SAN DIEGO ZOO INSTITUTE FOR CONSERVATION RESEARCH.

Project Report 2012

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

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EXECUTIVE SUMMARY

We report on the second 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 burrowing owls, re-establishment of this species is a crucial component of any sustainable recovery plan for burrowing owls 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 2012, we made progress toward three objectives: (1) use of translocation as a tool to establish California ground squirrels as ecosystem engineers; (2) creation of a habitat suitability model for California ground squirrels; and (3) continued pilot work on burrowing owl population and nesting ecology.

(1) Ground squirrel translocations. Our primary objective for year two was to continue to improve habitat conditions for BUOW by re-establishing ground squirrels, which create the burrows upon which BUOW depend for nesting. To create better habitat for BUOW, we continued management actions initiated in 2011 at two protected areas considered suitable for BUOW recovery (Rancho Jamul Ecological Reserve and Sweetwater parcel of the San Diego National Wildlife Refuge) and abandoned efforts at a third site where squirrel establishment proved more difficult due to unsuitable soils (Lonestar Ridge West Mitigation parcel on Otay Mesa). We followed the same experimental design as in 2011 with modifications. To increase statistical power, we established two new experimental sites (4 plots) in Rancho Jamul, bringing the total number of paired experimental plots to 9. Each of the 4 new plots received identical vegetation enhancement treatments: (1) mow, (2) mow plus soil disturbance (auger), and (3) a control treatment. At two experimental plots, we translocated a total of 118 squirrels. We used "soft-release" methods consisting of on-site above/below-ground acclimation chambers and supplemental feeding. We monitored the success of squirrel establishment and monitored squirrel habitat impacts (ecosystem engineering)

using burrow surveys and vegetation transects describing vegetation structure and other variables.

Due to the low rate of squirrel survival and establishment from 2011 translocations, we also conducted supplemental squirrel translocations to four of the 2011 sites where squirrel populations appeared to be established but at densities likely too low to achieve the desired ecosystem engineering effects. At these same four sites, SDSU replicated the habitat enhancement activities from year 1 (mow, mow + augur, control). The four sites consisted of the three Rancho Jamul sites and the upper Sweetwater site where translocation occurred in 2011. In an attempt to improve squirrel survival and establishment, we modified the translocation strategy in 2012 by (1) increasing effort to identify and translocate familiar groups of squirrels together, (2) using squirrels only from source site Marine Corp Base Coronado, which survived better in 2011, and (3) increasing food supplementation efforts. For supplemental translocations we also modified our approach by adding cover to assist with predator avoidance. We did not test the relative effects of these different modifications.

Results indicate that mortality rates are high for translocated ground squirrels, with more than half perishing during the first month. Predation appears to be the cause of most if not all mortalities. However, squirrel overwinter survival from the 2011 translocations was low but sufficient to establish small breeding populations. At least 24 squirrels occupied the experimental plots, as documented by trapping, but the numbers may have been as high as ca. 75, as it is known that half to two-thirds of squirrels will evade these trapping efforts. These squirrels, combined with 2012 supplemental translocations, achieved remarkable ecosystem engineering effects. At the time of 2011 translocations there were no burrow entrances, increasing to 131 after 6 months and 486 after 12 months (1 month following supplemental translocation). Assuming two burrow entrances per burrow for these newly established burrows, there may well be more than 200 burrow systems established during this relatively short period, despite difficulties encountered with squirrel survival. If this effect is self-sustaining, these results indicate that squirrel translocation may be more cost-effective in the long term than construction and maintenance of artificial burrows.

When comparing results for initial translocations in 2011 vs. 2012, our results indicate that the modifications we made to the release protocols in 2012 significantly increased short-term squirrel survival, although we cannot ascertain which actions were responsible for these improvements. Thus, increased release group familiarity, longer food provisioning support, or even inter-annual variation, may have improved survival. When comparing supplemental translocations to initial translocations, we found no differential effects on short-term survival. These two experimental groups purposefully differed with regard to several factors (in an effort to improve survival over 2011 outcomes), but taken together, these variables did not appear to have robust effects on survival.

Squirrel movement data provided additional insights. Squirrel settlement decisions were significantly influenced by the experimental treatment at the release acclimation enclosure, with squirrels released into control treatment subplots approximately six times more likely to disperse from the release site, often settling in the nearby mowed and augured treatment subplots, where more burrows were dug. Few squirrels (15-22%) moved off plot. Other measures of movement behavior were unaffected by any of the variables examined. With such a low level of retention of translocated squirrels on untreated tall vegetation treatments (controls), it is clear that any translocation program into unsuitable habitat will likely fail.

(2) Ground squirrel habitat suitability model. To increase our ability to successfully translocate California ground squirrels, we must first better understand their habitat requirements. One of our goals in 2012 was to conduct surveys for ground squirrels throughout San Diego County and examine habitat covariates to gain insight into the factors influencing their distribution and abundance. To better understand the relationship between occupied and unoccupied habitat, we collected habitat data from grasslands throughout San Diego County. Habitat plots were established along transects at sites with squirrel burrows and compared to those without burrows (presence-absence). We report preliminary findings here but emphasize that another year of data collection (ongoing at the time of this report) is needed before we can draw firm conclusions. Key habitat variables associated with squirrel burrow presence included less vegetative cover and higher percent sand and lower percent gravel in the soil. These findings are consistent with our interpretation of 2011 squirrel translocation results in which squirrels released into areas with hard, compacted soils were less likely to successfully settle, establish burrows, and reproduce. When completed, this study will provide a valuable reference when deciding on suitable habitat for establishing burrowing owl populations and selecting properties that mitigate impacts to burrowing owls. If soils or other ecological variables are not suitable for squirrels, then establishing self-sustaining habitat for burrowing owls will be difficult. Further management actions, however, such as those initiated at the Lonestar property, may allow successful establishment of squirrel populations even with less suitable soils.

(3) Pilot work on burrowing owl population and nesting ecology. We discovered and opportunistically monitored 18 active BUOW nests, most of them on or near the Lonestar study site, including 12 at Brown Field Airport. We monitored 5 owl pairs at the Lonestar site using 8 camera traps. Three nests produced a total of 3 fledged chicks, but productivity was markedly lower than in 2011 (when 39 chicks were fledged), perhaps because management activities undertaken at Lonestar reduced prey availability. Several sightings of overwintering burrowing owls on experimental plots indicate that the habitat created by our management activities is attractive to owls.

We were able to individually identify some of the burrowing owls sighted from leg bands attached in 2011, which has provided preliminary insights into overwintering, survival, site fidelity, and dispersal. A more targeted banding effort, coupled with an intensive re-sighting effort, is recommended for the future.

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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 (*Athene cunicularia hypugaea*). Another prominent grassland species, the California ground squirrel (*Otospermophilus beecheyi)*, is abundant and common, but generally undervalued even though it is an integral component of this ecosystem and is known to exert a strong positive interaction on burrowing owls.

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

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

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

Results from year one of this multi-year program were mixed and indicated that modifications to the translocation protocol were necessary to improve release success of relocated squirrels (Swaisgood & Lenihan 2012). Our results also highlighted the need to understand how soil characteristics affect squirrel establishment and retention. In year two (2012), we modified the protocols developed for ground squirrel translocation in 2011 and initiated data collection for a ground squirrel habitat suitability model. Although work was focused on refining the ground squirrel translocation methodology, we opportunistically monitored burrowing owls and continued pilot work using camera traps at owl nest burrows.

Project goals

The goals for 2012 were to:

1. Continue monitoring of squirrel translocation outcomes from 2011 translocations;
2. Conduct additional ground squirrel translocations using adaptive management practices:
   - Establish 2 new pairs of plots with squirrel releases occurring in late spring-early summer (i.e. replicate 2011 translocation protocols);
   - Supplement 4 sites from year 1 with protocol adjustments developed from our 2011 results;
3. Build a predictive ground squirrel habitat model for San Diego County;
4. Continue pilot work of burrowing owl nesting and population ecology.

Personnel

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

Field Team—Squirrel translocations & camera trapping:
Field Organizers: Colleen Wisinski, M.S., Maryke Swartz, M.S., JP Montagne (ICR in-kind contribution)
Field Technicians: Kira Marshall, Reed Newman (ICR in-kind contribution), Rosa Chung (ICR in-kind contribution)
Field Support: Richard Martelli, Chris Nagem (ICR in-kind contribution)
Volunteers from San Diego Zoo Global (ICR in-kind contribution): Stéphane Vernhet, DVM, Tinh Nguyen, Christina Smith, Robin Yen

Field Team—Squirrel habitat model:
Field Organizers: Lauren Anderson, Susanne Marczak
Field Technicians: Frank Santana, M.S., Rosa Chung (ICR in-kind contribution)
GIS Support: James Sheppard, Ph.D. (ICR in-kind contribution)

Permits

Fieldwork was conducted under the CDFW Scientific Collecting Permits of Maryke Swartz (SC-11629), Colleen Wisinski (SC-11839), and JP Montagne (SC-11422). 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 burrowing owls and other species of concern, in 2011 we initiated the development of a scientific, ecologically relevant, strategy for relocating California ground squirrels. Long-term success is contingent upon our ability to translocate California ground squirrels to the restoration sites in numbers sufficient for a population to establish itself at an ecologically functioning threshold where squirrels serve as ecosystem engineers (Kotliar *et al*. 2006; Soule *et al*. 2003). Many translocation programs are unsuccessful or marginally successful because of high mortality (O'Bryan & McCullough 1985, Jones & Witham 1990) and post-release dispersal away from the release site (review in Stamps & Swaisgood 2007). Post-release monitoring, attention to release group composition, and ecologically relevant modifications to the post-release habitat and social environment can have profound effects on the success of translocation programs (Stamps & Swaisgood 2007; Swaisgood 2010). Salmon & Marsh (1981) noted, "Our experience has been that California ground squirrels released into an area will rarely stay." In one translocation study, 83% of California ground squirrels relocated in a hard release without acclimation immediately abandoned the release site (Van Vuren *et al.* 1997). Our own results from 2011 suggested that some modifications to the protocols were needed to increase squirrel survival. As a result, in 2012, we continued to refine the California ground squirrel translocation protocols developed in 2011.

METHODS

General methods and procedures are described in detail in Swaisgood & Lenihan 2012 and are not repeated here except those that deviated from 2011 protocols.

Release sites

The release sites were all located on conservation areas within southwestern San Diego County that encompasses the largest remaining population of burrowing owls 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 burrowing owl recovery.

We carried out camera trapping and opportunistic monitoring of burrowing owls at Lonestar Ridge West Mitigation parcel on Otay Mesa (owned by the California

Department of Transportation) and along La Media Road adjacent to the Lonestar parcel (Figure 1).

All three of these sites have a history of burrowing owl presence. Lonestar harbors a breeding population and wintering burrowing owls have been observed at Sweetwater and Rancho Jamul. At the San Diego National Wildlife Refuge Sweetwater Unit, the Shinohara and Mother Miguel Grassland restoration areas each have ten artificial burrow sites. Rancho Jamul Ecological Reserve maintains a designated area managed for the soft release of displaced and rehabilitated owls.

Release plots

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.

Source Sites

In 2012 we used two sites in southern San Diego County as sources for California ground squirrel translocation. All squirrels translocated to Rancho Jamul 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. The Daley Ranch House located at Rancho Jamul Ecological Reserve (Figure 6; N 32° 40’ 47.41”, W 116°° 51’ 20.50”, elevation 240m) served as the capture location for squirrels translocated to Sweetwater East. In particular, capture areas included: areas surrounding the headquarters buildings, pastures, orchards, and landscaped areas. Squirrels were moved from Rancho Jamul as part of an informal agreement with CDFW reserve manager Tracie Nelson.

Figure 1. Study area map designating the three sites where field work took place in 2011 and 2012 (1) San Diego National Wildlife Refuge, Sweetwater Unit; (2) Rancho Jamul Ecological Reserve; and (3) Lonestar Mitigation Site, Otay Mesa.

