Project Report 2014

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 fourth year's progress in a multi-year program with the goal of developing a strategy to assist in the recovery of Western burrowing owls (BUOW; *Athene cunicularia hypugaea*) and their grassland ecosystem in San Diego County. There are two major components to this program. One project is designed to restore certain components of the grassland ecosystem to better support BUOW, focusing on exotic vegetation management and re-establishing fossorial mammals that dig burrows that BUOW depend on for nesting. The other project involves a series of studies designed to understand the ecological drivers and anthropogenic threats influencing BUOW population performance in San Diego County. This work is done in collaboration with San Diego State University (SDSU) and other partners.

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 burrowing owls, re-establishment of this species is a crucial component of any sustainable recovery plan for burrowing owls and the larger ecosystem. The installation of artificial burrows is an important management tool, but determining the relative effectiveness of these burrows requires research. Further, the use of artificial burrows is not self-sustaining and requires continuing high levels of resources to manage and replace them, whereas ground squirrels can become self-sustaining ecosystem engineers. Our program addresses both problems simultaneously: re-establishing natural burrows and improving artificial burrow deployment.

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. As a prerequisite to re-establishing squirrels, it is essential to know the factors influencing their distribution and abundance. We conducted county-wide surveys for squirrel burrows and habitat covariates and found that key habitat variables associated with squirrel burrow presence included less vegetative cover, higher percent sand and lower percent gravel and clay in the soil. Thus, a habitat suitability model indicates that squirrels will be successfully re-established at sites with more open habitat and soils that are conducive to digging. No further work was conducted on this project in 2014, but details are available in previous reports.

One of our primary objectives has been the development of ground squirrel translocations as a tool for creating BUOW habitat. We employed soft-release protocols that address ecological needs and species life-history characteristics to maximize chances of success. Details of lessons learned from these translocations and modifications to protocols have been reported previously, and results and analyses from long-term monitoring are reported here. To create better habitat for BUOW, we conducted experimental manipulations of vegetation habitat (a SDSU-led component) and we implemented a squirrel translocation program 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. Several experimental replicates were established and we examined the effects of several variables, including vegetation treatments and site habitat variables. We also included control replicates subjected to vegetation treatments but not squirrel translocation to determine if translocation was necessary or if managers could rely on natural squirrel dispersal.

Although squirrel survival rates were unexpectedly low, in most locations a sufficient number of squirrels remained to establish burrow systems, over-winter and commence with reproduction. Supplemental translocations to reinforce release sites had higher survival rates, possibly attributable to the presence of conspecifics or, alternatively, due to modifications we made to the release methods as part of adaptive management. Squirrels released into control plots without vegetation treatment rapidly dispersed and settled in treated areas where thick invasive grasses had been mowed. SDSU-led research indicated that squirrels had significant ecosystem engineering effects, creating more than 1000 burrows, 95% of which were located on translocation sites. The cost and effort involved in creating 1000 artificial burrows would be very high by comparison. The lack of recruitment of squirrels to matched-control sites indicates that in areas without nearby large squirrel populations, vegetation treatment alone will not encourage rapid colonization by squirrels. Taken together, these data indicate that the best management tool will often be to conduct vegetation treatment and translocate squirrels: either action in isolation did not result in success for our experiments (but see below for an exception).

The most important site characteristic predicting squirrel survival at the release site was soils, a finding consistent with the results from our habitat suitability model. More squirrels established on sites with metavolcanic rock, which has less soil compaction than the alluvial deposits where squirrel establishment was less successful. In addition, the presence of clay in the soils predicted dispersal, with squirrels moving farther if released on sites with high clay content. The clear implication of these findings is that efforts to establish squirrels on landscapes with unsuitable soils are likely to be fraught with difficulty.

We also conducted a pilot study in collaboration with the California Department of Fish & Wildlife to examine the possible conditions under which natural squirrel dispersal might be encouraged. Following the implementation of grazing 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. We found evidence for moderate levels of dispersal and burrow creation following grazing, but did not find support for our hypothesis that provision of cover for predator evasion would influence colonization. Results are preliminary, but hold promise that BUOW habitat may be created, albeit more slowly, by vegetation management alone, provided a large enough colony of squirrels is in proximity.

Our second major program involves a series of studies on BUOW with the long-term goal of understanding the ecological and anthropogenic factors that influence BUOW population dynamics to inform management strategies for San Diego County. These studies were selected to work in combination so that the sum of the results can provide greater insights than if they each were conducted in isolation. Three principle studies were implemented: (1) BUOW nesting and foraging ecology, using camera traps to monitor reproduction, survival, and prey delivery at nest burrows and data loggers to monitor microclimatic conditions at natural and artificial burrows; (2) a pilot study on BUOW population ecology using leg bands for individual identification; and (3) a pilot study on BUOW spatial ecology using GPS data loggers to monitor home range movements during the breeding season.

Reproductive success appears related to the frequency of prey deliveries and potentially the type of prey. Importantly, there is substantial variation among burrows in the proportion of invertebrate vs. vertebrate prey, indicating that some home ranges may be of higher quality than others. However, owls living at these burrows do not appear to increase their foraging range to access higher quality prey, and this appears to have impacts on reproductive success. This is an important consideration: BUOW may not show adaptive behavior to poor foraging conditions by expanding home range, thus managers will need to take special consideration when siting artificial burrows or encouraging BUOW colonization. If burrows are sited in poor foraging habitat, they may become an ecological trap, drawing in owls to areas of low productivity.

Our data also reveal that chick mortality (and perhaps egg mortality, which is more difficult to document) is a significant issue potentially limiting population recruitment. Sources of mortality vary in time and space, but two primary sources appear to be predators and infanticide. Infanticide is likely driven by other ecological conditions that make rearing of chicks more difficult, again pointing to possible habitat influences on productivity. Predation is not well understood in BUOW but it is clear that anthropogenically subsidized predators such as ravens (and possibly coyotes) have the potential to negatively impact these small vulnerable populations. Establishing new recovery sites for BUOW that are more removed from areas where these opportunistic predators are subsidized by human activities may help minimize this problem. If that is not possible, managers should be aware of the problem and consider predator control options if necessary.

We also initiated new research to determine the efficacy of artificial burrows as a strategy for recovering BUOW populations. Artificial burrows are an important management tool, but it is important to understand their limitations, and whether they can be improved. Our preliminary data suggest that reproductive success is lower in artificial than natural burrows, leading us to evaluate factors that may potentially explain this difference. Of course, natural and artificial burrows may differ with regard to many ecological variables, including the surrounding habitat, predation pressure, and foraging opportunities. Thus placement of artificial burrows needs to be closely scrutinized to ensure that we are not creating ecological traps, drawing in owls to areas of high mortality or low reproductive success. We evaluated microclimatic differences between artificial and natural burrows and found that artificial burrows performed more poorly in providing a stable microclimate buffering the nests from changes in outside temperature and humidity. It is plausible that the microclimate inside burrows led to egg or chick loss, explaining the lower reproductive success found in artificial burrows. Fortunately, this information is readily included in management strategies, as simple changes in the design of artificial burrow may bring about improvements.

The GPS telemetry data provide important information on the movements of owls, allowing us to determine where they forage and what risks they might encounter during the nestling period. Combining these data with information about prey delivery derived from our camera trap study, which is a major focus of our work in 2015, will allow us to understand how home range relates to access to prey. We also are conducting habitat surveys to characterize the vegetation and combining these data with geospatial information available for topography, soils, and other landscape features. In combination, these data will allow us to determine how the habitat characteristics in BUOW home ranges relate to foraging success, including the type and frequency of prey delivery to dependent offspring. These data in turn will be combined with our data on reproductive success, allowing us to correlate all of these variables with the number of chicks fledged. Our camera trap data also provide information on predation and other sources of mortality, and each of these factors may be associated with habitat characteristics and threats present in the home range. This combination of research efforts will give us a remarkable and unprecedented picture of the ecological factors driving population performance, which can serve as a roadmap for site selection for BUOW recovery and provide informed guidance for management of habitat for BUOW.

When establishing new areas for recovery of BUOW, criteria for site selection may be developed based on data from our research on ground squirrel and BUOW ecology and habitat assessments, as well as existing information available in the literature on the species. Evaluating and identifying potential BUOW recovery nodes is critical since the breeding population has been reduced to a single small population, posing a considerable risk of local extinction in San Diego County. These additional sites could help lower the risk and help increase BUOW population size.

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. Much data has been collected over the last 4 years through this collaborative adaptive management and research program. Findings and lessons learned from this program will form the basis for an appropriate management plan. The plan will include population viability estimates, key factors for establishing new breeding sites, optimal relocation techniques for both ground squirrels and BUOW, critical areas within the MSCP needed for protection, comparisons of management strategies, and management recommendations.

Table of Contents

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 (*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 burrowing owls.

Because the California ground squirrel is a "keystone" species that helps engineer California grassland ecosystems and provides critical resources for burrowing owls, re-establishment of this species is a crucial component of any recovery plan for burrowing owls 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 interactivity (Kotliar et al. 2006).

In 2011, the Institute for Conservation Research (ICR) and the Institute for Ecological Modeling and Management (IEMM) initiated a program to assist in the recovery of western burrowing owls 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, burrowing owls.

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 burrowing owl is found is less reliant on repeated human intervention. Our aim is to create suitable burrowing owl 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 burrowing owls and continued pilot work using camera traps at owl nest burrows. In year three (2013), we expanded our research on burrowing owls, 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. By obtaining a better understanding of the factors regulating population dynamics of burrowing owls, in terms of reproduction, survival, recruitment, and movement patterns, the results from this research will help inform the effective long-term management of burrowing owls in San Diego County. In 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 burrowing owls, 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. Results from this research will be incorporated into a strategic management plan to help conserve burrowing owls in this region.

The goals for 2014 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 burrowing owl nesting and foraging ecology by:
    - Using camera traps at active breeding burrows to document parental care, prey provisioning, predation/predators, and other visitors,
    - Comparing results from natural and artificial burrows,
    - Monitoring condition of artificial burrows and recommending repairs;
4. Examine burrowing owl population ecology through:
    - Banding and collecting genetic material from owls,
    - Monitoring reproductive output;
5. Examine burrowing owl spatial ecology using GPS dataloggers.

Personnel

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

Field Team—Squirrel monitoring:
Field Organizer: JP Montagne (ICR in-kind contribution)
Field Technician: Andrew Heath

Volunteers: Sara Alhawi, Megan Cookson, Amy Downey, Angelique Herman, Berlin Hernandez, Bryan King, Michael Macias, Jim Marsh, Chris Morrissey, Eliana Moustakas, Alanna Oakes, Rafael Rabines, Katrina Stenson (SDZG); 400 total hours.

Field Team—Burrowing owl monitoring:
Field Organizer (BUOW ecology): Colleen Wisinski, M.S.
Field Organizer (BUOW habitat): Susanne Marczak
Expert advisors: Jeff Lincer, Ph.D. (BUOW), Mathias Tobler, Ph.D. (software, data management; ICR in-kind contribution)
Field Technician: Elizabeth Reid-Wainscoat
Volunteers from San Diego Zoo Global (ICR in-kind contribution): Kathleen Esra, Stephanie Gobert, Carina Graham, Andrew Heath, Chris Heisinger, Kate Lambert, Kaye London, Gloria Marselas, Sara Meszaros, Sarah Palmer, Steve Rose, Subashini Sudarsan; ~700 total hours

Permits
Fieldwork was conducted under the CDFW Scientific Collecting Permits of Colleen Wisinski (SC-11839), Jeff Lincer (SC-1606), and JP Montagne (SC-11422). Burrowing owl 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, #14-009.

LONG-TERM MONITORING OF CALIFORNIA GROUND SQUIRREL TRANSLOCATIONS

Introduction

As a means to improve grassland habitat for burrowing owls 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). 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). 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). Our own translocation project met with mixed success and we have made carefully documented and controlled alterations to the release strategy, following adaptive management procedures, to increase squirrel survival.

Detailed reports on outcomes and methodologies of previous translocations as part of this project can be found in previous annual reports. In 2014, we monitored persistence of squirrels at six experimental plots in two release sites to assess minimum survival and retention of two plots established in 2012 and recorded colony persistence at four plots established in 2011.

Methods

We used the modified trapping methods and procedures described in Wisinski *et. al.* 2013.

Release sites

In 2014 we visited Rancho Jamul Ecological Reserve (Jamul) and San Diego National Wildlife Refuge (Sweetwater), two conservation areas located within southwestern San Diego County and described in previous reports (Swaisgood & Lenihan 2012; Wisinski *et. al.* 2013).

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

We first monitored persistence of squirrel colonies at the four release plots: Sweetwater East (SE) located in Sweetwater, Jamul South (JS), Jamul West (JW), and Jamul East (JE) in Rancho Jamul which were established in 2011 but received no translocations or habitat manipulation since 2012. . We also monitored minimum survival and retention at Jamul Baja (JB) and Jamul Central (JC). These two plots were established in 2012 and had received translocated squirrels nine months prior to monitoring. We conducted 2014 surveys between late May and the end of June using the same protocol as 2013: trapping twice daily, morning and evening.

Data analysis

Minimum long-term persistence — more than one year since last translocation to 2011 plots

We did not statistically analyze squirrel persistence at the 2011 plots due to very low capture numbers but we provide a summary in the results and discussion sections below.

Minimum survival and retention — Supplemental translocation to 2012 plots

The goal of this analysis was to determine the factors that best explain the success or failure of ground squirrel translocation, modeling the effects of ecological factors and release methods on squirrel survival and dispersal off translocation release plots. We modeled the persistence of 566 translocated squirrels with logistic regression in JMP 11 considering the effect of sex, year, release site, release type, release plot, and geology for the six plots that received two years of translocations (Table 1). Release plot was nested within geology and release site. We included the following interaction terms: geology*sex, geology*year, release site*release type and year*release type.

We also used linear regression to model the effects of ecological factors on colony persistence measured as the proportion of all squirrels retained per plot. We calculated this metric as the total number of all captured squirrels (including progeny and local recruits) divided by the number released the previous year for each plot and each translocation (Table A1.1). We used the same variables listed in Table 1 and the following interaction terms: geology*sex, geology*year, release site*release type, release plot*sex, and release site*sex.

In both analyses we used an information theoretic approach to evaluate models based on Akaike information criterion for small sample sizes (AICc). We retained all models within two AICc units of the model with the lowest AICc score within a confidence set, and used model averaging to calculate new weighted parameter estimates. We compared the relative importance of parameters and report odds ratios for the logistic regression.

Table 1. Description and values of independent variables used in spring capture analysis. *Spring capture is our dependent variable, in bold italics.*

Variable	Description	Possible values
Spring capture	***Was the squirrel trapped during spring trapping?***	***Yes, No***
Sex	Sex (missing data for 8 individuals)	Male, Female
Year	Calendar year of June trap monitoring	2012, 2013, 2014
Release site	Conservation areas where squirrels were released	Jamul, Sweetwater
Release type	Initial Release type (early summer) vs. Supplemental (late summer)	Initial, Supplemental
Release plot	Plot to which individuals were moved for both release types	JB, JC, JE, JS, JW, SE
Geology	Geological formation derived from SanGIS	Metamorphic rock, Alluvial deposit

Results

Long-term monitoring

Minimum long-term persistence — more than one year since last translocation 2011 plots

We monitored colony persistence on the four 2011 plots between 26 May and 13 June, after two years without active management. We detected six squirrels through capture or observation: SE=3, JE=1, JW=2, and JS=0 (Figure 1). Although this number is low compared with the number of squirrels translocated to these sites, we know that trapping greatly underestimates squirrel abundance. Additionally, drought conditions may have caused squirrels to estivate earlier thus lowering capture rates (see below). All squirrels were captured only during the morning trapping sessions. The three squirrels from the Jamul plots were juveniles, and the three from the Sweetwater plot were adult-sized, but may have been young of the year. We observed two juvenile squirrels at JW but only captured one.

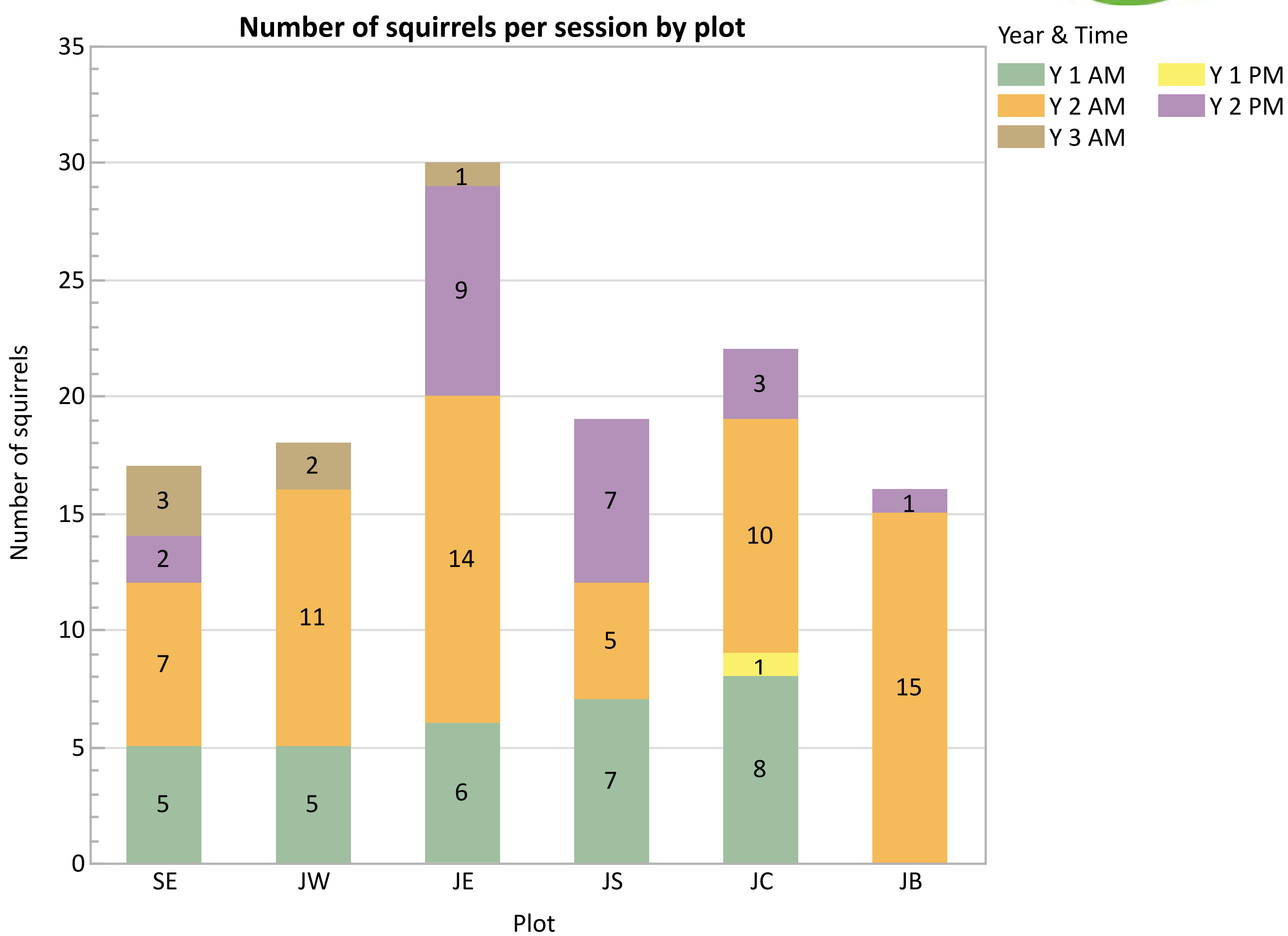

Figure 1. Summary of the number of squirrels captured on each plot one, two and three year(s) following translocation. *These numbers include translocated individuals, their progeny and immigrants from local populations. After 2011, we increased sampling by adding an evening session, therefore there are no values for Year 1 PM for SE, JW, SE and JS. We did not capture any new indivduals during Year 3's PM session. 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, and nine months after the supplemental translocation. JE, JS, JW and SE were monitored in 2012 and 2013, and, JB and JC were monitored in 2013 and 2014.*

Minimum survival and retention—Supplemental translocation to 2012 plots

We conducted long-term monitoring of the two 2012 plots from 23 to 27 June 2014, nine months after the supplemental translocation. Capture numbers for JC and JB improved from the first year to the second, mirroring our experience with the 2011 plots (Table 2; Figure 2). We captured 29 individual squirrels: 16 at JB and 13 at JC. Two individuals had been translocated to JC in 2012 and 11 were translocated in 2013 (4 at JB and 7 at JC). Sixteen squirrels were new juveniles from 2013 litters. This year, only one squirrel was caught *exclusively* in the evening sessions. Sex ratios were even at JC (six male, seven female) but very skewed at JB (two juvenile males to fourteen females).

