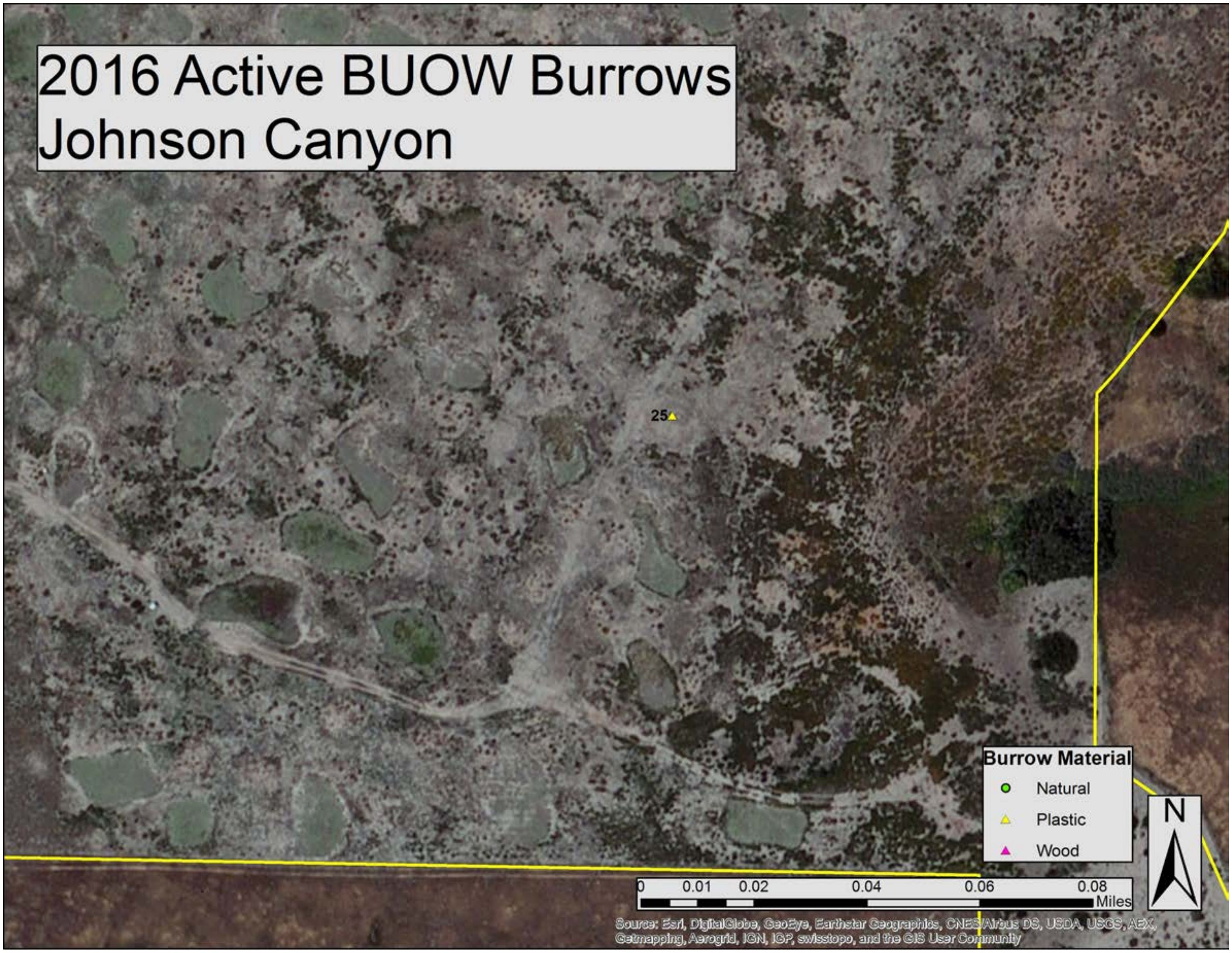


Figure 3-2e. Map of active BUOW burrows found at Johnson Canyon in 2016. Numbers refer to Table 3-1.

Banding

We banded BUOW during the period of 5 May to 15 September. We captured a total of 101 BUOW (Table 3-3, Appendix 2). We took blood and/or feather samples from every bird that was captured. The owls we captured represented 23 families (including one rehabilitated bird released at Johnson Canyon), with 46 of them caught at natural burrows, 54 of them caught at artificial burrows, and the one rehabilitated bird released at an artificial burrow.

Behavioral insights from banding

As a result of our on-going banding effort, we continued to document individual movements and behaviors. With the capability of identifying individuals, we were able to record multiple instances of burrow and/or mate switching after apparent nest failure, and extra-pair copulations (usually a breeding female visiting a neighboring, singleton male). In 2016, we also observed three "adoptions" at Lonestar, in which juveniles moved to neighboring burrows before/near fledging for a variety of reasons. Juvenile 28 over Z was banded at LS 13 on 26 May, but it had likely hatched at LS 21 (pending confirmation by genetic analysis). It apparently moved to LS 13 (~120 m away) on or around 19 May, when we banded the LS 21 brood, and remained there beyond fledging (estimated fledge date was May 30). It was fed and cared for by the breeding pair at LS 13, who had chicks about two weeks younger. Similarly, 26 over Z was hatched at LS 109, then moved to LS 97 (~150 m away) on 11 June and fledged there on 21 June. It was also cared for by the resident pair who had chicks about 5 days older. In both of these cases, it is unclear why these juveniles moved to the neighboring breeding territories before fledging and why the respective breeding pairs accepted them; however, this behavior is consistent with that observed by Johnson (1997) where, over a two-year period, at least 20% of juveniles no longer associated with their natal burrow within one month of emergence. The third adoption we witnessed was apparently the result of the juvenile being orphaned. At LS 142, both parents and three of four chicks disappeared within a 2-week period (adult female 33 over Y on 1 June, juvenile 16 over Z on 6 June, adult male 90 over Y on 8 June, juvenile 27 over Z on 8 June, and juvenile 49 over Z on 13 June; the remains of 27 over Z and 49 over Z were found on 14 June). Juvenile 05 over Z moved to LS 132 Natural (~175 m away) on 15 June and fledged there on 19 June. We suspect that these adoption behaviors are density-dependent and that the breeding population at Lonestar has reached a density consistent with BUOW coloniality behaviors.

Population dynamics

Using banding return rates, we can estimate juvenile recruitment rate and site fidelity for adults. In 2016, the return rates for both adults and juveniles were the highest we have recorded during the study. The adult return rate was approximately 93% and the juvenile return rate was approximately 34% (Table 3-4A). We used the resighting data from 2011-2016 to model apparent annual survival for adults and juveniles (Table 3-4B). We found adult survival was similar across years, particularly from 2013-2016 when we had a concerted banding effort and better resight data. Juvenile survival rates have been more variable between years, and were much higher in 2016 relative to 2014 and 2015.

We were able to band a high proportion of the population within our study sites in 2016; only 4-5 known adults and 4 known fledglings remained unbanded at the end of the season (not including the owls observed on private lands). Using the numbers of unbanded breeding adults as a proxy estimate of immigration, we saw 7-9 new females and 5-6 new males in 2016. This is likely an overestimate of the numbers of true immigrants as some proportion were likely birds hatched in Otay Mesa in 2015 that dispersed into our study sites or adult floaters that found open territories.

Table 3-3. Summary of BUOW banded in 2016. Asterisk indicates a bird banded in a previous year that was recaptured in 2016. Parentheses indicate a bird banded in a previous year that was resighted but not recaptured in 2016.

		Adults			Family Total		Genetic Samples	* Previously Banded (Year)	
	Burrow	Female	Male	Juvs	New	All	2016	Female	Male
Initial Nesting Attempts									
1	Euc 6	(1)	(1)	0	0	2	0	12/Y (2014)	72/X (2014)
2	LS 160 (A)	DC[1,2]	(1)	0	0	1	0		29/Y (2015)
3	LS 132 Natural	1*	(1)	5	5	7	6	34/Y (2015)	24/Y (2015)
4	LS 142 (A)	(1)	(1)	4	4	6	4	33/Y (2015)	90/Y (2015)
5	LS 144 (A)	(1)	(1)	0	0	2	0	62/Y (2015)	98/Y (2015)
6	LS 97 (A)	82/Y	49/Y	2	4	4	4		
7	LS 109 (A)	(1)	(1)	3	3	5	3	73/Y (2015)	67/Y (2015)
8	LS 67 (A)	(1)	(1)	0	0	2	0	03/Y (2014)	53/Y (2015)
9	LS 52 (A)	(1)	(1)	2	2	4	2	57/Y (2015)	04/Y (2014)
10	LS 21 (A)	(1)	(1)	7	7	9	7	87/X (2014)	71/X (2014)
11	LS 13 (A)	1*	81/Y	5	6	7	7	35/Y (2015)	
12	LS 185 (A)	1*	1*	5	5	7	7	28/Y (2015)	73/X (2014)
13	LS 175 (A)	(1)	(1)	0	0	2	0	C/C (2011)	00/Y (2014)
14	Lonestar Mound	75/Y	(1)	3	4	5	4		94/Y (2015)
15	8L	02/Z	1*	0	0	2	2		31/X (2013)
16	Gravel Lot	1*	1*	1	1	3	3	07/X (2013)	27/Y (2015)
17	Tripad North	(1)	(1)	0	0	2	0	30/Y (2015)	88/X (2014)
18	Tripad South	1*	(1)	4	4	6	5	94/X (2014)	89/X (2014)
19	Gailes	(1)	(1)	0	0	2	0	46/Y (2015)	20/Y (2014)
20	BCS	(1)	(1)	7	7	9	7	42/Y (2015)	78/X (2014)
21	Auto World Fence	(1)	(1)	2	2	4	2	50/Y (2015)	63/Y (2015)
22	Gorilla NN	(1)	(1)	0	0	2	0	77/X (2014)	31/Y (2015)
23	No Outlet	1*	(1)	4	4	6	5	39/Y (2015)	56/Y (2015)
24	La Media Stop Sign	1*	(1)	0	0	2	0	B/E (2011)	68/X (2014)

Table 3-3 continued.

Burrow		Adults: Female	Adults: Male	Juvs	Family Total: New	Family Total: All	Genetic Samples 2016	* Previously Banded (Year): Female	* Previously Banded (Year): Male
25	JC 15 (A)	(1)	(1)	4	4	6	4	37/Y (2015)	26/Y (2015)
26	Border Pacific	DC	DC	0	0	0	0		
27	Siempre Viva	DC	DC	0	0	0	0		
Renests/Late Nests									
a	Euc 6 renest	86/Y[2]	(1)	3	3	5	4		72/X (2014)
b	LS 159 (A)--LS 160 renest	76/Y[2]	(1)	6	7	8	7		29/Y (2015)
c	LS 40 (A)	45/Z	30/Z	5	7	7	7		
d	LS 176 (A)--LS 175 renest	(1)	(1)	2	2	4	2	C/C (2011)	00/Y (2014)
e	Parking Lot Palm--TPN renest	(1)	(1)	3	3	5	3	30/Y (2015)	88/X (2014)
f	Cabco--Gorilla NN renest	(1)	(1)	0	0	2	0	77/X (2014)	31/Y (2015)
g	Pacific Coast--LMSS renest	1*	(1)	4	4	6	5	B/E (2011)	68/X (2014)
Non-breeding?									
i	LS 194 & 201 (A)	Unknown[3]	(1)	0	0	2	0	See note	88/Y (2015)
ii	OSe7 (A)	(1)	(1)	0	0	2	0	66/Y (2015)	40/Y (2015)
iii	Pillbox	n/a	(1)	0	0	1	0		32/Y (2015)
iv	EAA	(1)	DC	0	0	1	0	62/Y (2015)	
v	Old Charlie	DC	DC	0	0	0	0		
vi	General Dynamics	n/a	DC	0	0	0	0	Banded[4]	Banded[4]
Other									
	Rehab, released at JC 1	58/Y, Unknown sex			1	1	1		
Totals[5]		6 new/ 13 total	3 new/ 6 total	81			101		

[1]DC = did not capture.
[2]Female from LS 160 is likely same female as LS 159, however, based on timing she may be the same female as from Euc 6 Renest. Both were originally unbanded so cannot confirm.
[3]Female never positively identified, unknown if previously banded.
[4]Two banded adults seen on camera in addition to unbanded male. Photos only from nighttime, so bands were unreadable.
[5]Totals are for captured birds only (not resighted birds).

Table 3-4. Banding resight rates and apparent annual survival (S) by year and age. (A) Percentage of birds seen 1, 2, 3, 4, and 5 years, respectively, after banding. (B) Estimates of apparent annual survival and 95% confidence intervals using Cormack-Jolly-Seber model.

A

Year	% resighted after:				
	1 yr	2 yrs	3 yrs	4 yrs	5 yrs
Adults (n)					
2011 (8)	0.38	0.50	0.13	0.13	0.13
2012 (0)	--	--	--	--	--
2013 (10)	0.60	0.30	0.10	--	--
2014 (27)	0.85	0.44	--	--	--
2015 (15)	0.93	--	--	--	--
Juveniles (n)					
2011 (14)	0.14	0.29	0.14	0.07	0.07
2012 (0)	--	--	--	--	--
2013 (53)	0.13	0.06	0.04	--	--
2014 (38)	0.16	0.08	--	--	--
2015 (44)	0.34	--	--	--	--

B

	S	95% CI
Adults		
2011/12	0.63	0.29—0.88
2012/13	0.91	0.40—0.99
2013/14	0.69	0.48—0.85
2014/15	0.69	0.53—0.82
2015/16	0.68	0.51—0.81
Juveniles		
2011/12	0.24	0.09—0.49
2012/13	0.48	n/a (n=1)
2013/14	0.16	0.08—0.28
2014/15	0.22	0.11—0.38
2015/16	0.41	0.26—0.96

Mortality

We documented 14 confirmed or likely juvenile mortality events during the 2016 breeding season, which represents 14% of the maximum number of chicks recorded (Tables 3-5 and 3-6). Of these events, 7 were depredations by non-BUOW predators and four were depredations by BUOW (one confirmed infanticide, two possible infanticides, and one additional potential infanticide perpetrated by a neighboring BUOW). As in the past, infanticide did not seem to be driven by mate loss. Predation was the leading cause of observed mortality. Once again, at the artificial burrows where we could check the nest chambers (directly or with a peeper camera), there continued to be a discrepancy between the number of eggs laid and the number of chicks that emerged (Table 3-6) suggesting that we are still missing a significant cause of juvenile mortality before emergence.

We recorded three events (2 predation and 1 non-predation) that likely resulted in the complete loss of the nest, one of which also resulted in the loss of the nesting female. At Euc 6, a striped skunk was seen (on camera) entering and exiting the burrow on 15 April (before emergence of any juveniles); after this visit, the adult female ("12 over Y") was not seen alive again. The male ("72 over X") remained at the same burrow and attracted a new, unbanded female (first seen 21 April). On 27 April we found two wings, and on 11 May we found the leg/USGS band of 12 over Y, which confirmed her depredation. At Gorilla NN, photos from 18 April show a coyote digging up the burrow and the adults stopped using the burrow around 22 April; nesting was unconfirmed but likely, with the assumption that this resulted in the complete destruction of the nest. The third nest lost was documented at Tripad North. Brown Field received ~1 inch of rain from 7-9 April; during this time, Juan Hernandez of Hernandez Environmental Services was on site to monitor the pair at this burrow and a neighboring pair during construction activities related to the runway resurfacing project. He spoke with us on 12 April because he thought the owls had moved as a result of the rains. We used a burrow scope to inspect the Tripad North burrow and found that the soil was very moist and muddy inside the burrow. The burrow had likely flooded or become too damp and muddy to sustain nesting. Again, nesting was unconfirmed but likely and this event apparently resulted in complete loss of the clutch.

In contrast to 2015, all three of these nest-loss events took place at natural burrows. In 2015, we speculated that the size and simplicity of artificial burrow tunnels may not discourage some nest predators as effectively as natural burrows, but this does not appear to be the case and lends support to our proposed new design for artificial burrows. In the next section, we synthesize our findings regarding artificial burrow design.

In 2016, we recorded six adult mortality events. Early in the year, we found two deceased second-year birds from separate mortality events, and after the breeding season, we recorded a depredation of an adult (also second-year) by a prairie falcon. We detail each of these incidents below. We also recorded the mortality of 12 over Y (described above), and suspect mortalities of 2 other adults (Table 3-5).

On 18 March, we found a dead BUOW (male 43 over Y) lying on top of the soil inside the chamber of artificial burrow LS 60 at Lonestar. The wooden burrow tunnels had apparently been washed in during the preceding rains, and inspection of the chamber indicated the owl had become trapped and likely starved to death; there was no evidence of predation or scavenging. It is possible the carcass became silted-in after the owl starved to the death, but the position of the carcass and soil obstructing the tunnel entrances to the chamber suggest otherwise. The mortality was immediately reported to Esther Burkett, and with her permission, the bird was collected. Tissue samples were taken by staff of San Diego Zoo and the remainder of the carcass was sent to the CDFW Wildlife Investigations Laboratory. The necropsy indicated that starvation was the cause of death and further testing revealed that the owl had been exposed to two anticoagulant rodenticides (Appendix 3). This is not an uncommon finding for raptors; however, the level of Difethiolone was one of the highest observed in a burrowing owl by lab staff (Krysta Rogers, pers. comm.). There were no signs of coagulopathy so this was considered exposure and not intoxication, but this finding raises important questions about the threat of rodenticide exposure to the Otay Mesa BUOW population. This owl was hatched and banded as a chick at Johnson Canyon in 2015 and found dead as a second-year bird. He likely spent his entire life in the small area around Johnson Canyon and Lonestar in proximity to warehouses, truck lots, and other industrial/commercial properties. As we observed from our GPS data in 2014 and 2015, the owls hunt on/near these parcels and likely encounter rodents that have been exposed to rodenticides often. Rodents that have experienced anticoagulant poisoning are likely easy prey for the owls as their locomotion and anti-predator behaviors are altered in the days preceding death (Cox and Smith 1992) and may be especially tempting to younger owls that are dispersing and newly-independent. Secondary poisoning may cause direct mortality or can lead to sublethal effects that reduce survival or reproductive success (see review in Klute et al. 2007).

