SAN DIEGO ZOO INSTITUTE FOR CONSERVATION RESEARCH.

Project Report 2013

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

Prepared by:
Colleen Wisinski, J.P. Montagne, Susanne Marczak, Debra M. Shier, Ph.D., Lisa A. Nordstrom, Ph.D., and Ronald R. Swaisgood, Ph.D.
Institute for Conservation Research, San Diego Zoo Global

Prepared for:
San Diego Foundation
Otay Mesa Grassland Mitigation Fund, 6649

EXECUTIVE SUMMARY

We report on the third year's progress in a multi-year program with the goal of developing a model program to assist in the recovery of Western burrowing owls (BUOW; *Athene cunicularia hypugaea*) and their grassland ecosystem in San Diego County. Current BUOW management is dependent on continued human intervention and may not be self-sustaining. Because the California ground squirrel (*Otospermophilus beecheyi*) is a keystone species that helps engineer California grassland ecosystems and provides critical resources for BUOW, re-establishment of this species is a crucial component of any sustainable recovery plan for BUOW and the larger ecosystem. Over time we plan to develop a set of protocols and strategies that can be adopted by managers in San Diego County and in other areas where BUOW conservation management is warranted. Our long-term goal is to assist in the establishment of a more natural grassland ecosystem in San Diego County by re-establishing ground squirrels and, ultimately, BUOW. The work described here is the product of the San Diego Zoo Institute for Conservation Research (ICR) and its partners, in particular, its research collaborators at San Diego State University (SDSU). Hereafter, we use the term "we" to describe activities conducted jointly by ICR and SDSU.

In 2013, we made progress toward three objectives: (1) use of translocation as a tool to establish California ground squirrels as ecosystem engineers; (2) developing methodology for monitoring natural squirrel dispersal into managed habitat at Rancho Jamul; (3) determining key habitat associations for California ground squirrels; and (4) monitoring BUOW population and nesting ecology in south San Diego County.

(1) Ground squirrel translocations. Our primary objective for year three was to continue to improve habitat conditions for BUOW by re-establishing ground squirrels, which create the burrows upon which BUOW depend for nesting. In 2013, we conducted our final squirrel translocations for the project, implementing two supplemental translocations at Rancho Jamul Ecological Reserve and continued long-term monitoring at squirrel translocation and control plots established in 2011 and 2012. Methods and design are as described in previous annual reports. Monitored outcomes of translocated squirrels document low dispersal rates, indicating that efforts to increase settlement were successful. Survival rates continue to be relatively low, but some plots such as Jamul Central—where a minimum of 58% of squirrels translocated in 2013 supplementations were known to survive and remain on plot for one month—are performing well. Predation appears to be the cause of most if not all mortalities. Year was a significant variable in our model for squirrel survival and we had higher survival and retention of squirrels at our initial translocations to Jamul Baja and Jamul Central in 2012, and

our supplemental translocations to all plots in 2012 and 2013, indicating that our adaptive management approach improved release success. After year 1, we made small modifications (addition of cover, attention to group membership and release timing) which resulted in increased survival rates.

We modeled squirrel survival with regard to several predictor variables and found that, among those variables tested, geologic formation had significant effects, with higher performance in metavolcanic rock and lower in the clay-rich alluvial deposits. This finding is consistent with our hypotheses regarding the importance of soil characteristics for squirrel habitat selection and survival. It is promising that 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, BUOW.

The moderate survival rates of translocated squirrels are offset by successful reproduction and subsequent recruitment of offspring into the populations established on experimental plots. Juvenile recruitment was higher following supplemental translocations, suggesting that supplemental translocation substantially improved colony establishment.

Movement and settlement patterns provided additional insights into habitat effects on the fate of translocated squirrels. We predicted that squirrels would take longer to settle if released in less suitable habitat, due to the time needed to disperse and locate more suitable habitat. Of the variables tested, clay presence in the soil had the most robust effect, with squirrels taking three times as long to settle and settling at distances almost seven times farther from the release site when the site contained more clay. These data indicate a clear preference for sites with less clay and may explain why some sites had successful squirrel establishment while others did not.

Vegetation treatments within the control and translocation plots had pronounced effects on the vegetation structure (see SDSU annual report; Deutschman & McCullough 2014). While effects of treatment on the release of native forbs were lacking, mowing treatments did effectively reduce vegetation density. It is unsurprising that vegetation treatment had no effect on squirrel survival because squirrels need only disperse a short distance to settle in an alternative treatment. Movement data provide confirmation. Squirrels released in control treatments were unlikely to remain there (7.1%), whereas those released in the augured (44.8%) or mowed (32.1%) treatments were approximately five times more likely to settle within the treatment where they were released. With such a low level of retention of translocated squirrels on untreated tall vegetation treatments (controls), it is clear that any translocation into a release site with a high percentage of invasive grasses will fail unless the site is manipulated by opening vegetation.

Burrow establishment and creation of disturbed open ground by translocated ground squirrels demonstrate the ecosystem engineering value of translocated ground squirrels. By October 2013, squirrels on translocation plots had created at least 779 burrows while only 35 burrows were documented on matched-pair control plots. Ground disturbance adjacent to burrows was also significantly greater in squirrel translocation plots, indicating that squirrel digging activity contributes to the creation of more open habitat favored by BUOW; however, squirrels at the level of density established did not have significant effects on vegetation structure or composition (Deutschman & McCullough 2014).

(2) Ground squirrel habitat suitability model. To increase our ability to successfully translocate California ground squirrels, we must first better understand their habitat requirements. In 2012 and 2013, we conducted surveys for ground squirrels throughout 16 San Diego County grasslands and examined habitat covariates to gain insight into the factors influencing their distribution and abundance. Habitat plots were compared between sites with squirrel burrows and compared to those without burrows (presence-absence). Site-level characteristics proved to be the best predictive variables in our analysis; while some of these characteristics remain unknown, site history of burning or grazing appear important. Squirrel presence was also predicted by lower amounts of vegetative cover and soil texture (favoring more sand and less silt, clay, and gravel). Vegetation species composition appears less critical so long as the vegetation cover is not too dense. These data provide the foundation for the first comprehensive habitat suitability model for California ground squirrels and can be applied to predict the likelihood of successful squirrel establishment at sites under consideration for BUOW recovery. If soils or other vegetation characteristics are not suitable for squirrels, then establishing self-sustaining habitat for BUOW may be difficult. However, if soils are suitable but vegetation is not, management actions (such as burning, grazing and mowing) that create more open vegetation, even if it remains non-native, may create suitable habitat. Management of soils will be more difficult, but mechanized softening of soils to allow digging (e.g. installation of berms), may allow successful establishment of squirrel populations even with less suitable soils.

(3) BUOW population and nesting ecology. We used a combination of direct observation, camera traps, and a pilot banding program to monitor population performance, foraging ecology, reproduction and survival, and conducted habitat evaluations to illuminate the role of habitat adjacent to burrows in determining nesting outcomes. We located 37 BUOW burrows within Management Unit 3 and confirmed breeding in 28 of these burrows. We monitored 18 burrows (9 natural, 9 artificial) throughout the entire breeding season using camera traps, and monitored 8 additional burrows weekly to document nesting and chick survival. The average total number of chicks at artificial burrows was lower (3.2) than at natural burrows (5.6), a marginally significant trend. Prey delivery rates were also significantly

higher at natural than artificial burrows, which may explain the greater number of chicks at natural burrows. Prey delivery rates were significantly correlated with number of chicks fledged. However, the number fledglings produced was similar for artificial (1.3) and natural burrows (1.7). These effects appear to be related to the habitat immediately surrounding the burrows: the Lonestar mitigation site which contained many of the artificial burrows is undergoing vegetation restoration and currently (temporarily) contains little vegetation to provide suitable habitat for prey species (significantly more bare ground and less vegetative cover). Although more open habitat is favored by BUOW, it is likely that sufficient vegetation is required to provide habitat for prey species. Nesting BUOW apparently were unable to compensate for poor foraging conditions by ranging further from their artificial burrows. The inter-relationships between foraging habitat, prey delivery, burrow microhabitat, reproductive output and chick survival are the subject of more focused investigation in 2014.

With the use of camera traps, we were able to document prey deliveries at BUOW nesting burrows. At most of the burrows, invertebrates made up the highest proportion of prey deliveries (an average of 75%). The remainder was comprised of, in rank order, unknown prey, small mammals, herps and birds. These data indicate the numerical importance of invertebrate prey, but do not address total biomass of prey types. Prey deliveries occurred at all hours of the day, but most deliveries occurred between 5 PM and 5 AM usually with a peak between 8 PM and midnight.

We documented 19 juvenile mortality events, which represent 24% of the maximum number of chicks recorded. Most mortality was attributed to infanticide, usually by the mother, and 6 were depredations by non-BUOW predators. Infanticide appears likely to occur when the female loses her mate, and thus his contributions to feeding the chicks, or is otherwise food limited.

Although population census through mark-recapture was not included in the proposed work, we captured and banded a total of 61 BUOW representing 17 families. The presence of a banded population will allow future population monitoring and inform construction of population models.

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INTRODUCTION

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

Because the California ground squirrel is a "keystone" species that helps engineer California grassland ecosystems and provides critical resources for BUOW, re-establishment of this species is a crucial component of any recovery plan for BUOW and the larger ecosystem. Ground dwelling squirrels influence the structure and composition of the grassland ecosystem, both directly as prey and indirectly through burrowing and foraging activities, suggesting a high level of 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 BUOW and their grassland ecosystem in San Diego County. Using an adaptive management approach (Walters 1986; Schreiber et al. 2004; Nichols & Williams 2006), ICR/IEMM collaboratively launched a multi-year study to restore ecological function to grassland communities in San Diego County by re-establishing ground squirrels and, ultimately, BUOW.

Project goals

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

Results from year one of this multi-year program were mixed and indicated that modifications to the translocation protocol were necessary to improve release success of relocated squirrels (Swaisgood & Lenihan 2012). Our results also highlighted the need to understand how soil characteristics affect squirrel establishment and retention. In year two (2012), we modified the protocols developed for ground squirrel translocation in 2011 and initiated data collection for a ground squirrel habitat suitability model. Although work was focused on refining the ground squirrel translocation methodology, we opportunistically monitored BUOW and continued pilot work using camera traps at owl nest burrows.
In year three, we expanded our research on BUOW, monitoring their nesting and foraging ecology at artificial and natural burrows, through the use of camera traps, direct observations, and habitat surveys. We also initiated a capture and banding effort to allow for identification of individuals. By obtaining a better understanding of the factors regulating population dynamics of BUOW, in terms of reproduction, survival, recruitment, and movement patterns, the results from this research will help inform the effective long-term management of BUOW in San Diego County.

In year three (2013) our goals were to:

1. Continue long-term monitoring of ground squirrel translocation outcomes from 2011 & 2012 translocations;
2. Conduct supplemental ground squirrel translocations to the plots established in 2012 and monitor outcomes;
3. Monitoring natural ground squirrel dispersal into managed habitat at Rancho Jamul Ecological Reserve;
4. Complete ground squirrel burrow survey across San Diego County grasslands and identify key habitat associations for ground squirrel presence;
5. Examine BUOW nesting and foraging ecology by:
    - Using camera traps at active breeding burrows to document parental care, prey provisioning, predation/predators, and other visitors,
    - Characterizing nest habitat at local (burrow) and landscape scales,
    - Banding and collecting genetic material from owls.

Personnel

Principle Investigators:
Ron Swaisgood, Ph.D.
Debra Shier, Ph.D. (ICR in-kind contribution)
Lisa Nordstrom, Ph.D.

Field Team—Squirrel translocations:
Field Organizer: JP Montagne (ICR in-kind contribution)
Field Technician: Andrew Heath
Field Support: Richard Martelli, Chris Nagem (ICR in-kind contribution)
Volunteers (SDZG or SDSU): Amy Downey, Bryan King, Michelle Morgan, Katrina Stenson, Catherine Tredick, Stéphane Vernhet, Ariana Ananda, Olivia D'Anne Crigler

Field Team—Squirrel and owl habitat surveys:
Field Organizer: Susanne Marczak
Field Technician: Miguel Kaminsky
Summer Fellow: Nan Nourn (ICR in-kind contribution)
GIS Support: Mathias Tobler, Ph.D. (ICR in-kind contribution), James Sheppard, Ph.D. (ICR in-kind contribution)
Volunteers from San Diego Zoo Global (ICR in-kind contribution): Jennifer Monteforte, Brandi Wilson

Field Team—BUOW monitoring:
Field Organizer: Colleen Wisinski, M.S.
Expert advisors: Jeff Lincer, Ph.D. (BUOW), Mathias Tobler, Ph.D. (software, data management)
Field Technician: Kira Marshall
Volunteers from San Diego Zoo Global (ICR in-kind contribution): Natalie Fowler, Miguel Kaminsky, Kaye London, Elizabeth Reid-Wainscoat, Steve Rose, Subashini Sudarsan, Kristen Watkins

Permits

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

CALIFORNIA GROUND SQUIRREL TRANSLOCATION

INTRODUCTION

As a means to improve grassland habitat for BUOW and other species of concern, in 2011 we initiated the development of a scientific, ecologically relevant, strategy for relocating California ground squirrels. Long-term success is contingent upon our ability to translocate California ground squirrels to the restoration sites in numbers sufficient for a population to establish itself at an ecologically functioning threshold where squirrels serve as ecosystem engineers (Kotliar *et al*. 2006; Soule *et al*. 2003). Many translocation programs are unsuccessful or marginally successful because of high mortality (O'Bryan & McCullough 1985, Jones & Witham 1990) and post-release dispersal away from the release site (review in Stamps & Swaisgood 2007). 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 and settlement. In 2013, no new modifications to translocation protocols were made, and we focused on completing the translocation program we began in 2011, notably by implementing two supplemental translocations to previously established release sites, and by continuing to monitor the long-term outcomes of translocations.

METHODS

General methods and procedures are described in detail in Swaisgood & Lenihan (2012) and are not repeated here.

Release sites

The release sites were all located on conservation areas within southwestern San Diego County that encompasses the largest remaining population of BUOW in the county (Rancho Jamul Ecological Reserve, San Diego National Wildlife Refuge—Sweetwater Unit; Figure 1). Working with our partners and stakeholders, we identified parcels of land within a network of protected areas that may hold promise for grassland restoration and BUOW recovery.

Release plots

The six release plots that we monitored in 2013 include: Jamul South (JS); Jamul West (JW); Jamul East (JE); Jamul Baja (JB); Jamul Central (JC); and Sweetwater East (SE); (Figures 2-3).

The 2011 release plots are shown on Figures 2-4. The two Lonestar plots (Otay North and Otay South) and one of the Sweetwater plots (Sweetwater West) had low squirrel survival rates and were judged to have unsuitable habitat (e.g. poor soil quality; see Swaisgood & Lenihan 2012). Thus, these plots were removed from any further monitoring or research. CalTrans initiated mitigation restoration activities at the Lonestar site, and based on our recommendations, they installed additional berms on the perimeter of the site that were intended to attract squirrels and provide suitable areas for natural burrow establishment. Opportunistic observations indicate that this strategy has been successful, as a number of the berms and artificial burrows at Lonestar are now occupied by ground squirrels.

In 2012, we conducted 2 new pairs of translocations at Rancho Jamul Ecological Reserve (see translocation experiment below; Figure 2). As in 2011, we selected new release plots in collaboration with IEMM. In 2013, we conducted two supplemental translocations to the release plots established in 2012, bringing to completion the active translocation portion of this project.

Source Sites

In 2013, all squirrels were captured at Naval Base Coronado (NBC) North Island from various locations south of the airfield (Figure 5; N 32° 41’ 28.54”, W 117° 12’ 27.22” elevation 7m). NBC is a highly converted habitat with an abundant squirrel population occupying buffer areas of mowed non-native grassland, sandy areas dominated by ice plant, and landscaped playing fields.

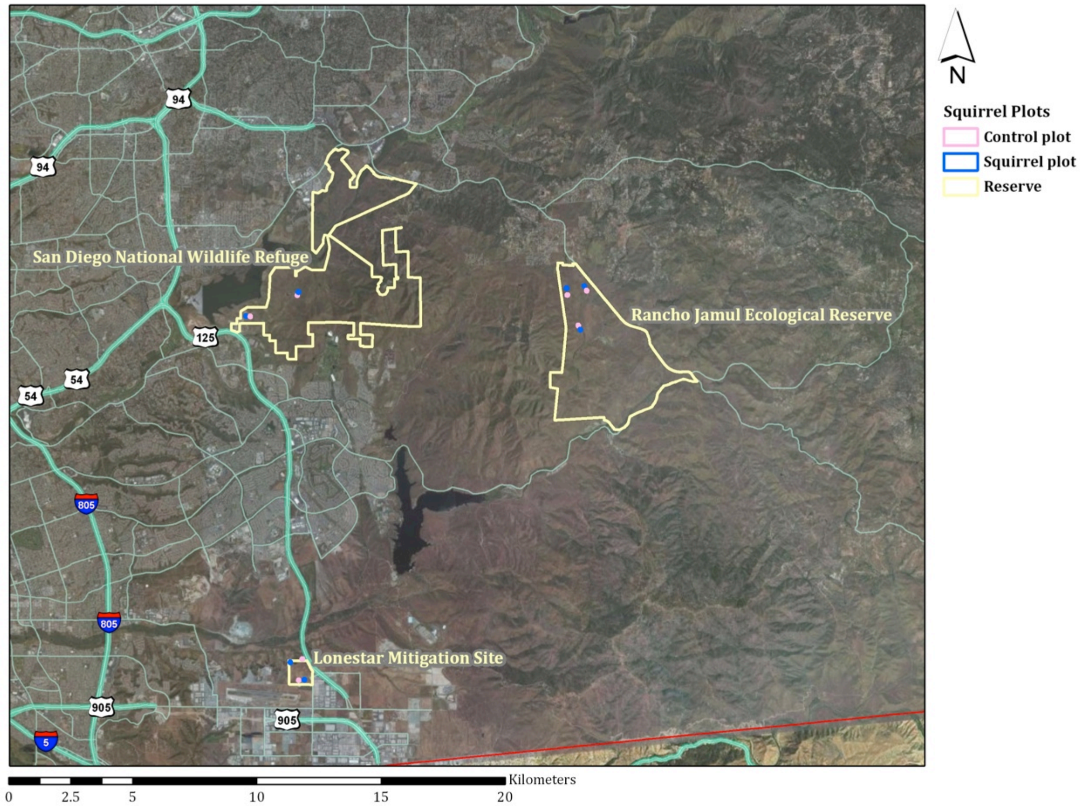

Figure 1. Study area map designating the three sites where field work took place from 2011 to 2013. *(1) San Diego National Wildlife Refuge, Sweetwater Unit; (2) Rancho Jamul Ecological Reserve; and (3) Lonestar Mitigation Site, Otay Mesa.*

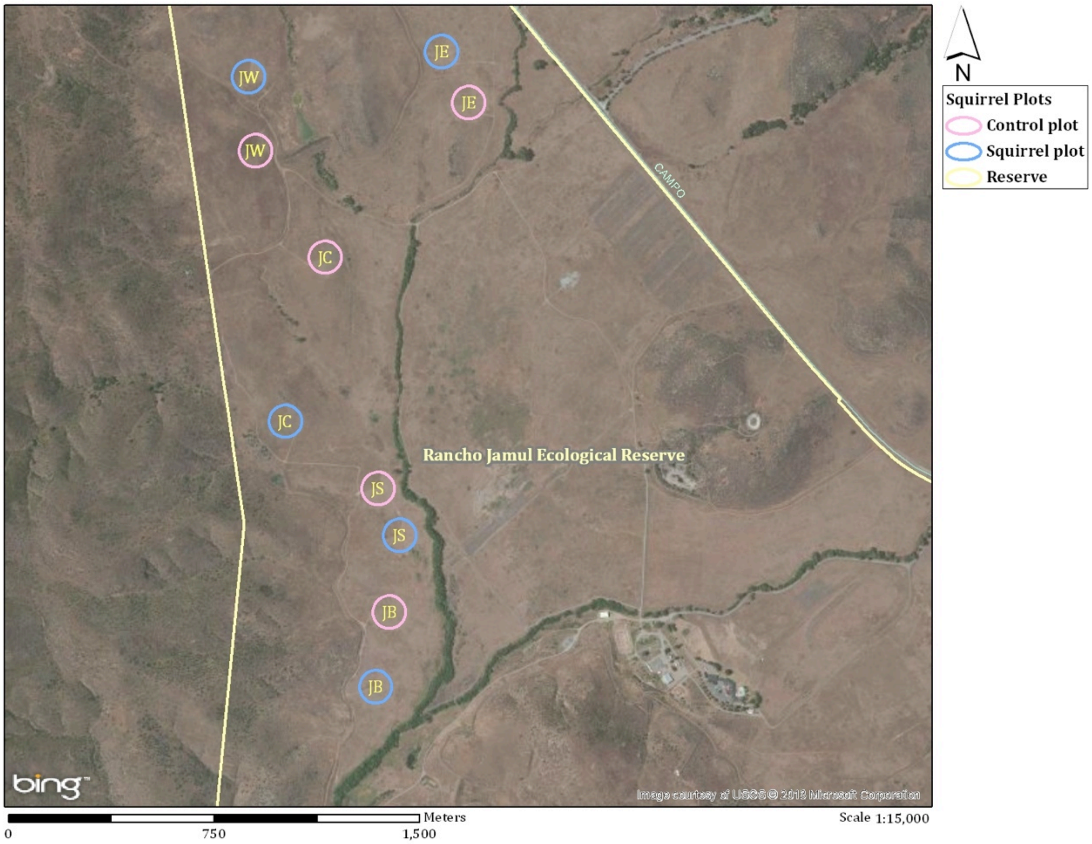

Figure 2. Rancho Jamul Ecological Reserve: 3 paired plots established in 2011 and 2 paired plots established in 2012. *(1) Jamul South (JS): 2011 (initial) & 2012 (supplement); (2) Jamul West (JW): 2011 (initial) & 2012 (supplement); (3) Jamul East (JE): 2011 (initial) & 2012 (supplement); (4) Jamul Baja (JB): 2012 (initial) & 2013 (supplement); and (5) Jamul Central (JC): 2012 (initial) & 2013 (supplement).*

