Monitoring and Adaptive Management of Burrowing Owl on Conserved Lands in Southern San Diego County

TASK D: DATA ANALYSIS AND SYNTHESIS

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Executive Summary

This document has been written to satisfy the reporting requirements for Task D, and reports on the completion of data analysis and synthesis tasks for assessing the efficacy of the habitat enhancement experiment. This report is based on a larger collaborative effort with the Institute for Conservation Research (ICR) at the San Diego Zoo. As detailed in the SOW, the results contained in this report include a broad and comprehensive analysis of data collected by SDSU under contract Amendment 1 to contract #5001562 with SANDAG and includes additional data collected by the ICR.

Introduction: The Western Burrowing Owl (*Athene cunicularia hypugaea*), is a species of special concern in California, and has been prioritized for study and conservation in the San Diego MSCP. Populations in southern, coastal CA are thought to be smaller and more restricted relative to historical levels. Habitat loss, change in habitat quality, and scarcity of suitable burrows are likely responsible for these declines in burrowing owl.

Objectives: The purpose of this study is to develop habitat enhancement techniques for re-establishing and maintaining low, open grassland habitat for owls. Low vegetation makes locating and capturing rodents easier and improves the owl's ability to detect predators. The study also evaluates the feasibility of increasing habitat quality and burrow availability by re-establishing self-sustaining populations of the California ground squirrel (*Otospermophilus beecheyi*).

Much of the significance of this study is in its focus on the reestablishment of California ground squirrel populations as ecosystem engineers that create burrows and enhance burrowing owl habitat. Soil type and condition may interfere with habitat enhancement treatments and decrease the success of squirrel reestablishment. In addition, land use activities like agriculture and grazing can compact the soil which may be associated with lower levels of burrowing activity. To evaluate these factors, this experiment includes three treatments: mowing, soil decompaction and squirrel translocation.

Methods: The habitat enhancement treatments manipulated habitat structure, soil compaction, and squirrel presence in a factorial experiment in order to evaluate the relationships between these three variables. We assessed whether California ground squirrel persistence and burrowing activity was higher after the vegetation treatments. Ongoing data collection includes assessment of whether squirrel activity maintains low, open habitat over the long term (i.e. effectiveness of squirrels as engineers).

We established 14 plots (in 7 pairs) across three study sites to allow us to account for variation due to site. The sites include Rancho Jamul Ecological Reserve (RJER, managed by CA DFG), the Lonestar Ridge West parcel on Otay Mesa (managed by CALTRANS), and the San Diego-Sweetwater National Wildlife Refuge (managed by the US FWS). The plots are circular, 100 m in diameter and divided into three wedges. One of three treatments (control, mowing, mowing plus soil decompaction) were assigned to each wedge. One plot from each pair received the squirrel translocation treatment, and the other plot did not.

Pre-treatment and post-treatment vegetation structure assessments were conducted in all wedges of each plot. A 25m transect was established in each treatment wedge and data on the vegetation structure was collected using a suite of qualitative and quantitative approaches. In addition, squirrel activity patterns and burrowing were recorded in each plot. Creation and/or enlargement of burrows was considered the key metric of the ecosystem engineering by squirrels.

Results: Mowing and soil decompaction treatments were completed on all plots in June 2011. Changes in the vegetation structure of experimental wedges were assessed in August 2011. As expected, the treatments had a significant short-term impact on the height and openness of the vegetation community. We are revisiting these plots in the 2012 growing season to measure the long-term impact of the treatments.

Approximately 50 squirrels were released per plot (range 29-59). Burrowing activity was documented in plots receiving translocated squirrels, but not in control plots. Moreover, squirrel activity was localized to the wedges receiving vegetation treatments. There is some evidence that squirrel burrowing activity was higher in the soil mowing plus decompaction wedge compared to mowing alone. The long-term persistence of squirrels varied by plot. Some plots experienced rapid declines and others remained fairly stable. Increased burrow densities and burrow size were sustained for a full year in three of the seven translocation plots.

Discussion:

In this first project year we made progress toward the primary goals of designing an effective translocation protocol for the California ground squirrels and documenting the ecosystem engineering effects of California ground squirrel burrowing activity at release sites. The results support the idea that both vegetation enhancement and squirrel re-introductions may be a powerful tool in restoring owl habitat. Even with extensive squirrel movements, dispersal, and mortality, on almost half of the plots enough squirrels stayed to produce extensive and significant burrowing disturbance. Immigration by resident squirrels to treated habitat was minimal; the current data indicates that a "build it and they will come" approach to habitat enhancement is not sufficient for establishing new squirrel populations on restoration sites within short time scales. It appears that site selection was an important factor determining squirrel persistence on each translocation plot; the development of a habitat suitability model may enable more accurate predictions of squirrel persistence in the future. High levels of burrowing activity in the sandy loam soils at Rancho Jamul relative to the other sites suggest that soil type and compaction may be important predictors of squirrel persistence. Follow-up vegetation treatments may also be needed in order to establish long-term squirrel persistence; in one Rancho Jamul plot we observed a decrease in squirrel activity that was potentially due to seasonal grass regrowth.

Conclusion: Although there is still much to learn from this experiment, the results from year one offer evidence that paired vegetation manipulation and squirrel relocation may be an effective management strategy. The data from ongoing efforts will provide insight into the long-term persistence of the squirrels as well as their sustained impact on the vegetation community. Data from year two will enhance our understanding of the costs and potential benefits of this approach.

Section 1. Introduction

The Western Burrowing Owl (*Athene cunicularia hypugaea*), is considered a species of special concern by the State of California (Shuford and Gardali 2008). Within San Diego, records indicate that burrowing owls previously inhabited a higher number of locations in the county than are currently occupied (Unitt 2004) leading the Multiple Species Conservation Program to designate burrowing owls as a priority species in San Diego county. Population declines and local extinctions have been recorded through surveys in southern and coastal locations undergoing urbanization (Gervais et al. 2008). A petition to list burrowing owls in the state of California was reviewed but later denied despite local declines due to the presence of a very large source population of burrowing owls in the Imperial Valley (CA DFG 2003), estimated at 5,600 pairs in 1992-1993 (DeSante et al. 2004). However, this population is currently declining for unknown reasons. Population size was estimated at 4900 in 2007 but only 3600 in 2008 (Manning 2009). Subsequent surveys indicate the decline has continued (D. Deutschman and J. Simonsen-Marchant, unpublished data). Local population declines are not limited to California, concern for Western burrowing owls is widespread with reports of loss in locations throughout the United States (Desmond et al. 2000).

The factors that are potentially responsible for declines in burrowing owl population size include reductions in habitat area and changes to habitat quality. Burrowing owl habitat in southern California has been reduced by urban development, exotic species invasions, and increases in fire frequency. In San Diego County, a large propotion of native species habitat has been lost to urbanization including housing and business development as well as consequent infrastructure. In addition, native grasslands have been converted to exotic annual grasslands dominated by species such as wild oat (*Avena fatua*) and brome (*Bromus diandrus*, *Bromus madritensis*). These invaders have been present in California for more than a century and are key species in the widespread type conversion of native (often perennial) grasslands to exotic annual grasslands (D' Antonio et al. 2007).

The purpose of this study is to develop habitat enhancement techniques for re-establishing and maintaining low, open grassland habitat for owls. For owls, low vegetation makes locating and capturing rodents easier. It also increases the odds that burrowing owls will detect predators before they strike. The study will also focus on increasing burrow availability by increasing the presence of the burrowing mammal most important to burrowing owls in the San Diego region, the California ground squirrel (*Otospermophilus beecheyi*). The presence of burrows available for occupancy may be an important factor for burrowing owl populations (Moulton et al. 2006). In addition to creating burrows, squirrels cut grass and forb stems during their normal foraging activity, and they trample the vegetation enough to keep the vegetation community lower and more open than it would be otherwise (Fitch 1948).

Much of the significance of this study is in its focus on the reestablishment of the California ground squirrel as an ecosystem engineer that supports burrowing owls through its burrowing and foraging activities. Therefore, we need to take the habitat requirements of squirrels into account. The effects on the California ground squirrel of type conversion to exotic annual grasslands are largely unstudied; however, forage for squirrels may be impacted by the abundance of native plants and seeds relative to exotic species. Thick thatch may impede foraging and burrow digging activities. Dense ground cover may also reduce the ability of

California ground squirrels to visually detect predators. The habitat enhancement treatments in this study are designed to reduce vegetation density and the amount of thatch cover on the soil surface. We will assess whether California ground squirrel persistence and burrowing activity is higher after the vegetation treatments. Since California ground squirrels alter vegetation structure through foraging activities, we also expect that in locations with greater squirrel activity, vegetation density and thatch cover will remain lower and bare ground cover will remain higher. The study design includes an examination of this positive feedback of squirrel activity on vegetation structure.

Soils also play a role in the success of habitat enhancement treatments. Higher levels of soil compaction may be associated with lower levels of burrowing activity. Many grasslands in San Diego County have previously been used for agriculture, grazing, and other activities that compact the soil, and we hypothesize that more compacted soils are less suitable for burrowing. Therefore the habitat enhancement treatments include a soil decompaction treatment.

The habitat enhancement treatments are designed to manipulate habitat structure, soil compaction, and squirrel presence in order to enable examination of the relationships between these variables. The purpose of these treatments is to contribute to the development of a protocol to produce self-sustaining squirrel populations after a onetime implementation by land managers, as a first step in re-establishing burrowing owl populations. One drawback of habitat enhancement is that it incurs costs of money and time, and if the treatment needs to be repeated periodically, future expenditures must be planned. Therefore, an important goal for habitat enhancement is to establish populations that sustain themselves in the long-term as wild populations.

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Section 2. Methods

Plot establishment

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. 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 due to concerns that the stronger afternoon heat of these sites 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.

Plot size and layout

The circular plots are 100 m in diameter, with an area of 7854 m^2 (1.94 acres). Each circle is 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. The wedges of each plot have been treated with two treatments (mowing, mowing plus decompaction), as well as a control treatment. In each pair of plots, one plot received the squirrel translocation treatment, and the other plot did not (Figure 1). The paired plot design allows us to separate the direct effects of vegetation manipulation from the ecosystem engineering effects of ground squirrels.