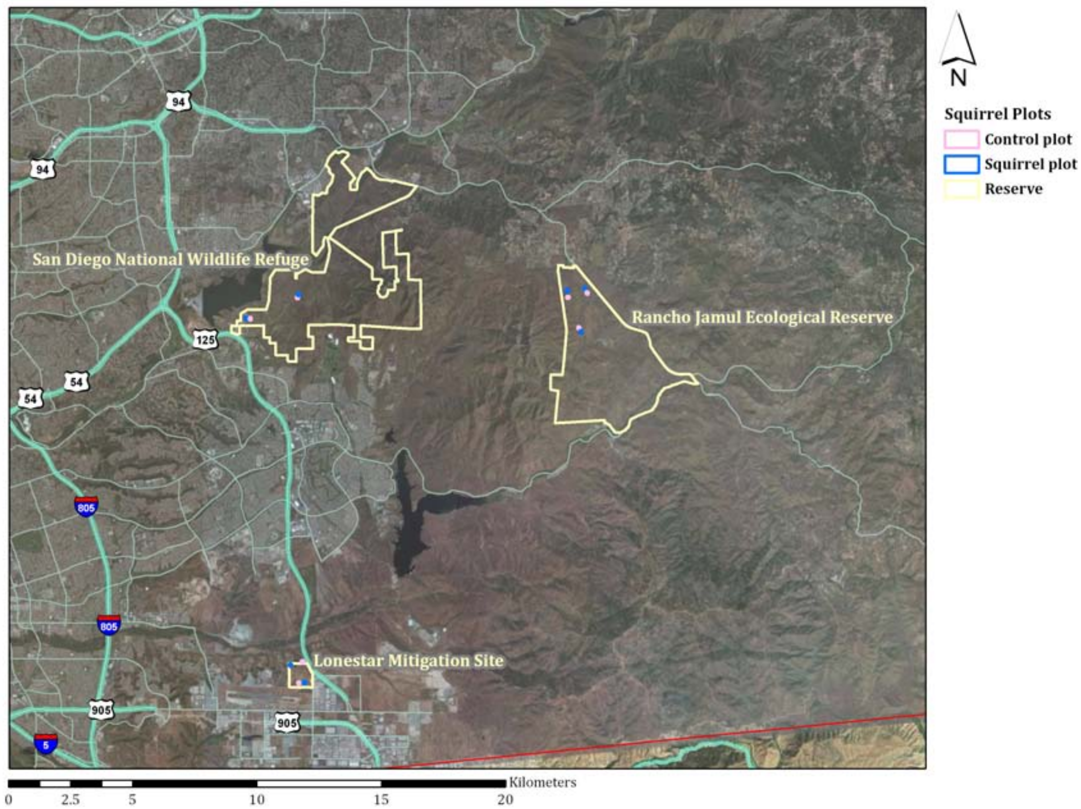


Figure 2. Rancho Jamul Ecological Reserve: 3 paired plots in 2011 and 5 paired plots in 2012. (1) Jamul South (JS): 2011 & 2012 (supplement); (2) Jamul West (JW): 2011 & 2012 (supplement); (3) Jamul East (JE): 2011 & 2012 (supplement); (4) Jamul Baja (JB): 2012 and (5) Jamul Central (JC): 2012

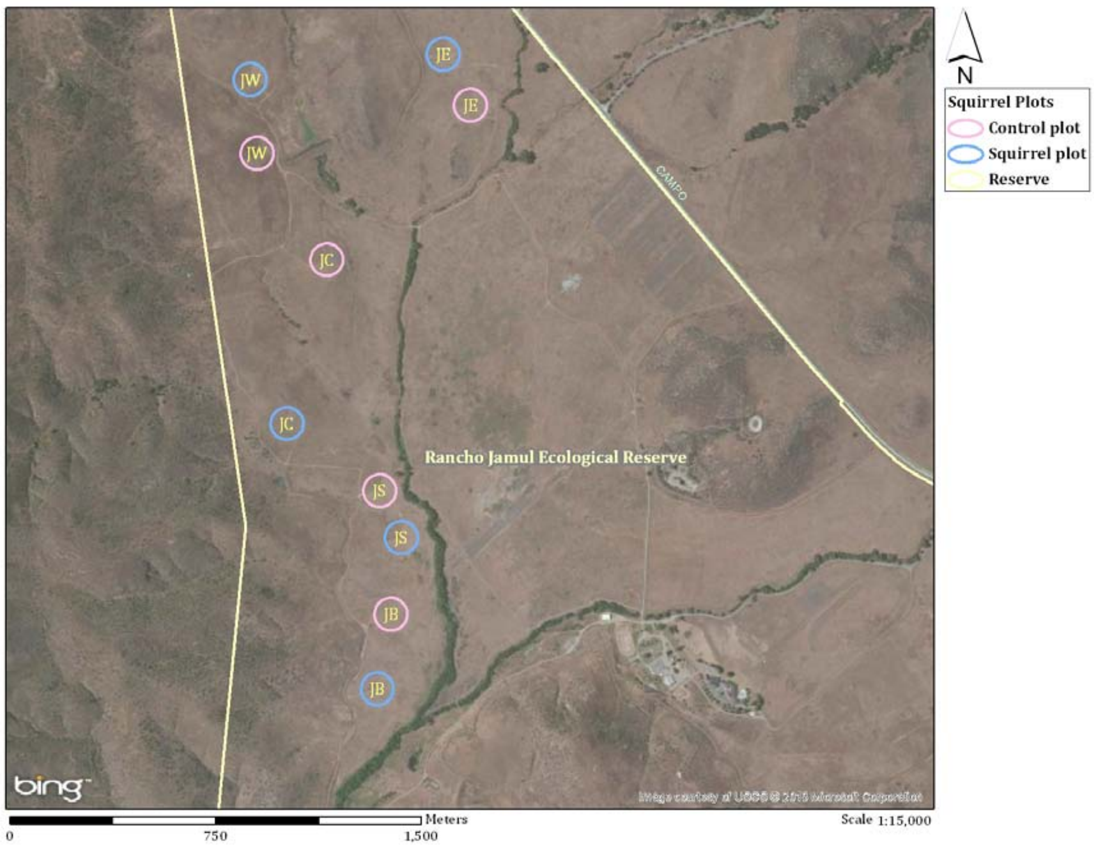


Figure 3. San Diego National Wildlife Refuge, Sweetwater Unit: 2 paired plots in 2011 and 1 paired plot in 2012. (1) Sweetwater West (SW): 2011 only; (2) Sweetwater East (SE): 2011 & 2012 (supplement)

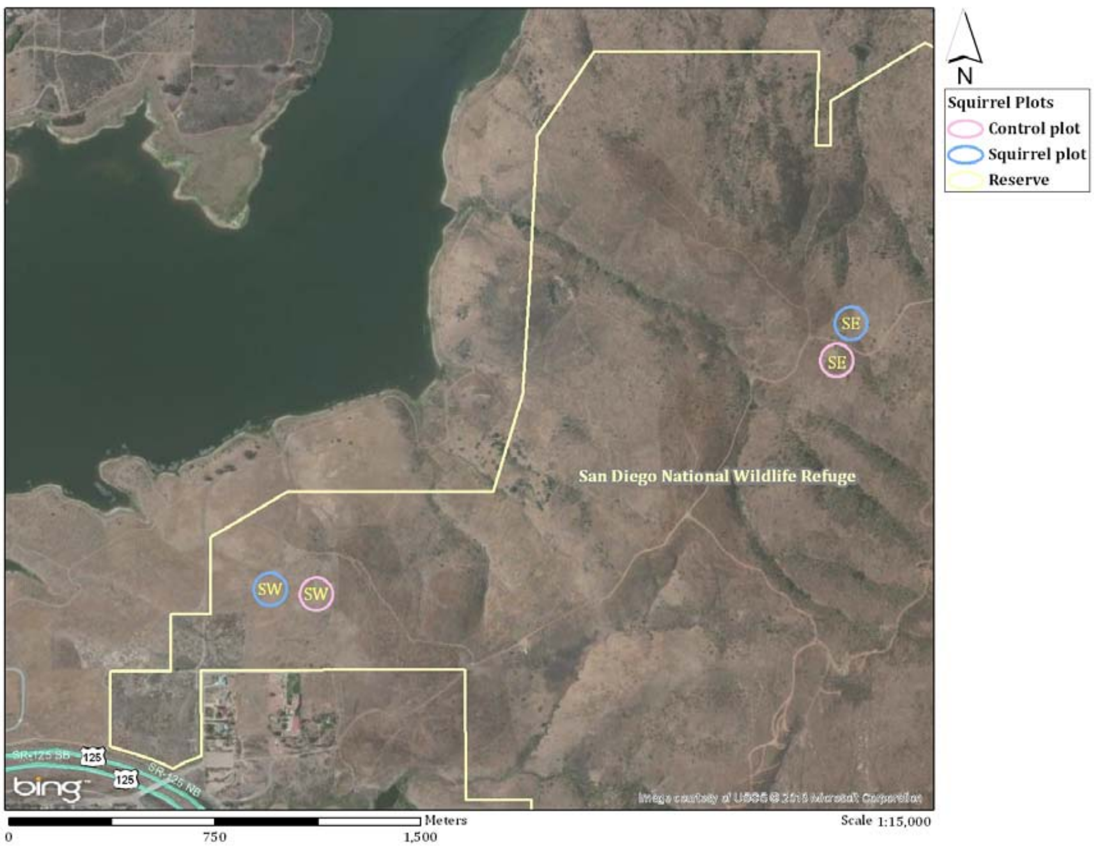


Figure 4. Lonestar Mitigation Site, Otay Mesa: 2 paired plots in 2011 only. Area of opportunistic burrowing owl monitoring; the pink line denotes the northern end of La Media Road where camera traps were placed at nest burrow entrances.

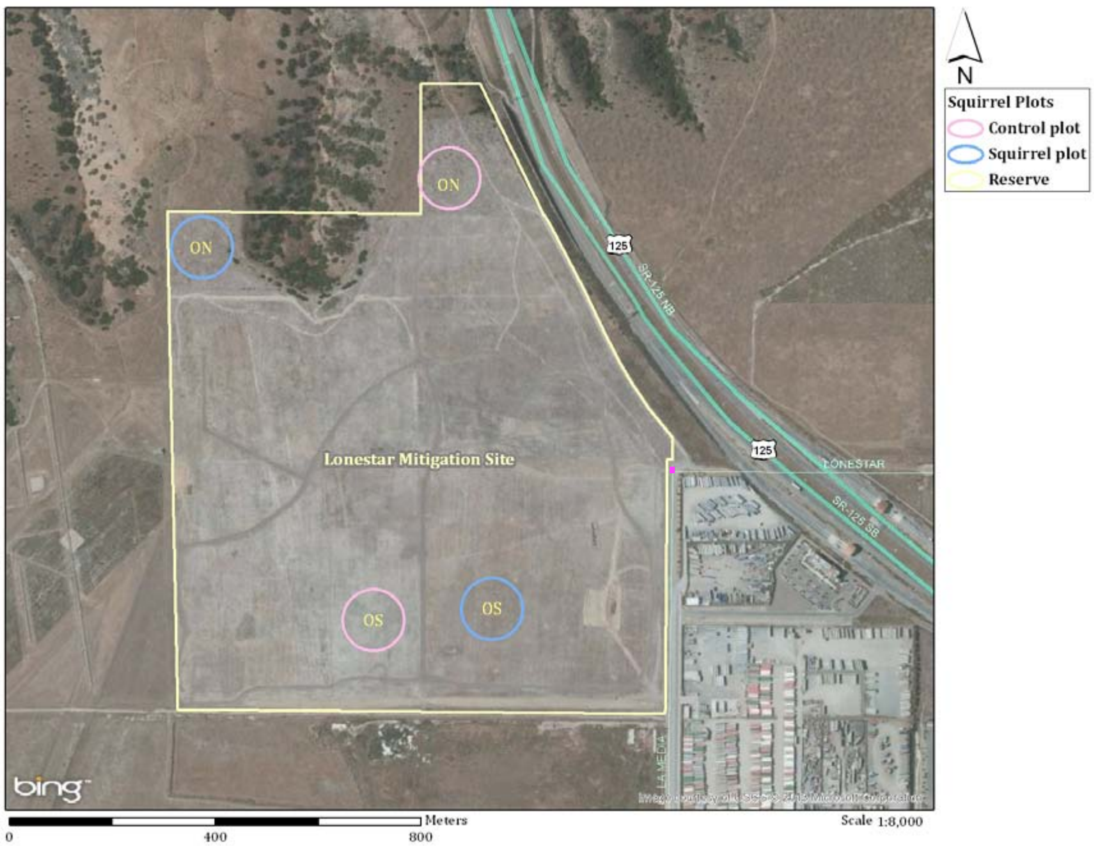


Figure 5. Naval Base Coronado, source site for all California ground squirrels translocated to Rancho Jamul Ecological Reserve. Squirrels moved to JB and JC were captured from the radar field and those moved to JW, JE, and JS were captured at the taxiway. Observation points used for determining familiarity are noted.