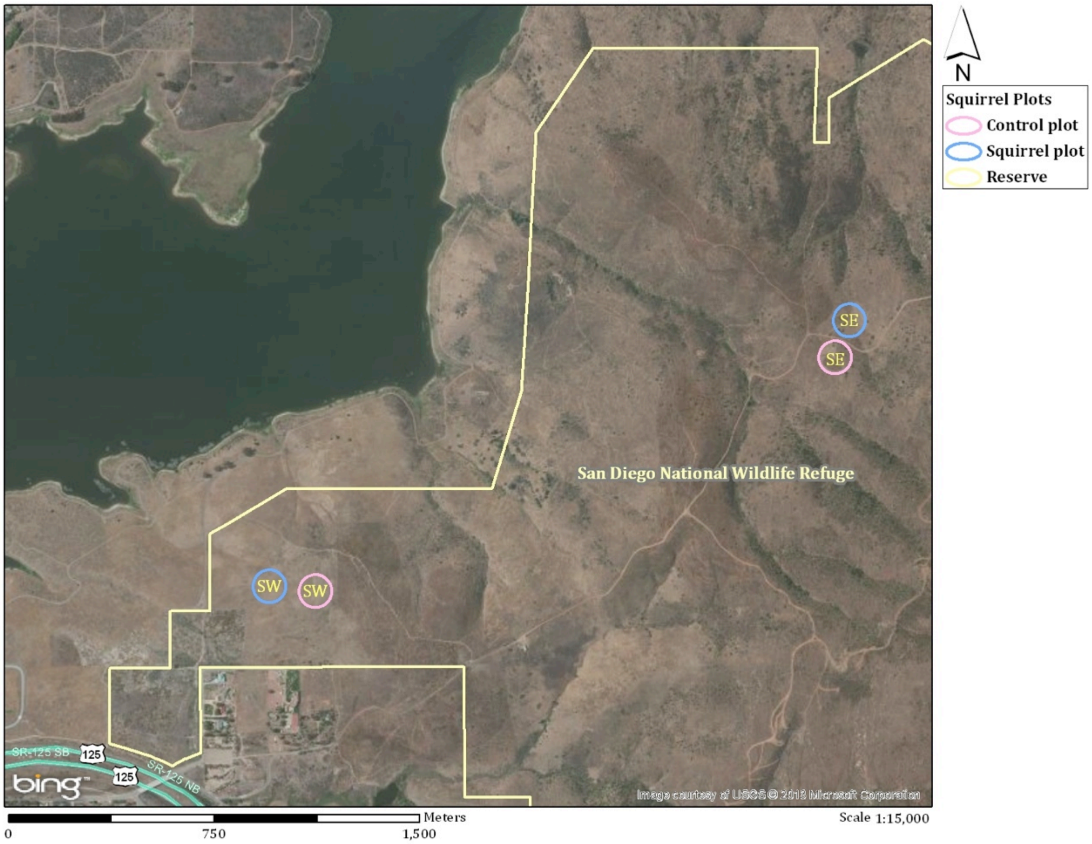

Figure 3. ***San Diego National Wildlife Refuge, Sweetwater Unit: 2 paired plots in 2011 and 1 paired plot in 2012.*** *(1) Sweetwater West (SW): 2011 only; (2) Sweetwater East (SE): 2011 & 2012 (supplement). No squirrels were released on SDNWR in 2013***.**

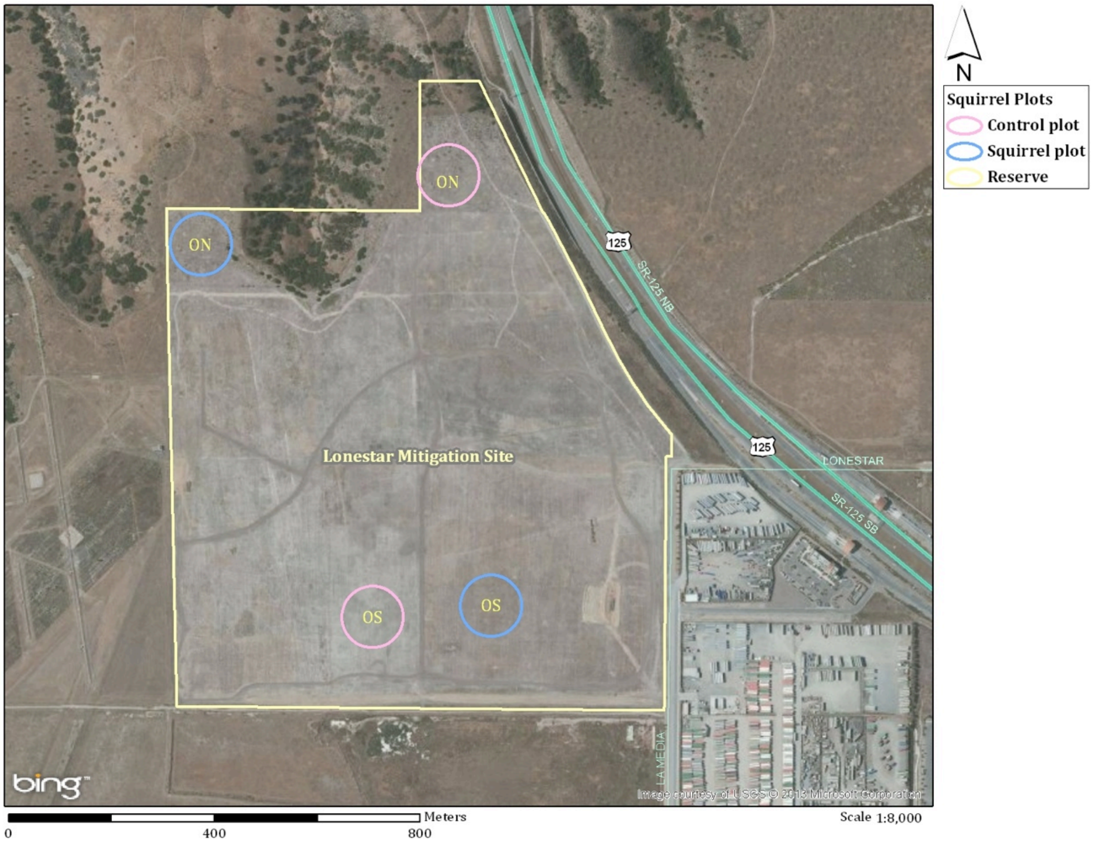

Figure 4. Lonestar Mitigation Site, Otay Mesa: 2 paired plots in 2011 only. *Area of BUOW monitoring; the pink line denotes the northern end of La Media Road.*

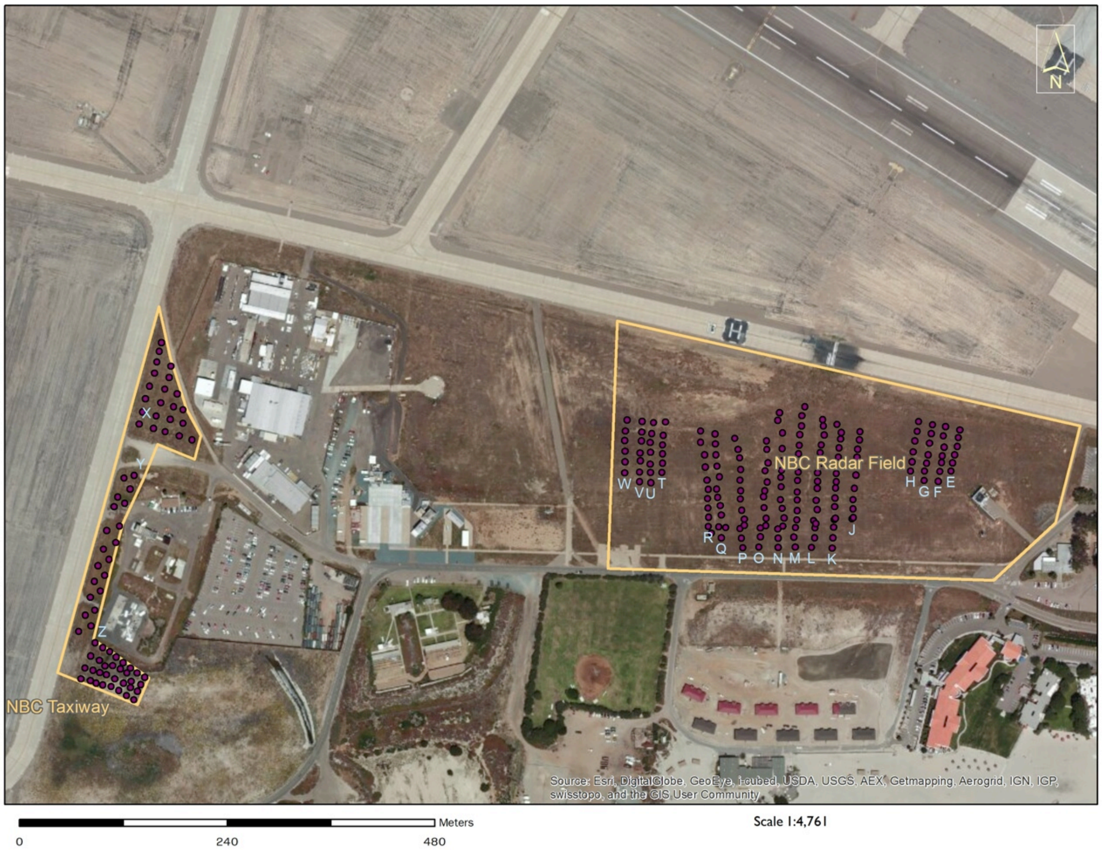

Figure 5. Naval Base Coronado, source site for all California ground squirrels translocated in 2013.

Experimental design and plots

In 2013, we established no new translocation sites, conducting only supplemental translocations to pre-existing release sites (see below). The experimental design is described in detail in previous project reports (Swaisgood & Lenihan 2012; Wisinski *et al*. 2013). Briefly, each circular plot is divided into three vegetation treatment areas: mow, mow + auger, and control (Figure 6). In addition, we employed a matched-pair design to determine the effects of squirrel translocation + vegetation management versus vegetation management only: 1) treatment plot (squirrels translocated to the plot) or 2) control plot (no squirrels translocated to the plot).

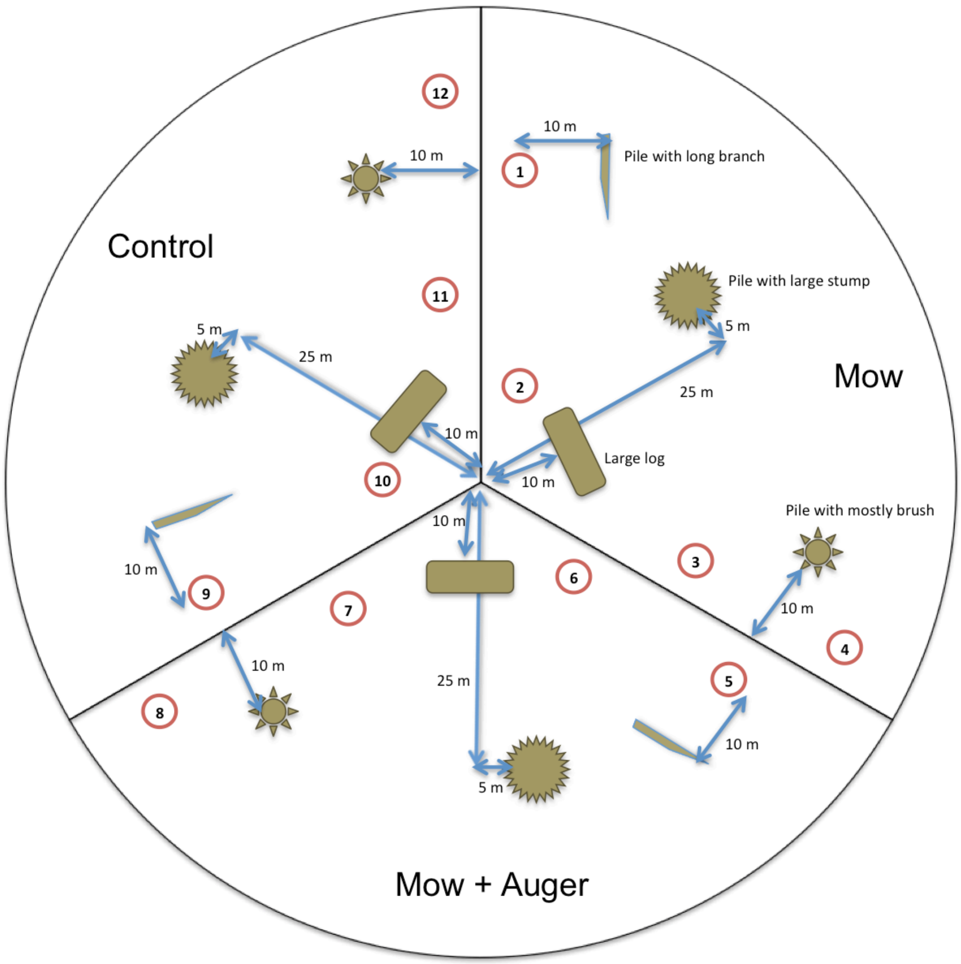

Figure 6. Diagram showing experimental treatment design and placement of brush piles (providing cover from predators) placed at the experimental and control plots. *Numbered circles indicate locations of artificial burrows. Diagram not to scale.*

Supplemental Translocations

We conducted supplemental translocations at two of our release plots established in 2012 (JB and JC; see Figure 2). Supplemental plots were subjected to the same treatments established for the 2012 supplemental plots, reflecting changes from the initial releases (details in our 2012 annual report, Wisinski *et al.* 2013). In 2012, we made several modifications to the initial translocation strategy for the supplemental translocations to attempt to improve translocation success. In 2013, we made the same modifications for JB and JC as for the 2012 translocations: we added cover, attempted to identify, capture and translocate squirrels in intact social groups, and released squirrels later in the season (mid-late August).

Translocation protocols

Processing, handling, on-site acclimation, and release of all California ground squirrels followed the protocols described in Swaisgood & Lenihan 2012 and modifications reported in Wisinski *et al.* 2013. No new changes to the protocol were necessary for 2013.

Acclimation cage assessment and modification

We assessed the acclimation cages on the JB and JC experimental plots with an inspection camera to determine suitability for reuse in the 2013 supplemental translocation. Six out of the 18 cages on each plot were clear, therefore six new cages were added to the perimeter of each plot for a total of 12 acclimation cages per plot (Figure 7) in order to accommodate our target population size or 45 squirrels per plot. We again used 12-inch concrete forming tubes for the underground portion of the cage. However, a few individuals self-released from the acclimation cages in 2012. Thus, in order to prevent self-release in 2013, we modified our design slightly. To do this we reduced the size of opening in the concrete form so that the plastic tube fit snuggly into the opening, and we wired the hardware cloth on the top and bottom.

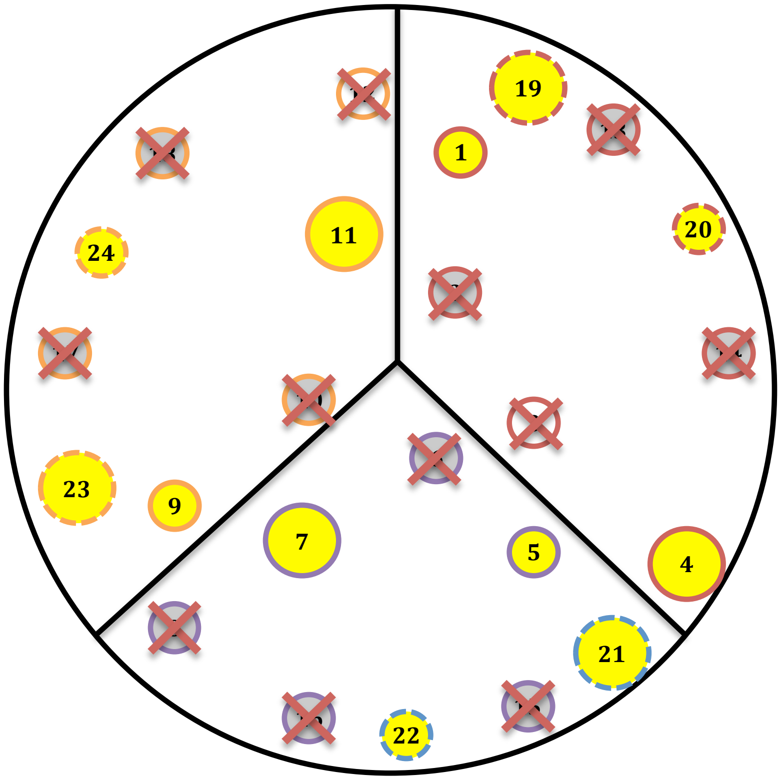

Figure 7. Acclimation cages. *Yellow circles indicate acclimation cages used in 2013. Solid-lined borders are 2012 cages that were reused; dashed-lined borders represent cages added in 2013. Circles with a red 'X' are those cages that were not used. The size of the circle represents the size of acclimation cage at the surface (3' x 3' vs. 2' x 3').*

Subjects

We marked 134 California ground squirrels (30 adults and 104 juveniles) from June to August 2013 at the NBC Radar Field (Figure 5). We recaptured and translocated 92 of the 134 squirrels into the two new release plots (Table 1); squirrels were released from acclimation at both plots on August 22, 2013.

Table 1. Total number of squirrels translocated in 2013. *Number transmittered is shown in parentheses.*

	Adult		Juvenile		
Plot	**Female**	**Male**	**Female**	**Male**	**Total**
Jamul Baja	4 (3)	7 (7)	22 (1)	13 (0)	**46 (11)**
Jamul Central	4 (3)	4 (4)	24 (2)	14 (2)	**46 (11)**
Total	**8 (6)**	**11 (11)**	**46 (3)**	**27 (2)**	**92 (22)**

Post-release monitoring and support

Upon release the ICR field team immediately began monitoring squirrels via:
1) radio-tracking, 2) retrapping, and 3) direct observations. Each technique was designed to contribute to the determination of squirrel retention on site, movement off site, and survivorship. We did not use camera trapping in 2013.

As in 2011 and 2012, a subset of squirrels was equipped with VHF radio-collars to allow tracking and monitoring of individual squirrels post-release (Swaisgood and Lenihan 2012). Twenty-two squirrels were collared with VHF transmitters using the same methodology as previous years (Table 1). We located collared squirrels daily for the first 30 days, then at minimum three times per week until collars were recovered. We averaged 70.8 relocations for squirrels that survived more than 4 months.

Translocated squirrels were trapped at both experimental plots for five days at one month post-release. We modified our trapping protocol by adding an evening session to maximize capture probability. Traps were opened by 7AM and 3PM, and checked at 10AM and 5:30PM so that traps were open no longer than 3 hours.

We supplemented squirrels with apples, yams and pelleted rodent feed following our 2012 protocol: providing food once per day for the first seven days, then 3 times per week for the next 15 weeks.

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

Between late May and the end of June 2013, we monitored all six plots: JB, JC, JW, JE, JS, and SE. We used the same trapping protocol as previous years, but we doubled our effort by adding a second session in the evening. This led to a 30% increase in captures, significantly improving our estimate of colony size on each of the plots.

Data Analysis

Long-term monitoring—(Following Spring Post-Release Survival)

Statistical analysis is pending final trapping of plots JB and JC in June 2014.

Short-term monitoring—(One-Month Post-Release Survival)

We examined 1-month post-release survival using trapping and telemetry data. We modeled survival with logistic regression in JMP 11 considering the effects of age, sex, source site, release plot, year, release type (initial vs. supplemental), individual weight at translocation, release treatment, and relevant interactions of these variables (Table 2). We added geological formation and soil type derived GIS layers provided by SanGIS. We also added number of squirrels per acclimation cage and excluded non-translocated squirrels from the analysis.

Table 2. Description and values of independent variables used in 1-month post-release survival analysis.

Variable	Description	Possible values
Survival at 1-month	Was the squirrel trapped during one month post-release trapping, or otherwise known to have survived from telemetry or later trapping?	Yes, No
Release type	Initial Translocation (early summer) vs. Supplemental (late summer)	Initial, Supplemental
Year	Calendar year	2011, 2012, 2013
Age	Age at translocation	Adult, Juvenile
Sex	Sex (missing data for 8 individuals)	Male, Female, or Unknown
Source site	Site from which individual was moved	Tulloch, Navy, or Jamul
Release plot	Plot to which individual was moved	JB, JC, JE, JS, JW, ON, OS, SE, SW
Weight	Weight of individual at translocation (if known); 4th root transformed to meet assumption of normally distributed data when necessary	Continuous value
Treatment	Treatment location of release burrow	Mow, Mow+Auger, Control
Geology	Geological formation derived from SanGIS	Metamorphic rock, Alluvial deposit
Soils	Generalized soil type derived from SanGIS	Clay present or absent

We used forward and backward stepwise regressions to compare whole effect models, and included an interaction term for age and sex since it proved meaningful in 2012. We used Baysian information criterion (BIC) to determine the best fitting models, then tested the model with nominal logistic fit.

We then examined the effect of all the variables listed above on settlement of collared squirrels as measured by number of days known to be alive, and their movement and settlement patterns derived from telemetry. We used four parameters for movement and settlement: 1) Days to Dispersal, 2) Days to Settlement, 3) Settlement Distance, and 4) Total Distance Moved (Table 3). To meet the assumption of multivariate normality, the variables for survival, days to dispersal, distance to settlement and total distance moved were cube root transformed, and days to settlement was square-root transformed. Finally, we examined the effect of these four movement and settlement parameters on survival of collared squirrels. We again used forward and backward stepwise regressions to compare whole effects, and selected the best fitting model based on BIC.

Table 3. Description and values for movement, settlement and dispersal variables.

