Project Report

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

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EXECUTIVE SUMMARY

We report on the first 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 (*Spermophilus 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. Hereafter, we use the term "we" to describe activities conducted jointly by ICR and SDSU.

Our immediate short-term objective for year one was to improve habitat conditions for BUOW by creating more open habitat that they favor, and re-establishing ground squirrels which create the burrows upon which BUOW depend for nesting. To create better habitat for BUOW in three protected areas considered suitable for BUOW recovery (Rancho Jamul Ecological Reserve, Lonestar Ridge West Mitigation parcel on Otay Mesa, and Sweetwater parcel of the San Diego National Wildlife Refuge), we established seven paired plots. Each of the 14 plots received identical vegetation enhancement treatments, consisting of three treatments: (1) mow (2) mow plus soil disturbance (augur), and (3) a control treatment. At seven experimental plots, we translocated a total of 327 squirrels (33-59 per plot). We used "soft-release" methods consisting of on-site above/below-ground acclimation chambers and supplemental feeding. We monitored the success of squirrel establishment using five complimentary methods: (1) direct observation, (2) live trapping (3) camera trapping (4) radio-tracking a subset of squirrels, and (5) burrow surveys. We monitored squirrel habitat impacts (ecosystem engineering) using burrow surveys and vegetation transects describing vegetation structure and other variables.

Results for year 1 experiments were mixed and point to lessons learned for future attempts to restore BUOW habitat. Of the seven experimental plots receiving translocated squirrels, our data indicate squirrel establishment at only three plots. The best evidence suggests that soil compaction was the primary determinant limiting successful squirrel establishment at three of the failed sites, but future research is needed to understand the effects of soil characteristics on squirrel establishment. Squirrel mortality (primarily due to predation) and off-plot dispersal was high, particularly at the failed sites. Our methods do not allow population estimation (due to low sample size), but combined methods at two of the successful plots on Rancho Jamul indicate that a minimum of at least 20% of squirrels released there remained on the plot 6 months later. This outcome is considerably better than that reported in the literature for previous attempts to

translocate California ground squirrels. Burrow surveys indicate successful squirrel establishment at the same plots as the other methods, with 130 burrows distributed across the three most successful plots and only a single burrow located on the other four plots 9 months following translocation.

The most robust result we discovered was the effect of the squirrel translocation treatment. Surveys in March 2012, 9 months following the translocations, indicated that squirrel burrowing activity was almost exclusively on translocation sites (131 burrows on translocation sites versus 1 on control sites). These results suggest that active translocation of squirrels will be needed to re-establish squirrel populations in at least some important sites for BUOW recovery. Vegetation treatments also affected squirrel establishment, with ca. 90% of burrowing activity located in one of the two mow treatments, indicating the importance of creating more open habitat for squirrel establishment.

BUOW were also detected using several of the habitat enhancement plots (both experimental and control), and were found to occupy some of the artificial acclimation chambers established for squirrels, providing early indications that the enhancements may have helped create suitable habitat for BUOW.

In addition to the habitat enhancement and squirrel translocation research, we also conducted pilot studies of BUOW and their predators. We deployed camera traps during the translocated squirrel acclimation period (when they were held in acclimation chambers before release) to monitor predator activity. We also deployed camera traps at two experimental plots at Rancho Jamul to monitor predators and squirrels post-release for 6 months. Results indicate that camera trapping is an effective tool of understanding predator activity and demonstrate that the common raven (a potential predator on pups), the red-tailed hawk, and the coyote were frequent visitors to the sites.

We discovered and opportunistically monitored 20 active BUOW nests, most of them near the Lonestar study site. The two nest sites we monitored on Sweetwater appeared to fail. At the Lonestar site we monitored 6 nests closely using camera traps. These nests fledged 39 chicks (an average of 6.5 chicks fledged per nest), indicating the high productivity of this area and a potential major role for population recruitment. All of the BUOW monitored in this area inhabited natural squirrel-dug burrows and appeared to benefit from an abundance of prey.

Our pilot work also included color-banding BUOW for individual identification. We captured and banded 21 individuals. Although we did not invest effort in systematic re-sighting, casual monitoring of the site allowed us to determine that some of the adults and juveniles banded on the Lonestar site during the breeding season were also present during the winter non-breeding season. This is the first known documentation of year-round use by individual birds at this site.

At the conclusion of this report we provide a list of specific recommendations to improve habitat enhancement and ground squirrel establishment at BUOW recovery sites, to obtain a better understanding of the population dynamics of BUOW in San Diego County, and to determine the factors that regulate BUOW populations. We also provide specific recommendations for management of each of the three sites where this research was conducted.

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INTRODUCTION

1.1 *Setting*

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. Private ownership holds 86% of California grasslands, as they are so favorable for human uses such as grazing, agriculture and housing developments (Davis, Stoms 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 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.

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 year-one of a multi-year study to restore ecological function to grassland communities in San Diego County by re-establishing ground squirrels and ultimately, burrowing owls.

1.2 *Justification for Translocation*

Because the California ground squirrel is a "key" 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). California ground squirrel colonies are increasingly associated with many special-status species including burrowing owl, but also golden eagle, San Joaquin kit fox, California tiger salamander, and California red-legged frog (Loredo and Van Vuren 1996; Thomsen 1971).

The case for burrowing owl dependency on ground squirrels in California appears strong. Burrow availability may limit burrowing owl abundance because owls rarely dig their own burrows, and as such, depend on other burrowing mammals, particularly California ground squirrels, for nest sites. Moreover, burrowing owls prefer the suite of habitat characteristics found on colony sites (Green & Anthony 1989; Clayton & Schmutz 1999) in which ground squirrel foraging and digging promote open areas of short grass and bare ground (Green & Anthony 1989) that enhance both burrowing owl foraging ability, and the viewing of approaching predators. The "ecosystem engineering" of ground squirrels also increases availability of some burrowing owl prey species such as grassland birds, ground beetles and centipedes (Lenihan 2007). Finally, ground squirrels may serve as antipredator sentinels, since both squirrels and owls fall prey to the same predators. Ground squirrels are highly vigilant animals that use antipredator vocalizations and visual displays to maintain an early warning system for predator detection and deterrence (Owings & Hennessy 1984; Loughry & McDonough 1988; Swaisgood *et al.* 1999). By "eavesdropping" on these antipredator alarms, burrowing owls may avoid predation, as suggested by the lower levels of predation on burrowing owls living in active black-tailed prairie dog towns (Desmond *et al.* 2000).

Human development of grasslands is certainly responsible for the decline of burrowing owls in San Diego, but the loss of burrowing owl populations in undeveloped areas (e.g. Camp Pendleton,Warner Ranch) cannot be explained by habitat conversion. Elimination of ground squirrels or crushing of burrows may have made these areas unsuitable as burrowing owl breeding sites. Continued eradication efforts keep ground squirrels at 10-20% of their historical carrying capacity (Marsh 1987), in numbers below the threshold density needed to adequately perform their role as ecosystem engineers (Kotliar 2000), thus contributing to the ecological simplification of grassland ecosystems and the loss of dependent species like the burrowing owl. Reversing these trends for ground squirrels will be a necessary component of any strategy to bring native grasslands and their inhabitants back into a more natural balance. Re-establishing a "pest" species might seem easy, but may not be so simple. As noted by Salmon & Marsh (1981), "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).

1.3 *Project Goals*

Our goal is to foster the re-establishment of ecosystem processes that are less reliant on constant human intervention and thus more cost-effective in the long-term. Initially, our aim is to create suitable burrowing owl habitat through the ecosystem engineering activity of ground squirrels that will be self-sustaining.

In conjunction with the south county interagency burrowing owl working group formed to address conservation issues facing owls we are pursuing three main objectives:

1. Increase our understanding of the role California ground squirrels play in "engineering" grassland ecosystems and burrowing owl habitat.
2. Develop an effective strategy for re-establishing ground squirrels in areas where they have been extirpated.

3. Increase conservation-relevant knowledge of burrowing owl ecology in San Diego County.

1.4 *Ground Squirrel Translocation Strategy*

As a means to improve grassland habitat for burrowing owls and other species of concern, we initiated the development of a scientific, ecologically relevant, strategy for relocating California ground squirrels. Success is contingent upon our ability to translocate California ground squirrels to the restoration site 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). Such methods have been established for black-tailed prairie dogs by a member of our team (Shier 2006; Shier & Owings 2006) and we will apply some of the lessons learned from her work to California ground squirrels. In some cases, these "ecologically relevant" modifications to the post-release environment can increase survival and reproduction by at least 5- to 10-fold. Thus, investing resources into developing a ground squirrel translocation strategy will decrease future costs.

Our efforts focus on two interconnected tasks:

1. Design an effective translocation protocol for the California ground squirrel in southern San Diego County by conducting controlled experiments within an adaptive management framework.
2. Using California ground squirrels as ecosystem engineers, monitor the effects of ground squirrel activity (digging and foraging) as an attractant for burrowing owls to more secure and sustainable protected habitat.

1.5 *Collaborative Project Development and Stakeholder Participation*

This program was designed as a collaborative effort to combine the expertise of two partner organizations, the San Diego Zoo Institute for Conservation Research (ICR) and the Institute for Ecological Modeling and Management at San Diego State University (IEMM at SDSU). The goals of this project were developed in consultation with an interagency group of south county land managers, scientists, and regulators (US Fish and Wildlife Service, CA Department of Fish and Game, San Diego Management and Monitoring Program, IEMM, and ICR). The experimental design for all aspects of this adaptive management program were co-developed to ensure that the two projects and resulting data can be integrated. In year one of this multi-year study, ICR's focus was to establish a successful ground squirrel translocation program to create self-sustaining burrowing owl habitat, along with preliminary ecological studies of the existing burrowing owl population. IEMM scientists conducted the translocation site vegetation enhancement, and monitored habitat utilization. ICR/IEMM collaborated to evaluate the efficacy of habitat enhancements.

1.6 *Personnel*

Principle Investigators:
Ron Swaisgood, Ph.D., Debra Shier, Ph.D., Colleen Lenihan, Ph.D.

Field Team:
Field Organizer: Colleen Lenihan, Ph.D.
Field Technicians: Colleen Wisinski, M.S., JP Montagne, Christine Slocomb, M.S., Frank Santana, M.S.
Interns: Kira Marshall, Stephanie Wakeling
Handyman: Kreg Mills
Camera technical advisor: Scott Stender
Volunteers from San Diego Zoo Global, High Tech High School

1.7 *Permits*

Prior to the start of fieldwork, we contacted all permitting agencies and acquired the appropriate state and federal permits required to conduct squirrel translocations and capture / color band burrowing owls. The following permits were obtained: Colleen Lenihan, Ph.D. renewed her CDFG Scientific Collecting Permit and consulted with Esther Burkett and Scott Osborn of CDFG to gain permission to handle burrowing owls and translocate California ground squirrels, SCP #801057-05; Colleen Lenihan also became a sub-permittee under Clark Winchell's USFWS Federal Bird Banding Lab master permit: #22452. This project was approved by SDZG's International Animal Care and Use Committee (IACUC) and operates in accordance with all IACUC provisions under Project #11-017.

STUDY AREA

2.1 *Study Area*

The study sites are all located on conservation areas within southwestern San Diego County, within a study area that encompasses the largest remaining population of burrowing owls in the county. Working with our partners and stakeholders, we identified parcels of land within a network of newly protected areas that may hold promise for grassland restoration and burrowing owl recovery. In collaboration with SDSU we established 7 paired plots across 3 study locations.

The study is being conducted on three sites in southern San Diego County (Figures 1-4):

1. Rancho Jamul Ecological Reserve, managed by the California Department of Fish and Game, three paired plots.
2. Lonestar Ridge West Mitigation parcel in Otay Mesa, owned by the California Department of Transportation, two paired plots.
3. Sweetwater parcel of the San Diego National Wildlife Refuge, managed by the U.S. Fish and Wildlife Service, two paired plots.

All three sites have a history of burrowing owl presence. Lonestar and Sweetwater harbor breeding populations, and wintering burrowing owls have been observed on Rancho Jamul, which also maintains a designated area managed for the soft release of displaced owls. The Shinohara restoration area, part of the National Wildlife Refuge, has ten artificial burrow sites.

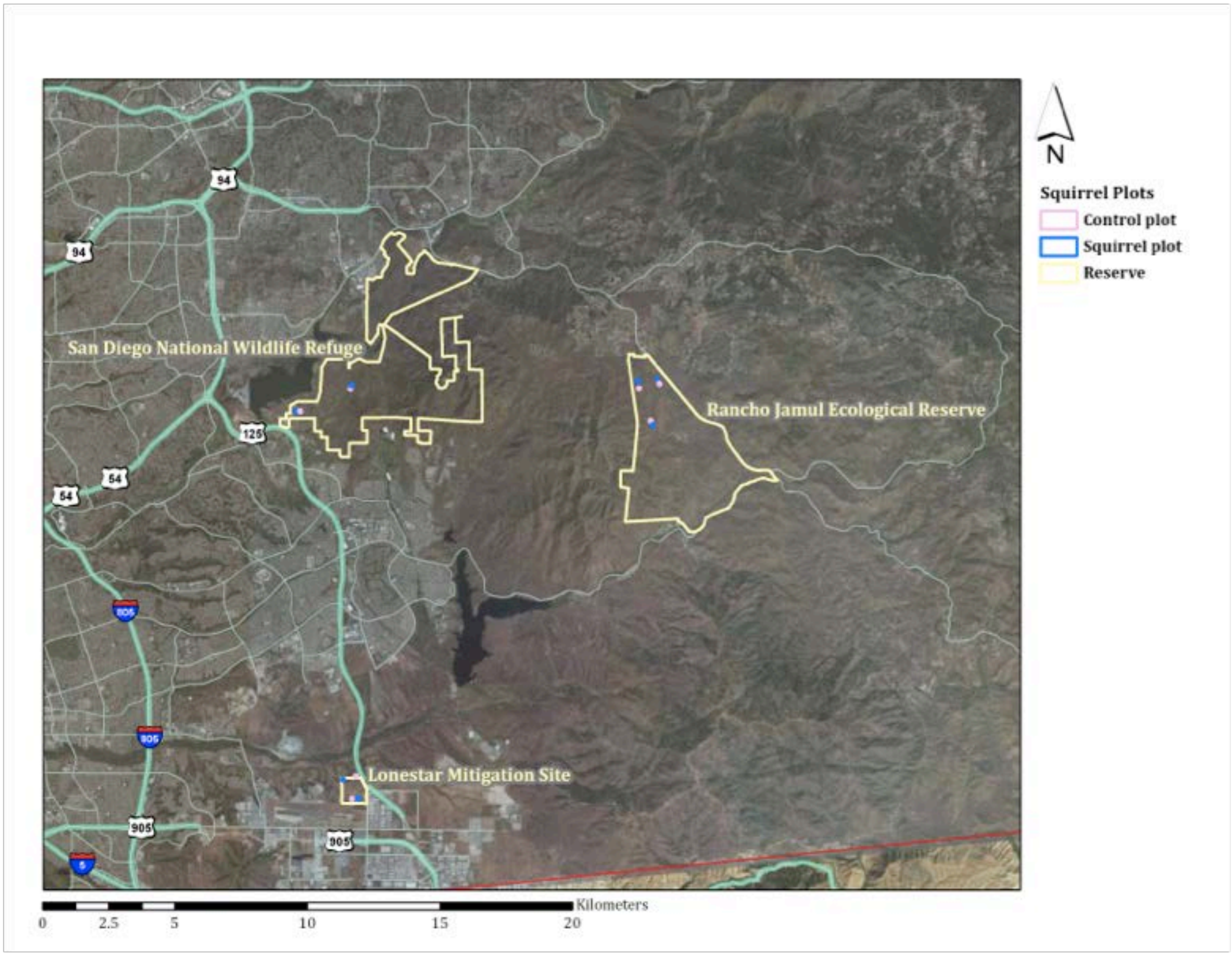


Figure 1. Study Area designating three translocation sites from north to south:

1. San Diego National Wildlife Refuge, Sweetwater Unit
2. Rancho Jamul Ecological Reserve
3. Lonestar Mitigation Site, Otay Mesa