Table 2. Total number of squirrels captured during long-term monitoring after each translocation. *Additional evening trapping is separated and in italics.*

Time of capture	Type of release	JB	JC	JE	JS	JW	SE	Total
Morning	1st Year (Initial)	0	8*	6	7	5	6*	**32**
	2nd Year (Supplemental)	15	10	14*	5*	11	7	**62**
Evening	*1st Year (Initial)*	*0*	*2**					***2***
	2nd Year (Supplemental)	*1*	*3*	*9**	*7**	*0*	*2*	***22***
Totals		**16**	**23**	**29***	**19***	**16**	**15***	**117**

** Asterisk denotes minor corrections to the values reported in Wiskinski 2013. Unknown individuals were reclassified and included in subsequent analyses.*

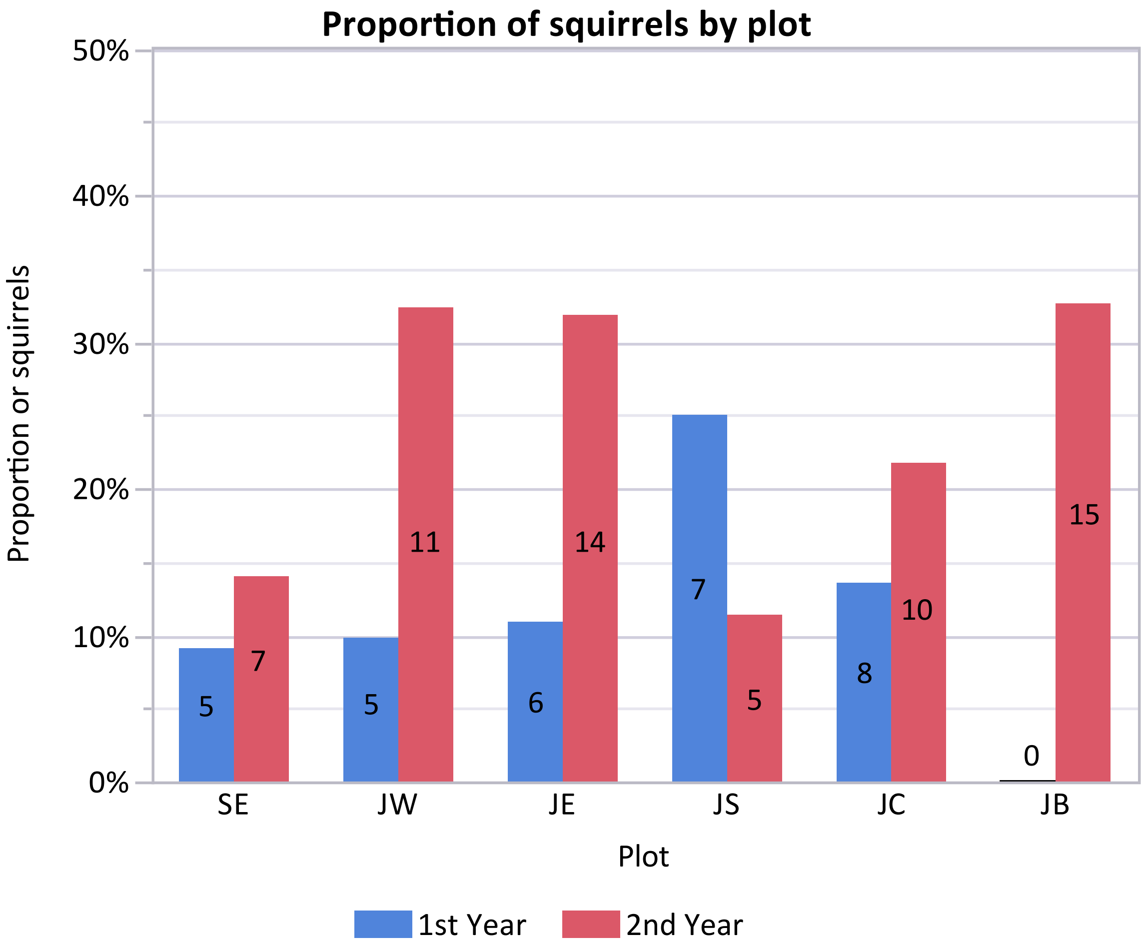

Figure 2. Summary of the proportion of squirrels captured on each plot one and two year(s) following translocation. *These numbers include translocated individuals, their progeny and immigrants from local populations. For comparison purposes, 23 individuals that were only caught during evening trapping sessions were excluded. All long-term monitoring was scheduled in June to maximize capture probability of juveniles prior to dispersal. JE, JS, JW and SE were monitored in 2012 and 2013, and, JB and JC were monitored in 2013 and 2014.*

Effects of ecological variables and translocation methodologies on survival

To better understand how release site characteristics, translocation methods and other factors influence translocation outcomes, we conducted analyses examining inter-relationships among these variables. Results from the logistic regression models indicate that geology, sex, release type, release site and year all have some explanatory power for whether or not a translocated squirrel was recaptured during the spring monitoring. These data include squirrels releases in initial and supplemental translocations from 2011-2013. The confidence set contained five models wherein the top model is only 1.7 to 2.6 times as likely to explain spring captures than the other four models, as calculated from the ratio of their Akaike weights (w); e.g. 0.34/0.13 = 2.6 (Table 3). Weighted parameter estimates are summarized in Appendix Table A1.2 and Figure 3. While all five factors are plausible explanations for squirrel captures, geology, sex and release type are 4 to 5.5 times more plausible than release site and year (see Appendix Table A1.3 for full two-way comparisons between factors).

We consider geology, sex and release type to be influential factors based on the 85% confidence interval around the weighted parameter estimates excluding zero (Figure 3a). There is also a significant interaction between sex and geology, and females were 4.4 times as likely to be captured than males where the parent geology was alluvial deposit, whereas on metavolcanic rock the odds decreased to 2.7 (Figures 3b and 4). In other words, males were much more likely to disperse or die (or were more difficult to recapture) when released on alluvial deposits than were females; in fact few males were recaptured on alluvial deposits. Retention and survival was much higher for males on metavolcanic rock than on alluvial deposits, as indicated by recapture rates. The odds of capturing translocated squirrels increased two-fold from initial to supplemental release type (OR=2.1, 85% CI=[1.3, 3.4]; Figures 3b and 5a). Initial and supplemental translocations differ with regard to several factors: provision of cover at the release site, additional food supplementation, and increased effort to release groups with social familiarity. In addition, for supplementation, the presence of squirrels and their effects on the environment would create different conditions at the release sites for these experimental groups. Thus, the greater success of supplemental release groups may be attributed to a combination of these factors. We had slightly higher capture rates at Jamul than Sweetwater, however we may discount this effect, as the odds are not significantly greater than one (OR=1.5, 85% CI = [0.8, 2.9]). Finally, capture rates for translocated squirrels increased across years: the odds were 1.9 times greater for 2012 than for 2013 (85% CI = [1.07, 3.48]), and 3.4 times greater for 2014 than for 2012 (85% CI = [1.66, 6.74]; Figures 3b and 5c). The odds ratio between 2013 than 2014 was not significantly greater than one (OR = 1.7, 85% CI = [0.98, 3.08]). Such results for interannual variation may arise from several factors, including factors outside of the experimental design, such as rainfall, temperature, predation pressure, foraging resources and other environmental factors. It may also result from changes in translocation procedures, as part of our adaptive management strategy, such as initial vs. supplemental releases, provision of cover, food provisioning, and effort to release familiar release groups. Some of this variation can be accounted for in the model, but some cannot. It is even possible that some of these factors influence trapability, further complicating interpretation of results. Some of the differences apparent across years in Figure 5 may also be attributable to the effects of translocation type, as the proportion of squirrels releases in supplementation vs. initial releases would increase across years. Therefore caution is warranted when interpreting the effect of year on these data.

The predictive power of release type (initial vs. supplemental) is also seen in Table 4 and Figure 6. The proportion of all squirrels captured to the number released the previous year was strongly influenced by release type, with weak support for the effects of release site and sex (Figure 6). We averaged parameters across four models in the confidence set, and the top model was less than 1.5 times more likely to explain capture proportions than the other models (Tables 5). The explanatory power of release type was twice as plausible as sex, and 2.3 times more plausible than release site. Sex was only 1.2 times more plausible than release site.

Table 3. The candidate set of models evaluating the effect of variables listed in Table 1 on spring capture of translocated squirrels. *The top model, #1, is listed with four additional models, the number of parameters in the model (K), -Log Likelihood, Akaike Information Criterion for small samples (AICc), the change in AICc between the model listed in the row and the top model (ΔAICc), and the Akaike weight (w) from which the evidence ratio is calculated.*

	Model	K	-Log Likelihood	AICc	Δ AICc	w	Evidence ratio
1	Sex, Release type, Geology, Geology*Sex	6	145.3	300.7	0	0.34	1.0
2	Sex, Release type, Geology, Geology*Sex, Site	7	144.8	301.8	1.06	0.20	1.7
3	Sex, Year, Geology, Geology*Sex	6	144.9	302.0	1.24	0.19	1.9
4	Release type, Geology	4	148.3	302.6	1.87	0.14	2.5
5	Sex, Release type, Geology	5	147.3	302.7	1.92	0.13	2.6

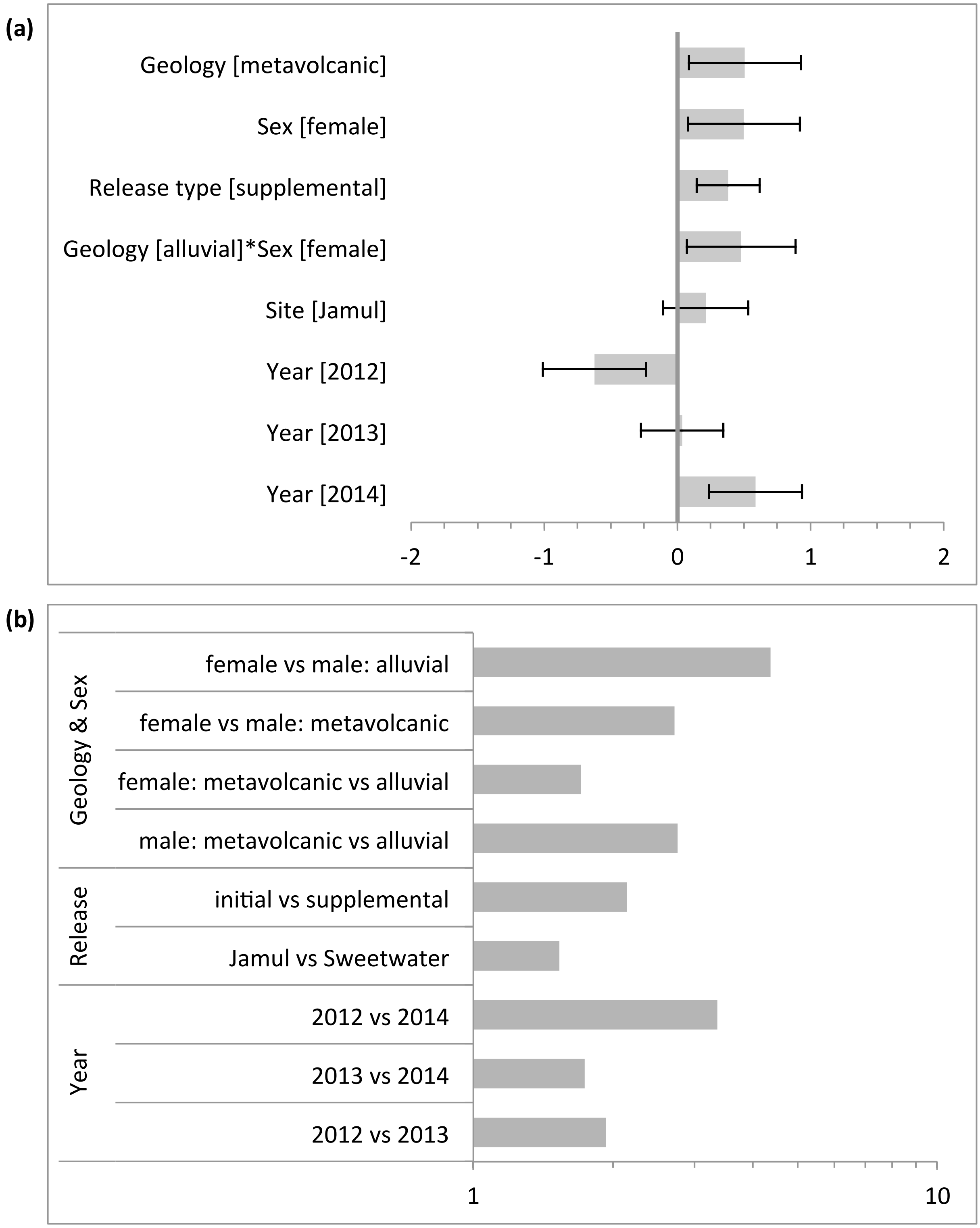

Figure 3. Weighted parameter estimates with 85% confidence interval (a), and odds ratios for model-averaged parameters (b).

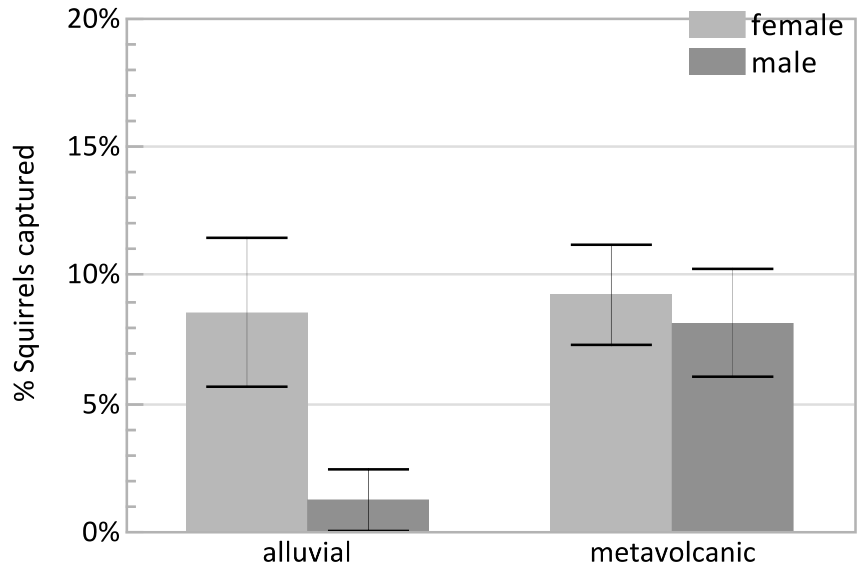

Figure 4. Logistic regression results. *Proportion of translocated squirrels captured by geologic formation differed between sexes. Females were much more likely to be captured than males on plots with alluvial deposit as the underlying geological formation.*

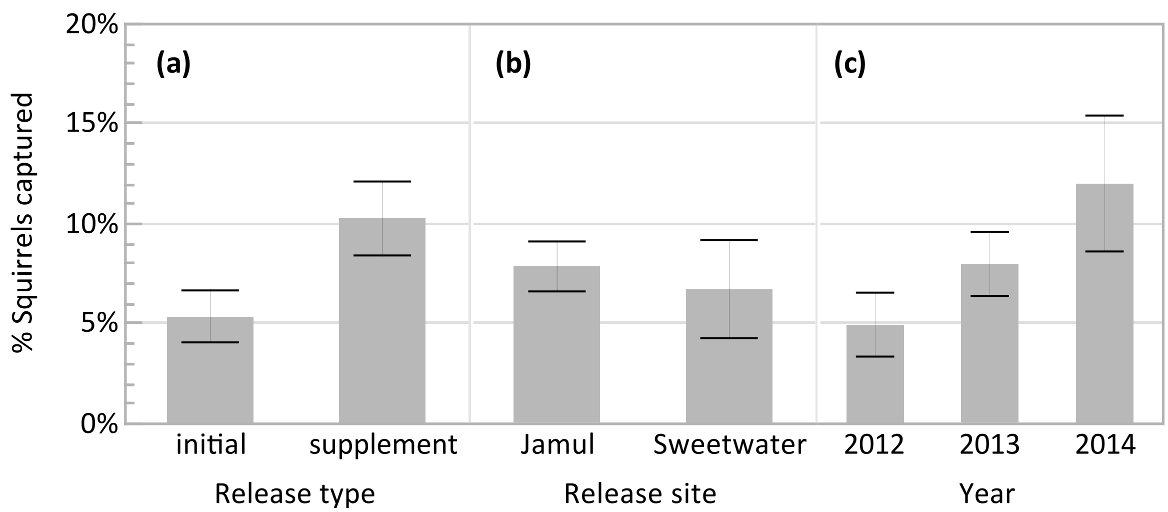

Figure 5. Logistic regression results. *Proportion of translocated squirrels captured by (a) release type, (b) release site and (c) year. Capture rates were higher after the supplemental release than the initial release, and rates improved across years.*

Table 4. Proportion of all captured squirrels to number released the previous year. *We used linear regression to examine the influence of release type, site, plot, geology and sex. We excluded Otay and SW plots from the analysis as no supplemental translocations were performed at these plots.*

			Initial release			Supplemental release		
Site	**Plot**	**Geology**	**Female**	**Male**	**All**	**Female**	**Male**	**All**
Jamul	JB	alluvial	0	0	**0.0%**	53.8%	10.0%	**34.8%**
	JC	metavolcanic	16.2%	17.4%	**16.7%**	21.4%	38.9%	**28.3%**
	JS	alluvial	42.9%	7.7%	**25.9%**	35.0%	20.8%	**27.3%**
	JE	metavolcanic	14.8%	8.0%	**11.5%**	66.7%	39.1%	**52.3%**
	JW	metavolcanic	12.0%	8.0%	**10.0%**	22.2%	43.8%	**32.4%**
Sweetwater	SE	metavolcanic	12.5%	4.3%	**9.1%**	23.3%	10.0%	**18.0%**
	SW	alluvial	0	0	**0**	-	-	**-**
Otay	ON	alluvial	0	0	**0**	-	-	**-**
	OS	alluvial	0	0	**0**	-	-	**-**

Table 5. The candidate set of models evaluating the effect of variables listed in Table 1 on the proportion of all squirrels captured to released. *The top model, #1, is listed with two more models, the number of parameters in the model (K), -Log Likelihood, Akaike Information Criterion for small samples (AICc), the change in AICc between the model listed in the row and the top model (ΔAICc), and the Akaike weight (w) from which the evidence ratio is calculated.*

	Model	**K**	**-Log Likelihood**	**AICc**	**Δ AICc**	**w**	**Evidence ratio**
1	Release type	3	-13.1	-19.1	0	0.29	1.0
2	Release type, Sex	4	-14.6	-19.0	0.03	0.28	1.0
3	Release type, Release site	4	-14.3	-18.5	0.59	0.22	1.3
4	Release type, Release site, Sex	5	-15.9	-18.4	0.63	0.21	1.4

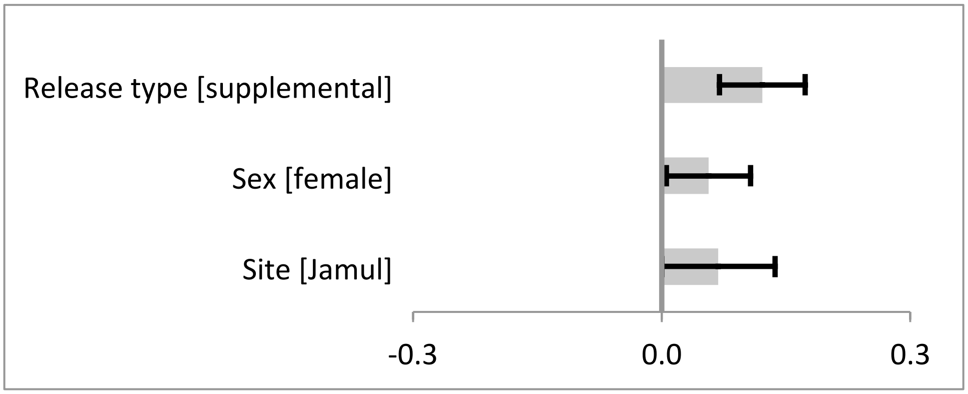

Figure 6. Weighted parameter estimates for proportion of squirrels captured to released with 85% confidence limits. *The 85% confidence interval for release type and sex do not include zero, therefore there is strong support for these factors influencing capture proportions.*

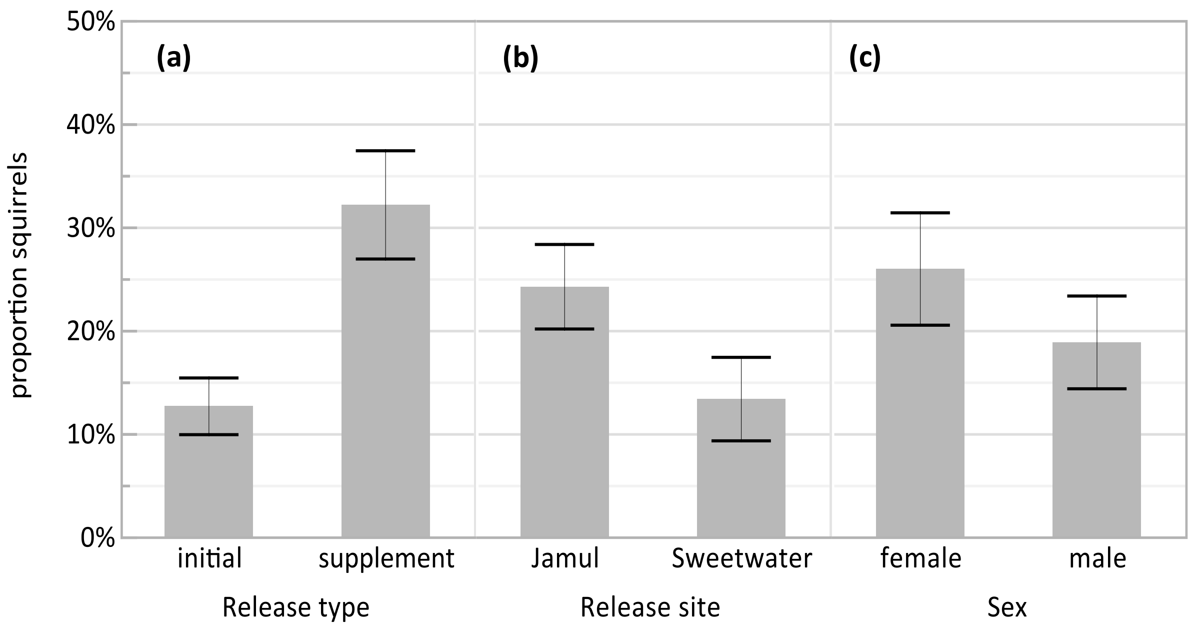

Figure 7. Linear regression results for colony persistence at each plot. *Mean proportions of all squirrels captured to released by (a) release type, (b) release site and (c) sex. Here, we calculated a metric that included progeny and immigrants from local populations captured during spring monitoring.*

Discussion

We now have empirical evidence to support the benefits of a supplemental soft-release translocation. We captured more of our translocated squirrels in supplemental translocations than in initial translocations to release sites with no resident squirrels present (Figures 5a and 7a). Squirrels in supplemental translocations may have fewer cases of dispersal from the plots due to conspecific attraction to vacant established burrow systems as well as the presence of remaining squirrels from the initial translocation. However this effect may also be driven by the alterations we made in supplemental translocations as part of our adaptive management approach. In supplemental translocations, we added brush piles for cover to counter high predations rates, increased the amount of food provisioned, increased efforts to release squirrels familiar with each other together, and changed the timing of the release from spring to fall. These changes were intentional and necessarily render it difficult to ascertain which of these variables are responsible for improved outcomes. Future research is needed to tease apart the contribution of these factors, but at present management recommendations are to follow these soft-release protocols and conduct supplemental translocations to maximize chances of success.

