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

TASK C FOR 2013:
FALL BURROW SURVEYS

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Section 1. Executive summary

This document has been written to satisfy the reporting requirements for 2013 SOW Task C, and summarizes the burrow survey from Fall 2013 to characterize squirrel activity.

Through fall of 2013 the overall footprint of squirrel activity on the plots continued to increase, and squirrel activity continued to be largely concentrated in the plots that received squirrel translocation. There was variation in the proportion of burrows found in the mowing-only treatment subplot relative to the mow/augur treatment subplot, but the overall correlation of burrowing activity with mowing treatment remained strong. The 2013 results continue to support the earlier project results that both mowing and squirrel translocation are required for significant levels of squirrel activity on the experimental plots. The results of repeated measures modeling with surface disturbance as a proxy for activity levels provide additional evidence for the interaction of squirrel translocation and mowing.

The numbers of burrows dropped slightly in all of the four translocation plots whose treatment plans were completed in 2012. However, the number of remaining burrows indicates either persistent activity levels or persistent effects of activity in the first year after the completion of the treatment plan.

The 2012 addition of the second year treatment protocol for vegetation treatment and supplemental squirrel translocation supported the persistence of treatment effects on squirrel burrowing activity. 2014 spring data collection will enable these analyses to be evaluated with higher replication as the two pairs added in 2012 reach their third year with both squirrel translocation and vegetation treatments completed.

Section 2. Introduction

Although the Western Burrowing Owl (*Athene cunicularia hypugaea*) is a widespread species that shows tolerance towards human disturbances, observations of population decline across its range have been published in the past 15 years (Sheffield 1997, Desmond et al. 2000, Poulin et al. 2005). In California, burrowing owl population declines and local extinctions have been recorded in southern and coastal locations undergoing urbanization (Gervais et al. 2008). In San Diego County, historical and recent surveys indicate that the number of occupied burrowing owl colonies is also declining (Unitt 2004). Some local declines in California have not been considered important because of the presence of a large source population of burrowing owls in the Imperial Valley, estimated at 5,600 pairs in 1992-1993 (DeSante et al. 2004). The burrowing owl is listed as a Species of Special Concern in California (a status that lacks protective measures), and is unlikely to be granted a higher priority status due to the Imperial Valley population. However, this source population is also currently declining for unknown reasons. A 28% decline was observed between 2007 and 2008 (Manning 2009), and a subsequent survey indicated a second year of decline (D. Deutschman, unpublished data). Managers in southern California have concerns about these warning signs, and there is interest in developing conservation strategies for the species at the regional level.

Three factors should be considered to be the ultimate underlying causes of burrowing owl population decline in southern California. Reduction in habitat area is the first factor, caused by urban development and invasion of grasslands by exotic annual grasses. In San Diego County, native species habitat has been lost to urbanization and the construction of housing, buildings, and roads (Gervais et al. 2008). The second factor is changes in habitat composition and structure. Native grasslands have been converted to exotic annual grass species, such as wild oat (*Avena barbata*) and brome (*Bromus diandrus*, *Bromus madritensis*), which are key invasive species that have been present in California for more than a century (D' Antonio et al. 2007). These species create taller and denser layers of vegetation and thatch which impede owl foraging and predator detection. The third factor is changes in the distribution and abundance of the fossorial mammal, California Ground Squirrel (*Otospermophilus beecheyi*), that produces burrows for burrowing owls. Ground squirrels are an important key to establishing self-sustaining burrowing owl populations in southern California, but squirrels were historically - and still are currently - widely perceived as pests that damage crops and need to be controlled (Marsh 1998). Squirrels have been targeted by control efforts and have been eradicated in many locations (Lenihan 2007).