Variable	Description	Possible values
Survival	Number of days tracked & known to be alive	Continuous integer
Days to Dispersal *	Number of days until the subject moved >5m from their release location.	Continuous integer
Days to Settlement **	Number of days until the subject was settled in a new location within the same 5m area for 7 days	Continuous integer
Settlement Distance *	The linear distance from release acclimation cage to their settlement location	Continuous value
Total Distance *	The sum of all linear distances between locations while the subject was known to be alive	Continuous value

* Cube root transformed to meet model assumption of normally distributed data

** Square root transformed to meet model assumption of normally distributed data

Results & Discussion

Long-term monitoring

Minimum survival and retention—2011 plots

In our third year of this program following two years of translocation, fifty-five squirrels were captured on the four 2011 plots averaging 13.75 squirrels per plot (Table 4). Three of the squirrels captured in 2013 were individuals translocated in 2011, and 16 were translocated in 2012. Four were recruits from the previous year; that is, first generation progeny that survived to adulthood. Twenty-nine were juveniles from 2013 litters. Four additional squirrels were new to the plots and were either progeny or immigrants from local populations. By doubling our trapping effort, we captured 13 individuals that were only caught during evening trapping. Because only morning trapping sessions were used to assess success in previous years, to compare our results to prior years, we excluded these 13 captures (Figure 8). There was no significant difference in total numbers of squirrels between plots ($F_{(5,4)} = 0.90$, $p = 0.56$). Although there was a trend towards more squirrels captured after the second year ($t_{(8)} = 1.65$, $p = 0.18$), with only four plots and two years we do not have a large enough sample size to attain sufficient statistical power (Figure 9). These data will be reanalyzed following trapping in June 2014.

Table 4. Total number of squirrels captured during long-term monitoring after each translocation. *Additional evening trapping in 2013 is separated and in italics.*

Time of capture	Type of release	JB	JC	JE	JS	JW	SE	Total
Morning	1st Year (Initial)	0	9	6	7	5	5	**32**
	2nd Year (Supplemental)	*	*	19	6	11	7	**43**
Evening	1st Year (Initial)		1					**1**
	2nd Year (Supplemental)			4	6	0	2	**12**
Total			***10***	***23***	***12***	***11***	***9***	

** 2nd year monitoring is scheduled for June 2014*

Numbers reflect minimum numbers of squirrels present and do not estimate the number of squirrels that were not trapped

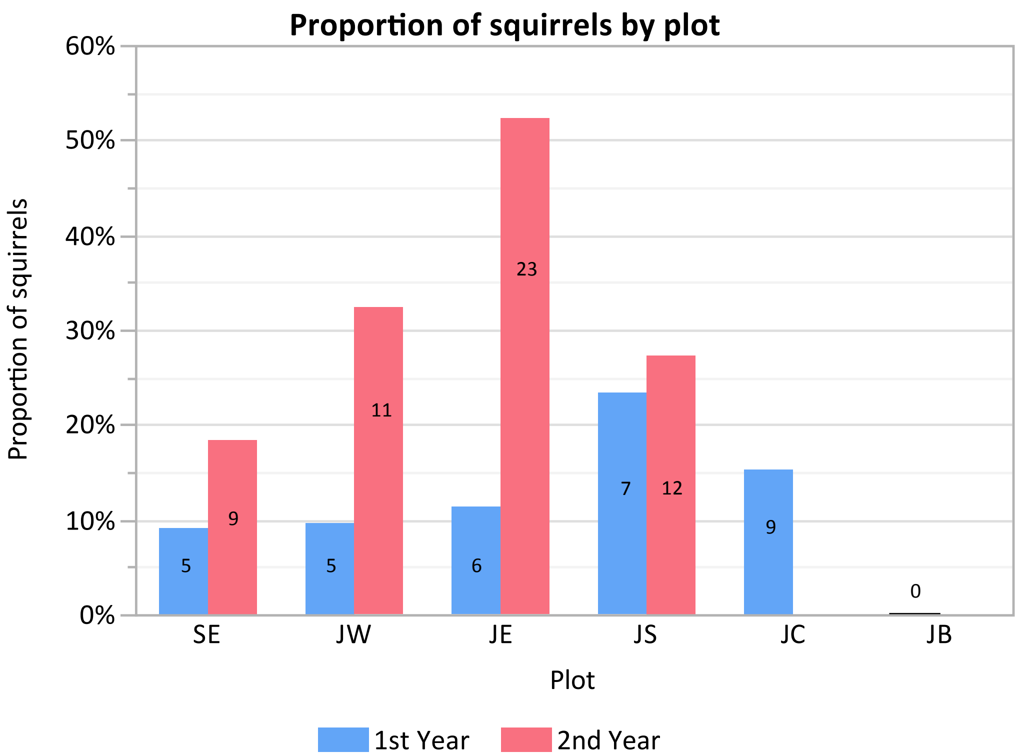

Figure 8. Summary of the number of squirrels captured on each plot one and two year(s) following translocation. *For comparison purposes, 13 individuals that were only caught during evening trapping sessions were excluded. These numbers include translocated individuals, their progeny and immigrants from local populations. All long-term monitoring was scheduled in June the following year post-translocation 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, while to date, JB and JC have only been monitored after the 1st year. Monitoring is scheduled for JB and JC in June 2014.*

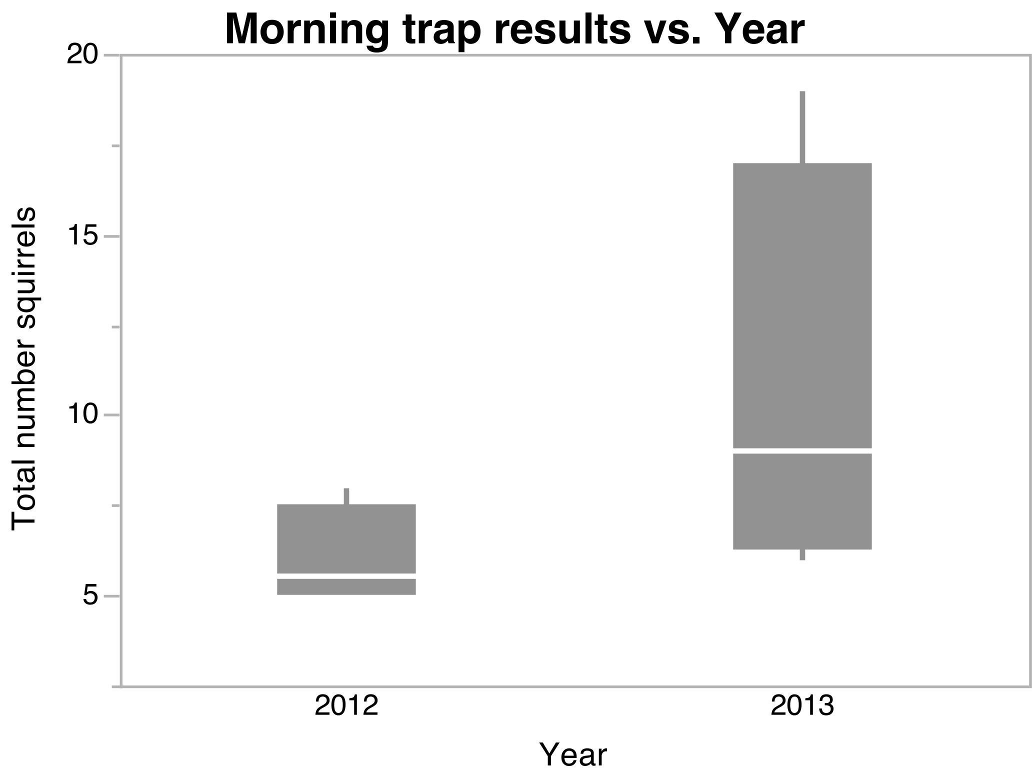

Figure 9. Boxplot comparing trapping results for 2011 plots, JE, JW, JS, SE. *Evening trapping was excluded for comparison purposes.*

Minimum survival and retention—2012 plots

The long-term monitoring results for JC and JB are mixed. We caught 10 individuals at JC, a two-fold improvement when compared to the first year trapping results of the 2011 plots (Figure 8). Six squirrels were translocation subjects, two were progeny and two were recruits (either large juvenile progeny or immigrants). As with the 2011 plots, one individual was captured only during evening trapping, and was excluded from the figure for comparison purposes. On the other hand, no squirrels were captured at JB. Our data provide no information to explain why JB failed. It is located adjacent to JS (a 2011 release plot) which had moderate success after year 1. JB was sited within the same geological formation as JS and adjacent to the same riparian habitat where raptors perch. However, annual variation in precipitation and predation pressure likely varied across years and may explain the difference in release success. An alternative explanation is related to the distance between a release site and a resident squirrel population. JB was closer to a resident squirrel population compared to JS and several resident squirrels were captured at JB during the one-month post release trapping effort. Short distances to resident populations can cause squirrels to move off of release sites, as seen with JW in 2012, and this may explain the failure of JB.

The change in our trapping protocol led to significant differences in our interpretation of long-term success. By adding a second evening trapping session, we captured thirteen additional individuals that would have been otherwise missed. Most dramatically, we double our estimated population size at JS from 6 to 12 squirrels.

These results suggest low survival to one year among translocated squirrels even if we assume a trapping rate of 30-50% following 2011 results (Swaisgood & Lenihan 2012).

Reproduction and population recruitment at experimental plots

The moderate survival rates of translocated squirrels are offset by successful reproduction and subsequent recruitment of offspring into the populations established on experimental plots. Juvenile recruitment greatly increased at plots JE and JW after the second year post-translocation (Figure 10). We also identified more juveniles at plot JS when we include results from the evening trapping sessions, during which time four out of the five juveniles were captured. These results suggest that supplemental translocation substantially improved colony establishment on the Rancho Jamul plots, while recruitment at the SE plot remained functionally the same.

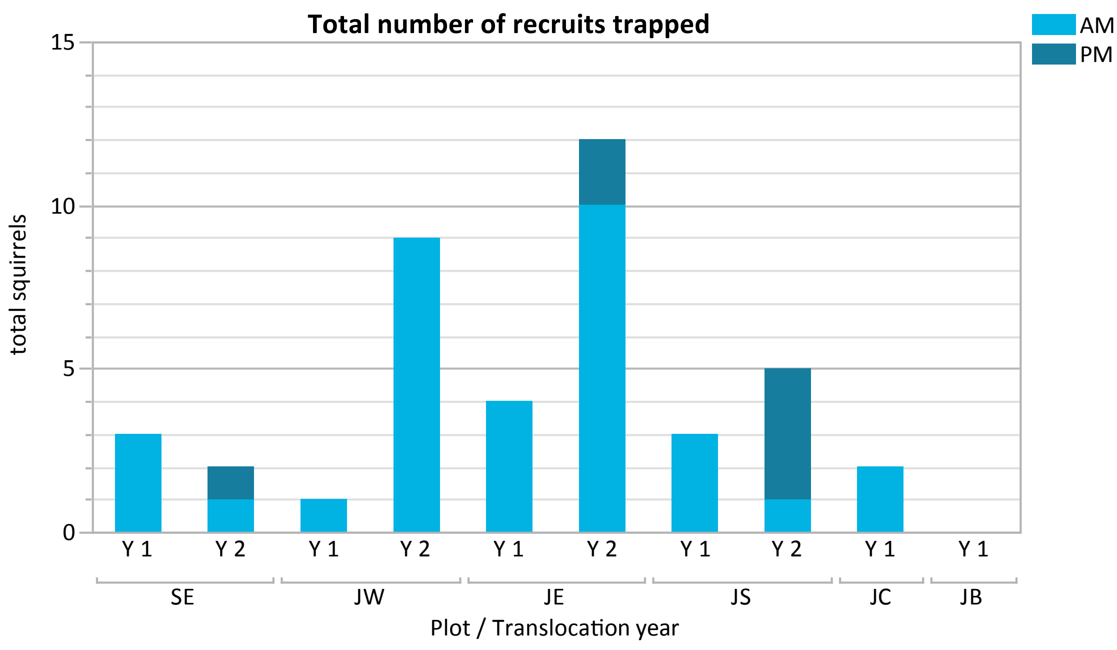

Figure 10. Total number of first generation (F1) progeny captured at the four 2011 plots, JE, JW, JS, SE by translocation year. *Light blue bars represent results from morning trapping sessions, and the dark blue bar represents seven juveniles that were only trapped during evening sessions conducted in 2013. JE and JW had much higher recruitment following the second year translocation, wheras JS had lower recruitment if we ignore results from the evening trap session.*

Short-term monitoring of 2013 translocations—(One-Month Post-Release Survival)

Plot JC continues to be our most successful squirrel colony with 58.7% of the recently translocated squirrels identified one month post-release (Figure 11). Twenty-five were trapped and two more collared squirrels were known to have survived through telemetry and direct observations. Additionally, two squirrels translocated in 2011 were identified as well as one first-generation recruit. The minimum survival estimate was lower at plot JB with 39.1% of translocated squirrels identified through trapping and telemetry. This estimate is similar to results from the 2011 translocation plots (32.4% for JW's supplemental group to 54.6% for JE's).

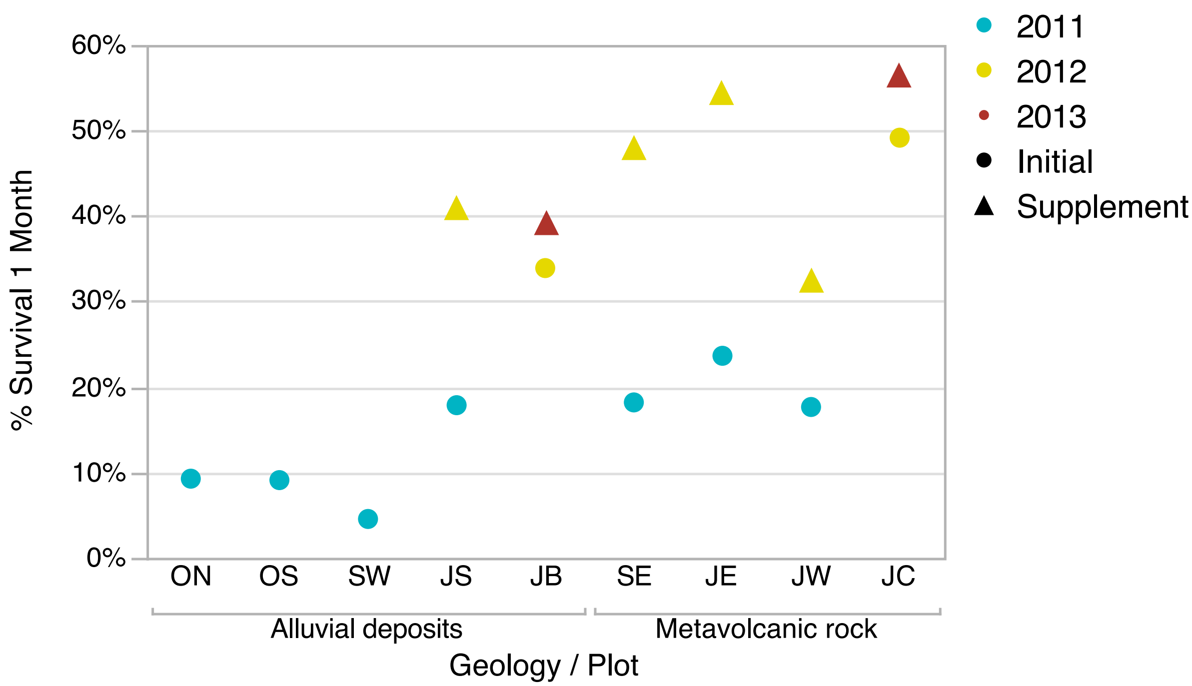

Figure 11. The percentage of translocated squirrels captured on each plot one month post-translocation by year, representing the minimum % squirrels known to have survived . *Plots are grouped by geologic parent material. Year is represented by color, circles represent initial (first year) translocations and triangles represent supplemental (second year) translocations. Overall, we had higher surivival / retention in 2012 and 2013 than in 2011, even when we exclude ON, OS and SW. Note that plots are more likely to have higher percentage of squirrels in areas of metavolcanic rock formation than in alluvial deposit.*

Our model indicates that year and geological formation are the best predictors for the establishment of new squirrel colonies ($G^2_{(3)} = 98.1$, $p < 0.0001$). We had a 4-fold increase in squirrel numbers from 2011 to 2012, and a 7-fold increase between 2011 and 2013. From 2012 to 2013, we also increased 1.6-fold, meaning for every 3 squirrels we found in 2012, we had 5 in 2013. We had higher survival and retention of squirrels at our initial translocations to JB and JC in 2012, and our supplemental translocations to all plots in 2012 and 2013, indicates that our adaptive management approach improved release success. After year 1, we made small modifications (addition of cover, attention to group membership and/or release timing) which resulted in increased survival rates. The fact that year was a variable with predictive value even when geological formation is included in the model suggests that these alterations to release strategy, in addition to any release site characteristics governed by geological formation, added to the likelihood of positive outcomes of our translocations.

That geologic formation had strong predictive value for squirrel survival is consistent with our hypotheses regarding the importance of soil characteristics for squirrel habitat selection and survival (see habitat suitability model section below). Our results clearly indicate that metavolcanic rock is associated with higher survival compared with alluvial deposits, with half as many squirrels captured in the latter. 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, BUOW.

Our model also appears to have some predictive power when compared to the results from long-term monitoring at plot JB where no squirrels were detected. The difference between geological formations is detectable at one month post-release, and predicted the ultimate fate of this plot: failed establishment of a squirrel population.

Short-term monitoring—(Telemetry)

Effects of translocation variables on survival and movement

Survival – All variables from Table 2 were initially examined with forward stepwise regression, and our model tested the effects of experimental treatment (mow, mow + auger, control), presence of clay and geological formation. The null model had the lowest BIC (359.4), suggesting no effect of the variables in the analysis. The BIC was 3.3 units higher if treatment and clay presence variables were included in the model, however when this model was tested, it failed to reach significance ($F_{(3,93)}$ = 1.9, p = 0.11, R^2 = 0.09; Figure 12). Evaluation of Figure 12 explains this possible trend: survival appears higher when clay was absent and may be somewhat lower in the control than the experimental treatment conditions, mow and mow + auger. It may be anticipated, however, that these variables will have relatively low explanatory power for survival, as squirrels may disperse from unsuitable habitat and settle in areas more suitable; this would be easily remedied with regard to experimental treatment, as dispersal of a few meters would place the squirrel in a different habitat treatment.

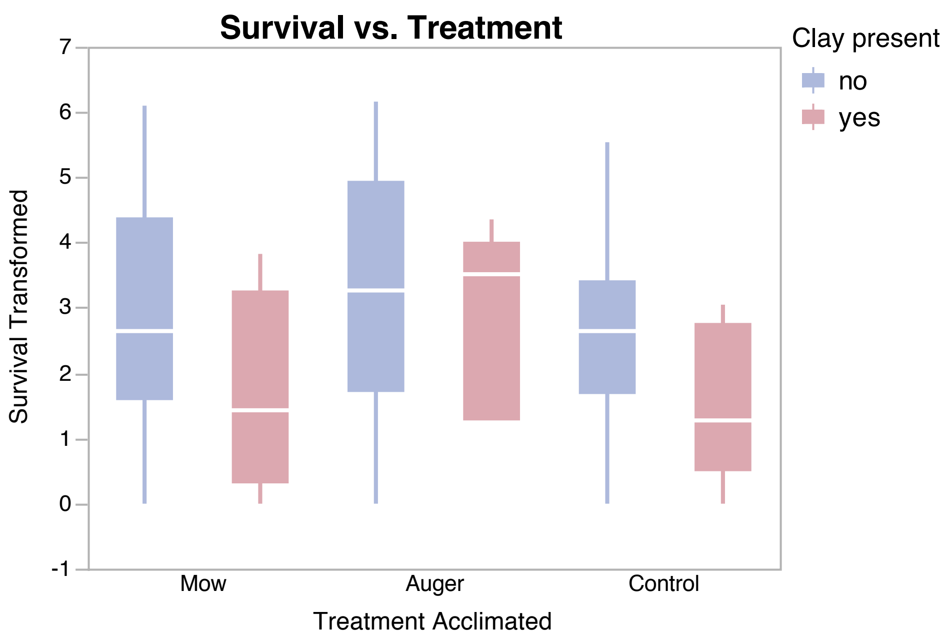

Figure 12. Effect of Site Preparation Treatments on Squirrel Release Success. *The model with the lowest BIC included treatment and presence of clay, but test results were not significant.*

Days to Dispersal **–** We predicted that squirrels released in less suitable habitat would disperse sooner than those released in more suitable habitat, with the number of days to disperse being an indicator of habitat rejection or acceptance. However, no variables included in our model affected the timing of dispersal from the release site. The best fitting model included clay presence as the only variable, however the effect was not significant (Welch's $F_{(1, 8.7)} = 2.8$, $p = 0.13$, $R^2 = 0.08$; Figure 13). The non-significant trend to delay dispersal when clay is present is in the opposite direction from that predicted, but may be explained by squirrels delaying dispersal until more suitable habitat is located, and in the case of soil containing clay, this habitat may be a great distance away and difficult to locate.