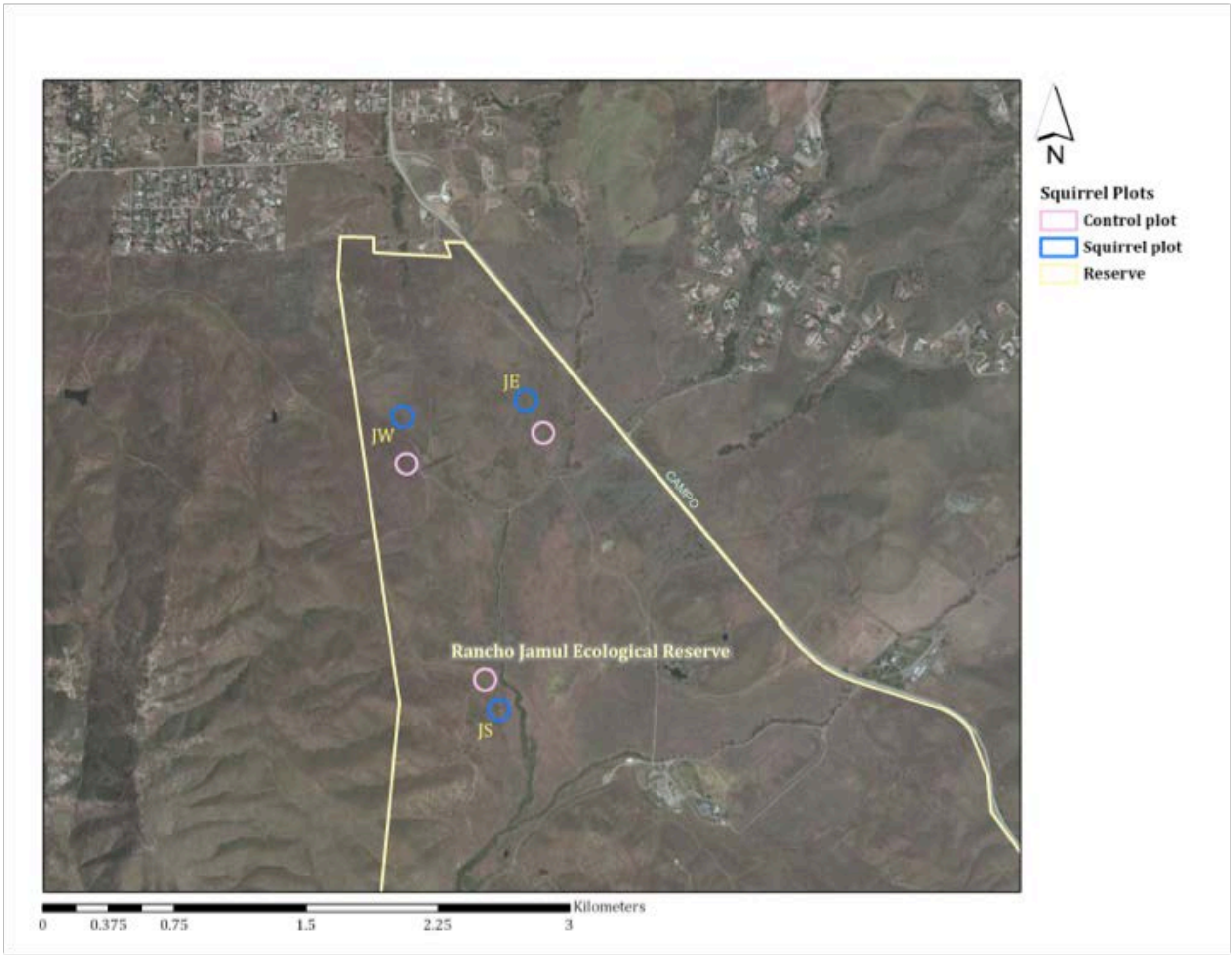


Figure 2. Rancho Jamul Ecological Reserve: 3-paired (squirrel plot, and no-squirrel control plot) replicates

1. Jamul South (JS)
2. Jamul West (JW)
3. Jamul East (JE)

Figure 3. Lonestar Mitigation Site, Otay Mesa: 2 paired replicates

1. Otay North (ON)
2. Otay South (OS)

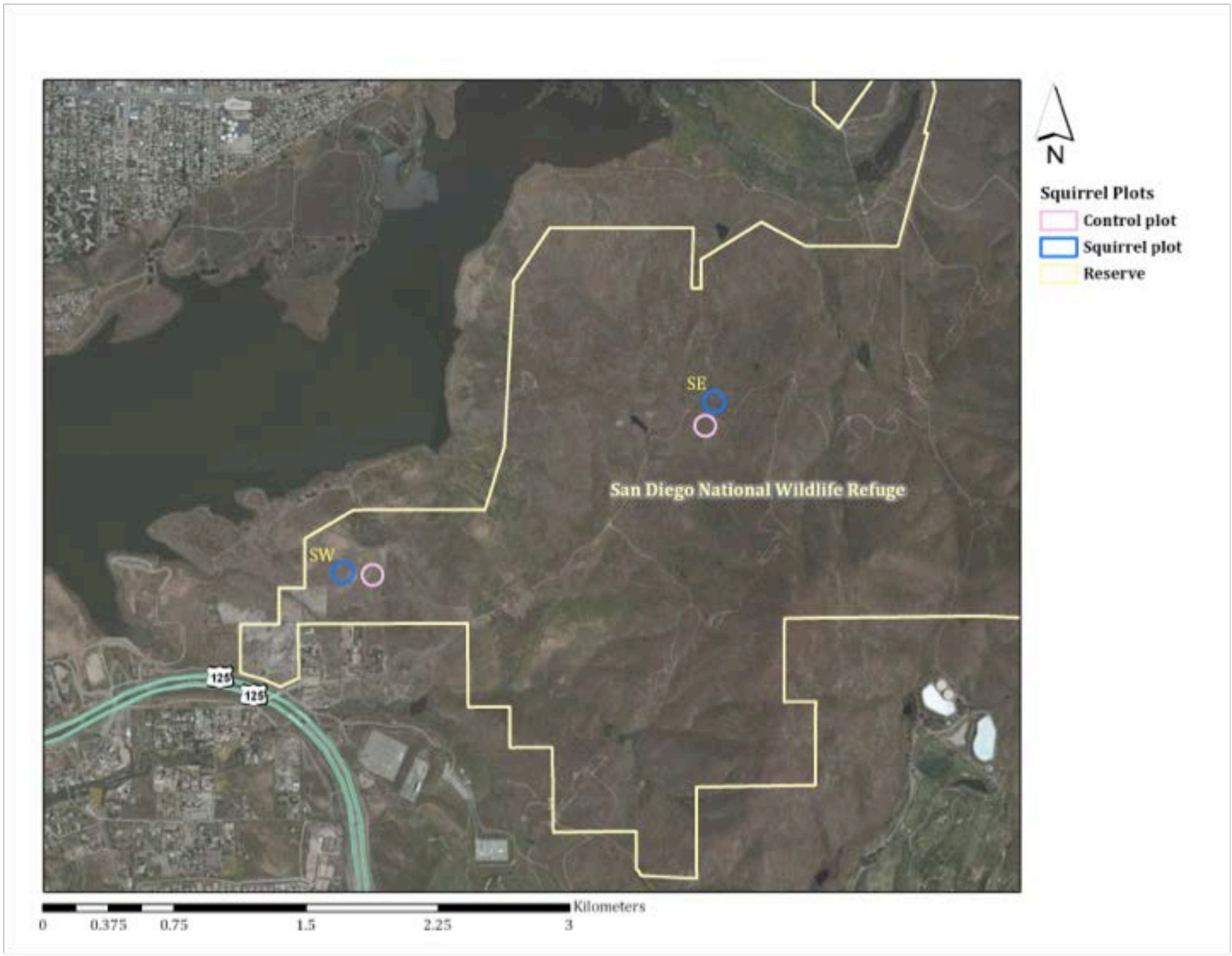


Figure 4. San Diego National Wildlife Refuge, Sweetwater Unit: 2 paired replicates

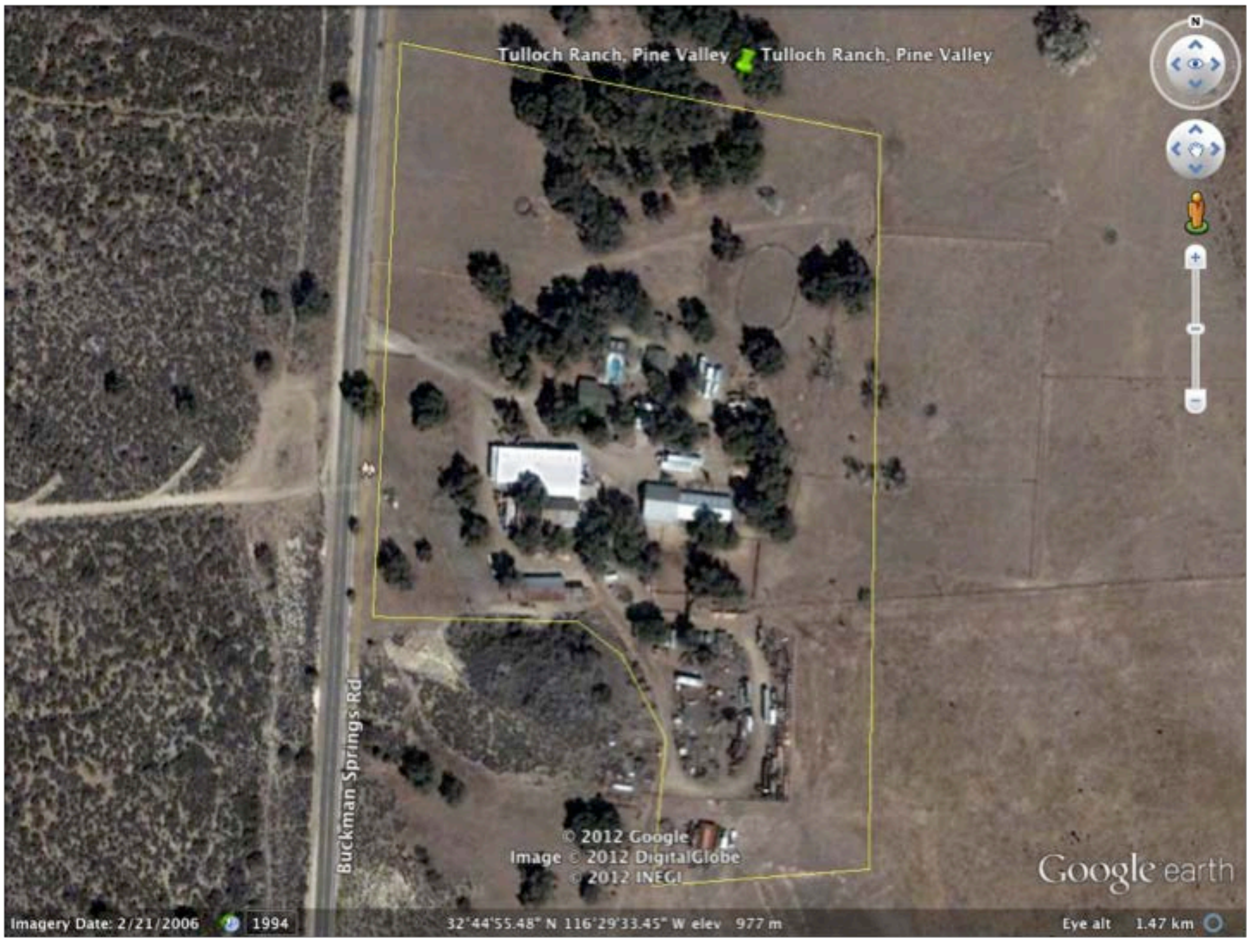
1. Sweetwater West (SW)
2. Sweetwater East (SE)

2.2 *Source Sites*

All of the translocated California ground squirrels were trapped within southern San Diego County from sites designated as inland or coastal source sites. Two inland sites were used to obtain squirrels for three experimental plots. The Tulloch Family Ranch is located in the southern foothills on Buckman Springs Road in Pine Valley (N 32°44’55.51”, W 116° 29’ 33.41”, elevation 977 m). ICR trapped squirrels around the ranch headquarter barns and in oak savanna and grassland areas used for grazing cattle. The Daley Ranch is located in Jamul (N 32° 40’ 47.41”. W 116°° 51’ 20.50”, elevation 240 m). Similar to the Tulloch ranch, squirrels were trapped from areas surrounding headquarter buildings, pastures, orchards, and landscaped areas.
One coastal site was used to trap squirrels to fill the remaining 4 experimental plots. Naval Base Coronado (NBC) granted ICR access to trap squirrels at various locations south of the airfield (N 32° 41’ 28.54”, W 117° 12’ 27.22”, elevation 7 m). 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.

Aerials below show the trapping area at the Tulloch Ranch, Daley Ranch, and Naval Base Coronado.



Daley Ranch HQ
Daley Ranch Truck Trail
© 2012 INEGI
© 2012 Google
Google earth
Imagery Date: 8/23/2010
1994
32°40'45.31" N 116°51'21.26" W elev 243 m
Eye alt 1.01 km


Munitions Curve
Taxiway
Parking Lot
NBC Radar Field
Garbage Wall
Rogers Rd
Heritage Park
Rifle Range
Moffett Rd
Dump
© 2012 Google
© 2012 INEGI
Google earth
Imagery Date: 8/23/2010
1994
32°41'24.64" N 117°12'47.37" W elev 4 m
Eye alt 1.41 km

TRANSLOCATION EXPERIMENT METHODS

3.1 *Site Set-up & Treatment: Paired Experimental Design*

ICR and IEMM worked together to select and designate site locations in the field, and to design the configuration of installed burrows within each plot. IEMM conducted the habitat enhancement treatments on each site in which each paired treatment (experimental squirrel treatment/no squirrel control) received identical habitat enhancement. ICR prepared the plots for squirrels, installing acclimation burrows, and conducting all aspects of the squirrel translocation.

3.1.1 *Plot Establishment*

The site selection rules were designed to include locations with an existing plant community of native or exotic grassland. Sites were established on a range of soil types; however, soil consisting of dense and heavy material such as clay may not be suitable for burrowing. Also, squirrels are not strong enough to move rocks and cobbles out of the way. For these reasons, the Diablo clay soil type was excluded as unsuitable for burrowing activity. We established 7 pairs of plots across the three study sites to allow us to account for variation due to site. The proposal called for up to 9 pairs of plots, but the number was reduced due to space constraints and management restrictions such as established buffer zones around breeding bird nests and cultural sites. The plots were paired for vegetation community, soil type, slope, and aspect. West-facing aspects were avoided to reduce exposure to high temperatures at relocation sites that may limit squirrel activity. The plots were spaced to maintain a distance of at least 75 m between plots in a pair, and at least 300 m between different pairs.

3.1.2 *Plot Size and Layout*

Each circular plot constitutes a “pie” 100 m diameter, with an area of 7854 m^2 (1.94 acres). Individual plots are divided evenly into three wedges on the compass bearings of 0, 120, and 240 degrees. Each wedge encompasses 2618 m^2 (0.65 acres) and is considered an experimental subplot consisting of the following treatments: (1) control, (2) a mowing and de-thatching, and (3) mowing, de-thatching, and soil de-compaction via auguring holes. In total, 30 acres of habitat were mowed and de-thatched, and hundreds of starter holes were augured for squirrels.

In each pair of plots, one plot received the squirrel translocation treatment, and the other plot did not (Figure 5). The paired plot design allows us to separate the direct effects of vegetation manipulation from the ecosystem engineering effects of ground squirrels.

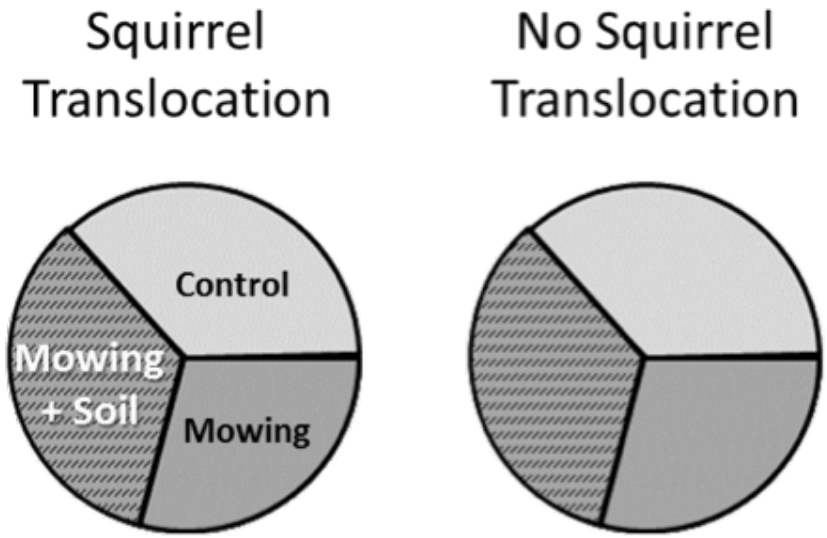


Figure 5. Paired design of the habitat enhancement/squirrel translocation experiment

3.1.3 *Habitat Treatment Methods*

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

Treatment 2: Mowing, thatch removal, and soil de-compaction. The mowing and thatch removal for Treatment 2 were the same as above. Soil de-compaction was conducted with a one-person handheld auger fit with a 6 in. auger bit. The target result was a hole 0.3 m deep on a 45-degree angle into the ground, with some variation due to soil compaction and rockiness. Twenty holes were drilled per wedge to produce a density of one hole every 10 m^2, evenly distributed across the wedge.