We found the remains of another dead second-year male (74 over Y) in LS 160 during a routine nest-check on 1 April. The desiccated and partially-eaten carcass was found inside the nest chamber along with the incubating female. It was unclear when and how the owl had died; it may have been depredated or scavenged by the nesting pair. The degraded state of the carcass made a necropsy impossible. After the breeding season, we captured a depredation of an adult burrowing owl on camera for the first time during our study. The adult male (also a second-year bird) from LS 109 (64 over Y) was killed by a prairie falcon (*Falco mexicanus*) on 7 October. Both adults of the pair were present before the falcon attacked and the female was able to escape into the burrow. This burrow has wooden tunnels with 4-inch (10 cm) openings which would not have allowed both owls to enter the burrow simultaneously. BUOW usually enlarge natural burrow openings to ~6 inches (~15 cm), which is the size of the openings of the plastic tunnels. The male may have been able to escape if the opening was larger and, as such, we recommend retrofitting the wooden tunnels at Lonestar to enlarge the openings.

Table 3-5. All mortality events recorded in 2016.

Site	Burrow	Mortality event	Date	Additional Info
Lonestar	Euc 6	Striped Skunk	15 Apr	Depredation of adult female (12 over Y) and likely all nest contents
	LS 142 (A)	Possible Depredations	June	Female (33/Y) last seen 1 June, Male (90/Y) last seen 8 June
		Likely Northern Harrier	8 Jun	27 over Z (juvenile) last seen at burrow on 8 June; remains found on 14 June
		Likely Northern Harrier	13 Jun	49 over Z (juvenile) last seen at burrow on 13 June; remains found on 14 June
	LS 160	Unknown	1 Apr	Dessicated, scavenged carcass of adult (74 over Y) was found in nest with incubating female
	LS 67 (A)	Starvation	28 May	Mortality of chick
		Likely BUOW	8 Jun	last seen at burrow on 7 June; BUOW chick remains seen on camera at LS 40 on 8 June
	Lonestar Mound	Infanticide or Starvation	4 Jun	Juvenile carcass seen being consumed on camera on 4 June
Brown Field	Tripad North	Flood	7-9 Apr	Nest apparently destroyed (see text for details)
	Tripad South	Infanticide	17 May	Mortality of chick
	Gorilla NN	Coyote	18 Apr	Nest dug up and destroyed
	No Outlet	Infanticide or Starvation	16 Apr	Juvenile carcass seen being consumed on camera on 16 April
Johnson Canyon	JC 15 (A)	Likely Raven	10 May	Max chick count corroborates
		Unknown	28 May	Chick collapsed and died
Late nests/renests				
Lonestar	Euc 6 Renest	Raven	11 Jun	Mortality of chick
Brown Field	Parking Lot Palm (TPN renest)	Raven	10 Jun	Mortality of chick
Non-breeding season				
Lonestar	LS 60	Starvation	18 Mar	Intact carcass of adult male (43 over Y) was found entombed in burrow (see text and Appendix 3)
	LS 109	Prairie Falcon	7 Oct	Depredation of adult male (64 over Y) at burrow entrance

Table 3-6. Nesting stage dates and productivity for 2016 at burrows monitored with camera traps or direct observation.

Burrow/Family	Cam Dates	Complete clutch and date (if peeped)[1]	Estimated First Egg Date[2]	Estimated Hatch Date[3]	First Chick Emergence Date[4]	Max # chicks (Date)	Estimated Fledging Date	# Juveniles Fledged[5]
Lonestar								
Euc 6	1 Apr-19 Jul	n/a	n/a	n/a	n/a	n/a	n/a	n/a
LS 160 (A)	23 Mar-11 May	6 (4/1)	17-Mar	None hatched	n/a	0	n/a	0
LS 132 Natural	20 Apr-8 Sep	n/a	5-Apr	5-May	19-May	6 (May 22-24)	19-Jun	5[6]
LS 142 (A)	15 Apr-4 Nov	5 (4/20)	5-Apr	5-May	19-May	4 (May 20-June 6)	19-Jun	1
LS 144 (A)	15 Apr-19 Jul	7 (4/15)	6-Apr	6-May	None emerged	0	20-Jun	0
LS 97 (A)	27 Apr-21 Oct	Nested in tunnel[7]	2-Apr	2-May	16-May	2 (May 16-fledge[8])	16-Jun	2[6]
LS 109 (A)	15 Apr-15 Dec	6 (4/20)	7-Apr	7-May	21-May	3 (May 23-June 10)	21-Jun	3
LS 67 (A)	20 Apr-24 June	7 (4/20)	7-Apr	7-May	21-May	2 (May 22-28)	21-Jun	0
LS 52 (A)	15 Apr-4 Nov	8 (4/20)	7-Apr	7-May	21-May	2 (May 21-fledge)	21-Jun	2
LS 21 (A)	18 Mar-4 Nov	9 (4/1)	16-Mar	15-Apr	29-Apr	7 (May 2-15)	30-May	7
LS 13 (A)	1 Apr-15 Dec	9 (4/15)	26-Mar	25-Apr	9-May	6 (May 16-26)	9-Jun	4[6]
LS 185 (A)	23 Mar-15 Dec	10 (4/5)	19-Mar	18-Apr	2-May	5 (May 6-fledge)	2-Jun	5
LS 175 (A)	15 Apr-31 May	6 (4/20)	5-Apr	None hatched	n/a	0	n/a	0
Lonestar Mound	18 Mar-15 Dec	n/a	2-Apr	2-May	16-May	5 (May 18)	16-Jun	3
Brown Field								
8L	Nest found late[9]	n/a	Unknown	Unknown	Unknown	Unknown[10]	Unknown	4
Gravel Lot	18 Mar-14 Dec	n/a	9-Mar	8-Apr	22-Apr	1 (April 22-fledge)	23-May	1
Tripad North	7 Apr-23 Sep	n/a	n/a	BU[11]	n/a	n/a	n/a	n/a
Tripad South	7 Apr-8 Sep	n/a	30-Mar	29-Apr	13-May	6 (May 17)	13-Jun	4
Gailes	7 Apr-14 Dec	n/a	n/a	BU	n/a	n/a	n/a	n/a
BCS	1 Apr-14 Dec	n/a	6-Mar	5-Apr	19-Apr	8 (April 26-29)	20-May	5
Auto World Fence	25 Apr-29 Aug	n/a	22-Apr	22-May	5-Jun	2 (June 9-fledge)	6-Jul	2
Gorilla NN	18 Mar-5 May	n/a	n/a	BU	n/a	n/a	n/a	n/a
No Outlet	25 Mar-19 Jul	n/a	3-Mar	2-Apr	16-Apr	5 (April 16)	17-May	4

Table 3-6 continued.

Burrow/Family	Cam Dates	Complete clutch and date (if peeped)[1]	Estimated First Egg Date[2]	Estimated Hatch Date[3]	First Chick Emergence Date[4]	Max # chicks (Date)	Estimated Fledging Date	# Juveniles Fledged[5]
La Media Stop Sign	18 Mar-7 Apr	n/a	n/a	BU	n/a	n/a	n/a	n/a
Johnson Canyon								
JC 15 (A)	12 Apr-5 Jul	Nested in tunnel[7]	25-Mar	24-Apr	8-May	5 (May 11)	8-Jun	3
Private								
Border Pacific	n/a	n/a	Unknown	Unknown	Unknown	Unknown[10]	Unknown	5
Siempre Viva	n/a	n/a	Unknown	Unknown	Unknown	Unknown[10]	Unknown	1 or 2
Renests/Late nests								
Lonestar								
Euc 6 (renest)	19 Jul-15 Dec	n/a	24-Apr	24-May	7-Jun	4 (June 10-11)	8-Jul	3
LS 159 (A) (LS 160 renest)	27 May-4 Nov	8 (5/27)	9-May	8-Jun	22-Jun	6 (June 28-July 15)	23-Jul	5
LS 40 (A)	11 May-21 Oct	Nested in tunnel[7]	4-May	3-Jun	17-Jun	5 (June 17-July 1)	18-Jul	4
LS 176 (A) (LS 175 renest)	31 May-15 Dec	5 (6/6)	27-May	26-Jun	10-Jul	2 (July 13-fledge)	10-Aug	2
Brown Field								
Parking Lot Palm (TPN renest)	25 Apr-8 Sep	n/a	15-Apr	15-May	29-May	5 (May 30-June 9)	29-Jun	3
Cabco (Gorilla NN renest)	5 May-24 Jun	n/a	n/a	BU	n/a	n/a	n/a	n/a
Pacific Coast (LMSS renest)	7 Apr-14 Dec	n/a	27-Mar	26-Apr	10-May	5 (May 15-22)	10-Jun	4

[1] The complete clutch size is a minimum estimate. The complete clutch date is the earliest date we observed the full clutch, but is likely not the actual date of clutch completion.
[2] When we were not able to determine the first egg date by direct observation, it was determined by back-dating 30 days from the estimated hatch date.
[3] When we were not able to determine the hatch date by direct observation, it was determined by back-dating 14 days from first chick emergence date.
[4] First date chicks were seen on camera trap.
[5] Juveniles were considered fledged if they reached 45 days of age.
[6] Does not include "adopted" juveniles for given nests. See Table 3-1 and text for more details.
[7] We were not able to observe the eggs because the owls did not nest in the burrow chambers.
[8] The maximum number of chicks was the same as the number fledged. These juveniles continued to occupy the burrow for varying amounts of time after their

respective fledge dates.
[9]Nest found 5 July (near or after fledging of juveniles) in an aviation safety zone where we were prohibited from setting up a camera.
[10]Number fledged used for maximum number of chicks for statistical analysis.
[11]BU = breeding unconfirmed.

Reproductive success
There was a wide range of estimated dates of first egg-laying (3 March—27 May, Table 3-6) and hatching (2 April—26 June); these dates include renesting attempts. There were five confirmed second nesting attempts, with one late nesting attempt. The 8L burrow/family was found around or after the juveniles had fledged when the male was observed sitting on the A/8L hold short sign on 5 July. Because the location was in multiple aviation safety zones, we were escorted to the area to find the burrow and were not allowed to set a camera up due to safety reasons. For all confirmed nesting attempts combined, the overall average maximum number of chicks per burrow was 3.6 (SE = 0.43, n=30) and the overall average maximum number of fledglings per burrow was 2.8 (SE = 0.35, n=30).

We found that fledging success (percent of burrows where we confirmed at least one juvenile had fledged) for first nesting attempts was variable, but was high overall. Apparent fledging success was 88% at Brown Field (7/8), 69% at Lonestar (9/13), and 100% at Johnson Canyon (1/1). Poggi and LORBOMA did not have any nests in 2016. We recorded 7 renesting (or late) attempts (4 at Lonestar, and 3 at Brown Field) and all but one were successful, a striking difference from past years with predominantly unsuccessful renests. Qualitatively, population performance appeared to be depressed during 2014-2015, likely due to drought conditions, but rebounded during 2016.

Productivity and Prey
Prey deliveries were catalogued at 7 natural burrows (6 at Brown Field and one at Lonestar) and 6 artificial burrows (5 at Lonestar and one at Johnson Canyon)(Table 3-2). We found that the number of prey deliveries per day did not differ significantly across years for 2013-2016 ($F_{3,68}$=1.14, p=0.34). ANOVA evaluations of the proportions of each prey group across years found few significant differences. The only prey group that did increase proportionately in 2016 was mammal prey at natural burrows ($F_{3,25}$=4.54, p=0.01).

Prey deliveries have been a significant factor influencing both how many chicks the parents support to emergence and nest success (whether at least one chick fledges). The number of prey deliveries further interacts with the proportion of the total comprised of invertebrates. The number of chicks fledged and the number of successful nests drops as the proportion of invertebrate prey deliveries increases. Year doesn't appear to be strongly predictive, when all sites are grouped together.

However, one additional consideration is that habitat conditions at Lonestar continued to improve in 2016. When productivity is considered across years at Lonestar alone, significant differences across year are observed (n=47, p<0.01). These differences are also significantly relatable to an interaction of prey delivery rate and the proportion of invertebrate prey (n=47, p<0.01).

The proportion of emergent chicks that fledged has also varied over the years with the highest in 2016 (Table 3-7). The higher number of chicks that survived to fledging is probably due to synergistic effects of a number of factors such as weather, density, habitat quality, and prey. Although the strong El Niño conditions predicted for 2016 did not come to fruition, moderate easing of the drought conditions in concert with the continuing habitat improvements at Lonestar appear to have resulted in increased reproductive output.

Table 3-7. Proportion of emergent BUOW chicks that fledged per year.

Year	Max # Chicks	# Fledglings	Proportion
2013	78	49	0.63
2014	68	30	0.44
2015	70	38	0.54
2016	107	83	0.78

Artificial vs. natural burrows

When we considered Lonestar by itself (as the only site with all three burrow material types), in 2016 the average maximum number of chicks was 3.8 (SE=0.75, n=8) at wood burrows, 2.0 (SE=0.87, n=7) at plastic burrows, and 3.75 (SE=1.31, n=4) at natural burrows. The average number of fledglings was 3.4 (SE=0.75, n=8) at wood burrows, 1.1 (SE=0.70, n=7) at plastic burrows, and 2.8 (SE=1.03, n=4) at natural burrows. These differences were significant, even when modeled across all years, with plastic burrows underperforming relative to natural and wood burrow types (Figure 3-3). Regression modeling across 2013-2016 at Lonestar indicates high levels of significant differences in plastic burrows for both the maximum number of emergent chicks (n=47, p<0.001) and number of fledglings (n=47, p<0.001).

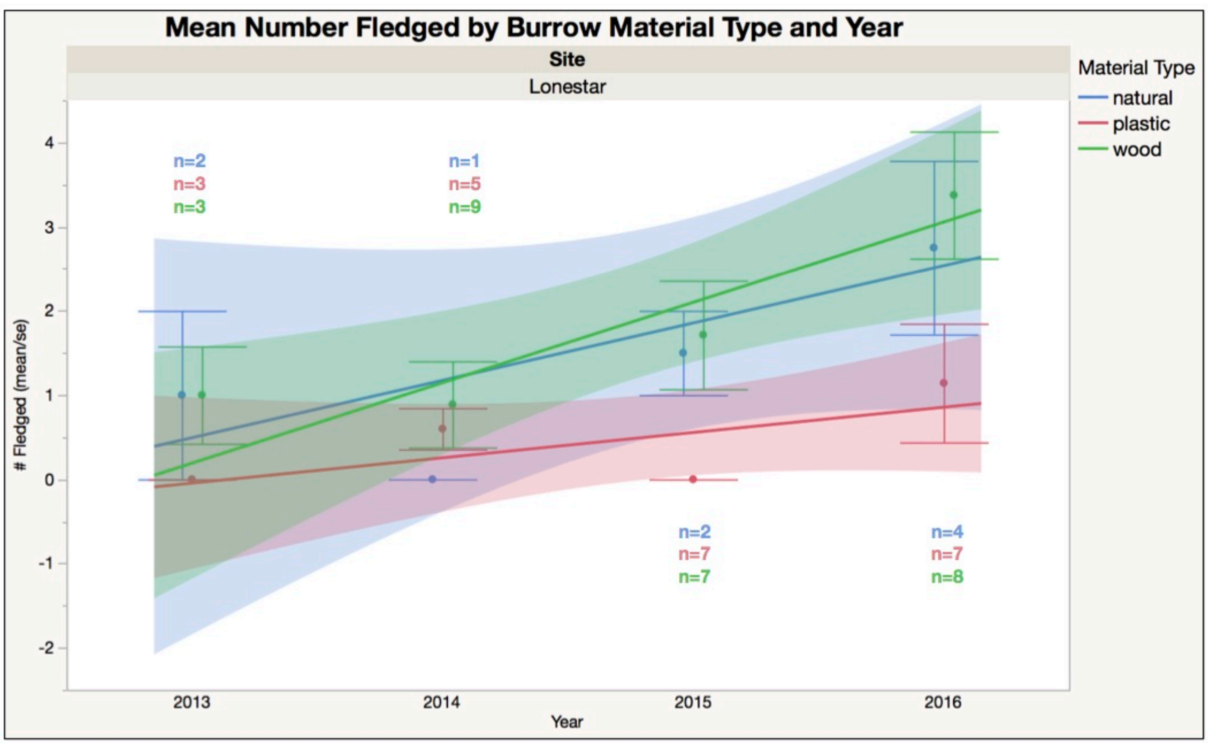


Figure 3-3. Mean juveniles fledged from each type of burrow at Lonestar during the breeding seasons of 2013-2016.

Over-winter BUOW presence at Rancho Jamul Ecological Reserve

During the fall of 2016 (4 November), ICR staff observed two BUOW at Rancho Jamul Ecological Reserve while placing conspecific cues (see Task G section). One owl was using artificial burrows in Complex 4 (see Figure 4-2) of the Burrowing Owl Habitat Management Area (BOHMA) and the other was in the central pasture area west of the wildlife pond. CDFW staff also observed an owl north of the JC squirrel plot on 6 December. ICR staff made a second fall/winter visit (15 December) and did not resight these owls.

Discussion & Conclusions

In 2016, reproductive success was high overall, as indicated by the proportionately higher nest success. The slight easing of drought conditions was not enough to support higher productivity across all sites, but may have supported the high return rate of 2015 juveniles. Significantly higher productivity was measured at the Lonestar site, where active restoration has created significant improvements in habitat quality. This increase in productivity was statistically linked to an interaction of prey delivery rate and the proportion of invertebrate prey. These factors have also been identified as influential in supporting the number of emergent chicks and the proportion of successful nests across all years and sites in the dataset.

One potential avenue for further evaluation is whether the increased reproductive success recorded at Lonestar may result from positive density-dependence in reproductive success as the colony size increases (Allee effects). Additional spatial analysis across a larger area with variable density may provide insight. The interesting result at Lonestar that productivity was significantly higher, but the prey was still composed largely of invertebrates and the number of prey deliveries per day was not significantly higher suggests another potential avenue to explore, in whether improvements in habitat and weather produce a concomitant increase in invertebrate prey quality, or whether reproductive success relies solely on higher caloric food sources. We have pellets sampled from 2013 through the present banked, which could be analyzed to better understand the prey used by the owls and fill in gaps in the camera trap data. We may also need to examine fine-scale weather data to see if temporal variation in temperature and/or precipitation can be linked to reproductive success.

We have also now documented lower reproductive success in plastic artificial burrows in two of the three metrics of reproductive success across multiple years. This provides evidence for a switch from plastic burrow materials to wood in artificial burrow design. We are in the process of implementing this change in our installations of artificial burrows, and we recommend a similar switch by other entities. See the following report section (Task D) for a full discussion of our recommendation for burrow design improvements.