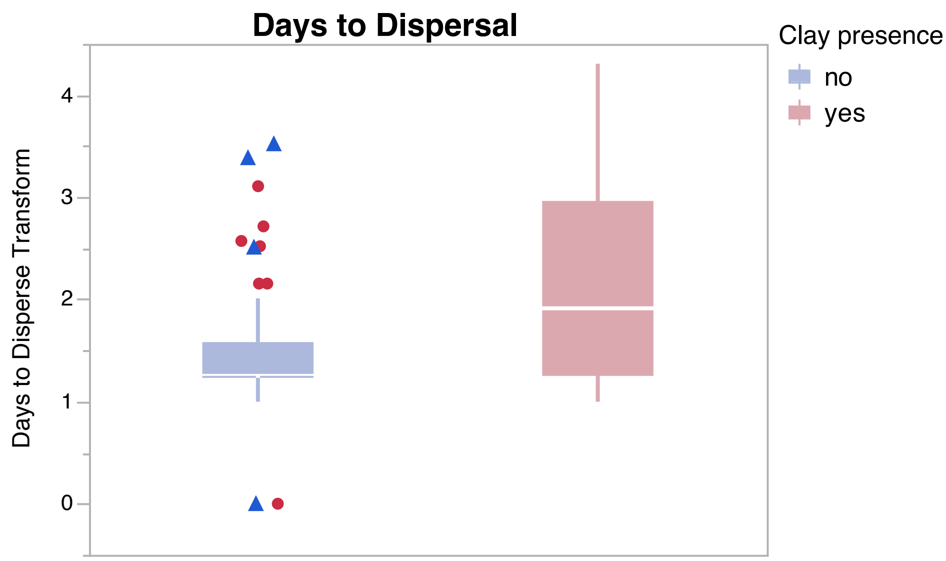

Figure 13. Days to Dispersal. *Forward & backward stepwise regression suggested presence of clay was a variable of interest, but it was not significant. Red circles indicate female collared squirrels and blue triangles are males.*

Settlement - Similarly, we predicted that squirrels would take longer to settle if released in less suitable habitat, due to the time needed to disperse and locate more suitable habitat. Of the variables tested, clay presence in the soil was the only variable to have a significant effect on dispersal time ($F_{(1,73)} = 13.2$, $p < 0.001$, $R^2 = 0.22$; Figure 14a). Squirrels placed on plots SE, ON and OS, containing more clay in the soil, took longer to settle than those on other plots. The median time for squirrels to settle on plots with clay present was 21 days, compared to and 7 days for squirrels on plots without clay. These findings are consistent with our prediction that squirrels are more likely to reject release sites containing high levels of clay and search for more suitable sites to settle.

Following the same rationale, we also predicted squirrels to respond to less suitable release site characteristics with greater settlement distances. Clay presence also influenced the distance squirrels traveled before settling, with squirrels moving farther on plots with clay than without ($F_{(1,48)} = 4.3$, $p = 0.04$, $R^2 = 0.08$; Figure 14b). The median distance squirrels traveled before settling on plots with clay was 312 meters, as opposed to 45.8 meters for squirrels on plots without clay, indicating greater acceptance of habitat with less clay-based soils.

Total distance moved, perhaps reflecting total search effort, was also significantly influenced by the presence of clay in the soil ($F_{(1,49)} = 10.2$, $p < 0.0001$, $R^2 = 0.39$). The median distance squirrels traveled was 393.1 meters on plots without clay soils and 953.8 meters on plots with clay (Figure 14c).

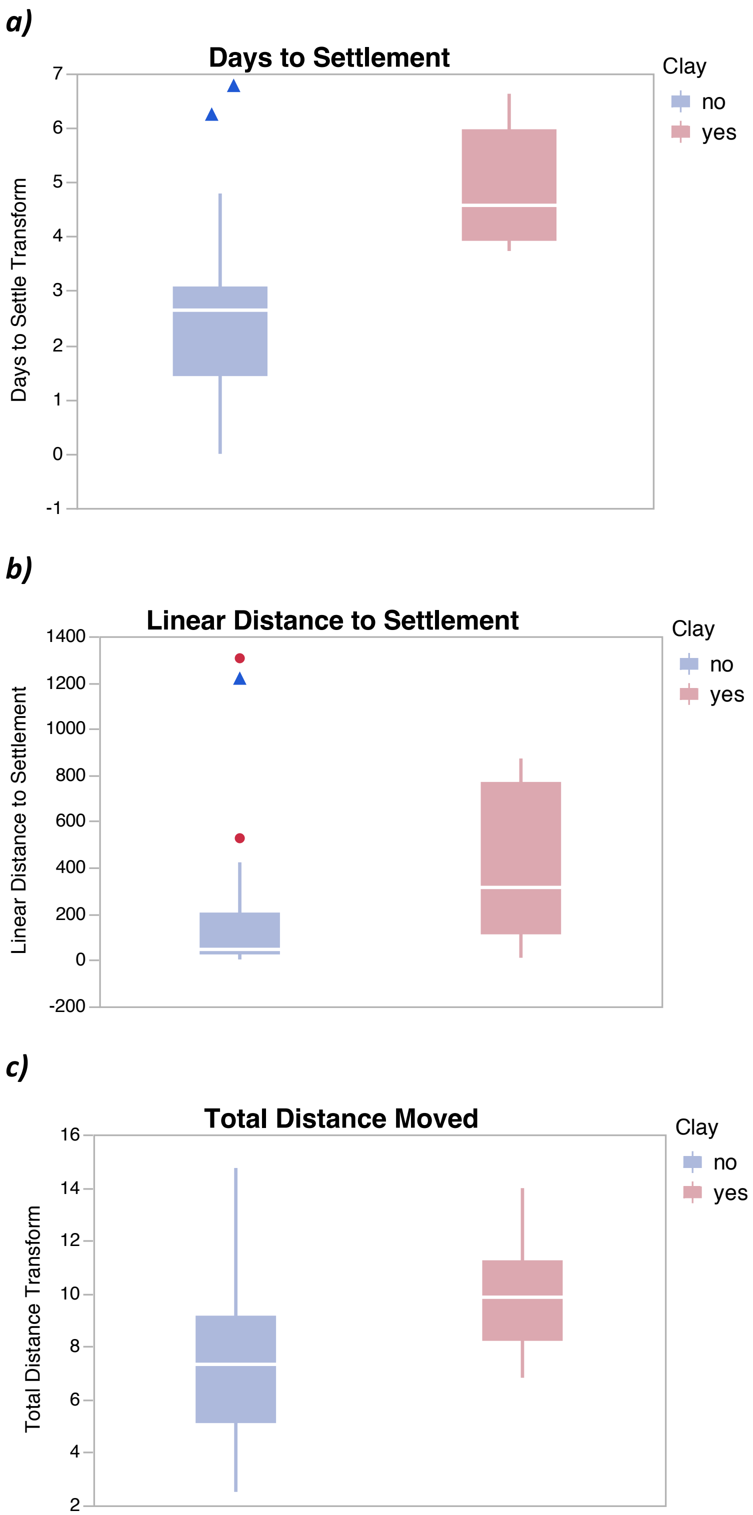

Figure 14. Effect of Clay Soil on Settlement in terms of a) Time to Settle; b) Distance to Settlement; and c) Total Distance Moved.

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Effect of Site Preparation Treatments on Settlement **-** Ground squirrel dispersal was not random with regard to treatment. Squirrel settlement decisions were influenced by the experimental treatment at the release acclimation enclosure (Likelihood ratio $X^2 = 22.7$, $p = 0.02$). Squirrels released in Control treatments were unlikely to remain there (7.1%), whereas those released in the Augured (44.8%) or Mowed (32.1%) treatments were approximately five times more likely to settle within the treatment they were released (Figure 15). Few squirrels moved off plot (10.3% overall), instead choosing to settle on one of the non-control treatments. With such a low level of retention of translocated squirrels on untreated tall vegetation treatments (Controls), it is clear that any translocation into a release site with a high percentage of invasive grasses will fail unless the site is manipulated by opening vegetation and possibly auguring.

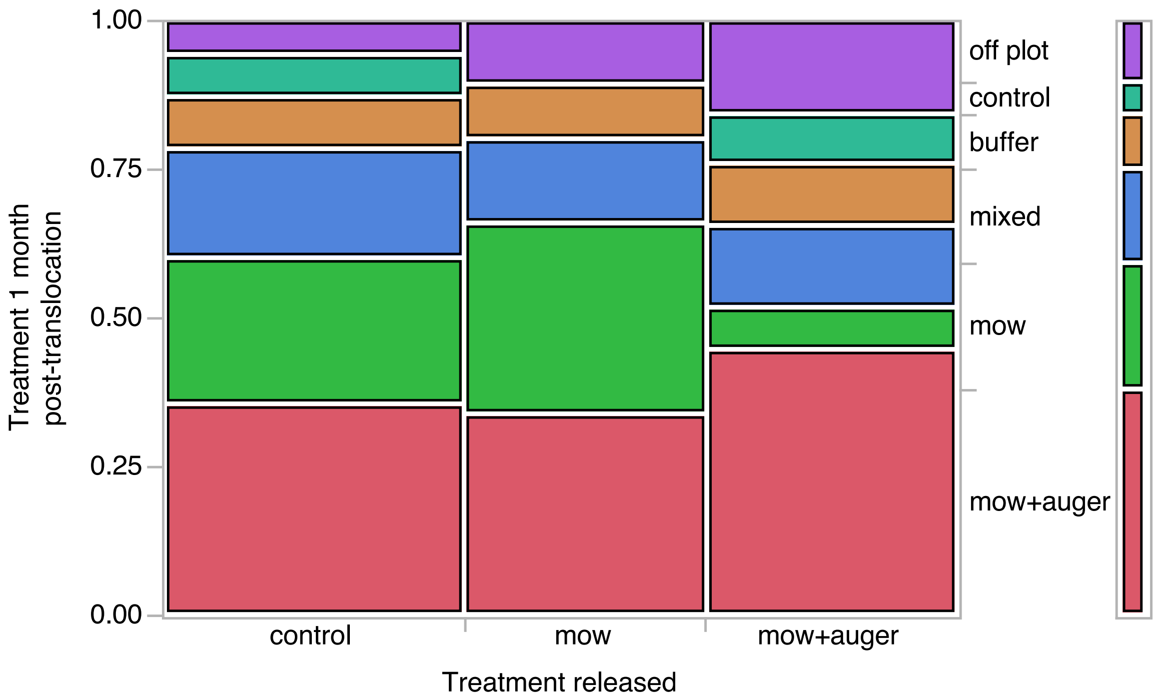

Figure 15. Settlement Locations One month Post-release as a Function of Treatment at Release Sites. *Data from 184 recaptured or collared squirrels.*

General discussion

Taken together, these results provide clear indication that soils, as measured by SanGIS maps of soil type and geological formation, are important predictors of ground squirrel survival, movement, reproduction and establishment following translocation. More fine-scale analysis of soil samples at the site may provide more accurate prediction, but these coarse-scale data provide reasonable guidance for site selection for establishment of California ground squirrels, and therefore for sites best suited for sustainably supporting populations of BUOW.

As in previous years, the data on vegetation and burrow establishment (Deutschman & McCullough 2014) support the hypothesis that squirrel translocation and vegetation management are important factors for the ecological restoration of grasslands to support BUOW. Across all translocation sites, ground squirrels established approximately 779 burrows compared to only 35 burrows established at matched-control sites, indicating that vegetation management alone will not likely attract sufficient numbers of squirrels to create the desired ecosystem engineering effects in a two- to three-year timeframe. However, vegetation management is necessary in areas characterized by dominant invasive grasses, as squirrel establishment and burrow creation continued to favor areas that were mowed or mowed + auger treatment. Ground disturbance, in the form of aprons free of vegetation around burrows, also was much greater at squirrel translocation sites, and tended to increase in size through time (Deutschman & McCullough 2014), creating more open ground favored by BUOW and other grassland species.

MONITORING NATURAL SQUIRREL DISPERSAL INTO MANAGED HABITAT

We are currently collaborating with CDFW to determine if habitat modification directly adjacent to a large source squirrel population may encourage dispersal and settlement under these circumstances. In 2013, we met with CDFW partners to discuss the development of a protocol for monitoring natural dispersal of ground squirrels in the Burrowing Owl Habitat Management Area at Rancho Jamul Ecological Reserve, followed by a brief site visit. We submitted a protocol designed to address three research questions to assist with management: 1) Does habitat restoration through grazing or herbicide treatment facilitate natural dispersal?; 2) If natural dispersal occurs, which age cohort is dispersing?; and 3) Does the placement of wood piles in managed habitat expedite natural dispersal? (Appendix 1). The study design for woodpile placement proposed in option 2 of the protocol will be implemented in January of 2014 by Paul Schlitt and Kyle Dutro (CDFW). Once woodpiles are placed, we will conduct a pilot burrow survey prior to habitat modification by cattle grazing. Biannual surveys will take place every April and September from 2014 through at least 2016.

CALIFORNIA GROUND SQUIRREL HABITAT SUITABILITY MODEL

INTRODUCTION

To increase our ability to successfully translocate California ground squirrels, we must first better understand their habitat requirements. In 2012 and 2013, we conducted surveys for ground squirrels throughout San Diego County grasslands and examined habitat covariates to gain insight into the factors influencing their distribution and abundance. Surprisingly little research has been conducted on the habitat requirements of California ground squirrels. Two recent studies provide the first empirical data on habitat preferences for this species. Ordeñana et al. (2012) assessed habitat associations of California ground squirrels on levees and found that they showed avoidance of tree cover and leaf litter and a preference for barren areas and grasslands on the landside and shrub cover on the waterside of levees. This relationship was most likely a function of food availability and visibility to detect predators. Frost and Osborne (in prep) studied habitat associations for artificial burrows in San Diego County and found somewhat divergent results, including a positive association with increased vegetative cover and lower vegetation height. While insightful, only the latter study was conducted in Southern California and neither included a full suite of ecological factors such as soil quality. Moreover, both were conducted in rather circumscribed contexts (water levees and artificial burrow sites). Thus, there is still much to learn about California ground squirrel habitat selection. Without an understanding of why squirrels are locally abundant at some sites while absent at others, we may be unsuccessful at selecting sites that have the best potential for restoration and that can support sustainable BUOW populations dependent on ground squirrel burrows. Better knowledge of ground squirrel habitat requirements will be instrumental in guiding any BUOW translocation program and may radically alter how mitigation sites are selected.

The goal of these surveys was to determine the ecological variables that affect distribution and relative abundance of ground squirrels. To better understand the relationship between occupied and unoccupied habitat, we collected habitat data from grasslands throughout San Diego County to develop a habitat suitability model. Habitat plots were established along transects at sites with burrows and compared with those without burrows (presence-absence). Surveys for California ground squirrel burrows (distinguished by size), rather than squirrels themselves, make surveys more efficient and virtually eliminate problems associated with detectability. While burrow numbers are not directly indicative of squirrel numbers, burrow entrances do serve as a good index of squirrel abundance (Owings & Borchert 1975; Ordeñana et al. 2013). Burrow surveys have the added benefit of sampling the chief squirrel-mediated habitat effect beneficial to BUOW. This variable (burrows) likely reflects a composite of ground squirrel abundance and soil suitability for burrow establishment. Habitat covariates recorded included: vegetation type and structure, percent bare ground, soil characteristics, distance to human activity, distance to permanent water, and other variables of interest. The results of this survey can be used to define key habitat factors and help identify critical habitat in San Diego County for both ground squirrels and BUOW.

METHODS

Study sites

We collected data from sixteen grassland sites throughout San Diego County (Figure 16):

1. Rancho Jamul Ecological Reserve
2. Wheatley Ranch (private property)
3. Ramona Grasslands Preserve
4. Barnett Ranch Preserve
5. Santa Ysabel Open Space Preserve
6. Goodan Ranch Sycamore Canyon Preserve
7. Simon Preserve
8. Los Rancho Peñasquitos Canyon Preserve
9. Poggi VOR
10. Proctor Valley
11. Eichenlaub Ranch
12. Pamo Valley
13. San Diego National Wildlife Refuse (Sweetwater)
14. Tulloch Ranch (private property)
15. Lake Henshaw
16. Camp Pendleton

Surveys were conducted in May-July 2012 for the first 8 sites and in April-July 2013 for the last 8 sites. We obtained permission to access the above sites from the relevant land manager (i.e. City of San Diego, San Diego County, Vista Irrigation District, Camp Pendleton, USFWS, Federal Aviation Administration, private land owners). Sites were selected based upon the following criteria: 1) be classified as a grassland ecosystem, 2) exist at an elevation of less than 1200 m, and 3) be of sufficient size for the 50 m long transect surveys within the site (minimum size was 10 hectares).

Figure 16. Map showing the approximate locations of the sixteen ground squirrel habitat sites throughout San Diego County (blue = 2012 sites, red = 2013 sites).

Transects

We used GIS software to create 15 random transects within each study site, each 50 m in length, with a minimum 25 m buffer around each transect (Figure 17). Fifteen transect surveys were conducted at all sites with the exception of Rancho Jamul Ecological Reserve (13 transects), Los Rancho Peñasquitos Canyon Preserve (7 transects) and Proctor Valley (13 transects) due to logistical issues.

A team of two field biologists walked on each side of the transect looking for burrows and additional signs of California ground squirrels (i.e., squirrels, calls, scat). We recorded the number and species of any predators observed, as well as the number and distance of ground squirrel signs, along the transect. Upon detection of a ground squirrel burrow, we established a 10x10 m plot with the burrow at plot center. If no burrow was detected along the 50 m transect, the plot was established such that its center was 5 m from the end of the transect. We used meter tapes to lay out the transect lines in a north to south orientation (see Appendix 2 for full protocol).

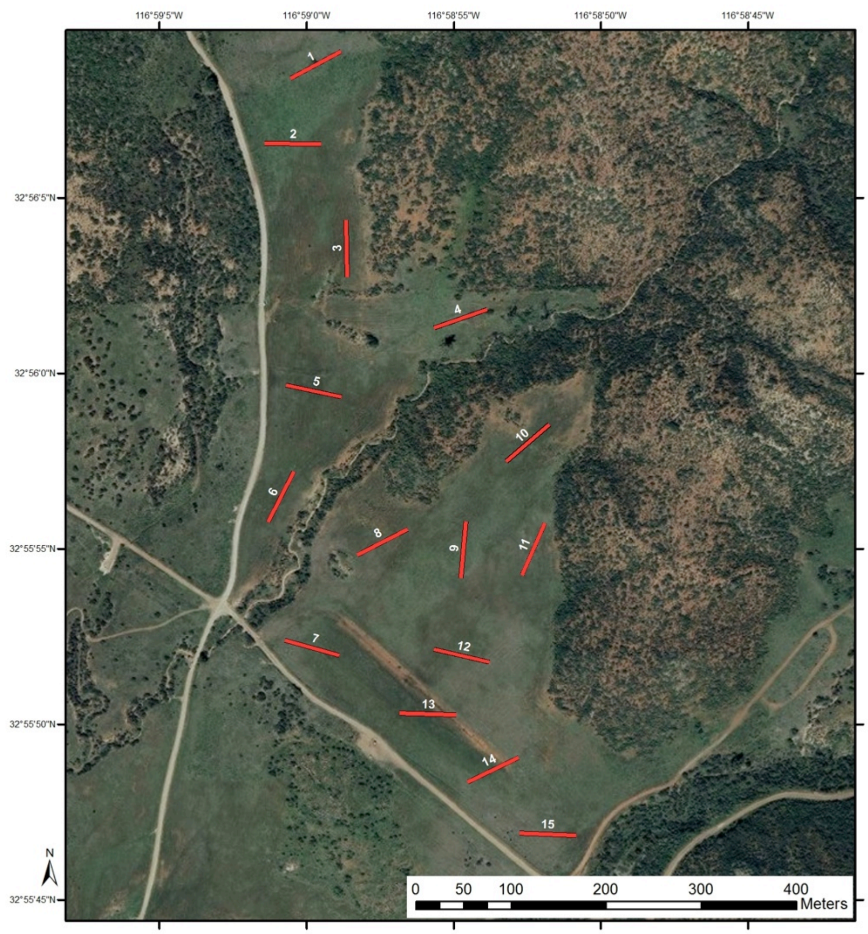

Figure 17. Example of transect layout (site: Goodan Ranch Sycamore Canyon Open Space Preserve).

Plots

For each 10x10 m plot, we collected the following data: (1) GPS location of plot-center/burrow; (2) elevation (m); (3) percent slope and aspect; (4) percent canopy cover; (5) community type (e.g. grassland or coastal sage scrub); (6) dominant species of grass, forb, and shrub; (7) whether the burrow was active (yes/no); (8) type of burrow protection, if applicable; and (9) site history (grazing/burn/rodenticide use), if known. In addition, we established 10 point-intercept transects, 10 m in length. We used a laser device for each point-intercept to eliminate biasing the selection, and collected data at every 0.5 m mark (2012 protocol) or 1 m mark

(2013 protocol) along each 10 m transect. Analysis of 2012 plot data showed no statistically significant difference between data collected at 0.5 m or 1 m marks. Thus, we transitioned to data collection at every 1 m marking in 2013 in order to increase survey efficiency. For each point, we collected data on (1) vegetation height (cm); (2) vegetation type for each canopy level (top canopy and up to three lower canopy levels, if necessary); and (3) soil surface (e.g., soil, rock, litter, woody debris, burrow, or basal intercept. Vegetation was categorized as exotic or native species, and annual or perennial for each vegetation type (e.g., grass, forb, rush/sedge, shrub, and tree). Photos of the surrounding habitat from plot center facing north, south, east, west and a photo of the burrow (if applicable) were also taken at each plot. Lastly, we collected three soil core samples: one at the plot center (or adjacent to a burrow if present), and the other two at 1 m away from the plot center, directly opposite each other.

Soil Sample Processing

The soil sample processing protocol (see Appendix 2) was recommended by Clark Winchell, USFWS Carlsbad office, and obtained from New Mexico State University, College of Agricultural, Consumer and Environmental Science. Processing equipment and lab space was provided courtesy of the USFWS Carlsbad office.

We stored the soil cores in aluminum tins and dried them completely in a soil oven. Once dried, we weighed the original sample and then used a sieve to separate all gravel 2 mm or larger from the sample and weighed it to obtain the percentage of the sample composed of gravel. The remaining soil was weighed to obtain the bulk density. We conducted soil texture analysis on the remaining sample to determine the percent composition of sand, silt, and clay.

Data Analysis

We examined each of the habitat variables and their intercorrelations. Significantly correlated variables were identified using Pearson's correlation coefficients and excluded from regression models together to prevent multicollinearity. Logistic regression models were used to determine habitat variables associated with squirrel burrow presence and were evaluated using BIC. Univariate logistic regression models were also run to help identify significant variables. Given the multiple comparisons, we then controlled for the false discovery rate (FDR) using the Benjamini-Hochberg linear step-up method to adjust the p-values (Benjamini & Hochberg 1995). Variables showing a tendency of association with squirrel burrow presence were included in multivariate models. Chi-square tests were also used for categorical data analysis.

RESULTS & DISCUSSION

In 2012 and 2013, we collected habitat and soil data at 90 squirrel burrow plots and 138 absence plots across the 16 grassland sites (Table 5). Squirrel activity was confirmed at 71 of the 90 burrow plots. Analyses were performed on both the full dataset and the subset of active burrows.