Figure 6. Daley Ranch House at Rancho Jamul Ecological Reserve, source site for all California ground squirrels translocated to SE in 2012.

Experimental Translocations

Experimental design and plots

In 2012, we replicated our 2011 translocation experiment at 4 new plots in Rancho Jamul to increase the sample size and statistical power (Figure 2, JB & JC). Each plot was either a: 1) treatment plot (squirrels translocated to the plot) or a 2) control plot (no squirrels translocated to the plot). We used the same plot selection criteria as in 2011.

We followed the same plot configuration as in 2011 except that: 1) six additional artificial burrows were added to accommodate an increased number of squirrels released at the plots, and 2) three of the burrows were constructed with double chambers to accommodate larger juvenile groups (Figure 7).

On all of the new experimental plots IEMM repeated the vegetation treatments from the previous year (mow, mow + auger, control).

Subjects

We marked 234 California ground squirrels (88 adults and 146 juveniles) from March to May, 2012 at the NBC Radar Field (Figure 5). Beginning May 22, 2012, we recaptured and translocated 118 of the 234 squirrels into the two new release plots (Table 1; Figure 2, JB, JC); squirrels were released from acclimation at both plots on June 7, 2012.

Table 1. Total number of squirrels translocated to 2012 plots. Number in () indicates number transmittered.

	Adult		Juvenile		
Plot	**Female**	**Male**	**Female**	**Male**	**Total**
Jamul Baja	14 (7)	5 (5)	20	20	**59 (12)**
Jamul Central	12 (7)	4 (4)	24	18	**58 (11)**
Total	**26 (14)**	**9 (9)**	**44**	**38**	**118 (23)**

Founder group familiarity

In 2011, we originally proposed to move squirrels in known family groups to ease their transition by maintaining social relationships. However, mark-recapture trapping prior to translocation was not possible, due to a later than anticipated start date. We were able to relocate ground squirrels residing within close proximity to each other and thus maintained groups that were familiar with one another throughout the translocation process.

In 2012, we attempted to identify family groups and neighbors in a more rigorous manner than in 2011. To accomplish this goal, we conducted mark-recapture trapping and observations at the NBC Radar Field (see Figure 5) during the spring pupping season. Initially, we captured, marked and released only adult ground squirrels for individual identification. We followed the same mark-recapture protocol with pups once they emerged. Upon release, we marked the burrow to which each squirrel ran with a numbered pin flag and recorded its location with a Trimble® GPS unit (Figure 8). We observed marked squirrels from three locations adjacent to the Radar Field (Obs A, B, and C in Figures 5 & 8) and used these data, along with the burrow co-occupation data, to determine family groups and familiarity. We trapped ground squirrels for relocation in late May. Our original target number was 60 squirrels per plot, for a total of 120 translocated squirrels. The target release group configuration for each plot comprised a minimum of six adult males, twelve adult females and their associated weaned pups.

Translocation protocols

Processing, handling, on-site acclimation, and release of all California ground squirrels followed the protocols described in Swaisgood and Lenihan 2012 with a few exceptions. We added the use of passive induction transponders (PIT tags, InfoPet) to eliminate the problem of lost ear tags which made squirrels unidentifiable. Also, in 2011 we experienced a few mortalities of adult female ground squirrels that were held with juveniles. We determined that these females likely experienced stress due to close proximity of weaned juveniles that would normally be dispersing at that time. As a result, we changed our holding and acclimation protocol so adult females are only kept with other adults. This eliminated the stress-related mortalities.

Post-release monitoring and support

Upon release the ICR field team immediately began monitoring squirrels in multiple ways: 1) radio-tracking, 2) retrapping, 3) camera trapping, and 4) direct observations. Each technique was designed to contribute to the determination of squirrel retention on site, movements off site, and survivorship.

As in 2011, a subset of squirrels was equipped with VHF radio-collars to allow tracking and monitoring of individual squirrels post-release (Swaisgood and Lenihan 2012). Forty-three squirrels were collared with VHF transmitters using the same methodology as 2011. We increased our tracking effort this year locating collared squirrels daily for the first 30 days, then at minimum three times per week until collars were recovered. We averaged 84.5 tracking days for twenty-three collared squirrels at JB and JC (Table 1), and 64.3 tracking days for the twenty individuals moved to JE, JW, JS and SE (Table 2). We were able to pinpoint exact locations when squirrels were underground. If a tracked individual was above ground we recorded the location it was first seen, and then retreated to prevent influencing dispersal. Locations and categorical spatial data (e.g. on vs. off plot, treatment) were recorded with Trimble™ GPS units. Radio signals for three squirrels were lost during the first two weeks and it is unknown whether the transmitters failed or were out of range due to distance or damage. We confirmed predation in 29 squirrels, and one additional collar was found intact, either due to predation or removal by the squirrel. Five more collars remained unmoving underground. In December, we excavated two burrow systems to retrieve these collars and in both cases they were intact inside grass bedding material. We removed collars from five squirrels between November 2012 and January 2013.

Relocated squirrels were retrapped at each translocation plot for five days at one month post-release.

In an attempt to reduce the dispersal of squirrels off research plots and facilitate settlement, we provided supplemental food in the form of apples, yams, and pelleted rodent feed to the released squirrels. Our approach for supplemental feeding in 2012 was longer in duration than in 2011. Food was provided once per day for the first seven days, then 3 times per week for the next 15 weeks.

Due to our success with using camera traps to remotely monitor squirrel activity at the plots in 2011, we deployed four camera traps at each plot. We used Reconyx® HC and Bushnell® TrophyCamHD black flash remote camera systems at the Jamul sites, and Cuddeback® Capture IR cameras at SE (due to the risk of theft, we used these cheaper older cameras). We placed cameras at the midpoint of the buffer zone between each plot wedge and at the plot center (Figure 9) and pointed them in a northerly direction to minimize the effects of the sun on photograph exposure. The supplemental food was placed approximately 1 m in front of each camera to increase the chances of identifying individual squirrels in the photographs. We changed camera batteries and retrieved SD data cards once per week. Due to a delay in camera shipment, we placed the cameras at the specified locations at JB and JC on 28 June (three weeks after release) and started operating them immediately. At the remaining plots, we placed the cameras before release and began operating them upon squirrel release. All cameras were in continual operation from respective start date to 31 January 2013. We ran a total of twenty cameras for 3808 camera-days with each camera gathering 35,000-40,000 photographs. Photo processing and data analysis are ongoing due to the significantly increased number of cameras and photographs and results are not discussed in this report.

Supplemental Translocations

We conducted supplemental translocations at 4 of our 2011 plots that had low numbers (assessed in February of 2012) and required higher numbers of squirrels to be viable (JW, JE, JS, and SE; see Figures 2 and 3,). We made several modifications to the 2011 translocation strategy for the supplemental translocations to attempt to improve translocation success in 2012. (1) **The addition of cover**. Many translocated squirrels were likely lost to predation. The highest rate of predation during a translocation is during the establishment phase when releasees are making settlement decisions. We predicted that adding cover would provide newly released squirrels above-ground shelter from predators and thus increase squirrel survival and retention. (2) **Founder group familiarity**. Familiarity among release group members has been shown to be an important determinant of survival and reproduction for small mammals such as kangaroo rats (asocial; Shier & Swaisgood 2012) and prairie dogs (highly social; Shier 2006). We increased our efforts to identify familiar groups by employing mark-observe-recapture methodology at the source site (see above). (3) **Release timing**. Survival may be higher for squirrels relocated in better physical condition. Adult females may be in better condition later in the season after having sufficient time to gain weight lost during reproduction. Juveniles may also show improved survival later in the summer because they are in better physical condition and/or have learned effective survival skills. We predicted that translocating squirrels in late summer-early fall would improve release success. Thus, we conducted supplemental translocations in mid-late August of 2012.

One-year post-release monitoring – 2011 plots

In late June, we retrapped at JW, JE, JS, and SE; this included ear-tagging unmarked squirrels (mostly juveniles that were likely offspring of translocated squirrels). We also used an inspection camera to assess the condition and occupancy of the artificial burrows. We used the recapture, inspection information, and social group relationships to determine how many squirrels could be translocated to each plot and to assign squirrels to acclimation cages.

Artificial burrow assessment

Eight artificial burrows were deemed unusable for the supplemental acclimation due to debris blockage so that instead of 12 acclimation burrows per plot we used 8 at JW, 10 at JE, 11 at JS, and 11 at SE.

Experimental design and plots

For all supplemental translocations, IEMM repeated the vegetation treatments from the previous year (mow, mow + auger, control) and ICR added cover in the form of brush piles, large logs, and stumps (Figure 10) to each experimental and control replicate in a systematic and balanced fashion (Figure 11). We did not experimentally test cover vs. no cover.

Subjects

For the supplemental translocation to the three Jamul plots, we marked 139 California ground squirrels (3 adults and 136 juveniles) in July and August at the NBC Taxi Way (Figure 5). Of those, 122 squirrels were trapped and translocated from July 30 through August 3. We placed 44 individuals at both JE and JW, and 34 at JS; all were released on August 13 (Table 2). For the supplement to SE, we marked 60 squirrels (4 adults and 56 juveniles) at the Daley Ranch House (Figure 6) in early August, trapped and translocated 50 individuals from August 14-18, and released 49 individuals on August 27 (Table 2).

Table 2. Total number of squirrels translocated to 2011 plots. Number in () indicates number transmittered.

	Adult		Juvenile		
Plot	**Female**	**Male**	**Female**	**Male**	**Total**
Jamul South			20 (1)	24 (4)	44 (5)
Jamul East		2 (2)	21	21 (3)	44 (5)
Jamul West			18 (3)	16 (2)	34 (5)
Sweetwater East		3 (3)	30* (1)	17 (1)	50 (5)
Total		**5 (5)**	**88 (5)**	**78 (10)**	**172 (20)**

*1 juvenile female was found dead in the acclimation cage before release at SE, therefore 49 squirrels were released at that plot.

Founder group familiarity

We conducted mark-recapture trapping and observations in mid-summer at the NBC Taxiway (Figure 5) and Rancho Jamul Headquarters (Figure 6). Squirrel activity was greatly reduced at that time of the season, therefore, familiarity was assessed primarily using trap and burrow locations.

Post-release monitoring and support

Our post-release monitoring effort for the supplemental plots followed the same protocols outlined above for the translocation experiment.

Data Analysis—One-Month Post-Release Survival

We examined 1-month post-release survival using retrap and telemetry data. We modeled survival using logistic regression in JMP 10 considering the effects of age, sex, source site, release plot, year, release type (early vs. late), individual weight at translocation, release treatment, and relevant interactions of these variables (Table 3). We excluded non-translocated squirrels from the analysis.

Due to all but one variable being categorical, most models we ran were single-predictor models. We considered each predictor variable in a stepwise fashion. Source site and release plot were confounded, so we never included them together in a model. Initially, we pooled all of the data across release types and years. First, we looked at the effect of release type, then we compared years both with and without the 2011 "failed plots" (two Otay and one Sweetwater). Next, we considered release type within year (2012 only) and the results suggested that we needed to evaluate each year and release type combination separately. Hereafter, "cohort" refers to year and release type combined. For each cohort, we considered the single-predictor models for age, sex, source site, release plot, weight, and a model that incorporated an interaction between age and sex (age + sex + age*sex). We did not have enough data to model the effect of the treatment in which a squirrel settled, but we did consider the effect of the treatment in which a squirrel was released both with the data pooled and by cohort.

Table 3. Description and values of independent variables used in 1-month post-release survival analysis.