The modeled estimates of San Diego adult and juvenile mortality levels 2013-2016 are comparable to those measured elsewhere across the species range. Hennessy et al. (in review) conducted a meta-analysis of published adult and juvenile mortality rates using

Bayesian Markov Chain Monte Carlo (MCMC) analysis and found a similar consistency in adult mortality estimates. The MCMC estimate of adult mean mortality was 0.35 with a 95% credible interval of 0.30-0.40, across a set of 5 studies that measured adult mortality. By comparison, juvenile survival was lower and much more variable, which is consistent with the boom-or-bust reproductive strategy of BUOW and the expected large spatial and temporal variation in offspring survival for r-selected species (Sæther and Engen 2015). The associated meta-analysis of published juvenile mortality rates also found little consistency in juvenile mortality estimates, with a MCMC estimate of mean mortality was 0.45 with a 95% credible interval of 0.26 – 0.64 for a set of seven studies (Hennessy et al. in review).

Specifically, on Otay Mesa juvenile survival rates more than doubled in 2013 and 2016 relative to 2014 and 2015, further indicating that 2016 was a somewhat better year for BUOW on Otay Mesa. Sensitivity analysis indicates that variability in juvenile mortality has subsequent effects on population growth (Hennessy et al. in review) and it is possible that higher survival could translate to higher population numbers if the trend extends beyond 2016.

In 2016, the return rates for both adults and juveniles were the highest we have recorded during the study. These updated survival estimates, especially given the high return rates measured for adults and juveniles in 2016, will allow for a more robust population viability analysis for the Otay Mesa population. However, the documented 12-15 immigrants between 2015 and 2016 represents a maximum estimate, as a few resident birds escape banding each year. The current population viability model indicates stability above 20 immigrants per year, suggesting that immigration is likely still not occurring at high enough rates to support a stable population (SDZ ICR 2016).This updated PVA will be conducted in 2017 to help guide adaptive management strategies aimed at ensuring sustainability of the population.

Given the necropsy results revealing high anticoagulant rodenticide exposure, we recommend that the BUOW stakeholder group engage in outreach regarding second-generation rodenticide use in areas that support BUOW breeding. This may be a significant threat to the health and reproductive success of the Otay Mesa population, and may contribute to its status as a population sink. Organizations such as San Diego Zoo Global and Audubon may be able to use their public relations resources to educate land and business owners about the risks of anticoagulant rodenticides for wildlife, pets, and humans. Further specific recommendations for burrow modifications aimed to lower mortality risk are covered in the following section.

TASK D: ARTIFICIAL BURROW ASSESSMENT

Introduction

Artificial burrows (for BUOW) have been used as an effective tool for mitigation, conservation, and research for several decades (Collins and Landry 1977, Henny and Blus 1981, Houston et al. 1996, Smith and Belthoff 2001, Poulin et al. 2006, Keppers et al. 2008, Barclay et al. 2011). Many different burrow designs have been used throughout western North America (e.g. Collins and Landry 1977, Poulin et al. 2001, Smith and Belthoff 2001, Belthoff and Smith 2003, Barclay 2008, Johnson et al. 2013), but an overreliance on the use of artificial burrows may have unintended consequences. It has been hypothesized that artificial burrows may sometimes serve as an ecological trap, drawing in owls to nest in areas that do not otherwise provide sufficient resources or expose the owls to greater risk of predation.

During 2014-2015, we pilot tested the use of iButtons to assess burrow microclimate. The results to date indicate that natural burrows tend to be better buffers from outside conditions and experience higher fledging success compared to artificial burrows. The difference in buffering effects may help explain the lower number of chicks from artificial burrows, since microclimate can affect hatching success, nestling growth, and survival (Deeming and Mainwaring 2015). In 2016, we continued comparative data collection on microclimate factors at both natural and artificial burrow sites in order to enable refinement of the design of artificial burrows. We hypothesized that the greater variability in temperature and humidity in the artificial burrows might be due to the double entrance configuration of the artificial burrows. Our objectives were to 1) compare microclimate conditions inside different artificial burrow designs, 2) evaluate differences in microclimate in artificial and natural burrows to help inform artificial burrow design, 3) compare productivity results from natural and artificial burrows, and 4) archive camera trap photos for future analysis of prey delivery data. Our overall goal was to use data collected this year and in past years to develop an artificial burrow design that more closely mimics the microclimate of natural burrows with the aim of making them more suitable for nesting BUOW. By adding data on the impacts of microclimate to our understanding of habitat around the burrow and larger landscape characteristics, we will better understand what constitutes optimal habitat for reproduction and survival at natural and artificial burrows. Design improvements will help maximize the efficacy of artificial burrows as a recovery tool for BUOW across their range, and especially as we begin to establish new population nodes in San Diego County.

Methods

Artificial burrow design experiment

Most artificial burrows currently installed on Otay Mesa have one chamber with two entrance tunnels extending from opposite sides of the chamber. We hypothesized that the differences we observed in the microclimates of natural and artificial burrows were a result of this two-tunnel design, which created a pass-through for convection heating and cooling. We wanted to test whether different burrow designs could more closely mimic natural burrow conditions. We designed a small replicated field experiment comparing the currently-used two-tunnel design ("standard") with two alternative designs ("curvy" and "Y"; Figure 4-1).

The standard design was intended to allow a means of escape if predators entered the burrow chamber; however, most of the natural burrows used for nesting by BUOW in Otay Mesa seem to have only one tunnel. We have observed nest depredations at both natural (one entrance) and artificial (two entrances) burrows, but these occurrences are very few. It is likely that the suboptimal microclimate of artificial burrows and predation of the juveniles post-emergence have a larger impact on population productivity. When designing the two alternative configurations, we attempted to mitigate for the microclimate shortcomings of the standard design while providing the necessary protection from predators.

The curvy design was a slight modification of the standard design. We maintained the two-tunnel concept but more than doubled the lengths of the tunnels and added several sharp turns, both vertically and horizontally, which were intended to mimic the complexity of a natural squirrel-dug burrow and reduce air flow into the chamber. For the Y design, we made a departure from the standard design, with a single entrance into the burrow chamber. So named because the burrow looks like the letter Y with the chamber at the bottom, we wanted to maintain two entrances at ground-level to allow more escape routes for the chicks while eliminating the convection current flowing through the chamber.

In late June, we installed burrows in five clusters of three burrows each (one standard, one curvy, one Y) in the BOHMA at Rancho Jamul Ecological Reserve (Figure 4-2). Burrows in each cluster had consistent slope and aspect and were spaced approximately 6-8 m apart. In some cases, we replaced or refurbished existing artificial burrows that had been damaged.

Assessing burrow microclimate

We used Hygrochron Temperature/Humidity Logger iButtons (model DS1923-F5#) to collect data from inside and outside natural and artificial burrows. In all cases, the outside iButtons were placed in small, wire mesh cages on a stake ~0.5m-high at ~1m from the burrow entrance; each stake had a sunshade to prevent the iButtons from receiving direct sunlight. Temperature and humidity readings were taken automatically once per hour.

Nest microclimate

In 2016, we continued to record burrow microclimate data from Otay Mesa to enhance our existing dataset, and we added the collection of data from active nests to relate microclimate to productivity. We placed iButtons inside unoccupied natural burrows at Brown Field and Lonestar using small Whiffle balls to protect them from any animals using the burrows. We chose natural burrows that did not contain nests (to avoid disrupting breeding), but that had served as nest burrows in the past or were near nest burrows. We also placed iButtons inside both occupied and unoccupied (control) artificial burrows at Lonestar. Because of the artificial burrow modifications made in 2015, we were able to easily install iButtons inside nest burrows after incubation had begun. To minimize disruption, we attached the iButtons (inside small wire cages) to the bottoms of the buckets used to plug the access chimneys during our weekly nest checks. This placement is possibly a source of bias because the microclimate at the top of the chamber may be different from that experienced by the eggs and chicks on the floor, but because of issues with iButtons being buried in the past and concerns about the difficulty of placing the iButtons on the chamber floor while eggs were present, we believe this is an acceptable proxy. Unoccupied control burrows were chosen using stratified (wood vs. plastic) random sampling.

The iButtons were placed throughout the month of April, depending on when eggs were laid, and removed in mid-August. There were a few exceptions to this due to nest failures and/or renesting.

<u>Experimental burrow microclimate</u>

To compare different artificial burrow designs in terms of microclimate, we placed iButtons protected by small, wire mesh cages on the inside wall of each burrow chamber in approximately the same lateral position and ~9 cm above the soil surface. We also chose five natural burrows in the BOHMA to receive iButtons as a control; they were placed in small Whiffle balls to protect them from any animals using the burrows. iButtons were inserted as far into the burrow as possible; however the complex configurations of the natural burrows limited the insertion distance (<1.5 m). Outside iButtons were placed in small, wire mesh cages on a stake ~0.5m-high at ~1m from the burrow entrance; each stake had a sunshade to prevent the iButtons from receiving direct sunlight. Each artificial burrow cluster received one outside iButton placed near the center of the cluster. All iButtons at RJER were deployed for the entire month of July.

Analysis of iButton data

The microclimate data collected from Otay Mesa was truncated for the period of 1-23 June 2016 to include the time period when data from all burrows overlapped. Even though the microclimate data were not from the specific incubation and nestling periods of the respective nests, the relative performance of the burrows is probably similar through time. To examine burrow microclimate, we calculated the average daily temperature and humidity, and the average daily coefficient of variation for temperature and humidity from inside each burrow. To measure the buffering effect, we calculated the average daily difference between the inside and outside temperature and humidity at each burrow. We compared mean levels of temperature and humidity levels among the different burrow designs using ANOVA. We used linear regression to explore the potential relationship between burrow microclimate and productivity.

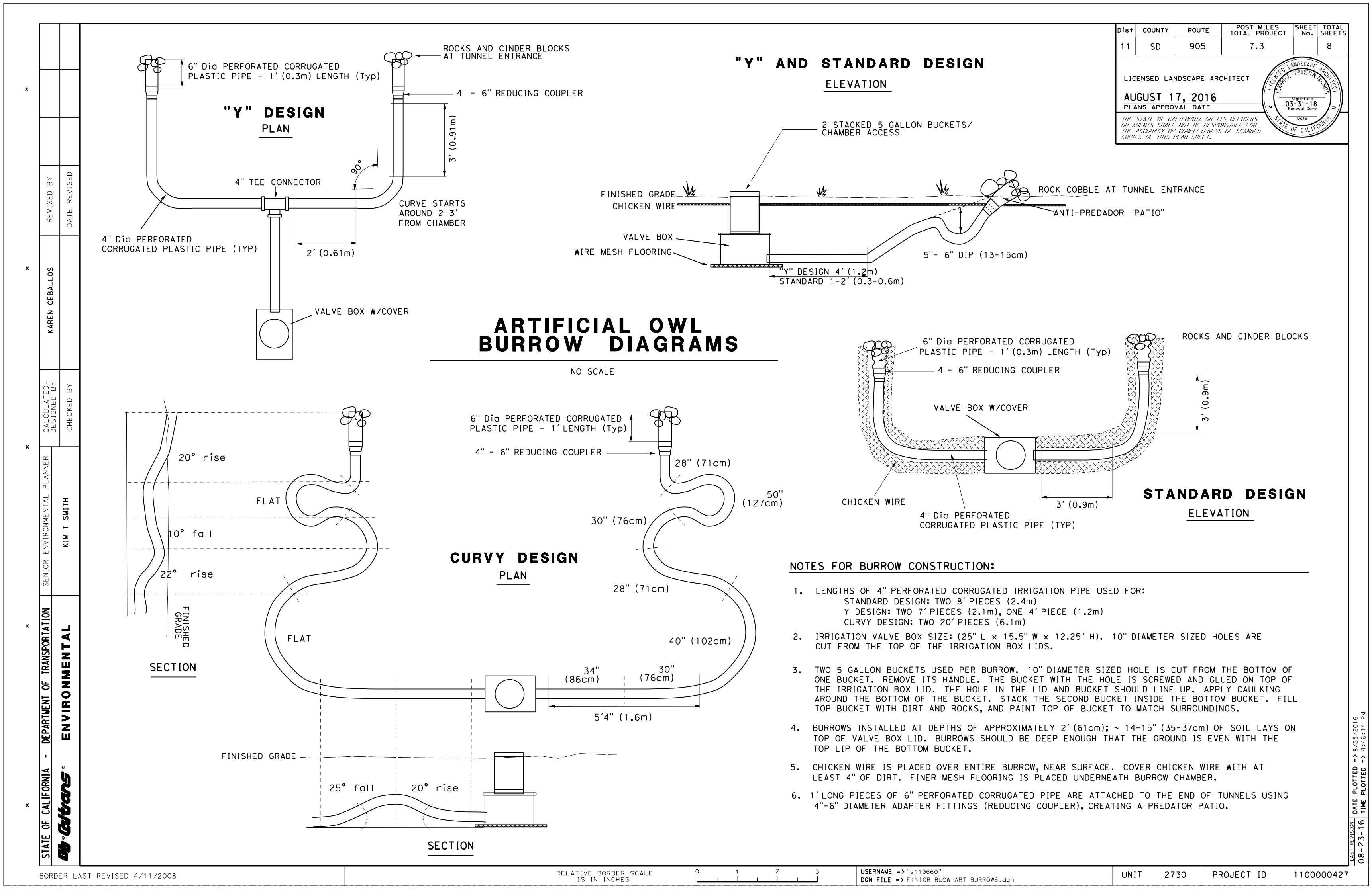


Figure 4-1. Diagrams of three artificial burrow designs tested at Rancho Jamul Ecological Reserve.

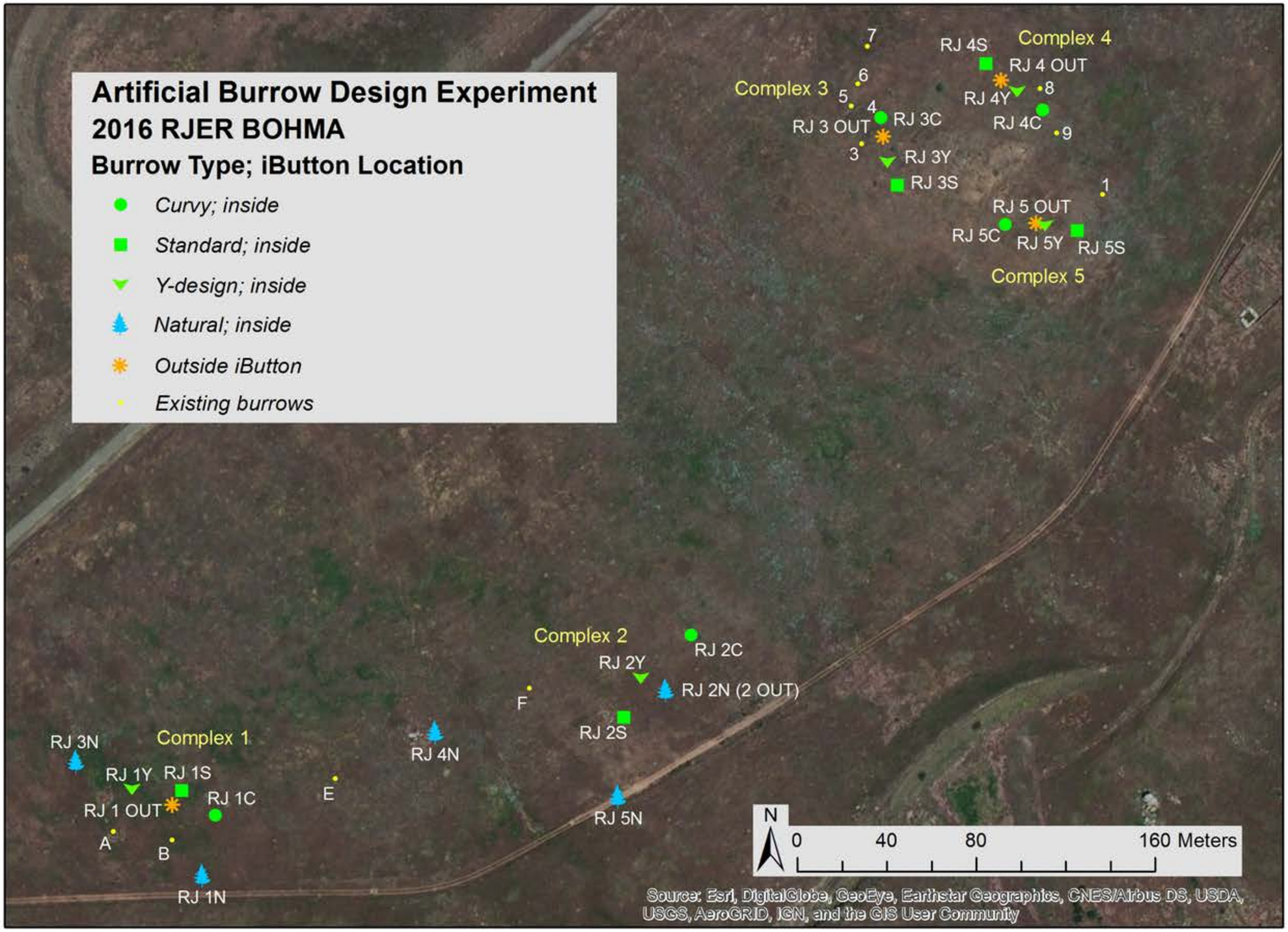


Figure 4-2. Map of artificial burrows by design-type and iButton dataloggers in the Burrowing Owl Habitat Management Area at Rancho Jamul Ecological Reserve.

Results & Discussion

Nest microclimate

Among artificial burrows at Lonestar with occupied nests, wood burrows had: 1) significantly higher inside humidity (t(8)=2.78, p=0.024), 2) a significantly lower coefficient of variation of inside humidity (t(8)=-2.60, p=0.032; i.e., humidity was more stable), and 3) a marginally significantly higher mean daily difference between inside and outside humidity (t(8)=2.22, p=0.058; i.e., better buffering) relative to plastic burrows. The inside temperature was also more stable (coefficient of variation was lower) in wood burrows but was not statistically significant at α=0.5 (t(8)=-1.90, p=0.093; Table 4-1).

Table 4-1. Microclimate metrics for nests in artificial burrows at Lonestar.

	Burrow Material Type			
	Plastic (n=4)		Wood (n=6)	
	Mean	(SE)	Mean	(SE)
Daily Inside Humidity	65.12	(7.60)	98.54	(9.30)
Daily Coefficient of Variation of Inside Humidity	7.27	(1.32)	2.86	(1.07)
Daily Difference in Inside/Outside Humidity	15.64	(5.77)	32.14	(4.71)
Daily Coefficient of Variation of Inside Temperature	3.55	(0.67)	1.90	(0.55)

One interesting outcome of this study was that the inside humidity metrics were bimodal for wood burrows (Figure 4-3). Upon further examination of the data, we found that this result could be accounted for by the number of functional burrow entrances—in a number of the wooden burrows, one tunnel was blocked making them functionally one-entrance burrows. We also had one plastic burrow with a collapsed tunnel, which exhibited similar patterns, however, we cannot examine possible interactions between the number of entrances and the burrow material due to very small sample sizes.