Plot orientation: In most plots, the treatments were assigned as follows: Treatment 1 (0-120 degrees), Treatment 2 (120-240 degrees), and Control (240-360 degrees). On plots adjacent to a feature such as a riparian strip or an archaeological site, the Control plot (no mowing or soil de-compaction) was located on the side nearest to the feature, so as to minimize disturbance. The only plot that this rule applied to was Sweetwater East Control, where the Control was assigned to the 0-120 degree wedge, Treatment 1 was assigned to the 120-240 degree wedge, and Treatment 2 was assigned to the 240-360 degree wedge.

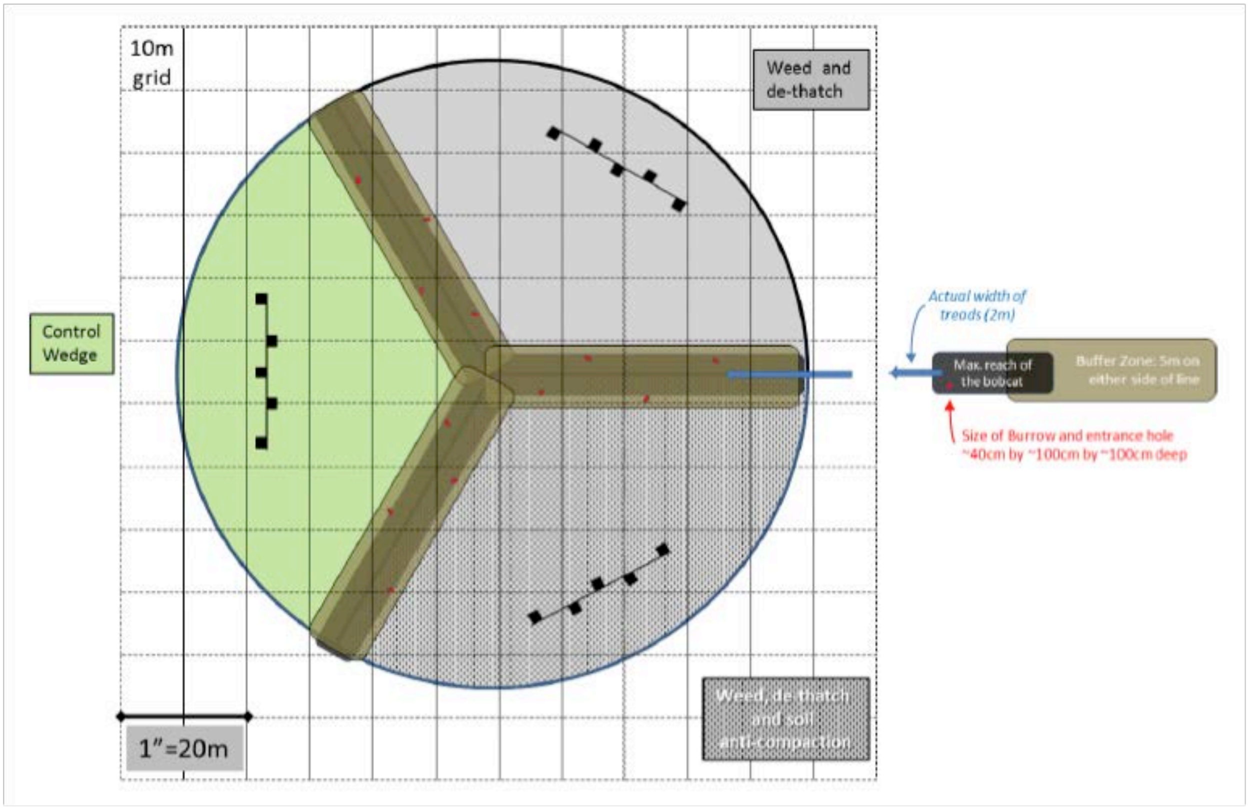


Figure 6. Scaled diagram of plot layout
The burrows were located along the strips dividing each treatment. Gray shading indicates both the footprint of the mechanized equipment used to install the burrows and the furthest reach of the digging arm. Burrows are denoted with red symbols that approximate the size of the burrow footprint. Vegetation transects are shown as a black line with squares that represent 1 m^2 quadrat locations.

3.1.4 *Installation of Below-ground Acclimation Burrows*

Translocation requires holding and acclimating squirrels on the experimental pie in underground cages. Using a backhoe to dig a one-meter trench, ICR installed 12 artificial burrows on both the control and experimental pies (Figure 6 and FIgure 7). Control plots received artificial burrows to limit any confounding effects associated with artificial burrow creation. On the experimental pie, a 19-gauge wire mesh cylindrical burrow chamber (30 cm diameter x 30 cm height) was buried to 1 m depth. Affixed to the burrow chamber was a tunnel (10 cm diameter perforated flexible black drain pipe) that sloped to the surface with a slight bend mimicking a natural squirrel burrow. In addition, a rectangular layer of chicken wire was laid over the top of the backfilled footprint of the underground chamber to deter predator digging. Similarly, on the control pie, the tunnel was installed to the same specifications to mimic the above/below ground disturbance and footprint.

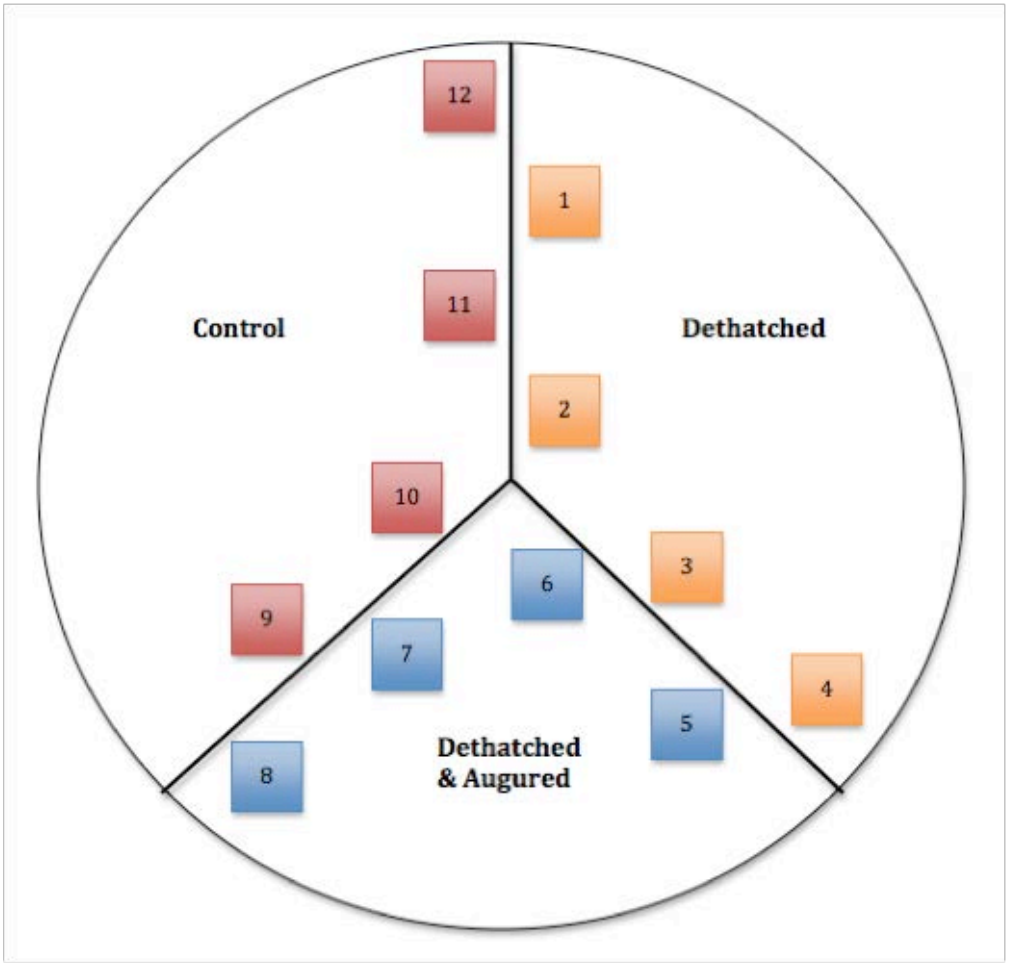


Figure 7. Diagram of acclimation setup

3.2 *California Ground Squirrel Procedures*

3.2.1 *Source-site Trapping*

California ground squirrels were captured for relocation from source sites at North Island Naval Base Coronado (NBC) and at local ranches in Pine Valley and Jamul. Our original target number was 30-50 squirrels per experimental replicate across 7 sites, for an approximate total of 300 translocated squirrels. 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 in 2011. Still, we aimed to increase the success of relocation efforts by trapping ground squirrels residing within close proximity and thus maintaining groups that would be familiar with one another throughout the translocation process. The target release group for one pie comprised a minimum of three adult males, and six adult females that were associated with weaned pups.

All live-trapping, processing, and radio-collar procedures followed the guidelines established by the American Society of Mammalogists. Squirrels were captured from designated source sites using Tomahawk® live traps and Black Fox® repeating one-way door traps baited with livestock feed (rolled oats, rolled barley, cracked corn, and molasses) or cat food kibble. Source sites were deliberately chosen for their high abundance of resident squirrels to increase trap efficiency. Source sites had existing lethal control practices in place, thus experimental translocation provided an alternative use for these animals. Traps were set in the early morning around burrow complexes, checked every half hour, and closed by late morning to avoid high temperatures. The translocation schedule required that capture of squirrels for one plot was completed in 4-6 days. At the end of each morning trap session, all squirrels were transported to the holding facility to be processed.

3.2.2 *Processing & Holding*

All California ground squirrels were transported in an enclosed vehicle to a temperature-controlled modular home located at Rancho Jamul Ecological Reserve, Daley Ranch Headquarters (generously provided by Tracie Nelson, CDFG reserve manager) to be processed and held prior to translocation. ICR biologists performed a health check, designed in consultation with a San Diego Zoo veterinarian, for all captured squirrels. To reduce fleas and disease transmission between both conspecifics and human handlers, biologists used flea powder in handling bags to dust newly captured squirrels. In addition, squirrels weighing over 300 g were also treated with 0.5 ml of Frontline (fipronil), placed on their skin at the back of the neck, during processing. This treatment is effective within 24 hrs and lasts for 30 days. For each squirrel, age, sex, weight and reproductive condition were recorded. Every squirrel was individually marked with standard ear tags (National Band and Tag) and a unique pelage dye for individual identification (see photos below).

Once squirrel litters are weaned and appear aboveground, they mix with nearby litters from neighboring females that are often kin, making it difficult to reliably pair adult females with young. For this reason, squirrels were sorted into four groups for holding and later translocation: (1) adult males housed individually in 60 x 90 x 30 cm hardware cloth cages, (2) females held together with known young, (3) adult females captured in close proximity, and (4) juveniles of similar age captured in close proximity; groups were housed in larger 90 x 90 x 30 cm cages. Squirrels were held on-site for 2-11 days depending on their capture date.

In consultation with SDZG's mammal keepers and animal nutritionist, biologists developed a plan to care for squirrels in holding. All cages were bedded with pine shavings and/or Bermuda grass hay. Burrow tubes made from PVC were placed within the cages as refuge shelters to mimick a squirrel burrow (see photos below). In the wild, California ground squirrels get most of their water from food, so in addition to a complete rodent block feed, squirrels in holding and acclimation were given free access to water via a bottle, as well as moisture-rich food such as apples, sweet potato and carrots.

Photos:
Above: California ground squirrels (juveniles) in holding cages after processing (ear-tags and dye-marks).
Below: Holding cage with burrow tube.

3.2.3 *Radio-telemetry*

Near the end of the holding period, a subset of adult squirrels (38 total) were equipped with VHF radio-collars to allow tracking and monitoring of individual squirrels post-release. ICR biologists followed the established guidelines for transmitter use, installing transmitters weighing less then 5% of an animal's body weight attached as a 4 g neck collar with an average battery life of six months (model: Holohil® PD-2C, www.holohill.com/bd2c.htm). SDZG veterinarians administered gas anesthesia at the holding facility to aid ICR field biologists in fitting collars onto adult squirrels. Collared squirrels were monitored post-anesthesia to assure recovery, and held for 24 hrs prior to being placed in acclimation cages on site. Upon release, all collared squirrels were tracked twice a week for 12 weeks. Any squirrels with active transmitters continued to be tracked at least once per week thereafter. Transmitter batteries were rated to 6 months, but some collars remained viable so tracking continued until February 2012. In addition, near the end of the transmitter s battery life in late October, ICR biologists took two plane flights over the area to aerially track missing squirrels.

3.2.4 *Acclimation On-site*

To limit dispersal, and allow squirrels to acclimate to the relocation site, we used a "soft release" method in which squirrels were held in acclimation cages on site for one week. All acclimation cages had an above- and below-ground component. Underground, the burrow chamber and tunnel serve as a refuge and initial home-burrow during the acclimation period and later post-release. The above-ground retention cage is attached to the burrow entrance in preparation one to two days before squirrels are taken from holding and put into acclimation. This design allows movement of squirrels between the burrow chamber and the above-ground retention cage, but precludes escape during the acclimation period. Acclimation cages consist of an underground nest chamber (30 cm diameter x 30 cm high) set 1 m underground, one plastic drain tile tube (10 cm diameter x 1.3 m length), which connects the nest chamber to the surface, and an above-ground wire retention cage (1 m x 1 m x 0.5 m) (see photo). As an added precaution, the footprint of the dug surface was covered with chicken wire to prevent predators from digging up the underground cage. In addition, the site was surrounded with a battery-powered electric-tape fence to deter predation attempts by coyotes. Three Cuddeback® camera traps were installed equidistant along the circumference of the circle to monitor the frequency of predator intrusions during the week squirrels were held in acclimation.

During the one-week acclimation period, squirrels were provided with water bottles and feed similar to the holding period. Squirrels were transported to the acclimation site and released into the above-ground cages in familiarity groups described above. Biologists observed each squirrel until it entered the burrow. All squirrels quickly found the burrow entrance and disappeared below-ground.

Photo: Below and above-ground acclimation setup before installation

3.2.5 *Release and Post-monitoring*

On release day, acclimation cages were removed during the mid-day heat when squirrels are generally inactive resting underground. Upon release, the ICR field team immediately began monitoring squirrels using a multiple approach that involved observations, radio-tracking and re-trapping; camera traps were also employed as a pilot project at two of the relocation sites. Each technique was designed to contribute to the determination of squirrel retention on site, movements off site and survivorship.

3.2.6 *Observations*

ICR recorded squirrel presence and behavior during ten-minute scan sampling sessions coinciding with peak squirrel activity during the first three and last three hours of daylight (Altman 1974). Observers recorded behavior in accordance with an ethogram developed for the relocation project (see inset). Observations occurred at each translocation pie immediately upon release of squirrels with decreasing frequency over the 5 weeks following release (6 hours for days 0-2 post-release, then once every 3 days for a month).

ETHOGRAM

PS1 – Point-in-time sampling (scan) 1

Digging	DG	Digging in dirt, including creating a new burrow and working an existing burrow
Feed	FD	Ingestion/manipulation of provisioned food items for consumption and chewing
Forage	FO	Ingestion/manipulation of natural food items for consumption and chewing
Groom / Stretch	GS	Includes grooming, dust bathing, scratching and stretching
Rest	RE	Stationary, lying with ventrum on substrate; not engaged in other behaviors on ethogram
Alert	AL	Stationary, alert, quadrupedal or sitting on hind legs (not standing bipedally)
Bipedal	BP	Standing on hind legs, forelegs off the ground
Tail flagging	TF	Repeated side-to-side motion of tail, with tail erect (associated with snake encounters; not to be confused with tail lashing, which is a side to side movement of tail (not erect, not piloerect) in social encounters)
Locomotion	LO	Any movement from point A to point B
Nest building	NB	Gathering nesting material
Agonistic	AG	Conspecific aggression, including chasing, biting, scratching, whether the actor or the recipient
Affiliative	AF	Greeting (nose-to-nose contact; sniffing conspecific), allogrooming (using paws or teeth to groom the fur of conspecific)

PS 2 – Point-in-time sampling (scan) 2 (head position)

Head up	HU	Head held above parallel with body (e.g., at 20 degrees or more…)
Head down	HD	Head held parallel with body or below

AO – All-occurrences (whenever these behaviors are observed, record them. Continue to scan visible squirrels between point-in-time samples)

Alarm calling	AC	Loud, repetitive calling
Burrow use	BU	Record activity in burrow, other then entering & exiting; identify burrow number. e.g., sitting vigilance within the burrow entrance
Enter burrow	BI	Record fully entering from burrow; identify burrow number
Exit burrow	BO	Record fully emerging from burrow; identify burrow number
Overnight burrow use	EM	Record emerging from burrow for the first time in the morning; identify burrow number

3.2.7 *Re-trapping Relocated Squirrels*

Re-trapping at each translocation site was conducted at four days, six weeks, and six months post-release. To reduce trampling damage on the plot habitat manipulation treatments, trap lines were configured in a sunburst pattern (Figure 8). Tomahawk traps were used along trap lines, and a single Black Fox Repeater trap was placed in the middle of the circle, totaling 55 traps set. Trap timing and processing are similar to methods used at source sites already described.