Table 5. Number of ground squirrel burrow presence and absence plots by site. *The number of active burrow sites are indicated in parentheses.*

	Burrow		
Site	**Absence**	**Presence**	**Total**
Barnett Ranch	0	15 (12)	15
Camp Pendleton	7	8 (5)	15
Eichenlaub Ranch	2	13 (9)	15
Lake Henshaw	12	3 (3)	15
Pamo Valley	4	11 (9)	15
Poggi VOR	8	7 (7)	15
Proctor Valley	13	0 (0)	13
Ramona Grasslands	5	10 (9)	15
Rancho Jamul	13	0 (0)	13
Rancho Penasquitos	2	5 (2)	7
Santa Ysabel	14	1 (1)	15
Simon Preserve	15	0 (0)	15
Sweetwater (NWR)	13	2 (1)	15
Sycamore Canyon	14	1 (0)	15
Tulloch Ranch	8	7 (6)	15
Wheatley Ranch	8	7 (7)	15
TOTAL	**138**	**90 (71)**	**228**

With the inclusion of 2013 surveys, we doubled our previous sample size from 110 to 228. Site level effects still remained significant ($G^2(15) = 124.85$, $p < 0.001$; BIC = 267.92). Known grazing or burns at sites could contribute to these site level effects. The presence of squirrel burrows was found to be more likely where grazing was known to occur ($\chi^2(1, n=208) = 3.60$, $p = 0.058$), as well as where burns had occurred ($\chi^2(1, n=187) = 3.37$, $p = 0.067$). The positive relationship between grazing and active squirrel burrows was even stronger ($\chi^2(1, n=191) = 7.07$, $p = 0.008$). Other landscape level features, such as minimum distance to water, urban development, or edge, could also be contributing to these site level effects. However, all of these variables are strongly linked to site and these site-level characteristics become non-significant ($p > 0.05$) once site is added as a random variable to the model. Further analyses of these landscape level features are being conducted using GIS to help better determine their significance for squirrel presence in an area.

Controlling for site, the multivariate model that best explained squirrel burrow presence included percent vegetative cover and percent sand ($G^2(17) = 141.37$, $p < 0.001$; BIC = 262.25). As vegetative cover increases, the likelihood of squirrel burrows being present decreases, whereas increases in sand in the soil composition, increases the odds of squirrel burrow presence (Table 6). Percent sand was highly negatively correlated with percent silt and clay ($r(227) = -0.8$, $p < 0.001$), so it is likely that a combination of soil texture, not just sand, is driving this relationship. These results are similar to the results obtained from the 2012 subset of data, where the key habitat variables were percent no cover and soil composition (% sand and % gravel). Not surprisingly, percent vegetative cover and no vegetative cover are negatively correlated ($r(227) = -0.5$, $p < 0.001$).

Table 6. Habitat variables associated with squirrel burrow presence identified using logistic regression. *The odds ratio range is the 95% confidence interval of the odds of squirrel burrow presence versus absence for each unit change in the variable.*

Variable	Coefficient	SE	χ^2	p	Odds Ratio
% Veg Cover	-2.536	0.873	8.45	0.004	0.01-0.41
% Sand	0.071	0.033	4.75	0.029	1.01-1.15

The results from univariate models are presented below (Table 7), with p-values adjusted to control the FDR. These analyses provide confirmation regarding the role of soil characteristics and vegetation structure revealed by the multivariate model. Five intercorrelated variables relating to soil characteristics attained significance, indicating that squirrel burrows were more likely to be present when the soil contained more sand, higher bulk density, less silt, less clay, and less gravel. Vegetation characteristics also appear to be important determinants of squirrel presence, again as reflected in a suite of intercorrelated variables. Squirrel presence was favored by less annual vegetation and more standing (dead) litter, as well as marginally significant trends for less vegetative cover, more bare ground, and less exotic vegetation. Because annual vegetation tends to be exotic and have less bare ground, these three variables are likely measuring the same general preference. For example, exotic and annual vegetation types were positively correlated with each other ($r(227) = 0.9$; $p < 0.001$) and were negatively associated with squirrel burrow presence. It is thus plausible to conclude that dense, annual exotic vegetation deters squirrel presence.

*Table 7. **Summary of habitat variables for squirrel burrow presence and absence plots.*** *The FDR q-values for each univariate logistic regression model are reported.*

Variable	Absence		Presence		Significance
	Mean	SD	Mean	SD	q-values
Soil - % Sand	53.96	13.69	62.62	10.66	0.002
Soil - % Silt	27.91	8.66	22.78	5.59	0.001
Soil Bulk Density	0.92	0.18	1.01	0.16	0.001
Soil - % Gravel	10.02	9.96	5.5	5.26	0.001
Soil - % Clay	18.13	8.29	14.61	6.84	0.002
% Annual	88.43	38.16	76.85	25.01	0.036
% Standing Litter	16.52	13.44	20.94	13.55	0.047
% Vegetative Cover	90.8	23.56	83.64	24.52	0.067
% Soil (Bare Ground)	3.63	6.29	5.56	7.05	0.074
% Exotic	83.62	37.52	74.4	26.39	0.084
% Perennial	13.27	27.58	7.64	14.99	0.119
% No Cover	4.31	8.23	5.85	7.9	0.274
Veg Height (cm)	16.24	9.95	14.39	10.54	0.273
% Litter	94.47	9.8	93.17	8.59	0.439
% Grass	65.3	28.27	62.24	25.87	0.545
% Forb	17.83	18	16.64	13.81	0.737
% Shrub	2.69	7.87	3.25	7.91	0.709
Slope (%)	5.4	6.06	5.18	4.86	0.857
Elevation (m)	432.62	336.29	436.99	312.57	0.970
% Native	8.48	16.43	8.28	12.99	0.921

We had predicted an association between soil characteristics and squirrels, given their fossorial behavior. The negative association between squirrel burrows and percent vegetative cover also confirms the results of previous observations. Ordeñana et al. (2012) similarly found a strong preference for barren areas along levees. However, these findings are in contrast to those of Frost & Osborne, who found more evidence of squirrel sign at artificial burrows with higher percent vegetative cover. This might have been due to site level differences where artificial burrows were located.

When comparing active burrow locations to inactive burrows (sites where burrows were absent were not included in this analysis), site was no longer a significant factor and the model with percent standing litter and percent no vegetative cover best explained the presence of active burrows (Table 8; $G^2(2) = 12.35$, $p = 0.002$). Among these sites that contain burrows, the likelihood of a burrow being active was significantly greater as percent no vegetative cover increased and percent standing litter decreased, perhaps reflecting squirrel digging and foraging activities that further open up the habitat by removing cover and standing vegetation. If this explanation is correct, these findings are the result of squirrel activity, not the cause.

Table 8. Habitat variables associated with active squirrel burrow presence vs. inactive burrows, identified using logistic regression. *The odds ratio range is the 95% confidence interval of the odds of active squirrel burrow presence versus inactive for each unit change in the variable.*

Variable	Coefficient	SE	χ^2	p	Odds Ratio
% No Cover	14.277	7.157	3.98	0.046	$17.20\text{-}3.84 \times 10^{13}$
% Standing Litter	-5.587	2.095	7.11	0.008	$4.80 \times 10^{-5}\text{-}0.20$

Clearly, together these results indicate that squirrels are associated with more open habitat, with less vegetative cover, and more sandy soils across grassland sites in San Diego County. When assessing potential restoration and/or relocation sites, the key variables for squirrel presence (soil composition and vegetative cover) will need to be combined with landscape and site level factors, in order to determine suitability for both squirrels and BUOW. Vegetation management will likely be needed in areas that otherwise have suitable soils and site characteristics. The results from BUOW habitat surveys will also be useful to help inform site selection for ground squirrel and BUOW sustainability.

BURROWING OWL NESTING AND FORAGING ECOLOGY

INTRODUCTION

Working with the BUOW partnership, SDSU IEMM developed a conceptual model explaining possible factors regulating BUOW population dynamics. Among the most fundamental variables identified in this model are burrows, habitat type (vegetation), prey abundance and availability, and predation. In 2011 and 2012, we conducted a pilot project to test the utility of using camera traps to document BUOW reproductive ecology and population dynamics. We found that camera traps placed at the nest burrow entrances allow us to count chicks to determine reproductive success, track prey deliveries by adult owls, and identify prey items. Due to our success with the pilot project, we made this research the focus of much greater effort in 2013.

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 those of 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.

In 2013, we also implemented a pilot project to characterize the habitat surrounding active BUOW nests in southern San Diego County, with the goal of increasing our understanding of habitat and nest-site selection in the species. In conjunction with results from the camera-trap BUOW nest monitoring effort, we hope to ultimately determine the relationship among habitat, nest site selection, and nest success. The results from these surveys can be used in conjunction with the results from the California ground squirrel habitat model to help identify critical habitat for both ground squirrels and BUOW, and inform decisions regarding where to promote natural burrows and/or install artificial burrows in the county.

In addition, we increased our banding effort in 2013. Color-banding, which allows for individual recognition of the birds, will help us 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 the BUOW in San Diego County.

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 (Figure 18) for monitoring BUOW nesting ecology:

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.

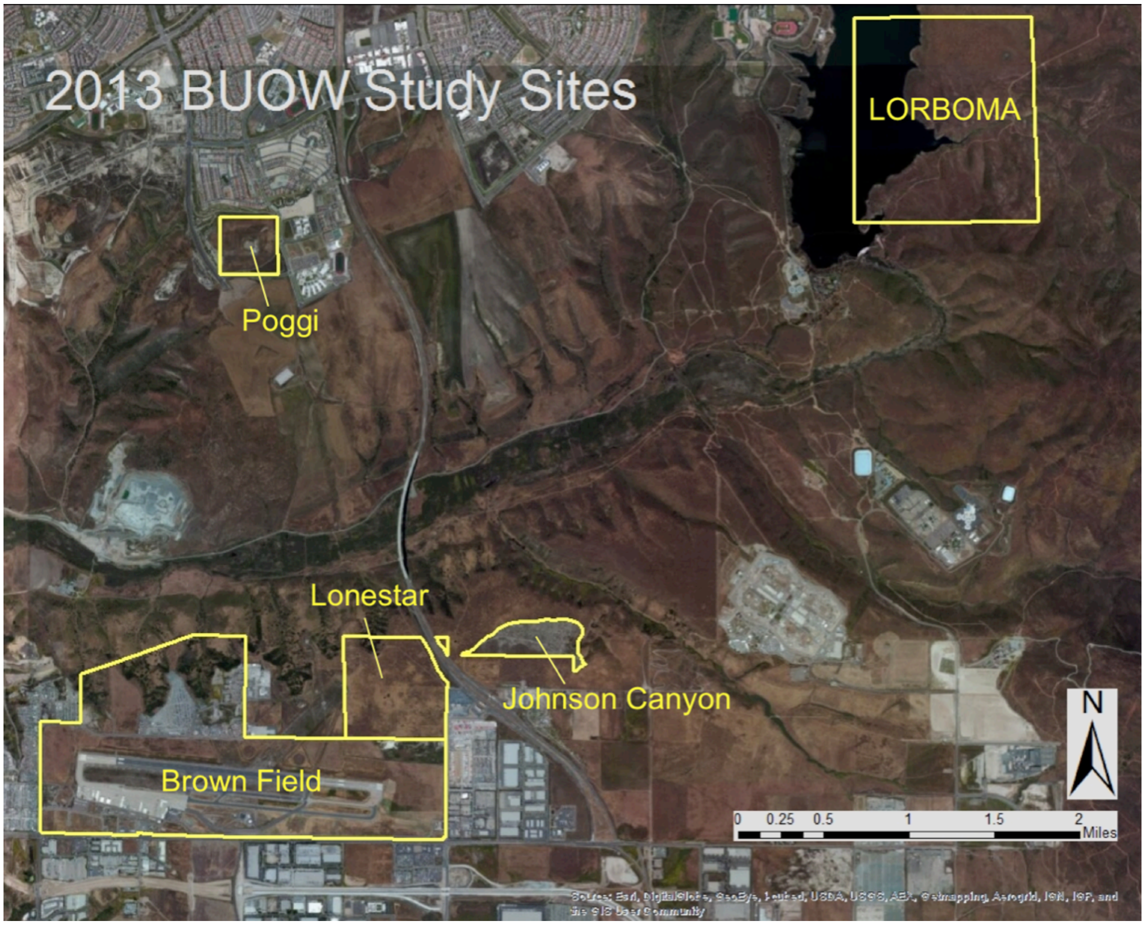

Figure 18. Map of the 2013 Burrowing Owl study sites.

Nest monitoring

Nest Visits

We compiled known natural and artificial burrow locations within Management Unit 3 from previous years' data, eBird, CNDDB, Califorinia Department of Fish and Wildlife, and CalTrans. We surveyed known locations, including the following sites with artificial burrows: Dennery Canyon, Goat Mesa, Rancho Jamul Ecological Reserve, LORBOMA, Johnson Canyon, San Diego National Wildlife Refuge (Shinohara area) and Lonestar. Sweetwater Authority would not grant access to the Sweetwater Reservoir, so we were unable to survey this site. At each site, we determined the status of artificial burrows (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 (see above Study Sites section).

We visited each site weekly and checked all burrows at a given site for activity (including the burrows at Brown Field that were not monitored using camera traps).

The number of owls seen, sex and age class of the owls, and the presence of ground squirrels or predators was recorded for each nest visit. In addition, incidental BUOW sightings or sign at squirrel translocation plots was recorded throughout the study period.

Camera Trapping

From our list of all active burrows at the five priority sites, we constructed a list of focal burrows for camera trap monitoring with the goal of obtaining a representative sample across sites and burrow types (natural or artificial) given our available number of camera traps. When we confirmed the presence of eggs or chicks at a focal burrow, we set cameras at each burrow entrance; natural burrows typically had one main entrance, while most artificial burrows were designed with two entrances). At all sites except Brown Field, all active burrows were focal burrows. We did not set cameras up at all active burrows at Brown Field due to the disproportionately high number of active burrows there; instead we chose a random subset of burrows that were spatially-representative of the airport property.

We used Reconyx® PC900 and Bushnell® TrophyCamHD remote camera systems to monitor the entrances of active nest burrows. Each camera was placed 1-3 m from the burrow entrance approximately 0.5-0.75 m above the ground and focused on the entrance and apron area of the burrow. Most of the cameras were set up straight out from the burrow entrance, but in a few cases, due to burrow configuration, we placed the camera at an angle to the entrance. 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. All blood and feather samples are being stored in the Frozen Zoo® at the San Diego Zoo Institute for Conservation Research.

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 3 for protocol with full keyword list). 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. Each tagged photo was examined 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. The maximum numbers observed were used to estimate the average total number of chicks and fledglings per burrow for comparisons between natural and artificial burrows. 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, herpetofauna, invertebrate, mammal, and unknown prey. We did not include site differences in our analyses because 3 of the 5 sites had fewer than 3 burrows.

BUOW Habitat Survey

Study sites and dates

We conducted our study in June–July 2013 at the 5 study sites in south County San Diego. Study sites were selected based upon the monitored BUOW nest sites in 2013. We obtained permission to access the sites from the relevant land manager (i.e. City of San Diego, San Diego County, Caltrans, Federal Aviation Administration).

Habitat characterization

A total of eighteen burrows (9 natural, 9 artificial) used by BUOW for nesting were surveyed within the study area. In addition to the nest locations, GIS was used to generate five random points within each of the study sites to characterize habitat at each site. Random points were restricted to a minimum separation distance of at least 50 m, and an exclusion buffer of 50 m was applied around each active nest to mitigate the possibility of disturbance. All surveys at or near the nesting site were done in consultation with the BUOW monitoring team (Colleen Wisinski and Jeff Lincer) to ensure that chicks were of an appropriate age and utilizing satellite burrows, so as to minimize potential impact. Surveys took no longer than 45 minutes to complete at a single nest burrow.

Vegetation and soil surveys within the 10 x 10 m line-point intercept plots were conducted using the same methodology as the California ground squirrel habitat surveys (see Appendix 2, section 5-8). Supplemental habitat data for the 10 x 10 m plots were also recorded to establish consistency with protocols used for recent habitat assessments of artificial burrows used by BUOW in San Diego County (Frost & Osborne, in prep). This included circular visual estimations (radius 3 m and 15 m) of open ground, vegetative cover and vegetative litter surrounding the burrow entrance, and any potential environmental stressors that could affect BUOW. Information about the physical characteristics of nest burrows and their immediate surroundings was also noted, including signs of BUOW activity such as presence of owl pellets and whitewash.

RESULTS & DISCUSSION

Nest monitoring

During the 2013 breeding season, we located 37 BUOW burrows (Table 9; Figures 19-24). We confirmed breeding (by presence of eggs or chicks) at 28 of these burrows and found an additional family toward the end of the breeding season when they moved into a previously unused burrow. We were not able to confirm breeding at the other burrows for a variety of reasons. If a burrow occurred on private land, we observed it from the nearest road and did not revisit it as the season progressed (due to project priorities and time constraints). In one such case, a pair was observed at a burrow before the breeding season began, but on the next visit, we discovered the entire area had been plowed. In two cases, we could not confirm breeding because only a single bird was observed at a burrow and then not observed subsequently. In these two cases, the individual may have been a wintering bird or it could have paired up and moved to a different burrow. At another two burrows, each had a pair present at some point, but they chose not to stay and breed there. Lastly, 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.

We monitored 26 burrows weekly from April through mid-September (1-26 in Table 9) and we monitored all others that did not occur on private land approximately monthly during the same period.

We found that the Lonestar site had markedly lower apparent fledging success (percent of burrows that fledged at least one juvenile) than the other sites (25% vs. 75% at Brown Field and 100% at each of Johnson Canyon, Poggi, and LORBOMA, although the sample size was limited at the last 3 sites). There are a few possible explanations for this lower success. First, this site is newly restored and lacks mature vegetation that could support a larger population of small mammals, herps, and invertebrates. As the site matures, it is likely that the habitat will support a larger and more diverse prey base. The Johnson Canyon site, which was seven-years post-restoration during the 2013 breeding season, was one of the most productive sites. Johnson Canyon is surrounded by open (albeit, non-native) grasslands and canyons with coastal sage scrub vegetation. Lonestar is similarly situated and has the potential to become a more productive site in the future. Second, these nests seemed to fail early in the breeding season (at the egg stage or young nestling stage), which suggests that the conditions (microclimate) inside the burrows may not be optimal for egg or chick survival. We will examine burrow microclimate (temperature and relative humidity) in 2014. Johnson Canyon and some burrows at Brown Field (i.e., Gravel Lot, Gailes, and Old Schoolhouse) experienced relatively high productivity (≥4 fledglings per burrow). This could potentially be explained by a number of variables, including better prey base, better nesting habitat, or more experienced parents.

Banding

We banded BUOW during the period of 22 May to 16 July. We captured a total of 61 BUOW (Table 10, Appendix 4), two of which were recaptures of adult birds that had been banded by us in 2011. We took blood and feather samples from 59 BUOW (including the 2 recaptures) and feather-only samples from two very small nestlings. The owls we captured represented 17 families, with 48 of them banded at natural burrows and 13 of them banded at artificial burrows. Because we used one-way door traps at the burrow entrances as our primary capture technique, most of the birds we captured were juveniles (51/61). The discrepancy in the numbers caught at natural vs. artificial burrows is likely due to the low nest success at Lonestar which limited the number of juveniles available to capture at artificial burrows.

Table 8. Breeding success at all BUOW burrows located in the Otay Mesa area during the 2013 breeding season.

Burrow	Site	Breeding?	Successful[1]	# Fledged[2]	Notes	Previously Banded Birds[3]
1. **Gate 1**[4]	Lonestar	Y	N	0		M: C over R, F: (Red) D over 25
2. **Euc 7 Fence**	Lonestar	Y	Y	2		F: B over A
3. **LS 160** (A)[5]	Lonestar	Y	N	0		
4. **LS 166** (A)	Lonestar	Y	N	n/a		
5. **LS 176** (A)	Lonestar	Y	Y	2		F: C over C
6. **LS 201** (A)	Lonestar	Y	N	0		F: C over E
7. **LS 132** (A)	Lonestar	Y	N	0		
8. **LS 146** (A)	Lonestar	Y	N	0		
9. **JC 6** (A)	Johnson Canyon	Y	Y	4		
10. **JC 19** (A)	Johnson Canyon	Y	Y	4		
11. **Poggi**	Poggi	Y	Y	2		
12. **LORBOMA** (A)	LORBOMA	Y	Y	2		
13. **Heritage & Datsun**	Brown Field	Y	N	0		
14. Cul-du-sac	Brown Field	Y	Y	2		
15. Sikorsky Hydrant	Brown Field	Y	Y	3		
16. Pipes Driveway	Brown Field	Y	Y	1		
17. **Gravel Lot**	Brown Field	Y	Y	4		
18. **Power Pole**	Brown Field	Y	Y	2		
19. Tripad North	Brown Field	Y	Y	2		F: B over R
20. Tripad Fence	Brown Field	Y	Unknown	Possibly 1		
21. Brittania	Brown Field	N	n/a	n/a	Abandoned/moved	
22. India	Brown Field	Y	Y	1		
23. **Gailes**	Brown Field	Y	Y	5		
24. Old Schoolhouse	Brown Field	Y	Y	5		

25. **La Media Stop Sign**	Brown Field	Unknown	n/a	n/a	Likely failed during incubation	F: B over E
26. **Berm abeam Napa**	Brown Field	Y	N	0		
27. Tire abeam Tower	Brown Field	Unknown	n/a	n/a		
28. Santa Luna	near Poggi	N	n/a	n/a	Abandoned/moved	
29. SR-125 Exit		Y	Y	1		
30. Border Pacific	Private	Unknown	n/a	n/a		
31. Airway Road	Private	Unknown	n/a	n/a	Burrow destroyed—field plowed	
32. All-right Storage	Private	Unknown	n/a	n/a		
33. San Ysidro HS		Unknown	n/a	n/a	only 1 bird, wintering?	
34. Innovative Cold Storage	Private	Unknown	n/a	n/a	only 1 bird, wintering?	
35. Sanyo	Private	Unknown	n/a	n/a	dead BUOW found on 6/19/13 (old; feathers, some bones)	
36. Satellite Array West	near Brown Field	Y	Y	1		
37. Satellite Array East	near Brown Field	Y	Y	2		
38. Auto World	Brown Field	Y	Y	2	family unbanded, found later in season (not natal burrow)	

[1]Nests were considered successful 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.
[4]Bold indicates burrows with cameras.
[5](A) indicates artificial burrows.