We also examined productivity in relation to burrow material type with nesting data from the 2013-2016 breeding seasons. When we modeled the number of fledglings by burrow material type and year, we found that there was not a significant year effect (p=0.41), so we pooled across years to examine the effect of material type. For confirmed first nesting attempts, we found significant differences in fledgling numbers with plastic artificial burrows having fewer fledglings. This was true both when we examined all nests across all sites ($F_{2,94}$=6.76, p=0.002) and when we restricted the analysis to include only the nests at Lonestar (the only site with all three types of burrows; $F_{2,44}$=7.50, p=0.002, see Section C for productivity details).

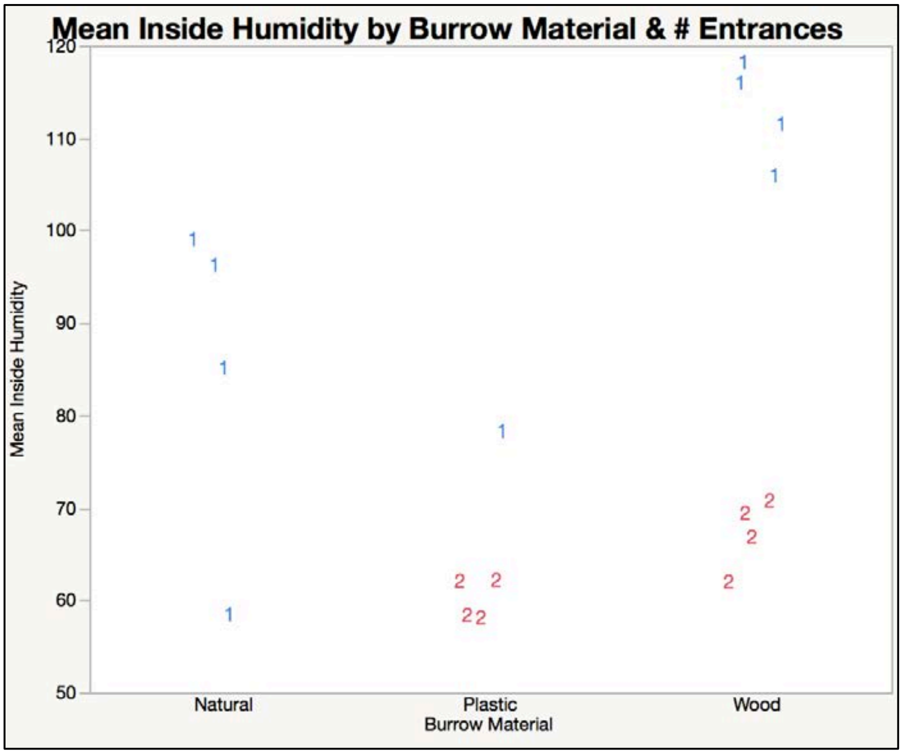


Figure 4-3. Mean inside humidity for nest and control burrows in Otay Mesa. Numbers indicate the number of functional entrances.

Experimental burrow microclimate

We found significant differences among the 3 burrow types for mean inside humidity ($F_{3,14}$=13.55, p=0.0002), coefficient of variance (CV) of inside humidity ($F_{3,14}$=6.56, p= 0.005), and mean daily differences in inside/outside humidity ($F_{3,14}$=4.21, p=0.03). We found that, overall, the Y design resulted in more favorable humidity conditions than the other two artificial designs (Table 4-2). Using post-hoc Tukey tests, we found that mean inside humidity was significantly higher in Y than all other burrow styles (standard p=0.0003, curvy p=0.0074, natural p=0.0011); humidity inside Y burrows had a significantly lower CV than both standard (p=0.005) and curvy burrows (p=0.021), but not natural burrows; mean daily differences in inside/outside humidity were significantly higher in Y than the standard burrow design (p=0.04) but were similar to those of curvy and natural burrows. We found that the Y design buffered the best against outside extremes in humidity and had the most stable humidity of the different burrows. Humidity in the Y burrows was similar to what we observed in the natural burrows on Otay Mesa in 2014 and 2015 (Table 4-2).

Concerning temperature, we did not see any significant differences between the three artificial burrow designs, but the natural burrows had significantly different temperature conditions than the artificial burrows. Natural burrows experienced higher mean and CV of inside temperatures than the artificial burrows ($F_{3,14}$=7.77, p=0.003 and $F_{3,14}$=5.63, p=0.01, respectively). The natural burrows also had significantly greater differences in inside/outside temperatures than all artificial burrow designs ($F_{3,14}$=12.64, p=0.0003).

The temperature findings in natural burrows were not in agreement with our predictions. We had trouble getting the iButtons into natural burrows at Rancho Jamul, and it was difficult to find burrows that were not actively in use. We excluded two natural burrows, 1N and 5N, from our analysis because both were compromised by squirrel activity, and data from the other three may not be representative due to the short depths (49, 101, and 148 cm, respectively) we were able to insert the iButtons. These difficulties could explain our unexpected results regarding natural burrows. We also noted that the soil at the Rancho Jamul site had a significantly lower percentage of clay than Otay Mesa ($F_{1,162}$=293.574, p<0.0001). Soil with more clay content tends to hold moisture better and might explain why the burrows at Otay Mesa, especially the natural burrows, experienced lower inside temperatures and high humidity. Rancho Jamul tends to be drier and hotter than Otay Mesa, which may also help explain why the natural burrows experienced warmer, less stable temperatures than those in Otay Mesa. While we did see higher temperatures in all our burrows in Rancho Jamul, the range of temperatures for all burrow types were within the thermoneutral zone of BUOW (25-37°C, Coulombe 1970). Burrow temperatures fell short of the optimal temperatures for development of avian embryos (35.5-38.5°C, Webb 1987), but there are many strategies birds can use to increase the surrounding temperature for incubating eggs.

Table 4-2. Microclimate metrics for three different artificial burrow designs and natural burrows at the BOHMA at RJER. Bold indicates means that are significantly different from other groups.

	Artificial Burrows											
	Standard n= 5		Y n=5		Curvy n=5		Natural n=3*		2014 Otay Natural n=3		2015 Otay Natural n=4	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Inside Humidity	47.43	4.24	**81.89**	4.24	58.37	4.24	47.61	5.48	83.51	4.95	95.37	4.47
CV of In Hum	8.94	1.05	**2.77**	1.05	7.77	1.05	7.01	1.35	2.70	1.17	1.77	0.78
In/Out Hum Diff	22.35	0.97	**26.51**	0.97	23.38	0.97	26.34	1.26	23.97	1.61	22.80	2.62
Inside Temp	29.97	0.21	29.96	0.21	29.52	0.21	**31.16**	0.27	--	--	--	--
CV of In Temp	1.42	0.74	0.57	0.74	0.55	0.74	**5.03**	0.96	--	--	--	--
In/Out Temp Diff	7.67	0.08	7.94	0.08	7.77	0.08	**8.42**	0.10	--	--	--	--

*Two natural burrows (1N and 5N) were excluded from this analysis

Implications for artificial burrow design

Relative humidity within most natural animal-dug burrows remains at near-saturation (White et al. 1978, Birchard 1979, Wilson and Kilgore 1978, Birchard and Kilgore 1980). Coulombe (1971) found that natural BUOW burrows in Imperial Valley had an average relative humidity of 71.8% during the breeding season, and we observed high relative humidity levels in natural burrows on Otay Mesa in 2014 (83.51%, Swaisgood et al. 2015) and 2015 (95.37%, Hennessy et al. 2016). The results from nests in wood artificial burrows at Lonestar were similar to these measurements. In addition, we found that the Y burrow design buffered more effectively against outside extremes in humidity and had the most stable humidity of the different burrow designs. Humidity plays an important role in bird development; gas exchange occurs through eggshell pores, and the surrounding humidity affects the amount of water lost by the egg (Ar and Rahn 1980). Humidity that is too high or too low can hinder proper embryonic development and hatching (Birchard and Kilgore 1980). When humidity is too low, the embryo or the entire egg may become dehydrated (Tullett 1984), but humidity that is too high can inhibit moisture loss, resulting in insufficient air for the chick to breathe or insufficient space for the chick to break the shell (Ar and Rahn 1980). Because BUOW have evolved to breed in natural burrows, which have relatively high humidity (Birchard and Kilgore 1980), it is likely that BUOW eggs have adaptations to help them lose the appropriate amount of water in very humid conditions. The high humidity conditions we observed in the Y burrows seem consistent with those observed in natural burrows and are likely more in-line with the humidity conditions under which BUOW eggs evolved so should not be detrimental to incubation.

The stable and well-buffered humidity conditions of the "one-entrance" wood burrows and the Y burrow design are likely favorable for BUOW breeding because a stable microclimate may reduce the energetic costs of the incubating female (Brady 2004). While we did not observe significant results regarding temperature, consistent humidity may be more important for successful incubation. While birds can control both the temperature and water loss (related to humidity) of their eggs, it is most likely easier for BUOW to overcome temperature deficiencies of artificial burrows than humidity deficiencies. There are a variety of strategies birds use to control egg temperature, such as altering their brood patch, turning and/or fanning the eggs, and changing their position over the eggs. Birds can also control humidity using methods like bringing more water into the burrow and closing off the eggs' pores by laying over the eggs. Because BUOW have larger clutches, it may be harder for them to effectively cover up all the pores of their eggs to alter the amount of water loss. BUOW also inhabit fairly arid environments, where it is sometimes difficult to find water to bring back to the burrow. If BUOW can indeed more easily influence temperature than humidity, both the Y design and results from the one-entrance wood burrows show a promising improvement for artificial burrows because, although they do not seem to buffer temperature as well as natural burrows, the stable humidity conditions they provide may be a more significant factor for increasing incubation success.

We have also noticed that the owls seem to prefer to place their egg clutches near the corners of the chambers when possible (i.e., in wood burrows) and are aware that other researchers have seen the same behavior (D. Johnson, pers. comm.). This may be more analogous to the configuration of nest chambers in natural burrows and may help the birds regulate the temperature or humidity of their eggs. Consequently, tunnel entrance into the chamber may be important and should perhaps be offset to allow better nest placement in the chamber.

Recommendations for artificial burrows

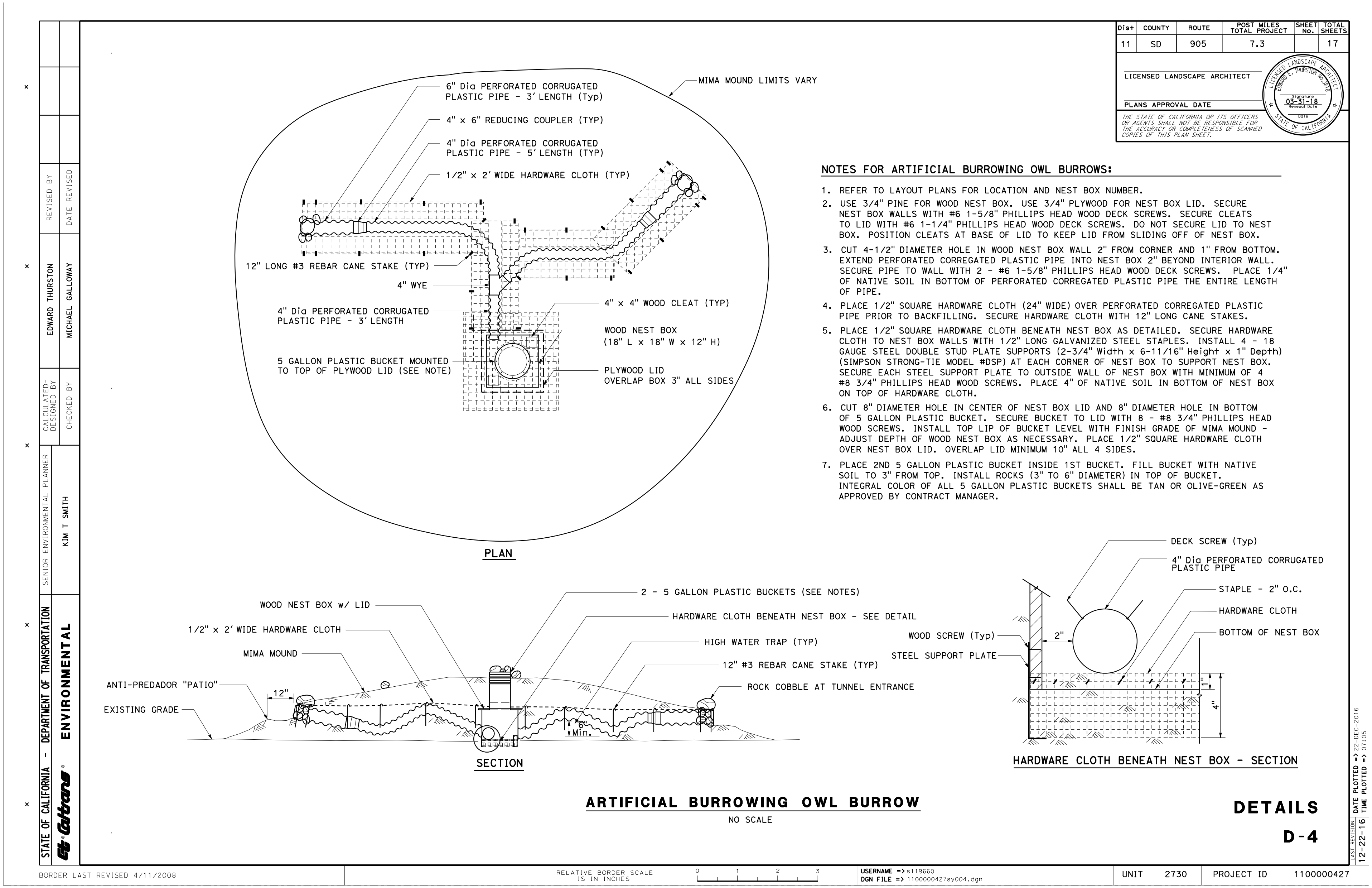
Based on all of the information we have gathered, we developed an artificial burrow design that combines many features from the existing designs outlined by Johnson et al. (2013; Figure 4-4). We recommend a wooden chamber (18 in x 18 in x 12 in [45 cm x 45 cm x 30 cm]) with an access chimney and perforated corrugated irrigation tubing in a Y configuration using a wye connection (not a tee connection) to allow for scoping and cleaning of the tunnels. The tunnel entering the chamber should connect near a corner (off-set from center) to give the owls more options for egg placement. Hardware cloth (1/2 inch [1.27 cm] mesh) should be placed underneath the chamber to maintain integrity of the chamber floor, and ~4 inches (~10 cm) of native soil should be placed over the mesh for nesting substrate. Footings of ~2-4 inches (~5-10 cm) made of wood or metal can be used to allow for space for native soil substrate; alternatively, the nest chamber could be made taller to accommodate the soil substrate.

We also recommend retrofitting the openings of the wood burrow tunnels at Lonestar and elsewhere to ensure that the design of artificial burrows is not contributing to mortality of adult (and juvenile) BUOW. Openings of ~6 inches (~15 cm) should be the standard for all artificial burrows in the area. Consistent with this larger entrance size, we have observed that BUOW often excavate natural burrow openings when they move in. In both natural and artificial burrows, the tunnel width decreases within 1-2 feet of the entrance. This discourages larger-bodied predators, although even in natural burrows skunks and opposums sometimes successfully predate the burrow.

Inhabitants of a burrow can strongly influence the burrow microclimate through their movements, metabolic activity, and evaporative water loss and these interactions have not yet been successfully measured using current methods. We recommend exploring the use of dummy eggs with temperature/humidity loggers to better understand the conditions experienced by eggs and chicks in the nest. In addition, there is a strong need for more accurate natural burrow data. It is unlikely that we are reaching the burrow chamber itself with our current equipment and set-up, and the iButtons are often altered (slightly buried or moved around) resulting in compromised data. We should continue to pursue better ways to attain accurate natural burrow data, especially considering that advances in technology (e.g. miniature robots) may make this possible in the near future.

According to Johnson et al. (2013), comprehensive goals for artificial burrows should include: "1) use as a strategic, broad-scale, conservation tool to slow the rate of population decline, 2) support local and regional reintroduction and augmentation efforts, 3) provide a basis for scientific studies and the efficient monitoring of population trends and demography, 4) use in specific relocation efforts related to construction activities, and 5) use as a practical educational and engagement tool." In addition, we recommend burrow use as a stop gap measure during periods of squirrel establishment, to augment the supply of natural burrows. As we move forward with comprehensive management and conservation of BUOW in San Diego County, strategic and coordinated installation, monitoring, and maintenance of artificial burrows should be an integral part of the strategy (see Appendix 4 and the Burrowing Owl Conservation and Management Plan for San Diego County).

Figure 4-4. Plan for new artificial burrow design. Plan developed in collaboration with CalTrans.



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TASK E: EVALUATE POTENTIAL BURROWING OWL RECOVERY SITES

Finalized regional habitat model

Potential sites for future BUOW species management were identified based on regional habitat suitability modeling begun in 2015 and finalized in 2016. The model is based on abiotic and land use conditions in BUOW-occupied sites across southern California, excluding desert areas. The abiotic variables include minimum temperature in April, maximum temperature in August, annual precipitation, elevation, slope, percent clay to a depth of 150 centimeters (cm), and percent sand to 150 cm. The land use factors are percent cover of urban, coastal sage scrub, chaparral, grassland, riparian, and agricultural areas within one kilometer of each site. See Hennessy et al. (2016) for a complete description of the methodology.

The BUOW habitat suitability maps presented below were based on a regional approach to BUOW habitat suitability designed to overcome the current absence of BUOWs in interior grassland sites in San Diego County. As the largest remaining grasslands in the County, these sites historically supported breeding populations of BUOW and would be considered suitable habitat except for the current absence of owls. A second reason for taking a regional approach is that most San Diego County BUOW occurrence records come from the Otay Mesa area. Unfortunately, Otay is unlike most suitable habitat locations in the county due to unique clay soils and proximity to the coast. Consideration of coastal sites for BUOW habitat is an issue since almost all of these areas are already heavily developed, and are unavailable for future BUOW management actions. Unfortunately, the current presence of BUOW on Otay Mesa is probably due more to chance than to the suitability levels of the habitat. Therefore it was necessary to expand the focal area in order to capture BUOW occurrence records from interior grassland sites such as those in western Riverside County. Clusters of BUOW occurrences were subsampled in order to leverage the habitat information from a wide range of sites and produce a model with good generalizability to San Diego County. The final habitat suitability map is presented below (Figure 5-1).