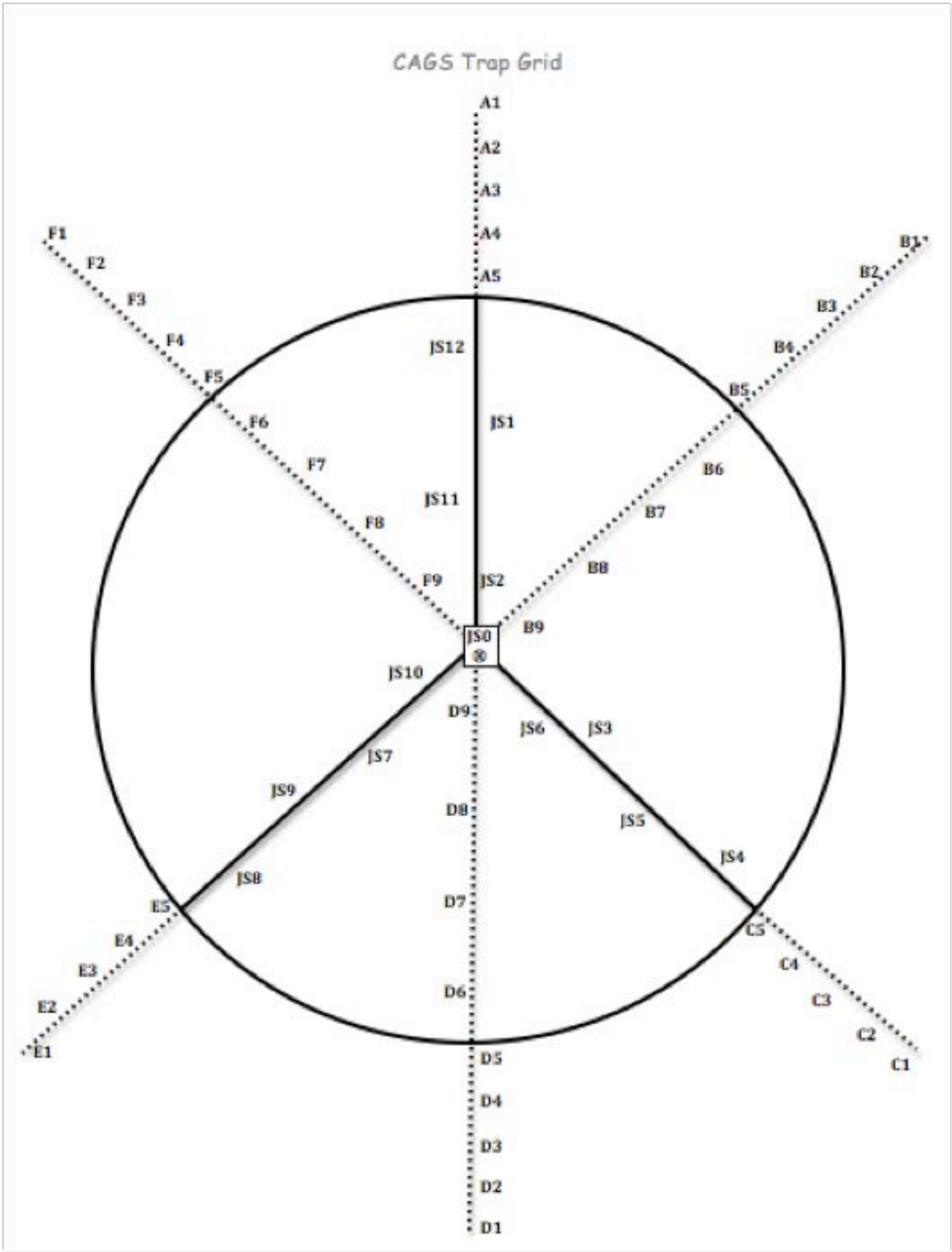


Figure 8. Diagram of trap configuration setup on Translocation Plot

3.2.8 *Pilot Camera Trap Monitoring Project*

Camera traps (2 brands: Reconyx® HC, and Bushnell® Black flash remote camera systems) were also used to monitor squirrels at two relocation sites in Jamul. Initiated by Kira Marshall, ICR summer intern, as an independent project, eight cameras were deployed at two experimental pie translocation sites (4 cameras per pie) to monitor squirrel activity. The information from the cameras proved interesting and valuable, so ICR biologists continued to maintain cameras on a weekly basis by changing batteries and retrieving SD data cards. Cameras have been in continual use on these two sites since release day. In order to retrieve relevant data from thousands of photos, we set up a photo database using the "Camera Base" version 1.4 software (developed by an ICR scientist) to manage, organize and format camera data for export into statistical analysis packages.

3.3 *Burrowing Owl Monitoring*

3.3.1 *Nest Monitoring*

During our first year of work we monitored burrowing owl presence and breeding activity within the vicinity of the study locations. In 2011, burrowing owls were resident breeders adjacent to two of the study sites: (1) Shinohara restoration area, part of the Sweetwater Unit of San Diego NWR, and (2) south and east of the Caltrans Lonestar mitigation site, Otay Mesa. ICR biologists opportunistically surveyed and monitored nests within these areas, including two trips onto the Brownfield Municipal Airport with the permission of the Senior Airport Operations Assistant, Chris Cooper. Nests adjacent to the study sites that were consistently accessible were monitored more closely by observation and remote cameras to determine reproductive success. All burrowing owl nest location data has been submitted to CDFG's California Natural Diversity Database (CNDDB).

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3.3.2 *Banding*

In mid-May ICR biologists conducted two trapping sessions with Clark Winchell of USFWS to band burrowing owls adjacent to the Lonestar site. At this time, most burrowing owl chicks are active above-ground, allowing capture of fledglings and their adult parents. We captured multiple individuals within one family unit by employing a modified push-door Tomahawk trap set carefully at a single active nest entrance (Winchell 1999).

Each burrowing owl captured was banded with one aluminum USFWS band on the left leg and a green Acraft® color band with a unique alpha-numeric code on the right leg. Color bands fitted on the long naked legs of burrowing owls can be deciphered and recorded easily using binoculars or a spotting scope. In this way, banded burrowing owls are reliably identified as individuals allowing researchers to record location and nesting success during the life of the banded owl.

3.3.3 *Nest Entrance Cameras*

ICR conducted a burrowing owl nest camera pilot study to determine the type and value of data available from placing remote camera traps near a nest burrow entrance. We established a total of 8 camera traps at nest burrow entrances where owls were exhibiting active breeding behavior. Six nest cameras were installed along the southern and eastern border of the Caltrans Lonestar mitigation site in Otay Mesa, and 2 nest cameras were set up at artificial burrow nest sites within the Shinohara mitigation area, San Diego NWR. Cameras were placed in the field in mid-May and removed in mid-July. Remote cameras allowed us to collect data on nest provisioning, prey identification, non-owl visitors, and reproductive success. Photos downloaded from nest cameras were organized into a database developed by an ICR research scientist. "Camera Base" version 1.4 software manages and formats camera data for export into statistical analysis packages and will be used in future research to analyze camera data related to prey delivery, reproductive success, nest attendance, and provisioning rates.

3.3.4 *Non-breeding season monitoring*

ICR continued monitoring study sites for presence of wintering burrowing owls. Surveys were conducted during the winter of 2011-2012 on all 7 paired plots. During surveys, every installed acclimation burrow and newly excavated burrow was examined for animal sign, particularly evidence of burrowing owls, including visual sighting of a live or dead owl, feathers, pellets, or mute. In addition, incidental burrowing owl sightings or sign at paired plots was recorded throughout the study period.

RESULTS

A total of 344 California ground squirrels were captured and taken into holding. Of those, 327 were put into acclimation cages and released at 7 relocation sites. During holding, 16 squirrels died, and one was re-released at the original source site. The first release occurred on June 7 at a single translocation site, Jamul South. After that initial release, squirrels were released at two experimental pies every two weeks until the last release on July 18. The number of California ground squirrels released per pie averaged 46.7 squirrels. Over the 7 relocation sites, 220 coastal/ NBC squirrels were placed in acclimation at 4 translocation plots, and 107 inland squirrels/ Tulloch and Daley Ranch were placed at 3 plots. Conservatively, our minimum target number was 30-40 squirrels per pie, but we sought to translocate 50 or more to increase translocation success.

Table 4.1. Summary of California ground squirrels translocated

Relocation Site	Source	Total Released	Total Males	Total Females	Total Juveniles
Otay South	Inland Tulloch Ranch	33	4	10	19
Otay North	Coastal NBC	59	7	14	38
Sweet Water W	Inland Daley Ranch	45	3	17	25
Sweet Water E	Coastal NBC	53	3	8	42’
Jamul S	Inland Tulloch Ranch	29	3	12	14
Jamul W	Coastal NBC	55	9	7	39
Jamul E	Coastal NBC	53	5	7	41
Total Squirrels		327	34	75	218

4.1 *Post-release retention and fate of translocated California ground squirrels*

4.1.1 *Post-release Observations*

Behavioral observations proved more difficult than expected based on previous experience of ICR researchers. Squirrel activity may have been suppressed by observer presence and, without an elevated blind, identifying individual squirrels was difficult. Nonetheless, it was possible to count the number of unique individual squirrels seen above-ground during an observation period, providing a relative indicator of squirrel numbers and a minimum number of squirrels present on the experimental plot. Figure 9 indicates that (1) squirrel above-ground activity was low initially, as the maximum number of squirrels observed typically occurred a few days post-release; (2) squirrel numbers likely declined at most sites during the first month post-release, especially at Sweetwater West, Otay North, Otay South, and Jamul South; and (3) squirrel activity remained high at Jamul East, Jamul West, and Sweetwater East.

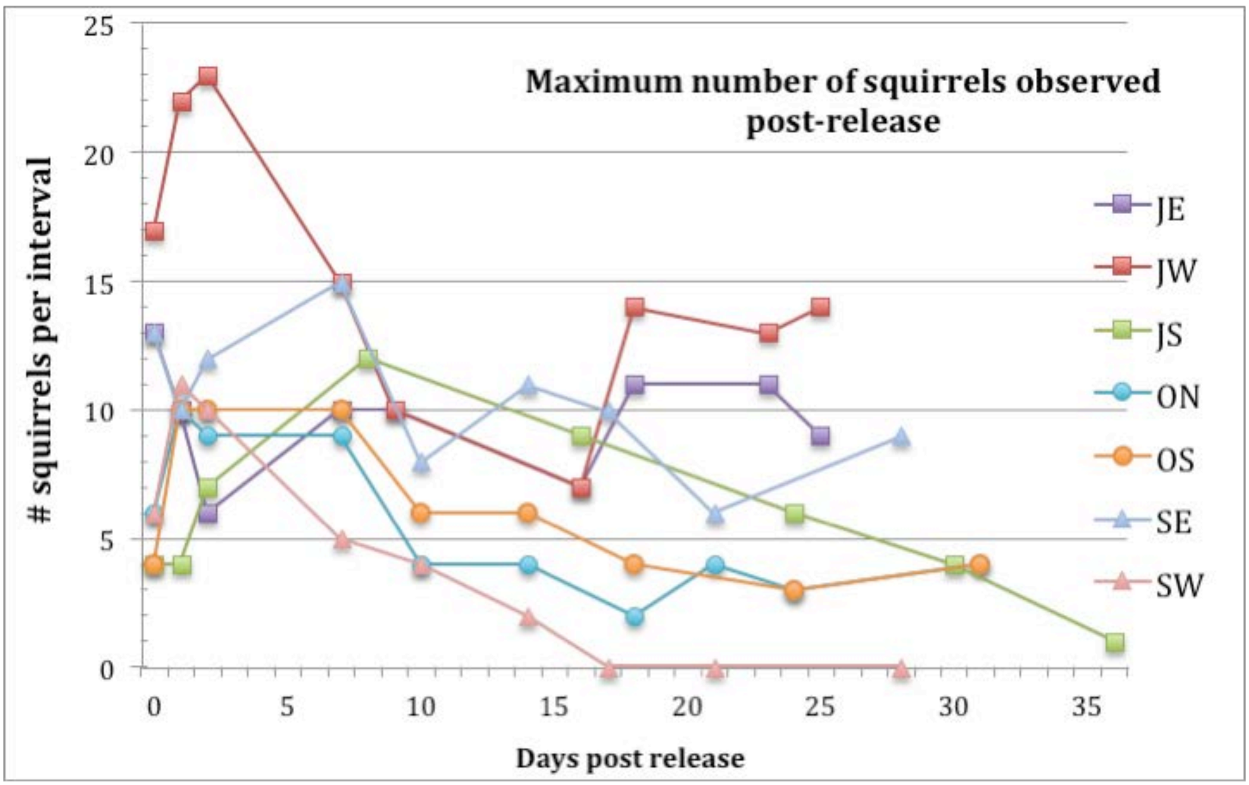


Figure 9. Maximum number of squirrels seen above ground at the experimental plot during an observation period of 3 hours. This number is not a population estimate, and reflects the minimum number of squirrels remaining at an experimental plot. Each line represents one translocation plot. Study location name (plot code): Rancho Jamul (JE, JW, JS), Lonestar, Otay Mesa (ON , OS), San Diego National Wildlife Refuge, Sweetwater Unit (SW, SE).

4.1.2 *Post-release Re-trapping*

Juveniles were re-trapped at a much higher frequency than adults since 68% of translocated squirrels were juveniles. In addition, adult squirrels enter seasonal torpor after the breeding season and may have been underground six weeks post-release, but would have been active above-ground during the trap session six months post-release that was timed to coincide with mating season.