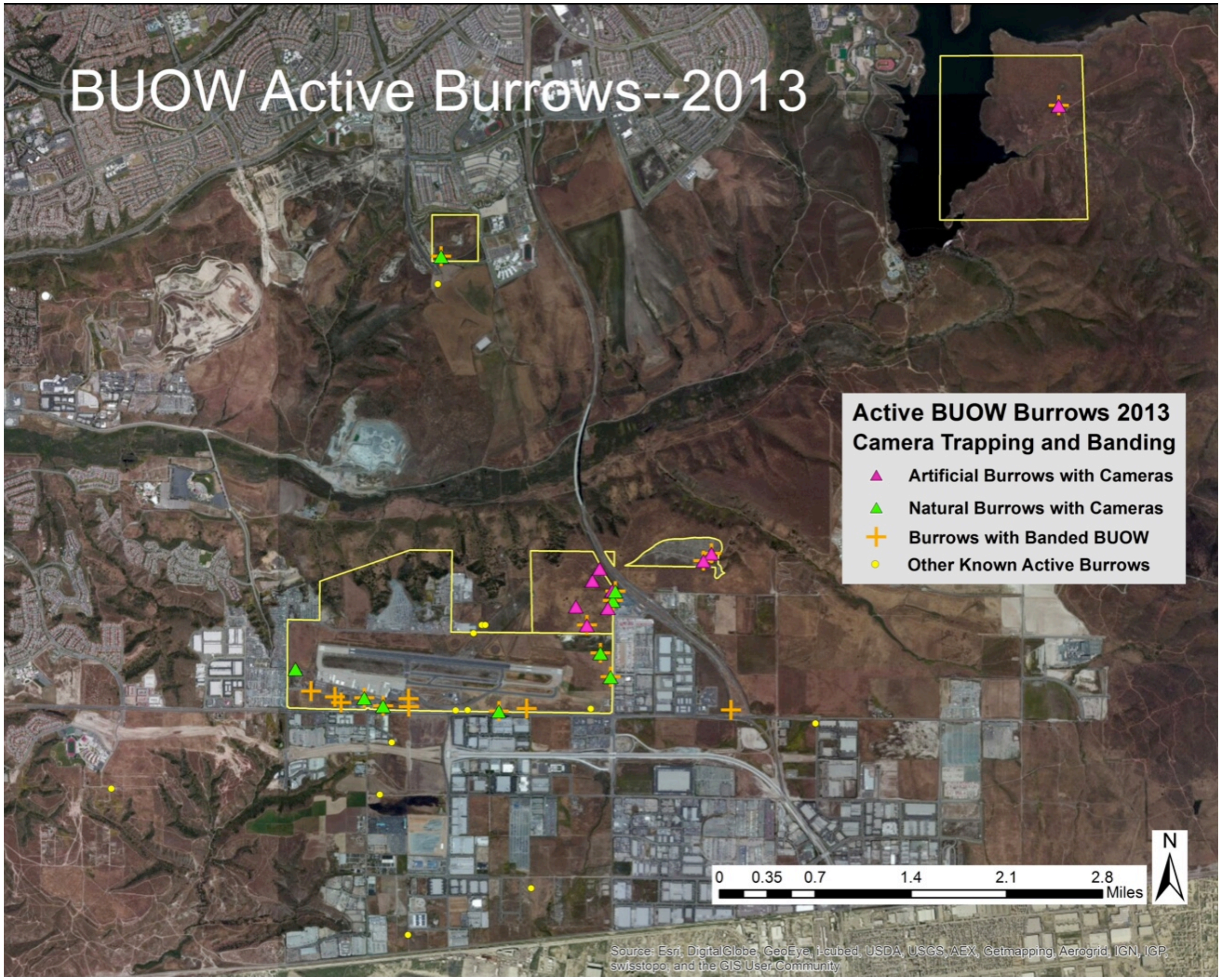

Figure 19. Map of all active BUOW burrows found in 2013.

Figure 20. Map of 2013 active BUOW burrows at Lonestar (numbers in Table 9).

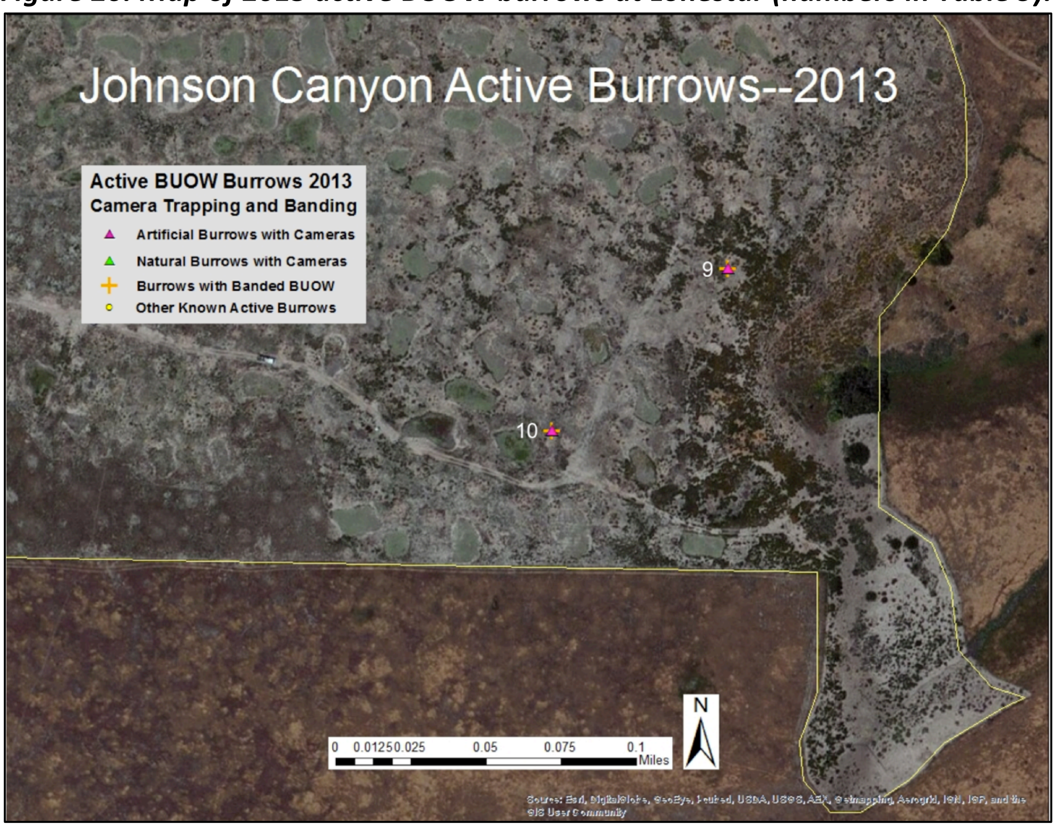

Figure 21. Map of 2013 active BUOW burrows at Johnson Canyon (numbers in Table 9).

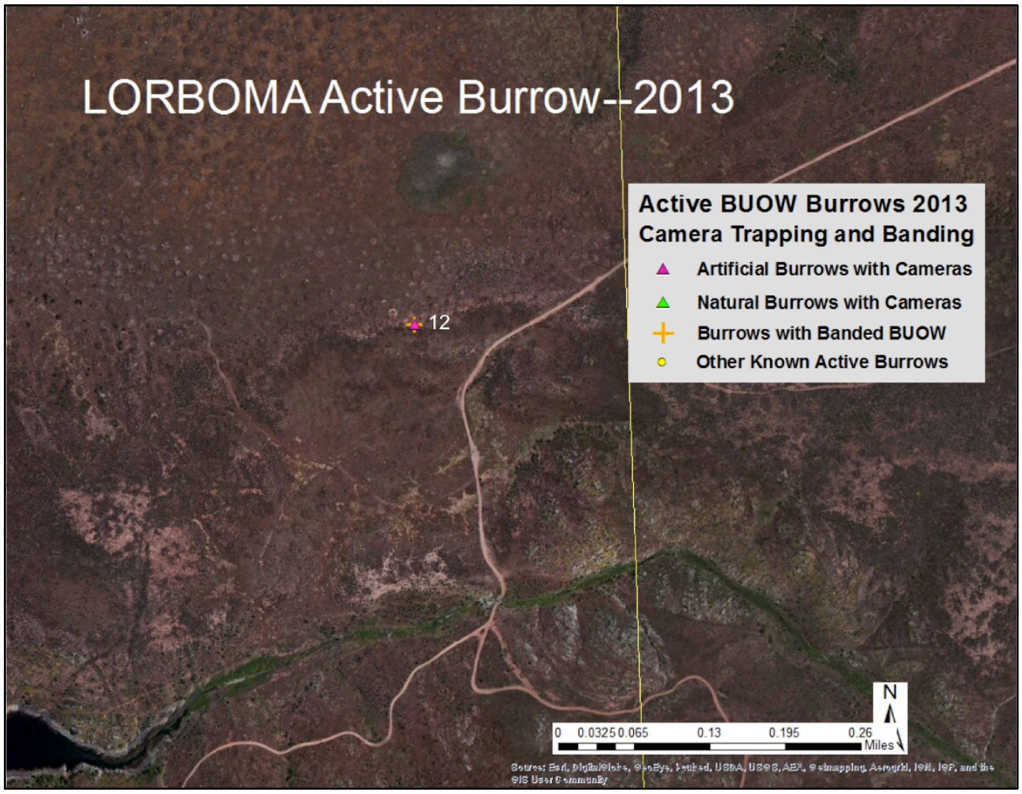

Figure 22. Map of 2013 active BUOW burrows at LORBOMA (numbers in Table 9).

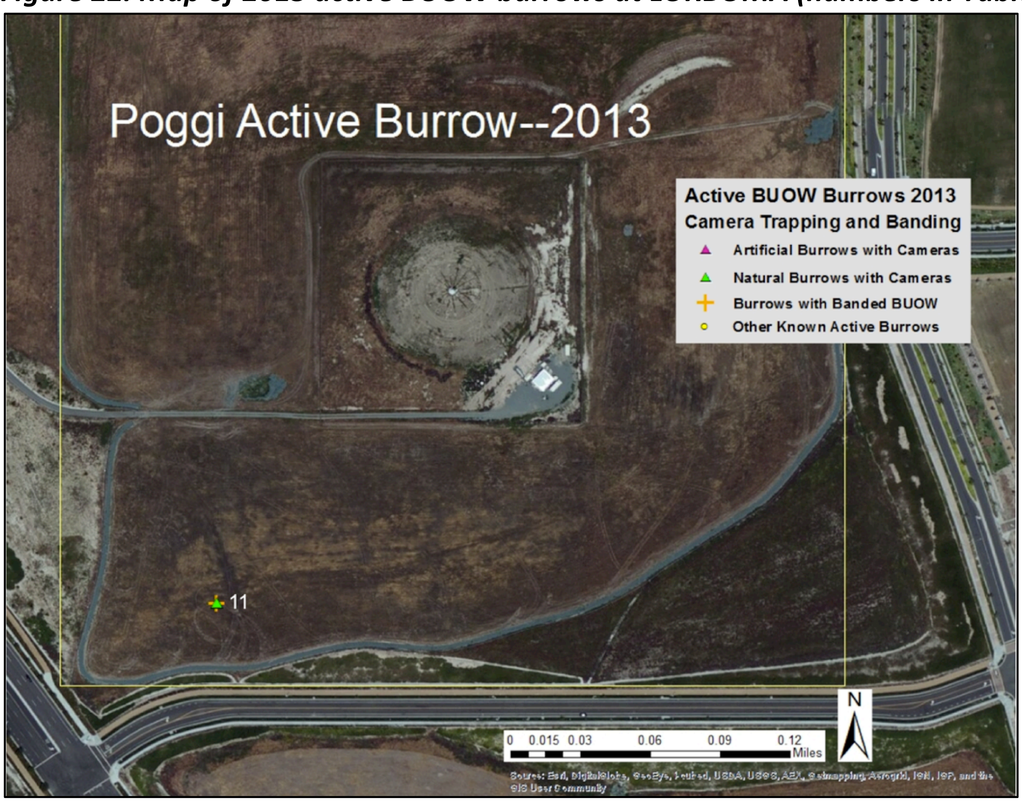

Figure 23. Map of 2013 active BUOW burrows at LORBOMA (numbers in Table 9).

Figure 24. Map of 2013 active BUOW burrows at Brown Field (numbers in Table 9

Table 9. Summary of BUOW banded in 2013. Asterisk indicates a bird banded in a previous year that was recaptured in 2013.

		Family	Adults: Female	Adults: Male	Juveniles	Total per Family
Natural	1	BF: Cul-du-sac	1		3	4
	2	BF: Gailes			6	6
	3	BF: Gravel Lot	1		4	5
	4	BF: Berm abeam Napa			2	2
	5	BF: Pipes Driveway	1	1	1	3
	6	BF: Power Pole	1		2	3
	7	BF: Old Schoolhouse			5	5
	8	BF: Sikorsky Hydrant			3	3
	9	BF: Tripad Fence			4	4
	10	BF: Tripad North			2	2
	11	PO: Poggi	1	1	4	6
	12	LS: Euc 7 Fence	1*		3	4
	13	OM: SR-125 Exit			1	1
Artificial	14	JC: JC 19			2	2
	15	JC: JC 6			4	4
	16	LO: LORBOMA			3	3
	17	LS: LS 176	1*	1	2	4
		Totals	7	3	51	61

Camera trapping

We monitored 18 burrows (9 natural, 9 artificial) throughout the entire breeding season using camera traps. Camera traps ran from 10 April to 9 September for a total of 2454 camera days and collected approximately 1.5 million photos. Volunteers were recruited and trained, and completed the first tier of photo processing. Quality control was then completed by more experienced staff. Most changes in prey identification during quality control were related to whether a prey item was categorized as "unknown invertebrate prey" or "unknown prey" (meaning volunteers were unable to assign the prey item to a taxon group). Due to the small size of most invertebrate prey, it is not surprising that "invertebrate" and "unknown" categories were significantly correlated ($r(17) = -0.598$, $p = 0.009$).

Another limitation in prey identification was the type of camera used. Night photos from the Bushnell cameras were often washed out and made prey identification difficult which would also lead to an inflation in the number of prey items tagged as "unknown" (volunteers were able to detect a prey item, but image quality precluded finer scale identification). We may also have missed prey deliveries that occurred at night at the burrows with Bushnell cameras. We also found that burrow configuration, which affected how the cameras were set up, might lead to some differences in volunteers' ability to detect or identify prey. We had a large number of occurrences in which a possible prey delivery was seen, but because of the birds' angle to the camera, it was difficult or impossible to determine 1) if a prey delivery had actually taken place (these photos were not tagged) or 2) what the prey item was ("unknown prey"). These possible prey deliveries were not included in the total number of prey deliveries at each burrow, but ranged from 0 to 422, potentially increasing the total number of prey deliveries by 0-108%. Setting the camera up at an angle to the burrow entrance may facilitate the ability to detect whether a prey delivery actually occurred and what the prey item was. In some cases, the prey item was too small to be seen (e.g. earwigs), but we could clearly see a beak-to-beak exchange. These photos were tagged as "prey unseen" and were included in the "unknown prey" category.

Prey

We recorded prey deliveries categorized by type at the 18 monitored burrows (Table 11). At most of the burrows, invertebrates made up the highest proportion of prey deliveries. At some of the burrows, the proportion of unknown prey deliveries was over 25%, although many of these unknowns are likely invertebrate prey.

Prey deliveries occurred at all hours of the day, but there was a distinct pattern to the timing of prey deliveries (Figure 25). Most deliveries occurred between 5 PM and 5 AM usually with a peak between 8 PM and midnight. The most distinct patterns were seen at burrows with juveniles.

Productivity, in terms of numbers fledged, was positively related to the number of prey deliveries per camera trap day ($R^2 = 0.45$, $F_{(1,16)} = 12.96$, $p = 0.002$). This relationship between prey deliveries and numbers fledged was even stronger for the 21 days post emergence period ($R^2 = 0.57$, $F_{(1,13)} = 16.93$, $p = 0.001$). A similar relationship was found for maximum number of chicks ($R^2 = 0.58$, $F_{(1,13)} = 18.30$, $p = 0.001$). However, we did not find a significant relationship between productivity and the proportion of mammal or invertebrate prey delivered. Interestingly, productivity was negatively related to proportion of herpetofauna prey ($R^2 = 0.51$, $F_{(1,16)} = 16.78$, $p = 0.001$). This is probably a reflection of the habitat and prey availability around the burrow since the number of prey deliveries per camera trap day was negatively correlated with the percent of herpetofauna prey ($r(17) = -0.537$, $p = 0.02$). The relationship between prey types and productivity will be further examined during the 2014 breeding season.

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Table 10. Summary of all prey deliveries seen in camera trap photos during the entire 2013 breeding season.

Site	Burrow	Camera Type	Prey Deliveries/ Camera Trap Days	Birds* (%)	Inverts (%)	Herps (%)	Mammals (%)	Unknown (%)
Lonestar	Gate 1	Reconyx	3.00	0	85	2	8	5
	Euc 7 Fence	Reconyx	3.61	0	71	1	3	25
	LS 160 (A)	Bushnell	1.61	0	76	3	9	11
	LS 166 (A)	Bushnell	2.59	3	84	3	8	1
	LS 176 (A)[1]	Bushnell	1.40	0	64	2	5	30
	LS 201 (A)	Bushnell	3.64	<1	94	0	5	<1
	LS 132 (A)	Bushnell	0.66	0	86	5	5	5
	LS 146 (A)	Bushnell	1.55	11	73	3	12	1
Johnson Canyon	JC 6 (A)	Both	5.29	<1	88	0	2	9
	JC 19 (A)	Reconyx	8.74	<1	81	<1	5	13
Poggi	Poggi[1]	Both	6.08	<1	66	2	16	16
LORBOMA	LORBOMA (A)[1]	Both	3.01	0	70	1	18	10
Brown Field	Heritage and Datsun	Reconyx	3.08	0	60	1	32	6
	Gravel Lot[2]	Reconyx	9.11	0	66	0	4	29
	Power Pole[1]	Reconyx	10.12	<1	70	1	1	28
	Gailes[1]	Both	10.88	<1	73	<1	12	15
	La Media Stop Sign[2]	Reconyx	2.93	2	71	3	12	14
	Berm abeam Napa	Reconyx	8.78	<1	73	3	7	17

*Does not include infanticide of BUOW fed to young.

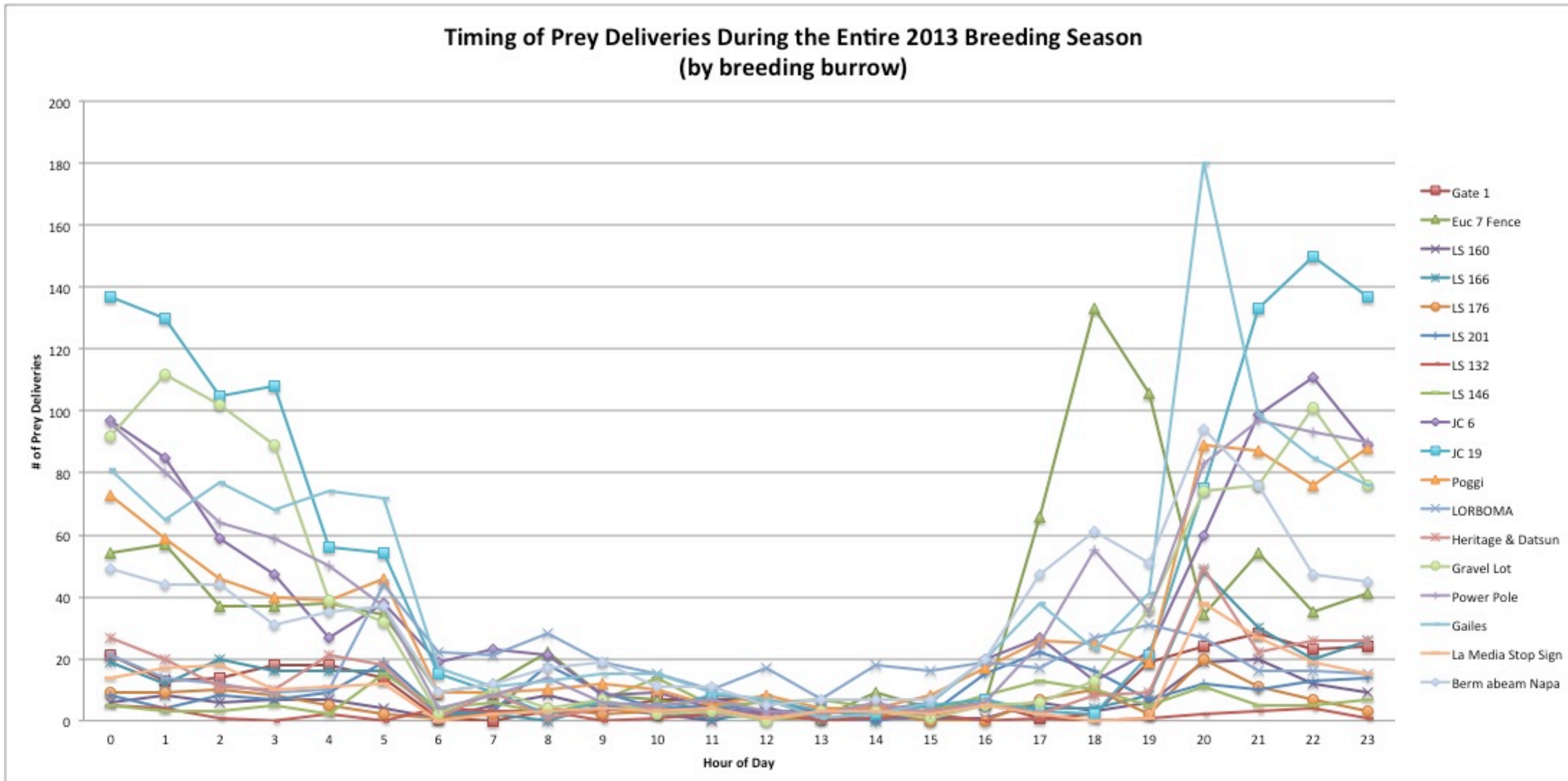

Figure 25. Graph of timing of prey deliveries seen in camera trap photos during the entire 2013 breeding season.