The habitat suitability model is designed to help managers quickly identify areas important for BUOW recovery. This model provides a large-scale evaluation of site suitability for both currently available sites and areas that may not yet be available for conservation, but could potentially provide conservation opportunities in the future.

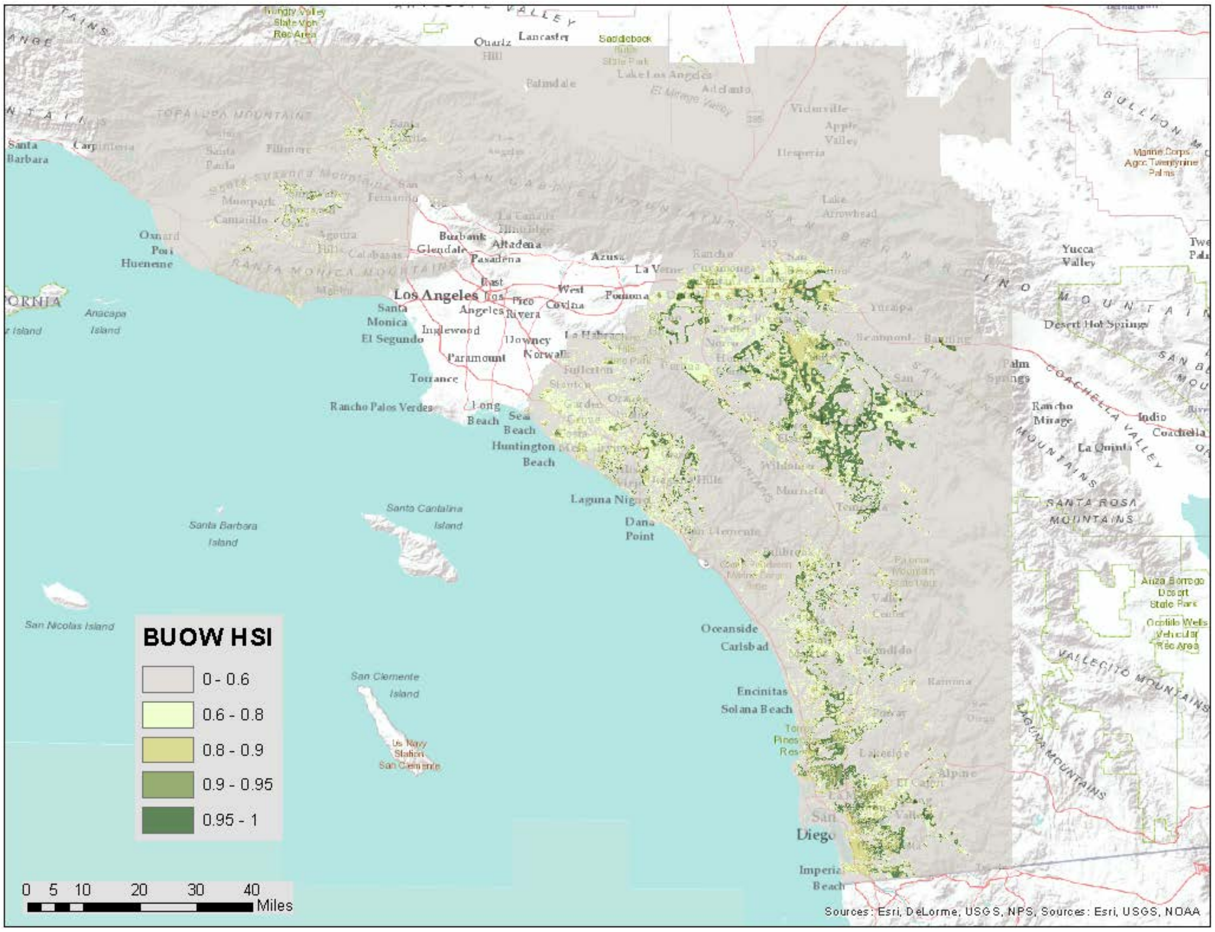

Figure 5-1. Habitat suitability model for BUOWs in portions of San Diego, Riverside, San Bernadino, Orange, and Los Angeles Counties. A habitat suitability index value has been calculated for every point in the gridded extent (150 m) based on the eigenvector of the component selected from principal components analysis. On this scale, one represents habitat that perfectly matches the environmental characteristics of known occupied habitat, and zero represents poor habitat.

Rapid assessments

The most promising sites were then subjected to further evaluation through field-based rapid assessments. A field-based evaluation at any site considered for BUOW management is a necessary next step, due to the difference in spatial scale between the suitability map and individual owl habitat selection and use. The spatial scale of the habitat suitability model is (at minimum) 150 m, the distance between individual data points in the grid of environmental input variables. However, the minimum mapping unit of some input layers, such as the polygon-based soils data derived from SSURGO, should not be assumed to be 150 m. The scale of the input layers should be a consideration when using this suitability map. As a result, the suitability of areas of interest must be verified with a field evaluation at the smaller scales at which owls will be using habitat.

To further evaluate and characterize the sites, a rapid assessment protocol was developed in 2016 and carried out at nine sites (Table 5-1) located across four of the SDMMP management units (Figure 5-2). The rapid assessment protocol includes a suite of standardized fine-scale field surveys of prey (small mammal) availability, predator pressure, vegetation, and soil texture. Implementation of the rapid assessment involves an initial GIS analysis to generate randomized sampling points. Data collection occurs in 3-4 site visits over a 10-day period.

The rapid assessments enable a comparison between sites, since the methodology is standardized. The data should not be interpreted to represent absolute population levels, as would be captured by longer term or higher intensity sampling. However, these data provide an indication of relative levels among sites, and give a snapshot of current conditions. Since prey availability and predator pressure are often not captured by the types of monitoring that are likely to be ongoing at these sites, they fill a gap in existing knowledge.

Rapid assessment protocols and full results of the rapid assessments are reported in the revised Burrowing Owl Conservation and Management Plan for San Diego County. Please refer to the Conservation and Management Plan when citing the methodology or results of the rapid assessments. The rapid assessment methodology is available for implementation on new sites of interest. It could also be utilized in the future to provide an updated report on the condition of sites that were evaluated in 2016.

Table 5-1. List of sites assessed in 2016 with managing agency and management unit (MU) under the SDMMP.

Site	Managing Agency	MU
Barnett Ranch Preserve	County of San Diego	4
Hollenbeck Canyon Wildlife Area	CA Dept of Fish and Wildlife	3
Johnson Canyon	Caltrans	3
La Zanja Open Space	City of San Diego	6
Lonestar	Caltrans	3
Pamo Valley	City of San Diego	5
Ramona Grasslands Preserve	County of San Diego	5
Ramona Mitigation Bank	Private mitigation lands	5
Rancho Jamul Ecological Reserve	CA Dept of Fish and Wildlife	3

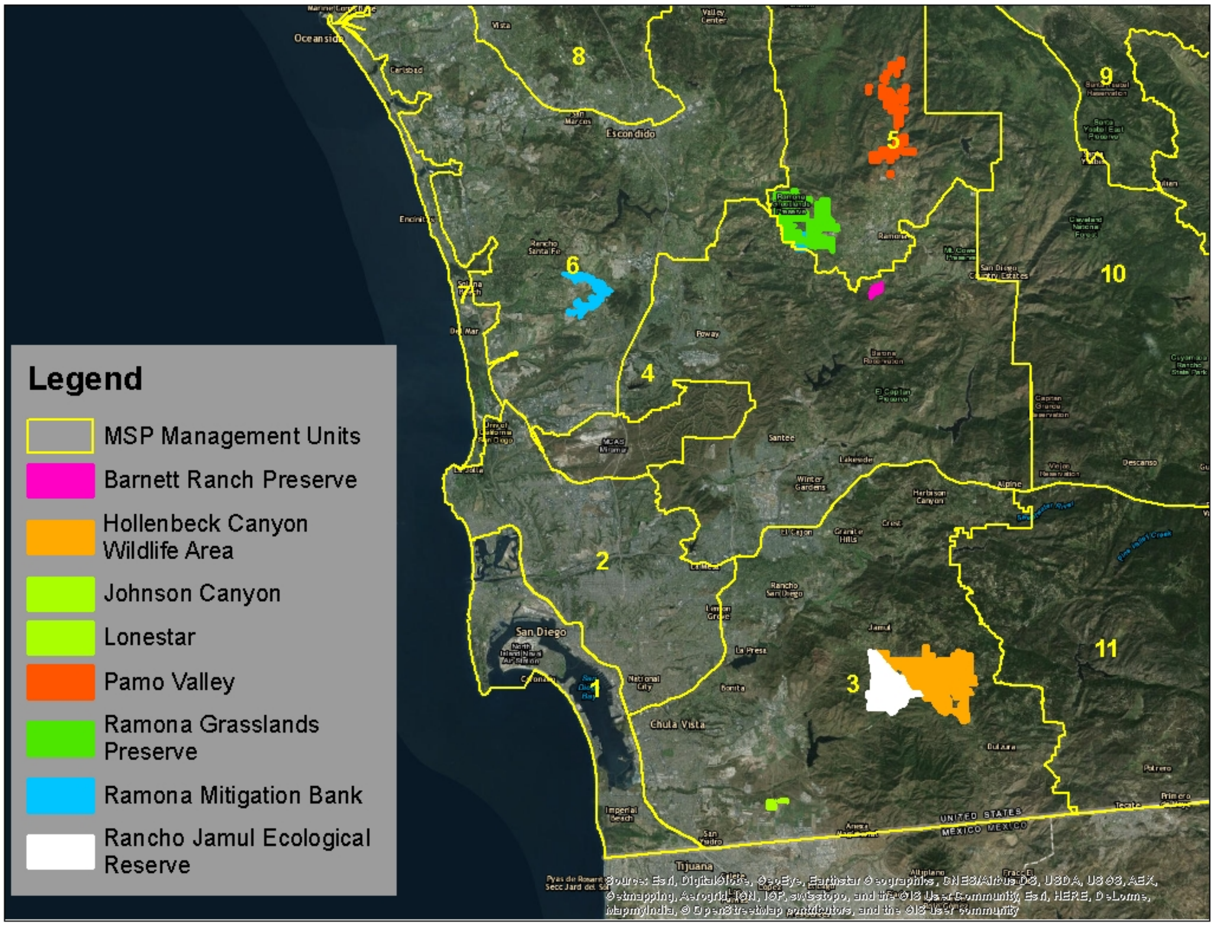

Figure 5-2. Sites included in the rapid assessments in 2016.

UNMANNED AERIAL SYSTEM TRIAL

In 2016, as part of the development of a rapid assessment tool for fine-scale site selection, we proposed use of an unmanned aerial system (UAS) to collect vegetation height and bare ground cover from aerial imagery. The promise of this approach is that high resolution data may be collected relatively quickly over greater extents of land than by using field sampling methods such as point intercept. The flexibility offered by this method could enable collection of vegetation data at the same spatial and temporal scales at which owls utilize habitat with a lower investment of crew time and effort. As a result, managers would be better able to rapidly identify areas important for BUOW recovery and priority management efforts. However, use of UAS technology for habitat evaluation is still under development. In 2016, we conducted a successful UAS trial in conjunction with rapid assessment data collection.

We deployed a PrecisionHawk™ Lancaster fixed-wing unmanned aerial system to survey the 16.5 hectare burrowing owl habitat management area (BOHMA) within the Rancho Jamul Ecological Reserve (RJER) on the 2nd September 2016 (Figure 5-3). The UAS flew at an altitude of 30 meters along overlapping transects and scanned the BOHMA using an 18.4

megapixel 10mm visual sensor and blue/green/red/near-infrared multispectral imager. We processed the 1,190 georeferenced images captured by the UAS into a continuous 0.98 cm resolution orthomosaic using Pix4Dmapper-Pro™ imaging software corrected using ground control points acquired with a Juniper Systems Geode™ realtime sub-meter GPS receiver. We then used ERDAS Imagine™ geospatial software to conduct a supervised classification analysis on this orthomosaic that was validated with ground-truthed georeferenced imagery. Our resulting model classified the orthomosaic into two broad landcover categories: 1) vegetation and 2) bare ground/rock. As a result, the BOHMA habitat was classified into 11.11 hectares vegetation (67.1 %) and 5.44 hectares bare ground/rock (32.9 %).

The trial showed that this approach is feasible at these scales, both in terms of the land area surveyed and in terms of the resolution required to make a credible estimate of bare ground and grass cover. The ability to capture grassland at 1 cm resolution was a significant achievement.

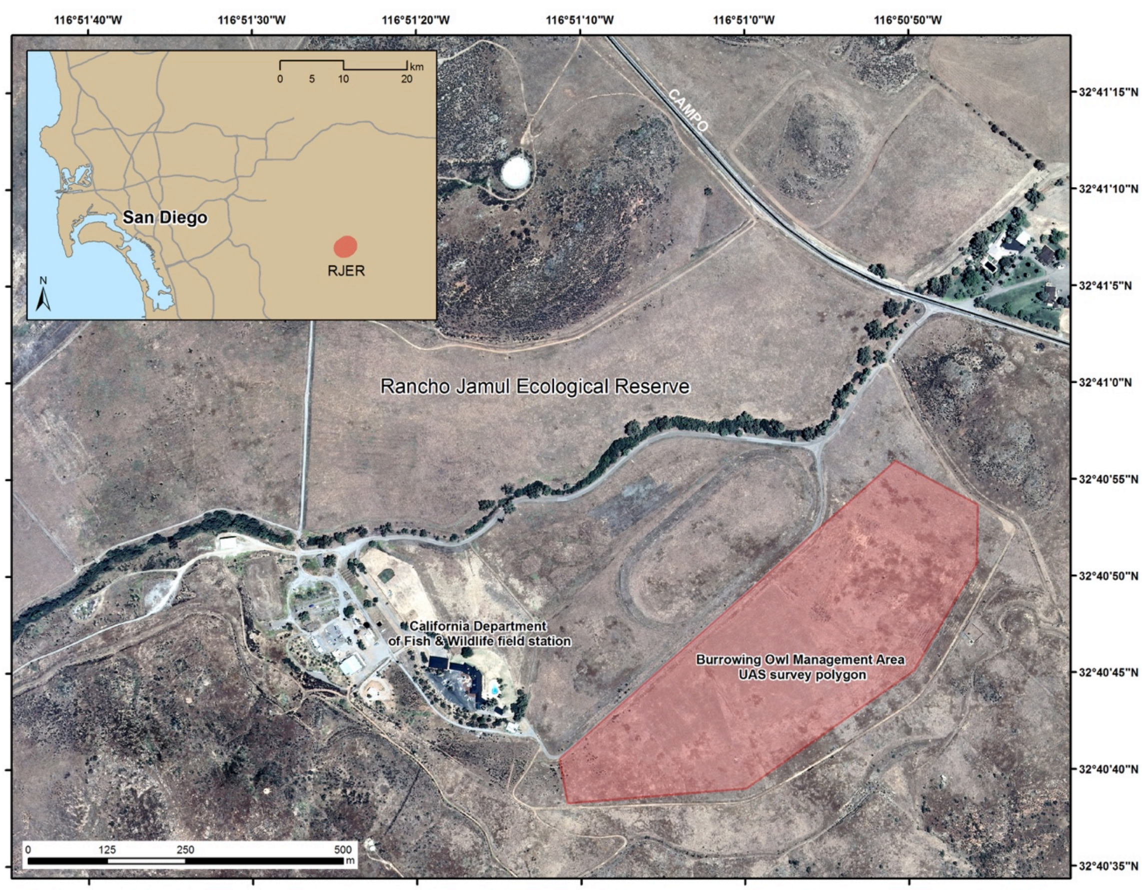

Figure 5-3. Location of the Rancho Jamul Ecological Reserve in southern San Diego County and the 16.5 hectare BOHMA and UAS survey area (red polygon).

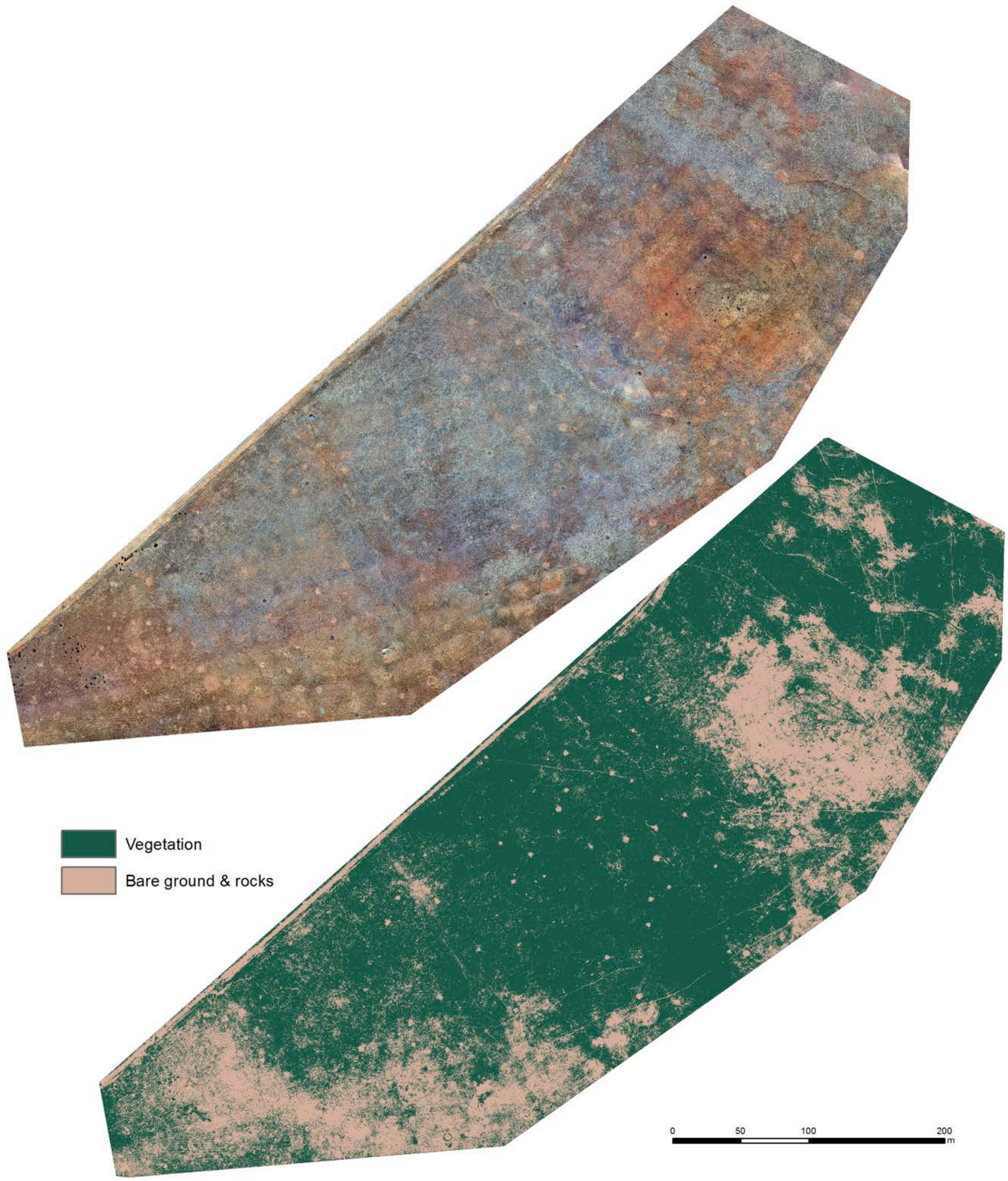

Figure 5-4. Overview comparison of the composite 0.9 cm resolution orthomosaic image of the BOHMA (top) and the landscape classification model (bottom) categorizing the BOHMA habitat into vegetation and bare ground/rocks.