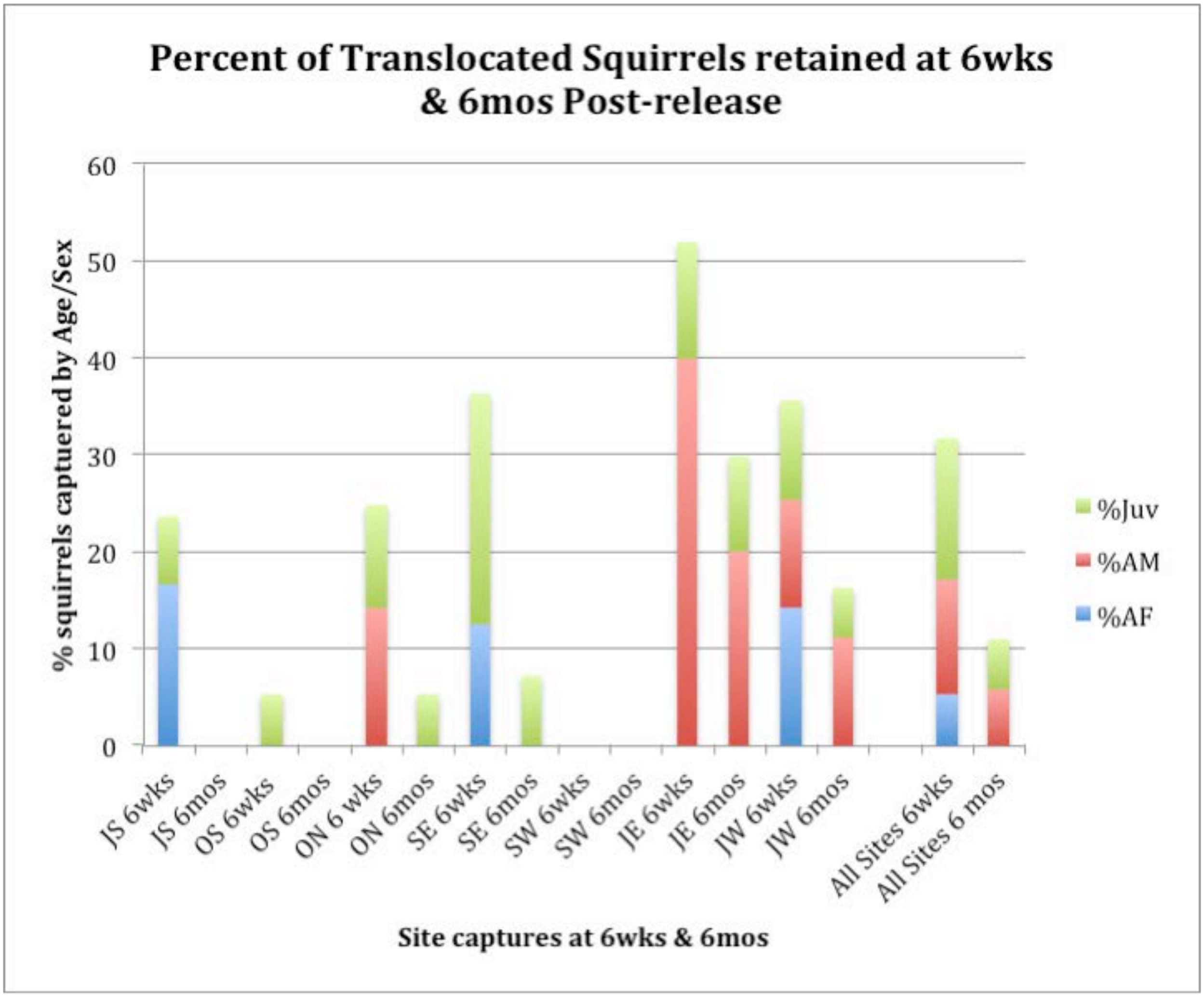
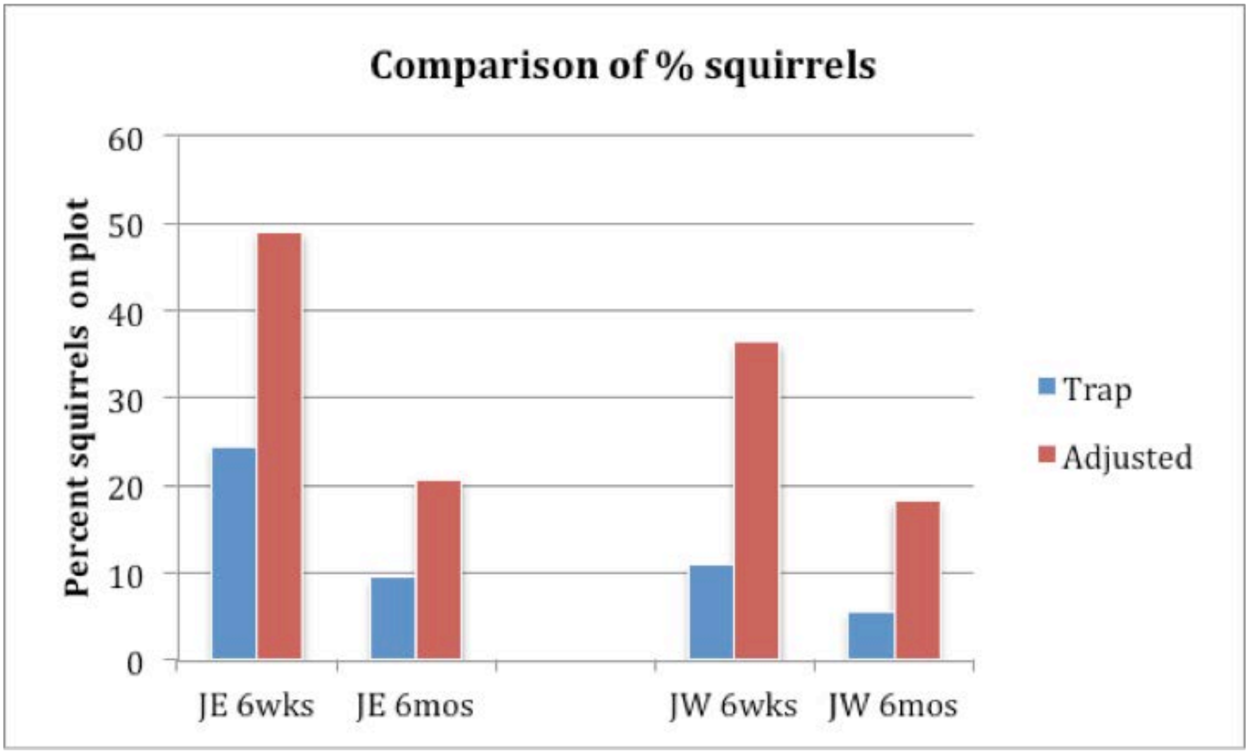


Figure 10. Post-release, live-trap captures of California ground squirrels as a function of age and sex at 6 weeks and 6 months post-release. Juv = juvenile; AM = adult male; AF = adult female. These numbers represent the minimum proportion of squirrels surviving, as determined by capture.

4.1.3 *Pilot Study: Jamul Camera Trap Sub-sample*

Camera traps installed at two Jamul sites as part of an intern's field project introduced another method of tracking squirrel retention on site. Photos taken at the acclimation burrow entrances allowed ICR biologists to individually identify squirrels both by dye-marks renewed during trapping efforts, and by distinctive physical characteristics. In this way, we were able to adjust the estimate of squirrels retained on site by combining the number of squirrels recently trapped plus the number of squirrels seen only on cameras. Camera trap data substantially increased the number of squirrels detected on-site by 2-3 times, but only in conjunction with trapping, because dye marks aided the identification of individual squirrels. Squirrel retention adjusted upward using camera data still represents the minimum estimate since cameras cover only one-third of the available acclimation burrows and none of the newly excavated burrows where squirrels may reside escaping detection. These data indicate a *minimum* of approximately 20% of translocated squirrels surviving and remaining on Rancho Jamul E and W plots for 6 months.

Photo: Two young California ground squirrels identified by dye-mark from Jamul camera trap photo 7-21-2011.



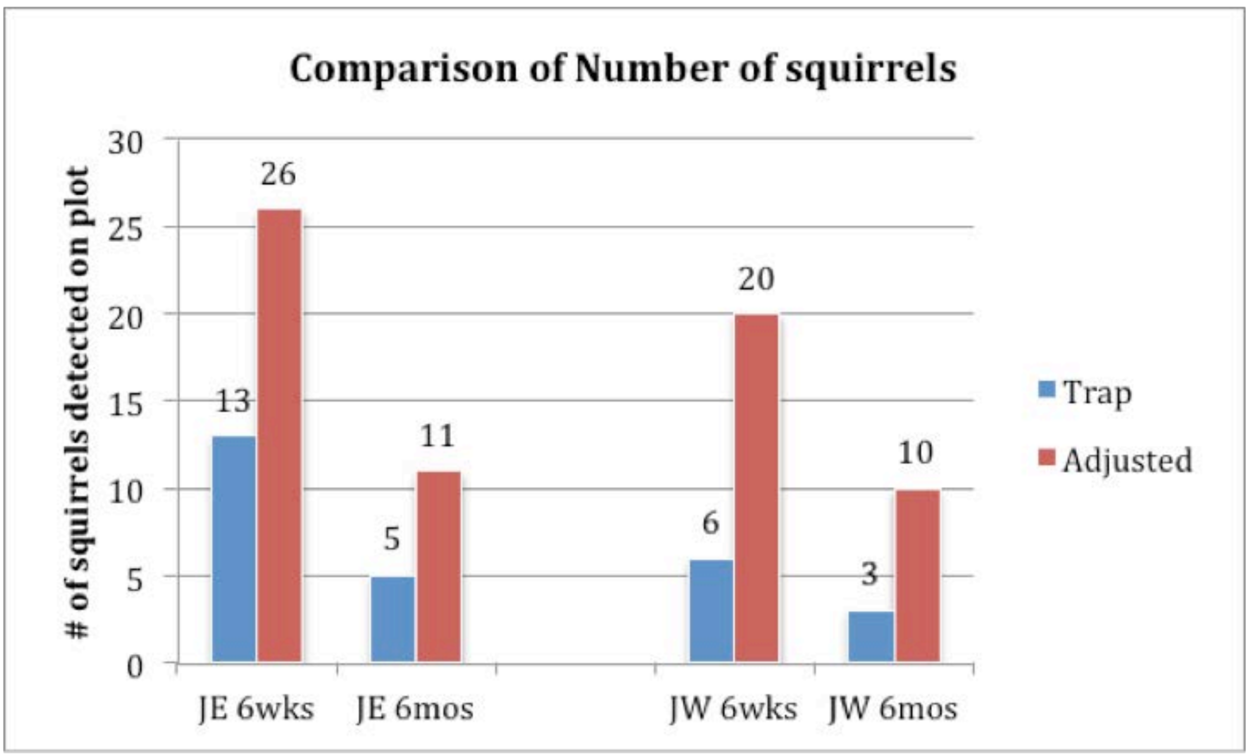


Figure 11. The proportion (above) number (below) of uniquely identifiable squirrels detected by live trapping (blue) and by a combination of camera trap and live trap (red) detected in pilot camera trap study at Rancho Jamul East (JE) and West (JW). This observed adjustment increases estimates of squirrel retention on site by 2x at 6wks, 2.2x at 6mos. JW adjustment increases squirrel retention estimates by 3.3x for both 6wks and 6mos post-release.

4.1.4 *Survival and Movement of Squirrels with Radiocollars.*

Thirty-eight squirrels were fitted with VHF radiocollars and tracked to determine the fate of released squirrels (Tables 4.2 & 4.3). Of these 38 squirrels, 5 were known dead 18 days post-release and 2 additional squirrels were known dead 36 days post release, for a minimum mortality rate of 18%. All known mortalities were associated with evidence of predation. Mortality appears highest during the immediate post-release period, when squirrels may be most at risk to predation. By 36 days post-release, 17 squirrels were lost to the study due to lost signals or detached collars. These problems also were more common during the initial 18-day period. Signal loss resulted from interference from the Brownfield Municipal Airport / U.S. – Mexico border and inability to track squirrels that moved into inaccessible adjacent lands. We worked with a pilot with extensive radio-tracking experience, but were unable to recover signals even after two flights over the larger study area. The fates of these squirrels are unknown. Of the 21 squirrels with known fates, 14 were known to be alive at 36 days, and 7 were known to be dead, indicating a possible survival rate as high as 67%.

Predation was distributed across sites; the main predators were presumably coyote and red-tailed hawk. Six radio collars were found in good condition, indicating that they may have slipped off of squirrel necks, precluding further monitoring by tracking. One of these squirrels was re-sighted at a camera trap after losing the collar, confirming the survival associated with collar detachment.

Table 4.2 Fate of radiocollared squirrels at 18 days post-release.

Site	Total # Collars Fitted	Alive at 18 days	Killed by Predator	Lost Signal	Detached Collar
JS	3	2	1	-	-
JE	6	2	1	2	1
JW	6	5	-	1	-
OS	5	2	-	3	-
ON	6	2	2	2	-
SE	6	1	-	5	-
SW	6	3	-	3	-
Total	**38**	**17**	**5**	**16**	**1**

Table 4.3 Fate of radiocollared squirrels at 36 days post-release.

Site	Total # Collars Fitted and Still Collared After Day 18	Alive at 36 Days	Killed by Predator	Lost Signal	Detatched Collar
JS	2	2	-	-	-
JE	2	1	1	-	-
JW	5	4	1	-	-
OS	2	1	-	1	-
ON	3*	3	-	-	1*
SE	2**	1	-	1	-
SW	3*	2	-	1	-
Total	19	14	2	3	1

* 2 squirrels at ON were lost by day 18, but found again by day 36 - 1 alive, the other with a detached collar.
** 2 squirrels at SE were lost by day 18, but found again by day 36 - 1 alive, 1 dead.

Movement data for radiotracked squirrels indicate variability in the squirrel's response to different sites, with Sweetwater sites associated with the largest post-release movements (Table 4.3). The Sweetwater East release site had by far the greatest dispersal distances, moving an average of 1.6 km between the first and last relocation. These data indicate the great capacity for squirrels to disperse if release site habitat is rejected. In addition to the apparent poor soil suitability at the release site, many of these squirrels appeared attracted to areas with large resident conspecific populations that were at a distance from the release site. The Otay release sites also had compacted soils, and settlement on the pies was very limited. However, nearby berms and dirt mounds containing resident squirrels provided a close, and apparently attractive, site where many squirrels settled.

Table 4.4 Movement measurements for squirrels released

	Mean Total Days Tracked	Mean Total # of Relocations	Mean Total Distance Traveled (m)	Mean Distance between Consecutive Relocations (m)	Mean Distance between First and Last Relocations (m)	Mean MCP Home Range Area (Ha)
Jamul East	50.8	11.2	598.0	146.3	295.9	2.1
Jamul South	123.0	16.3	502.4	63.4	222.1	0.8
Jamul West	109.3	19.7	1112.2	98.0	171.8	4.9
Otay North	82.8	12.6	434.9	57.9	247.9	3.8
Otay South	25	7.3	139.2	72.1	107.8	0.3
Sweetwater East	54	4.2	1806.3	415.3	1602.1	17.4
Sweetwater West	41.8	4.5	1052.4	267.1	457.8	12.2
Averages	**69.5**	**10.8**	**806.5**	**160.0**	**443.6**	**5.9**

4.2 *Camera Trap Visitors*

A number of vertebrate species visited the experimental pies and were captured by remote cameras set at the Jamul burrows or along the periphery of all 7 translocation plots during acclimation. Of the potential predators of ground squirrels, the raven (a predator of pups) and the coyote were most common. Red-tailed hawks were also captured on camera traps, indicating that they will come down to ground level where they may prey on squirrels. As an aerial predator, red-tailed hawks are undoubtedly more common predators than camera trap data would indicate. Variability in predator activity may be an important predictor of squirrel translocation success, and may explain differential mortality among sites. This pilot project indicates that camera traps can be a valuable tool for monitoring predator activity, documenting squirrel presence, and documenting large vertebrate diversity as part of a larger monitoring and management program.

Table 4.5 Species identified from camera traps set at Jamul E & W translocation plots

Common Name	Total # of Events*	Photos per Camera Days	Total # Camera Stations
California Ground Squirrel	1907	9.35	8
Common Raven	214	1.05	7
Coyote	192	0.94	8
Rabbit	173	0.85	4
Mule Deer	61	0.30	4
Red-tailed Hawk	24	0.12	6
Burrowing Owl	21	0.11	2
Weasel	15	0.07	4
Barn Owl	5	0.02	4
Great-horned Owl	1	0.0049	1
Unknown Bird Species	94	0.45	8
Unidentified Species	12	0.06	6

*Event = independent (>1 hr between events)
Camera traps at 2 translocation plots (JNE and JNW) on the Rancho Jamul Ecological Reserve (4 cameras / plot, 8 total cams) ran for 204 camera trap days from 7/18/11 to 2/6/12.

Photo: Immature red-tailed hawk attempts to capture squirrel at Jamul West acclimation burrow 8-29-2011


Photo: Coyote inspecting JE acclimation burrow #9, 11-18-2011


Photo: Coyote with pup walking outer edge of SW translocation plot, 7-21-2011

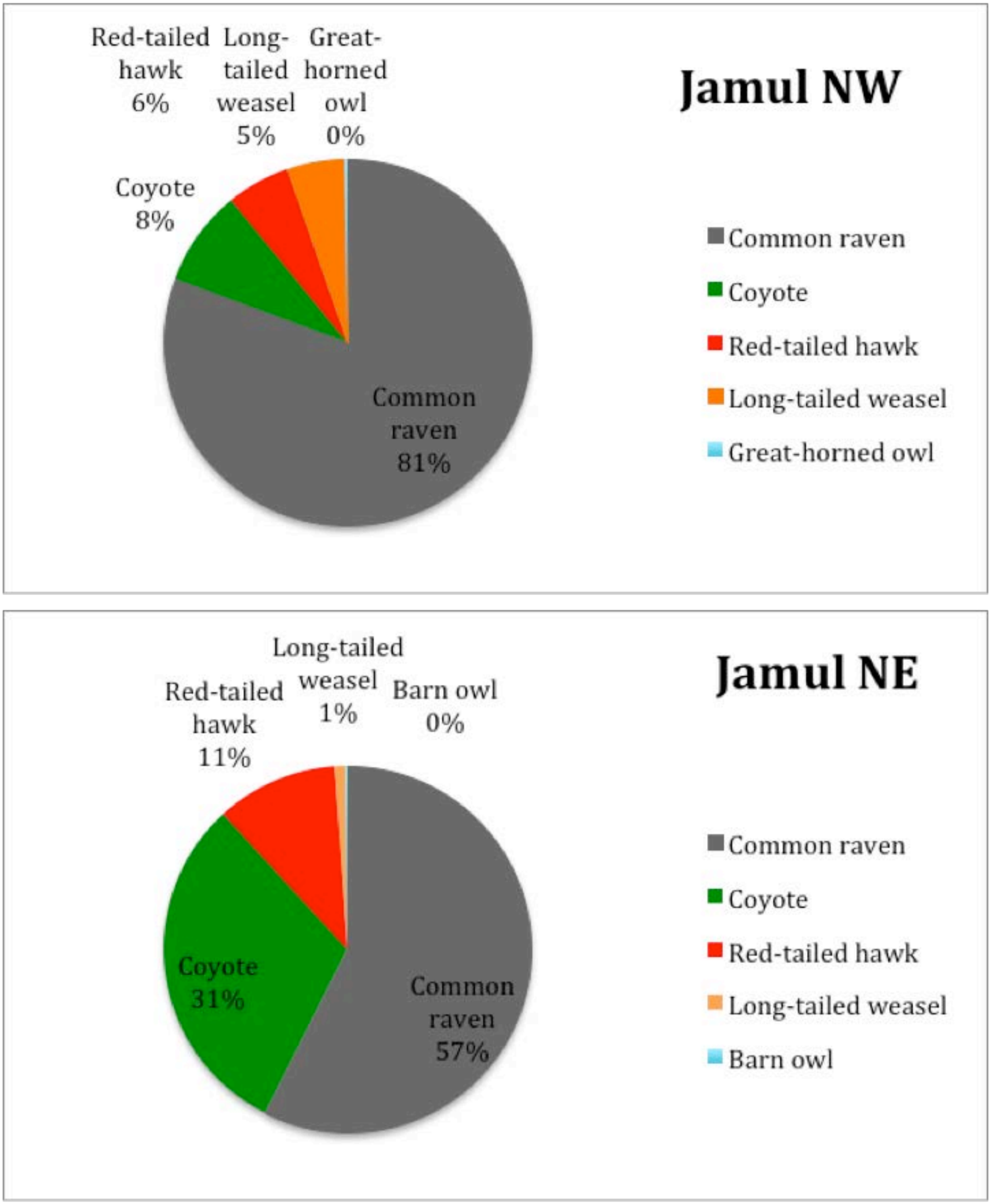


Figure 12. Predator species identified on camera traps at (a) Jamul W, and (b) Jamul E

4.3 *Ecosystem Engineer Effects*

For details of ecosystem engineer effects, see SDSU report to SANDAG.