The intent of this study is to design a method for restoring burrowing owl habitat through re-establishing key ecological processes (George and Zack 2001). It will focus on the California ground squirrel as an ecosystem engineer responsible for creating burrows and maintaining the low, open vegetation structure preferred by owls (Green and Anthony 1989). The presence of burrows available for occupancy is an important factor for owl habitat selection, and research has shown that burrowing owls respond positively to the placement of artificial burrows in relocation and site restoration projects (Trulio 1995, Smith and Belthoff 2001, Belthoff and Smith 2003, Smith et al. 2005). However, there are disadvantages to the use of artificial burrows, in that they require periodic maintenance and replacement, and have the effect of acclimating owls to artificial conditions in locations that may not otherwise provide appropriate habitat. The intent of this project is to develop an alternative method of increasing burrow availability by avoiding the use of man-made structures and increasing the presence of burrowing mammals.

In addition to the creation of burrows, squirrels cut and trample grass and forb stems during their normal foraging activity, and there have been qualitative observations that their activity maintains a lower and more open vegetation community (Fitch 1948). For owls, low vegetation makes detection of predators and prey easier. Squirrel effects on vegetation structure are important because of the widespread invasion of exotic annual grass and forb species into California grasslands. Exotic grasses grow quickly after winter and spring rains, competing with native grass species for soil nutrients, moisture, and space. They die and then dry out completely as daytime temperatures increase from spring to the summer season. The aboveground plant material produced is tall and dense, and as it dries out it piles up on the ground in a thick layer of thatch (Corbin and D'Antonio 2004).

Currently, ground squirrels are more likely to be found occupying the margins, rather than the interior, of grasslands with mixed native and exotic species composition, suggesting that some component of the habitat is not suitable. The shift in vegetation composition from historic conditions suggests that vegetation structure could be the driving factor. Dense ground cover may reduce the ability of ground squirrels to move around and to visually detect predators.

Thick thatch may impede foraging and burrow digging activities. However, the effects of exotic annual grass and forb species on the California ground squirrel are largely unstudied.

One component of the restoration plan should be the reduction of current vegetation height and thatch depth. Mowing can realistically be conducted at the spatial scale needed to create adequate amounts of habitat for both burrowing owls and squirrels. Most owl foraging activities are concentrated to within about 600 m of the burrow (Haug and Oliphant 1990, Gervais et al. 2003), and it is feasible to mow at this scale. It should be anticipated that mowing could influence the balance between native and exotic grass species, but most grasslands are already highly invaded by exotic annual species.

Altering vegetation structure does not guarantee squirrels will colonize the site. It is possible that nearby resident squirrels may discover the treated area and colonize, but it also may be necessary to establish new squirrel colonies through translocation. Issues associated with translocation include rapid dispersal from the release site as individuals attempt to return to familiar territory or to find better habitat, and negative outcomes of dispersal such as increased squirrel mortality from predation or starvation. However, it may be possible to develop translocation protocols that increase the probability of survival to an acceptable level. For example, using acclimation cages can decrease the probability of dispersal by increasing the amount of acclimation time and decreases mortality by protecting squirrels from predators during the initial, most vulnerable period on the new site (Poulin et al. 2006). Translocating family groups and neighbors together can also decrease dispersal by preserving family and community organization (Shier 2006).

A third component that should be included addresses soil compaction, because grassland sites may have been impacted historically by grazing or agricultural activities. In addition, some selected sites may contain soils with larger proportions of dense material like clay. A treatment to physically reduce soil compaction may benefit owls by enabling faster squirrel burrowing rates. One important consideration is that the degree of decompaction should be kept low enough to enable the formation of stable burrow walls. A treatment such as auguring holes that resemble starter burrows would be more appropriate than tilling, which breaks up soils more thoroughly to lower depths. However, the approach needs to be tested experimentally first because soil disturbance may promote the germination of exotic annual grass seeds, and may cause increases in exotic grass cover, an unintentional consequence that should be avoided.

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.

References

Belthoff, J. R. and B. W. Smith. 2003. Patterns of artificial burrow occupancy and reuse by burrowing owls in Idaho. Wildlife Society Bulletin **31**:138-144.