As in previous reports, geologic formation had strong predictive value for squirrel survival, consistent with our hypotheses regarding the importance of soil characteristics for squirrel habitat selection and survival. Our results clearly indicate that metavolcanic rock is associated with higher survival compared with alluvial deposits, an effect largely driven by low retention of males on alluvial deposits. Although these categories are rather crude in their ability to predict specific soil characteristics on the ground at release sites, alluvial deposits are associated with higher proportions of clay, which reduces suitability for squirrels. It is promising that these readily available maps of geologic formation may provide at least rough guidance regarding the most promising sites to attempt to establish squirrels, and their ecological dependents, burrowing owls. In 2013 we reported findings from a complimentary analysis, which showed that the presence of clay as determined by soil maps provided by SANGIS was associated with lower recapture rates. Taken together, these findings strongly indicate that soils that support burrow excavation are more suitable for ground squirrels and will promote establishment of translocated or naturally dispersing squirrels.

Previously we reported females had slightly lower survival than males based on capture rates one-month post-release. However there is strong support for females having higher survival rates after a longer term, both twelve months after an initial translocation and nine months after the supplemental one. A caveat is that these differences in capture rates may not be due to survival differences, instead explained by sex differences in trappability. The sex difference is driven largely by the difference seen between geologic formations, where 8.5% of female squirrels were recaptured on the two plots on alluvial deposit, compared to only 1.2% of males. In comparison the ratio on metavolcanic rock parent material was 9.2% female to 8.1% male. This suggests that males are more likely to disperse from lower quality geological habitat than females. Alternatively, rather than dispersal, higher mortality rates may explain the differences between the sexes; for example male squirrels may spend more time exposed with fewer refuges.

Finally, the presence of squirrels at the 2011 plots more than two years after any active management indicates that the colonies are persisting, at least at low densities. The historical dimensions of the 2014 drought make our data difficult to interpret. Lower survival rates are to be expected, but it is also possible that drought caused earlier and more persistent estivation. At the time of our trapping (June) there was very little vegetation remaining due to the early termination of seasonal rainfall in 2014. We know from previous research that live traps capture a small proportion of existing squirrels even in good years. That at least some squirrels remained through the drought indicates that there may be sufficient squirrels for future reproduction and population expansion if conditions improve.

As in previous years, the data on vegetation and burrow establishment (Deutschman & McCullough 2015) support the hypothesis that squirrel translocation and vegetation management are important factors for the ecological restoration of grasslands to support burrowing owls. Across all sites, ground squirrels established more than 1000 burrows, 95% of which were located on translocation sites. Additionally some of the squirrel burrows on matched-control sites were created by translocated squirrels dispersing off the release site. It is worth noting that the creation of 1000 burrows is an achievement that would be difficult and expensive to replicate with artificial burrows, which would also have the added expense of human maintenance costs in perpetuity.

Despite the lack of strong persistent effects of mowing, this experimental treatment had large effects on squirrel activity (Deutschman & McCullough 2015). Few squirrel burrows were located in unmanipulated control treatments, whereas mowed areas had large numbers of burrows. Apparently, the conditions produced by mowing encouraged squirrels to colonize treated areas. However, this was only the case at translocation release plots; few squirrel burrows were found at mowed control plots where no squirrels were released.

We anticipate that the primary usage of this management protocol will be the creation of burrow habitat for burrowing owls on protected, targeted sites. Managers might best leverage the findings of this experiment by identifying target sites where owl occupancy is desired, and where either component of vegetation management and squirrel presence is already in place. Since both were necessary for significant burrow habitat creation, managers could seek opportunities to create the combination in locations where, for example, vegetation density is already kept low by grazing or other disturbance, or in locations with an existing squirrel population. Adding vegetation management to a site with a small population of resident squirrels may increase the size of the colony and squirrel activity levels.

SAN DIEGO ZOO INSTITUTE FOR CONSERVATION RESEARCH.

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 set aside a Burrowing Owl Habitat Management Area where burrowing owls have been soft-released into artificial burrows and efforts have been made to improve the landscape to retain owls after release. The goal of this effort 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 conducted vegetation treatment in conjunction with systematic placement of woodpiles allowing us to address the following questions:

Question 1: Does vegetation management through grazing influence natural dispersal of California ground squirrels?

Beginning March 20th 2014, the BOHMA was grazed by cattle to remove non-native grasses and forbs.

Question 2. If natural dispersal occurs, which age cohort is dispersing?

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 primarily responsible for digging these burrows. If we determine that natural dispersal of ground squirrels can be facilitated via vegetation management, information on which age cohort disperses into managed habitat will enable us to determine the ideal time of year for these vegetation treatments.

Question 3. Does the placement of woodpiles in managed habitat expedite natural dispersal?

Observations from ground squirrel settlement following translocation indicate that squirrels use woodpiles for 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 on the BOHMA February 2014.

Methods

We are conducting biannual burrow surveys with thirty-two transects placed systematically on the BOHMA. In 2014 we surveyed March 7th for a baseline before cattle were introduced. We conducted another survey April 30th with cattle on the field, and the fall survey on October 9th post-grazing.

Placement of transects on the landscape

We first identified the boundary around the source population, denoted by the hatch marked area in Figures 8 and 9. From this boundary we placed thirty-two transect points at four distances from the source population: 50m, 150m, 250m and 350m (Figure 9). Each distance has eight transect points that are 25m apart, alternating between woodpile and control point. These points are staggered between distances, so that the southernmost point at the 50m distance is a woodpile, then the southernmost point at the 250m distance is a control, and so on (Figure 9). Woodpiles and control points were given a unique ID and the locations recorded with GPS.

Burrow transects

We surveyed for burrows within 25m by 10m rectangular transects centered over a woodpile or control point. The long side of all transects was oriented to 40º north. We defined transect boundaries with a premeasured rope (Figure 10). We marked all burrows greater than 7cm within the 250m^2 transect area, recorded the location with GPS and collected the following information (Figure 11):

1) Opening diameter (≥ 7cm),
2) Opening status (clear, debris, plugged),
3) Presence/absence of fresh digging (recent activity),
4) Presence/absence of a three dimensional apron,
5) Presence/absence of latrines & feces,
6) Any additional signs of ground squirrels.

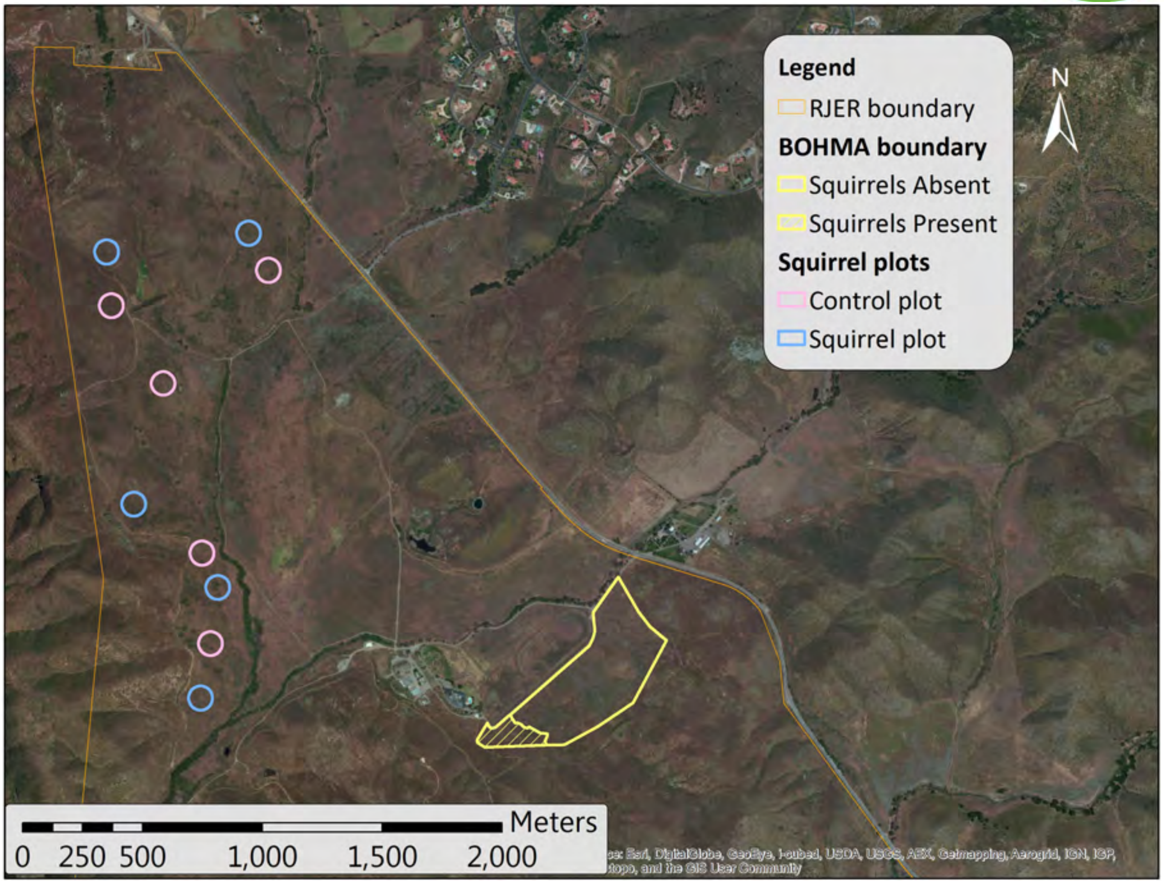

Figure 8. Overview of Rancho Jamul Ecological Reserve (RJER). *The Burrowing Owl Habitat Management Area is outlined in yellow. Squirrels were present in the southwest section of the area, closest to the CAF&W office building. The translocation plots are included for reference.*

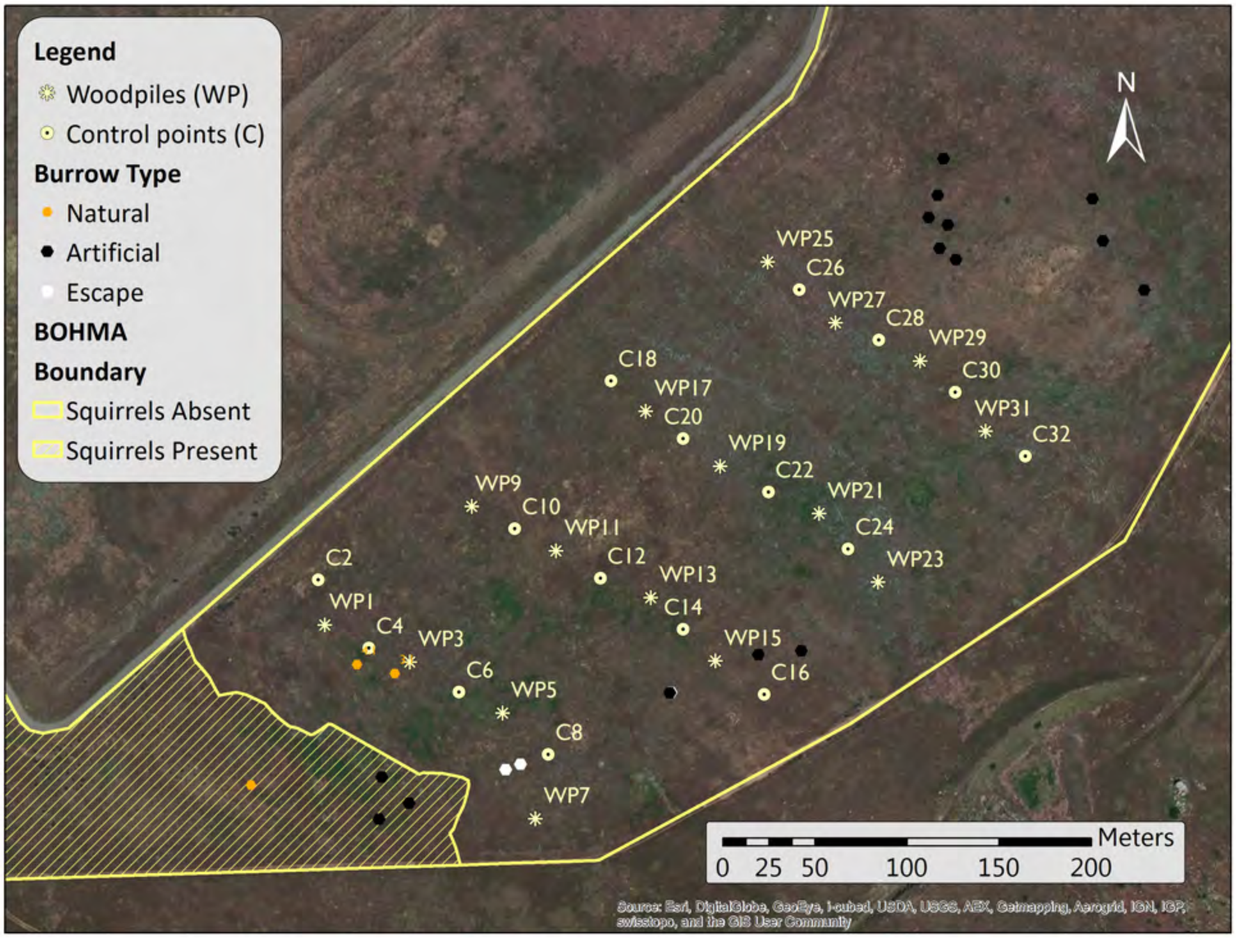

Figure 9. Placement of woodpiles within the BOHMA. *We placed four woodpiles at four distances from the source population of squirrels: 50m, 150m, 250m and 350m. Black points indicate artificial burrows built within the BOHMA. The white points are an artificial refuge not intended for nesting owls. The orange point within the area squrrels are present was a natural burrow where a burrowing owl had been recorded. The two orange points near control point C4 and woodpile WP3 were recorded with GPS January 2014 and indicate burrows large enough to allow squirrels, but with no sign of use.*

Figure 10. Burrow survey transects at woodpile (top) and control point (bottom) at the BOHMA.

Figure 11. Burrows are measured, logged with GPS, and marked with aluminum tags.

Results

We recorded 31 individual burrows in 2014. Six of the burrows fit our criteria but may have been collapsed gopher burrows and are excluded, for a total of 25 squirrel burrows (Table 6, Figure 12). During the March baseline survey we counted six squirrel burrows. In April, we recorded four burrows along transects most proximal to the source population. Burrow collapse was likely due to the presence of cattle and/or rain. In October we recorded seventeen burrows, including two at the farthest distance, 350m (Figure 13).

Table 6. Burrow counts for BOHMA surveys. *Six burrows that may have been collapsed gopher holes are in parentheses. Two March survey burrows were reencountered in April and excluded from the total.*

Month	Control	Woodpile	Total
Mar	3	3 (2)	6
Apr	2 (3)	2 (1)	4
Oct	6	11	17
Total	**10**	**15**	**25**

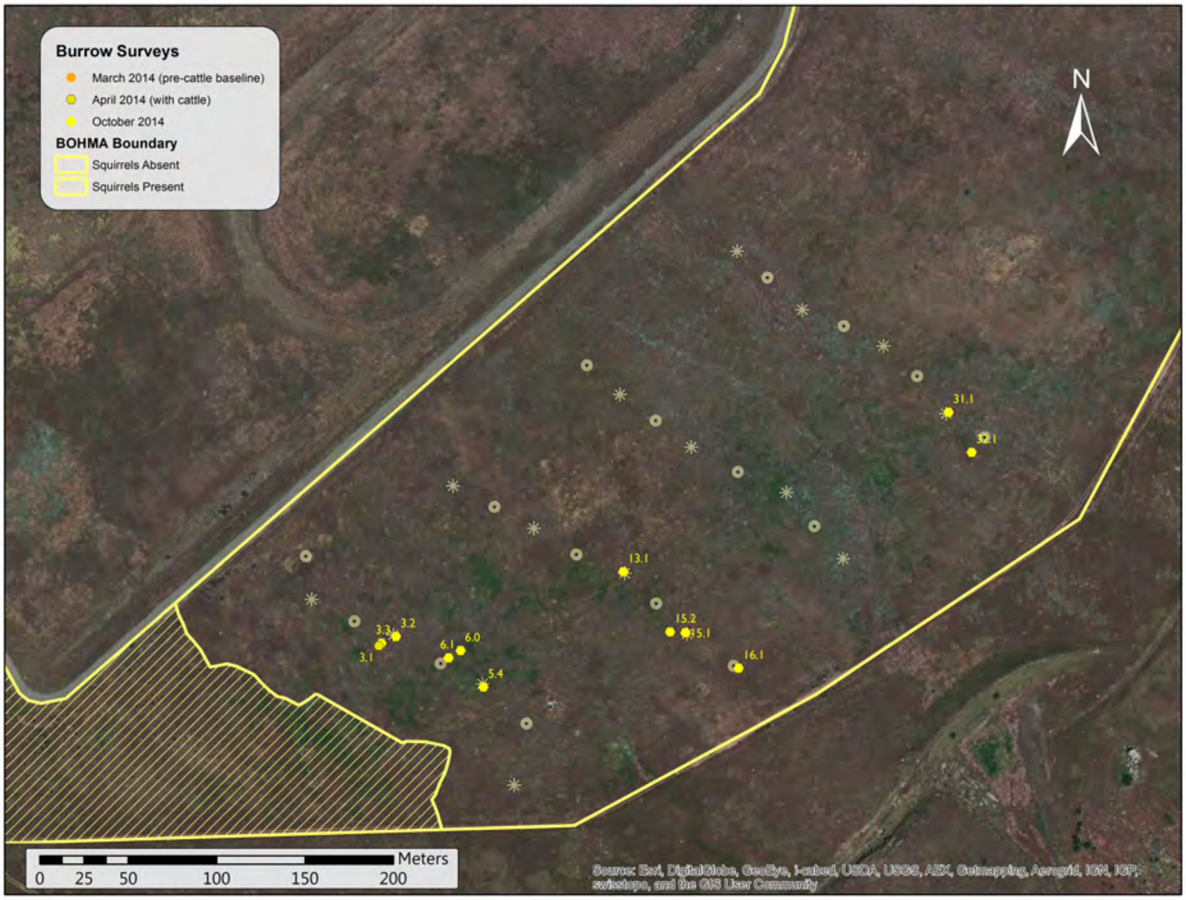

Figure 12. Location of burrows found during 2014 surveys. *We recorded 8 burrows in the spring (orange points) and 19 burrows in the fall (yellow points). In March and April all burrows were located within the first line of transects, 50 meters from the source population, and evenly split between woodpile and control transects. For the fall transect we recorded 8 burrows in control transects and 11 in woodpile transects 50m, 150m and 350m from the source population.*

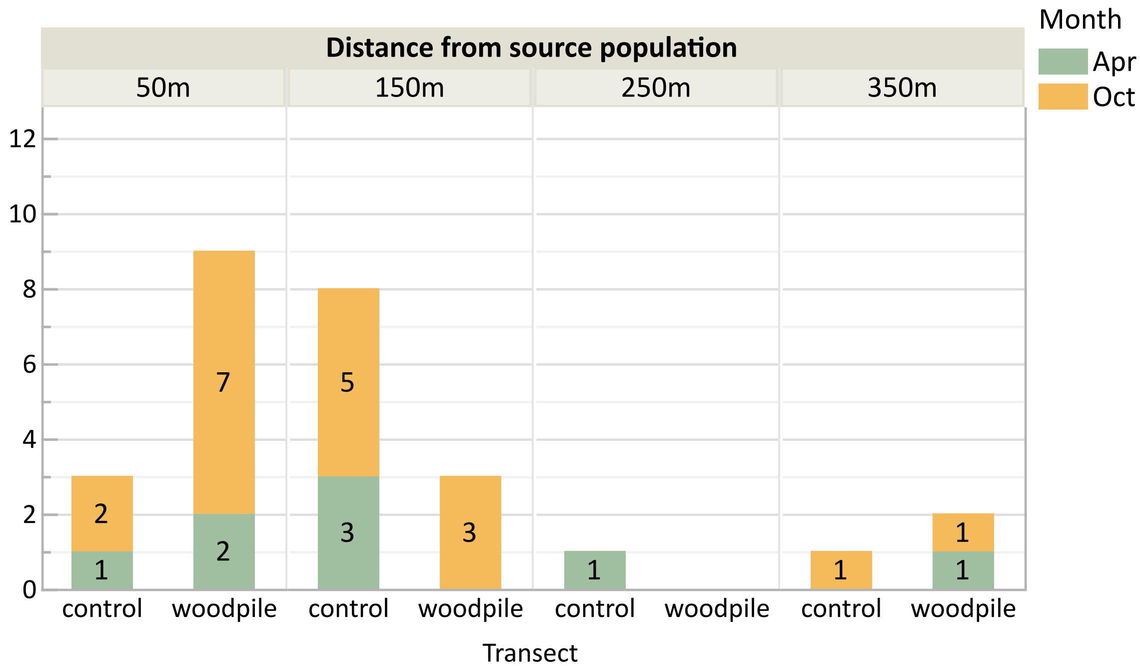

Figure 13. Number of burrows recorded at woodpiles and control points at four distances from the source population of squirrels in the BOHMA. *We excluded six burrows that may have been collapsed gopher burrows, and the six burrows recorded during baseline surveys in March.*

Discussion

Although small in scale and in need of replication, these results show a clear pattern of colonization by ground squirrels following implementation of a grazing regime. Prior to and immediately following (40 days after cattle arrived) commencement of the grazing treatment, few burrows were located in the areas adjacent to the source population. However, by Fall 2014, approximately 7 months after initiating the grazing treatment, the number of burrows approximately tripled, with a few appearing at a distance of 350m from the source population.

Our results fail to support our hypothesis that the presence of cover would influence establishment of burrows. Squirrels were equally likely to establish burrows at control plots away from cover as at plots with provisioned cover. There are several plausible explanations for this finding. One is the type of cover provided. A pile of branches may not be a sufficient deterrent from predators. Future research in this area should consider provision of large tree trunks or boulders, which, although logistically difficult and more expensive, may provide better protection from predators and be favored by squirrels. Another plausible explanation is that this kind of cover is useful to have in the home range of squirrels, but is not preferred for burrow site selection. Under this scenario, the cover was attractive to squirrels, facilitating colonization, but because it afforded additional refuges to escape predators when foraging above ground. These branch piles would be particularly effective for evading aerial predators, but may not deter predators that dig out squirrel burrows. To evaluate this hypothesis, burrow monitoring should be established at a matched-control site that has no cover provisioned. If more burrows are established in areas that contain cover, even if the burrows are not located under the cover, this finding would indicate that cover has value for facilitating squirrel colonization. We plan to incorporate such a design in future tests of this hypothesis.