TASK F: CONSERVATION AND MANAGEMENT PLAN

The first draft strategic management plan for BUOW in San Diego County was released in August 2016. Feedback was gathered from stakeholders, and a major revision was released in December 2016. The revised document has been renamed the "Burrowing Owl Conservation and Management Plan for San Diego County." Please refer to and cite the Plan for population viability estimates for the Otay population, key factors for establishing new breeding sites, optimal relocation techniques for both ground squirrels and BUOW, and other relevant management strategies.

In 2016, we also continued to build and update the draft plan with new data. The Plan also reports the habitat suitability model results and the full results of the 2016 rapid assessments, including data and graphics. Together with discussion of management recommendations for each rapid assessment site, these sections consolidate the current information about critical areas within the county needed for protection.

This task also included two additional action items: 1) to evaluate and categorize the condition of artificial burrows in MSP Management Unit 3; and 2) to begin developing an implementation schedule for maintenance of artificial burrows. For the first item, we are submitting all current information about burrows in Appendix 4, attached to this report. For the second item, we propose a database framework for tracking burrow status. The database is designed to track the most recent information on individual burrows, and contains both site-level and burrow-level fields, linked by site. The proposed database framework is also attached in Appendix 4.

TASK G: TRIAL BURROWING OWL CONSPECIFIC CUES

Looking ahead in San Diego County in the next several years, there will probably be inadequate numbers of BUOW (some displaced through ongoing development in Otay Mesa) to conduct sufficient active translocations to recovery node sites. In other avian species with inadequate numbers of individuals available for reestablishment, conservation breeding methods have been successfully utilized. BUOW captive breeding programs have shown that the species breeds readily, producing many young (Leupin and Low 2001). However, one of the most significant obstacles to successful population establishment is post-release dispersal away from the release site, which increases risk exposure and mortality rates (Stamps and Swaisgood 2007; Le Gouar et al. 2011; Shier and Swaisgood 2012; Batson et al. 2015). Temporarily holding animals in acclimation enclosures at the release site may increase retention (Bright and Morris 1994; Batson et al. 2015), but this method alone does not always yield success (Shier, 2006; Shier and Swaisgood 2012). Thus, a major consideration in re-establishment efforts is to find mechanisms to retain or "anchor" animals in suitable habitat at the release site.

Post-release movements may be reduced by addressing the behavioral cues that conspecifics exchange (Shier 2006; Stamps and Swaisgood 2007; Shier and Swaisgood 2012). Conspecific cues influence settlement decisions, in that individuals may avoid settlement into unoccupied suitable habitat because there are no signs that members of the same species have used the area (Stamps 1988). Previous successful efforts to manipulate conspecific cues have utilized bird song playbacks (Ahlering et al. 2010), model decoys (Kotilar and Burger 1984), whitewash (Sarrazin et al.1996), and dung (Linklater and Swaisgood 2007). For BUOW, incorporating the use of pellets, whitewash, and/or acoustic callbacks into existing translocation protocols may increase the probability of settlement for newly released BUOW. Another potential strategy is to place rescue birds in hacking cages on the settlement site. These birds would not be released, but would serve as a conspecific anchor to encourage settlement by released birds. For burrowing owls, which are a colonial species, the presence of conspecific individuals may provide an even greater effect on successful settlement than pellets and whitewash.

In 2016, we began trialing techniques at the BOHMA at Rancho Jamul to encourage settlement and breeding of overwintering birds. Testing these management actions will help prepare RJER, as well as other locations, become viable BUOW recovery nodes and marks another step towards BUOW recovery in San Diego County. In the future, we plan to use (and continue testing in an adaptive management framework) conspecific cueing methods for active translocations of BUOW that occur in the county.

Methods and Preliminary Results

As a first step, we began testing conspecific cues in the BOHMA at Rancho Jamul Ecological Reserve to encourage settlement and breeding of overwintering owls. In the BOHMA, there are five complexes of artificial burrows; we applied experimental whitewash at the entrances of a subset of artificial burrows. All burrows in complexes 1,3, and 5 received the experimental treatment while the burrows at complexes 2 and 4 did not receive any whitewash and served as a control subset (Figure 7-1, Table 7-1). We used white latex paint to mimic owl droppings. Four sets of droppings were applied to each burrow entrance in the experimental subset (8 total per burrow, Figure 7-2); each set of droppings consisted of ~2-5 ml of paint forcefully ejected from a 10-ml syringe. After application, we took reference photos of each burrow entrance in the experimental subset for comparison in the future. We applied conspecific cues on 4 November, and made our first follow-up visit on 15 December. Although a BUOW was present in the BOHMA during our visit on 4 November, we did not see the owl or find any new sign during our 15 December visit. We will continue to make monthly checks of the burrows including noting any new BUOW sign or changes to the cues at the burrow entrances, as well as photo documentation of each burrow/entrance for comparison with previous visits.

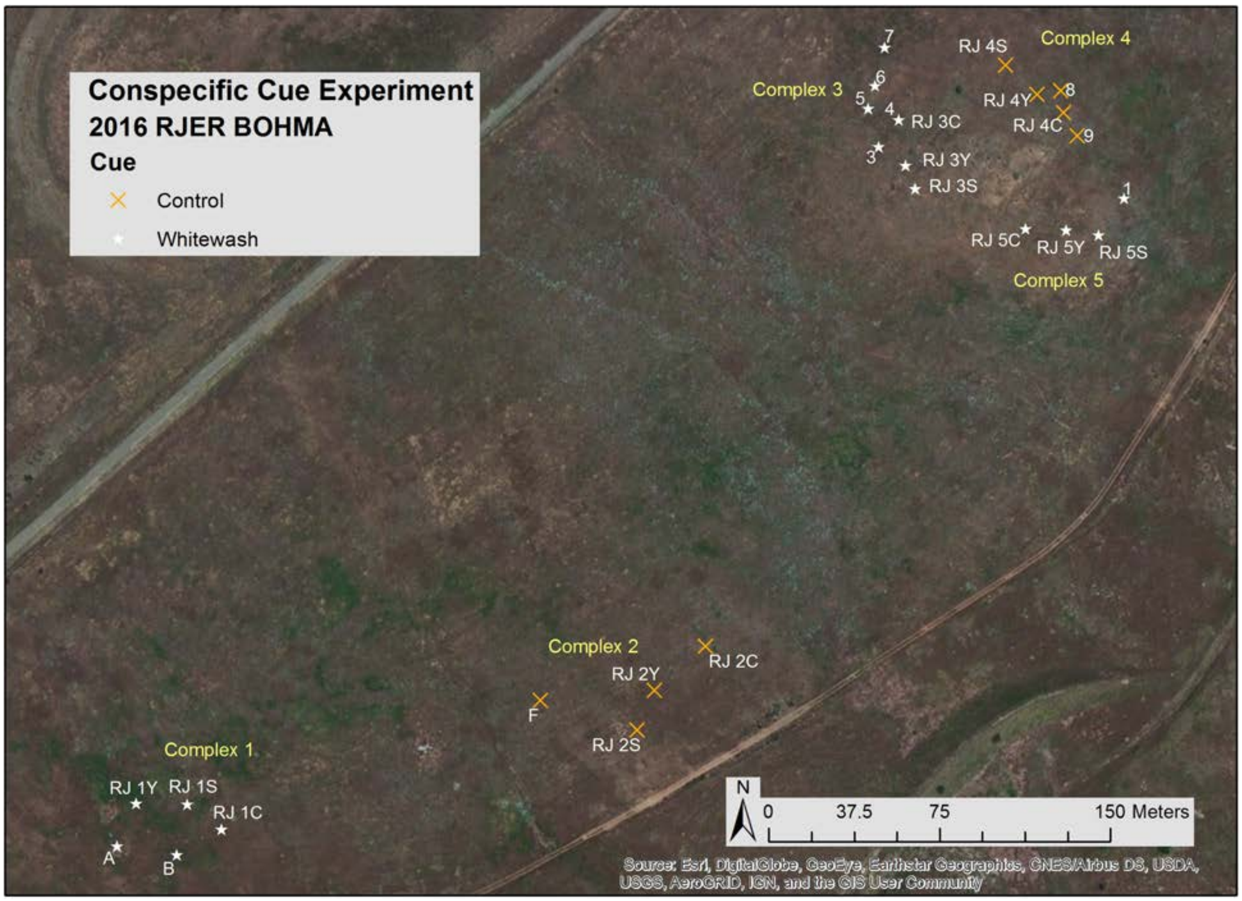

Figure 7-1. Map of artificial burrows in Burrowing Owl Habitat Management Area at Rancho Jamul Ecological Reserve.

Table 7-1. List of artificial burrows, styles, and cues.

Burrow	Complex	Burrow Style[1]	Conspecific Cue
RJ 1C	1	Curvy	Whitewash
RJ 1S	1	Standard	Whitewash
RJ 1Y	1	Y-design	Whitewash
RJ 2C	2	Curvy	Control
RJ 2S	2	Standard	Control
RJ 2Y	2	Y-design	Control
RJ 3C	3	Curvy	Whitewash
RJ 3S	3	Standard	Whitewash
RJ 3Y	3	Y-design	Whitewash
RJ 4C	4	Curvy	Control
RJ 4S	4	Standard	Control
RJ 4Y	4	Y-design	Control
RJ 5C	5	Curvy	Whitewash
RJ 5S	5	Standard	Whitewash
RJ 5Y	5	Y-design	Whitewash
RJER 1	5	Existing	Whitewash
RJER 3	3	Existing	Whitewash
RJER 5	3	Existing	Whitewash
RJER 6	3	Existing	Whitewash
RJER 7	3	Existing	Whitewash
RJER 8	4	Existing	Control
RJER 9	4	Existing	Control
RJER A	1	Existing	Whitewash
RJER B	1	Existing	Whitewash
RJER E[2]	n/a	Existing	n/a
RJER F	2	Existing	Control

[1]See Section D for description of burrow styles.
[2]This is an escape tunnel (no chamber) located between Complexes 1 and 2. It was not used for this trial.

Figure 7-2. Examples of experimental whitewash applied to artificial burrow entrances at the RJER BOHMA.

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APPENDIX 1. CAMERA TRAP PHOTO PROCESSING PROTOCOL 2016

We have collected a large number of photographs from Burrowing Owl (BUOW) nest burrows. In order to make use of the information contained in the photos, we need to classify what is in each picture. The photos are saved on a high capacity external hard drive. They are organized by site, burrow, camera, and week of collection.

Photo processing occurs in the program Adobe Bridge, which allows us to tag each photo with relevant keywords. We are interested in recording: 1) the frequency of predation events and type of predators, 2) human disturbances, 3) other species present in the photos (either "Visitors" or "Predators", 4) copulation, 5) other interesting events and photos, 6) the maximum number (and band codes, if present) of adult and juvenile burrowing owls present at each burrow per day, and 7) the frequency of prey deliveries and the types of prey.

We use Reconyx Hyperfire camera traps. Photos are taken in series of 3 and are labeled as such (1/3, 2/3, 3/3). Photos may also be taken using a Bushnell NatureView with variable focal-length lenses (these photos are not labeled with the series numbers).

<u>Independent Events</u>

It is important that we only record independent events, which means that you should only mark the first occurrence of each prey delivery or other event—DO NOT tag more than one photo in each series or each event. For example, if a rabbit is delivered and appears in several series of photos, only mark the first photo in which it appears (you can also mark the most illustrative photo instead of the first one, but only mark ONE).

In order to save time, do not tag every photo that contains a burrowing owl, only mark those that contain the types of events listed above (and see the following list of keywords).

In order to estimate the productivity and survival of the owls at each burrow, we need to keep track of how many and which owls appear in the photos each day. We do this by counting the maximum number of adults and the maximum number of juveniles seen each day. If the birds are banded, we also want to keep track of the band codes seen each day. The photo at right shows an example of the bands with alphanumberic code.

<u>The Binder</u>

There is a large binder called "BUOW 2016 Cam Trap Processing" which contains the datasheets needed for photo processing. It is divided by burrow and within each burrow section further divided by camera. Each camera has three types of datasheet associated with it (see below).

<u>Datasheets</u>

- Check sheet—Each camera has a check sheet that lists all of the file folders that contain photos from that camera. Each folder should be checked off as it is processed (enter the date it was processed in the "DONE" column and your initials in the "Initials" column).

- Maximum BUOW Counts Sheet—We keep track of the adults and juveniles separately by keeping a tally for each day photos were taken. "Date" refers to the photo date, "Max Adults/Chicks Seen" should be filled in with tally marks, "Bands" should be filled in with all band codes seen on a given day that apply to the appropriate age class. The band codes used at a burrow are listed at the bottom of the Max Count datasheet (if there are no band codes on the sheet, no owls were banded at that burrow). The band in the picture above would be referred to as "02 over X" and should be written on the datasheet as it appears on the band. Again, fill in the date processed and your initials.

- Good Pictures & Interesting Events Sheet—This data sheet is used to describe photos that are marked as "Good Picture" or "Other interesting event" (see keyword list below for further explanation). On the data sheet, note the photo file name and date and give a brief description of the photo. Initial and date each line.

<u>Logging on to computer/server</u>
To sign in to the computer, click the Novell Logon icon. Then click the "Computer Only Logon" option. Enter username: buow and password: buow1. At ZENworks prompt, click cancel.

To log in to the server where the photos are stored (folder: buow(Aae-storage P:), enter the username: buow and password: buow2013.

<u>Using Adobe Bridge</u>
We will use Adobe Bridge to record predation events/types, human disturbances, visitor species, predator species, copulation, and other interesting events. Bridge is set up to easily navigate to the appropriate folder, view photos, and tag each photo with keywords using a pre-designed checklist. You can also select multiple photos at a time and simultaneously tag them.

To open Bridge, click on the Start Menu and Bridge is at the top of the pane.

<u>Navigating to folders</u>
All folders are stored on the "Aae-storage" drive under "buow". The pathway is Computer→buow(Aae-storage P:)→Cam Trap Originals→Cam Traps—BUOW→[Year]→[Site]→[Burrow]→[Camera]

<u>Keyword list</u>

- Good/Bad Picture
    - Bad Picture –Picture quality is too poor to see what is in it. This might be a result of the photo being washed out or the camera having condensation on it. You can mark a picture as a bad picture even if you tag something in it (this will indicate a low level of confidence in the identification). Mark all

photos that are "bad"—you can do this quickly by selecting all photos that apply in the middle bottom pane of the Bridge, then clicking the "Bad Picture" box in the keyword pane.
    - Good Picture –Mark this for photos that are exemplary of the owls or their behavior—in short, photos that would be good in a presentation, on a poster, or in a report. "Good Picture" can be marked for any photo (not just ones that are tagged for other reasons). Note the photo file name and a short description on the datasheet.
    - QC for Colleen –Used during QC process, flags photo for examination by Colleen
- Human Disturbance
    - Human –Mark if a person/people is/are in the frame and within ~50m of the burrow.
    - Misc. human disturbance –Mark for any human-related disturbance that doesn't fit into the other categories.
    - Vehicle –Mark if a vehicle(s) is in the frame and within ~50m of the burrow.
    - Watering –This category is primarily for Lonestar; mark if there are workers watering or if the spray from a hose is seen in the frame.
- Interesting Events
    - Adult predation event –Mark in the event that an adult burrowing owl is killed by another animal (including another burrowing owl).
    - Copulation –Mark when two owls are seen copulating on camera.
    - First Emergence –For each camera, mark the photo when the first chick of the nesting attempt emerges from the burrow. There should only be one for each camera (but consult staff for special circumstances). Please continue to note this on the Interesting Events data sheet too.
    - Interesting prey –Mark if an interesting prey item is delivered to the burrow.
    - Juvenile Predation event –Mark in the event that a juvenile burrowing owl is killed by another animal (including another burrowing owl).
    - Other interesting events –Mark interesting events that don't fit into the above categories or prey deliveries. Note the photo file name and a short description on the datasheet.
- Predator Species: This refers to predator species that may appear on camera (but not as a prey item). This should be used to indicate the predator species in the case of a predation event.
    - Burrowing owl –Mark if a burrowing owl is the predator.
    - Bobcat –Mark if a bobcat is present in the photo.
    - Coyote –Mark if a coyote is present in the photo.
    - Domestic cat –Mark if a domestic cat is present in the photo.
    - Domestic dog –Mark if a domestic dog is present in the photo.
    - Opossum –Mark if an opossum is present in the photo.
    - Other –Mark for predator species other than those in this list (note on Interesting Events data sheet).
    - Raccoon – Mark if a raccoon is present in the photo.
    - Raptor –Mark if a raptor other than a burrowing owl is present in the photo.

- Raven/crow –Mark if a raven or crow are present in the photo.
- Skunk –Mark if a skunk is present in the photo.
- Snake –Mark if a snake or lizard is present in the photo.
- Weasel –Mark if a weasel is present in the photo.