Juvenile mortality

We documented 19 confirmed or likely juvenile mortality events during the 2013 breeding season, which represents 24% of the maximum number of chicks recorded (Table 12). Of these events, 6 were depredations by non-BUOW predators and 12 were depredations by BUOW. Infanticide occurred at 5 of the 18 burrows and was usually done by the adult female, although in one case, a nestling appeared to have killed another nestling. No predation events were recorded at LS 160, LS 166, LS 176, LS 201, LS 132, LS 146, JC 19, Gravel Lot, La Media Stop Sign, or Berm abeam Napa. We recorded one additional mortality event at Berm abeam Napa in which a chick appears to succumb to starvation.

Table 11. All juvenile mortality events recorded in 2013.

Site	Burrow	Mortality event	Date	Additional Info
Lonestar	Gate 1	Infanticide	7-May	
		Infanticide	8-May	
		Cooper's hawk	8-May	
	Euc 7 Fence	Infanticide	7-May	
		Infanticide	8-May	
		Infanticide	8-May	
		Likely Infanticide	11-May	Infanticide not caught on camera, but juvenile BUOW seen eating fresh BUOW carcass; max count data corroborate
Johnson Canyon	JC 6 (A)	Likely Infanticide	6-May	Observed small nestling outside of burrow; was placed back in burrow
Poggi	Poggi	Infanticide	15-Jun	
		Possible Siblicide	19-Jun	Banded juvenile (804-19746) appears to be attacked by unbanded sibling and isn't seen again
LORBOMA	LORBOMA (A)	Infanticide	28-May	
		Infanticide	29-May	
Brown Field	Heritage and Datsun	long-tailed weasel	25-May	weasel likely killed both juveniles and potentially adult female based on max count
	Power Pole	California king snake	5-Jun	
		common raven	5-Jun	Predation unconfirmed but likely, nestling at burrow entrance doesn't retreat; max count data corroborate
		common raven	6-Jun	
	Gailes	Infanticide	10-Jun	Banded juvenile (15 over X) is killed by adult BUOW
		Cooper's hawk	11-Jul	Banded juvenile, band unreadable in photo
	Berm abeam Napa	Likely Starvation	28-May	Juvenile appears to collapse and does not move again; max count data corroborate

We suspect the high number of infanticide events was due to food limitation. At the Gate 1 burrow, the adult male (green band "C over R") was consistently seen on the camera trap photos until 3 May when he disappeared (and was not seen subsequently on camera or through direct observation). Late on 7 May, the adult female (banded red "D over 25") killed one nestling, then killed a second one early on 8 May. If her mate left or died, she would have had difficulties feeding all 5 nestlings that were present at the time. By killing her offspring, she was able to reduce the amount of food that was needed to feed her brood, and to feed her remaining offspring with the ones she had killed.

In another example, the adult female (green band "B over A") at the Euc 7 Fence burrow was seen killing three of her offspring and likely killed a forth (half of her brood). At least three of the chicks that were killed exhibited some maiming or deformities before they were killed. However, it is unclear whether they were hatched with deformities or whether the deformities were caused by attacks from other family members (e.g., on a few occasions healthy chicks were seen pecking at the deformed chicks).

Reproductive success

There was a wide range of estimated dates of first egg-laying (7 March—8 May,) and hatching (6 April—3 June; Table 13). The overall average total number of chicks per burrow was 4.4 (SE = 0.65, n = 18) and the overall average total number of fledglings per burrow was 1.5 (SE = 0.41, n = 18). The average total number of chicks at artificial burrows was 3.2 (SE = 0.86, n = 9) and at natural burrows was 5.6 (SE = 0.84, n = 9). The average total number of fledglings was 1.3 (SE = 0.58, n = 9) at artificial burrows and 1.7 (SE = 0.62, n = 9) at natural burrows.

Table 12. Nesting stage dates and productivity at burrows monitored with camera traps.

Burrow	Cam Dates	Complete clutch and date (if peeped)	Estimated First Egg Date[1]	Estimated Hatch Date[2]	First Chick Emergence Date[3]	# Chicks at 1st Emergence	Max # chicks (Date)	Estimated Fledging Date	# Juveniles Fledged
Gate 1	Apr 23-Jul 18	n/a	Mar 20	Apr 19	May 3	1	5 (May 7)	Jun 3	0
Euc 7 fence	Apr 23-Aug 9	n/a	Mar 18	Apr 17	May 1	2	8 (May 4*)	Jun 1	2
LS 160 (A)	May 6-Aug 1	6 (May 6)	Apr 13	May 13	May 27	2	2 (May 27 & 28)	Jun 27	0
LS 166 (A)	Apr 23-Aug 1	7 (May 6)	Apr 25	none hatched	none	none	0 (no eggs hatched)	n/a	n/a
LS 176 (A)	May 6-Aug 1	7 (May 14)	Apr 19	May 19	Jun 2	3	3 (June 2-9)	Jul 3	2
LS 201 (A)	May 6-Jul 3	5 (May 14)	May 8	Jun 3	none	none	1 (June 4**)	Jul 18	0
LS 132 (A)	May 7-Jul 11	7 (May 14)	Apr 13	May 13	May 27	3	3 (May 27)	Jun 27	0
LS 146 (A)	Apr 23-Aug 1	7 (May 3)	Apr 23	May 23	Jun 6	1	1 (June 6)	Jul 7	0
JC 6 (A)	Apr 23-Aug 16	n/a	Mar 21	Apr 20	May 4	1	5 (May 8-21)	Jun 4	4
JC 19 (A)	Apr 16-Aug 16	n/a	Mar 7	Apr 6	Apr 20	1	7 (May 6, 7, 9, 11)	May 21	4
Poggi	Apr 25-Aug 9	n/a	Apr 23	May 23	Jun 6	1	6 (June 9)	Jul 7	2
LORBOMA (A)	Apr 25-Sept 9	7 (April 25)	Apr 3	May 3	May 17	2	7 (May 21-22)	Jun 17	2
Heritage and Datsun	May 2-Aug 16	n/a	Apr 1	May 1	May 15	2	4 (May 17-23)	Jun 15	0
Gravel Lot	May 2-Aug 1	n/a	Mar 25	Apr 24	May 8	1	7 (May 16 & 18)	Jun 8	4
Power Pole	May 3-Aug 1	n/a	Mar 20	Apr 19	May 3	5†	7 (May 4-5)	Jun 3	2
Gailes	May 3-Aug 1	n/a	Apr 3	May 3	May 17	2	8 (May 22)	Jun 17	5
La Media Stop Sign	May 2-July 9	n/a	no data	no data	none	none	0	n/a	n/a
Berm Abeam Napa	Apr 10-Jun 25	n/a	Apr 10	May 10	May 24	2	5 (May 26-28)	Jun 24	0

[1]First egg date was determined by back-dating 30 days from estimated hatch date. For LS 166 and LS 201, dates were estimated from peeper data.
[2]Hatch date was determined by back-dating 14 days from first chick emergence date. For LS 166 and LS 201, dates were estimated from peeper data.
[3]First date chicks were seen on camera trap.
*Max of 6 chicks seen on camera on May 4, however there was a max of 5 chicks seen on May 11 (after 3 infanticides).
**1 chick seen with peeper, 0 seen on camera trap.
†First day camera was up.

Artificial vs. natural burrows

The difference in the average total number of chicks at natural and artificial burrows was marginally significant at the $\alpha=0.05$ level ($t(16) = 1.94$, $p = 0.07$), with an average of 5.6 chicks at natural burrows compared to 3.2 at artificial. However, we did not find a statistically significant difference in the total number of fledglings between natural and artificial burrows ($t(16) = 0.39$, $p = 0.70$).

The number of prey deliveries per camera trap day was significantly higher at natural burrows compared to artificial burrows ($U = 111$, $p = 0.03$, $r = 0.52$). We did not find significant differences in prey type by burrow type, except for a higher percentage of invertebrate prey at artificial burrows ($U = 62$, $p = 0.04$, $r = 0.48$). This probably is due to differences in habitat and prey availability at the natural and artificial burrow sites.

Because most of the artificial burrow sites were located in a new restoration area (i.e., Lonestar), these sites tended to have more bare ground ($t(16) = -3.52$, $p = 0.003$) and less percent vegetative cover ($t(16) = 2.41$, $p = 0.03$) and exotic, annual vegetation ($t(16) = 2.73$, $p = 0.01$), than the natural burrow sites, located mainly at Brown Field. These habitat characteristics also appear to be suitable for ground squirrels. However, the soil at these artificial burrow sites contained higher percent clay and silt and lower percent sand ($t(16) = 2.76$, $p = 0.01$), which may create difficulties for ground squirrel establishment without some other modifications, such as berms, mima mounds, or cover piles. The general lack of vegetation may also have temporarily reduced prey availability for BUOW in the area, which may increase as the native vegetation becomes established in the Lonestar restoration area. Examining BUOW foraging areas will help further elucidate the relationship between BUOW productivity, habitat, and prey type deliveries. Further analyses are planned as we continue to collect data in 2014.

From this preliminary data, the artificial burrows appeared to have fewer chicks, but productivity in terms of number of fledglings was similar to natural burrows. Although there are some differences between Lonestar and the rest of the sites, these are probably temporary because of the newness of the Lonestar restoration. We will be able to address this in more detail in the 2014 breeding season using iButton dataloggers to examine burrow microclimate and GPS dataloggers to examine foraging areas.

Over-winter BUOW presence at Rancho Jamul Ecological Reserve

During the 2013-2014 winter, ICR staff focused on monitoring and removing radio collars from squirrels at the JB and JC plots. They did not observe BUOW using the JC and JB translocation plots during this winter period. However, previous winter sightings of BUOW occurred at the JE and JS plots which ICR staff did not visit during the winter period.

Three rehabbed BUOW from Project Wildlife were banded by ICR staff and released (using a hack cage/soft release method) by CDFW staff at the Rancho Jamul BUOW Management Area. All three owls seemed to leave the area immediately and were not subsequently observed at Rancho Jamul.

Other wildlife at/near burrows

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

- American crow
- American kestrel
- brewer's blackbird
- cactus wren
- common raven
- Cooper's hawk
- greater road runner
- horned lark
- loggerhead shrike
- mourning dove
- northern harrier
- northern mockingbird
- Say's phoebe
- red-tailed hawk
- black-tailed jackrabbit
- California ground squirrel
- coyote
- desert cottontail
- domestic dog
- kangaroo rat spp.
- long-tailed weasel
- striped skunk
- various mouse and vole spp.
- Virginia opossum
- California king snake
- coastal patchnose snake
- southern Pacific rattlesnake
- western fence lizard

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Appendix 1. California Ground Squirrel Dispersal Monitoring Protocol

Protocol for Monitoring Natural Dispersal of California Ground Squirrels into the Burrowing Owl Habitat Management Area (BOHMA) at the Rancho Jamul Ecological Reserve

Purpose

The goal of this effort is to encourage the natural dispersal of California ground squirrels from an existing colony at the Rancho Jamul Ecological Reserve into an adjacent Habitat Management Area designated for Burrowing Owls. In this protocol, we describe the methods to conduct burrow surveys to monitor natural squirrel dispersal in response to vegetation treatment (by grazing or herbicide) or vegetation treatment in conjunction with systematic placement of woodpiles into the BOHMA (see below). In December 2013 or January 2014, the site will be uniformly grazed or treated with herbicide, which will allow us to address two questions:

1. Does habitat restoration through grazing or herbicide treatment facilitate natural dispersal?
2. Which age class(es) is (are) dispersing?

CDFW will be installing 3 woodpiles in early December of 2013. Should resources be available to add 17 more woodpiles, this would provide the opportunity to answer a third question:

3. Do woodpiles accelerate natural dispersal?

We have designed alternative survey methods based on whether or not the effect of woodpiles will be addressed. Option 1 below will answer questions 1 and 2 above. Option 2 will address all 3 questions.

Question 1: Does vegetation management (grazing or herbicide) affect natural dispersal of California Ground Squirrels?

We assume vegetation treatment will be uniform across the entire BOHMA. The first surveys should take place immediately after treatment to record a pre-dispersal baseline while burrows are easily detectable.

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). 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 wood piles 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.

We recommend placing woodpiles between 70 and 200 meters apart (Dobson and Davis 1986, Boellstorff and Owings 1995). The rationale for keeping them closer to 70m is this distance is within a squirrel's average home range size. Placing woodpiles at the edge of a resident squirrel's home range would provide easy access to existing burrows as well as the woodpile, and thus may provide protection from predators while encouraging the use of habitat at the edge of their home range. This distance could be increased to as much as 250m to encourage more long distance dispersal, however, as the distance between existing burrows and wood pile cover is increased, the risk of predation is increased due to increased exposure.
To answer this question systematically, placement of multiple woodpiles in each 100m section of habitat is required. If this is done, we can address all three questions with one simple methodology.

Methods

Materials

- GPS unit
- Compass
- 100m tape measure
- Clipboard with datasheets
- Marking whiskers
- Aluminum marking tags

Burrow transects

All transects will have the same compass bearing. The observer(s) will walk each 25m line and record, mark and take a GPS location for all burrows that fall within five meters of each side of the transect line (for an area of $250m^2$). Burrows smaller than 7cm in diameter will be excluded. The following criteria will be recorded for each burrow:

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

We recommend conducting burrow surveys two times during the year in March and August/September for three to five years to capture any dispersal movements both within year and over the long term. Should new burrows be documented during the spring surveys, we can assume adult ground squirrels are dispersing because there are no juveniles this time of year. However, if we document new burrows during the August/September survey, we would assume that juveniles are digging these burrows, as this is the period of year when juvenile ground squirrels disperse.

Placement of transects on the landscape

Option 1 – Effect of vegetation treatment and age

The BOHMA is roughly 800m by 350m* with the CAGS source population in the southwest end of the area. We propose running a minimum of 40 25m line transects, equally distributed across four increasing distances from the source populations; 100m, 300m, 500m and 700m (10 transects per distance, see figure 1) with a distance of 30m between transect centers.

*Because the BOHMA is not an exact rectangle, this design may be geographically constrained requiring either GIS to select transect locations at each distance or placement of fewer than 10 transects/distance.

Placement of transects on the landscape

Option 2 – Effects of vegetation treatment, age and woodpile placement on dispersal

Based on our experience with woodpile use by translocated squirrels, we suggest each pile be a minimum 1m tall and 2m diameter. We also recommend the individual pieces of wood have a minimum 10cm (4") diameter.

Again, we propose surveying a minimum of 40 pairs of 25m line transects, equally distributed across four increasing distances from the source populations; 100m, 300m, 500m and 700m (10 transects/distance, see Figure 2) with a distance of 30m between transects. However, in this design we propose 2 treatments: (1). Woodpile: transects in this treatment will have a wood pile centered at the 12.5m point (n=5 per distance category); (2). Control: control transects will not contain a woodpile (n=5/distance). Woodpile and Control treatments will be alternated within each distance (see Figure 2). The control transect locations will be identified with standard marking whiskers. Wood piles and control transects will be given a unique ID and the location recorded with GPS.

Figure 1. The BOHMA is roughly estimated at 800m by 350m. Each grid square is $10m^2$. Yellow bars represent 25m x 10m line transects. The red squares represent the three woodpiles proposed for December 2013, although exact placement is yet to be determined.

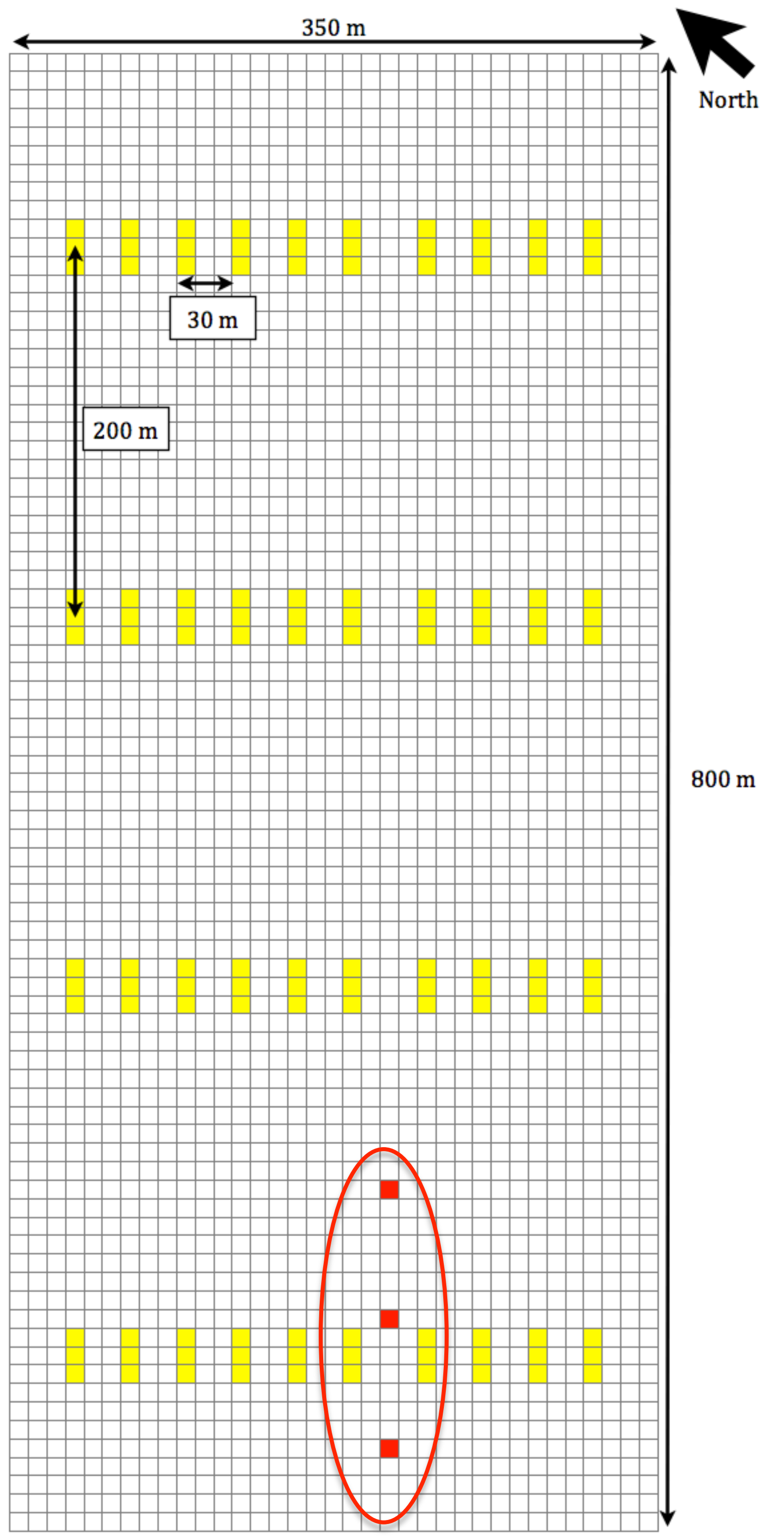
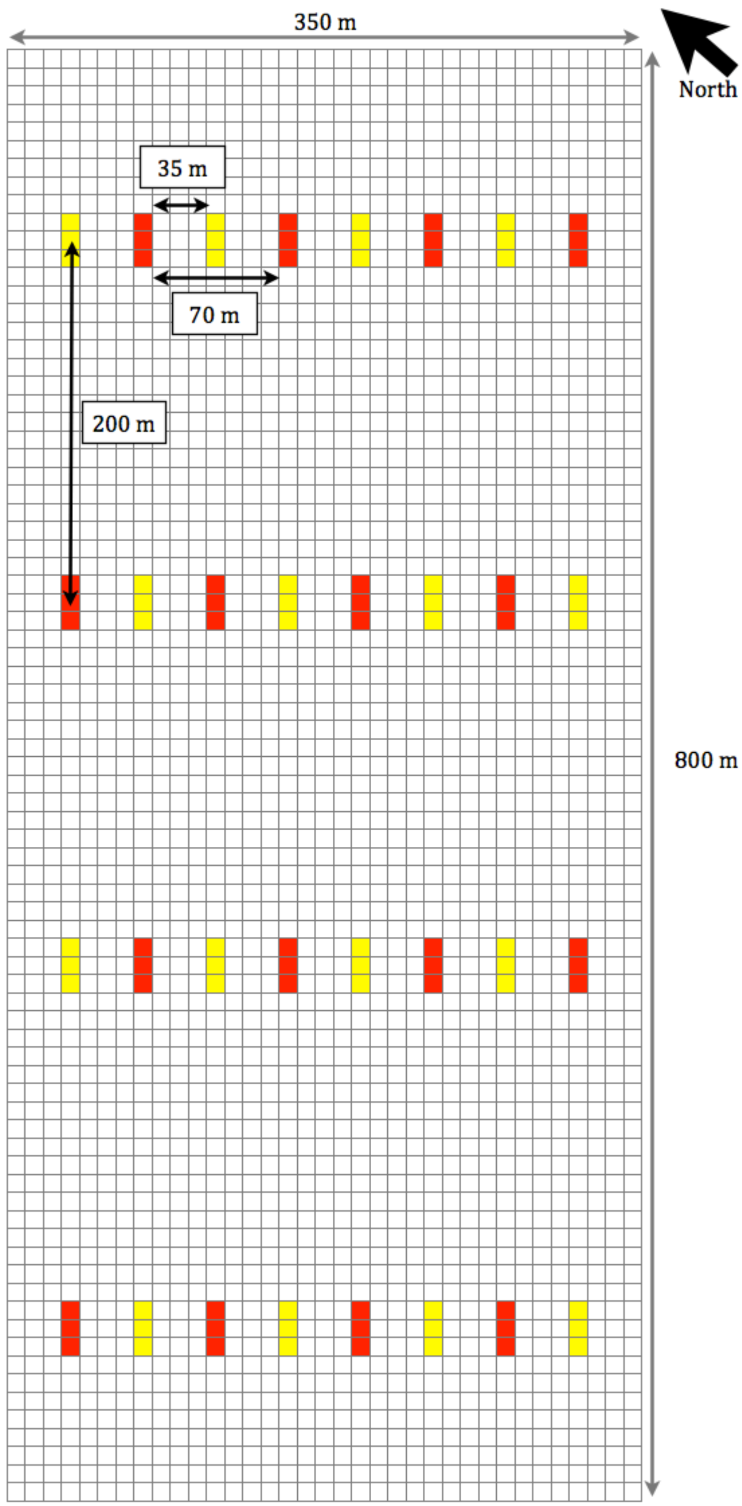