Variable	Description	Possible values
Release type	Initial Translocation (early summer) vs. Supplemental (late summer)	Initial, Supplemental
Year	Calendar year (supplemental translocations excluded)	2011, 2012
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	Continuous values
Cohort	Year and Release Type combined	2011 Initial, 2012 Initial, 2012 Supplemental
Treatment	Treatment of release burrow	Mow, Mow+Auger, Control

Figure 7. Diagram showing the layout of the two new pairs of plots (JB and JC) that were established in 2012. Numbered circles indicate artificial burrow locations. Double-lined circles denote burrows with double chambers.

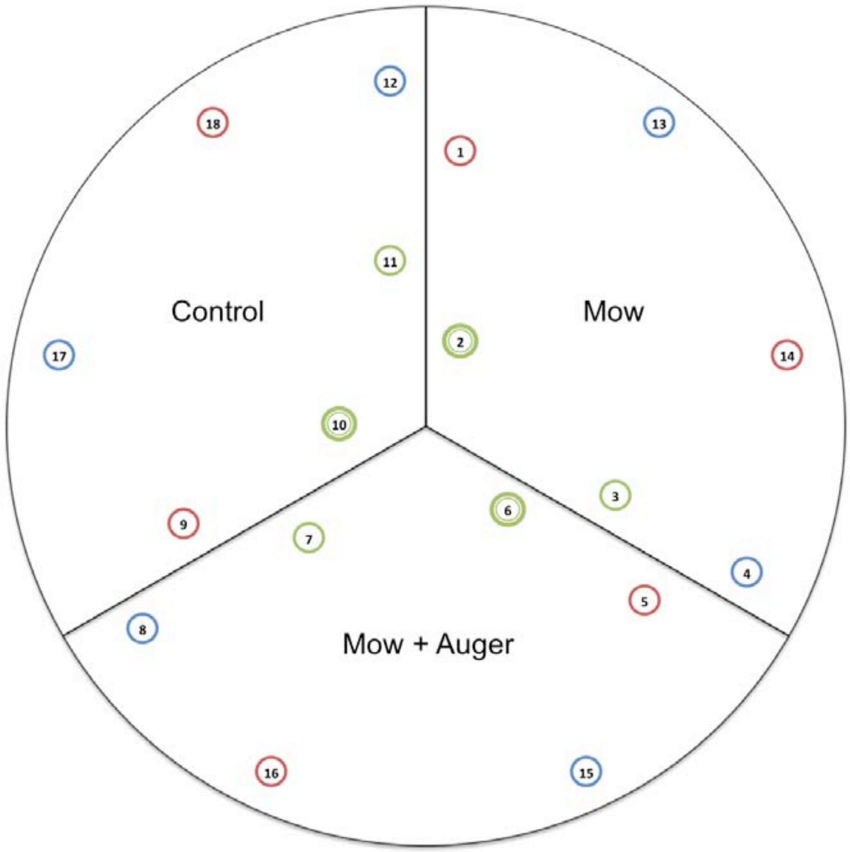


Figure 8. Naval Base Coronado, source sites with ground squirrel burrow locations.

Figure 9. Diagram showing the locations of remote cameras placed at each squirrel release plot (the orange boxes depict the cameras and the blue arrows show the direction the cameras faced).

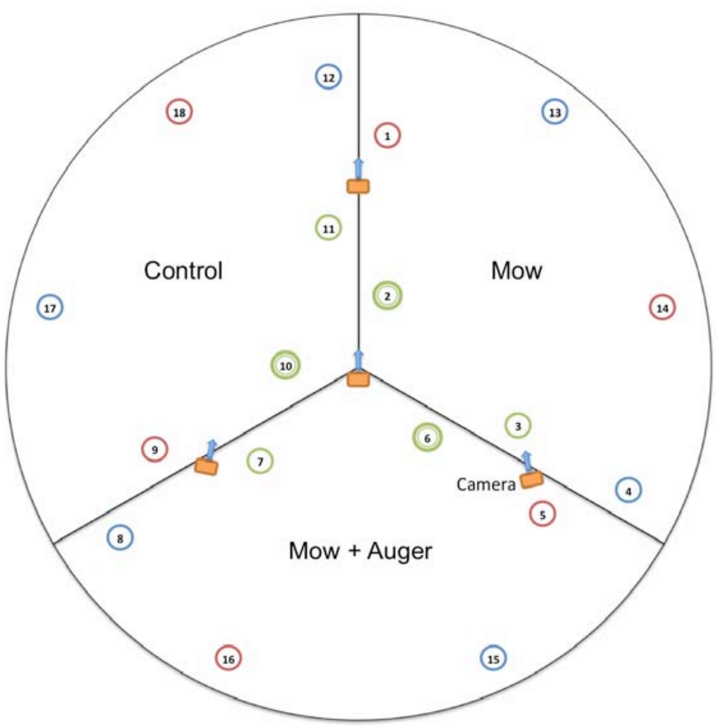
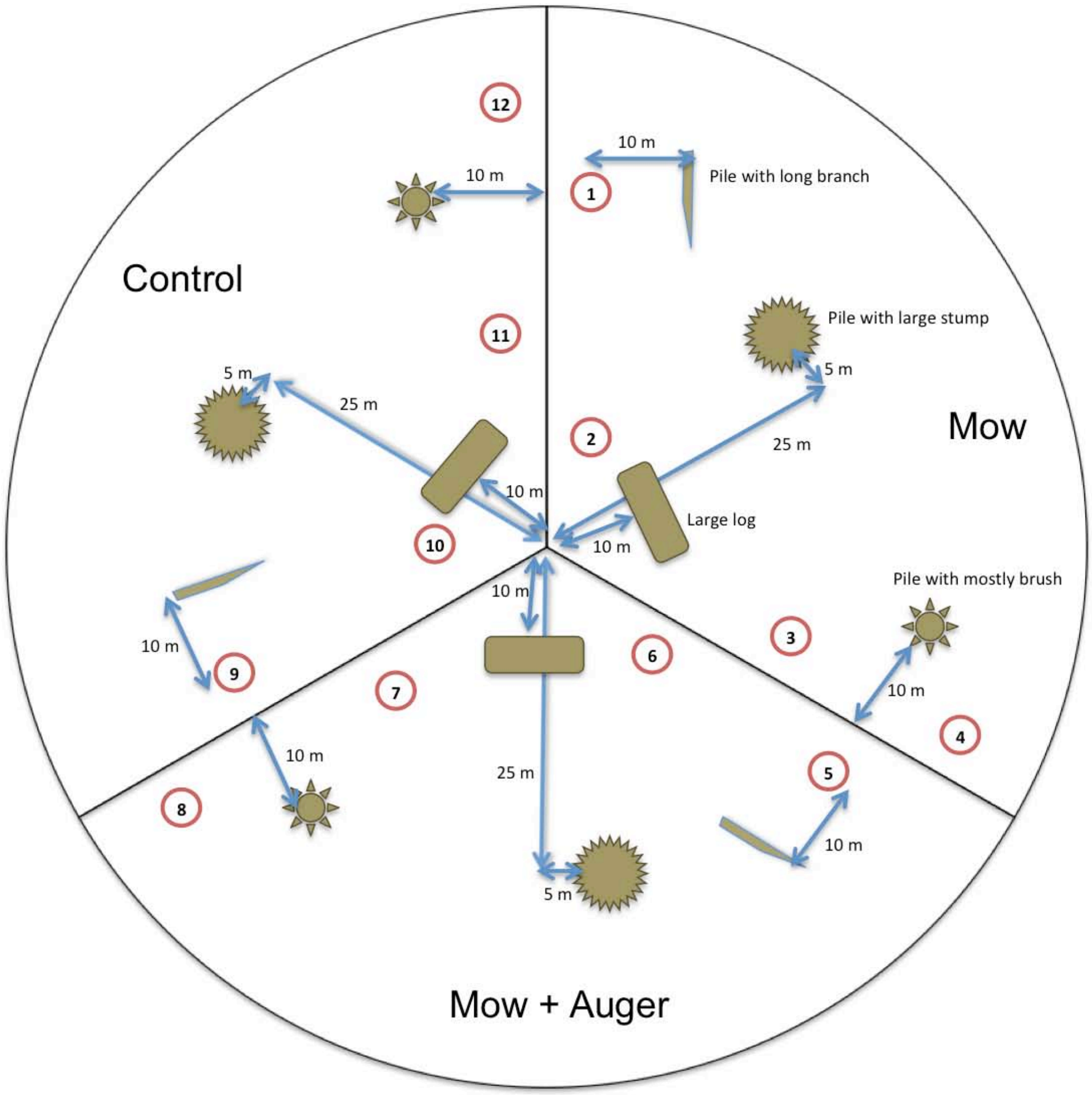


Figure 10. Example of a brush pile placed at one of the 2011 sites to provide cover for squirrels. This picture shows a natural burrow that was established under the brush pile.

Figure 11. Diagram showing placement and types of brush piles placed at the experimental and control plots that were established in 2011. Numbered circles indicate locations of artificial burrows. Diagram not to scale.



RESULTS & DISCUSSION

Detailed data tables displaying outcomes for individual study sites are presented in Appendix 1.

Minimum survival & retention—2011 plots

At one-year post-release, twenty-four squirrels were captured on the four 2011 plots with an average of six individuals per plot (Table 4). Eight of the 24 were marked squirrels that had been translocated in 2011 and 13 were presumed to be offspring of the translocated squirrels based on their trap locations and the burrows to which they ran upon release. 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). However, the presence of juveniles on the release plots indicates establishment of successful reproduction by the translocated squirrels, partially offsetting the losses to mortality. This successful early establishment indicates that if squirrels are translocated in high enough numbers to compensate for losses from dispersal and predation, translocation with soft-release is a viable strategy for re-establishing squirrels.

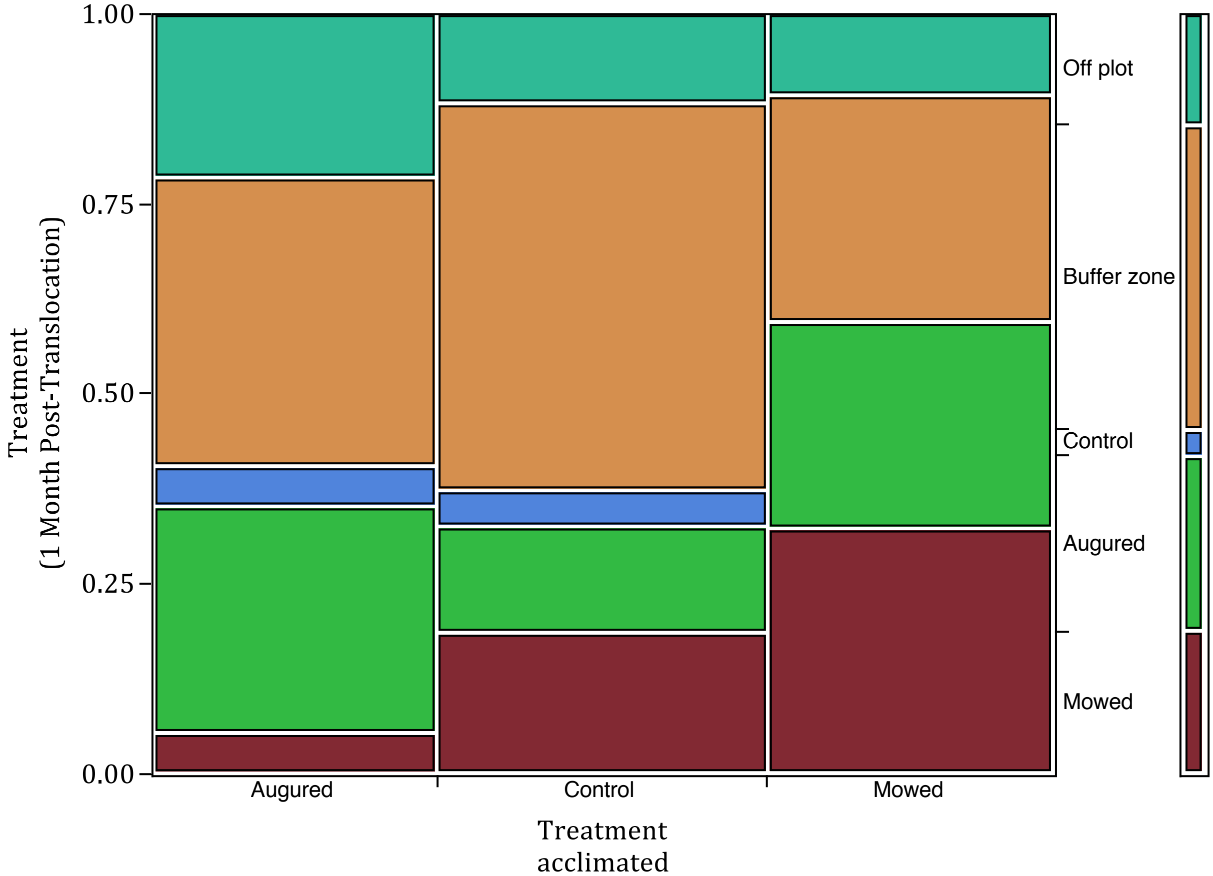
Table 4. Squirrels captured 1-year post translocation. Numbers in parentheses indicate translocated individuals.