Although results are preliminary in nature and generalizations difficult to draw at this juncture, our findings have some promising implications for management. For sites that have a significant source population of squirrels, a manager might expect at least slow dispersal and colonization by squirrels in response to grazing alone. The action of grazing opens up the dense thatch associated with many invasive grasses in Southern California, providing habitat more suitable to ground squirrels. Restoration programs that rely on re-establishment of this important ecosystem engineer may be enhanced by controlled grazing as a part of a larger management strategy.

BURROWING OWL NESTING AND FORAGING ECOLOGY

Introduction

Working with the western burrowing owl (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, we continued to monitor BUOW nesting and foraging ecology using a variety of tools, including camera traps, color banding, and GPS telemetry.

We established camera traps at a number of natural and artificial burrows at sites with varying habitat characteristics. Understanding the relative productivity of BUOW at different locations and habitat types is a critical first step for better management. These data will be especially important for assessing the viability of management actions involving establishment 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. 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.

Artificial and natural burrows may also differ with regard to microclimate inside the burrow, microhabitat immediately surrounding the burrow, or the landscape features and habitat quality in the owl’s home range. To address these possibilities, we used data loggers placed inside and immediately adjacent to burrows to monitor temperature and humidity variables and conducted habitat analysis of the vegetation surrounding artificial and natural burrows. These variables are explored with regard to their potential to affect nesting success and offspring viability.

We also continued to build on our previous banding efforts. 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 effort, we also collected genetic material that has been stored and will provide for future genetic analyses of BUOW of San Diego County.

In addition, we examined the spatial ecology of BUOW in 2014. While band re-sighting is instrumental for understanding recruitment and site fidelity, it alone cannot provide the level of spatio-temporal data needed to understand BUOW movement patterns, home range size, and resource use in this region. Due to recent technological advances creating GPS units small enough to be used on BUOW, we were able to use telemetry to help fill these knowledge gaps. Information gained from this research can be incorporated into the BUOW recovery plan to help guide site selection, identify key foraging or other critical habitat areas, and inform management actions.

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 14); 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 newly restored vernal pool and BUOW mitigation site. The site contains 75 artificial burrows and is characterized by sparse, mostly native, vegetation with some patches of non-native grass. There are also some natural burrows on the perimeter along La Media Road. 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.

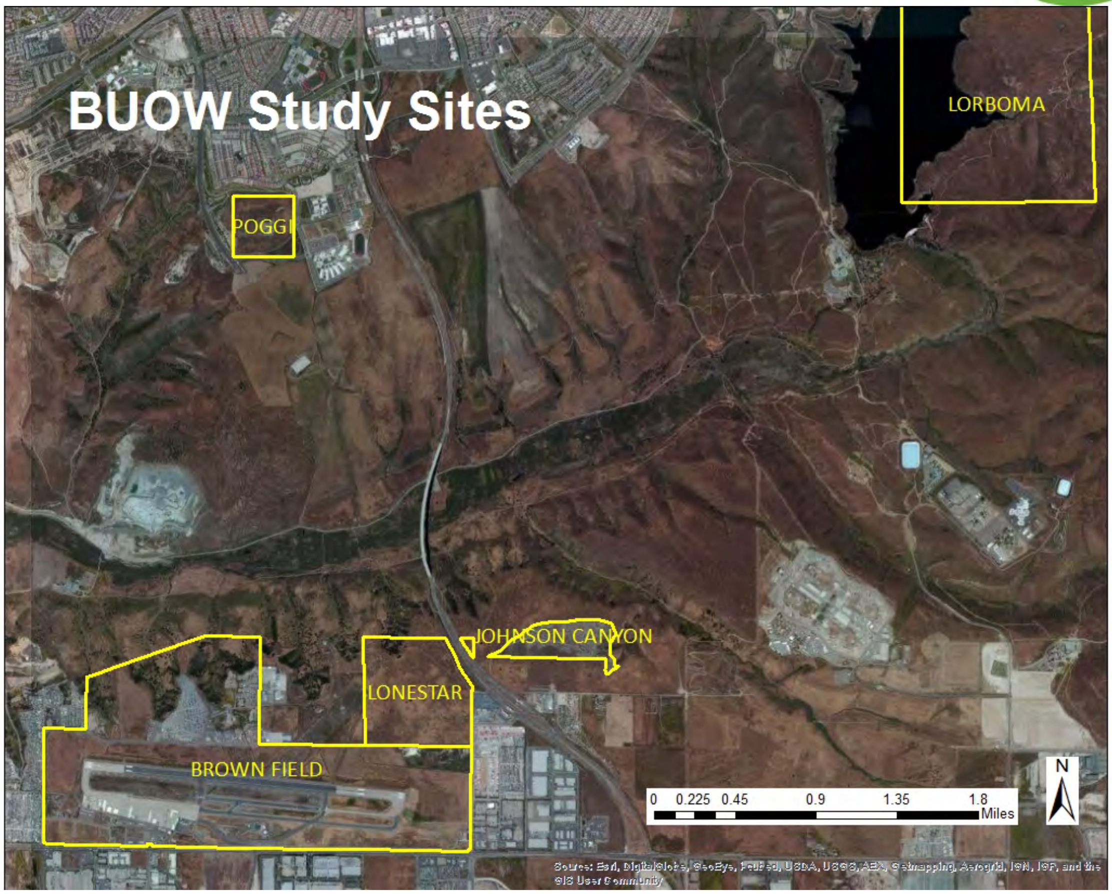

Figure 14. Map of the 2014 BUOW study sites.

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 2014, we continued to work at these five sites.

All known burrows at the 5 study sites were checked weekly (including the burrows at Brown Field that were not monitored using camera traps—see next section). 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 squirrel translocation plots were recorded throughout the study period. We also checked all artificial burrows in Management Unit 3 that were accessible and collected data on BUOW use and condition of the burrows (Appendix 4).

Camera Trapping

In 2014, we set cameras at burrow entrances (usually 1 for natural burrows and 2 for artificial burrows) when we confirmed the presence of eggs or chicks. At all sites except Brown Field, all active burrows received camera traps. We did not set cameras up at all active burrows at Brown Field because two burrows were located under the helicopter pads and we could not safely install cameras without impeding normal airport activities. The helicopter pads have been repainted to discourage their use (this was required by CalTrans for other reasons) so we will revisit the possibility of setting cameras at these burrows in 2015.

We used Reconyx® PC900 remote camera systems to monitor the entrances of active nest burrows (we discontinued use of the Bushnell TrophyCam HDs due to the low quality of nighttime images). 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. Based on our results from 2013, 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.

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 prioritized the burrows monitored by camera traps; however, we also targeted non-focal burrows if the nestlings were an appropriate age for banding. Each captured owl was banded with two aluminum bands: a USGS band and a green alphanumeric Acraft band. Standard morphometric measurements were taken for each bird. Blood samples were taken from the brachial vein and 2-4 body feathers were pulled; in the case of very small nestlings, only body feathers were taken. If appropriate based on feather development, 1-2 flight feathers were taken for cell culture. All blood, feather, and tissue samples are being stored in the Frozen Zoo® at the Beckman Center, San Diego Zoo Institute for Conservation Research.

GPS Dataloggers

To identify foraging areas, we affixed GPS dataloggers to a subset of breeding adults during the nestling period. We focused on this breeding stage to increase the chances of recapturing tagged individuals (to retrieve the data) since breeding adults are very territorial during this period. We also decided to tag only adult males because they do most of the hunting during this period; consequently, telemetry data for males would be most informative for understanding foraging movements. Additionally, the females develop a brood patch, which interferes with the harness attachment. We used PinPoint 100 GPS units from Lotek/Biotrack. The units weighed 4.5 – 5g and were attached with a Teflon ribbon harness that weighed ~0.6g. In order to keep all attachments under 5% of body weight, we were restricted to tagging males weighing over 143g. At the time of GPS tag attachment, we only affixed USGS bands (not auxiliary bands) and did not collect genetic samples to further reduce the weight and stress on the bird. Color bands were added and genetic samples were taken upon recapture and GPS tag removal for each bird. The tags were able to log a total of 100 locations so were set up to take locations every 1.5 hours from 8:15 PM to 5:15 AM over an approximately 2-week period. This schedule was determined using the activity patterns observed from camera trap data in 2013 (Wisinski et al. 2014).

Each location reading (latitude and longitude) taken by the GPS units was accompanied by the date and time, the number of satellites used by the tag to determine the location, and a degree of precision (DOP) estimate. We conducted a beacon test by placing a GPS datalogger programmed with the same schedule for location fixes at a known location. This allowed us to quantify the accuracy of the GPS tags and to determine which data points should be omitted based on their respective number of satellites and DOP.

iButton Dataloggers

We used Hygrochron Temperature/Humidity Logger iButtons (model DS1923-F5#) to examine burrow microclimate. We placed iButtons inside and outside a subset of natural and artificial burrows to compare the buffering abilities of the different burrow types and construction materials. To avoid disrupting breeding activity, we used only burrows that were not occupied during the 2014 breeding season. We placed iButtons in natural burrows at Brown Field that had been used for breeding in 2013 (Gailes, Heritage and Datsun, and La Media Stop Sign/Berm abeam Napa). We attempted to use only artificial burrows that had been used in 2013, but due to burrow configuration, we had difficulty placing the iButtons in some of the wooden burrows. As a result, we selected 6 alternate burrows: 3 wooden and 3 plastic burrows at Lonestar (wooden: LS 13, LS 70, LS 176; plastic: LS 28, LS 144, LS 201). We also used one of the 2011 translocation squirrel burrows at Lonestar (OS 7), an artificial burrow from Johnson Canyon (JC 17), and two artificial burrows from LORBOMA (LO 33 and 34). The iButtons that were inserted into the burrows were placed inside small Whiffle balls to protect them from any animals using the burrows. The outside iButtons were placed on an ~0.5m-high stake at ~1m from the burrow entrance; each stake had a sunshade to prevent the iButtons from receiving direct sunlight. The iButtons were placed in the field during the breeding season (April through July). Temperature and humidity readings were taken automatically once per hour.

Camera trap data processing

All camera trap photos were organized by burrow and date. We used Adobe® Bridge to examine all of the photos for the presence and type of prey items and the presence of non-BUOW visitors (including predation events and humans) and to tag each photo with pertinent information (see Appendix 2 for protocol with full keyword list; note the protocol and keyword list were modified slightly from 2013 to streamline processing time). 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. For each day, 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.

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. We also examined the types of prey delivered by burrow type using non-parametric Mann-Whitney U tests. For these analyses, we used the total number of prey deliveries divided by the number of camera trap days to standardize between burrows and the proportions of bird, herptofauna, invertebrate, mammal, and unknown prey. In addition, we examined daily prey deliveries from chick emergence through 3 weeks post-emergence at each burrow to more closely examine the relationship between prey deliveries and fledging success. We excluded any burrows where no chicks emerged or where no prey deliveries were captured on camera during the 3-week period. We did not include site differences because 3 of the 5 sites had fewer than 3 burrows. We also excluded the data from the Poggi and Cul-du-Sac burrows because we were never able to confirm that eggs had been laid.

Analysis of GPS data

We used the beacon test data to measure the error for the GPS dataloggers. We converted the latitude and longitude into UTMs, then measured the straight line distance between these coordinates and the true coordinates of the test GPS datalogger. We examined the error (in meters) of each location by DOP class and number of satellites and found that by omitting locations with >3 DOP and ≤3 satellites, 80% of the locations were within 5.5m of the true location.

Using the results of the beacon test, we removed all bird locations with >3 DOP and ≤3 satellites for home range analysis. We used the adehabitatHR package in R to calculate home ranges for each bird using both minimum convex polygons (MCP) and fixed kernel density estimation (KDE).

Analysis of iButton data

Because iButtons were deployed for differing lengths of time, we truncated the data to include only the period of 6 June to 5 July, 2014. 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 tested whether the respective mean values differed by burrow material type (natural, plastic, wood) using ANOVAs. We were not able to look at inside/outside differences for the LORBOMA burrows because the outside iButton was missing upon retrieval.

Results & Discussion

Nest monitoring

During the 2014 breeding season, we located 32 BUOW burrows and monitored 29 burrows weekly from April through mid-September (Table 7, Figure 15); the Poggi site was checked less frequently after burrow abandonment due to time constraints. The other 3 burrows were located on private land and were monitored 1-3 times during the same period. We confirmed breeding (by presence of eggs or chicks) at 26 of the 32 burrows. We were not able to confirm breeding at the other burrows for a variety of reasons. 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. 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 also visited all accessible artificial burrows within Management Unit 3 and recorded their condition and use (Appendix 4).

We found that fledging success (percent of burrows where we confirmed breeding that fledged at least one juvenile) was highly variable. Fledging success was 100% at LORBOMA (1/1), 86% at Brown Field (6/7), 46% at Lonestar (6/13), and 0% at Johnson Canyon (0/1). We were unable to confirm breeding activity at Poggi. We recorded 4 renesting attempts (2 at Lonestar, 1 at Brown Field, and 1 at Johnson Canyon), but none of the renests were successful. The variability in fledging success is likely due to the continuing and worsening drought conditions in the region. In addition, vegetation at Lonestar was limited following removal of invasive plants to encourage native plant recovery and may have afforded poor habitat for BUOW prey. Food limitation is likely driving much of the variation in productivity and the severity of the limitation is probably very localized (even within a site; see GPS results on home range below). A food availability study along with supplemental feeding could be used to test this hypothesis. The Johnson Canyon site, one of the most productive sites in 2013, experienced no reproduction in 2014 for unknown reasons, though only one pair nested there. Reproductive success at Lonestar varied with the most productive burrows on the western half of the site. These birds may have had better access to the grasslands to the west of the site as suggested by the GPS telemetry data collected in 2014. However, further spatial data is needed to better understand their use of this area for foraging.

The wide range of variation in fledging success points to considerable potential for management actions to enhance population performance. This variation between sites suggests that there are factors, such as food or predation, that differ among sites; when fully understood these factors or the habitat covariates that give rise to them, may be targeted for management action to facilitate higher reproductive output, potentially providing surplus animals to disperse and colonize other sites. Where productivity is low, these sites may attract owls to nest but may act as an ecological sink population. Here habitat improvements may be required or it may be desirable to deter BUOW from nesting there. Further research is needed to determine underlying causal variables for varying fledging success, but we have already begun to make some inroads into understanding potential drivers of the system (see below).

Banding

We banded BUOW during the period of 5 May to 3 September. We captured a total of 72 BUOW (Table 8, Appendix 3), two of which were birds banded by us in 2011, and three of which were birds banded by us in 2013. We also recaptured 3 birds banded by Jeff Kidd in 2013 as part of a translocation of a pair of owls to Lonestar. We took blood and feather samples from all but one bird (LS 185 Berm male). The owls we captured represented 22 families, with 41 of them caught at natural burrows and 30 of them caught at artificial burrows. In 2013, we used one-way door traps at the burrow entrances as our primary capture technique, and caught mostly juveniles. In 2014, we added the use of call/playback and greatly increased our ability to capture adults (particularly adult males). We also targeted adults as part of the spatial ecology monitoring. The discrepancy in the numbers caught at natural vs. artificial burrows is likely still due, in part, to the lower number of chicks that emerged at Lonestar which again limited the number of juveniles available for capture at artificial burrows.

As a result of our banding effort, we were able to individually identify owls and document movements, site fidelity, recruitment, as well as several interesting situations during the breeding season. A description of some of these observations follows. Together they indicate that nesting is a dynamic process, with several cases of mate loss followed by re-nesting with a new mate, burrow switching, nest abandonment, and disappearance of one or both mates. In a few cases (LS 52, Poggi, Tire abeam Tower/Algae Pond), a pair was present early in the breeding season but left early and may or may not have initiated nesting. At LS 52, we never saw signs of breeding in the artificial chamber, but there was an adjacent squirrel-dug chamber that we could not adequately access to determine breeding status. At Poggi, the male from 2013 (banded "44 over X") apparently initiated a nest with an unbanded female, but disappeared on 15 April. A new male moved in, but the pair left the burrow on 25 April. At Tire abeam Tower/Algae Pond (two burrows that were close to each other), a pair was observed early but were not seen at either burrow again after 2 May.

We observed two instances (Lycoming/Gravel Lot and LS 185 Berm/Hack Burrow) of burrow switching after the apparent mortality of an owl's mate. A pair banded as adults in 2013 (F: "30 over X", M: "32 over X") apparently initiated nesting at Lycoming while "07 over X" (a female banded as an adult at Gravel Lot in 2013) seemed to initiate nesting with her unbanded mate at Gravel Lot. The Lycoming female "30 over X" was last seen on 14 March, but the male "32 over X" remained at the burrow. The unbanded male from Gravel Lot disappeared on 22 April and "32 over X" showed up at the burrow on 24 April and paired up with "07 over X" for the remainder of the breeding season. A single chick emerged from the Gravel Lot burrow on 12 May and disappeared on the same day. Based on the timing, it could have been either the offspring of the original, unbanded male or the product of extra-pair copulation. The newly formed pair then moved to the Lycoming burrow on 17 May but it was uncertain if they attempted to nest there. They returned to the Gravel Lot burrow some time during the last week of May (after a skunk was documented entering the Lycoming burrow via camera trap) and renested (confirmed by the emergence of a chick on 7 July).

In a similar situation, “34 over X” (a male banded as a juvenile in 2013) apparently initiated a nest with an unbanded female at Hack Burrow while an unbanded pair intiated a nest at LS 185 Berm. The female from Hack Burrow and the male from LS 185 Berm each disappeared around the same time (14 and 12 May, respectively). “34 over X” moved to LS 185 Berm and appeared to pair up with the remaining female, then both birds moved to LS 185 (although we could not confirm the identity of the female since she was not banded). We never found evidence of a renest attempt at LS 185 although the pair remained there together for the rest of the breeding season.

Another interesting anecdote from the 2014 season is that of Red “D over 25”, a female that was banded as a juvenile at Naval Air Station North Island (NASNI) in 2011 and has attempted to breed in the Lonestar area in all subsequent years. In 2014, she attempted to breed at Lonestar (LS 107) but none of her eggs hatched. She was observed at LS 107 from 4 April – 13 May. Her next known location was near the Johnson Canyon mitigation site (“Lonestar Road” burrow in Table 7) from 10-18 June where she was observed with “02 over X” (a bird banded as a juvenile in 2013). On June 24, Adam Eidson (USDA APHIS Wildlife Services) observed her near her natal burrow at NASNI. We saw her back at Lonestar (Euc 7 Fence burrow) starting 30 June where she remained until at least 1 December (our last field visit of 2014). It is likely that she returned to NASNI to try to renest due to natal philopatry, but did not find any other owls and immediately returned to the Otay area. According to Adam Eidson, she was the only BUOW observed at NASNI in 2014.

From our previous banding efforts, we were also able to calculate juvenile recruitment rate and site fidelity for adults. In 2014, the return rate for adults was approximately 63%, with 5 of the 8 banded adults in 2013 resighted. Although this return rate suggests high adult survival, trapping effort was limited in 2013 so this return rate may not be representative. By contrast, only 10% (5/51) of the juveniles banded in 2013 were resighted in 2014, suggesting high mortality, high dispersal rates from natal territory, or both. As we continue our banding efforts, we will be able to track trends in survivorship, recruitment and site fidelity over time, with the ultimate goal of developing a population model. This was the first year we banded a large proportion of this population, so results from recapture will be informative in 2015 and beyond.

Table 7. Breeding success at all BUOW burrows located in the Otay Mesa area during the 2014 breeding season.

Burrow	Site	Breeding?	Successful[1]	# Fledged[2]	Notes	Previously Banded Birds[3]
1. LS 3 (A)[4, 5]	Lonestar	Y	Y	4		
2. LS 23 (A)	Lonestar	Y	N	0	X5 band removed 5/19/14 (plastic broken and causing leg irritation)	M: White AA, F: White X5
3. LS 42 (A)	Lonestar	Y	Y	3	1 juvenile died after fledging	M: White X4
4. LS 52 (A)	Lonestar	Unknown	n/a	n/a	Pair seen early in season, but breeding never confirmed; single bird seen through June	
5. LS 97 (A)	Lonestar	Y	N	0		
6. LS 105 (A)	Lonestar	Y	N	0		
6. LS 105 (A)--renest	Lonestar	Y	N	0		
7. LS 107 (A)	Lonestar	Y	N	0	None of eggs hatched	F: Red D over 25
8. LS 112 (A)	Lonestar	Y	Y	1		
9. LS 129 (A)	Lonestar	Y	N	0		
10. LS 133 (A)	Lonestar	Y	Y	1		
11. LS 160 (A)	Lonestar	Y	N	0		
11. LS 160 (A)--renest	Lonestar	Y	N	0		
12. LS 193 (A)	Lonestar	Y	Y	1		
13. LS Squirrel Plot (A)	Lonestar	Y	Y	1	Nest found late (after chick emergence), camera set up late	F: C over C, M: 51 over X
14. Euc 17 Fence	Lonestar	Y	N	0	Family moved to LS 166 when chick was 1-2 weeks old; camera was moved	
15. LS 185 Berm	Lonestar	Unknown	n/a	n/a	Male last seen 5/12/14; female later moved to LS 185	
16. Hack Burrow*	Lonestar	Unknown	n/a	n/a	Female last seen 5/14/14; male later moved to LS 185	M: 34 over X
17. JC 17 (A)	Johnson Canyon	Y	N	0		
17. JC 12 (A)--renest	Johnson Canyon	Y	N	0		
18. LORBOMA 33 (A)	LORBOMA	Y	Y	2		
19. Poggi	Poggi	Unknown	n/a	n/a	Nest was abandoned early in the season	1st M: 44 over X
20. Cul-du-sac	Brown Field	Unknown	n/a	n/a		F: 16 over X

Burrow	Site	Breeding?	Successful[1]	# Fledged[2]	Notes	Previously Banded Birds[3]
21. La Media Stop Sign	Brown Field	Y	Y	3		F: B over E
22. Lycoming*	Brown Field	Unknown	n/a	n/a	Female last seen 3/14/14; male later moved to Gravel Lot	M: 32 over X, F: 30 over X
23. Gravel Lot	Brown Field	Y	N	0	Original pair was 07 over X with an unbanded male (last seen 4/22/14)	F: 07 over X, M: 32 over X
23. Gravel Lot--renest	Brown Field	Y	N	0		same as above
24. India	Brown Field	Y	Y	4		
25. Old Schoolhouse	Brown Field	Y	Y	2	1 juvenile died after fledging	
26. Tripad South	Brown Field	Y	Y	3	Minimum number fledged	
27. Tripad North	Brown Field	Y	Y	4	Minimum number fledged	F: 01 over X
28. White Poles*	Brown Field	Y	Y	1		
29. Tire abeam Tower/Algae Pond*	Brown Field	Unknown	n/a	n/a	Nesting activity suspected but never confirmed, bird last seen at burrow 4/22/14	
30. Border Pacific	Private	Unknown	n/a	n/a	2 BUOW seen over course of season, breeding not confirmed	
31. Big Toy Depot	Private	Unknown	n/a	n/a	Only 1 bird, wintering?	
32. Lonestar Road	Private	N	n/a	n/a	Likely temporary stopover, birds only seen here from 6/10-6/18/14	F: Red D over 25, Adult: 02 over X

[1]Nests were considered successful if 1 or more juveniles fledged (reached 45 days of age).
[2]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).
[3]All alphanumeric bands are green unless otherwise specified; green and red bands are aluminum, white bands are plastic.
[4]Bold indicates burrows with cameras.
[5](A) indicates artificial burrows.
* Cameras were placed at these burrows temporarily to attempt to determine breeding status and identities of banded individuals.