Corbin, J. D. and C. M. D'Antonio. 2004. Competition between native perennial and exotic annual grasses: Implications for an historical invasion. Ecology **85**:1273-1283.

D' Antonio, C. M., C. Malmstrom, S. A. Reynolds, and J. Gerlach. 2007. Ecology of Invasive Non-native Species in California Grassland. Pages 67-86 *in* M. R. Stromberg, J. D. Corbin, and C. M. D' Antonio, editors. California Grasslands Ecology and Management. University of California Press, Berkeley.

DeSante, D., E. D. Rulen, and D. K. Rosenberg. 2004. Density and abundance of burrowing owls in the agricultural matrix of the Imperial Valley, California. Studies in Avian Biology **27**:116-119.

Desmond, M. J., J. A. Savidge, and K. M. Eskridge. 2000. Correlations between burrowing owl and black-tailed prairie dog declines: A 7 year analysis. Journal of Wildlife Management **64**:1067-1075.

Fitch, H. S. 1948. Ecology of the California ground squirrel on grazing lands. American Midland Naturalist **39**:513-596.

George, T. L. and S. Zack. 2001. Spatial and temporal considerations in restoring habitat for wildlife. Restoration Ecology **9**:272-279.

Gervais, J. A., D. K. Rosenberg, and R. G. Anthony. 2003. Space use and pesticide exposure risk of male burrowing owls in an agricultural landscape. Journal of Wildlife Management **67**:155-164.

Gervais, J. A., D. K. Rosenberg, and L. A. Comrack. 2008. Species accounts: Burrowing Owl.*in* W. D. Shuford and T. Gardali, editors. California Bird Species of Special Concern: a ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds 1. Western Field Ornithologists, Camarillo, California, and CA DFG.

Green, G. A. and R. G. Anthony. 1989. Nesting success and habitat relationships of Burrowing Owls in the Columbia Basin, Oregon. Condor **91**:347-354.

Haug, E. A. and L. W. Oliphant. 1990. Movements, activity patterns, and habitat use of burrowing owls in Saskatchewan. Journal of Wildlife Management **54**:27-35.

Lenihan, C. M. 2007. The Ecological Role of the California Ground Squirrel (Spermophilus beecheyi). University of California, Davis.

Manning, J. A. 2009. Burrowing Owl population size in the Imperial Valley, California: survey and sampling methodologies for estimation. Final Report to the Imperial Irrigation District, Imperial Valley, California, USA. April 15, 2009.

Marsh, R. E. 1998. Historical review of ground squirrel crop damage in California. International Biodeterioration & Biodegradation **42**:93-99.

Moulton, C. E., R. S. Brady, and J. R. Belthoff. 2006. Association between wildlife and agriculture: Underlying mechanisms and implications in burrowing owls. Journal of Wildlife Management 70:708-716.

Poulin, R. G., L. D. Todd, K. M. Dohms, R. M. Brigham, and T. I. Wellicome. 2005. Factors associated with nest- and roost-burrow selection by burrowing owls (Athene cunicularia) on the Canadian prairies. Canadian Journal of Zoology-Revue Canadienne De Zoologie **83**:1373-1380.

Poulin, R. G., L. D. Todd, T. I. Wellicome, and R. M. Brigham. 2006. Assessing the feasibility of release techniques for captive-bred burrowing owls. Journal of Raptor Research **40**:142-150.

Sheffield, S. R. 1997. Current status, distribution, and conservation of the Burrowing Owl (Speotyto cunicularia) in midwestern and western North America. Pages 399-407. *in* J. R. Duncan, D. H. Johnson, and T. H. Nichols, editors. Biology and conservation of owls of the Northern Hemisphere, Second International Symposium, USDA Forest Serv. Gen. Tech. Rept. NC-GTR-190.

Shier, D. M. 2006. Effect of family support on the success of translocated black-tailed praire dogs. Conservation Biology **20**:1780-1790.