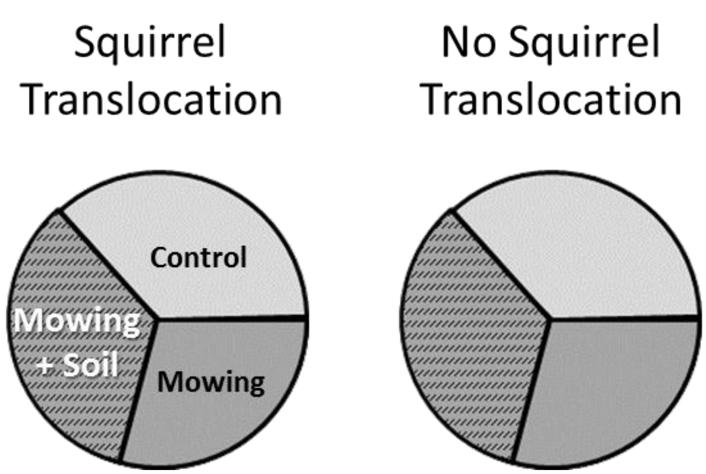

Figure 1. Paired design of the habitat enhancement/squirrel translocation experiment.

Installation of below-ground acclimation burrows

ICR prepared the plots for squirrels, installing acclimation burrows and conducted all aspects of the squirrel translocation. The translocation procedure called for a soft release, requiring holding squirrels on the experimental pies in artificial burrows with protected above- and belowground spaces for one week before release. The method is intended to allow squirrels time to acclimate to the relocation site, and to reduce initial mortality and dispersal from the translocation site. ICR installed 12 artificial burrows per plot on both the control and experimental pies (Figure 1). The control plots received artificial burrows to control for any confounding effects associated with artificial burrow creation. A backhoe was utilized to dig a trench approximately one meter deep and one meter long. Acclimation cages consist of an underground nest chamber (30 cm diameter x 30 cm high) set 1.0 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) (Figure 2). As an added precaution, the footprint of the dug surface was covered with chicken wire to prevent predators from digging up the underground cage.

Figure 2. Above- and belowground components of artificial burrows before installation.

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 decompaction. The mowing and thatch removal for treatment 2 were the same as above. Soil decompaction 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 decompaction) was located on the side nearest the feature, to minimize disturbance. The only plot that this rule applied to was SWTR5C, 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.

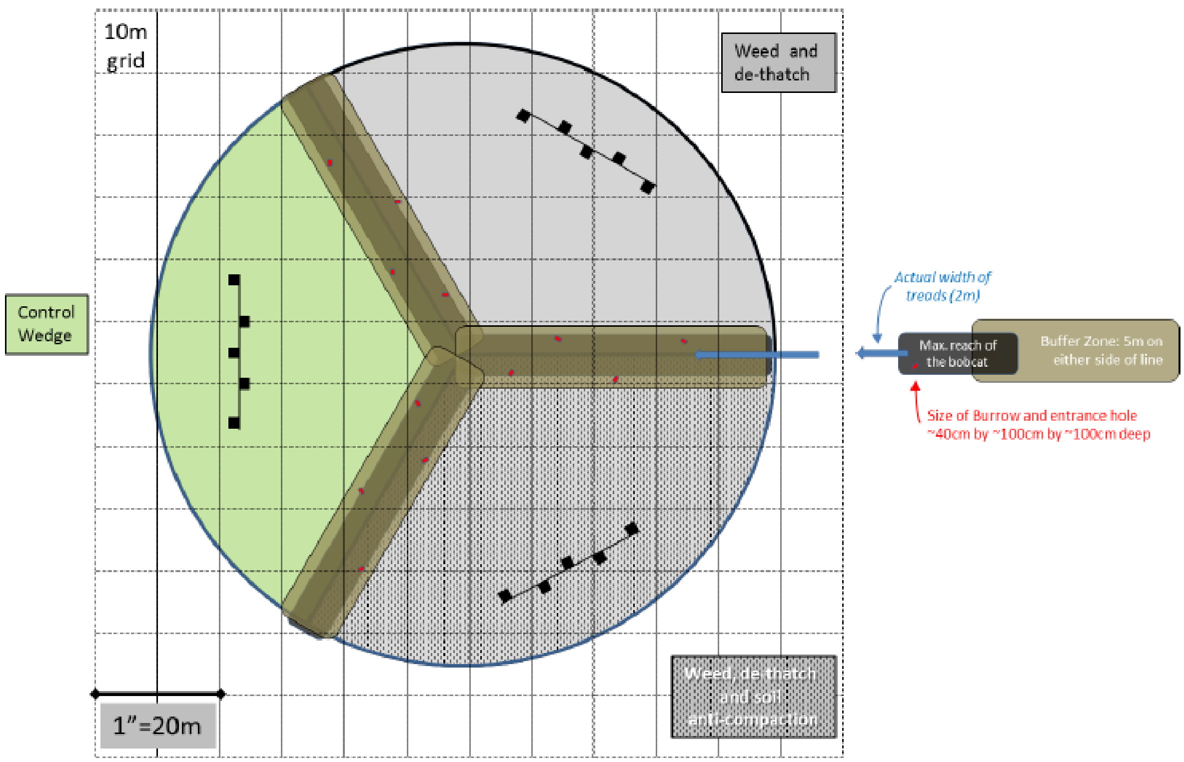

Figure 3. Scaled diagram of plot layout. The artificial burrows were located along the strips dividing each treatment to give squirrels an equal choice between vegetation treatments. Gray shading indicates both the footprint of the mechanized equipment used to install the burrows and the furthest reach 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.

Squirrel translocation procedures

Source site trapping

ICR captured California ground squirrels for relocation from source sites at North Island Naval Base Coronado (NBC) and at local ranches in Pine Valley and Jamul. The original target number was 30-50 squirrels per experimental replicate across 7 sites, for an approximate total of 300 translocated squirrels. The trapping protocol was intended to keep squirrels living in close proximity on the source site together throughout the translocation process, in order to maintain familiar social groups of individuals. The target release group for one pie comprised a minimum of three adult males and six adult females, plus their weaned pups.

All live-trapping, processing, and radio-collar procedures followed the guidelines established by the American Society of Mammalogists (Gannon et al. 2007). Traps were set in the early morning around burrow complexes, checked every half hour, and closed by late morning to avoid high temperatures. Squirrel capture for each experimental plot was completed over a span of 4-6 consecutive days. At the end of each morning trap session, all squirrels were transported to the holding facility to be processed.

Squirrel processing and holding

ICR biologists performed a health check, designed in consultation with a San Diego Zoo veterinarian, for all captured squirrels, and a flea treatment was administered. Age, sex, weight and reproductive condition were recorded for each squirrel, and each individual was marked with standard ear tags (National Band and Tag) and a unique pelage dye for individual identification. 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 gm neck collar with an average battery life of six months (model: Holohil® PD-2C, www.holohill.com/bd2c.htm).

Acclimation period

The above-ground retention cage was attached to the burrow entrance one to two days before squirrels were transferred from holding to acclimation. The experimental plot 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.

ICR transported the squirrels to the acclimation site and released them into the aboveground cages in the familiarity groups described above, to acclimate for one week. During transfer, each squirrel was observed until it entered the burrow. All squirrels quickly found the burrow entrance and disappeared belowground. Squirrels were provided with water bottles and feed similar to the holding period for the duration of the acclimation period.

Squirrel release

After one week, acclimation cages were removed at mid-day, when squirrels are generally inactive and resting underground. After release ICR monitored squirrels with 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.

Assessment methods

A pretreatment vegetation structure assessment was conducted in all wedges of each plot. The post-treatment habitat assessment was conducted once, after both the vegetation and squirrel translocation treatments had occurred. Assessments consisted of both qualitative (photopoints) and quantitative methods.

Vegetation Cover and Composition

For each treatment wedge, a 25 m transect was established (Figure 3). We collected point count data by reading 50 points per transect, one each 0.5 m. We recorded all species touching the point, and characterized the ground surface (bare ground, rock, litter, fine woody debris, etc).

For each transect, we also conducted five ocular estimates of cover utilizing a 1 m^2 quadrat. Cover estimates were by cover type (ie. bare, rock, fine woody debris) to characterize the ground surface, and totaled 100% per quadrat. We also estimated cover by species to characterize the plant community. The species data was intended to record all species in the quadrat. Species cover values represent the canopy cover of each species, and may add to greater or less than 100% cover per quadrat. These sampling methods characterized plant cover by invasive plant status (native versus non-native) and functional group (shrub, grass, forb), and assessed bare ground and thatch cover.

Vertical Structure

Vertical structure was assessed using a Robel pole vertical obstruction method, to a height of 1 m (Herrick et al. 2005). Vertical structure measures habitat structure in terms of height and homogeneity of vegetation cover, which provides information about habitat suitability for wildlife.

The Robel pole was placed at three points along the transect in each treatment wedge (at 5, 12, and 19 m). Two observations were read at each position from a distance of 5 m. The pole is divided into ten segments that are 10 cm long, plus another level of subdivision into 5 cm bands. The data sheet is recorded for the presence/absence (1/0) of visual obstruction at each band. A band is counted as obstructed if 25% or more of the band is obstructed (by vegetation, rock, woody debris, etc.)

Squirrel Monitoring

Upon release, ICR tracked all collared squirrels 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.

Pilot Camera Trap Monitoring

ICR installed Camera traps (2 brands: Reconyx® HC, and Bushnell® Black flash remote camera systems) to monitor squirrels at two relocation sites in Jamul. Four cameras were installed at each of two experimental plots to monitor squirrel activity. The data from the cameras proved valuable so the cameras were maintained so that they have been in continual use on these two sites since release day. Data was managed using the database software Camera Base, version 1.4.

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

Several areas of ground squirrel foraging and digging activity were identified by shallow scratches in the soil and by scat. These were recorded either as GPS points or polygons, depending on extent.