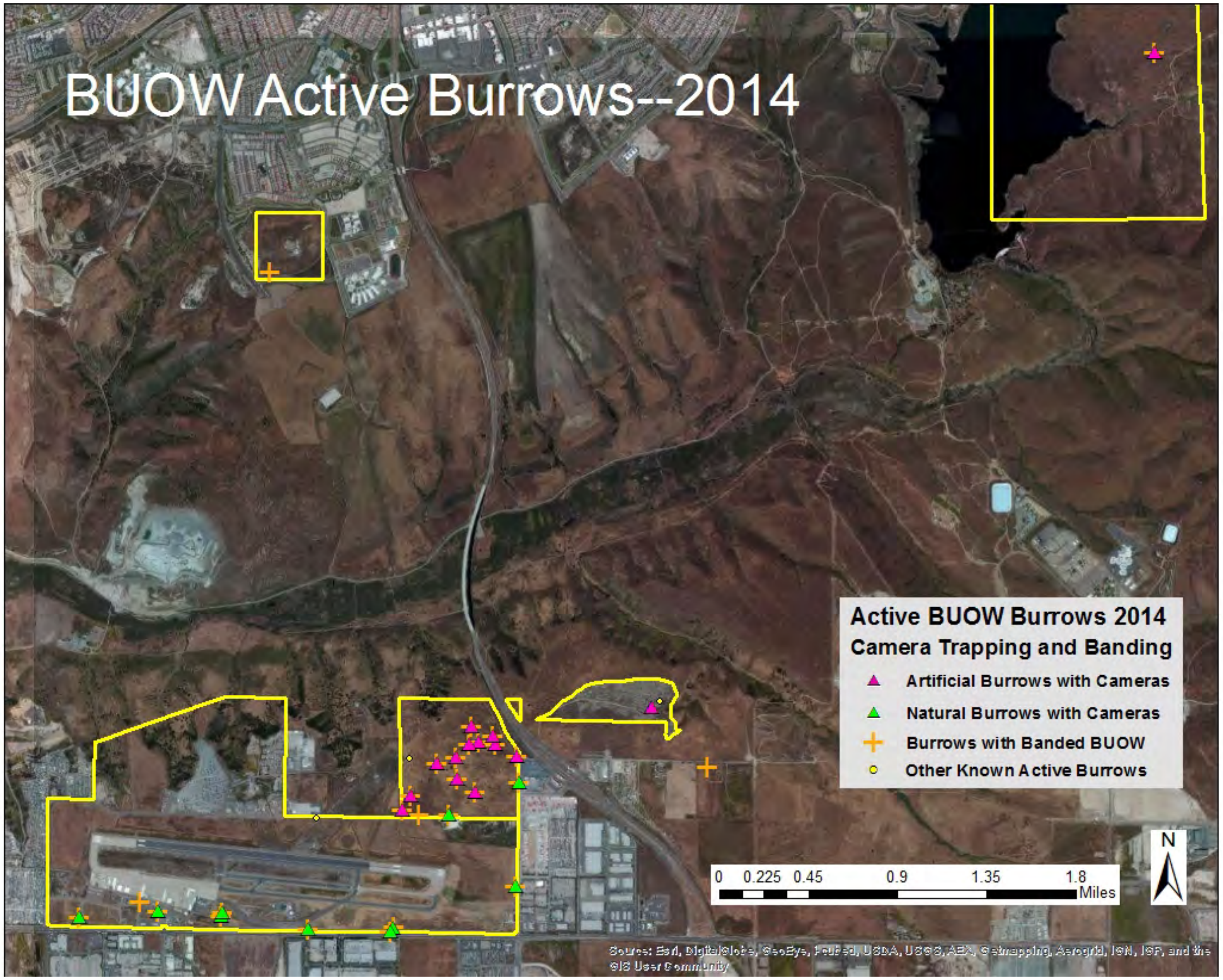

Figure 15a. Map of all active BUOW burrows found in 2014.

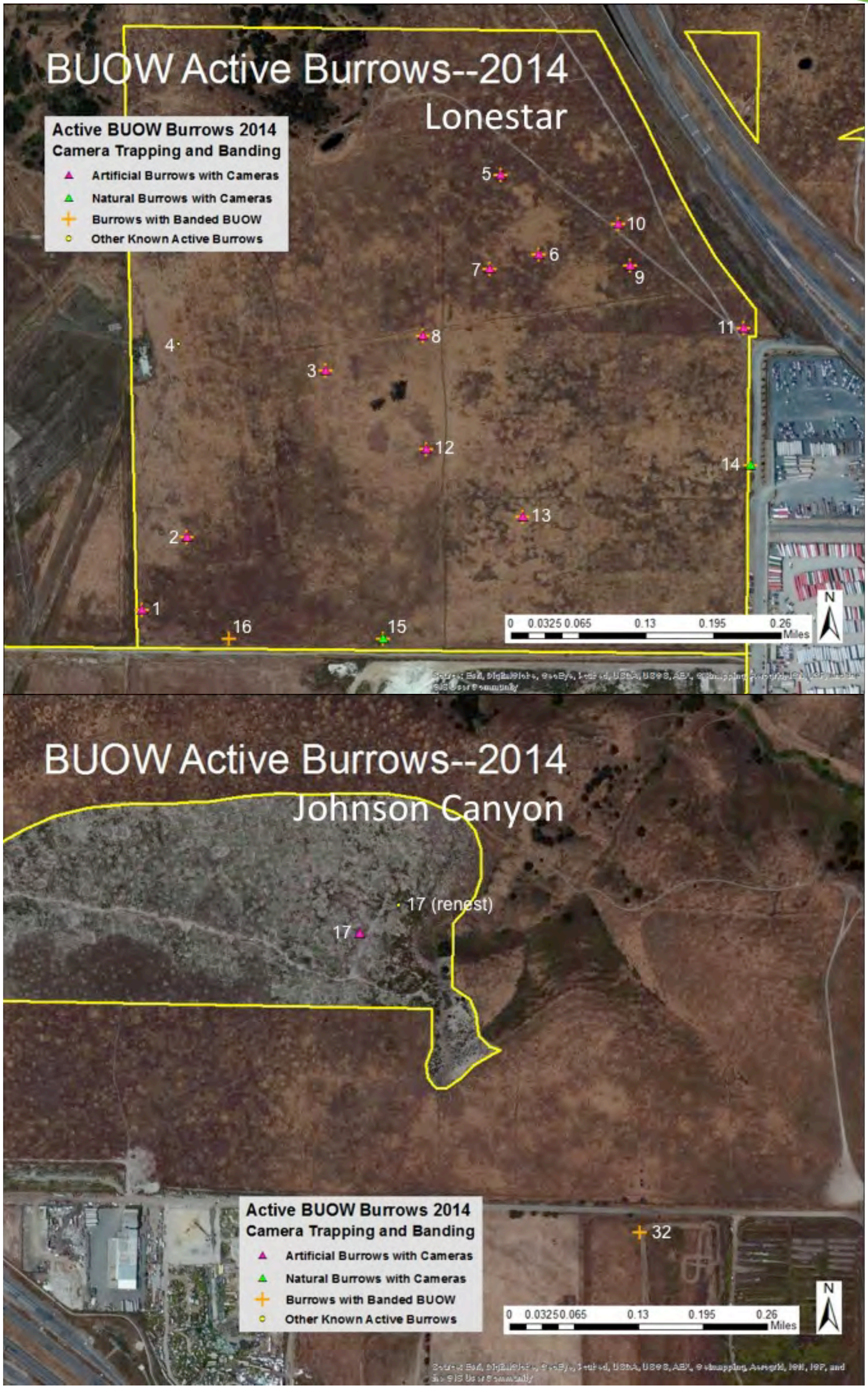

Figure 15b. Map of active BUOW burrows found in 2014. *Numbers refer to burrows listed in Table 7.*

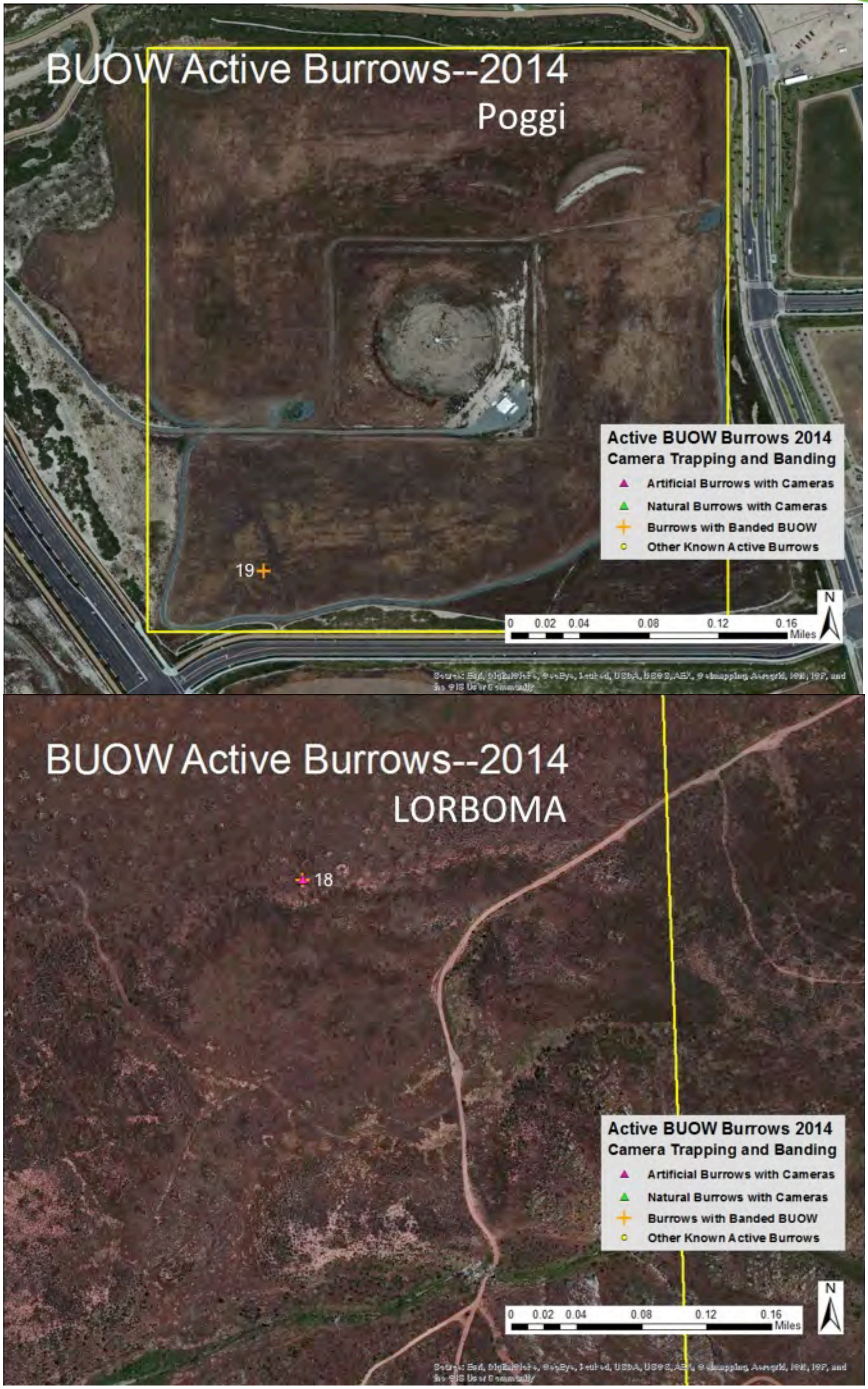

Figure 15c. Map of active BUOW burrows found in 2013. *Numbers refer to burrows listed in Table 7.*

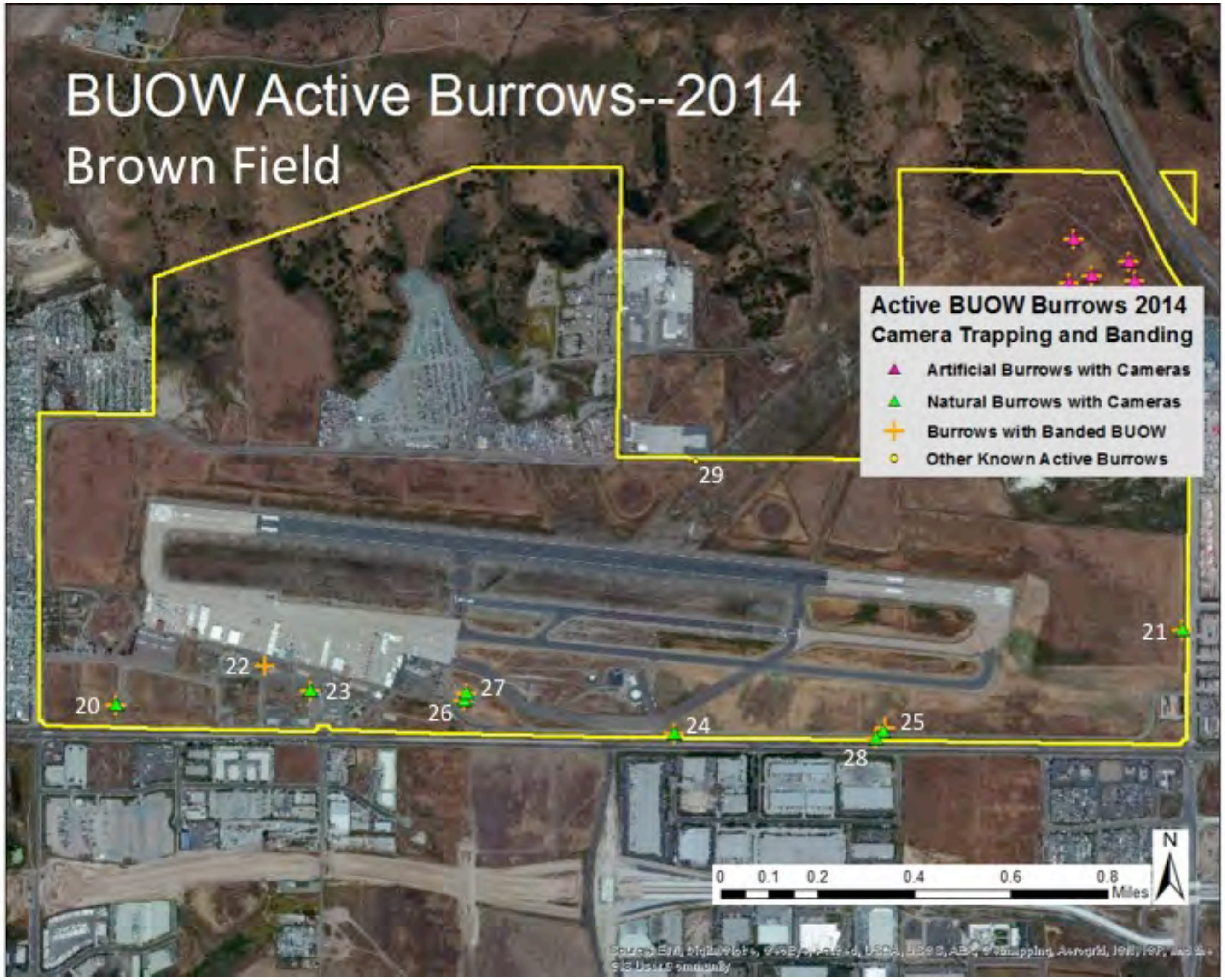

Figure 15d. Map of active BUOW burrows found in 2014. *Numbers refer to burrows listed in Table 7.*

Table 8. Summary of BUOW banded in 2014. *Asterisk indicates a bird banded in a previous year that was recaptured in 2014. Parentheses indicate a bird banded in a previous year that was not recaptured in 2014.*

		Family	Adults: Female	Adults: Male	Juveniles	Total per Family
Natural	1	BF: Cul du sac	1*	1		2
	2	BF: LMSS	1*	1	3	5
	3	BF: Gravel Lot	(1)	1*		2
	4	BF: India	1	1	4	6
	5	BF: Schoolhouse	1		5	6
	6	BF: Tripad South	1	1	4	6
	7	BF: Tripad North	1*	1	5	7
	8	BF: White Poles	1	1	2	4
	9	LS: Euc 17 Fence	1	1	1	3
	10	LS: 185 Berm		1		1
Artificial	11	LS: LS 3	1	1	3	5
	12	LS: LS 23	1*	1*		2
	13	LS: LS 42	1	1*	3	5
	14	LS: LS 97			2	2
	15	LS: LS 105		1		1
	16	LS: LS 107	(1)			1
	17	LS: LS 112	1	1	1	3
	18	LS: LS 129	(1)	1		2
	19	LS: LS 133	1[1]	1	1	3
	20	LS: LS 160	1	1		2
	21	LS: LS 193		1	1	2
	22	LS: Squirrel Plot	1*	(1)	1	2
	23	LO: LO 33		1	2	3
	24	JC: JC 17/12				0
		Totals	19	20	38	77

[1]An adult female was caught at LS 102; it may have been the female from LS 133 but we cannot be certain.

Camera trapping

We monitored 22 burrows (8 natural, 14 artificial) during the breeding season using camera traps (the Poggi burrow was abandoned early so we have limited data). Camera traps ran from 3 April to 9 September for a total of 2030 camera days and collected approximately 1.2 million photos. Volunteers were recruited and trained, and completed the first tier of photo processing. Quality control was completed by staff. Changes in prey identification were related to whether a prey item was categorized as "unknown prey" (meaning volunteers were unable to assign the prey item to a taxon group). Most changes resulted in a prey item being recategorized from the "unknown" category to the "invertebrate" category.

In 2013, we determined that the camera angle to the burrow entrance affected our ability to detect and/or identify prey deliveries. In 2014, we set the cameras up perpendicular to the burrow entrances, which facilitated better identification of prey items. We still had situations in which a prey item could not be positively identified to taxon ("prey seen unknown") or the prey item was too small to be seen (e.g. earwigs), but we could clearly see a beak-to-beak exchange ("prey unseen"). These photos were combined into the "unknown prey" category for analysis.

Prey

We recorded a total of 12,771 prey deliveries at the 22 monitored burrows (Table 9), with an additional 2,808 exchanges that were likely prey deliveries but could have been preening events or other interactions between the owls. These "possible" prey deliveries were not included in data analysis. At all of the burrows, invertebrates made up the highest proportion of prey deliveries. At some of the burrows, the proportion of unknown prey deliveries was relatively high; this was probably a result of not having the cameras set at an optimal angle due to burrow configuration. Prey deliveries occurred at all hours of the day, but there was a distinct pattern to the timing of prey deliveries (Figure 16). Most deliveries occurred between 5 PM and 5 AM usually with a peak between 8 PM and midnight. This was the same pattern that we observed in 2013.

As was the case in 2013, productivity (in terms of numbers fledged) was positively related to the number of prey deliveries per camera trap day, however the relationship was only marginally significant (R^2 = 0.18, $F_{(1, 17)}$ = 3.72, p = 0.071). This analysis is based on total prey items delivered and does not take into account the size or quality of the prey item so it is perhaps not surprising that this relationship was not strong. However, the lack of clear association was driven largely by a single statistical outlier: a burrow having only a single chick that failed to fledge, but one of the highest prey delivery rates. When this outlier was removed from the analysis, the fit of the regression line improved and the relationship became significant (R^2 = 0.38, $F_{(1, 16)}$ = 9.68, p = 0.007). We also found a significant *negative* relationship between the maximum number of chicks and the proportion of invertebrates delivered (R^2 = 0.21, $F_{(1, 17)}$ = 4.63, p = 0.046). This result could suggest that invertebrate prey is suboptimal, but the relationship was weak and was not observed in 2013. Due to the small sample size, more data is needed to determine the effect of prey types on productivity and optimal foraging conditions for BUOW. The data collected in 2015, combined with the previous data, will help us unravel the complex relationships driving productivity and will allow us to make more informed decisions about future management actions. For example, habitat management supporting alternative prey species, such has herpetofauna, birds, and mammals, could be used if it is found that these prey items lead to greater population productivity. We found a significant positive correlation between the proportions of birds and herptofauna ($r(19)=0.7826$, $p<0.0001$) although neither of these categories made up a high proportion of prey at any one burrow (except for herptofauna at LORBOMA at 14%). This finding suggests that prey base evaluations for herps might also predict prey availability for birds, and vice versa, providing managers with a possibly less labor-intensive index of prey availability.

Table 9. Summary of all prey deliveries seen in camera trap photos during the entire 2014 breeding season.