Shuford, W. D. and T. Gardali. 2008. California Bird Species of Special Concern: A ranked assessment of species, subspecies, and distinct populations of birds of immediate conservation concern in California. Studies of Western Birds. Western Field Ornithologists, Camarillo, California, and California Department of Fish and Game, Sacramento.

Smith, B. W. and J. R. Belthoff. 2001. Effects of nest dimensions on use of artificial burrow systems by burrowing owls. Journal of Wildlife Management **65**:318-326.

Smith, M. D., C. J. Conway, and L. A. Ellis. 2005. Burrowing owl nesting productivity: a comparison between artificial and natural burrows on and off golf courses. Wildlife Society Bulletin **33**:454-462.

Trulio, L. A. 1995. Passive relocation- a method to preserve burrowing owls on disturbed sites. Journal of Field Ornithology **66**:99-106.

Unitt, P. 2004. San Diego County bird atlas. Proceedings of the San Diego Society of Natural History **39**.

Section 3. Methods

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 2 new pairs of plots at Rancho Jamul Ecological Reserve in 2012. 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 an unmanipulated control. 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.

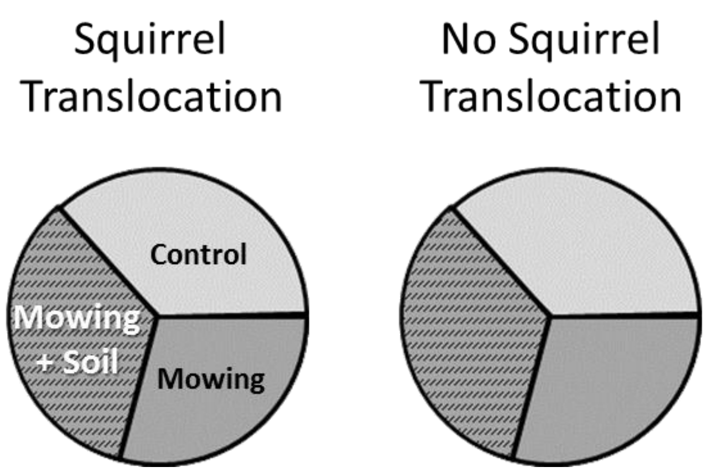

Figure 1. Paired design of the habitat enhancement/squirrel translocation experiment.

Treatment methods

In 2012 the same vegetation and soil decompaction methods were utilized as in 2011. A brief summary follows:

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 noticeable 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 all plots established in 2012, the treatments were assigned as follows: treatment 1 (0-120 degrees), treatment 2 (120-240 degrees), and control (240-360 degrees).