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Section 3. Study sites and plot locations

Study sites

The study is being conducted on three sites in southern San Diego County. Rancho Jamul Ecological Reserve is managed by the California Department of Fish and Game for sensitive habitat and species conservation. It consists of former agricultural fields and pasture on sandy loam soils. The current plant community primarily consists of non-native grasslands, riparian habitat, and coastal sage scrub on slopes (Figure 4).

The 164 acre Lonestar Ridge West parcel on Otay Mesa is owned by the California Department of Transportation (Caltrans) and is managed for species habitat (San Diego fairy shrimp, Quino checkerspot butterfly, burrowing owl, and sensitive plant species). The site currently consists primarily of non-native grassland, with small areas of coastal sage scrub, disturbed vernal pool wetlands, and eucalyptus woodlands on gravelly clay loam soils, but restoration activities are ongoing (Figure 4).

The San Diego-Sweetwater National Wildlife Refuge is managed by the U.S. Fish and Wildlife Service for sensitive habitat and species conservation. Primary management activities include exotic species removal and the restoration of vernal pools and coastal sage scrub. The current plant community consists of native and exotic grassland species and coastal sage scrub. Soils are silt loam, with cobbles (Figure 4).

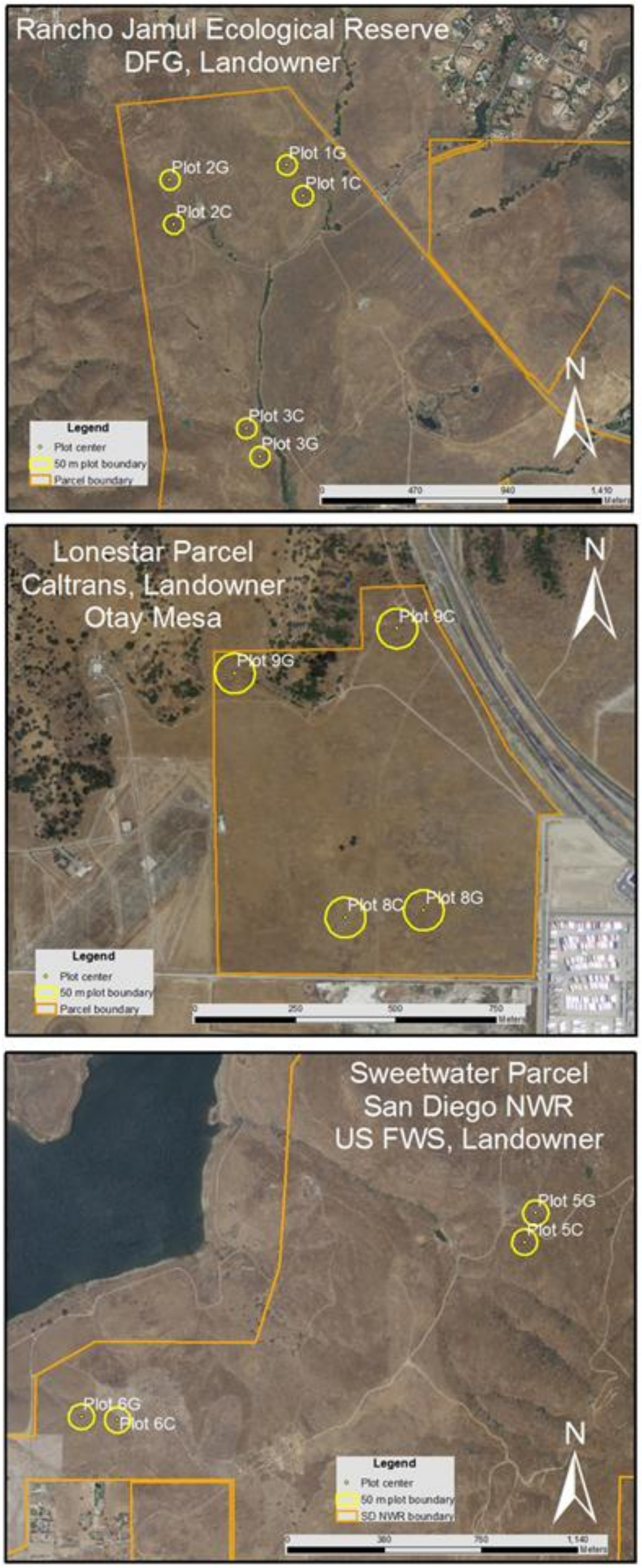


Figure 4. Maps of plot locations across the three research sites.

Plot nomenclature and location data

Site codes were assigned to denote whether plots were located at Rancho Jamul (RJER), Sweetwater (SWTR), or Otay Mesa (OTAY). The plots are labeled with a unique numeral, plus a letter denoting which of the paired plots was the control (C, "Control") or the squirrel translocation (G, "Ground squirrel") plot. The GPS information needed to locate the plots is presented in Table 1.

Table 1. Final plot locations (Coordinate system WGS 84)

Site	Plot	X Coordinate	Y Coordinate
RJER	1C	-116.8632070	32.6951596
	1G	-116.8640860	32.6965543
	2C	-116.8701832	32.6938240
	2G	-116.8703999	32.6958499
	3C	-116.8661811	32.6845262
	3G	-116.8654600	32.6832400
SWTR	5C	-116.9679560	32.6936797
	5G	-116.9675031	32.6947163
	6C	-116.9849724	32.6872751
	6G	-116.9864816	32.6873812
OTAY	8C	-116.9674745	32.5764402
	8G	-116.9653895	32.5766168
	9C	-116.9661466	32.5829479
	9G	-116.9704641	32.5819183

Section 4. Results

Squirrel translocation results

For additional details on the squirrel translocation data and results, see the ICR end-of-year report. ICR translocated a total of 327 squirrels to the experimental plots, including 34 males, 75 females, and 218 juveniles. The first release occurred on June 7 at RJER3. After that, 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 ranged from 29 to 59 (average 46.7). The minimum target number was 30-40 squirrels per pie, but more squirrels were translocated when possible to increase the chances of success.

Translocated squirrel survival and retention- first 30 days

ICR's behavioral observations provided counts for the number of unique individual squirrels seen above ground during observation periods. These values are a relative indicator of squirrel numbers and only provide a minimum number of squirrels present on the experimental plot. However, the data showed that squirrel above-ground activity was low initially, as the maximum number of squirrels observed typically occurred a few days post-release (Figure 5). The observations also indicate that squirrel numbers declined at most sites during the first 30 days post-release, especially at SWTR6, OTAY8, OTAY9, and RJER3. However, squirrel activity remained high at RJER1, RJER2, and SWTR5.

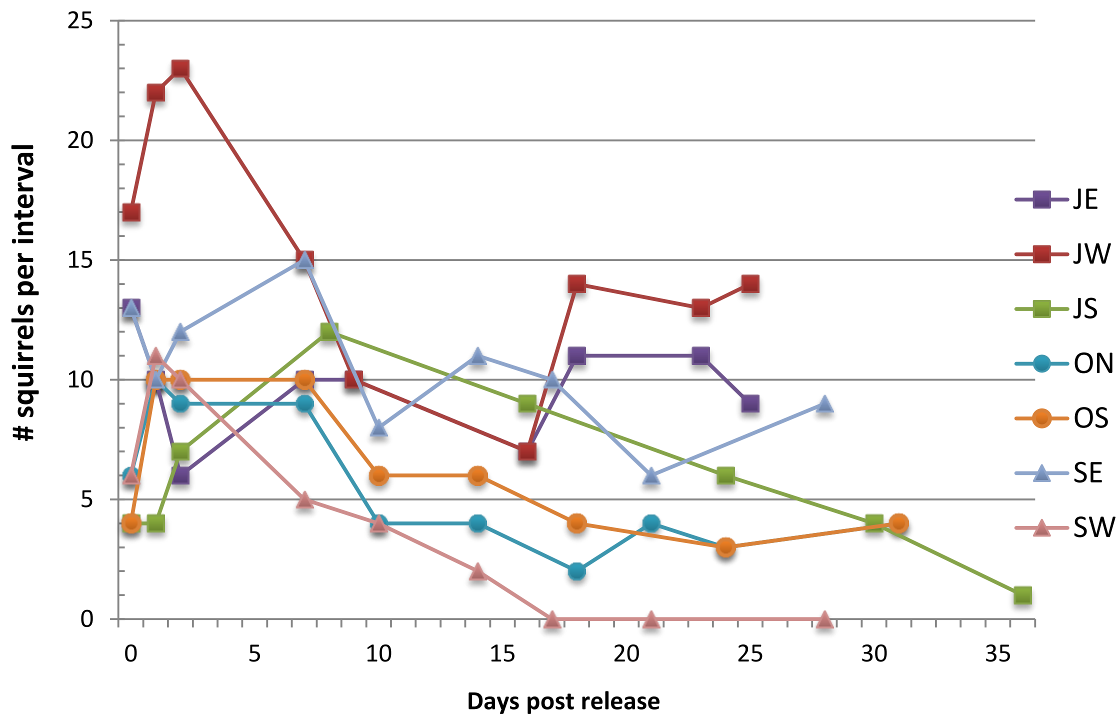


Figure 5. Maximum number of squirrels observed above ground at the experimental plot during an observation period of 3 hours. These values estimate the minimum number of squirrels remaining at an experimental plot, and do not represent a population estimate. Each line

represents one translocation plot. Plot codes: JE=RJER1, JW=RJER2, JS=RJER3, ON=OTAY9, OS=OTAY8, SW=SWTR6, SE=SWTR5.

Translocated squirrel survival and retention- first 6 months

ICR's retrapping and camera data indicated retention levels up to 6 months after translocation. At 6 weeks the percentage of retrapped squirrels was 32% across all sites (range 0 - 52%), and at 6 months the retrapped percentage was 11% across all sites (range 0 - 30%). Juveniles were re-trapped at a much higher frequency than adults, but this reflected the higher percentage (68%) of translocated squirrels that were juveniles. In addition, adult squirrels enter seasonal torpor after the breeding season and may have been underground six weeks post-release. However, adults would have been active aboveground during the trap session six months post-release, since it was timed to coincide with mating season.