	Adult		Juvenile		Total
Plot	**Female**	**Male**	**Female**	**Male**	
Jamul East	1 (1)	1 (1)	1	3	6 (2)
Jamul West	3 (2)	1	1	1	6 (2)
Jamul South	2 (2)	1	4		7 (2)
Sweetwater East	1 (1)	1 (1)	3		5 (2)
Grand Total	**7 (6)**	**4 (2)**	**9**	**4**	**24 (8)**

Settlement patterns and burrow establishment

Ground squirrel dispersal was not random with regard to treatment. Squirrel settlement decisions were influenced by the experimental treatment at the release acclimation enclosure (X^2=17.8, p=0.02). Inspection of Figure 12 reveals that squirrels released in Control treatments were unlikely to remain there (4.7%), whereas those released in the Augured (29.7%) or Mowed (32.4%) treatments were approximately six times more likely to remain near the release site. Few squirrels (15-22%) moved off plot, instead choosing to settle on one of the non-control treatments and, interestingly, the buffer zones, which are essentially the same treatment as Mowed. With such a low level of retention of translocated squirrels on untreated tall vegetation treatments (Controls), it is clear that any translocation program into unsuitable habitat will likely fail.

Figure 12. Settlement outcomes 1 month post-release as a function of Treatment at acclimation site. Data from 117 transmittered squirrels.



Data from burrow surveys support this conclusion (Deutschman & McCullough 2013), with the majority of natural burrow entrances located in Augured or Mowed experimental treatment sections.

Burrow entrance data also indicate that translocations were successful in achieving ecosystem engineering effects with regard to burrow creation. Across translocation plots established in 2011, 131 burrow entrances were found 6 months post-release, compared to only a single burrow found on matched-control plots. A year after translocation, the number of burrow entrances had increased substantially at translocation plots to 486. This increase in burrows cannot be attributed solely to the burrowing activity of squirrels released one month before the survey in the supplemental translocations, indicating a robust year-round presence and burrowing activity of the relatively small proportion of squirrels surviving and reproducing from the initial translocation. Control plots also contained more burrows in 2012 (80 entrances) and evidence suggests that dispersal and colonization by translocated squirrels to matched-control plots nearby is responsible for some of the burrow establishment on control plots. In some cases nearby resident squirrels also settled on control plots, but it is unclear whether they were attracted primarily by the habitat modification or the established presence of dispersing translocated squirrels.

Short term post-release survival (4-6 weeks)

Site Preparation

There was no effect of release site preparation treatment (mow vs. mow + auger vs. control) on short term squirrel survival (G-stat=0.922065, p=0.6306). This result makes biological sense as the release burrows are situated along the boundaries between treatments, and squirrels can move quickly and establish a new burrow within a day. This re-settlement outside of control treatments and into mowed treatments is observed in the burrow entrance data (Deutschman & McCullough 2013)

2011 vs. 2012

The 2012 squirrel translocations were more successful in the short term compared to the 2011 translocations (β=-0.72, $p<0.0001$), supplemental translocations excluded. Because the three plots that failed in 2011 may have been driving the lower survival in 2011, we reanalyzed the short term survival data excluding those plots. Our results indicate that even with the data from the failed 2011 plots removed, 2012 squirrel translocations were significantly more successful than 2011 releases (β=-0.55, $p<0.0001$). These results suggest that the modifications we made to the release protocols in 2012 increased squirrel survival. Specifically, the increased effort to determine familiar groups and the longer period during which supplemental food was provided likely contributed to the increased survival of squirrels in 2012.

2011

In 2011, the source of the translocated squirrels was predictive of survival. Squirrels from Navy Base Coronado were significantly more likely to survive in the short term compared to squirrels from Tulloch Ranch and Daley Ranch House (β=0.588, $p=0.05$). This enhanced survival may be due to the heavier weight and better body condition of squirrels from Navy Base Coronado, allowing them to survive off of stored fat reserves for longer while establishing in a novel environment. Further, results show an interaction effect between age and sex. Adult females were significantly less likely to survive following release when compared to adult males and juveniles (β=-0.463, $p=0.006$). The lower adult female survival is likely explained by the minimal effort to identify family groups and/or the shorter duration of food supplementation in 2011. The reduced food supplementation would disproportionately affect adult females in the late spring post-reproduction period because a majority of females are reproductive during this time period and reproduction (pregnancy and lactation) is energetically expensive and negatively influences body condition.

2012

For both 2012 release groups (initial translocation and supplement), none of the variables we considered (see Table 3) was predictive of survival. Juvenile survival did not differ significantly between the release groups, therefore, release timing did not have an effect on survival indicating that juveniles can be translocated at any time of the season after they are independent from their mothers. In addition, any effects of having a previously established population from the previous year's translocation did not affect survival in the squirrels in the supplemental translocation.

In the short term, release type (initial translocation vs. supplement) was not predictive of release success (p=0.84). However, release type and release timing were confounded. All initial releases were conducted in the late spring/early summer and the supplements were conducted in late summer/early fall. Release type also differed with regard to provision of cover, indicating that efforts to provide squirrels with additional behavioral options for coping with predation did not result in any significant survival advantage. This finding is somewhat surprising, as squirrels clearly used the brush piles as refuge, running to them when disturbed and often constructing burrows under them. It is plausible to conclude that none of these variables impacted survival, although the less parsimonious explanation that positive effects of one variable cancelled the negative effects of the other cannot be ruled out.

These survival analyses are restricted to short term assessment. We will continue to collect data in the 2013 season that will allow us to examine long term success and survival.

Radio Telemetry

The overall mortality rate for radio-collared squirrels with known fates (i.e. confirmed death or collar removed N=34) was 85.3%. Mortality was 30.8% by the first week, and 58.8% by the end of the first month. Tables 5 and 6 summarize the number of squirrels still alive at the end of each time interval. Five collared squirrels survived through the end of the study when we retrapped them to remove their collars, and only one dispersed and settled away from a plot.

Table 5. Total number of collared squirrels (N) still surviving at the end of the first four weeks.

Plot	N	1 wk	2 wk	3 wk	4 wk
Jamul Baja	**12**	10	8	6	5
Jamul Central	**11**	4	4	4	4
Jamul South	**5**	3	2	2	2
Jamul East	**5**	2	2	2	2
Jamul West	**5**	3	2	2	0
Sweetwater East	**5**	5	5	3	1
Total	**43**	**27**	**23**	**19**	**14**

Table 6. Total number of collared squirrels (N) still surviving at the end of each month.

Plot	N	1 mo	2 mo	3 mo	4 mo
Jamul Baja	**12**	5	1	0	0
Jamul Central	**11**	4	2	1	1
Jamul South	**5**	2	1	1	n/a
Jamul East	**5**	2	2	2	n/a
Jamul West	**5**	0	0	0	n/a
Sweetwater East	**5**	1	1	1	n/a
Total	**43**	**14**	**7**	**5**	**1**

There were no differences in movement behavior by sex (days to settlement: Welch's F=2.88, p=0.11; distance to settlement: F=0.07, p=0.70) (Table 7). Further, radio collared squirrels that were released into different release site treatments (mowing, mowing + auger, control) showed no differences in time to settlement (Welch's $F_{12.3}$=0.32, p=0.73), distance to settlement (F=0.65, p=0.53) or days to dispersal (F=0.22, p=0.80), although the data reported above indicate clearly that squirrels released into Control treatments relocated short distances into adjacent subplots receiving vegetation enhancement. These preliminary results indicate that release site treatment may not influence longer distance post-release movement, such as dispersing off plot, in California ground squirrels following translocation.

Table 7. Average movement measurements for radio-collared squirrels for each plot.

Plot	Mean Total Days Tracked	Mean # of Relocations	Mean days to Dispersal	Mean days to Settlement	Mean Distance to Settlement (m)	Mean Total Distance Moved (m)
JB	70.2	40.9	19.0	8.3	225.8	283.2
JC	62.3	31.0	4.0	7.2	158.6	480.4
JE	72.2	34.8	2.0	2.0	65.6	305.8
JS	47.8	30.2	14.0	6.7	420.4	1185.3
JW	45.0	27.8	17.0	7.0	309.0	439.2
SE	95.2	47.0	11.0	6.0	547.6	840.0

Although the data from transmittered squirrels indicate high mortality rates, trapping data (see Appendix 1) suggest survival may be higher overall. For the two translocations to new plots, we re-trapped 24% and 50% of the released squirrels 1 month after release. For the 4 supplemental translocations to plots established in 2011 (and retaining a resident population established in 2011) we re-trapped 30-48% of the translocated squirrels 1 month post-release. We know that re-trap data underestimate actual population size, so these survival rates are minimum estimates for squirrels surviving *and* remaining on the plot (where trapping was conducted). We know from telemetry data that additional squirrels remain alive off plot. These results are quite promising, but there is still reason for concern regarding the telemetry data suggesting continued mortality (due to predation) during the second month post-release.

When compared with published results from previous efforts to translocate California ground squirrels, these results are good. In one study, 83% of translocated ground squirrels immediately abandoned the release site (Van Vuren *et al.* 1997). However, is surprising that similar efforts with other small, endangered mammals (kangaroo rats), using very similar strategies, have been substantially more successful than translocation of a "pest" species (e.g. Shier & Swaisgood 2012).

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. One of our goals in 2012 was to conduct surveys for ground squirrels throughout San Diego County and examine 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, although 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 at 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 burrowing owl populations dependent on ground squirrel burrows. Better knowledge of ground squirrel habitat requirements will be instrumental in guiding any burrowing owl 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 began to collect habitat data from grasslands throughout San Diego County to develop a predictive 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 burrowing owls. This variable (burrows) likely reflects a composite of ground squirrel abundance and soil suitability for burrow establishment. Habitat covariates recorded included: vegetation type, vegetation structure (height), percent bare ground, soil characteristics, distance to human activity, distance to permanent water, and other variables of interest. The results of this survey can then be used to define key habitat factors and help identify critical habitat in San Diego County for both ground squirrels and burrowing owls.

METHODS

Study sites and dates

We collected data from the following eight grassland sites (Figure 13) throughout San Diego County from 14 May – 30 July 2012:

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.

We obtained permission to access the above sites from the relevant land manager (i.e. City of San Diego, San Diego County, private land owner). Sites were selected based upon the criteria that they 1) be classified as a grassland ecosystem, 2) exist at an elevation of less than 1200 m, and 3) be of a size such that 15 transects could be surveyed within the site.

Transects

We used GIS software to randomly select 50 transects, with a minimum 25 m buffer around each transect, within each study site. If size allowed, we conducted a maximum number of 15 transects at each study site (Figure 14). This was achieved at six of the eight study sites; the exceptions were 13 transects at Rancho Jamul Ecological Reserve and 7 transects at Rancho Peñasquitos 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). 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 1 for full protocol).

Point-line intercept data collection

We used a laser point-intercept device (Figure 15) to eliminate biasing the selection, and collected the following data at every 0.5 m mark along each 10 m 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,
3. Soil surface: Soil, Rock, Litter, Log/Woody Debris, Burrow, Basal Intercept.