- Prey: This refers to the type of prey that the BURROWING OWLS bring to the burrow.
  - Amphibian prey - Mark if an amphibian is brought as prey.
    - Bird prey - Mark if a bird is brought as prey.
  - Burrowing Owl prey - Mark if a burrowing owl is the prey item. Should be marked in conjunction with "Adult/Juvenile Predation event" (in most cases it will be a juvenile).
  - Invertebrate prey - Mark if prey is insect/arachnid
  - Mammal prey - Mark if a mammal is brought as prey.
  - Possible feeding - Mark if a prey delivery occurs, but you can't see beak-to-beak contact. For this case, you are less than 75% sure the interaction was a prey delivery.
  - Prey seen unknown - Mark if you are able to see a prey item but are not able to narrow it down further.
  - Prey unseen - Mark if you are able to see beak-to-beak contact (indicating prey was exchanged), but you are not able to see a prey item. You must be able to see the beak-to-beak contact.
  - Probable feeding - Mark if a prey delivery occurs, but you can't see beak-to-beak contact. For this case, you are more than 75% sure the interaction was a prey delivery.
  - Reptile prey - Mark if prey is reptile.
- Visitor Species: This refers to other species (that are not potential BUOW predators) that may appear on camera (but not as a prey item).
  - Bird other –Mark if a bird other than a burrowing owl, cactus wren, raptor, raven/crow, or roadrunner is present in the photo.
  - Burrowing owl –Mark if a burrowing owl is seen in a photo with another species.
  - Cactus wren –Mark if a cactus wren is present in the photo.
  - CAGS –Mark if a California ground squirrel is present in the photo.
  - K-rat –Mark if a kangaroo rat is present in the photo.
  - Lizard –Mark if a snake or lizard is present in the photo.
  - Mouse/vole –Mark if a mouse or vole is present in the photo.
  - Other –Mark for species other than those in this list.
  - Rabbit –Mark if a rabbit is present in the photo.
  - Roadrunner –Mark if a roadrunner is present in the photo.
  - Woodrat –Mark if a woodrat is present in the photo.

Miscellaneous guidelines

- Make sure to mark species within the correct category (some species are listed in both categories).

- Make sure to note the presence of a burrowing owl if there is something else in the picture (vehicle, visitor species, etc.). However, if it is just a burrowing owl, you do not need to mark it.
- If you accidentally move items in the keyword list around, please re-organize it properly.
- If there is a frequent visitor (squirrel, rabbit, etc.) that is in a large number of the photos, only mark its appearance once per hour unless it is directly impacting an owl's behavior (in which case ALWAYS mark the respective visitor species as well as the presence of the burrowing owl).
- Only mark Human Disturbances that involve individuals or vehicles not associated with the San Diego Zoo Institute for Conservation Research team.

APPENDIX 2. 2016 BUOW BANDING DATA

Table A2-1. All burrowing owls captured in 2016 (auxiliary bands were green).

Family/Capture Burrow	Date	Age	Sex	USGS band ID	Aux band ID	DNA Sample	Banding Year
8L	15-Sep-16	Adult	Female	1004-18360	02 over Z	Blood	2016
8L	21-Jul-16	Adult	Male	0804-19731	31 over X	Blood	2013
Auto World Fence	29-Jun-16	Chick	Unknown	1004-18340	44 over Z	Blood	2016
Auto World Fence	29-Jun-16	Chick	Unknown	1004-18341	55 over Z	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15570	38 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15571	41 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15572	52 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15573	69 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15574	70 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15579	87 over Y	Blood	2016
BCS	05-May-16	Chick	Unknown	1004-15580	93 over Y	Blood	2016
Gravel Lot	05-May-16	Adult	Female	0804-19707	07 over X	Blood	2013
Gravel Lot	05-May-16	Adult	Male	1004-15514	27 over Y	Blood	2015
Gravel Lot	19-May-16	Fledgling	Unknown	1004-15590	83 over Y	Blood	2016
Pacific Coast	20-May-16	Adult	Female	1084-05304	B over E	Blood	2011
Pacific Coast	20-May-16	Chick	Unknown	1004-15591	00 over Z	Blood	2016
Pacific Coast	20-May-16	Chick	Unknown	1004-15592	11 over Z	Blood	2016
Pacific Coast	20-May-16	Chick	Unknown	1004-15593	22 over Z	Blood	2016
Pacific Coast	20-May-16	Chick	Unknown	1004-15594	33 over Z	Blood	2016
No Outlet	05-May-16	Adult	Female	1004-15513	39 over Y	Blood	2015
No Outlet	05-May-16	Chick	Unknown	1004-15576	47 over Y	Blood	2016
No Outlet	05-May-16	Chick	Unknown	1004-15577	71 over Y	Blood	2016
No Outlet	05-May-16	Chick	Unknown	1004-15578	80 over Y	Blood	2016
No Outlet	10-May-16	Chick	Unknown	1004-15581	92 over Y	Blood	2016
Parking Lot Palm	13-Jun-16	Chick	Unknown	1004-18331	01 over Z	Blood	2016
Parking Lot Palm	13-Jun-16	Chick	Unknown	1004-18332	12 over Z	Blood	2016
Parking Lot Palm	13-Jun-16	Chick	Unknown	1004-18335	23 over Z	Blood	2016
Tripad South	06-Jun-16	Adult	Female	0804-19794	94 over X	Blood	2014
Tripad South	03-Jun-16	Chick	Unknown	1004-18324	03 over Z	Blood	2016

Family/Capture Burrow	Date	Age	Sex	USGS band ID	Aux band ID	DNA Sample	Banding Year
Tripad South	13-Jun-16	Fledgling	Unknown	1004-18333	15 over Z	Blood	2016
Tripad South	16-Jun-16	Fledgling	Unknown	1004-18334	20 over Z	Blood	2016
Tripad South	29-Jun-16	Fledgling	Unknown	1004-18342	38 over Z	Blood	2016
JC 15	26-May-16	Chick	Unknown	1004-15595	61 over Z	Blood	2016
JC 15	26-May-16	Chick	Unknown	1004-15596	72 over Z	Blood	2016
JC 15	26-May-16	Chick	Unknown	1004-15597	83 over Z	Blood	2016
JC 15	26-May-16	Chick	Unknown	1004-15598	94 over Z	Blood	2016
Euc 6 Renest	29-Jun-16	Adult	Female	1004-18338	86 over Y	Blood	2016
Euc 6 Renest	29-Jun-16	Chick	Unknown	1004-18336	13 over Z	Blood	2016
Euc 6 Renest	29-Jun-16	Chick	Unknown	1004-18337	24 over Z	Blood	2016
Euc 6 Renest	29-Jun-16	Chick	Unknown	1004-18339	35 over Z	Blood	2016
Lonestar Mound	06-Jun-16	Adult	Female	1004-18325	75 over Y	Blood	2016
Lonestar Mound	06-Jun-16	Chick	Unknown	1004-18326	21 over Z	Blood	2016
Lonestar Mound	06-Jun-16	Chick	Unknown	1004-18327	08 over Z	Blood	2016
Lonestar Mound	06-Jun-16	Chick	Unknown	1004-18328	19 over Z	Blood	2016
LS 109	02-Jun-16	Chick	Unknown	1004-18313	04 over Z	Blood	2016
LS 109	02-Jun-16	Chick	Unknown	1004-18314	26 over Z	Blood	2016
LS 109	02-Jun-16	Chick	Unknown	1004-18315	59 over Z	Blood	2016
LS 13	26-May-16	Adult	Female	1204-61185	35 over Y (White X5)	Blood	2013
LS 13	26-May-16	Adult	Male	1004-18307	81 over Y	Blood	2016
LS 13	26-May-16	Chick	Unknown	1004-18302	29 over Z	Blood	2016
LS 13	26-May-16	Chick	Unknown	1004-18303	Tarsus too small	Blood	2016
LS 13	26-May-16	Chick	Unknown	1004-18304	Tarsus too small	Blood	2016
LS 13	26-May-16	Chick	Unknown	1004-18305	07 over Z	Blood	2016
LS 13	26-May-16	Chick	Unknown	1004-18306	18 over Z	Blood	2016
LS 132	02-Jun-16	Adult	Female	1004-15520	34 over Y	Blood	2015
LS 132	02-Jun-16	Chick	Unknown	1004-18319	09 over Z	Blood	2016
LS 132	02-Jun-16	Chick	Unknown	1004-18320	10 over Z	Blood	2016
LS 132	02-Jun-16	Chick	Unknown	1004-18321	48 over Z	Blood	2016
LS 132	02-Jun-16	Chick	Unknown	1004-18322	51 over Z	Blood	2016
LS 132	02-Jun-16	Chick	Unknown	1004-18323	76 over Z	Blood	2016
LS 142	02-Jun-16	Chick	Unknown	1004-18309	05 over Z	Blood	2016
LS 142	02-Jun-16	Chick	Unknown	1004-18310	16 over Z	Blood	2016

Family/Capture Burrow	Date	Age	Sex	USGS band ID	Aux band ID	DNA Sample	Banding Year
LS 142	02-Jun-16	Chick	Unknown	1004-18311	27 over Z	Blood	2016
LS 142	02-Jun-16	Chick	Unknown	1004-18312	49 over Z	Blood	2016
LS 159	07-Jul-16	Adult	Female	1004-18343	76 over Y	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18344	37 over Z	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18345	58 over Z	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18346	62 over Z	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18347	73 over Z	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18348	84 over Z	Blood	2016
LS 159	07-Jul-16	Chick	Unknown	1004-18349	95 over Z	Blood	2016
LS 176	27-Jul-16	Chick	Unknown	1004-18358	56 over Z	Blood	2016
LS 176	27-Jul-16	Chick	Unknown	1004-18359	67 over Z	Blood	2016
LS 185	19-May-16	Adult	Female	1004-15518	28 over Y	Blood	2015
LS 185	26-May-16	Adult	Male	0804-19773	73 over X	Blood	2014
LS 185	19-May-16	Chick	Unknown	1004-15588	39 over Z	Blood, Feather	2016
LS 185	19-May-16	Chick	Unknown	1004-15589	06 over Z	Blood, Feather	2016
LS 185	26-May-16	Chick	Unknown	1004-18301	50 over Z	Blood	2016
LS 185	09-Jun-16	Chick	Unknown	1004-18329	17 over Z	Blood	2016
LS 185	09-Jun-16	Chick	Unknown	1004-18330	41 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15582	81 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15583	92 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15584	36 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15585	14 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15586	69 over Z	Blood	2016
LS 21	19-May-16	Chick	Unknown	1004-15587	47 over Z	Blood	2016
LS 21	26-May-16	Fledgling	Unknown	1004-18308	28 over Z[1]	Blood	2016
LS 40	07-Jul-16	Adult	Female	1004-18351	45 over Z	Blood	2016
LS 40	07-Jul-16	Adult	Male	1004-18350	30 over Z	Blood	2016
LS 40	07-Jul-16	Chick	Unknown	1004-18352	57 over Z	Blood	2016
LS 40	07-Jul-16	Chick	Unknown	1004-18353	68 over Z	Blood	2016
LS 40	07-Jul-16	Chick	Unknown	1004-18354	74 over Z	Blood	2016
LS 40	07-Jul-16	Chick	Unknown	1004-18355	91 over Z	Blood	2016
LS 40	07-Jul-16	Chick	Unknown	1004-18356	82 over Z	Blood	2016
LS 52	02-Jun-16	Chick	Unknown	1004-18316	32 over Z	Blood	2016

Family/Capture Burrow	Date	Age	Sex	USGS band ID	Aux band ID	DNA Sample	Banding Year
LS 52	02-Jun-16	Chick	Unknown	1004-18317	43 over Z	Blood	2016
LS 97	08-Jul-16	Adult	Female	1004-18357	82 over Y	Blood	2016
LS 97	02-Jun-16	Adult	Male	1004-18318	49 over Y	Blood	2016
LS 97	26-May-16	Chick	Unknown	1004-15599	25 over Z	Blood	2016
LS 97	26-May-16	Chick	Unknown	1004-15600	60 over Z	Blood	2016
Rehab	15-Apr-16	Adult	Unknown	1004-15575	58 over Y	Feather	2016

[1]Banded at LS 13, genetic analysis required for final family assignment.

APPENDIX 3. NECROPSY REPORT FOR BUOW CARCASS FOUND INSIDE LS 60

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WILDLIFE INVESTIGATIONS LABORATORY
California Department of Fish and Wildlife
1701 Nimbus Road, Suite D
Rancho Cordova, CA 95670
Phone: 916-358-2790/Fax: 916-358-2814

Necropsy Report

- FINAL RESULTS –

WIL Case ID: Z16-388	**Species:** Burrowing Owl		**Animal ID:** R Leg: Green 43 over Y L Leg: 1004-15555 USFWS
Collection: 3/18/2016	**Submission:** 3/23/2016	**Sex:** Male	**Age:** Second Year
City, County, State: Otay Mesa, San Diego, CA		**Post-mortem Condition:** Moderate autolysis	
Submitter Information: Colleen Wisinski San Diego Zoo Institute for Conservation Research 15600 San Pasqual Valley Road Escondido, CA 92027 Email: cwisinski@sandiegozoo.org		**Laboratory Contact:** Krysta Rogers Wildlife Investigations Laboratory California Dept. of Fish and Wildlife Email: Krysta.Rogers@wildlife.ca.gov Phone: 916-358-1662	

<u>Clinical History:</u> Burrowing Owl found dead inside artificial burrow chamber at the Lonestar Ridge West Mitigation Site adjacent to commercial development. The burrow tunnels had apparently washed in during recent rain. Inspection of the chamber suggested the owl had become trapped and likely starved to death. The owl is marked with an auxiliary band on the right leg: Green 43 over Y and a USFWS band on the left leg: 1004-15555; the owl was banded as a juvenile on 06/09/2015. The left eye was removed post-mortem and prior to submission to CDFW WIL on 03/23/2016. The carcass was stored in a freezer until the post-mortem exam.

<u>Summary of Findings:</u> This second year male burrowing owl weighs 115g at necropsy. The carcass is moderately autolyzed with mild sloughing of the feathers and noticeable odor. The owl is in poor nutritional condition with no adipose stores and severe atrophy of the pectoral muscles. Dried mud is present on the feathers of the head and wings along the carpal joints and primaries. Dirt also is present on the bill and in the oral cavity. No obvious signs of external trauma are observed. The thyroids appear pink and are of normal size. The lungs are diffusely dark pink and appear wet. The organs are reddish-brown in color. The heart and spleen appear normal. The liver appears atrophied. The spleen is of normal size. The gall bladder is enlarged with bile. The stomach is empty and a brownish-black pasty material overlays the koilin. Bone marrow is present in the femur. No blood is present under the skull and the brain appears normal. The testes are small and inactive.

<u>Laboratory Findings/Diagnosis:</u> Starvation and Anticoagulant Rodenticide exposure

Ancillary testing:

- Negative for West Nile Virus by qRT-PCR (kidney)
- Heavy metals within acceptable limits or not detected (liver; wet weight)
    - Lead, not detected
    - Manganese, 4.9 ppm
    - Mercury, not detected
    - Arsenic, not detected
    - Molybdenum, 0.86 ppm

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Necropsy Report

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– FINAL RESULTS –

  - Zinc, 55 ppm
  - Copper, 15 ppm
  - Cadmium, not detected

- Elevated Iron 1,200 ppm (liver; wet weight)
- Anticoagulant rodenticide screen positive for Brodifacoum (Trace) and Difethialone (0.12 ppm) (liver)

Comments: Cause of death is starvation based on the lack of adipose stores, severe atrophy of the pectoral muscle, atrophy of the liver, and enlarged gall bladder which is consistent with the history of the owl being trapped in its burrow without access to food. Additionally, the Iron level in the liver is significantly elevated which is a common finding for emaciated raptors (average for healthy burrowing owls is 240 ppm (n = 5)). The anticoagulant rodenticides, Brodifacoum and Difethialone, were detected in the liver. However, no signs of coagulopathy were observed suggesting exposure rather than intoxication.

Gross necropsy was performed at CDFW WIL on 03/23/2016
Final report issued on 12/14/2016

APPENDIX 4. ARTIFICIAL BURROW CONDITION DATABASE DEVELOPMENT AND CURRENT RECOMMENDATIONS

Creation of new artificial burrow database

In this appendix we provide the outline format for the proposed county-wide database to track the condition of artificial burrows. We provide site-level recommendations for needed maintenance action in MU3, and list recent information about the status of individual burrows at these sites.

Proposed format of database

We suggest a relational database format with two tables linked by site: 1) a table for recording site-level data and 2) a table for recording information about specific burrows. To make the database simple and user-friendly, we suggest keeping only one record per burrow, and updating the single record each year with updated information. This approach is focused on keeping only the most recent information about burrows. The downside to this approach is that the database usage for other data-mining purposes will be limited. We considered whether it would be practicable to ask managers to update a three-table relational database (designed to store separate burrow reports through time), and at this time we believe this would place too great a burden on managers.

However, we further suggest that managers keep and update their own Excel version of the burrow table, which would keep a full record of specific land manager notes through time, along with room for the addition of other user-defined fields. The proposed format follows:

Table A4-1. Proposed format of Site table

Field	Description or Categories
Site	Name of the preserve or parcel
Land ownership	Name of agency or other owner
Manager	Name of the current manager
Contact info	Current phone and email of the manager
MSCP conservation status (MSCP_CN layer)	This can be found in the MSCP_CN layer in the SanGIS Data Warehouse
Habitat type	native grassland, non-native grassland, disturbed, desert grassland, coastal scrub
Vernal Pool	Y/N
Current vegetation management regime	grazing, mowing, herbicide, burning
Management frequency	monthly, annual, infrequently as needed
Squirrel presence at site	Y/N
BUOW presence at site	Y/N

Table A4-2. Proposed format of Burrow table

Site	Linked to Site field in Site table
Burrow ID	Unique identifier
Date	MM/DD/YYYY
Burrow condition	Categories: good, fair, poor
Condition notes	
Burrow maintenance needed	Categories: clean nest box, clean entrance, repair entrance, repair belowground tunnel or chamber (heavy equipment needed)
Closed	Categories: Y/N
Vegetation management needed	Categories: mowing, grazing, herbicide
Additional action items	
Evidence of BUOW use of burrow	Categories: pellets, feathers, whitewash
Additional fields (user-defined)	Location of photos and/or additional information in table/report formats

Reporting schedule

By October 1 of each year, managers should submit their end-of-breeding season evaluation of burrow condition (good/fair/poor). If burrow condition is fair or poor, or there is another clear need for maintenance, then a list of needed action items to bring the burrow back into good condition should also be provided.