Camera trap data at two plots at Rancho Jamul and observation data indicated that the trap data underestimated squirrel abundance. Photos taken at the acclimation burrow entrances enabled identification of individual squirrels both by dye-marks and distinctive physical characteristics. The photos enabled an adjustment to the estimate of squirrels retained on site by adding the number of squirrels seen only in photos to the number of squirrels trapped on the plot (for the two plots with cameras). The camera trap data increased the number of squirrels detected by 2 to 3 times at both the 6 week and 6 month benchmarks. These adjusted estimates of squirrel retention still represent a minimum estimate since even within the two plots with cameras, there were cameras at only one-third of the acclimation burrows. The cameras also did not capture activity at any newly excavated burrows.

Squirrel movement, mortality, and predation

Movement data for radiotracked squirrels indicate variability in squirrel response to different sites. Individual squirrels were tracked for as long as possible. Overall, the average tracking time was 70 days, but the tracking time varied depending on squirrel fates. The tracking data indicate that radiocollared squirrels moved around frequently, and that mean individual overall distances ranged by site from 140 to 1806 m. Mean net distances were much smaller, ranging by site from 58 to 415 m.

Of the 38 radiocollared 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. By 36 days post-release 17 squirrels were lost to the study due to lost signals or detached collars. Of the 21 squirrels with known fate, 14 were known to be alive at 36 days and 7 were known dead, indicating a possible survival rate as high as 67%.

The cameras provided evidence of the range and abundance of wildlife species seen on the plots, including predators. The most common predators seen were ravens, coyotes, red-tailed hawks, and long-tailed weasels (Table 2).

Table 2. All wildlife species identified from camera traps at RJER translocation plots. Photos came from cameras placed long-term at two plots, plus the cameras placed at all 7 plots during the acclimation period.

Common Name	Total # events*	photos/cam day	Total # cam 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	0.10	2
Weasel	15	0.07	4
Barn Owl	5	0.02	4
Great-Horned Owl	1	0.005	1
Unknown Bird Species	94	0.46	8
Unidentified Species	12	0.06	6

*event = independent (>= 1 hr between events) trigger event (series of 3 photos)
Camera traps at 2 translocation plots (RJER1 and RJER2) 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.

At the two plots with long running cameras (RJER1 and RJER2), ravens accounted for the largest percentages of predator sightings (81 and 57%, respectively) out of the total number of sightings per plot. Coyotes, red-tailed hawks, and long-tailed weasels followed (Figure 6).

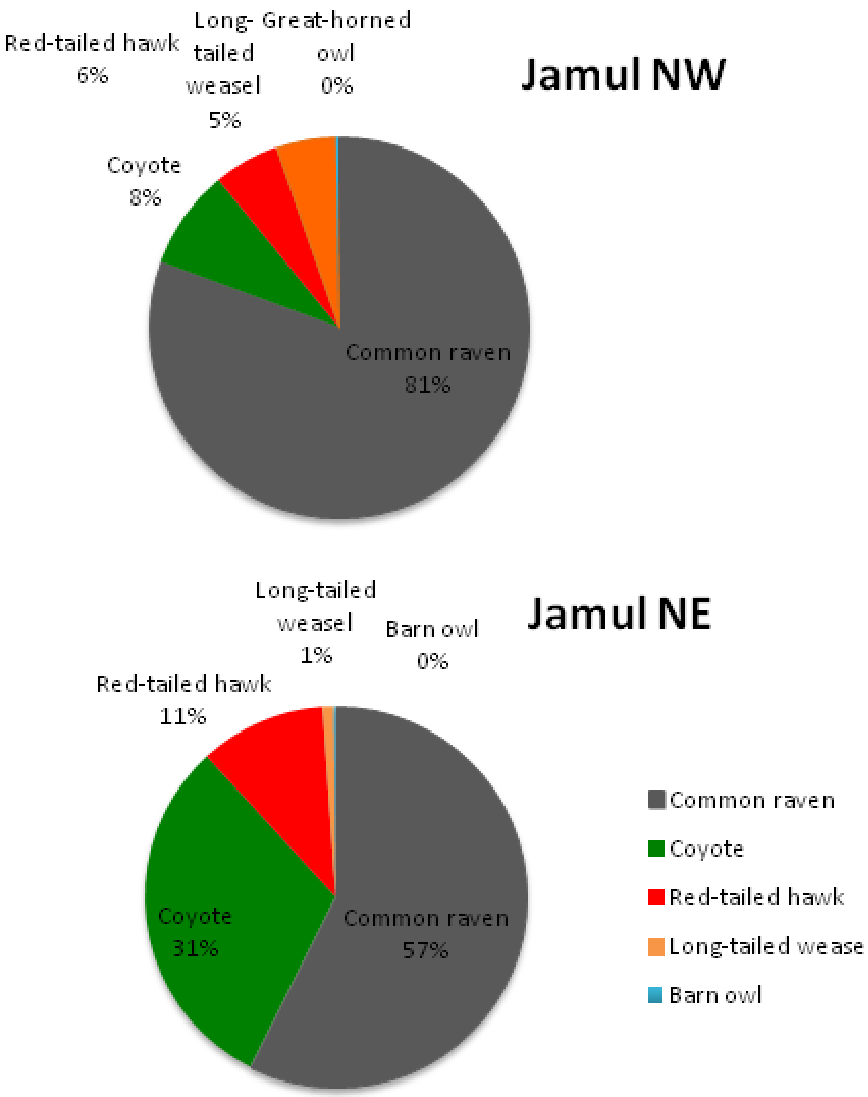


Figure 6. Predator species identified on camera traps at RJER2 (Jamul NW) and RJER1 (Jamul NE).

Ecosystem engineering effects from squirrel translocation

Translocated squirrel activity- 2 months after translocation

Squirrel translocation led to squirrel activity and persistence on the plots. The translocations were not successful in all plots, but 2 months after translocation there was squirrel persistence and activity on 5 of the 7 translocation plots. These included all of the translocation plots at Jamul, and one plot each at Otay and Sweetwater. Almost all activity was seen on the translocation plots (Figure 7). At the only control plot where squirrel burrowing activity was measured, a radio-collared squirrel was documented moving from the translocation plot to the control plot, which was within view of the translocation plot.

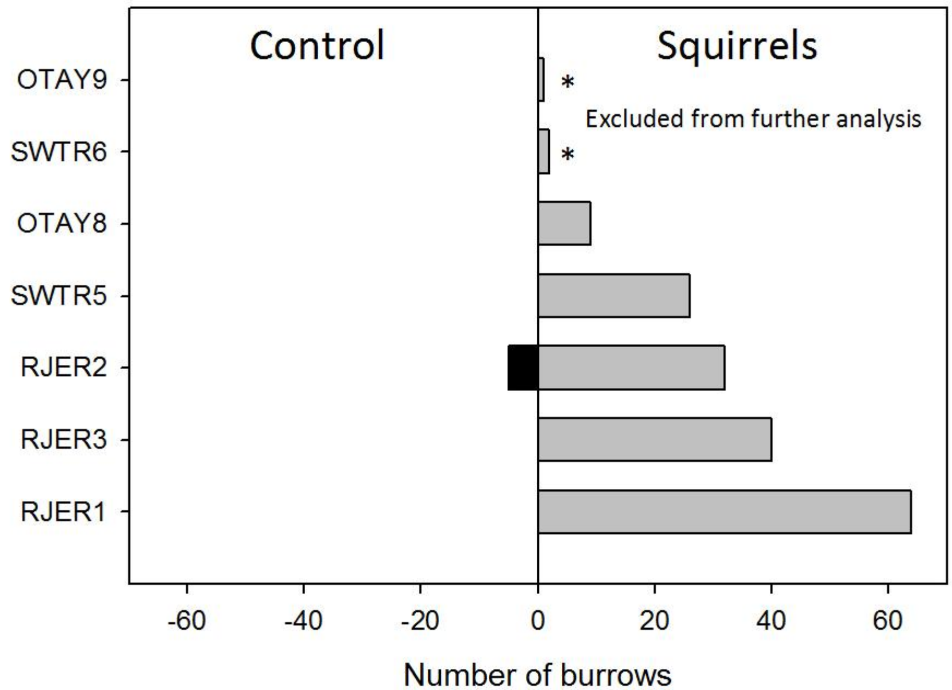


Figure 7. Comparison of burrowing activity levels on paired control and translocation plots in September 2011, 2 months after translocation.

Translocated squirrel activity- 9 months after translocation

Nine months after translocation there was squirrel persistence and activity on 3 of the 7 translocation plots. Activity levels were measured on the plots at Jamul and one of the two Sweetwater translocation plots. Experimental effects were evaluated with significance tests, in this case Pearson chi-square tests for goodness of fit using a binomial distribution. As seen in the first round of monitoring, squirrel activity was measured almost exclusively in the plots that received squirrel translocations (Table 3). No activity was measured on the control plots, aside from one burrow found in the control wedge of the control plot (SWTR5). The greatest level of activity- 57% of the total- was observed in the translocation plot for RJER1, while RJER2 and SWTR5 each accounted for 21% of all burrowing activity.

Table 3. Squirrel activity by plot pair, March 2012.

Plot	Control	Translocation	Total	Binom p value
RJER1	0	75	75	<0.001
RJER2	0	28	28	<0.001
RJER3	0	1	1	
SWTR5	1	27	28	<0.001
Total	**1**	**131**	**132**	

We conducted an abbreviated search for burrows and activity in the translocation plot for RJER3, because visibility was restricted at that time by thatch regrowth. The plot will be surveyed again after mowing, to confirm the low activity levels measured. The plot is excluded from further analysis for now.

Vegetation treatments

Pre and post-treatment vegetation monitoring was conducted to quantify the amount of change to vegetation structure (Table 4). The impacts of treatment to vegetation structure will be reported in 2012 Task A.

Table 4. Efficacy of mowing treatments. Vegetation density results were measured using a Robel pole method in August 2011, 2 months after treatment. The units represent the percentage of the vertical column from 20-40 cm above the soil surface that were occupied by vegetation.