Plot-center data collection

We collected the following data from the center of the 10x10 m plot:

1. GPS location of plot-center/burrow (decimal degrees),
2. Elevation (m),
3. % Slope and Aspect (slope direction),
4. % Canopy cover,
5. Community type,
6. Dominant species of Grass/Forb/Shrub,
7. If burrow is active (yes/no),
8. Type of burrow protection, if applicable,
9. Site history (grazing/burn/rodenticide use), if known,
10. Predators (# and species) seen while conducting transect,
11. Additional signs of ground squirrels (# and distance from transect),
12. Photos of the surrounding habitat from plot center facing North, South, East, West. A photo of the burrow was also taken, if applicable.

We collected three soil core samples, with one taken at the plot center (or adjacent to a burrow if present), and the other two taken 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 were provided courtesy of the USWFS Carlsbad office.

We stored the soil cores collected in the field in aluminum tins and dried them completely in a soil oven. Once dried, we weighed each sample to obtain the bulk density. Using a sieve, we separated all gravel 2 mm or larger from the sample and weighed it to obtain the percentage of the sample composed of gravel. We conducted soil texture analysis on the remaining sample to determine the percent composition of sand, silt, and clay (Figure 16).

Figure 13. Map showing the approximate locations of the eight ground squirrel habitat sites throughout San Diego County.

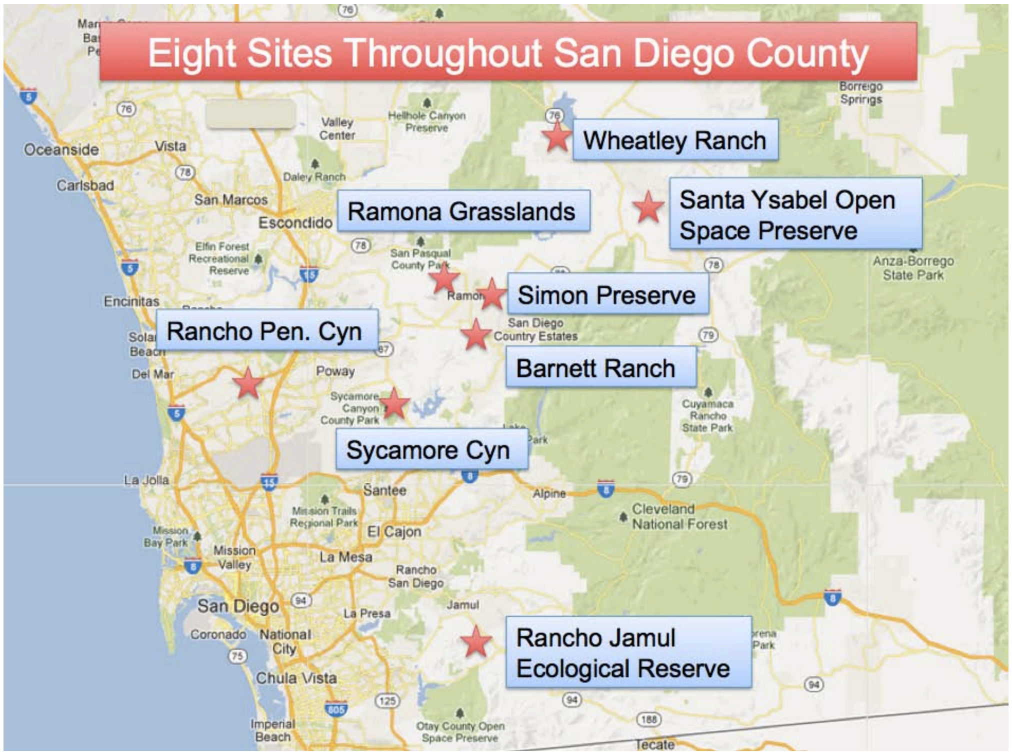


Figure 14. Example of transect layout (transects conducted at the Goodan Ranch Sycamore Canyon Open Space Preserve).

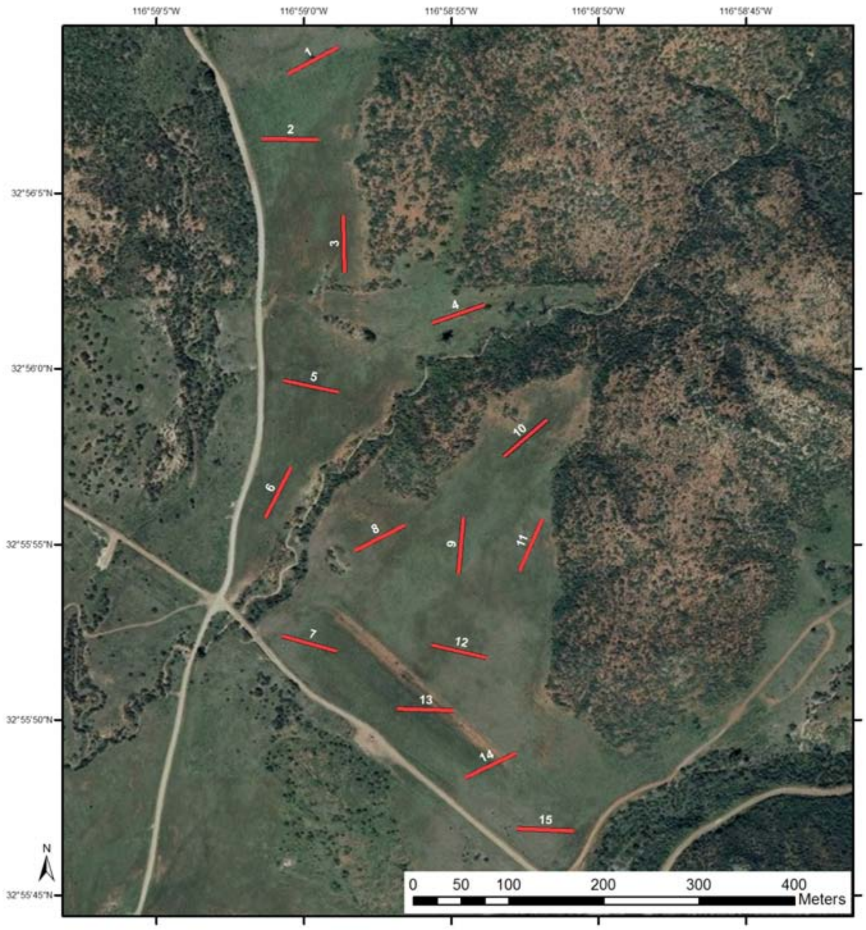


Figure 15. Field biologist Lauren Anderson using a laser point-intercept device to collect data on vegetation height and type on a 10x10 m plot at Rancho Jamul Ecological Reserve.

Figure 16. Soil solutions in graduated cylinders await measurements as sediment settles over a period of 3 hours. Relative density measurements are taken using a hydrometer at 40 seconds, 2 hours, and 3 hours after mixing.

RESULTS & DISCUSSION

We collected habitat data at 40 squirrel burrow plots and 70 absence plots across the 8 grassland sites (Table 8). Squirrel activity was confirmed at 31 of the 40 burrow plots. Analyses were performed on both the full dataset (40 burrows, 70 absence plots) and the subset of active burrows (31 active burrows, 70 absence plots). However, the results were similar for both datasets. Consequently, the results from the full dataset are reported. The results presented are preliminary, pending additional data.

Table 8. 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
Ramona Grasslands	5	10 (9)	15
Rancho Jamul	13	0 (0)	13
Rancho Peñasquitos	2	5 (2)	7
Santa Ysabel	13	2 (1)	15
Simon Preserve	15	0 (0)	15
Sycamore Canyon	14	1 (0)	15
Wheatley Ranch	8	7 (7)	15
Total	**70**	**40 (31)**	**110**

Due to the small sample size, site explained most of the variation between squirrel burrow presence and absence (G^2=76.879, p<0.001; R^2=0.53). Controlling for site, key habitat variables associated with squirrel burrow presence included no vegetative cover, percent sand, and percent gravel (G^2=90.674, p<0.001; R^2=0.63; Table 8), although this model was not better than the site only model (BIC=105.24 compared to 104.93 for the site only model). The positive association between squirrel burrows and percent no cover 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. A better understanding of any methodological and situational differences is required to interpret these divergent findings.

We also had predicted an association between soil characteristics and squirrels, given their fossorial behavior. Squirrels appeared to select sites with soils that had a lower percent gravel and higher percent sand content (Tables 9 and 10). Percent sand was highly correlated with percent silt and clay (Pearson correlation coefficient = -0.8) and it is likely a combination of soil texture, not just sand, that is driving this relationship (Figure 17). Vegetation composition and structure did not test significant (p>0.05), although this may change as more data are collected.

Due to the low number of sites available for analysis, the analysis presented here includes site as a variable to control for any confounding effects. Inclusion of site as a variable also makes it difficult to detect any effects of landscape level features, such as minimum distance to urban development, habitat edge, and water, that are influenced by site-level characteristics. Increasing the number of sites should address this problem.

In 2013, we plan to conduct surveys at additional sites to increase statistical power and generalizability across the variable San Diego County landscape. A more thorough analysis of the data will be conducted once the additional data have been collected. We will also conduct surveys at squirrel translocation sites to better understand outcomes of our translocation efforts.

Table 9. 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
% No Cover	0.248	0.106	5.53	0.019	1.08-1.67
% Sand	0.132	0.055	5.70	0.017	1.03-1.30
% Gravel	-0.335	0.157	4.55	0.033	0.50-0.95

Table 10. Summary of habitat variables for squirrel burrow presence and absence plots.

Variable	Absence		Presence	
	Mean	SD	Mean	SD
Elevation (m)	503.71	313.55	481.64	307.68
Slope (%)	5.40	6.03	4.30	4.25
% Grass	62.18	25.25	58.50	27.91
% Forb	22.76	16.60	23.42	14.07
% Shrub	1.49	6.08	3.17	7.78
% Native	8.67	23.22	9.06	18.79
% Exotic	81.58	24.04	77.08	27.35
% Annual	81.34	23.07	77.14	27.41
% Perennial	8.63	23.64	7.10	16.00
% No Cover	1.71	2.97	3.45	5.69
% Litter	97.72	3.22	96.79	5.01
% Bare Ground	1.80	2.87	2.17	2.54
Mean Veg Height (cm)	16.66	10.10	19.06	11.52
Distance to Edge (m)	183.20	135.53	124.80	96.24
Distance to Urban Development (m)	523.00	243.38	383.13	226.96
Distance to Road (m)	340.73	261.33	422.43	393.95
Distance to Water (m)	620.57	350.09	419.43	268.71
Soil - % Sand	54.97	9.39	62.25	5.98
Soil - % Silt	28.51	5.50	24.58	3.99
Soil - % Clay	16.52	5.88	13.17	3.86
Soil - % Gravel	9.72	9.01	5.68	3.35
Soil Bulk Density	0.91	0.18	0.91	0.09

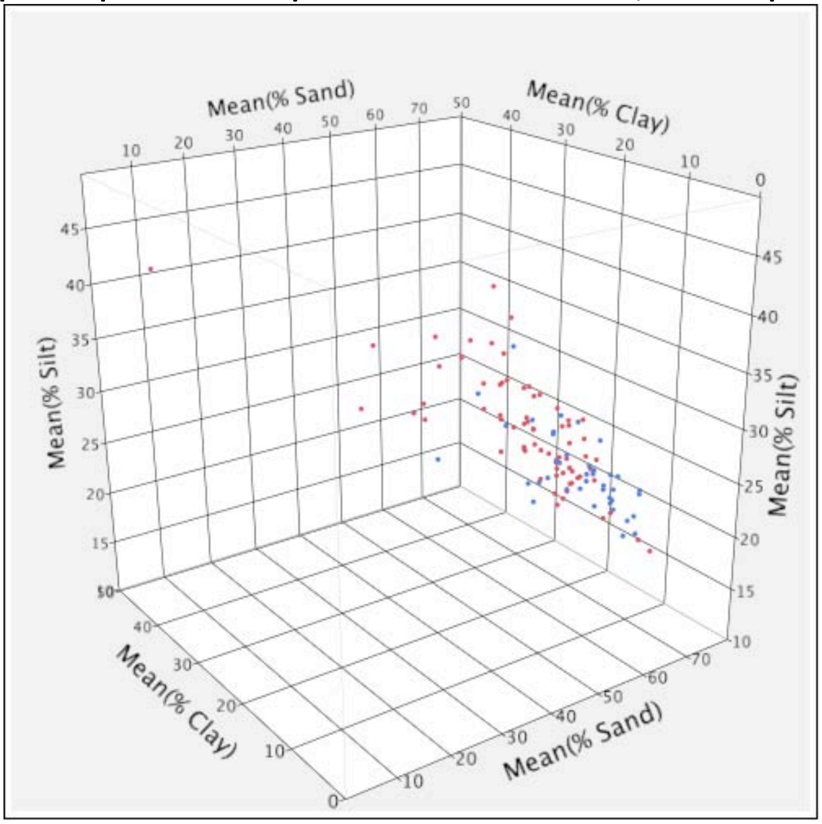


Figure 17. Soil texture in terms of percent composition of sand, silt, and clay for each plot. Squirrel burrow plots are indicated in blue; absence plots in red.