Site	Burrow	Prey Deliveries/ Camera Trap Days	Birds (%)	Inverts (%)	Herps (%)	Mammals (%)	Unknown (%)
Lonestar	LS 3 (A)	19.80	<1	80	<1	2	18
	LS 23 (A)	16.67	<1	89	<1	4	7
	LS 42 (A)	7.30	<1	80	<1	<1	18
	LS 97 (A)	4.10	<1	72	0	4	24
	LS 105 (A)*	2.41	0	65	2	4	28
	LS 107 (A)	3.43	0	90	1	4	4
	LS 112 (A)	12.40	0	93	0	<1	7
	LS 129 (A)	4.59	0	77	<1	17	5
	LS 133 (A)	8.85	0	84	2	8	6
	LS 160 (A)*	4.96	<1	73	3	17	6
	LS 193 (A)	3.27	<1	76	<1	3	20
	LS Squirrel Plot (A)	6.86	<1	80	<1	4	16
	Euc 17 Fence	1.86	1	88	2	6	3
	LS 185 Berm	1.56	0	92	0	5	3
Johnson Canyon	JC 17/12 (A)*	5.66	0	75	<1	14	10
LORBOMA	LORBOMA 33 (A)	4.27	2	66	14	8	11
Poggi	Poggi	6.10	<1	86	0	3	11
Brown Field	Cul-du-sac	0.68	0	67	0	32	1
	La Media Stop Sign	8.58	0	54	<1	4	41
	Gravel Lot*	5.29	<1	87	<1	5	7
	India	6.58	<1	67	<1	9	23
	Old Schoolhouse	5.90	0	71	0	3	26

*Data for these burrows include renests.

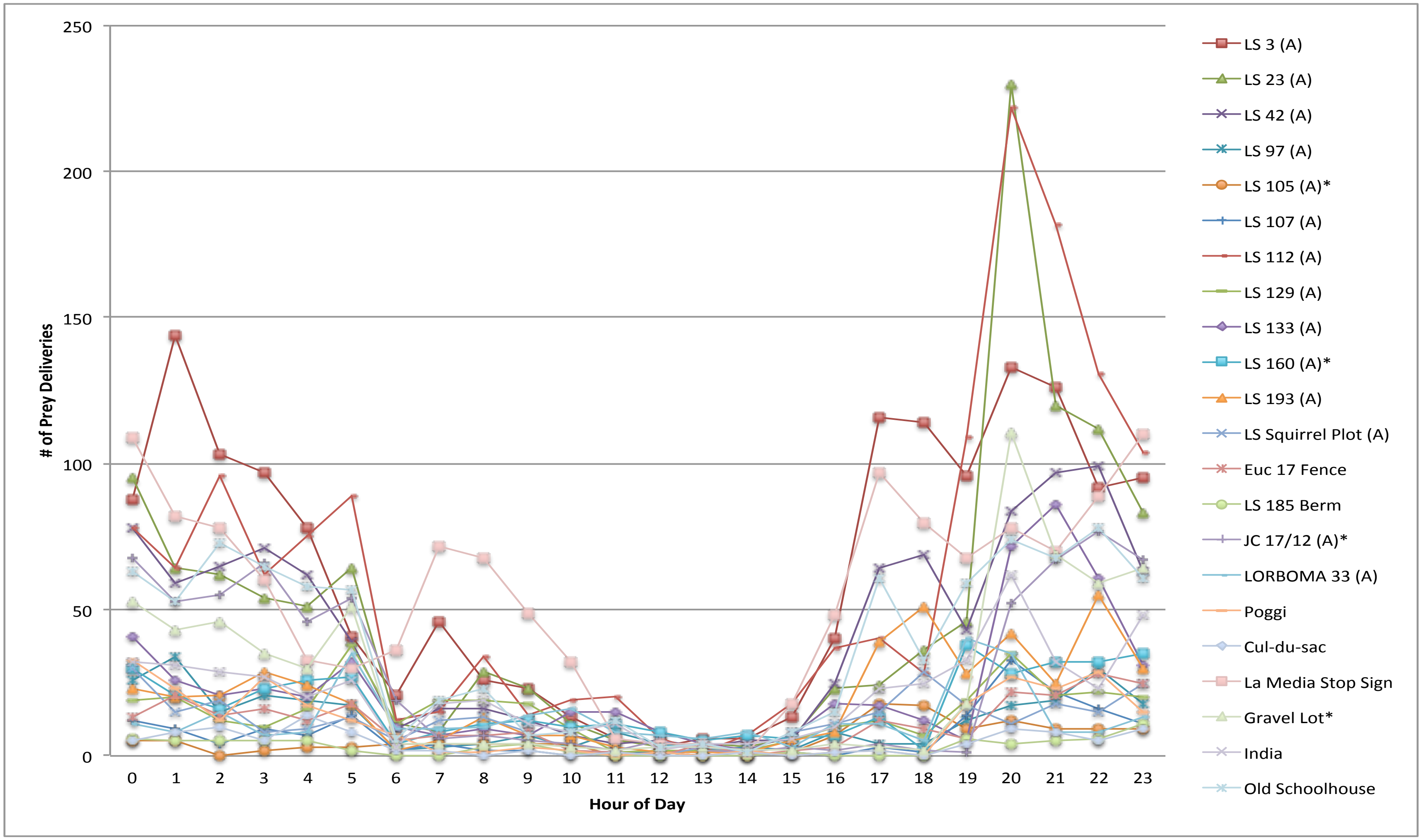

Figure 16. Graph of timing of prey deliveries seen in camera trap photos during the entire 2014 breeding season. *Burrows with an asterisk include renests.*

Juvenile mortality

We documented 19 confirmed or likely juvenile mortality events during the 2014 breeding season, which represents 28% of the maximum number of chicks recorded (Table 10). Of these events, 13 were depredations by non-BUOW predators and 4 were depredations by BUOW. Infanticide occurred at 3 of the 22 burrows and was usually done by the adult female. In 2013, the infanticides appeared to be driven by mate loss and/or poor foraging conditions, but in 2014 the cause was less clear. Also in contrast to 2013, when infanticide was the most common documented cause of juvenile mortality, in 2014 common ravens (*Corvus corax*) were the leading cause of observed mortality. 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 11) suggesting that we may be missing a significant cause of juvenile mortality before emergence.

We recorded two mortality events where the exact cause of death was unknown. In one case (LS 42), a recent fledgling appeared to succumb to disease or starvation, and in the second (LS 23), a chick that seemed to be blind in one eye (possibly as a result of inbreeding) disappeared about one week before fledging. One depredation event (at Old Schoolhouse) was directly observed in the field (not on camera). In that case, a recent fledgling flushed away from the burrow and was subsequently attacked and killed by common ravens. The carcass was collected and tissue samples were taken for cell culture. This cell line is preserved in the Frozen Zoo® at the Beckman Center, San Diego Zoo Institute for Conservation Research. The remainder of the carcass was sent to the Wildlife Investigations Laboratory of CDFW for rodenticide testing.

More than half of all juvenile mortality was attributed to raven predation. Ravens are efficient predators of eggs and chicks of many species, and because of human subsidization have increased in number. Their impacts on endangered species in California are substantial, affecting species as diverse as western snowy plovers, California least terns (Boylan et al. 2015), and desert tortoises (Kristan and Boarman 2003). Predation can be anticipated to have increasing impacts in the human-altered landscapes of the anthropocence through expanding, subsidized, and invasive predator populations and mesopredator release (Crooks and Soule 1999; Gompper and Vanak 2008). Our preliminary results suggest that more attention should be devoted to understanding predation effects on BUOW populations in San Diego County, where fragmentation and subsidization has led to large increases in some predators, in particular the common raven. Future research should target ravens as possible factors limiting population recruitment for BUOW.

Table 10. All juvenile mortality events recorded in 2014.

Site	Burrow	Mortality event	Date	Additional Info
Lonestar	LS 23 (A)	Infanticide	7-May	Unbanded pinkie brought out of burrow by female
		Infanticide	8-May	Unbanded pinkie brought out of burrow by female
		Unknown—possible birth defects	3-Jun	Likely blind in one eye, may have had other impairments
	LS 42 (A)	Unknown—disease or starvation?	6-Jul	Fledgling died at LS 40; apparently from disease or starvation
	LS 97 (A)	Unknown—likely predation	8-Jun	Last seen on camera June 8; band and feathers found near LS 97 on June 19
	LS 105 (A)	Raven	5-May	Confirmed on camera
		Likely Raven	5-May	Predation unconfirmed but likely; max count data corroborate
	LS 129 (A)	Raven	19-May	Confirmed on camera
		Likely Raven	19-May	Predation unconfirmed but likely; max count data corroborate
	LS 133 (A)	Likely Raven	23-May	Predation unconfirmed but likely; max count data corroborate
	LS 160 (A)	Raven	8-May	3 juveniles attacked by raven in one set of images; 2 remaining juveniles attacked 10 mins later in next set of photos
		Raven	8-May	
		Raven	8-May	
		Raven	8-May	
		Raven	8-May	
	Euc 17 fence	Infanticide	9-Jun	
Johnson Canyon	JC 12 (A) (renest)	Infanticide	5-Jul	
LORBOMA	LO 33 (A)	Coyote	22-May	
Brown Field	Old Schoolhouse	Raven	3-Jun	Observed in field; fledgling killed by ravens; carcass collected for tissue culture and rodenticide testing

Table 11. Nesting stage dates and productivity for 2014 at burrows monitored with camera traps or direct observation.

Burrow	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]
LS 3 (A)	Apr 4-Jun 19	7 (4/10)	24-Mar	23-Apr	7-May	4 (May 8-June 5)	7-Jun	4
LS 23 (A)	Apr 10-Jun 19	7 (4/25)	27-Mar	26-Apr	10-May†	1 (May 10-June 3)	10-Jun	0
LS 42 (A)	Apr 25-Sep 9*	4 (4/25)	29-Mar	28-Apr	12-May	4 (May 16-25)	12-Jun‡	3**
LS 97 (A)	Apr 11-Jun 19	8 (4/17)	31-Mar	30-Apr	14-May	3 (May 14-29)	14-Jun	0
LS 105 (A)	May 1-Jun 24	unknown§	18-Mar	17-Apr	1-May	2 (May 1-5)	1-Jun	0
LS 105 (A)--renest	May 1-Jun 24	4 (5/29)	19-May	16-Jun	none	0	n/a	0
LS 107 (A)	Apr 25-Jun 13	6 (5/13)	25-Apr	none hatched	none	0	n/a	0
LS 112 (A)	Apr 4-Jul 31*	7 (4/11)	26-Mar	25-Apr	9-May	2 (May 14-18)	9-Jun	1
LS 129 (A)	Apr 4-Jun 19	6 (4/17)	3-Apr	3-May	17-May	2 (May 17-19)	17-Jun	0
LS 133 (A)	Apr 11-Aug 22*	5 (4/25)	3-Apr	3-May	17-May	2 (May 17-23)	17-Jun	1
LS 160 (A)	Apr 4-Jun 26	9 (4/10)	23-Mar	22-Apr	6-May	5 (May 8)	6-Jun	0
LS 160 (A)--renest	Apr 4-Jun 26	5 (5/29)	21-May	18-Jun	none	0	n/a	0
LS 193 (A)	Apr 4-Aug 22	6 (4/25)	12-Apr	12-May	26-May	1 (May 26-July 12)	26-Jun	1
LS Squirrel Plot (A)	May 22-Sep 4	n/a	12-Apr	12-May¶	22-May or earlier¶	4 (May 23-24)	26-Jun	1
Euc 17 fence	Apr 18-Sep 3*	n/a	25-Apr	25-May	8-Jun	2 (June 8-9)	9-Jul	0
LS 185 Berm	Apr 25-Jun 5	n/a	no data	no data	none	n/a	n/a	n/a
JC 17 (A)	Apr 4-May 29*	6 (4/16)	6-Apr	6-May\\	none	0	n/a	0
JC 12 (A)--renest	May 15-Jul 31	no data	8-May	7-Jun	21-Jun	4 (June 23-July 4)	22-Jul	0
LO 33 (A)	Apr 3-Sep 9*	7 (4/11)	25-Mar	24-Apr††	8-May	4 (May 13-22)	8-Jun	2
Poggi	Apr 3-May 15	n/a	n/a	no data	no data	n/a	n/a	n/a
Cul du Sac	Apr 8-Aug 28	n/a	no data	no data	none	n/a	n/a	n/a
La Media Stop Sign	Apr 8-Sep 9	n/a	12-Mar	11-Apr	25-Apr	3 (April 28-Aug 5)	26-May	3
Gravel Lot	Apr 8-Aug 8	n/a	29-Mar	28-Apr	12-May	1 (May 12)	12-Jun	0
Gravel Lot--renest	Apr 8-Aug 8	n/a	24-May	23-Jun	7-Jul	1 (July 7-9)	7-Aug	0
India	Apr 8-Jun 24	n/a	25-Mar	24-Apr	8-May	5 (May 10-12)	8-Jun	4

Table 11 continued.

Burrow	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]
Old Schoolhouse	Apr 8-Aug 8	n/a	16-Mar	15-Apr	29-Apr	7 (May 5)	30-May	2**
Tripad South‡‡	n/a	n/a	5-Apr	5-May	19-May	4 (June 6)	19-Jun	3
Tripad North‡‡	n/a	n/a	24-Mar	23-Apr	7-May	5 (May 27)	7-Jun	4
White Poles§§	Aug 15-Sep 3	n/a	8-Jun	8-Jul¶	8-Aug	2 (Aug 8-16)	22-Aug	1

[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]First egg date was determined by back-dating 30 days from estimated hatch date.
[3]Hatch date 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.
*Cameras were moved to satellite burrows as chicks/fledglings moved; camera dates indicate range of dates for a given family not the specific burrow.
†First emergence of healthy chick--two chicks seen on camera before this date due to infanticide (see Table 10).
‡Actual fledge date was later--owlets grew slowly and were too small for auxiliary bands until after estimated fledge date.
§ Eggs never seen with peeper scope, chicks heard peeping in chamber on 25 April.
¶Chick age at capture was estimated using the wing chord measurement; hatch date was estimated by back-dating. Chicks had already emerged at the time cameras were deployed.
\\Burrow chamber opened on 6 May and no chicks were seen but peeping was heard from the burrow tunnel.
††Actual hatch date—one egg was pipped and peeping on 30 April at nest check.
**One of the fledglings from each of these burrows was known to have died shortly after fledging.
‡‡ Burrows were not monitored with cameras so all dates are estimates and number fledged is a minimum estimate from observation data.
§§ Camera was set up late only to keep track of nest status. All dates are estimates. The first emergence date is earliest date when chicks seen at the burrow entrance; actual emergence is likely earlier.

Reproductive success

There was a wide range of estimated dates of first egg-laying (12 March—8 June, Table 11) and hatching (11 April—8 July); these dates include renesting attempts. There were four confirmed second nesting attempts (LS 105, LS 160, JC 17/12, and Gravel Lot), and there was a very late nest (White Poles) which we suspect was a second or third attempt. However, we did not find the nest until the juveniles had emerged and we do not know if the pair had attempted to breed at a different burrow earlier in the season. For all nesting attempts combined, the overall average maximum number of chicks per burrow was 2.7 (SE = 0.37, n=26) and the overall average maximum number of fledglings per burrow was 1.2 (SE = 0.29, n=26).

Reproductive success was lower in 2014 compared to 2013, although the difference between years was nonsignificant. However, this potential downward trend in population performance needs to be monitored, particularly in light of the continuing drought conditions. Our indicators of reproductive success derived from camera traps provide critical information for analyzing the effects of other factors, such as habitat, foraging patterns, and burrow characteristics. By continuing to monitor reproductive success along with other ecological variables, we will be better able to determine the important drivers of reproductive success.

GPS Data and Home Range Estimates

Of the 20 males we captured during the breeding season, most were too light to satisfy the 5% of body weight rule. We were able to attach GPS dataloggers to six adult males during the nestling period for their respective broods (Table 12). The Cul-du-Sac male had sufficient body weight for datalogger attachment, but he did not have dependent juveniles; because of concerns about our ability to recapture him to retrieve the data, we did not place a datalogger on him. Five of the outfitted owls were recaptured after the scheduled period of data collection (~2 weeks) and their location data were retrieved. Two of these five dataloggers malfunctioned and only took half of the programmed points (~1 week). These units were subsequently returned to the manufacturer for repair and returned to us for redeployment in the future. The remaining male (from LS 185 Berm) was outfitted with a datalogger on 9 May and was last seen on camera on 12 May; we were not able to recapture him to retrieve the data and his disposition is unknown.

The maximum distance traveled from the breeding burrow was 1199.94m and the average maximum distance across all individuals was 847.25m (SD = 361.73m). We used a 95% MCP and a 95% kernel utilization distribution (KUD) with the smoothing factor (h) set to 40m for all individuals to estimate the home range sizes. The two different methods gave similar results with average home range size estimates of 0.22 km^2 and 0.24 km^2, respectively. This is likely an underestimate of their actual home range size given the short 2-week time interval. However, this estimate does accurately reflect the area used for foraging while provisioning chicks, and thus the foraging area which likely determines the reproductive outcome. Although large individual variation in home range size can occur

(Haug and Oliphant 1990; Gervais et al. 2003), we found that 90% of all locations were within 560m of the respective burrow. Similarly, Haug and Oliphant (1990) and Gervais et al. (2003) found that the majority of foraging locations (95% and 80%, respectively) were within a 600 m radius around a nest site. Moreover, Gervais et al. (2003) found that distance to nest site was a key factor explaining adult male owl foraging site selection. These results illustrate the importance of the habitat immediately surrounding the breeding burrow both in terms of its foraging quality and the potential hazards to the birds. For example, three of the owls had home ranges that overlap major roadways in Otay Mesa (Figure 17). Consequently, the siting of artificial burrows, habitat restoration, and other management activities should take into account the habitat, food availability, and risks of disturbance or other negative impacts to BUOW within this small (500-600 m radius) spatial scale.

Table 12. Summary of GPS data and home range estimates for five BUOW.

Burrow & Bird ID[1]	Total # Locations	Proportion Locations Discarded[2]	# Locs for HR Analysis	95% MCP (km^2)	95% KUD (km^2)[3]	Maximum Distance from Burrow (m)	Start Date/Time (PDT)	End Date/Time (PDT)
LS 3: 71 over X	48	0.354	31	0.1593	0.2329	499.93	5/9/14 21:45	5/16/14 5:15
LS 23: White AA	101	0.356	65	0.3754	0.3361	993.84	5/19/14 23:15	6/2/14 23:15
LS 160: 62 over X	102	0.304	71	0.1706	0.2523	1199.94	5/5/14 21:45	5/20/14 2:15
LMSS: 68 over X	50	0.5	25	0.2979	0.2106	1121.50	5/12/14 23:15	5/19/14 21:45
White Poles: 20 over Y	100	0.29	71	0.1189	0.181	421.03	8/14/14 21:43	8/28/14 23:15
Mean	80.2	0.361	52.6	0.2244	0.2426	847.25		
SD	28.5	0.083	22.69	0.1078	0.0586	361.73		

[1]Owl from LS 185 Berm not included, no data were retrieved.
[2]Locations that had a DOP>3 and Satellites≤3 were omitted from analysis.
[3]The smoothing factor (h) was set to 40m for all individuals.

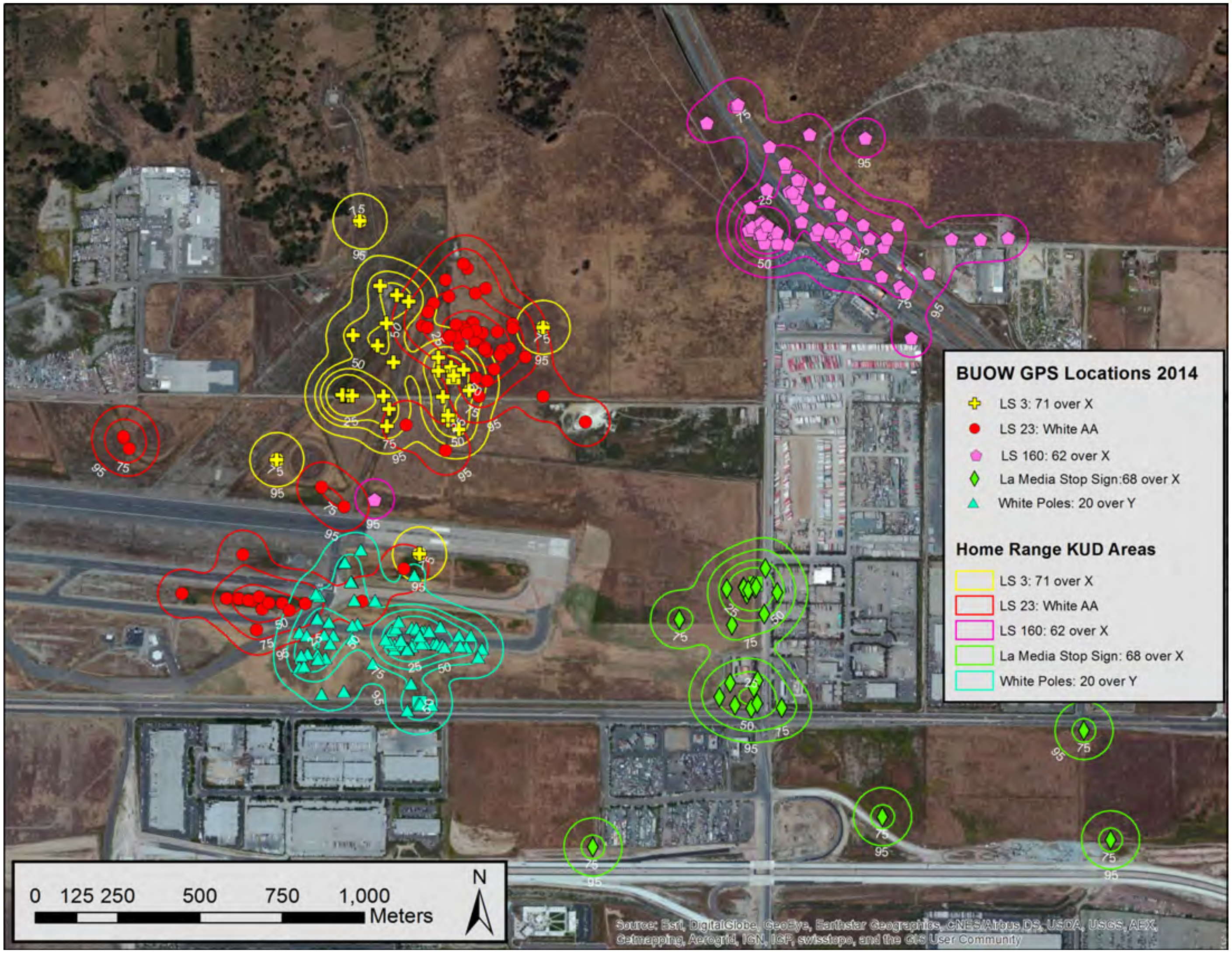

Figure 17. Map of kernel home ranges for five BUOW; contour lines indicate 25%, 50%, 75%, and 95% KUD, respectively.