Treatment	Pre-treatment	Post-treatment
Mowing	91%	4%
Mowing and decompaction	93%	4%
Control	93%	37%

In terms of the vegetation treatments, most squirrel activity, in the form of burrows, was found in areas that had been treated with mowing (RJER1 95%; RJER2 93%; SWTR5 89% relative to the unmowed control) (Figure 8). This pattern was also observed in the first round of monitoring. However, in the second round of monitoring the proportion of burrows occurring in treatment areas that were also augured (relative to areas that were only mowed) increased (RJER1 61%; RJER2 96%; SWTR5 79%) from the values measured in the first round of monitoring (RJER1 50%; RJER2 68%; SWTR5 81%). Soil auguring was associated with greater numbers of burrows than the mowing treatment alone ($p<0.001$), however the degree to which it matters depends greatly on the pair ($p=0.002$). In RJER2 burrowing activity was seen almost exclusively in the augured treatment area, in RJER1 activity was spread out more evenly (60% augured/ 40% mowed only) and SWTR5 was intermediate between the two others. 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.

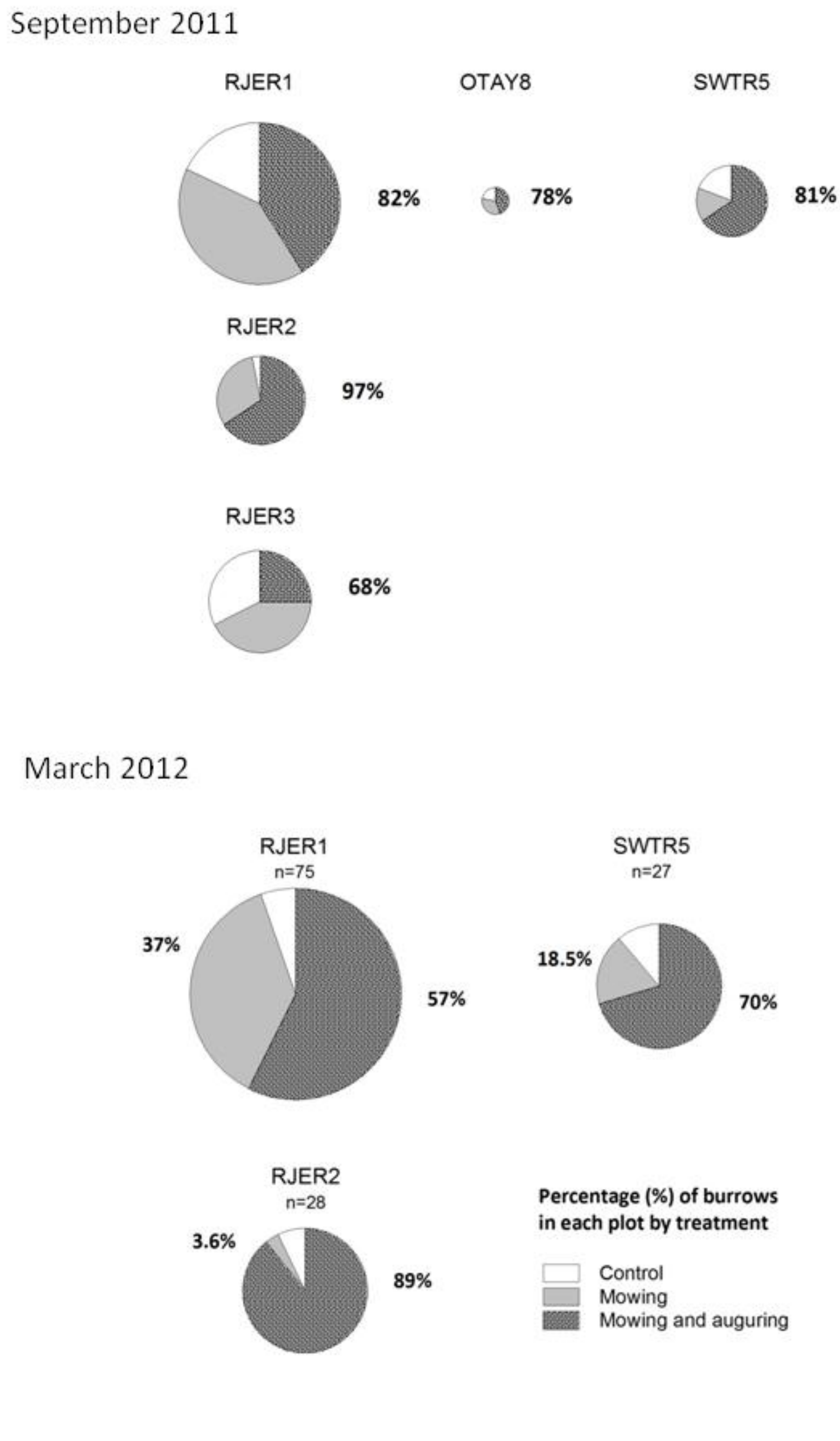


Figure 8. Proportion of burrowing activity by vegetation treatment. Control plots and plots with low activity levels were excluded from this analysis. Pies are sized to reflect the relative number of burrows in each plot.

Burrow size

The proportion of burrows 10 cm or greater increased (RJER1 51%; RJER2 43%; SWTR5 78%) relative to the values measured in the first round of monitoring for all three plots (RJER1 36%; RJER2 22%; SWTR5 11.5%) (Figures 9-10). These results indicate that the squirrels have continued to develop and enlarge their burrows with time. In addition, the proportion of large burrows is different between the three sites. SWTR5 has more large burrows than the other two plots (p=0.02). 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. The burrow aprons were measured to estimate the area of disturbed ground from burrow creation. At RJER1 the total plot area disturbed was 28.4 m^2, at RJER2 total area disturbed was 6.5 m^2, and at SWTR5 the area disturbed was 19.4 m^2.

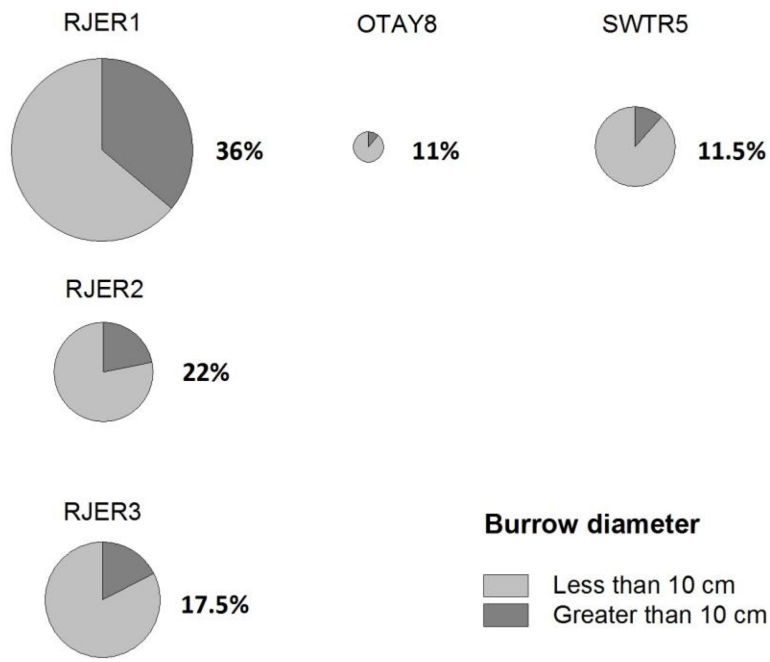


Figure 9. Proportion of burrows with entrance diameter greater than 10 cm., September 2011. Control plots and plots with low activity levels were excluded from this analysis.

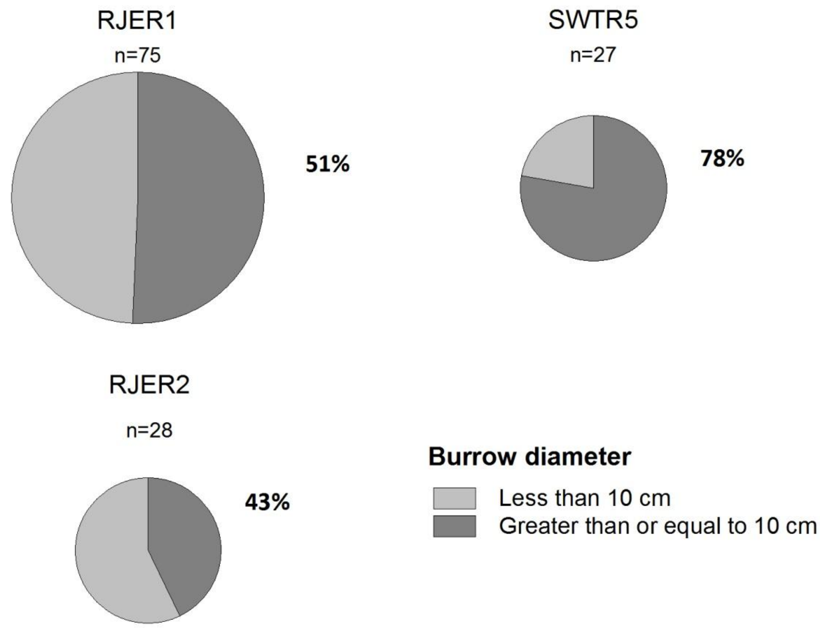


Figure 10. Proportion of burrows with entrance diameter greater than 10 cm., March 2012. Control plots and plots with low activity levels were excluded from this analysis.

Discussion

In collaboration with our scientific partners at ICR, in 2011 we made progress toward our primary goals of (1) designing an effective translocation protocol for the California ground squirrels by conducting controlled experiments within an adaptive management framework and (2) documenting the ecosystem engineering effects of California ground squirrel burrowing activity at release sites. These intermediate goals are pursued with the long-term goal of creating self-sustaining habitat suitable for burrowing owls in mind. However, 2011 was the first year of a multi-year project, and 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.

This initial year of research showed that immigration by resident squirrels to treated habitat was minimal; the current data indicates that a “build it and they will come” approach to habitat enhancement is not sufficient for establishing new squirrel populations on restoration sites within the short time scales of most projects. The use of soft release methods did appear to reduce squirrel mortality relative to the mortality levels seen on other squirrel translocation projects (Van Vuren et al. 1997).