BURROWING OWL MONITORING: PILOT PROJECT

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 burrowing owl reproductive ecology and population dynamics. We deployed camera traps at burrowing owl nest burrows and opportunistically monitored owl nest burrows during the breeding season. Only 8 cameras were deployed and the time invested in this task was minimal, so all results are preliminary. In 2013 we will make this research the focus of greater effort.

METHODS

We opportunistically surveyed and monitored nests along La Media Road near the Lonestar Mitigation Site and along the boundaries of Brown Field Municipal Airport. We continued the camera trap pilot work that was started in 2011. We monitored 5 owl pairs along the eastern border of the Lonestar site (see Figure 4 in California Ground Squirrel Translocation Section) using camera traps. A total of 8 cameras were deployed because of owl movement between burrows. Cameras were placed in the field in early-April and removed in early-October. The remote cameras allowed us to identify banded burrowing owls, as well as to collect data on nest provisioning, non-owl visitors, and reproductive success. In addition, incidental burrowing owl sightings or sign at paired plots was recorded throughout the study period.

RESULTS & DISCUSSION

<u>Opportunistic nest monitoring</u>

We located 18 active burrowing owl nest burrows in the vicinity of the Brown Field Municipal Airport and adjacent to the Caltrans Lonestar Mitigation site (Figure 18). The two nests that were located on the Shinohara restoration area of the San Diego NWR in 2011 were not active in 2012. Three nests in the La Media Road/Lonestar area produced young, but productivity was markedly lower than in 2011 (Table 11). During the winter of 2011-2012, restoration activities began at the Lonestar Mitigation site. This included mowing and clearing a large area of non-native grasses that likely harbored a large small mammal population. The removal of the vegetation may have reduced the small mammal population and impacted the prey base of the owls. The area also experienced lower precipitation during the 2012 rainy season which likely also impacted the owl's prey base. We opportunistically monitored 12 nests along the south, east, and west boundaries of Brown Field Airport (Figure 18). We observed a maximum of 22 burrowing owls and 4 nest sites with young at this site.

Table 11. Summary of Lonestar burrowing owl nests monitored in 2012

Nest Burrow	Color Bands (Adults)	Max Chicks	Status	Notes
Gate 1	M: Green C over R F: Green C over H	0		Both banded as adults in 2011
Gate 2	M: unbanded F: Green B over A	2	1 fledged	"BA"banded as chick in 2011 (offspring of "CR" & "CH")
Euc 5/7	M: unbanded F: Red D over 25	0		"D25" banded as chick in 2011 at NBC
Euc 7 fence	M: unbanded F: Green C over W	1	1 fledged	"CW" banded as adult in 2011
Euc 17/ Euc 17 fence	Both unbanded	1	1 fledged	

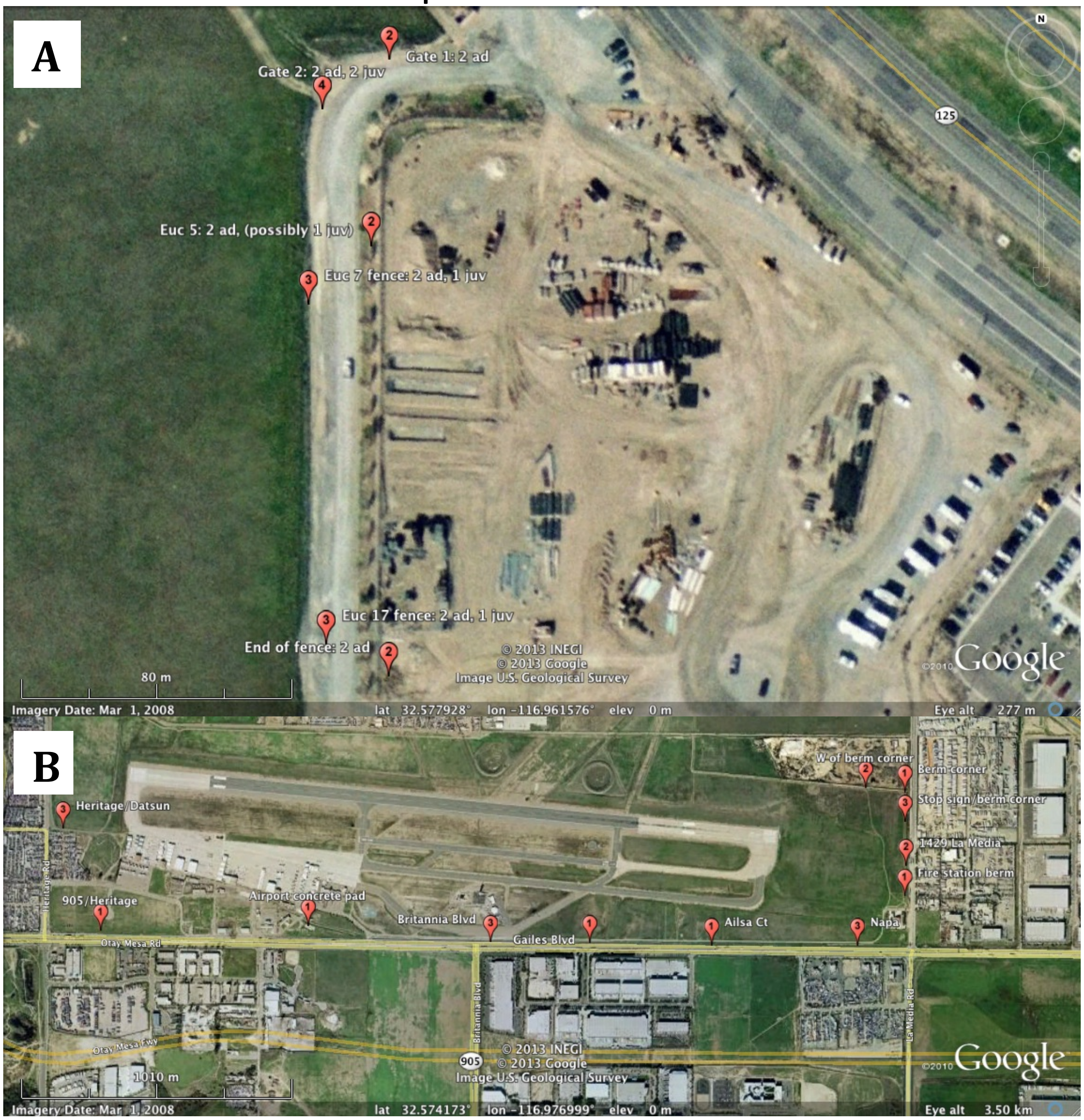
Over-winter burrowing owl presence at experimental plots

At the Rancho Jamul study area, we first detected a burrowing owl at acclimation burrow #7 of the JS control plot on October 10, 2012, and on October 12, an owl (likely the same one) was flushed from burrow #8 of the JS translocation plot. On November 2 and 7, we flushed an owl from burrow #2 at the JE translocation plot. An unbanded burrowing owl showed up in camera trap photos taken at the JB translocation plot on December 5 and 6, and an owl was flushed from burrow #2 of the same plot on January 7, 2013. Burrowing owls regularly winter, but no longer breed, in the Jamul area (Tracie Nelson, John Martin, pers. comm.). Rancho Jamul Ecological Reserve is used as a designated soft release site for rehabilitated burrowing owls as needed throughout the year. In all cases except the camera trap photos, we were unable to determine if the burrowing owls on the experimental plots were banded so individual identification remains unknown.

The pilot banding effort in 2011 already began to pay some dividends in 2012. From these limited data, we now know that birds will return to the same area to nest in the subsequent year. In terms of population recruitment, we found evidence of chicks fledging and returning to the same site to breed, as well as individuals that dispersed from elsewhere (Naval Base Coronado) to breed on the Lonestar site. With a larger number of owls banded and systematic recapture effort, we will be able to better understand survival, individual fitness, dispersal, and other population parameters.

A more targeted banding effort, coupled with intensive re-sighting effort, is recommended for the future. Color-banded burrowing owls will allow individual recognition of birds from known nest sites. Data on fledging numbers will provide information on reproductive success, an important component of population models. Comparison of reproductive success across sites will help identify local factors that may influence reproductive output and chick survival. Return of banded young in future years will provide insights into recruitment and dispersal and settlement patterns. Once burrowing owls leave the study area, any band re-sighting will be instrumental to our understanding of spatial movements, of which we know virtually nothing.

Figure 18. Maps depicting locations of burrowing owl nests, numbers in red flags denote the maximum number of owls seen at that location. (A) Nests monitored at Lonestar; all had cameras except "End of fence" location. (B) Nests monitored along the boundaries of Brown Field Airport.



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Appendix 1. Data tables and site-specific results from squirrel translocation

Translocation to two additional (new) sites at Rancho Jamul

Based on the higher success rate in establishing squirrels at Rancho Jamul in the 2011 translocations, we selected two additional sites to attempt to establish squirrel populations. The source site for all translocated squirrels was Naval Base Coronado.

Jamul Baja

At Jamul Baja we released 59 squirrels on June 7 2012.

One month post-release we conducted 5 days of re-trapping and made 45 captures of 14 individuals. Thus, a *minimum* (we know that trapping severely underestimates population size) of about 24% of translocated squirrels remained alive on site for > 30 days. In addition, several of the translocated squirrels dispersed and settled along nearby riparian habitat occupied by resident squirrels. We placed traps there for 3 days and caught an additional 5 translocated squirrels (9%) and 13 resident squirrels. These existing resident squirrels appeared to serve as an attractant anchoring dispersing squirrels there (conspecific attraction). At least 33% of translocated squirrels remained alive (on and off plot) for 30 days.

Cohort	**Status**		Adult	Juvenile	Unknown	**Total**
2012	Released	Female	2	5		7
		Male	1	5		6
	Escaped	Female			1	1
2012 Total			**3**	**10**	**1**	**14**
Total			**3**	**10**	**1**	**14**

Retrap rates (not including Unknown Escaped individuals): Ad = 16%, Juv = 25%

Telemetry data collected over a longer timeframe, but on a small proportion of squirrels, indicate very high mortality rates. By approximately 3 months post-release 75% (9/12) were known dead. Of these, 100% of deaths are accounted for with known or suspected predation (based on in-field evidence).

Mortalities

Age	**Sex**	**Ear Tag**	**Dye Mark**	**Total Days Survived Post-Release**	**Circumstances/Cause of Mortality**
A	F	1025	∩	5	Collar found west of JC; unknown predator
A	F	1066	A	28	Collar found near road W of JB control pie; unknown predator

A	F	1077	♥	9	Collar found in creek bed; unknown predator
A	M	1078	78	78	Collar and tip of tail found ~75m NE of pie; suspected coyote predation
A	F	1083	O	20	Carcass (skin and collar) found in creek, scavenged by crawfish; suspected raptor predation
A	F	1085	Ξ	18	Collar, tail, and jaw found W of pie/road; unknown predator
A	F	1099	H	39	Collar and remains found W of JS; unknown predator
A	M	1174	H4	41	Suspected Barn Owl predation
A	M	1208	M8	40	Suspected Barn Owl predation

Jamul Central
At Jamul Central 58 squirrels were released on June 7 2012.

One month post-release we conducted 5 days of re-trapping and made 74 captures of 29 individuals, indicating that a minimum of 50% remained on site for at least 30 days.