Artificial vs. natural burrows

The average maximum number of chicks was 2.4 (S.E. 0.42, n=17) at artificial burrows and 3.3 (S.E. 0.69, n=9) at natural burrows. The average maximum number of fledglings was 0.76 (S.E. 0.29, n=17) at artificial burrows and 1.9 (S.E. 0.56, n=9) at natural burrows. We did not find a statistically significant difference between natural and artificial burrows in the maximum number of chicks (t(26)=1.14, p=0.27) or in the number of fledglings (t(26)=1.77, p=0.10). However, the small sample sizes create low power to detect statistically significant differences. Because there was no significant difference between years, we combined the data for both 2013 and 2104. Using the combined dataset, we found that natural burrows had a significantly higher fledging rate than artificial burrows (t(54)=2.14, p=0.04).

Interestingly, we found that burrow microclimate was affected by burrow type. The mean daily inside humidity differed significantly by burrow type ($F_{2,10}$=10.400, p=0.004), as did the mean daily coefficient of variation of inside humidity ($F_{2,10}$=4.905, p=0.033; Table 13). We also found that the mean daily differences between inside and outside were marginally significant for humidity ($F_{2,8}$=3.835, p=0.068) and significant for temperature ($F_{2,8}$=10.750, p=0.005; Table 13). These effects were driven by large differences in performance between the natural burrows versus artificial burrows made of either wood or plastic, which did not differ from each other. The humidity inside natural burrows was higher and less variable than the humidity inside artificial burrows. Natural burrows were also better at buffering against outside conditions, as indicated by the finding that inside temperature and humidity were more divergent from outside conditions in natural than artificial burrows. Thus natural burrows were warmer than artificial burrows during the nighttime and were cooler during the hottest part of the day. Temperature and humidity are critical factors in avicultural methods for chick and egg care and are known to have major effects on hatchability of eggs and chick survival. Maintaining constant conditions is a critical factor, so the less variable microclimate afforded by the natural burrows may account for the differences in fledging rates and may also have undetected impacts on egg outcomes.

These results indicate that natural burrows are better buffers against outside climatic conditions. The factors giving rise to these differences are at present unknown, but differences in soil versus wood or plastic substrates may explain these effects. Alternatively, architectural differences between natural and artificial burrows may account for the differences in microclimate. Natural burrows are known to have twists and turns that may influence airflow. In addition, the natural burrows we examined seemed to have only one entrance, whereas all of the artificial burrows we examined had two entrances that created a pass-through for airflow that may explain the drier and more variable conditions in artificial burrows, as well as the tendency for artificial burrows to change more readily with outside conditions.

We do not have the data to support any clear causal relationships between burrow type, microclimate, and reproductive success. Clearly, factors such as prey availability, predation, and parental quality must also influence reproductive outcomes. There is no reason to suspect that parental quality varies systematically with burrow type and so should not introduce bias or explain differences in fledging rates. The prey availability hypothesis is also not supported by our camera trap data on prey delivery: the number of prey deliveries did not differ significantly between natural and artificial burrows (U=33, Z=-0.14, p=0.89), nor did any of the prey types. From the camera trap data, we documented predation at 6 out of 14 artificial burrows (43%) and only 1 out of 8 natural burrows (13%); however, this difference was nonsignificant (Fisher's Exact p=0.19).

These findings lead us to conclude that differences in microclimate and its effects on egg and/or chick survival may be contributing to differences in reproductive output. If these somewhat preliminary observations hold up with the additional data collected in 2015, there are clear management implications. These findings are encouraging because it means that modification of artificial burrows to make them more like natural burrows may have positive impacts on population performance, a hypothesis that should be tested subject to adaptive management protocols. The differences in predation, although nonsignificant with our small sample size, suggest that perhaps the placement of artificial burrows in unsuitable habitat could be creating an ecological trap. However, we were unable to detect differences in prey availability between natural and artificial burrows, so this statement remains more speculative at this time.

Table 13. Microclimate at natural burrows and two types of artificial burrows (plastic and wood).

	Burrow Material Type					
	Natural (n=3)		Plastic (n=7)*		Wood (n=3)	
	Mean	(SE)	Mean	(SE)	Mean	(SE)
Daily Inside Humidity	83.51	(4.95)	57.56	(3.24)	58.37	(4.95)
Daily Coefficient of Variation of Inside Humidity	2.70	(1.17)	5.54	(0.77)	7.88	(1.17)
Daily Difference in Inside/Outside Humidity	23.97	(1.61)	19.18	(1.24)	18.26	(1.61)
Daily Difference in Inside/Outside Temperature	14.95	(1.04)	9.38	(0.80)	9.19	(1.04)

*Sample size for daily difference in inside/outside humidity and temperature was reduced to 5 due to the loss of the outside iButton.

Over-winter BUOW presence at Rancho Jamul Ecological Reserve

During the 2014-2015 winter, ICR staff did not observe BUOW using Rancho Jamul Ecological Reserve for overwintering. However, CDFW staff released five rehabilitated BUOW from Project Wildlife (three of which were banded by ICR staff) at the Rancho Jamul Burrowing Owl Management Area using a soft release method. One owl was observed by CDFW staff at the JC squirrel plot for approximately 1 week after release and up to three others used the release burrow and the surrounding area for approximately 2 weeks following release.

Other wildlife at/near burrows

We documented a number of other species at or using the owl burrows including other bird species, mammals, herptofauna, and invertebrates. Other species seen on camera at owl burrows included:

- American crow
- American kestrel
- Bell's sparrow
- Brewer's blackbird
- cactus wren
- California thrasher
- California towhee
- common raven
- Cooper's hawk
- great horned owl
- greater road runner
- hooded oriole
- horned lark
- kingbird spp.
- mourning dove
- northern harrier
- northern mockingbird
- passerine spp.
- rock pigeon
- rock wren
- western meadowlark
- black-tailed jackrabbit
- bobcat
- California ground squirrel
- coyote
- desert cottontail
- domestic dog
- kangroo rat spp.
- long-tailed weasel
- raccoon
- striped skunk
- various mouse and vole spp.
- woodrat spp.
- California king snake
- other various snake spp.
- western fence lizard

General Discussion & Conclusions

These studies of BUOW were selected to allow for integration of data across studies so that the sum of the results can provide greater insights than if they each were conducted in isolation. The GPS data on spatial movements provide important information on the movements of owls, allowing us to determine where they forage and what risks they might encounter. Combining these data with information about prey delivery derived from our camera trap study, which is a major focus of our work in 2015, will allow us to understand how home range relates to access to prey. We also are conducting habitat surveys to characterize the vegetation and combining these data with geospatial information available for topography, soils, and other landscape features. In combination, these data will allow us to determine how the habitat characteristics in BUOW home ranges relate to foraging success, including the type and frequency of prey delivery to dependent offspring. These data in turn will be combined with our data on reproductive success, allowing us to correlate all of these variables with the number of chicks fledged. Our camera trap data also provide information on predation events and other sources of mortality, and each of these factors may be associated with habitat characteristics and threats present in the home range. This combination of research efforts will give us a remarkable and unprecedented picture of the ecological factors driving population performance, which can serve as a roadmap for site selection for BUOW recovery and provide informed guidance for management of habitat for BUOW.

Many of the conclusions from the synthesis of the above variables will be available after the addition of data collected in 2015, but some preliminary conclusions can be drawn now. Reproductive success appears related to the frequency of prey deliveries and possibly type of prey. Importantly, there is substantial variation among burrows in the proportion of invertebrate vs. vertebrate prey, indicating that some home ranges may be of higher quality than others. However, owls living at these burrows do not appear to increase their foraging range to access higher quality prey, and this appears to have impacts on reproductive success. This is an important consideration: BUOW may not show adaptive behavior to poor foraging conditions by expanding home range, thus managers will need to take special consideration when siting artificial burrows or encouraging BUOW colonization. If burrows are sited in poor foraging habitat, they may become an ecological trap, drawing in owls to areas of low productivity.

Our data also reveal that post-emergence chick mortality (and perhaps egg and pre-emergence chick mortality, which are more difficult to document) is a significant issue potentially limiting population recruitment. Sources of mortality vary in time and space, but two primary sources appear to be predators and infanticide. Infanticide is likely driven by other ecological conditions that make rearing of chicks more difficult, again pointing to possible habitat influences on productivity. Predation is not well understood in BUOW but it is clear that anthropogenically-subsidized predators such as ravens (and possibly coyotes) have the potential to negatively impact these small vulnerable populations. Establishing new recovery sites for BUOW that are more removed from areas where these opportunistic predators are subsidized by human activities may help minimize this problem.

Lastly, we initiated new research to determine the efficacy of artificial burrows as a strategy for recovering BUOW populations. Artificial burrows are an important management tool, but it is important to understand their limitations, and whether they can be improved. Our preliminary data suggest that reproductive success is lower in artificial than natural burrows, leading us to evaluate factors that may potentially explain this difference. Of course, natural and artificial burrows may differ with regard to all of the ecological variables discussed above, including the surrounding habitat, predation pressure, and foraging opportunities. Thus placement of artificial burrows needs to be closely scrutinized to ensure that we are not creating ecological traps, drawing in owls to areas of high mortality or low reproductive success. While we did not find a difference in prey deliveries, we did observe microclimatic differences between artificial and natural burrows. Artificial burrows performed more poorly in providing a stable microclimate buffering the nests from the changes in temperature and humidity outside. It is plausible that the microclimate inside burrows led to egg or chick loss, explaining the lower reproductive success found in artificial burrows. Fortunately, this information is readily included in management strategies, as simple changes in the design of artificial burrow may bring about improvements.

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Appendix 1. *Additional data tables and site-specific results from squirrel monitoring at translocations sites and the Burrowing Owl Habitat Management Area*

Table A1.1. *Proportion of all squirrels captured during spring trap monitoring to total released by translocation, capture year, plot and sex.*

Translocation	Capture Year	Plot	Female	Male
Initial	2012	SE	12.5%	4.3%
		JE	14.8%	8.0%
		JW	12.0%	8.0%
		JS	42.9%	7.7%
	2013	JB	0.0%	0.0%
		JC	16.2%	17.4%
Supplement	2013	SE	23.3%	10.0%
		JE	66.7%	39.1%
		JW	22.2%	43.8%
		JS	35.0%	20.8%
	2014	JB	53.8%	10.0%
		JC	21.4%	38.9%

Table A1.2. Weighted parameter estimates table for spring trap results. *Estimates and unconditional standard errors (U.S.E.) were calculated through model averaging**.** The relative importance of each parameter is also listed.*

Parameter	Weighted estimate	U.S.E.	Lower 85% CI	Upper 85% CI	Relative importance
Intercept	-2.888	0.307	-3.33	-2.45	
Geology [alluvial]	-0.506	0.291	-0.93	-0.09	1.00
Sex [female]	0.498	0.292	0.08	0.92	0.86
Release type [initial]	-0.381	0.165	-0.62	-0.14	0.81
Geology [alluvial]*Sex [female]	0.478	0.284	0.07	0.89	0.73
Release site [Jamul]	0.213	0.222	-0.11	0.53	0.20
Year [2012]	-0.622	0.269	-1.01	-0.23	0.19
Year [2013]	0.035	0.215	-0.28	0.34	

Table A1.3. Comparative plausibility of parameters influencing presence of squirrels during spring monitoring. *The values represent the relationship of the column factor to the row factor; e.g. Geology is 5.4 times more plausible than Year.*

	Geology	Sex	Release type	Geology *Sex	Site
Sex	1.2				
Translocation	1.2	1.1			
Geology*Sex	1.4	1.2	1.1		
Site	4.9	4.3	4.0	3.6	
Year	5.4	4.7	4.4	4.0	1.1

***Table A1.4. Weighted parameter estimates table for proportion of squirrels captured to released.** Estimates and unconditional standard errors (U.S.E.) were calculated through model averaging**.** The relative importance of each parameter is also listed.*

Parameter	Weighted estimate	U.S.E.	Lower 85% CI	Upper 85% CI	Relative importance
Intercept	0.213	0.036	0.159	0.266	
Release type [supplemental]	0.098	0.029	0.054	0.142	1.00
Release site [Jamul]	0.054	0.039	-0.004	0.112	0.31
Sex [female]	0.036	0.029	-0.008	0.079	0.24

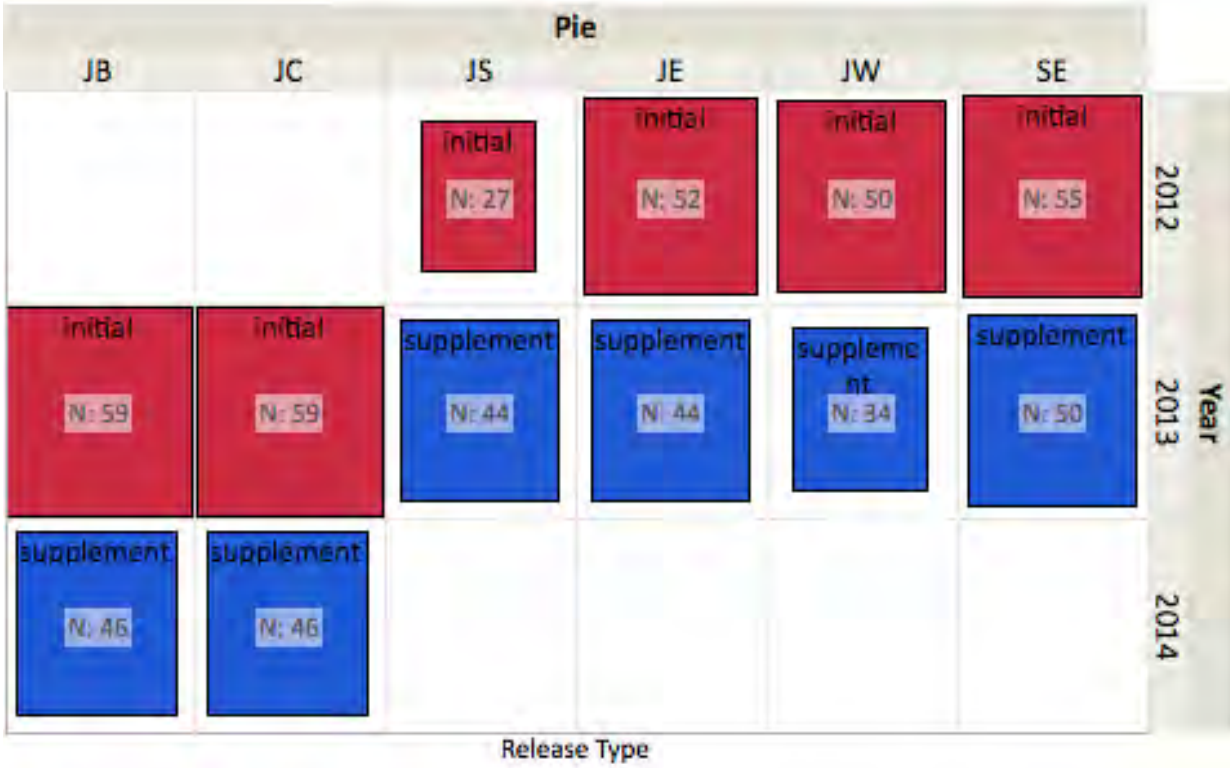

Figure A1.1. Number of squirrels included in logistic regression analysis. *210 rows (squirrels) were excluded, including progeny, recruits OS, ON, SW plots and select individuals with missing data.*

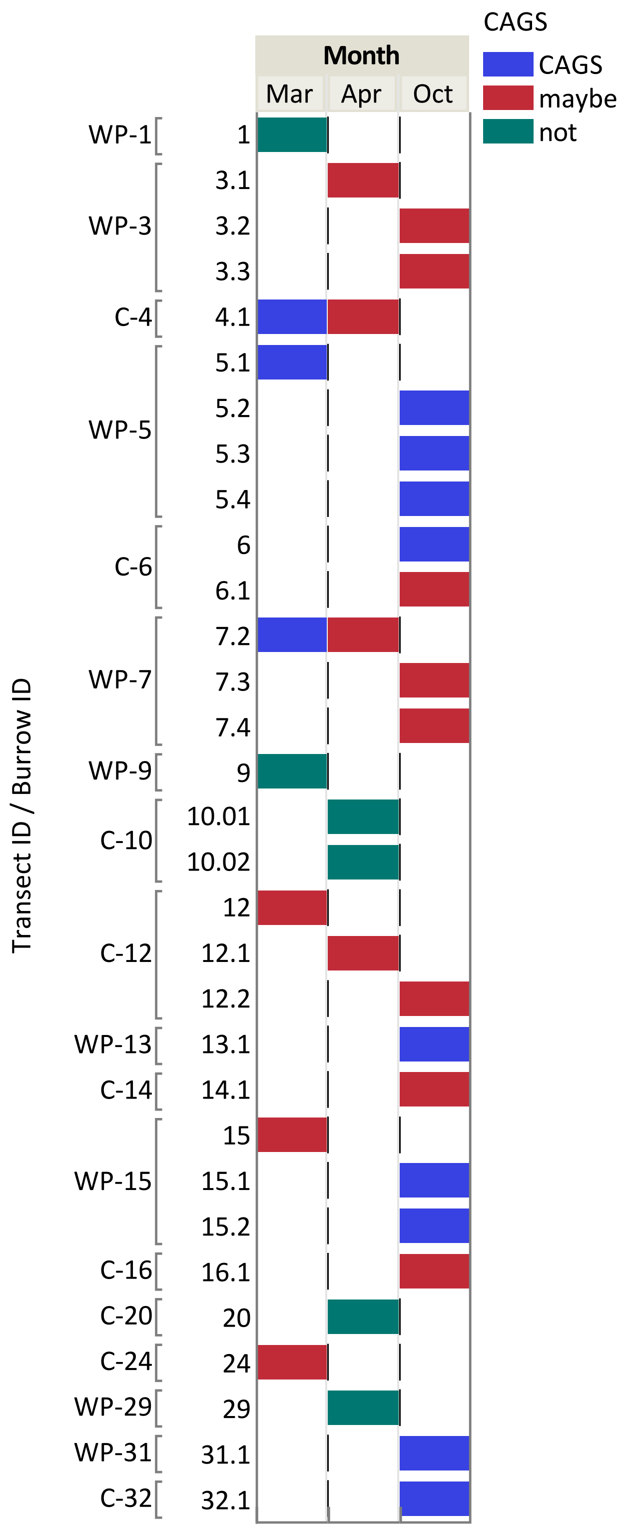

Figure A1.2. All 31 burrows recorded in 2014. *Blue squares represent burrows with evidence of squirrel activity. Red squares indicate probable squirrel burrows, and green squares are most likely collapsed gopher burrows that fit our size criteria.*

Appendix 2. Camera Trap Photo Processing Protocol

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

We use Reconyx Hyperfire camera traps. Photos are taken in series of 3 and are labeled as such (1/3, 2/3, 3/3).

Independent Events

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.

The Binder

There is a large binder called "BUOW 2014 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).

Datasheets

- 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 appear 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.

Logging on to computer/server

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.

Using Adobe Bridge

We will use Adobe Bridge to record prey deliveries/types, predation events/types, human disturbances, other 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.

Navigating to folders

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→2014→[Site]→[Burrow]→[Camera]

Keyword list

- 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.

- 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.
  - 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.
- Prey: This refers to the type of prey that the BURROWING OWLS bring to the burrow.
  - 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.
  - 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.
  - Reptile prey - Mark if prey is reptile.
- Visitor/Predator Species: This refers to other species that may appear on camera (but not as a prey item). It will refer to a predator in the case of a predation event.
  - 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 the predator or 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.
- 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.
- K-rat –Mark if a kangaroo rat is present in the photo.
- mouse/vole –Mark if a mouse or vole is present in the photo.
- raccoon – Mark if a raccoon is present in the photo.
- rabbit –Mark if a rabbit 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.
- roadrunner –Mark if a roadrunner is present in the photo.
- skunk –Mark if a skunk is present in the photo.
- snake/lizard –Mark if a snake or lizard is present in the photo.
- weasel –Mark if a weasel is present in the photo.
- woodrat –Mark if a woodrat is present in the photo.
- other species –Mark for species other than those in this list.

<u>Miscellaneous guidelines</u>

- Make sure to mark prey items as prey items, not as visitor species (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 3. 2014 BUOW Banding Data

Table of all burrowing owls captured in 2014 (auxiliary bands were green unless specified).