Results from burrow surveys substantiate trends identified using other methods for monitoring squirrel activity, such as direct observation, camera traps, telemetry, and live trapping. During our first burrow survey, conducted in September jointly with SDSU, we found a > 30-fold increase in burrow construction on sites where squirrels were translocated compared to control sites which received only habitat enhancement (Table 4.4). A second survey in March 2012, 9 months following the translocations, indicated that squirrel burrowing activity was almost exclusively on translocation sites (131 burrows on translocation sites versus 1 on control sites). These results are highly significant statistically ($p < 0.01$, binomial test). There was also great variability among plots. Squirrels never established much burrowing activity at the Otay site plots or Sweetwater West, and apparently lost their foothold on Jamul South, where we could only locate a single burrow in March 2012. This plot was dominated by thick thatch in March, making any burrows present more difficult to detect. Our trapping and observational data also indicate that squirrels failed to thrive at Jamul South, possibly due to a high level of early predator activity. With the exception of Jamul South, the sites with the least compacted soils (Jamul West, Jamul East, Sweetwater East) had the highest burrowing activity.

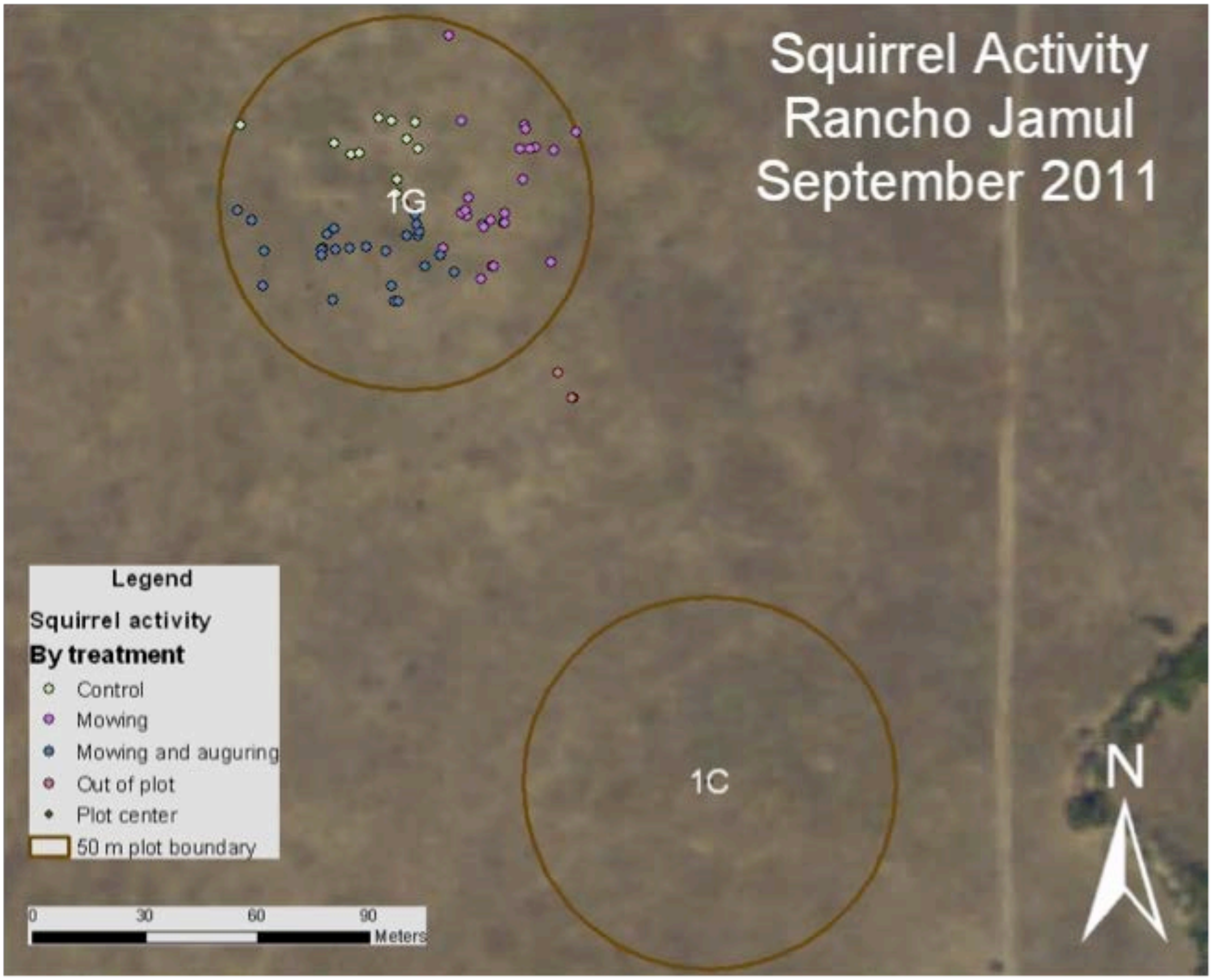
The proportion of burrows 10 cm or greater, increased relative to the values measured in the first round of monitoring in September for all three occupied plots, indicating that squirrels have continued to develop and enlarge their burrows with time. Several burrow complexes had multiple entrances, large aprons, and evidence of recent activity in the form of fresh squirrel scat or piles of discarded *Avena* hulls**.** While the reduction of active burrows from September to March likely reflects mortality and dispersal from the release site, the continued activity indicates that a small population has been established and is beginning to exert ecosystem engineering effects on the environment.

Vegetation treatment within plots also affected squirrel burrowing activity, with most burrows located in areas treated with mowing, and few burrows established in the un-mowed control (March 2012 data indicates 89%-95% of burrows located in mowed treatments). In September 2011, the mowed and augured treatment did not differ from the mowed only treatment, but in March 2012, we found that soil auguring was associated with greater numbers of burrows than the mowing treatment alone ($p<0.001$, binomial test). This result was surprising because we expected auguring to be more important early in the translocation, when the squirrels might have a greater need for refuge, rather than six months later when they have had a chance to establish burrows.

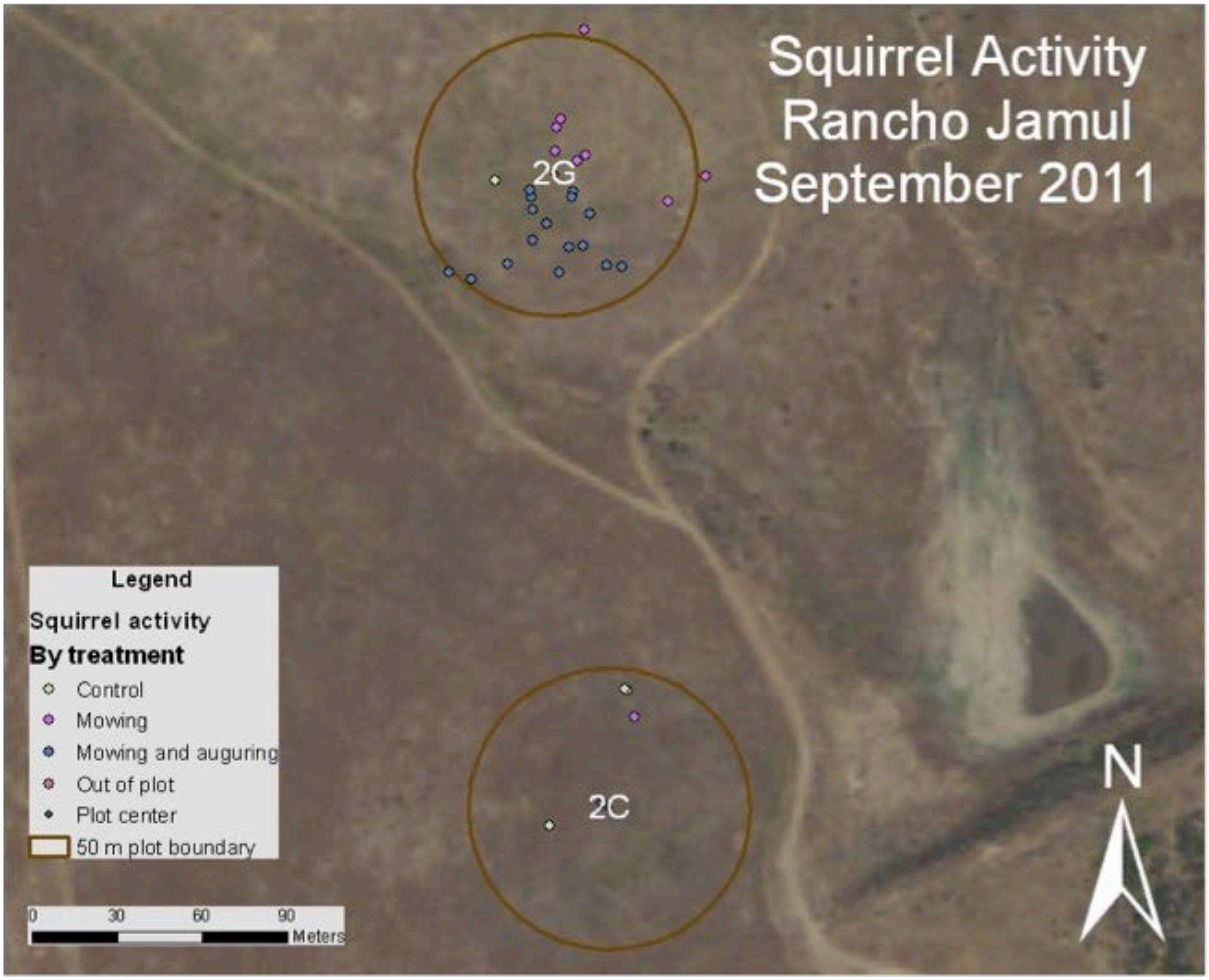
Table 4.4. Squirrel activity in plots, measured as the number of burrows with diameter greater than 7 cm in September 2011

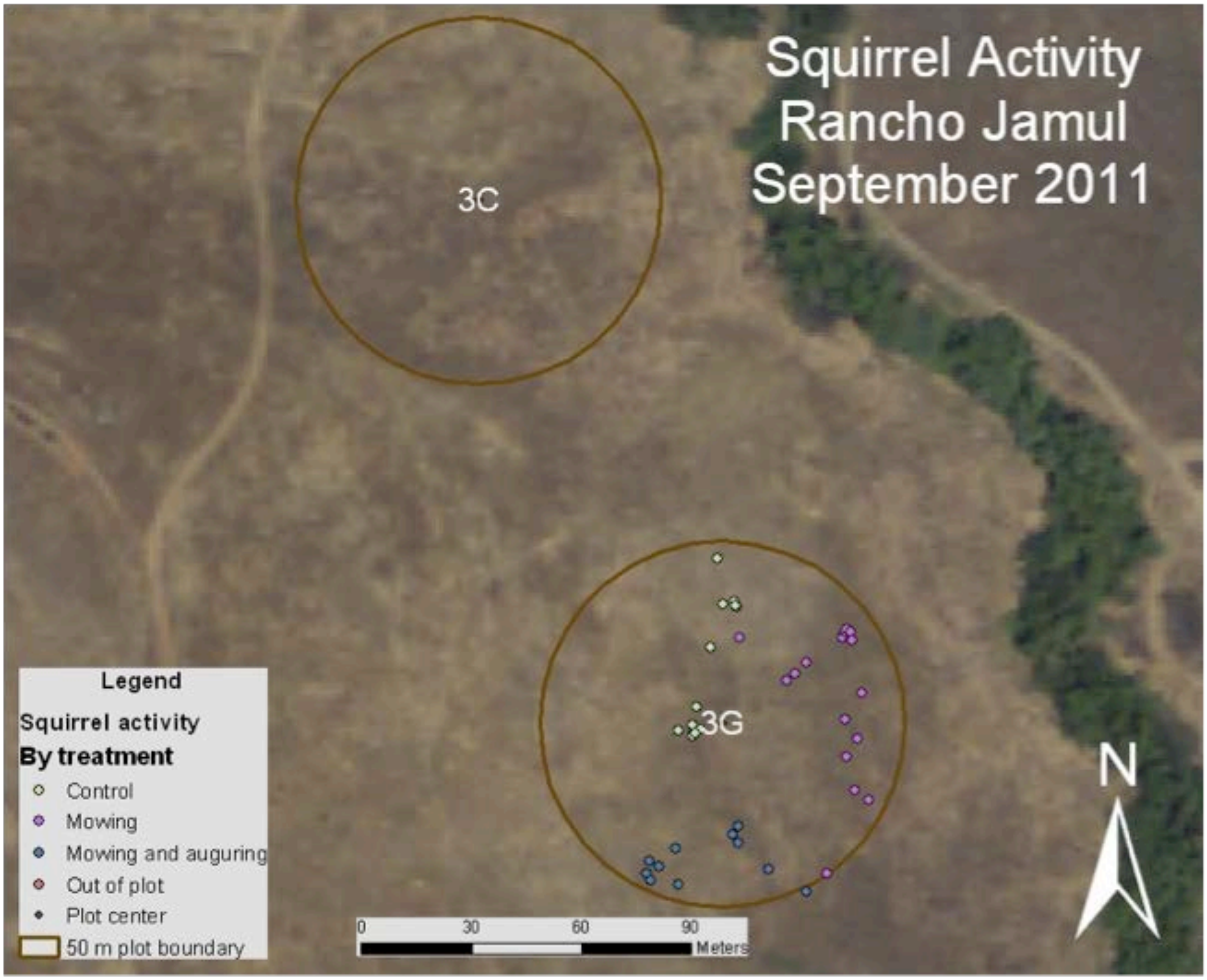
Plots	Control	Translocation	Total
ON*	-	1	1
SW*	-	2	2
OS	-	9	9
JE	-	64	64
JW	5	32	37
JS	-	40	40
SE	-	26	26
Total	**5**	**171**	**176**

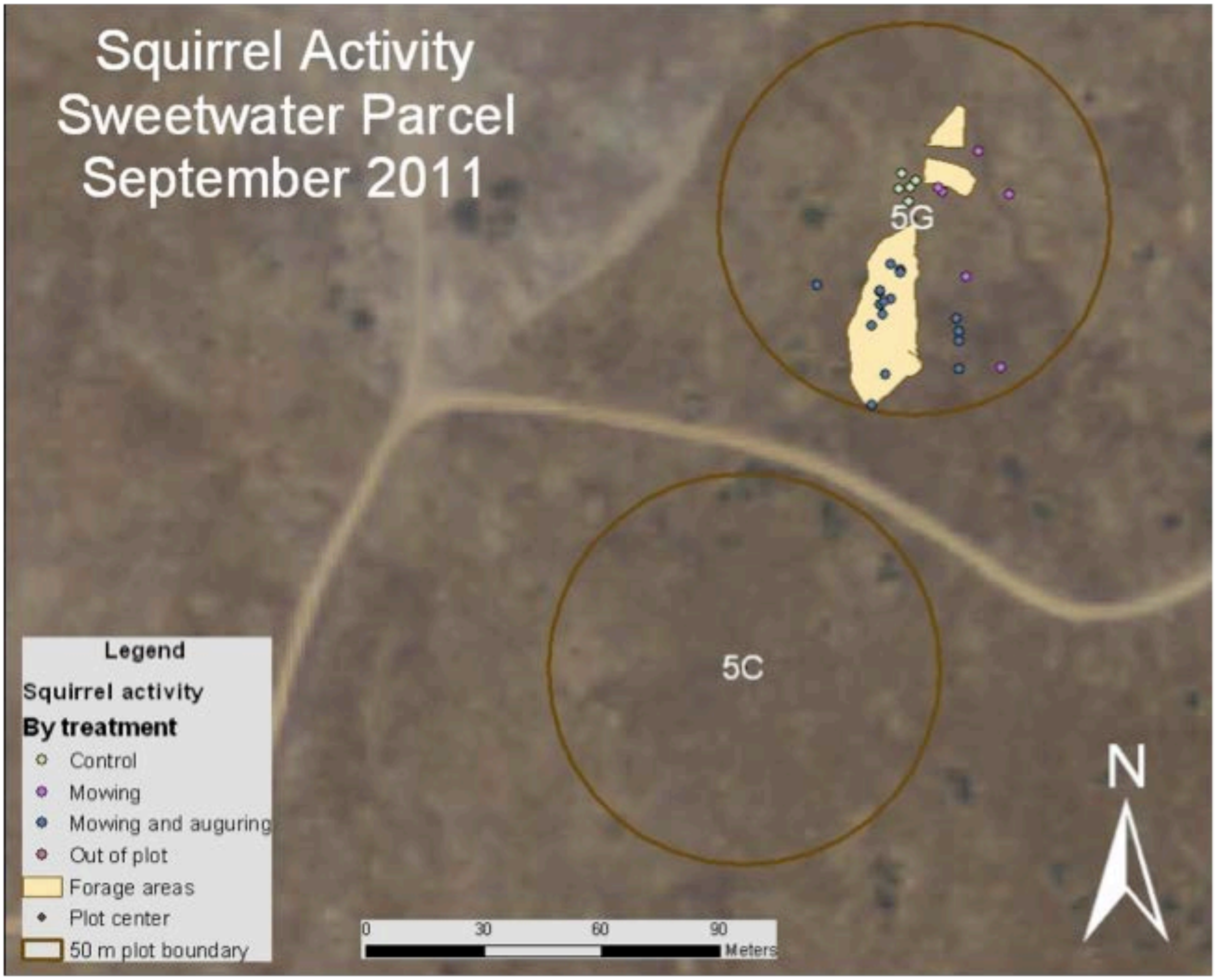
*Excluded from further analysis due to low values.