Cohort	**Status**		Adult	Juvenile	Unknown	**Total**
2012	Released	Female	3	14		17
		Male	1	9		10
	Escaped	Female		1	1	2
2012 Total			**4**	**24**	**1**	**29**
Total			**4**	**24**	**1**	**29**

Retrap rates (not including Unknown Escaped individuals): Ad = 27%, Juv = 57%

However, as for Jamul Baja, telemetry data indicate very high mortality rates, with 9/11 (82%) known dead approximately 3 months post-release. Again, predation appears to be the primary cause of death.

Mortalities

Age	**Sex**	**Ear Tag**	**Dye Mark**	**Total Days Survived Post-Release**	**Cause of Mortality**
A	F	1004	11	53	Collar found in coyote feces ~100m E of pie
A	F	1007	W	60	Carcass found intact N of pie; suspected raptor depredation (dropped by raptor)
A	F	1020	20	74	Collar found under oak deadfall near coyote scat ~200m W of pie; suspected coyote predation
A	F	1022	U	3	Collar and bits of bloody fur found on rock ~150m W of pie; suspected raptor predation
A	M	1028	28	2	Found collar off road E of creek under power lines; suspected raptor predation
A	F	1047	♦	2	Collar found on hill W of JS/S of JC; unknown predator
A	M	1052	52	1	Found dead ~50m E of pie, carcass intact; suspected raptor predation (dropped by raptor)

A	F	1072	^	3	Collar found just N of pie; unknown predator
A	M	1207	M7	3	Collar found W of pie; unknown predator

Supplemental translocations to Rancho Jamul and Sweetwater sites

We conducted supplemental translocations at four of the seven 2011 release sites, selecting those sites that had some squirrel establishment, but were in need of supplementation to increase the possibility for long-term establishment of squirrel populations. Several modifications to the translocation strategy were made to increase squirrel survival and retention, including provision of cover, increased effort to relocate family groups or individuals familiar with one another, and changing the season of translocation to late summer when juveniles are more mature and self-sufficient. Few adults were active at this time of year, so most translocated squirrels were maturing young of the year (near adult size).

Jamul East

We released 44 squirrels on Jamul East on August 13 2012.

Retrapping of the 2012 cohort occurred September 17-21. In total, we had 52 captures of 21 unique individuals at JE one month post-release, indication at least 48% of translocated squirrels remained alive and on plot for more than 1 month.

Cohort	**Status**	**Sex**	Adult	Juvenile	**Total**
2011	Released	Male	1		1
2011 Total			**1**		**1**
2012	Released	Female		6	6
		Male		14	14
2012 Total				**20**	**20**
Total			**1**	**20**	**21**

Retrap rates of 2012 Cohort: Ad = 0%, Juv = 47.6% (not including Unknown Escaped individuals)

Radiotracking of translocated squirrels indicates that 3 of 5 (60%) remained alive for at least 2 months post-release. Predation is implicated in both mortalities.

Mortalities

Age	**Sex**	**Ear Tag**	**Dye Mark**	**Total Days Survived Post-Release**	**Cause of Mortality**
A	M	1266	R6	2	Intact carcass found ~20m NE of pie; could not determine cause of death, but seemed to have

					spinal injury possibly from raptor attack
A	M	1306	V6	7	Collar and fur found ~500m N of pie; unknown predator

Jamul West

We released 34 squirrels on Jamul West on August 13 2012.

Retrapping of the 2012 cohort occurred September 17-21. In total, we had 26 captures of 13 unique individuals at JW one month post-release. Two of these individuals were "new," most likely offspring from the 2011 translocation cohort.

Cohort	**Status**	**Sex**	Adult	Juvenile	Unknown	**Total**
2012	Released	Female		4		4
		Male		6		6
2012 Total				**10**		**10**
New	Released	Male	1	1		2
New Total			**1**	**1**		**2**
Unknown	Escaped	Male			1	1
Unknown Total					**1**	**1**
Total			**1**	**11**	**1**	**13**

Retrap rates of 2012 Cohort: Juv = 29.5%
(not including Unknown Escaped individuals, and no adults were moved)

Radiotracking of translocated squirrels indicates that 1 of 5 (20%) remained alive for at least 2 months post-release. Predation is implicated in all mortalities.

Age	**Sex**	**Ear Tag**	**Dye Mark**	**Total Days Survived Post-Release**	**Cause of Mortality**
J	M	1260	R0	4	Collar and tail found in control center brush pile; unknown predator
J	M	1286	T6	5	Predation (coyote), collar found several hundred meters S of pie in coyote feces
J	F	1288	T8	26	Collar, top of skull, and some viscera found ~100m NE of pie; unknown predator
J	F	1262	R2	32	Collar found SE of pie; unknown predator

Jamul South

We released 44 squirrels on Jamul South on August 13 2012.

Retrapping of the 2012 cohort occurred September 17-21. In total, we had 45 captures of 20 unique individuals at JS one month post-release. Four of these individuals were "new," most likely offspring from the 2011 translocation cohort.

Cohort	Status	Sex	Adult	Juvenile	Unknown	Total
2012	Released	Female		12		12
		Male		4		4
2012 Total				**16**		**16**
New	Released	Female		1		1
		Male	1	1		2
	Escaped	Unknown			1	1
New Total			**1**	**2**	**1**	**4**
Total			**1**	**16**	**1**	**20**

Retrap rates of 2012 cohort: Juv = 36.4%
(not including Unknown Escaped individuals, and no adults were moved)

Radiotracking of translocated squirrels indicates that 3 of 5 (60%) remained alive for at least 2 months post-release. Predation is implicated in all mortalities.

Mortalities

Age	Sex	Ear Tag	Dye Mark	Total Days Survived Post-Release	Cause of Mortality
J	M	1142	E2	15	Collar found on top of grass near game trail and perch tree of RTHA; far from JS; unknown predator
J	M	1332	Y2	4	Chewed collar found on JB control pie (squirrel had moved there previous day); suspected coyote predation
J	M	1363	?3	32	Collar found ~200m SW of pie, no remains; unknown predator

Sweetwater East

We released 50 squirrels on Sweetwater East on August 27 2012.

Retrapping of the 2012 cohort occurred October 1-5. In total, we had 38 captures of 20 unique individuals at SE one month post-release. One of these squirrels was the off spring of squirrels translocated in 2011.

Cohort	Status		Adult	Juvenile	Total
2012	Released	Female		9	9
		Male	1	7	8
	Escaped	Male		2	2
2012 Total			**1**	**18**	**19**
2011 F1	Released	Female		1	1

2011 F1 Total		**1**	**1**
Total	**2**	**19**	**20**

Retrap rates of 2012 cohort: Ad = 33.3%, Juv = 34.0%
(not including Unknown Escaped individuals)

Radiotracking of translocated squirrels indicates that 3 of 5 (60%) remained alive for at least 2 months post-release. Predation is implicated in all mortalities. An additional squirrel escaped its collar and was known to be alive for at least 27 days.

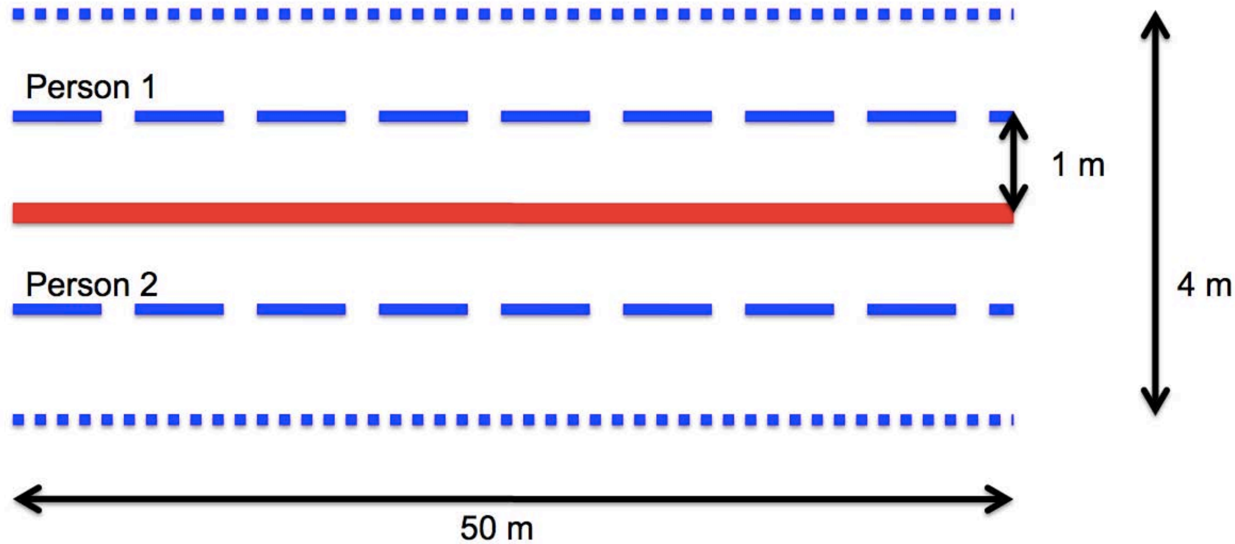
Mortalities

Age	Sex	Ear Tag	Dye Mark	Total Days Survived Post-Release	Cause of Mortality
J	M	1413	13	20	Tail and collar found ~20m W of SE control pie; unknown predator

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)

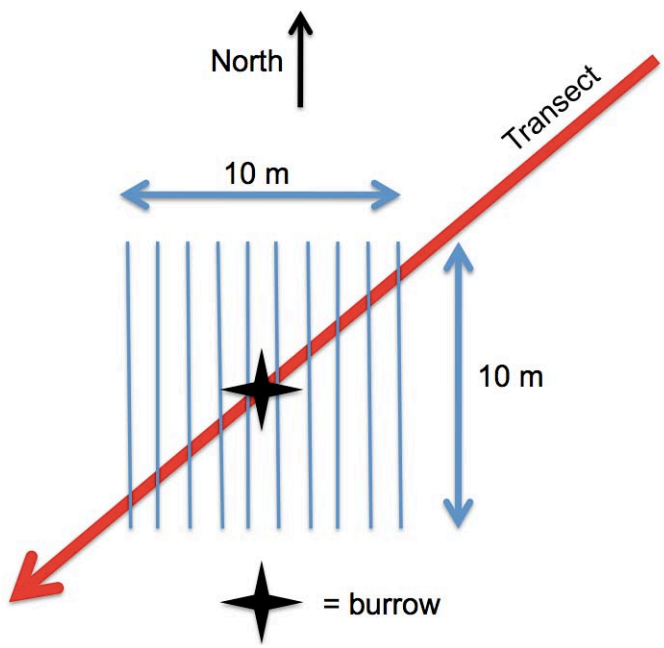
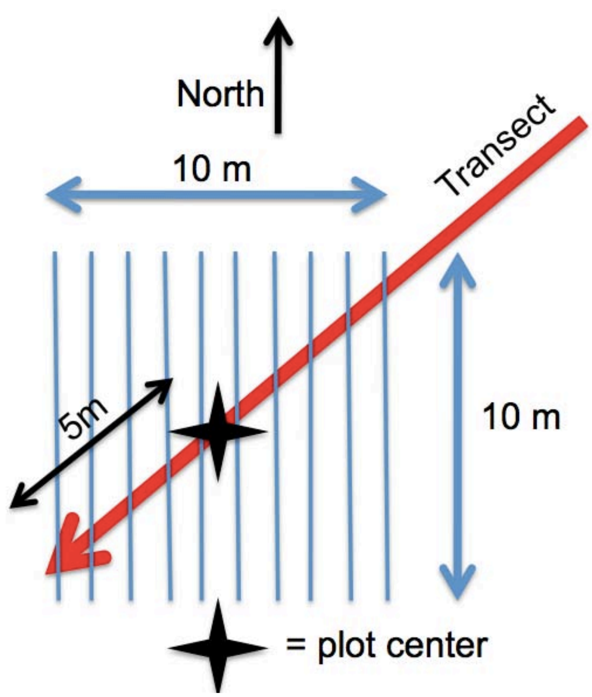


Figure 3. 10x10m Plot Set-Up for Absence Transect (not drawn to scale)



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 hexametaphospahte 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 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.