Burrow	Date	Age	Sex	USGS band ID (on left)	Aux band ID (on right)	DNA Sample type(s)	Original Banding Year	
BF Cul Du Sac	30-Jun-14	adult	male	804-43290	15 over Y	Blood, feather	2014	
BF Cul Du Sac	30-Jun-14	adult	female	804-19716	16 over X	Blood, feather	2013	
BF Gravel lot	13-May-14	adult	male	804-19732	32 over X	Blood, feather	2014	
BF India	12-May-14	adult	male	804-19779	79 over X	Blood, feather	2014	
BF India	13-May-14	chick	unknown	804-19780	80 over X	Blood, feather	2014	
BF India	13-May-14	chick	unknown	804-19781	81 over X	Blood, feather	2014	
BF India	13-May-14	chick	unknown	804-19782	82 over X	Blood, feather	2014	
BF India	13-May-14	adult	female	804-19783	83 over X	Blood, feather	2014	
BF India	13-May-14	chick	unknown	804-19784	84 over X	Blood, feather	2014	
BF LMSS	7-May-14	adult	male	804-19768	68 over X	Blood, feather	2014	GPS
BF LMSS	9-May-14	adult	female	804-05304	B over E	Blood, feather	2011	
BF LMSS	12-May-14	chick	unknown	804-19777	77 over X	Blood, feather	2014	
BF LMSS	12-May-14	chick	unknown	804-19778	78 over X	Blood, feather	2014	
BF LMSS	29-May-14	fledge	unknown	804-43274	65 over X	Blood, feather	2014	
BF Old Schoolhouse	7-May-14	chick	unknown	804-19765	TARSUS TOO SMALL	feather	2014	FZ
BF Old Schoolhouse	7-May-14	chick	unknown	804-19766	TARSUS TOO SMALL	Blood, feather	2014	
BF Old Schoolhouse	7-May-14	chick	unknown	804-19767	TARSUS TOO SMALL	Blood, feather	2014	
BF Old Schoolhouse	22-May-14	chick	male	804-19795	95 over X	Blood, feather, tissue	2014	FZ
BF Old Schoolhouse	22-May-14	adult	female	804-19797	97 over X	Blood, feather	2014	
BF Old Schoolhouse	23-May-14	chick	unknown	804-19798	98 over X	Blood, feather	2014	
BF Tripad North	9-May-14	adult	female	804-19701	01 over X	Blood, feather	2013	
BF Tripad North	9-May-14	chick	unknown	804-19774	74 over X	Blood, feather	2014	
BF Tripad North	9-May-14	chick	unknown	804-19775	75 over X	Blood, feather	2014	
BF Tripad North	9-May-14	chick	unknown	804-19776	76 over X	Blood, feather	2014	
BF Tripad North	18-May-14	adult	male	804-19788	88 over X	Blood, feather	2014	
BF Tripad North	18-May-14	chick	unknown	804-19790	90 over X	Blood, feather	2014	
BF Tripad North	18-May-14	chick	unknown	804-19792	92 over X	Blood, feather	2014	

Natal Burrow	Date	Age	Sex	USGS band ID (on left)	Aux band ID (on right)	DNA Sample type(s)	Original Banding Year	
BF Tripad South	18-May-14	adult	male	804-19789	89 over X	Blood, feather	2014	
BF Tripad South	18-May-14	chick	unknown	804-19791	91 over X	Blood, feather	2014	
BF Tripad South	22-May-14	adult	female	804-19794	94 over X	Blood, feather	2014	
BF Tripad South	22-May-14	chick	unknown	804-19596	96 over X	Blood, feather	2014	
BF Tripad South	29-May-14	chick	unknown	804-43273	46 over X	Blood, feather	2014	
BF Tripad South*	03-Sep-14	fledge	unknown	804-43296	19 over Y	Blood, feather	2014	
BF White Poles	14-Aug-14	adult	Female	804-43293	16 over Y	Blood, feather	2014	
BF White Poles	14-Aug-14	chick	unknown	804-43294	17 over Y	Blood, feather	2014	
BF White Poles	14-Aug-14	chick	unknown	804-43295	18 over Y	Blood, feather	2014	
BF White Poles	14-Aug-14	adult	Male	804-43292	20 over Y	Blood, feather	2014	GPS
LO 33	30-May-14	chick	unknown	804-43275	66 over X	Blood, feather	2014	
LO 33	30-May-14	chick	unknown	804-43276	67 over X	Blood, feather	2014	
LO 33	30-May-14	adult	male	804-43277	69 over X	Blood, feather	2014	
LS 105	3-Jun-14	adult	male	804-43278	00 over Y	Blood, feather	2014	
LS 112	5-May-14	adult	male	804-19763	63 over X	Blood, feather	2014	
LS 112	13-Jun-14	fledge	unknown	804-43283	04 over Y	Blood, feather	2014	
LS 112	13-Jun-14	adult	female	804-43284	06 over Y	Blood, feather	2014	
LS 129	6-May-14	adult	male	804-19764	64 over X	Blood, feather	2014	
LS 133	9-May-14	adult	male	804-19770	70 over X	Blood, feather	2014	
LS 133	22-May-14	chick	unknown	804-19793	TARSUS TOO SMALL	Blood, feather	2014	
LS 133*	08-Aug-14	adult	female	804-43291	93 over X	feather	2014	
LS 160	5-May-14	adult	male	804-19762	62 over X	Blood, feather	2014	GPS
LS 160	17-Jun-14	adult	female	804-43285	07 over Y	Blood, feather	2014	
LS 185 berm	9-May-14	adult	male	804-19769	Never recaptured		2014	GPS
LS 193	9-May-14	adult	male	804-19773	73 over X	Blood, feather	2014	
LS 193	26-Jun-14	fledge	unknown	804-43289	14 over Y	Blood, feather	2014	
LS 23	19-May-14	adult	male	1204-61171	White AA	Blood, feather	2013	GPS
LS 23	19-May-14	adult	female	1204-61185	White X5	Blood, feather	2013	

Natal Burrow	Date	Age	Sex	USGS band ID (on left)	Aux band ID (on right)	DNA Sample type(s)	Original Banding Year	
LS 3	9-May-14	adult	male	804-19771	71 over X	Blood, feather	2014	GPS
LS 3	15-May-14	chick	unknown	804-19785	85 over X	Blood, feather	2014	
LS 3	15-May-14	chick	unknown	804-19786	86 over X	Blood, feather	2014	
LS 3	15-May-14	adult	female	804-19787	87 over X	Blood, feather	2014	
LS 3	3-Jun-14	fledge	unknown	804-43281	03 over Y	Blood, feather	2014	
LS 42	15-May-14	adult	male	1204-61183	White X4	Blood, feather	2013	
LS 42	27-May-14	chick	unknown	804-43271	05 over Y	Blood, feather	2014	
LS 42	27-May-14	chick	unknown	804-43272	10 over Y	Blood, feather	2014	FZ
LS 42	27-May-14	adult	female	804-19800	99 over X	Blood, feather	2014	
LS 42	5-Jun-14	chick	unknown	804-43282	11 over Y	Blood, feather	2014	
LS 97	3-Jun-14	chick	unknown	804-43279	01 over Y	Blood, feather	2014	
LS 97	3-Jun-14	chick	unknown	804-43280	02 over Y	Blood, feather	2014	
LS Euc 17 Fence	9-May-14	adult	male	804-19772	72 over X	Blood, feather	2014	
LS Euc 17 Fence	18-Jun-14	chick	unknown	804-43286	13 over Y	Blood, feather	2014	
LS Euc 17 Fence	24-Jun-14	adult	female	804-43288	12 over Y	Blood, feather	2014	
LS Squirrel Plot	12-Jun-14	adult	female	1084-05314	C over C	Blood, feather	2011	
LS Squirrel Plot	18-Jun-14	chick	unknown	804-43287	09 over Y	Blood, feather	2014	
Rehabbed BUOW Released at Rancho Jamul Ecological Reserve:								
RJBOMA (RJ 11)	11-Dec-14	adult	unknown	804-43297	21 over Y	Blood, feather	2014	
RJBOMA (RJ 11)	11-Dec-14	adult	unknown	804-43298	22 over Y	Blood, feather	2014	
RJBOMA (RJ 11)	15-Dec-14	adult	unknown	804-43299	23 over Y	Blood, feather	2014	

GPS denotes an owl outfitted with a GPS datalogger.
FZ denotes that a cell culture from this individual is preserved in the Frozen Zoo.

Appendix 4. Condition of artificial burrows

We assessed the condition of all artificial burrows in MU3 that we were allowed to access. Each burrow entrance was examined from the outside. We also examined the chambers of burrows that had full access from above (removable lids), which are noted in the "Access?" column. We noted any sign of BUOW activity (e.g. white wash, pellets, prey remains) and graded the burrows based on whether they were accessible to owls and the amount of maintenance they would require. "Poor" indicates that the burrow is currently unusable to BUOW and requires considerable maintenance to make it accessible. "Fair" indicates that the burrow may be usable with a small amount of maintenance (e.g. cleaning or weeding). "Good" indicates that the burrow is currently usable without any present maintenance needs. If the chamber was accessible from the top, we also took the condition of the chamber into account when grading it. The burrows at Lonestar are checked regularly for owl breeding activity and, as such, are also examined for damage. They are undergoing active management and ongoing repairs as needed so we do not report their condition here.

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Dennery Canyon	1 (102)	32.572792	-117.013608	No Sign	Fair	Woodrat activity; both entrances blocked by loose cholla	
Dennery Canyon	2 (no stake)	32.572890	-117.013458	No Sign	Fair	Woodrat activity; both entrances blocked by loose cholla	
Dennery Canyon	3 (103)	32.572912	-117.013378	No Sign	Fair	Woodrat activity; both entrances blocked by loose cholla	
Dennery Canyon	4 (no stake)	32.573250	-117.012847	No Sign	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)	32.573745	-117.012792	No Sign	Poor	Elevated entrances; Woodrat activity; both entrances blocked by loose cholla	
Dennery Canyon	6 (105)	32.573525	-117.012387	No Sign	Fair	South entrance has debris and cobwebs; West entrance clogged by loose cholla	
Dennery Canyon	7	32.573707	-117.012472	No Sign	Fair	South entrance has debris and cobwebs; West entrance blocked by sticks	

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Dennery Canyon	8	32.573682	-117.012258	No Sign	Fair	South entrance blocked by loose cholla; West entrance blocked with sticks and loose cholla	
Dennery Canyon	9	32.574157	-117.012060	No Sign	Poor	Woodrat resident; debris and woodrat feces	
Dennery Canyon	10 (106)	32.574013	-117.012190	No Sign	Poor	Extensions; woodrat scat; West entrance has cobwebs	peeper tube
Dennery Canyon	11	32.574093	-117.012327	No Sign	Poor	Extensions; both entrances have sticks and cholla	peeper tube
Dennery Canyon	12 (108)	32.576347	-117.013738	No Sign	Poor	West entrance has barn owl feather; East entrance has cholla debris and scat; woodrat resident	
Dennery Canyon	13 (no stake)	32.576508	-117.013683	No Sign	Poor	West entrance dug out by coyote; East Entrance filled in	
Dennery Canyon	14	32.576355	-117.013445	No Sign	Poor	Elevated entrances; cobwebs and cholla. Debris and droppings at West Entrance	
Dennery Canyon	15	32.576032	-117.012965	No Sign	Poor	Extensions; North entrance has debris, droppings, scat. South entrance has cobwebs and debris.	peeper tube
Dennery Canyon	16	32.576202	-117.012782	No Sign	Poor	Extensions; Both entrances have cholla, sticks, droppings. Huge rattlesnake shed.	peeper tube
Dennery Canyon	17	32.576088	-117.012812	No Sign	Poor	West entrance filled in with sticks. South entrance filled with cholla, sticks and droppings. Snake shed.	
Johnson Canyon	1 or 2*	32.580245 OR 32.580182	-116.951203 OR -116.951250	No Sign	Poor	N entrance filled in, South open but blocked by shrubs. *Are 1 and 2 switched on map? If so, 2 completely filled/can't find it.	
Johnson Canyon	3	32.580850	-116.951308	No Sign	Poor	1 entrance full of cholla, couldn't find second entrance.	

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Johnson Canyon	4	32.581058	-116.951143	No Sign	Poor	Both entrances filled with cholla	
Johnson Canyon	5	32.581542	-116.951775	No Sign	Fair	Rabbit activity	
Johnson Canyon	6	32.582223	-116.951970	Lots of sign, whitewash, bones, pellets, feathers	Good	Used as breeding burrow in 2013.	
Johnson Canyon	7	32.582542	-116.951868	Old prey remains	Fair	West entrance--filled; North entrance--rabbit activity	
Johnson Canyon	8	32.582703	-116.951842	Old whitewash, old pellet, old prey remains	Good	South entrance--rabbit activity; North entrance--old BUOW sign, little damage	
Johnson Canyon	9	32.582908	-116.951885	No Sign	Poor	South entrance--lots of coyote damage; East entrance--beehive, honeycomb in entrance	
Johnson Canyon	10	32.582532	-116.952058	Whitewash, pellets (west entrance)	Good	East entrance--rabbit activity; West entrance--BUOW activity	
Johnson Canyon	11	32.582505	-116.952175	Active, whitewash	Good	Rabbit sign	
Johnson Canyon	12	32.582262	-116.952032	No Sign	Good/Fair	South entrance--blocked by cholla; North entrance--rabbit activity	
Johnson Canyon	13	32.582083	-116.952122	Old sign	Fair	North entrance partially filled in	
Johnson Canyon	14	32.583253	-116.951732	Whitewash, bones	Good	West entrance--partially dug up	
Johnson Canyon	15	32.582020	-116.952303	Minimal sign	Good		
Johnson Canyon	16	32.581863	-116.952588	Whitewash, pellets, decoration, in/out activity	Good	South entrance--small cholla	
Johnson Canyon	17	32.581918	-116.952593	Whitewash, pellets, prey remains	Good	Chamber and nest dug out partially, entrances chewed on	chamber accessible from top
Johnson Canyon	18	32.581582	-116.952557	Whitewash, pellets, prey remains	Good		
Johnson Canyon	19	32.581565	-116.952817	Whitewash	Fair	Rabbit activity; one entrace open, one entrance has cholla	
Johnson Canyon	20	32.581238	-116.952542	No Sign	Fair	Beehive in entrance	
Johnson Canyon	21	32.581467	-116.952518	Owl, whitewash, pellets, in/out activity	Good	South entrance--shrubs; North entrance--lots of cholla	

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
LORBOMA	30	32.622058	-116.916105	Lots of whitewash, pellets	Good	West entrance--BUOW sign, East entrance--woodrat sign	chamber accessible from top
LORBOMA	31	32.622180	-116.915780	Old whitewash	Good	Woodrat sign	chamber accessible from top
LORBOMA	32	32.621972	-116.915782	Old whitewash	Good	Rabbit sign	chamber accessible from top
LORBOMA	33	32.622210	-116.915857	Whitewash, prey remains	Good	Coyote/bobcat sign	chamber accessible from top
LORBOMA	34	32.622143	-116.915690	Whitewash	Fair	Bobcat sign; East entrance--pipe dug up	chamber accessible from top
LORBOMA	35	32.622325	-116.915538	Lots of whitewash, crushed pellets	Good		chamber accessible from top
LORBOMA	36	32.622370	-116.915500	Lots of whitewash, crushed pellets, feathers	Good		chamber accessible from top
LORBOMA	37	32.622345	-116.915445	Owl, lots of whitewash, crushed pellets, feathers	Good		chamber accessible from top
LORBOMA	38	32.622160	-116.915262	Feathers, pellet with crawfish, whitewash	Good		chamber accessible from top
LORBOMA	39	32.622377	-116.915337	Whitewash, crushed pellets, prey remains	Good		chamber accessible from top
LORBOMA	40	32.622158	-116.915240	No Sign	Good/Fair		chamber accessible from top
LORBOMA	41	32.620633	-116.915313	No Sign	Good		
LORBOMA	42	32.620580	-116.915117	Some whitewash	Good		
LORBOMA	43	32.620700	-116.915648	No Sign	Good		
LORBOMA	44	32.620398	-116.916080	No Sign	Good		
LORBOMA	45	32.620418	-116.916092	Whitewash, pellets	Good		
LORBOMA	46	32.620462	-116.915230	Whitewash, pellets	Good		
LORBOMA	47	32.620608	-116.917040	Whitewash	Good	vegetation in entrance	
LORBOMA	48	32.620518	-116.915823	Whitewash, pellets, bones	Good		

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
LORBOMA	49	32.620500	-116.915638	Old whitewash & pellets	Good	Small *Malosma* near South entrance	
LORBOMA	50	32.620362	-116.916457	Whitewash, pellets, bones	Good		
LORBOMA	51	32.620233	-116.916328	No sign	Good	Rabbit activity	
LORBOMA	52	32.620273	-116.916083	No Sign	Good	Rabbit activity	
Shinohara	1	32.683375	-116.991077	No Sign	Fair	Squirrel Activity	
Shinohara	2	32.683712	-116.991415	No Sign	Fair	Squirrel Activity	
Shinohara	3	32.684543	-116.991218	No Sign	Fair	Squirrel Activity	
Shinohara	4	32.684870	-116.991258	No Sign	Poor	Lots of squirrel activity, artificial burrow buried by squirrels	
Shinohara	5	32.685695	-116.989635	Old whitewash, old pellets	Fair		
Shinohara	6	32.685908	-116.989262	No Sign	Poor	Squirrel shoulder blade, squirrel digging; tunnel damaged	
Shinohara	7	32.685530	-116.988983	Some whitewash (might not be BUOW)	Fair	Squirrel digging, Squirrel bone?	
Shinohara	8	32.687058	-116.988472	No Sign	Fair/Poor	Lots of Suirrel digging	
Shinohara	9	32.686350	-116.988263	No Sign	Fair/Poor	Squirrel digging	
Shinohara	10	32.686035	-116.987723	No Sign	Fair/Poor	Squirrel digging	
Mother Miguel	11	32.687385	-116.983335	No Sign	Good	Weeds at both entrances	
Mother Miguel	12	32.687252	-116.983310	No Sign	Poor	East entrance visible, half buried	
Mother Miguel	13	32.686295	-116.983175	Old pellets and prey remains	Fair	both entrances have weeds, *ArtCal* in east entrance (and rattlesnake seen), potential BUOW sign 30m to W	
Mother Miguel	14	32.686585	-116.982953	Old crushed pellet and prey remains	Good/Fair	Weeds at both entrances	
Mother Miguel	15	32.685577	-116.982355	Few prey remains	Good	Both entrances look O.K. Coyote Scat	
Mother Miguel	16	32.685768	-116.982355	No Sign	Poor	Only East entrance visible, half filled in	
Mother Miguel	17	32.685372	-116.981393	Few prey remains	Good/Fair	*ArtCal* in East entrance, potential BUOW sign 20m to NW	

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Mother Miguel	18	32.685652	-116.981410	Old pellets	Fair	Weeds in West entrance	
Mother Miguel	19	32.686197	-116.980883	No Sign	Good		
Mother Miguel	20	32.686210	-116.980360	No Sign	Good	North entrance filled in/buried	
Goat Mesa	1	32.551883	-117.000228	Old whitewash	Good	Digging in SE corner of mound; Southern Pacific Rattlesnake in S entrance	
Goat Mesa	2	32.551813	-117.000045	Old whitewash	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	32.551678	-116.999682	Old whitewash, old pellet, old prey remains	Good	Southern Pacific Rattlesnake in N entrance	
Goat Mesa	4	32.553305	-117.000133	No Sign	Good	W entrance has been repaired	
Goat Mesa	5	32.553488	-117.000093	No Sign	Good		
Goat Mesa	6	32.553677	-116.999783	No Sign	Good	W entrance has been repaired	
Rancho Jamul	1	32.680085	-116.846862	No Sign	Fair		
Rancho Jamul	2	32.680223	-116.847955	Old pellets & mute	Fair		
Rancho Jamul	3	32.680223	-116.848008	Old pellets & mute	Fair		
Rancho Jamul	4	32.680363	-116.847990	Prey remains	Fair		
Rancho Jamul	5	32.680463	-116.848130	Old pellets & mute	Fair		
Rancho Jamul	6	32.680555	-116.848075	No Sign	Fair		
Rancho Jamul	7	32.680872	-116.848098	No Sign	Fair		
Rancho Jamul	8	32.680643	-116.847343	No Sign	Fair		
Rancho Jamul	9	32.680447	-116.847163	Old pellets & mute	Fair		
Rancho Jamul	10	32.677972	-116.849247	No Sign	Fair		
Rancho Jamul	11	32.677583	-116.851710	No Sign	Fair		
Lonestar	3	32.575602	-116.970828			wood	peeper tube
Lonestar	7	32.575989	-116.969774			plastic	peeper tube
Lonestar	13	32.576535	-116.969309			wood	peeper tube
Lonestar	14	32.576576	-116.969594			plastic	peeper tube
Lonestar	21	32.576149	-116.970539			wood	peeper tube
Lonestar	23	32.576454	-116.970203			wood	peeper tube
Lonestar	27	32.576877	-116.970788			plastic	peeper tube
Lonestar	28	32.576842	-116.970300			plastic	peeper tube

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Lonestar	36	32.578415	-116.969740			plastic	peeper tube
Lonestar	40	32.578383	-116.968864			wood	peeper tube
Lonestar	42	32.578415	-116.968269			wood	peeper tube
Lonestar	44	32.578670	-116.968659			plastic	peeper tube
Lonestar	47	32.579098	-116.969118			plastic	peeper tube
Lonestar	52	32.578724	-116.970319			wood	peeper tube
Lonestar	53	32.579204	-116.970142			wood	peeper tube
Lonestar	60	32.579539	-116.969281			wood	peeper tube
Lonestar	67	32.579881	-116.969199			plastic	peeper tube
Lonestar	70	32.580231	-116.969408			wood	peeper tube
Lonestar	97	32.580717	-116.965820			plastic	peeper tube
Lonestar	100	32.580554	-116.965380			wood	peeper tube
Lonestar	102	32.580085	-116.966122			plastic	peeper tube
Lonestar	105	32.579775	-116.965286			wood	peeper tube
Lonestar	107	32.579611	-116.965976			wood	peeper tube
Lonestar	109	32.579511	-116.966657			wood	peeper tube
Lonestar	112	32.578821	-116.966909			plastic	peeper tube
Lonestar	113/114	32.578816	-116.966649			plastic	peeper tube
Lonestar	121	32.579182	-116.964996			wood	peeper tube
Lonestar	128	32.579699	-116.963607			plastic	peeper tube
Lonestar	129	32.579647	-116.964010			plastic	peeper tube
Lonestar	132	32.579804	-116.964532			wood	peeper tube
Lonestar	133	32.580133	-116.964177			wood	peeper tube
Lonestar	142	32.581370	-116.964498			plastic	peeper tube
Lonestar	144	32.581233	-116.964172			plastic	peeper tube
Lonestar	146	32.580873	-116.963757			plastic	peeper tube
Lonestar	148	32.580296	-116.963459			wood	peeper tube
Lonestar	150	32.580026	-116.963235			wood	peeper tube
Lonestar	159	32.579124	-116.962430			plastic	peeper tube
Lonestar	160	32.578916	-116.962434			wood	peeper tube
Lonestar	166	32.577354	-116.962893			plastic	peeper tube
Lonestar	168	32.577398	-116.962538			wood	peeper tube
Lonestar	170	32.576032	-116.964832			plastic	peeper tube
Lonestar	175	32.575887	-116.964863			plastic	peeper tube

Site	Burrow # (Field)	Latitude	Longitude	BUOW Activity	Condition	Notes	Access?
Lonestar	176	32.575835	-116.965107			wood	peeper tube
Lonestar	180	32.575599	-116.964271			wood	peeper tube
Lonestar	185	32.575875	-116.967461			wood	peeper tube
Lonestar	190	32.575675	-116.966950			plastic	peeper tube
Lonestar	193	32.577486	-116.966863			plastic	peeper tube
Lonestar	194	32.577566	-116.966733			wood	peeper tube
Lonestar	200	32.577532	-116.966019			wood	peeper tube
Lonestar	201	32.577502	-116.966273			plastic	peeper tube