By the following February 1, before the beginning of the BUOW breeding season, managers should submit reporting on the completion of tasks.

Additionally, some management tasks will need to occur after February 1st to be effective, such as vegetation management after spring growth. Manual removal of vegetation in proximity to burrow entrances during breeding season should also occur. Care should be taken to minimize any disturbances to occupied burrows.

2016 Artificial Burrow Recommendations for Management Unit 3

Recommendations are based on ICR's current knowledge of the artificial burrows at the following sites. Details about these burrows may be found in the table of burrow information following this page.

Site	Condition notes	Recommendations
Lonestar	All burrows modified in late 2015 with chimneys, except for two: 1. The hack burrow on the west end of the southern berm. Excavated by coyotes, but believed repaired in 2016. 2. AB 132 was left unmodified to avoid disturbing natural squirrel burrows in immediate vicinity.	1. Hack burrow repair should be confirmed. Burrow should be modified with chamber chimney. 2. AB 132 should remain unmodified as long as squirrels are active around it.
Johnson Canyon	All burrows modified in late 2015 with chimneys. Pack rats continue to block the burrow entrances with cholla.	1. Check condition of all burrows by October 1 of each year. 2. Clean out all burrows
Dennery Canyon	Most burrows lack peeper access to chambers, and many burrows have hanging entrances unlikely to be used by BUOW.	1. All burrows need to be fully refurbished (tunnels reset, chimney access installed). 2. We are not recommending closure at this time due to the fluid habitat situation on Otay Mesa. Future need for these burrows is unknown.
LORBOMA	Burrows on the ridgetop have chamber access, but burrows at base of ridge do not.	1. Burrows at base of ridge should be refurbished with chamber access.
Sweetwater-Shinohara	Burrows have wooden chambers that lack access. Squirrel activity in the area is extensive, and squirrels have "taken over" many of the burrows. The burrows can't be checked or cleaned out, but the squirrel activity at the site supports BUOW.	1. Burrows should be left as is until a more intensive management need for them arises.
Sweetwater-Mother Miguel	Most burrows are in good condition but lack access to burrow chambers and peeper tubes. Squirrel activity at this site is lower than at Shinohara.	1. Burrows should be left as is until a more intensive management need for them arises. 2. Condition should be assessed but "peeping" through the tunnels may not be possible due to wooden tunnels. Consider modifications.
Rancho Jamul Ecological Reserve	15 new burrows were installed in 2016 with three different configurations. One configuration appears to outperform the other two in maintaining even chamber temperature and humidity. In addition, 12 older burrows are present. These lack chimneys and peeper tubes, and some have very short entrance tunnels.	1. Discuss and decide whether to reinstall 10 new burrows with the optimal configuration and wooden chambers. 2. Modify older burrows with chimney access to chamber. Replace short tunnels if possible.
Sweetwater Authority	Number and condition of artificial burrows unknown at this time.	1. Obtain information on burrows from Pete Famolaro and make recommendations if necessary.

Artificial Burrow Status by Site

The following table lists the most recent information on specific burrows in MU3. The table lists the burrow ID, GPS location, most recent condition information, other notes, level of access to the nesting chamber, and whether the burrow has been modified already with the chimney-type bucket access.

In an effort to make pre-existing artificial burrows more useful for both management and research, the artificial burrows at the Lonestar Ridge West and Lonestar Ridge East (Johnson Canyon) Mitigation sites were modified in late 2015. The goal of the modification was to allow access to the burrow chambers in order to be able to monitor the condition of and clean out the burrow chambers for management and allow us to collect productivity data, install iButtons, and monitor nests to facilitate conservation research. At nearly all burrows, a "chimney" modification was installed that included attaching a bucket with the bottom removed to the top of the existing chamber box (Johnson et al. 2010).

Key for Burrow Modifications

- **Single bucket with lid**: 5 gallon bucket closed with lid.
- **Single collared bucket with lid:** Single 5 gallon bucket with top removed, placed around bottom of bucket, and secured as a collar. Bucket closed with lid.
- **Tall bucket with lid:** Single tall 6 gallon bucket closed with a lid.
- **Two buckets:** Two 5 gallon buckets stacked. One has access to the chamber through the bottom, the other placed inside the first and filled with dirt and rocks to secure and seal it.
- **Two buckets with collar:** Same as two buckets above, but with the top of a third bucket secured around the outside bucket to increase the height of the chimney.

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Dennery Canyon	1 (102)	32.57279	-117.014	Fair	Woodrat activity; both entrances blocked by loose cholla		
Dennery Canyon	2 (no stake)	32.57289	-117.013	Fair	Woodrat activity; both entrances blocked by loose cholla		
Dennery Canyon	3 (103)	32.57291	-117.013	Fair	Woodrat activity; both entrances blocked by loose cholla		
Dennery Canyon	4 (no stake)	32.57325	-117.013	Fair	Woodrat activity west entrance blocked by loose cholla; snake skin shed in one entrance; debris/cobwebs in south entrance		
Dennery Canyon	5 (no stake)	32.57375	-117.013	Poor	Elevated entrances; Woodrat activity; both entrances blocked by loose cholla		
Dennery Canyon	6 (105)	32.57353	-117.012	Fair	South entrance has debris and cobwebs; West entrance clogged by loose cholla		
Dennery Canyon	7	32.57371	-117.012	Fair	South entrance has debris and cobwebs; West entrance blocked by sticks		
Dennery Canyon	8	32.57368	-117.012	Fair	South entrance blocked by loose cholla; West entrance blocked with sticks and loose cholla		
Dennery Canyon	9	32.57416	-117.012	Poor	Woodrat resident; debris and woodrat feces		
Dennery Canyon	10 (106)	32.57401	-117.012	Poor	Extensions; woodrat scat; West entrance has cobwebs	peeper tube	
Dennery Canyon	11	32.57409	-117.012	Poor	Extensions; both entrances have sticks and cholla	peeper tube	
Dennery Canyon	12 (108)	32.57635	-117.014	Poor	West entrance has barn owl feather; East entrance has cholla debris and scat; woodrat resident		
Dennery Canyon	13 (no stake)	32.57651	-117.014	Poor	West entrance dug out by coyote; East Entrance filled in		
Dennery Canyon	14	32.57636	-117.013	Poor	Elevated entrances; cobwebs and cholla. Debris and droppings at West Entrance		
Dennery Canyon	15	32.57603	-117.013	Poor	Extensions; North entrance has debris, droppings, scat. South entrance has cobwebs and debris.	peeper tube	
Dennery Canyon	16	32.5762	-117.013	Poor	Extensions; Both entrances have cholla, sticks, droppings. Huge rattlesnake shed.	peeper tube	

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Dennery Canyon	17	32.57609	-117.013	Poor	West entrance filled in with sticks. South entrance filled with cholla, sticks and droppings. Snake shed.		
Johnson Canyon	1	32.580245	-116.951203	Poor			two buckets
Johnson Canyon	2	32.580182	-116.951250	Poor	N entrance filled in, South open but blocked by shrubs.		single collared bucket with lid
Johnson Canyon	3	32.58085	-116.951	Poor	1 entrance full of cholla, couldn't find second entrance.		single collared bucket with lid
Johnson Canyon	4	32.58106	-116.951	Poor	Both entrances filled with cholla		two buckets
Johnson Canyon	5	32.58154	-116.952	Fair	Rabbit activity		two buckets
Johnson Canyon	6	32.58222	-116.952	Good	Used as breeding burrow in 2013.		two buckets
Johnson Canyon	7	32.58254	-116.952	Fair	West entrance--filled; North entrance--rabbit activity		single collared bucket with lid
Johnson Canyon	8	32.5827	-116.952	Good	South entrance--rabbit activity; North entrance--old BUOW sign, little damage		two buckets
Johnson Canyon	9	32.58291	-116.952	Poor	South entrance--lots of coyote damage; East entrance--beehive, honeycomb in entrance		two buckets
Johnson Canyon	10	32.58253	-116.952	Good	East entrance--rabbit activity; West entrance--BUOW activity		two buckets
Johnson Canyon	11	32.58251	-116.952	Good	Rabbit sign		two buckets
Johnson Canyon	12	32.58226	-116.952	Good/Fair	South entrance--blocked by cholla; North entrance--rabbit activity		single bucket with lid
Johnson Canyon	13	32.58208	-116.952	Fair	North entrance partially filled in		single bucket with lid
Johnson Canyon	14	32.58325	-116.952	Good	West entrance--partially dug up		two buckets
Johnson Canyon	15	32.58202	-116.952	Good			single collared bucket with lid
Johnson Canyon	16	32.58186	-116.953	Good	South entrance--small cholla		single collared bucket with lid

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Johnson Canyon	16	32.58186	-116.953	Good	South entrance--small cholla		single collared bucket with lid
Johnson Canyon	17	32.58192	-116.953	Good	Chamber and nest dug out partially, entrances chewed on	accessible from top	Did not modify
Johnson Canyon	18	32.58158	-116.953	Good			single bucket with lid
Johnson Canyon	19	32.58157	-116.953	Fair	Rabbit activity; one entrace open, one entrance has cholla		two buckets
Johnson Canyon	20	32.58124	-116.953	Fair	Beehive in entrance		single bucket with lid
Johnson Canyon	21	32.58147	-116.953	Good	South entrance--shrubs; North entrance--lots of cholla		single collared bucket with lid
LORBOMA	30	32.62206	-116.916	Good	West entrance--BUOW sign, East entrance--woodrat sign	accessible from top	
LORBOMA	31	32.62218	-116.916	Good	Woodrat sign	accessible from top	
LORBOMA	32	32.62197	-116.916	Good	Rabbit sign	accessible from top	
LORBOMA	33	32.62221	-116.916	Good	Coyote/bobcat sign	accessible from top	
LORBOMA	34	32.62214	-116.916	Fair	Bobcat sign; East entrance--pipe dug up	accessible from top	
LORBOMA	35	32.62233	-116.916	Good		accessible from top	
LORBOMA	36	32.62237	-116.916	Good		accessible from top	
LORBOMA	37	32.62235	-116.915	Good		accessible from top	
LORBOMA	38	32.62216	-116.915	Good		accessible from top	
LORBOMA	39	32.62238	-116.915	Good		accessible from top	
LORBOMA	40	32.62216	-116.915	Good/Fair		accessible from top	

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
LORBOMA	41	32.62063	-116.915	Good			
LORBOMA	42	32.62058	-116.915	Good			
LORBOMA	43	32.6207	-116.916	Good			
LORBOMA	44	32.6204	-116.916	Good			
LORBOMA	45	32.62042	-116.916	Good			
LORBOMA	46	32.62046	-116.915	Good			
LORBOMA	47	32.62061	-116.917	Good	vegetation in entrance		
LORBOMA	48	32.62052	-116.916	Good			
LORBOMA	49	32.6205	-116.916	Good	Small *Malosma* near South entrance		
LORBOMA	50	32.62036	-116.916	Good			
LORBOMA	51	32.62023	-116.916	Good	Rabbit activity		
LORBOMA	52	32.62027	-116.916	Good	Rabbit activity		
Shinohara	1	32.68338	-116.991	Fair	Squirrel Activity		
Shinohara	2	32.68371	-116.991	Fair	Squirrel Activity		
Shinohara	3	32.68454	-116.991	Fair	Squirrel Activity		
Shinohara	4	32.68487	-116.991	Poor	Lots of squirrel activity, artificial burrow buried by squirrels		
Shinohara	5	32.6857	-116.99	Fair			
Shinohara	6	32.68591	-116.989	Poor	Squirrel shoulder blade, squirrel digging; tunnel damaged		
Shinohara	7	32.68553	-116.989	Fair	Squirrel digging, Squirrel bone?		

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Shinohara	8	32.68706	-116.988	Fair/Poor	Lots of Squirrel digging		
Shinohara	9	32.68635	-116.988	Fair/Poor	Squirrel digging		
Shinohara	10	32.68604	-116.988	Fair/Poor	Squirrel digging		
Mother Miguel	11	32.68739	-116.983	Good	Weeds at both entrances		
Mother Miguel	12	32.68725	-116.983	Poor	East entrance visible, half buried		
Mother Miguel	13	32.6863	-116.983	Fair	both entrances have weeds, ArtCal in east entrance (and rattlesnake seen), potential BUOW sign 30m to W		
Mother Miguel	14	32.68659	-116.983	Good/Fair	Weeds at both entrances		
Mother Miguel	15	32.68558	-116.982	Good	Both entrances look O.K. Coyote Scat		
Mother Miguel	16	32.68577	-116.982	Poor	Only East entrance visible, half filled in		
Mother Miguel	17	32.68537	-116.981	Good/Fair	ArtCal in East entrance, potential BUOW sign 20m to NW		
Mother Miguel	18	32.68565	-116.981	Fair	Weeds in West entrance		
Mother Miguel	19	32.6862	-116.981	Good			
Mother Miguel	20	32.68621	-116.98	Good	North entrance filled in/buried		
Goat Mesa	1	32.55188	-117	Good	Digging in SE corner of mound; Southern Pacific Rattlesnake in S entrance		
Goat Mesa	2	32.55181	-117	Good	Loose dirt in N ent (rodent?); digging in SE corner of mound; tall sign post immediately behind N entrance (probably too close)		
Goat Mesa	3	32.55168	-117	Good	Southern Pacific Rattlesnake in N entrance		

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Goat Mesa	4	32.55331	-117	Good	W entrance has been repaired		
Goat Mesa	5	32.55349	-117	Good			
Goat Mesa	6	32.55368	-117	Good	W entrance has been repaired		
Rancho Jamul	1	32.68009	-116.847	Fair			
Rancho Jamul	2	32.68022	-116.848	Fair			
Rancho Jamul	3	32.68022	-116.848	Fair			
Rancho Jamul	4	32.68036	-116.848	Fair			
Rancho Jamul	5	32.68046	-116.848	Fair			
Rancho Jamul	6	32.68056	-116.848	Fair			
Rancho Jamul	7	32.68087	-116.848	Fair			
Rancho Jamul	8	32.68064	-116.847	Fair			
Rancho Jamul	9	32.68045	-116.847	Fair			
Rancho Jamul	10	32.67797	-116.849	Fair			
Rancho Jamul	11	32.67758	-116.852	Fair			
Lonestar	3	32.5756	-116.971		wood	peeper tube	two buckets
Lonestar	7	32.57599	-116.97		plastic	peeper tube	two buckets
Lonestar	13	32.57654	-116.969		wood	peeper tube	two buckets with collar

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Lonestar	14	32.57658	-116.97		plastic	peeper tube	two buckets with collar
Lonestar	21	32.57615	-116.971		wood	peeper tube	two buckets with short collar
Lonestar	23	32.57645	-116.97		wood	peeper tube	two buckets
Lonestar	27	32.57688	-116.971		plastic	peeper tube	two buckets with collar
Lonestar	28	32.57684	-116.97		plastic	peeper tube	two buckets
Lonestar	36	32.57842	-116.97		plastic	peeper tube	two buckets
Lonestar	40	32.57838	-116.969		wood	peeper tube	two buckets with short collar
Lonestar	42	32.57842	-116.968		wood	peeper tube	two buckets
Lonestar	44	32.57867	-116.969		plastic	peeper tube	single collared bucket with lid
Lonestar	47	32.5791	-116.969		plastic	peeper tube	two buckets
Lonestar	52	32.57872	-116.97		wood	peeper tube	two buckets with collar
Lonestar	53	32.5792	-116.97		wood	peeper tube	single (short) collared bucket with lid
Lonestar	60	32.57954	-116.969		wood	peeper tube	two buckets
Lonestar	67	32.57988	-116.969		plastic	peeper tube	two buckets
Lonestar	70	32.58023	-116.969		wood	peeper tube	two buckets
Lonestar	97	32.58072	-116.966		plastic	peeper tube	Did not install bucket, covered with heavy rocks.
Lonestar	100	32.58055	-116.965		wood	peeper tube	two buckets with lid

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Lonestar	102	32.58009	-116.966		plastic	peeper tube	One tall bucket with lid
Lonestar	105	32.57978	-116.965		wood	peeper tube	two buckets
Lonestar	107	32.57961	-116.966		wood	peeper tube	two buckets
Lonestar	109	32.57951	-116.967		wood	peeper tube	two buckets
Lonestar	112	32.57882	-116.967		plastic	peeper tube	two buckets
Lonestar	113/114	32.57882	-116.967		plastic	peeper tube	single collared bucket with lid
Lonestar	121	32.57918	-116.965		wood	peeper tube	two buckets (one tall)
Lonestar	128	32.5797	-116.964		plastic	peeper tube	two buckets (one tall)
Lonestar	129	32.57965	-116.964		plastic	peeper tube	two buckets
Lonestar	132	32.5798	-116.965		wood	peeper tube	Did not modify
Lonestar	133	32.58013	-116.964		wood	peeper tube	two buckets
Lonestar	142	32.58137	-116.964		plastic	peeper tube	two buckets
Lonestar	144	32.58123	-116.964		plastic	peeper tube	two buckets
Lonestar	146	32.58087	-116.964		plastic	peeper tube	two buckets
Lonestar	148	32.5803	-116.963		wood	peeper tube	two buckets
Lonestar	150	32.58003	-116.963		wood	peeper tube	two buckets
Lonestar	159	32.57912	-116.962		plastic	peeper tube	two buckets
Lonestar	160	32.57892	-116.962		wood	peeper tube	two buckets
Lonestar	166	32.57735	-116.963		plastic	peeper tube	two buckets

Site	Burrow # (Field)	Latitude	Longitude	Condition	Notes	Chamber Access?	Modification
Lonestar	168	32.5774	-116.963		wood	peeper tube	two buckets (one tall)
Lonestar	170	32.57603	-116.965		plastic	peeper tube	two buckets (one tall) with collar
Lonestar	175	32.57589	-116.965		plastic	peeper tube	two buckets (one tall)
Lonestar	176	32.57584	-116.965		wood	peeper tube	two buckets (one tall)
Lonestar	180	32.5756	-116.964		wood	peeper tube	two buckets
Lonestar	185	32.57588	-116.967		wood	peeper tube	two buckets with collar
Lonestar	190	32.57568	-116.967		plastic	peeper tube	two buckets with collar
Lonestar	193	32.57749	-116.967		plastic	peeper tube	two buckets
Lonestar	194	32.57757	-116.967		wood	peeper tube	two buckets with collar
Lonestar	200	32.57753	-116.966		wood	peeper tube	two buckets
Lonestar	201	32.5775	-116.966		plastic	peeper tube	two buckets