While the use of protection from predators (such as above- and below-ground caging, chicken wire, and electric fencing) helped protect the translocated squirrels during the holding period, we knew there would be mortality from predators after release. We also expected squirrel dispersal, since the plots were open to surrounding habitat, and anticipated the effect of conspecific attraction, evident from the dispersal of radio-collared squirrels towards resident groups. But one important result from year one is that even with extensive squirrel movements, dispersal, and mortality, on almost half of the plots enough squirrels stayed to produce extensive and significant burrowing disturbance.

The first year results show that burrowing activity was much higher on mowed relative to unmowed areas. This result was expected, due to the restrictions on squirrel movement posed by the tall, dense habitat structure created by exotic annual grasses and the resulting thick layers of thatch on the soil surface. At this time we believe that the unexpectedly strong signal of auguring after 8 months is inconclusive. The number of burrows in the augured treatment wedge varied greatly by plot, and we did not see any evidence that squirrels dug in or around augured holes.

The camera trap photos showed that plots with mowing and squirrel translocation attracted visits by a wide range of other species, both predators and non-predators, providing evidence that a dynamic set of community interactions occurred during the first year after vegetation treatments and squirrel translocation. We observed burrowing owls investigating and using the artificial burrows installed for the project. Other interesting anecdotal observations included the use of squirrel-dug burrows by rattlesnakes at Sweetwater. In the second year, use of the camera traps could be expanded to explore questions such as whether the number or distribution of visits by predators and non-predator species is different on plots without translocated squirrels.

The sites used for this first year were chosen based on a few primary factors: an assessment of habitat suitability for squirrels based on existing published data, and the proximity of existing squirrel and burrowing owl populations. We focused on sites where a relationship with the managing agency was already established. We also limited ourselves to sites in the southern half of the county since the funding for this project originated in that part of the county and we made it a priority to use the funding in a way that provided a tangible local benefit. The first year results show that across the three sites and 7 experimental paired research plots, retention and/or survival of squirrels up to 8 months post-translocation was much higher at some sites than others.

It appears that site selection was an important factor determining squirrel persistence on each translocation plot. The data indicates that much of the decline in squirrel numbers occurred in the first 30 days post-release. The pattern of decline in squirrel numbers was quickly evident at the plots that ultimately lost their squirrel populations (SWTR6, OTAY8, OTAY9). However, in the plots where squirrel activity remained high during the first 30 days (RJER1, RJER2, RJER3 and SWTR5), squirrel activity was still evident from fresh burrowing activity 8 months after release at all sites except RJER3. It may be possible to predict squirrel persistence more accurately in future translocations. The development of a habitat suitability model for squirrels is a high priority for the second year of research.

Among the factors that potentially determine whether squirrels persist, the first year results indicate that soil type and compaction may be important predictors of translocation success and squirrel persistence. The soils at Rancho Jamul Ecological Reserve consist of sandy loam soils previously used for agricultural fields and pasture, and we qualitatively observed lower levels of soil compaction and fewer cobbles there than at either Sweetwater or the Lonestar parcel on Otay

Mesa. The silt loam soils at Sweetwater have a large proportion of cobbles, and the soil on Otay Mesa consists of heavy, compacted, gravelly clay loam. Another priority for the second year of research will be more detailed, quantitative measurement of soil type and compaction at the three research sites.

The first year results also suggest that follow-up vegetation treatments may also be needed in order to establish long-term squirrel persistence. The decrease in squirrel activity at RJER3 between 2 and 8 months after translocation could have been due to seasonal grass regrowth. The plant community at Rancho Jamul is strongly dominated by exotic annual grass species such as *Avena barbata* and *Bromus* sp., and these species showed strong growth on the translocation plots at Rancho Jamul during the spring months of 2012 (plant community changes will be reported in 2012 Task A report). There is uncertainty about what the short- and long-term impacts of repeated treatments will be on this grassland community. Mowing treatments will be carried out on the plots in 2012, as well as a second year of plant community monitoring.

The use of mowing for habitat enhancement has been a topic of discussion throughout the project. In this case we are using it as a proxy for the changes in habitat structure that a larger scale treatment such as grazing would produce. The use of mowing was appropriate at the small spatial scale of this field experiment. It would also be an appropriate treatment for small conservation sites. The conservation activities involved in re-establishing squirrel colonies and creating burrowing owl habitat may not be limited to large sites. The use of fire to alter habitat structure is another important potential management tool. Currently, the managers at Rancho Jamul Ecological Reserve are developing a fire management plan for the reserve that we believe may provide both larger-scale habitat enhancement, and an opportunity to expand the temporal and spatial scale of this research effort.

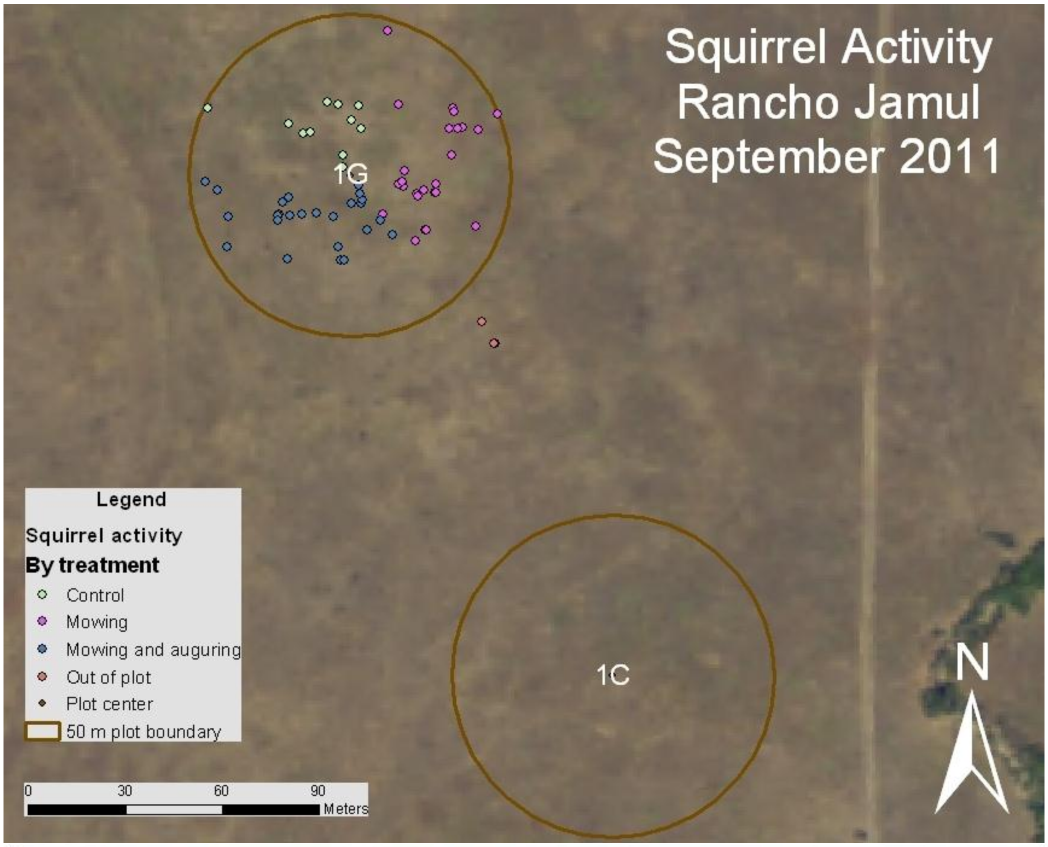
Conclusion

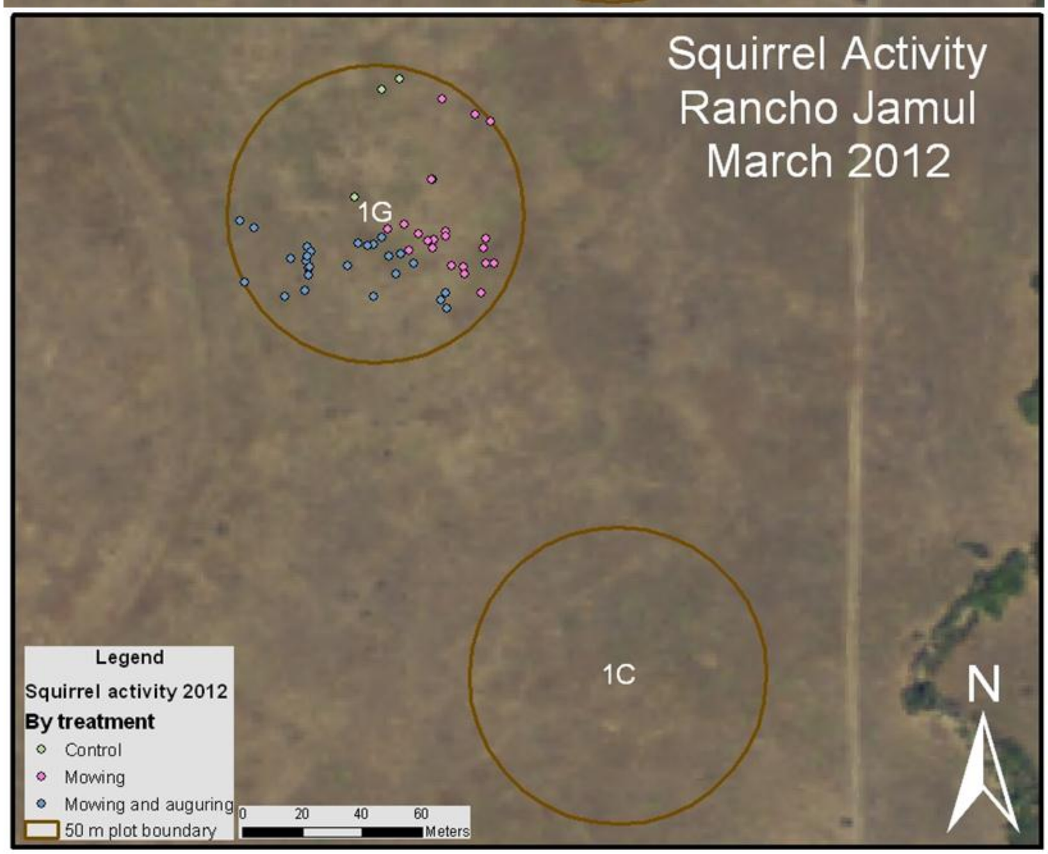
While the ultimate goal of this experiment is to develop a protocol capable of creating self-sustaining squirrel populations as a first step in re-establishing burrowing owl populations, this document reports only the first year of results. Research efforts to assess long-term efficacy and cost effectiveness are ongoing. Ideally, management applications of this protocol would involve a short-term habitat enhancement treatment that creates habitat conditions capable of supporting wild populations of squirrels and owls over the long-term. The methods used in the protocol- habitat enhancement and squirrel reestablishment- both incur substantial costs of money and time. If the treatments need to be repeated periodically, the cost will be higher still. It will be necessary to evaluate project goals and cost effectiveness before using these methods. However, since California ground squirrel is an ecosystem engineer, reestablishment of squirrel populations is likely to support a range of grassland ecosystem processes in addition to the stated goal of supporting owl populations. Although there is still much to learn from this experiment, the results from year one offer evidence that paired vegetation manipulation and squirrel relocation may be an effective management strategy. The data from ongoing efforts will provide insight into the long-term persistence of the squirrels as well as their sustained impact on the vegetation community. Data from year two will enhance our understanding of the costs and potential benefits of this approach.