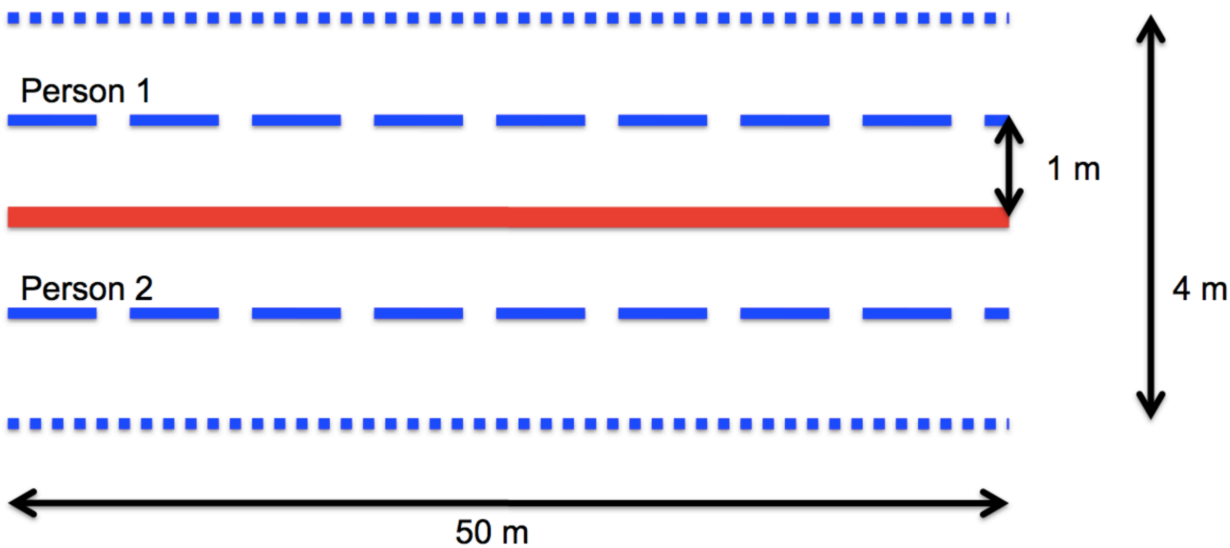
Figure 2. The same simplified diagram of the BOHMA as in Figure 1, but with 2 treatments: woodpile and control placed uniformly across the BOHMA. Each colored bar represents a 25m x 10m line transect, red for the woodpile treatment and yellow for the control transect.



Appendix 2. Habitat Suitability Model Protocol

1.) Transect map generated through ArcGIS within sampling polygon.
    a. 50 m in length.
    b. Minimum 25 m buffer around each transect.
    c. 15 transects within a site, if site size allows.
2.) Two people walk each transect.
    a. One observer walks on each side of the transect, so that they are each 1 m away from the transect, and 2 m away from each other (Figure 1).
    b. Observers scan 1 m to the left and 1 m to the right.
    c. Total area covered = 200 m^2

Figure 1. Transect Protocol (not drawn to scale)



3.) If a ground squirrel burrow is detected (Presence Transect), then a 10x10 meter plot is established with the burrow at plot center (see Figure 2 for example).
    a. Ten parallel transects, 10 m in length and spaced 1 m apart will be laid on the ground (pointed North-South) using meter tapes.
4.) If a ground squirrel burrow is NOT detected after completion of the 50 m transect (Absence Transect), then a 10x10 meter plot is established with the plot center 5 m back along the transect (see Figure 3 for example).
    a. Ten parallel transects, 10 m in length and spaced 1 m apart will be laid on the ground (pointed North-South) using meter tapes.

Figure 2. 10x10m Plot Set-Up for Presence Transect (not drawn to scale)

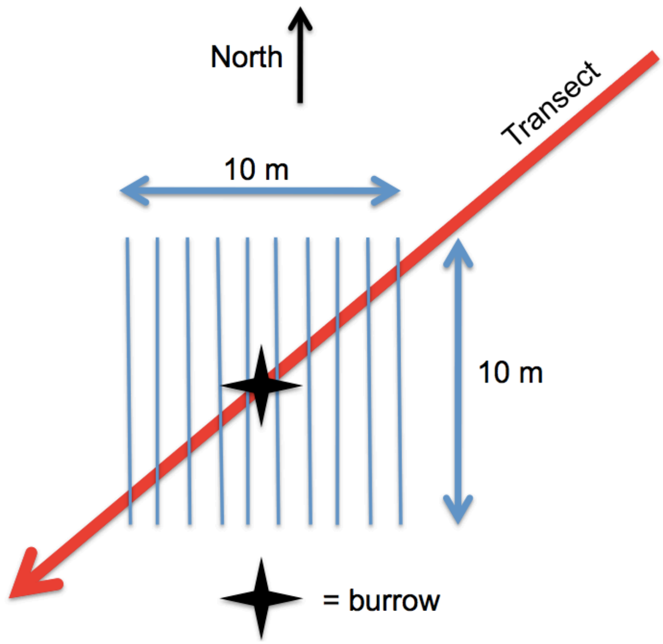
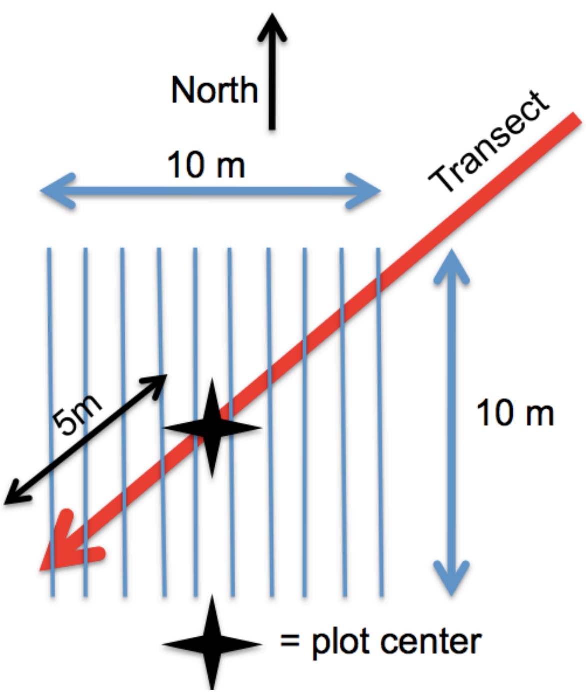


Figure 3. 10x10m Plot Set-Up for Absence Transect (not drawn to scale)



5.) Point-Line Intercept Data Collection

   a. Using a laser point intercept device, select the point at the 0.5 m mark at which data will be collected. Note if you are starting at the North or South end of the transect.
      1. Vegetation height, rounded to nearest 5 cm.
      2. Vegetation type for each canopy level (top canopy and up to three lower canopy levels, if necessary)
         a. Vegetation category: Grass, Forb, Shrub, Tree, Dead Cover, Litter, None
         b. Exotic/Native
         c. Annual/Perennial
         d. Soil surface: Soil, Rock, Litter, Log/Woody Debris, Burrow, Basal Intercept

6.) Plot-Center Data Collection

   a. At plot-center, collect the following data:
      i. GPS location of plot-center/burrow (decimal degrees)
      ii. Elevation (m)
      iii. % Slope and Aspect (slope direction)
         1. One person stands at the highest point within the 10 m plot and the other person stands at the lowest point. The person at the highest point looking towards the lowest point should take the slope reading.
         2. Aspect is taken by the lowest person in the direction of the highest person.
      iv. % Canopy cover
      v. Community type: Grassland, Forbland, Coastal Sage Scrub, Chapparal, Oak Woodland, Riparian, Ecotone
         1. If Ecotone, list the two dominant community types
      vi. Dominant species of Grass, Forb, Shrub
         1. If codominance occurs, list up to two species per category
      vii. Elevated Structures
         1. Type: Tree, Snag, Fence, Telephone/Electric Pole, Rocky Outcrop/Rock, Brushpile, Log, Shrub
         2. Distance (m)
            a. If over 100 m away, record as “ > 100 m”
         3. Direction
      viii. Record if burrow is active (yes/no)
      ix. Burrow Protection (if applicable)
         1. Type: Tree, Snag, Fence, Telephone/Electric Pole, Rocky Outcrop/Rock, Brushpile, Log, Shrub
         2. Species (If Tree of Shrub)
         3. Maximum height and width of protection source
      x. Site History
         1. Grazing/Burn/Rodenticide use, if known.
      xi. Predators (# and species) seen while conducting transect

xii. Additional signs of CAGS (# and distance from transect) (i.e. burrows/CAGS)

b. Take photos of the surrounding habitat from plot center facing North, South, East, West. Take a photo of the burrow if applicable.

7.) Soil Collection at Plot Center

a. Collect three soil cores, with one being at plot center and the other two 1 m distance away, equidistant from each other.

b. After soil core is taken, use a soil knife to take an additional soil sample.

8.) Soil Sample Processing (protocol from New Mexico State University, College of Agricultural, Consumer and Environmental Science)

a. Oven-dry soil samples in a soil oven

b. Take weight of entire sample

c. Using a mortar and pestle, break up soil clumps and pass through a 2 mm sieve to remove gravel and large particles. Weigh the gravel/material that did not pass through the sieve to obtain percent-gravel.

d. Weigh 40-50 g of the sieved, fine texture soil into a stirring cup.

e. Fill the cup half way with distilled waiter and ad 100ml of a 5% solution of dispersing agent (Sodium hexametaphosphate).

i. To make dispersing agent solution: Dissolve 40g of sodium hexametaphosphate into 1L of distilled water. Allow to stand 4 hours before using. Solution should be used within 1 month.

f. Using a mixer (in our case a milkshake making machine), stir the solution on low for at least 5 min.

g. After 5 min, transfer the stirred mixture to a 1 L graduated cylinder and fill with distilled water to the 1000 ml mark.

h. Prepare a 1L graduated cylinder which contains 100ml of dispersing agent and 900ml of distilled water. This will be referred to as the BLANK.

i. Using a plunger, carefully mix the soil solution thoroughly by pulling the plunger upwards in short jerks. When the suspension is well mixed, removed the plunger and record start time to the second.

j. Slowing insert the hydrometer into the suspension and read at the end of 40 seconds. Repeat this procedure two more times to obtain an average 40 second reading. Rinse the hydrometer with distilled water between uses.

k. After the third 40 second reading, carefully insert a digital thermometer into the solution and record the temperature. After the temperature reading, do not disturb the cylinder. It must remain undisturbed for reading at the 2 hour and 3 hour marks.

l. While the cylinder containing the soil suspension is settling, record the hydrometer and temperature readings of the BLANK solution.

m. Two hours after the initial 40 second reading of the suspension, record the hydrometer and temperature readings again. Only one hydrometer reading need be taken. Also take readings for the BLANK solution.

n. Three hours after the initial 40 second reading of the suspension, record the hydrometer and temperature readings again. Only one hydrometer reading need be taken. Also take readings for the BLANK solution.

o. Processing is competed for the sample, and may be disposed of.

Appendix 3. 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 BUOW present at each burrow per day.

We use two different types of camera traps: Reconyx Hyperfire and Bushnell TrophyCam HD. There are some differences in the photos that are taken by each type of camera. The Bushnell photos are prone to being over exposed at night. Photos are taken in series of 3 (the series are labeled in the Reconyx photos, but not the Bushnells).

<u>Independent Events</u>

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

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

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

<u>The Binder</u>

There is a large binder called "BUOW 2013 Cam Trap Processing" which contains the datasheets needed for photo processing. It is divided by burrow and within each burrow section further divided by camera. Each camera has three types of datasheet associated with it (see below).

<u>Datasheets</u>

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

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

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

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

<u>Using Adobe Bridge</u>
We will use Adobe Bridge to record 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.

<u>Navigating to folders</u>
All folders are stored on the "Aae-storage" drive under "buow". The pathway is Computer→buow(Aae-storage P:)→Cam Trap Originals→Cam Traps—BUOW→2013→[Site]→[Burrow]→[Camera]

<u>Keyword list</u>

- Day/Night: The time of day; should be indicated for each photo that is tagged.
    - Day –Mark color photos as day.
    - Night –Mark black & white photos as night.
- 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 BUOW is killed by another animal (including another BUOW).
    - 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 BUOW is killed by another animal (including another BUOW).
    - 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 BUOW bring to the burrow.
    - Bird
        - Bird prey –Mark if a bird is brought as prey.
        - Burrowing Owl prey –Mark if a BUOW is the prey item. Should be marked in conjunction with "Adult/Juvenile Predation event" (in most cases it will be a juvenile).
    - Invertebrates
        - unknown invertebrate prey –Mark if prey is insect/arachnid but you can not tell what it is specifically.
        - beetle/roach prey –Mark if prey is beetle- or roach-like.
        - centipede/millipede prey –Mark if prey is a centipede or millipede.
        - cricket/grasshopper prey –Mark if prey is cricket- or grasshopper-like.
        - moth/butterfly prey –Mark if prey is moth- or butterfly-like.
        - snail prey –Mark if prey is a snail.
        - spider/scorpion prey –Mark if prey is an arachnid.

- Mammal
    - CAGS prey –Mark if prey is a California ground squirrel.
    - Gopher prey –Mark if prey is a pocket gopher.
    - K-rat prey –Mark if prey is a kangaroo rat.
    - Mouse/Vole prey –Mark if prey is a mouse or vole.
    - Rabbit prey –Mark if prey is a rabbit.
    - unknown mammal prey –Mark is prey is mammal but you can not determine what it is specifically.
- 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/Amphibian (Herp)
    - Frog prey –Mark if prey is a frog.
    - Lizard prey –Mark if prey is a lizard.
    - Snake prey –Mark if prey is a snake.
    - unknown reptile prey –Mark if prey is reptile but you are unable to determine what type of reptile specifically.

- 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 BUOW, cactus wren, raptor, raven/crow, or roadrunner is present in the photo.
    - BUOW –Mark if a BUOW is the predator or if a BUOW 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.
    - rabbit –Mark if a rabbit is present in the photo.
    - raptor –Mark if a raptor other than a BUOW 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.
    - other species –Mark for species other than those in this list.

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Appendix 4. BUOW Banding Data

Table of all burrowing owls captured in 2013. All auxiliary bands were green.

Natal Burrow	Date	Age	Sex	USGS band ID (on left)	Aux band ID (on right)	DNA Sample type(s)	Original Banding Year
Euc 7 Fence	27-May-13	adult	female	1084-05301	B over A	blood, feather	2011
Euc 7 Fence	22-May-13	juvenile	unknown	804-19702	02 over X	blood, feather	2013
Euc 7 Fence	22-May-13	juvenile	unknown	804-19703	03 over X	blood, feather	2013
Euc 7 Fence	27-May-13	juvenile	unknown	804-19713	13 over X	blood, feather	2013
LS 176	26-Jun-13	adult	female	1084-05314	C over C	blood	2011
LS 176	26-Jun-13	juvenile	unknown	804-19752	52 over X	blood	2013
LS 176	26-Jun-13	adult	male	804-19751	51 over X	blood	2013
LS 176	26-Jun-13	juvenile	unknown	804-19753	53 over X	blood	2013
JC 6	23-May-13	juvenile	unknown	804-19708	08 over X	blood, feather	2013
JC 6	23-May-13	juvenile	unknown	804-19709	09 over X	blood, feather	2013
JC 6	24-May-13	juvenile	unknown	804-19710	10 over X	blood, feather	2013
JC 6	24-May-13	juvenile	unknown	804-19711	11 over X	blood, feather	2013
JC 19	2-Jul-13	juvenile	unknown	804-19754	54 over X	blood	2013
JC 19	2-Jul-13	juvenile	unknown	804-19755	55 over X	blood	2013
Poggi	18-Jun-13	adult	male	804-19744	44 over X	blood	2013
Poggi	18-Jun-13	adult	female	804-19745	45 over X	blood	2013
Poggi	18-Jun-13	juvenile	unknown	804-19746	TARSUS TOO SMALL	feather	2013
Poggi	25-Jun-13	juvenile	unknown	804-19748	48 over X	blood	2013
Poggi	25-Jun-13	juvenile	unknown	804-19749	49 over X	blood, feather	2013
Poggi	25-Jun-13	juvenile	unknown	804-19750	50 over X	blood	2013
LORBOMA	7-Jun-13	juvenile	unknown	804-19723	23 over X	blood, feather	2013
LORBOMA	7-Jun-13	juvenile	unknown	804-19724	24 over X	blood, feather	2013
LORBOMA	7-Jun-13	juvenile	unknown	804-19725	25 over X	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
Cul du sac	13-Jun-13	adult	female	804-19740	40 over X	blood, feather	2013
Cul du sac	13-Jun-13	juvenile	unknown	804-19741	41 over X	blood, feather	2013
Cul du sac	13-Jun-13	juvenile	unknown	804-19742	42 over X	blood	2013
Cul du sac	13-Jun-13	juvenile	unknown	804-19743	43 over X	blood, feather	2013
Sikorsky Hydrant	16-Jul-13	juvenile	unknown	804-19756	56 over X	blood	2013
Sikorsky Hydrant	16-Jul-13	juvenile	unknown	804-19757	57 over X	blood	2013
Sikorsky Hydrant	16-Jul-13	juvenile	unknown	804-19758	58 over X	blood	2013
Pipes Driveway	11-Jun-13	adult	female	804-19730	30 over X	blood, feather	2013
Pipes Driveway	11-Jun-13	juvenile	unknown	804-19731	31 over X	blood, feather	2013
Pipes Driveway	11-Jun-13	adult	male	804-19732	32 over X	blood, feather	2013
Gravel Lot	23-May-13	juvenile	unknown	804-19704	04 over X	blood, feather	2013
Gravel Lot	23-May-13	juvenile	unknown	804-19705	05 over X	blood, feather	2013
Gravel Lot	23-May-13 11-Jun-13 (aux)	juvenile	unknown	804-19706	06 over X	blood, feather, mouth swab	2013
Gravel Lot	23-May-13	adult	female	804-19707	07 over X	blood, feather	2013
Gravel Lot	28-May-13	juvenile	unknown	804-19722	22 over X	blood, feather	2013
Power Pole	22-May-13	juvenile	unknown	804-19799	00 over X	blood, feather	2013
Power Pole	22-May-13	adult	female	804-19701	01 over X	blood, feather	2013
Power Pole	24-May-13	juvenile	unknown	804-19712	12 over X	blood, feather	2013
Tripad North	11-Jun-13	juvenile	unknown	804-19728	28 over X	blood, feather	2013
Tripad North	11-Jun-13	juvenile	unknown	804-19729	29 over X	blood, feather	2013
Tripad Fence	12-Jun-13	juvenile	unknown	804-19735	35 over X	blood, feather	2013
Tripad Fence	12-Jun-13	juvenile	unknown	804-19736	36 over X	blood, feather	2013
Tripad Fence	12-Jun-13	juvenile	unknown	804-19737	37 over X	blood	2013
Tripad Fence	12-Jun-13	juvenile	unknown	804-19738	38 over X	blood, feather	2013
Gailes	27-May-13	juvenile	unknown	804-19714	14 over X	blood, feather	2013
Gailes	27-May-13 7-Jun-13 (aux)	juvenile	unknown	804-19715	15 over X	feather	2013

Natal Burrow	Date	Age	Sex	USGS band ID (on left)	Aux band ID (on right)	DNA Sample type(s)	Original Banding Year
Gailes	27-May-13	juvenile	unknown	804-19716	16 over X	blood, feather	2013
Gailes	12-Jun-13	juvenile	unknown	804-19733	33 over X	blood, feather	2013
Gailes	12-Jun-13	juvenile	unknown	804-19734	34 over X	blood, feather	2013
Gailes	12-Jun-13	juvenile	unknown	804-19739	39 over X	blood, feather	2013
Old Schoolhouse	27-May-13	juvenile	unknown	804-19717	17 over X	blood, feather	2013
Old Schoolhouse	27-May-13	juvenile	unknown	804-19718	18 over X	blood, feather	2013
Old Schoolhouse	27-May-13	juvenile	unknown	804-19719	19 over X	blood, feather	2013
Old Schoolhouse	28-May-13	juvenile	unknown	804-19720	20 over X	blood, feather	2013
Old Schoolhouse	28-May-13	juvenile	unknown	804-19721	21 over X	blood, feather	2013
Berm abeam Napa	7-Jun-13	juvenile	unknown	804-19726	26 over X	blood, feather	2013
Berm abeam Napa	11-Jun-13	juvenile	unknown	804-19727	27 over X	blood, feather	2013
SR-125 Exit	19-Jun-13	juvenile	unknown	804-19747	47 over X	blood, feather	2013
Rehabbed BUOW Released at Rancho Jamul Ecological Reserve:							
RJBOMA (RJ 11)	16-Dec-13	adult	Unknown	804-19759	59 over X	blood	2013
RJBOMA (RJ 11)	16-Dec-13	adult	Unknown	804-19760	60 over X	blood	2013
RJBOMA (RJ 11)	16-Dec-13	adult	Unknown	804-19761	61 over X	blood	2013