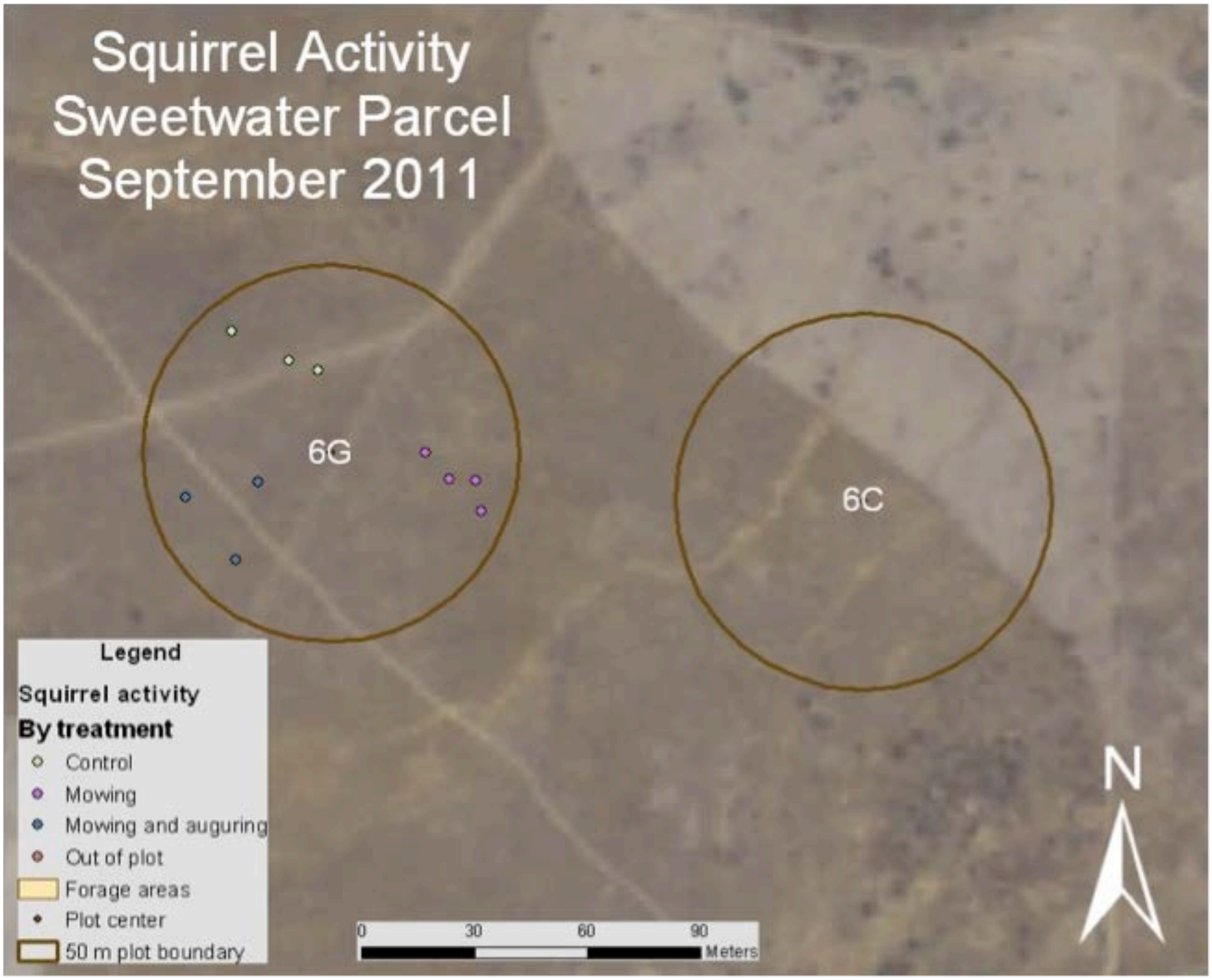


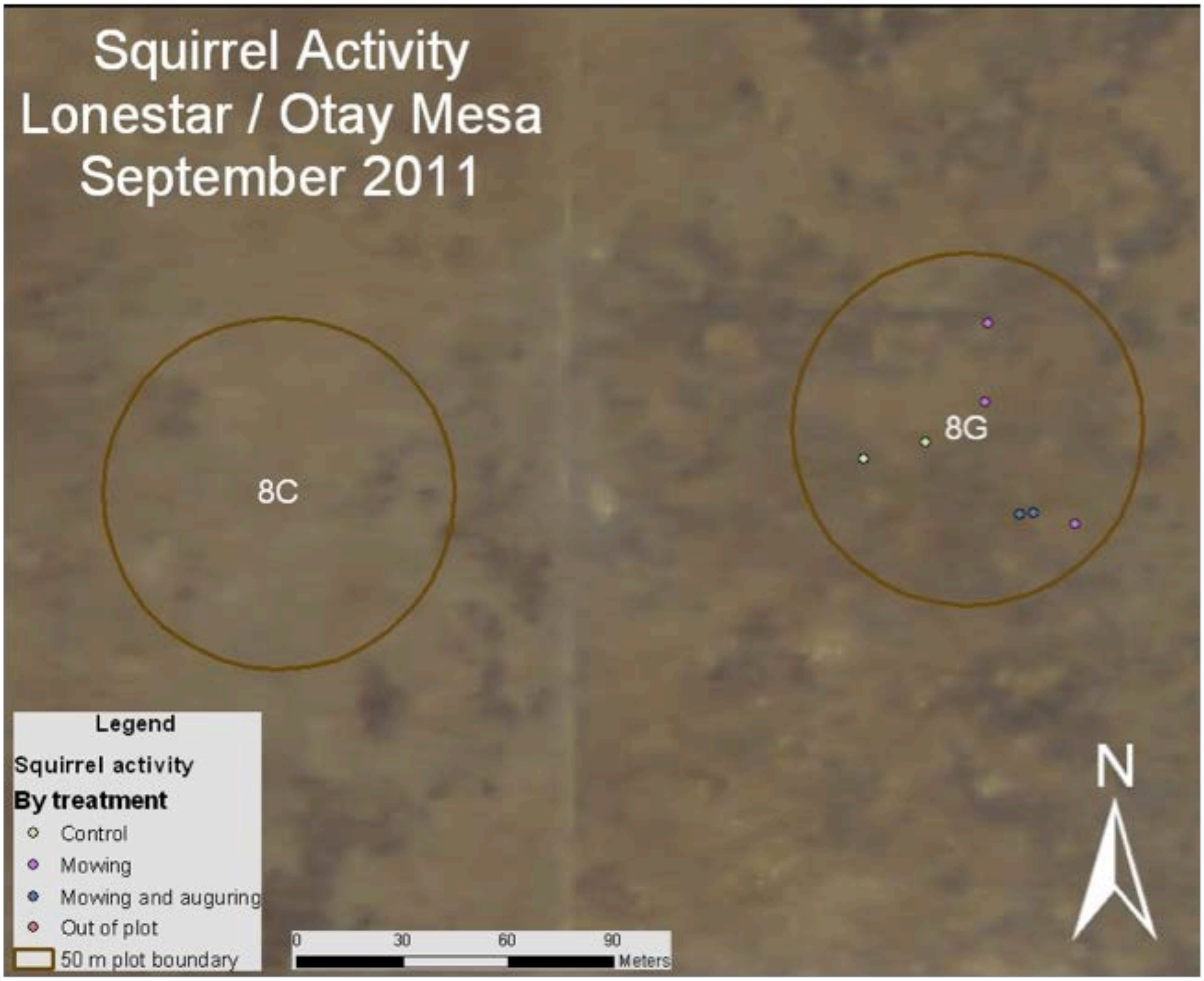
Squirrel Activity
Rancho Jamul
September 2011
1G
1C
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
Plot center
50 m plot boundary
0
30
60
90
Meters
N


Squirrel Activity
Rancho Jamul
September 2011
2G
2C
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
Plot center
50 m plot boundary
0
30
60
90
Meters
N


Squirrel Activity
Rancho Jamul
September 2011
3C
3G
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
Plot center
50 m plot boundary
0
30
60
90
Meters
N


Squirrel Activity
Sweetwater Parcel
September 2011
5G
5C
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
Forage areas
Plot center
50 m plot boundary
0
30
60
90
Meters
N


Squirrel Activity
Sweetwater Parcel
September 2011
6G
6C
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
Forage areas
Plot center
50 m plot boundary
0
30
60
90
Meters
N


Squirrel Activity
Lonestar / Otay Mesa
September 2011
8C
8G
Legend
Squirrel activity
By treatment
Control
Mowing
Mowing and auguring
Out of plot
50 m plot boundary
0
30
60
90
Meters
N

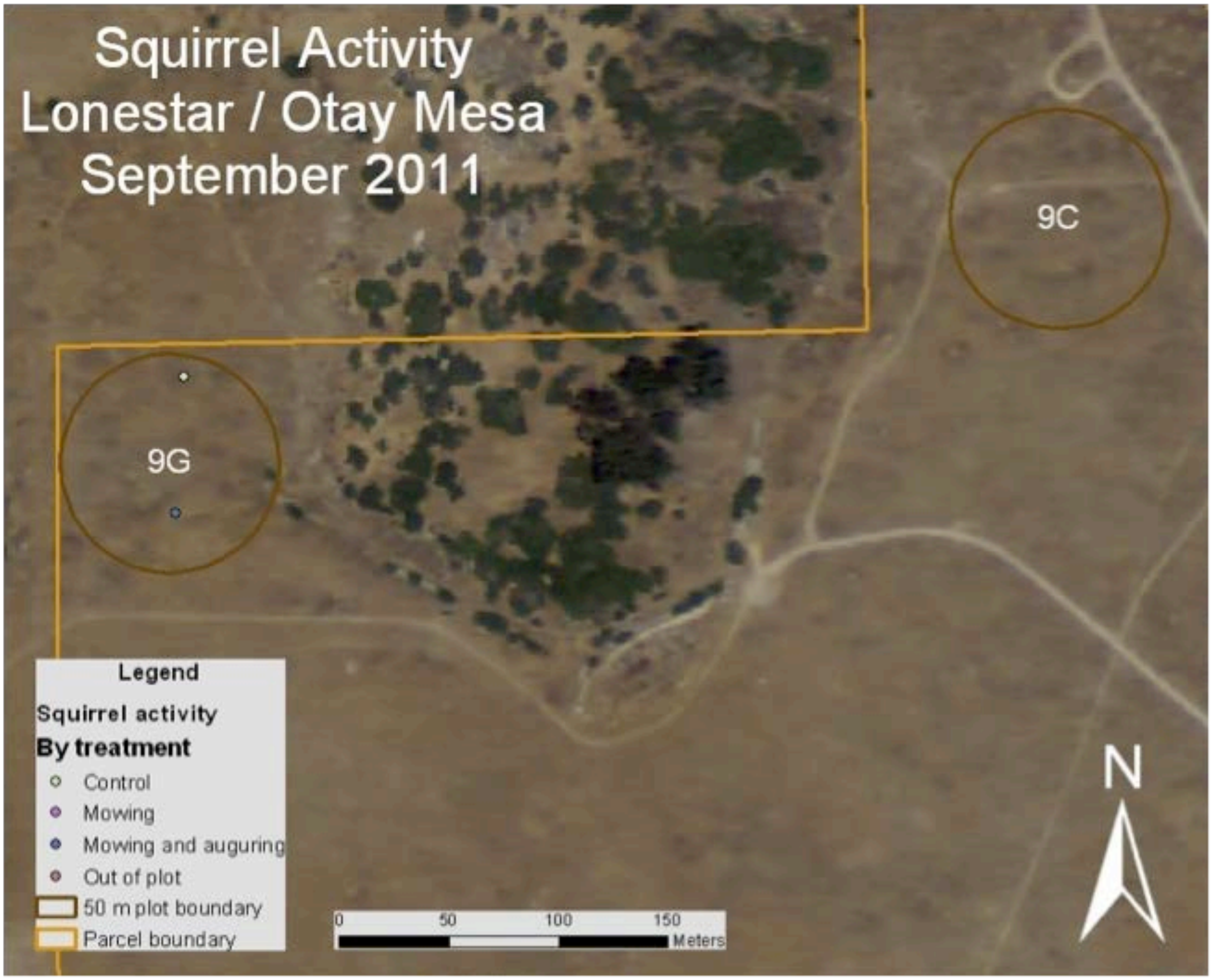


Figure 13. Burrowing and digging activity of translocated California ground squirrels 8-10 weeks post-release.

4.4 *Burrowing Owls*

4.4.1 *Nest Monitoring*

We located 20 active burrowing owl nest burrows; 18 nests were located in the vicinity of the Brownfield Municipal Airport adjacent to the Caltrans Lonestar study site, and the remaining 2 nests were located on the Shinohara restoration area within the San Diego NWR, Sweetwater unit. Both nests at Shinohara failed to produce young. Neither observations nor camera data revealed the presence of young above-ground or any prey deliveries to the nest burrow that would indicate the presence of nestlings. Adult males were observed at the burrow entrance while females remained underground presumably incubating eggs, but nestlings never surfaced and females eventually returned to the surface without chicks. We suspect these two nests failed during incubation. Along the southern and eastern borders of the Lonestar study site, we monitored 6 nests closely. All 6 nests in this area produced fledged young (mean = 6.5 chicks/nest, range = 3-9 chicks). Within the boundaries of the Brownfield Airport we intermittently monitored 12 active nests south and east of the main runways. All 12 were active during breeding season with adults in attendance. At 6 nests we observed 2-4 fledged young; the status of the remaining 6 were unknown, due to our limited allowable time on the airfield.

ICR biologists discovered that the burrows housing the Lonestar 1 and 2 nests were later collapsed and destroyed by human activity during the winter of 2011.

Table 4.5 Summary of Lonestar burrowing owl nests monitored in 2011

			Color Bands	
Nest Burrow	**Chicks Observed**	**Status**	**Adult**	**Chick**
LNSTR1	9	Fledged	2	4
LNSTR2	8	Fledged	1	3
LNSTR3	7	Fledged	2	0
LNSTR4	5	Fledged	1	0
LNSTR5	3	Fledged	0	2
LNSTR6	7	Fledged	2	4
Total	**39**		**8**	**13**

Photos: Selections from Nest burrow camera traps installed near Lonestar study site, Otay Mesa. A combination of observations and photos were used to determine the number of chicks in each brood.

Lonestar 6: Adult with 6 chicks, 5-14-2011


Lonestar 1: 9 chicks, 5-12-2011

Lonestar 2: 8 chicks, 5-12-2011

4.4.2 *Color Banding*

We trapped and banded 21 burrowing owls (13 nestlings, 8 adults) from the six closely monitored nests around the Lonestar study site. On return visits to the Lonestar site throughout the fall/winter, we observed banded adults and immature owls indicating that some breeding pairs and their young remain within the local area throughout the year.

Photo: Color banded adult male hovering. Lonestar Study Site, Otay Mesa .