References

Van Vuren, D, A.J. Kuenzi, I. Loredo, and M.L. Morrison. 1997. Translocation as a Nonlethal Alternative for Managing California Ground Squirrels. Journal of Wildlife Management **61**(2): 351-359.

Appendix. Burrowing Activity
September 2011 – March 2012


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
March 2012
1G
1C
Legend
Squirrel activity 2012
By treatment
Control
Mowing
Mowing and auguring
50 m plot boundary
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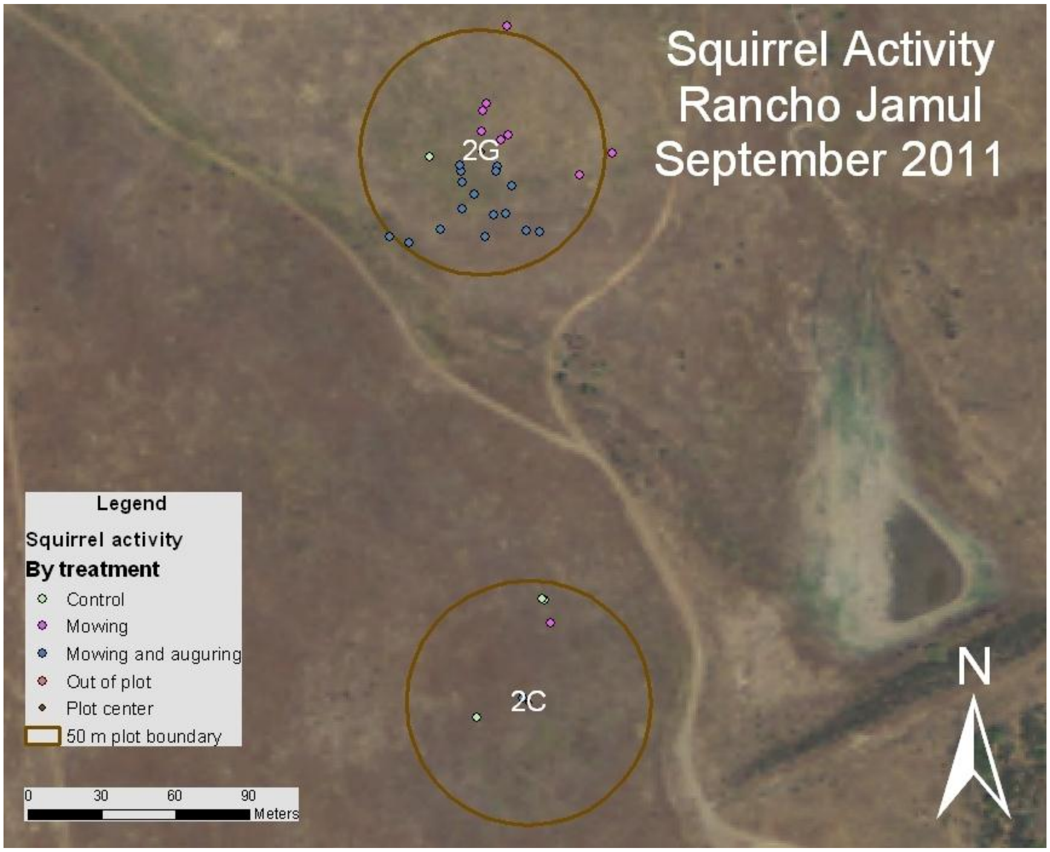
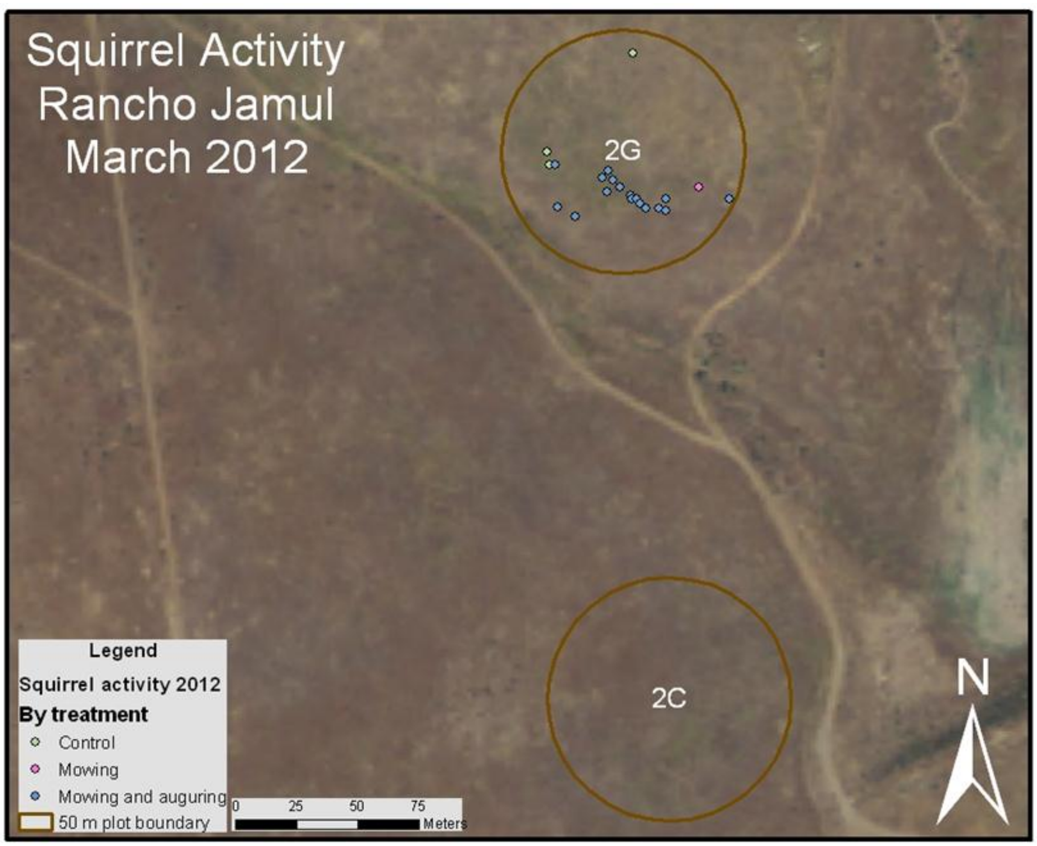
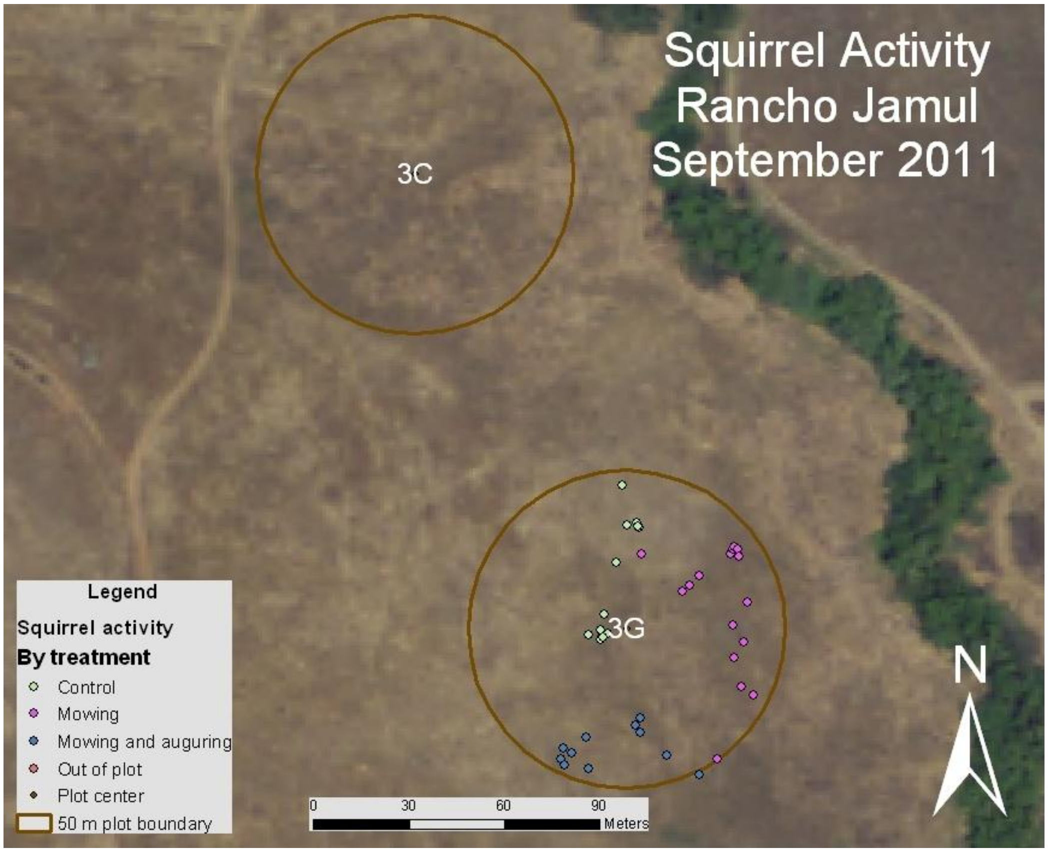
20
40
60
Meters
N


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
March 2012
2G
2C
Legend
Squirrel activity 2012
By treatment
Control
Mowing
Mowing and auguring
50 m plot boundary
0 25 50 75
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
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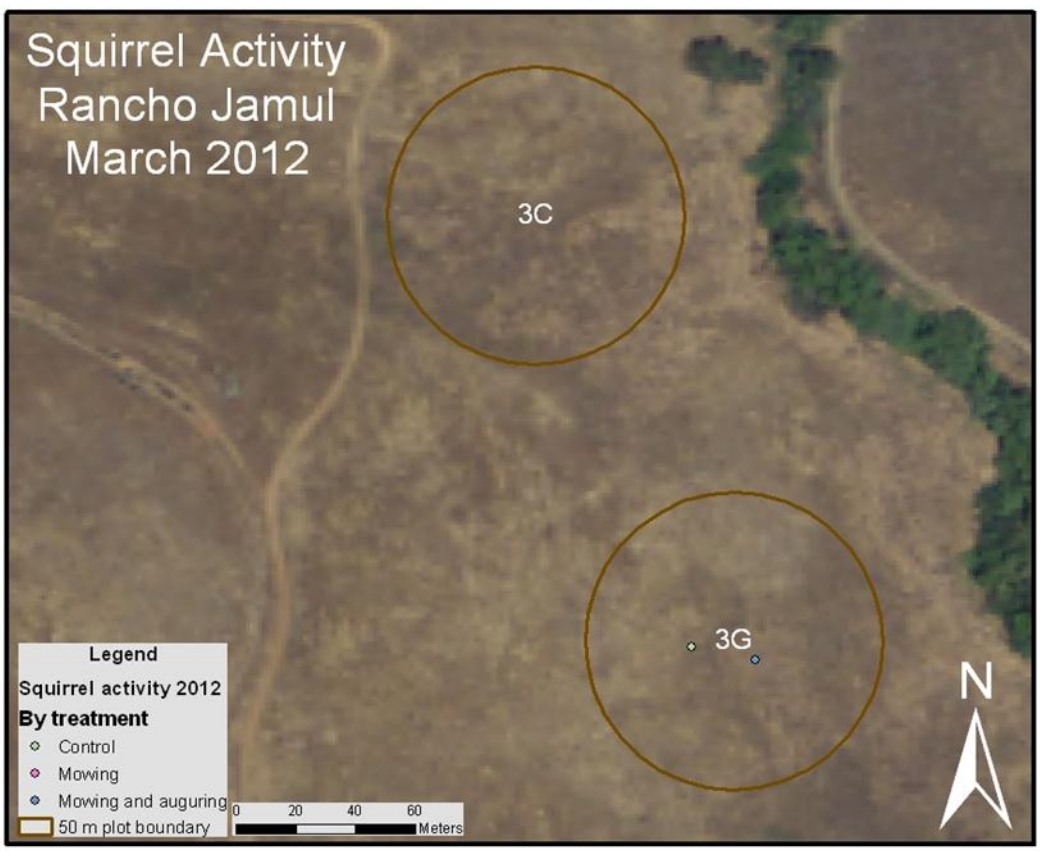
30
60
90
Meters
N


Squirrel Activity
Rancho Jamul
March 2012
3C
3G
Legend
Squirrel activity 2012
By treatment
Control
Mowing
Mowing and auguring
50 m plot boundary
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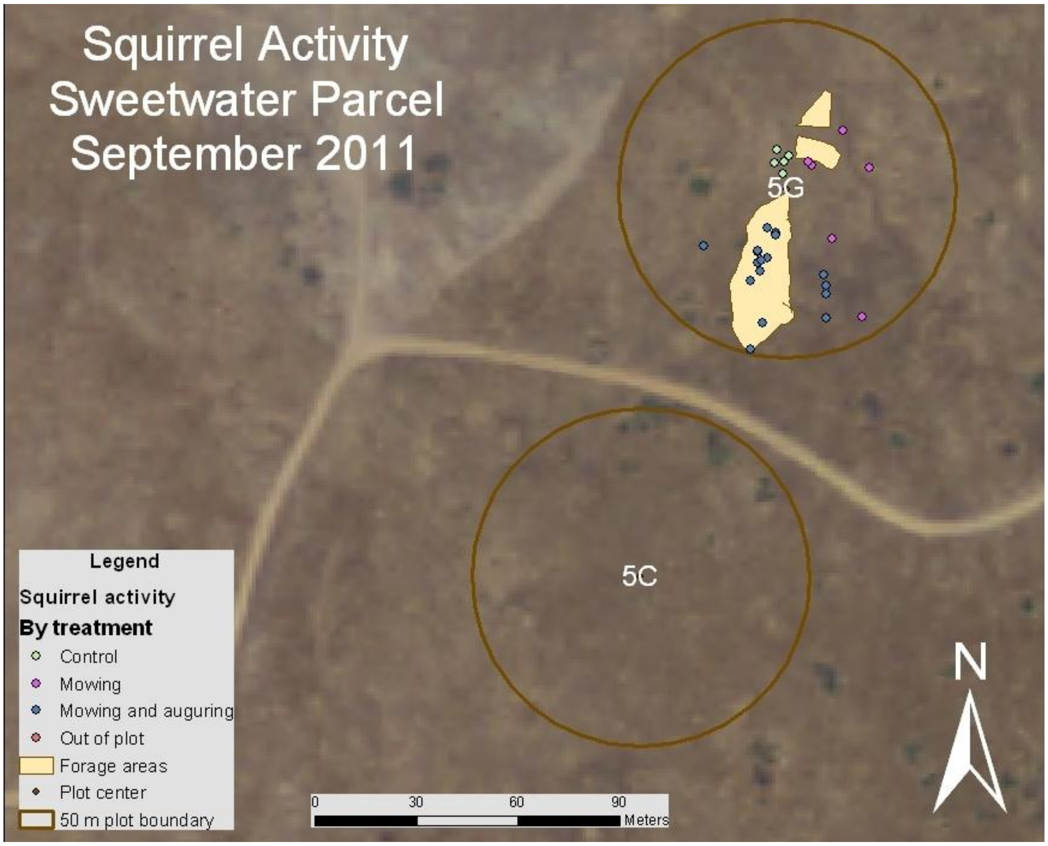
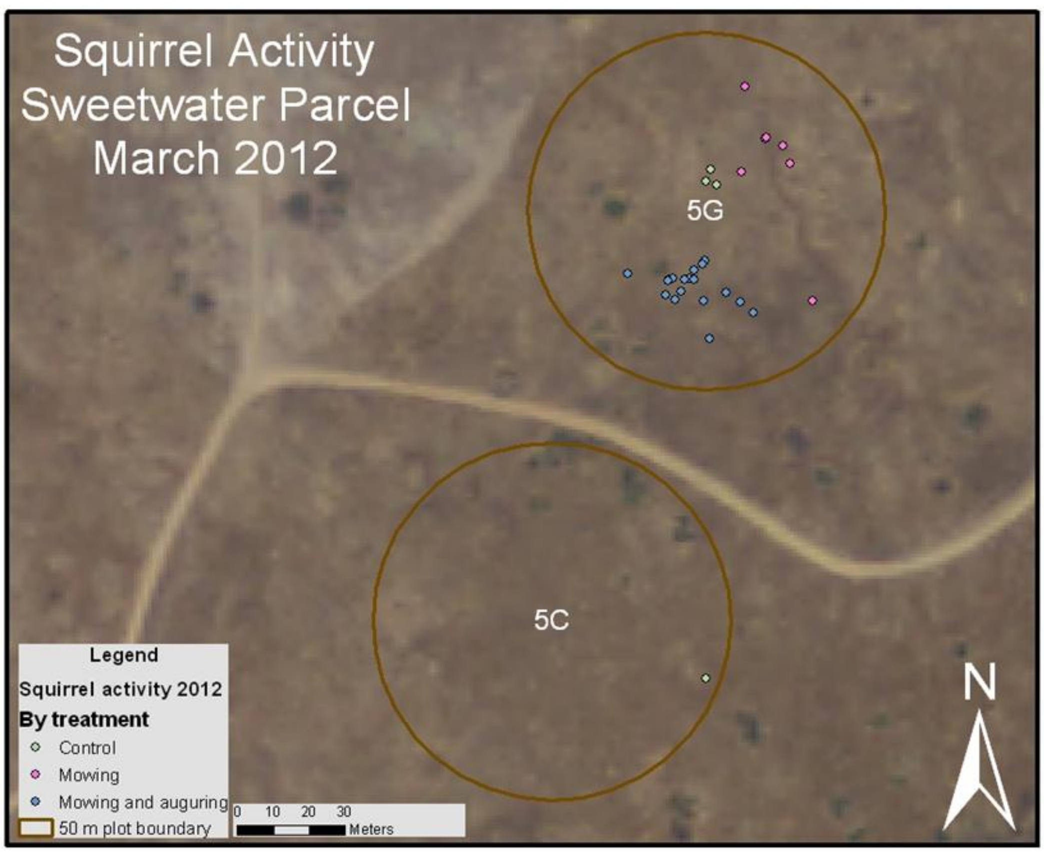
20
40
60
Meters
N


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
March 2012
5G
5C
Legend
Squirrel activity 2012
By treatment
Control
Mowing
Mowing and auguring
50 m plot boundary
0 10 20 30
Meters
N