4.4.3 *Over-winter Burrowing Owl Presence at Experimental Plots*

Burrowing owls were detected using the squirrel acclimation burrows installed by ICR for the translocation experiment. Burrowing owls were observed repeatedly at paired plots at both the Lonestar and Rancho Jamul study area. At Lonestar, both sets of paired (experiment/control) plots totaling 4 pies, host burrowing owls. Burrowing owls fledging from the surrounding nest burrows quickly discovered the enhanced habitat within the plots and were first observed on September 9, 2011. ICR biologists observed 1-3 burrowing owls occupying each of the four plots simultaneously. The two southern plots may have provided important alternate roosting burrows for locally raised owls following the overwinter destruction of the two most successful nest sites along the southern boundary of the Lonestar site (nest burrows were collapsed and backfilled by unknown human actors). Burrowing owls occupied all four plots throughout the winter of 2011/2012 and have been observed continually on those plots well into spring 2012.

At the Rancho Jamul study area, a burrowing owl was first detected at the Jamul East translocation plot by remote cameras on Oct 25, 2011 until January 19, 2012. A second burrowing owl was discovered during burrow surveys in March 2012 at the Jamul East control plot. 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. ICR biologists were unable to determine if the burrowing owls on the translocation plots were banded, so individual identification remains unknown.

Photos below: Selection from Jamul E burrow #9

10/30/2011 - Burrowing owl arrives and takes shelter in acclimation burrow #9.

11/25/2011 - Burrowing owl defends burrow entrance from relocated California ground squirrel.

DISCUSSION

In collaboration with our scientific partners at SDSU, in 2011 we made progress toward our primary goals of (1) designing an effective translocation protocol for California ground squirrels by conducting controlled experiments within an adaptive management framework and (2) documenting ecosystem engineering effects that California ground squirrels have at release sites. These intermediate goals are pursued with the long-term goal of creating self-sustaining habitat with burrowing owls in mind. Pilot work on burrowing owls was also initiated to begin to understand the population dynamics and ecology of the species in southern San Diego County. However, 2011 was year one of multi-year project. The full ramifications of the management actions taken here will require years to document through continued monitoring. More importantly, future management actions will be necessary to achieve long-term goals related to improved ecosystem function and burrowing owl recovery.

5.1 *Ground Squirrel Translocations*

We used four different techniques for monitoring squirrel translocation outcomes: (1) direct observation, (2) live trapping, (3) camera trapping (pilot project at two experimental plots), and (4) burrowing activity. We found no clear single method that can be used in isolation from other techniques. None provided a means for accurately estimating population size, due to small N and detectability issues. Direct observation proved more difficult than previous experience suggested and is not considered an optimal method. Live trapping, the standard method for monitoring small mammal populations, proved very labor intensive and had an apparently low trap success rate, consistent with previous studies reporting low trapping success. Camera trapping effort was moderate, yet may have identified up to three times the number of individual squirrels compared with live trapping on the two plots where we trialed this method. However, live trapping and marking helped observed identify individual squirrels by providing visible marks on a subset of the individuals captured on camera trap photos.

As with previous studies of translocated ground squirrels (see review in ICR 2011 proposal to SDF), we found ground squirrels have great potential for long-distance post-release dispersal, as determined by radiotracking a subset of squirrels. Rejection of habitat at the release site, followed by such long-distance dispersal, is an important prediction of mortality across a variety of mammalian species and also renders estimates of survival difficult when re-capture/re-sighting is limited. In the present study, squirrels from Sweetwater East dispersed the greatest distance, moving an average of 1.6 km in the first 36 days post-release. Many of these long-distance movements likely ended in mortality via predation, starvation, or other factors. Squirrels dispersing from the release site also may not contribute the desired ecosystem engineering impacts at the location needed for burrowing owl recovery or other restoration efforts. Dampening post-release movements should be an important component of future efforts.

Our results suggest that dispersal was greatest when there was either the “push” of unsuitable habitat (e.g. soil type) at the release site or “pull” of suitable habitat elsewhere. Two plausible factors may have affected translocated squirrel settlement in Otay, where dispersing squirrels were known to settle around nearby horse farms that also contained resident squirrels: (1) If squirrels were attracted to settle there because of the presence of conspecifics, then *conspecific attraction* (discussed in ICR 2011 proposal to SDF) may have played a causal role. This hypothesis predicts that dispersing individuals use the presence of conspecifics to identify suitable habitat and therefore select sites already occupied by other squirrels; (2) Alternatively, it is possible that the anthropogenically modified habitat near the horse farms was more similar to the habitat at the source site (a ranch). If so, the *Natal Habitat Preference Induction (NHPI)* hypothesis (discussed in ICR 2011 proposal to SDF) was supported. NHPI occurs when animals imprint on the habitat at place of birth and, when dispersing, select habitat that is more similar to their natal habitat.

The overall success of the squirrel translocation program appears to be moderate. Translocations to three sites (Sweetwater East, Otay North and Otay South) failed immediately, with most squirrels dispersing or dying shortly after release. A fourth, Rancho Jamul South, failed more slowly, with squirrel mortality and/or dispersal occurring more gradually, but with little evidence for remaining squirrels 9 months following release in Winter-Spring 2012.

Previous hard-release translocations reported in the literature resulted in the loss of virtually all squirrels to dispersal and mortality within a few days (see review in ICR proposal to SDF, 2011). Therefore, it is clear that the soft-release techniques we used, most notably on-site acclimation chambers and supplemental feeding following release, were beneficial. Future squirrel translocations should, at a minimum, use these soft-release techniques. Other modifications to release techniques should also be trialed to develop higher success rates (specific recommendations below).

These early results indicate that natural squirrel dispersal or immigration into sites with enhanced habitat was minimal and thus ground squirrel translocation will remain an important part of any strategy designed to rapidly restore the ecological functions that ground squirrels provide. Although resident squirrel populations were observed near the experimental plots, it is unknown whether squirrels living in higher density and closer proximity would be more likely to immigrate to the experimental plots, although in some cases the reverse was true: we found that some squirrels released near areas with resident populations dispersed and settled in previously occupied areas. A future study could address this question by conducting habitat enhancement experiments at varying distances from squirrel colonies of varying sizes. The rate of natural dispersal and colonization could then be monitored and compared with results from experimental translocations.

In our study, only two squirrels immigrated into the seven experimental habitat enhancement replicates, suggesting that the enhancement measures taken here were insufficient to attract squirrels to settle. Nine months following the translocation, burrow surveys showed that translocation plots in the four successfully colonized experimental replicates contained more than 130 active burrows, compared to only a single burrow established on matched control plots that did not receive translocated squirrels. All seven experimental sites were selected in areas deemed otherwise suitable for burrowing owls, and in areas where burrowing owl re-establishment was desirable, as determined by an ad hoc burrowing owl partnership team. Future efforts to restore habitat for burrowing owls will undoubtedly take a plurality of approaches, but our results indicate that squirrel translocation will remain an important tool to reestablish fossorial mammals at many sites that do not have sufficiently large nearby squirrel populations to allow for rapid recolonization. Creation of open habitat alone in these circumstances will not achieve desired results expeditiously.

5.2 *Mechanisms that Affect Translocation Success: Release Site Selection*

Results indicate that release site selection may play a critical role in ground squirrel translocation success. Across the three sites and 7 experimental paired research plots ("pies"), retention and/or survival of squirrels for 6 months post-translocation at some sites was much better than others. Soil type seems to be the most likely variable responsible for this difference, and our working hypothesis is that the hard, compacted soils at some sites made burrow establishment too difficult, forcing squirrels to disperse and/or making them more vulnerable to predation, exposure and other threats. Consistent with this view, squirrels established more burrows on sites with softer soils and most burrowing activity on hard soil was seen alongside artificial burrows where the soil was previously disturbed. Tracking dispersing squirrels and re-sighting of un-collared, marked squirrels indicate that some of these squirrels dispersed to nearby dirt mounds and established burrows in the loose soils there.

Selection of study sites was limited to accessible conservation properties within southern San Diego County. In addition, the first translocation program was carried out without rigorous data on ground squirrel habitat suitability to guide site selection, and thus we viewed releases at these sites to be probes to determine habitat suitability in the absence of better predictive data. The results are consistent with our *a priori* hypotheses that it would be more difficult to establish squirrel populations at mitigation sites such as Otay Mesa, where the quality of soil appeared less suitable.

To increase our ability to successfully translocate or attract dispersing ground squirrels, we must first better understand their habitat needs. Surprisingly little research has been conducted on the habitat requirements of California ground squirrels. We recommend presence/absence survey studies of ground squirrels in San Diego County that examine habitat covariates to gain a better understanding of the factors influencing the distribution and abundance of ground squirrels. There is currently no scientific basis for understanding why ground squirrels are locally abundant at some sites and absent at many others. If we do not understand this relationship, we may be unsuccessful at selecting sites that will support sustainable burrowing owl populations dependent on ground squirrel burrows. Indeed it is possible that some selected mitigation sites will never support burrowing owls without continued human intervention in the form of burrow creation, if the habitat will not support ground squirrels. Thus, better knowledge of ground squirrel habitat requirements will be instrumental in guiding any burrowing owl recovery program and may radically alter how mitigation sites are selected.

5.3 *Ground Squirrels as Ecosystem Engineers*

Determining how well our goal of restoring ecological function was met will require long-term monitoring. Observations indicate that the plots with highest squirrel retention have many natural burrows and disturbed surface soils with more open vegetation. The number of burrows available on squirrel release plots far exceeded those on control plots, indicating that translocated ground squirrels are already beginning to perform their role of ecosystem engineers, at least with regard to provision of burrow refuges for other species. With time, squirrels enlarged burrows and created vegetation-free “aprons” around the burrow opening, as indicated in data collected 9 months after translocation. Interestingly, several burrowing owls have been sighted on our treatment plots, indicating that owls may find this newly created habitat suitable. Whether this initial level of burrowing can be sustained at the established squirrel densities is unclear. Continuing monitoring of squirrel activity and vegetation characteristics at the seven 2011 experimental plots is required, and supplemental translocations and vegetation enhancement treatments are recommended for sites retaining squirrel populations in 2012.

5.4 *Burrowing Owl Population Dynamics*

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 year 1 most of our efforts focused on burrows and habitat. In future years, inclusion of prey availability and foraging ecology studies is recommended.

In 2011, ICR initiated a banding effort for burrowing owls, intended as a pilot project for future study. Although this effort was minimal, it showed great promise for future use to understand population dynamics and insight into life history variables for the southern San Diego County population. For example, opportunistic monitoring by ICR biologists at the Lonestar site documented that birds banded during the nesting season remained on site throughout the fall and winter. It was previously not known that individual birds at this site use it for both breeding and over-wintering, suggesting that the open habitat that prevails in the Otay Mesa area is important as both breeding and wintering habitat year-round. 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.

In 2011, we conducted a pilot project to test the utility of using camera traps to document squirrel translocation outcomes and burrowing owl reproductive and foraging ecology. We deployed camera traps at burrowing owl nest burrows, California ground squirrel release site acclimation cages, and along the periphery of paired plots. Results indicate that camera traps at burrowing owl nests allow us to count chicks to determine reproductive success, track prey deliveries by adult owls, identify prey items, and detect nesting failures. We consider the use of camera traps to study the reproductive ecology of the San Diego County population and to understand site-specific factors that affect variation in reproductive success to be an important future effort to advance local BUOW conservation. We recommend studies of how prey availability affects nest attendance, feeding of chicks, chick growth, and chick survival. Together with our data on habitat and burrows, prey surveys and chick survival estimates will help inform the third cornerstone variable affecting BUOW population dynamics: prey. Anecdotal evidence from 2011 suggests that prey availability can play an important role in nest productivity. The most successful nest sites (the two nests destroyed at the Lonestar site) had ample evidence of surplus prey, with dozens of headless vole bodies left uneaten around the burrows.

These camera traps also facilitated data collection in our broader study. They allowed us to monitor squirrels on experimental sites, as individually identifiable marks can be read from the photos. In addition, they have proven effective at documenting use of experimental sites by BUOW, providing valuable data on the effectiveness of our experimental treatments in attracting owls. Brief visitation to sites by owls that fail to establish themselves (site rejection) may indicate that we have failed to provide all the habitat characteristics important to BUOW.

ICR biologists also documented the unfortunate human-caused destruction of two of the most productive BUOW nest burrows documented during this study. These two burrows were located 5 m apart within one small berm along an airport access road between the Lonestar site and Brownfield Airport in the Otay area. Combined, both burrows fledged 17 young owlets from 2 adult pairs allowing ICR biologists, on multiple occasions, the rare sight of observing up to 21 owls at a time. Apparently, these burrows were intentionally destroyed, underscoring the need to actively manage protected sites to encourage BUOW to move out of vulnerable areas and into protected areas.

Habitats that are optimal for squirrels may not always be available where burrowing owl recovery actions are needed. It is possible to establish squirrel populations in less suitable habitat, but these sites will likely require greater human intervention and continued maintenance; that is, they will be less self-sustaining. For example, it is clear that in areas with hard-compacted soils, ground squirrels will utilize areas where soils have been softened, such as dirt mounds and berms. At priority sites for burrowing owls these habitat modifications should precede efforts to establish ground squirrels. Otay Mesa is such a site, where—although our results suggest that the soils may not be suitable for ground squirrels—there is a large population of BUOW. Many of these BUOW are currently residing in highly vulnerable areas on private property, along roadsides, and in other highly disturbed areas. Establishment of ground squirrels, burrows, and suitable vegetation cover in nearby protected areas, such as Caltrans mitigation sites, may encourage these owls to move to safer areas better suited for long-term sustainability. While the Otay area may not contain the best soils to create a self-sustaining system engineered by ground squirrels, active management is recommended because it will provide the best short-term solution to ensure that one of the last BUOW strongholds in the County is not lost.

RECOMMENDATIONS

6.1 *Release Site Selection and Management*

- Conduct presence/absence survey studies of ground squirrels in San Diego County that examine habitat covariates to gain a better understanding of the factors influencing the distribution and abundance of ground squirrels.
- Obtain a more data-based understanding of soil characteristics at current and future squirrel release sites or sites under consideration for BUOW recovery effort.
- Take into consideration conspecific attraction and possibility that nearby resident squirrel population may draw translocated squirrels away from the release site.
- Test other methods of habitat enhancement, including grazing and prescribed fire, where feasible.

6.2 *Squirrel Translocation Methodology*

- Release > 50 individuals at each experimental plot.
- Take measures to reduce predation-related mortality at release site, such as provision of cover.
- Trial other methods to increase post-release retention and survival, such as efforts to identify family group membership and release as an intact family group, or at least with group members familiar with one another.
- Continue to develop best-practice, cost-effective methods for monitoring squirrel populations established at BUOW recovery sites through translocation or natural dispersal:
  - Increase exploratory use of camera traps as a means for monitoring squirrel populations and their predators, as well as visitation and use by BUOW.
  - Trial use of Passive Integrated Transponders (PIT tags) for permanent identification of individual squirrels and scanners (Radio Frequency Identification; RFID) placed near burrows or feeding stations to monitor squirrel survival and retention post-release.
  - Once a successful squirrel translocation strategy has been established, consider greater, and perhaps exclusive, reliance on low-cost monitoring via burrow surveys.
- Determine the circumstances and speed with which natural squirrel dispersal will lead to site recolonization following habitat enhancement, obviating the need for squirrel translocation.
- *Site-specific Recommendations*
  - At the Rancho Jamul plots, and the larger Rancho Jamul area, soils appear to be suitable for ground squirrel establishment and burrowing activity, so continued efforts to enhance habitat and re-establish squirrels there are recommended. As a CDFG rehabilitated BUOW release site, Rancho Jamul has great potential for BUOW recovery. Large-scale methods to enhance habitat, such as prescribed burns and grazing, are recommended. Squirrel translocations are recommended for sites without large nearby resident squirrel populations.

- At Sweetwater, habitat suitability appears more variable, with some sites possibly containing soils suitable for ground squirrel burrowing and others with soils too compacted to be attractive to translocated squirrels. Thus, continued efforts to re-establish squirrels, including the use of translocation, is recommended but site selection should be guided better by knowledge of soil characteristics and other factors influencing ground squirrel habitat suitability.

6.3 *Burrowing Owl Population and Reproductive Ecology*

- Monitor spatial pattern and temporal trends in San Diego County BUOW population using a combination of banding and camera trapping for mark/recapture analysis.
- Study factors affecting BUOW dispersal and habitat selection, foraging habitat, prey base, reproductive success, nesting ecology, predation, and other variables that may determine BUOW population viability and distribution on the landscape.
- Evaluate habitat for BUOW and ground squirrels in south San Diego County and countywide, establishing criteria for site characteristics that govern suitability for BUOW and map suitable sites for BUOW recovery actions countywide.
- Develop a San Diego County and regional conservation strategy for BUOW, which addresses the role of small fossorial mammals.

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