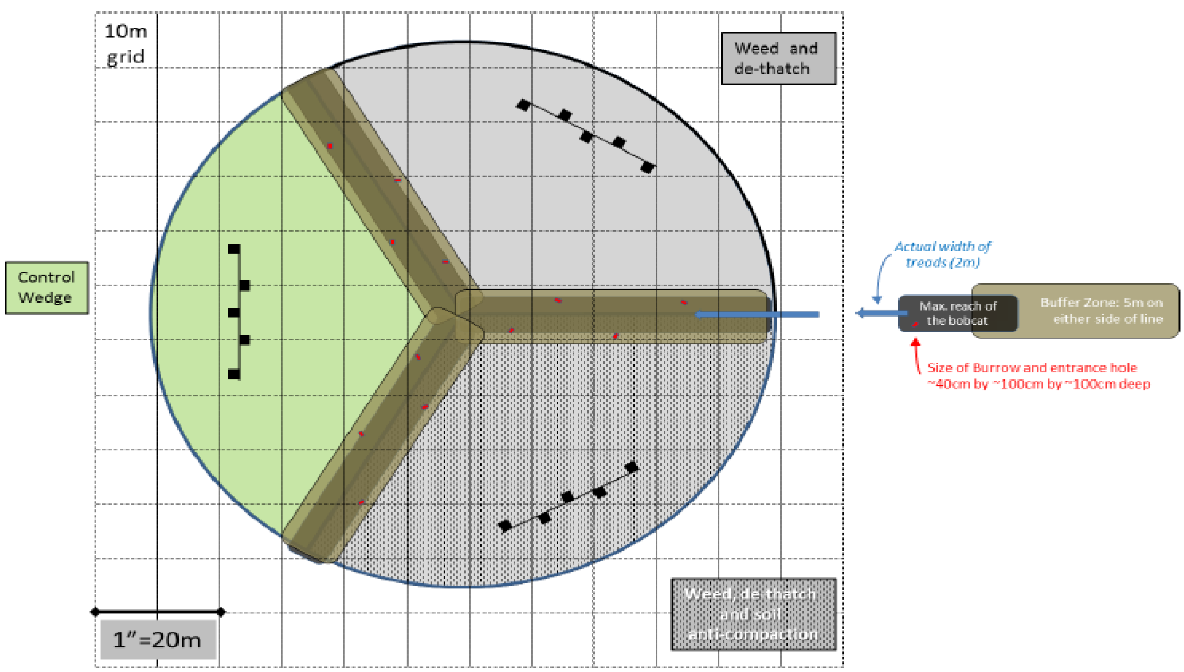

Figure 2. Scaled diagram of plot layout. The burrows were located along the strips dividing each treatment. Gray shading indicates both the footprint of the mechanized equipment used to install the burrows and the furthest reach of the digging arm. Burrows are denoted with red symbols that approximate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

Assessment methods

The post-treatment habitat assessment was conducted in all plots after both the vegetation and squirrel translocation treatments had occurred. Assessments consisted of both qualitative (photopoints) and quantitative methods.

Burrowing Activity

Observers 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.

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 Wildlife 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.

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). This site was included in the first year of the study, but further experimental treatments and monitoring have been discontinued due to ongoing Caltrans management activities that have significantly altered the site.

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.

References

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico.

Section 4. Results and Discussion

Squirrel Burrowing Activity

In fall of 2013 the overall footprint of squirrel activity on the plots continued to increase, and squirrel activity continued to be largely concentrated in the plots that received squirrel translocation (Table 1). Higher numbers of burrows were recorded in October 2013 than in March 2013 for the two translocation plots that received translocated squirrels in August. The numbers of burrows dropped slightly in all of the four translocation plots whose treatment plans were completed in 2012. However, the number of remaining burrows indicates either persistent activity levels or persistent effects of activity in the first year after the completion of the treatment plan. The pattern of increasing numbers of burrows in control plots observed through early 2013 was weaker in the current round of burrow surveys, and the overall number of burrows in control plots dropped.

Table 1. 2013 squirrel activity by plot pair, measured as the number of burrows equal to or greater than 7 cm diameter. The March 2013 sample represents activity levels 6 months after 2012 supplemental translocation. The October sample represents activity after August 2013 supplemental translocation

	March 2013				October 2013		
Plot	**Control**	**Translocate**	**Total**		**Control**	**Translocate**	**Total**
2012RJERN	4	106	110		4	210	214
2012RJERS	2	29	31		7	55	62
RJER1	12	234	246		9	207	216
RJER2	8	128	136		10	115	125
RJER3	24	175	199		5	127	132
SWTR5	2	68	70		0	65	65
Total	52	740	792		35	779	814

Figure 3 shows that for the fall 2013 data, there was variation in the proportion of burrows found in the mowing-only treatment subplot relative to the mow/augur treatment subplot, but the overall correlation of burrowing activity with mowing treatment remained strong. For the two plots established in 2012, the proportion of activity in each mowing subplot, which had been fluctuating, did stabilize within the ranges observed in the four older plots.

For the four plots established in 2011, the distribution of burrows across the subplots remained relatively stable from 2012 through the end of 2013. The data continues to indicate that once a burrow complex is established, the squirrels continue digging in the immediate vicinity of the complex.

These results continue to provide evidence that mowing is important in supporting squirrel burrowing activity, and that the auguring treatment does not play a strong role in burrow placement.

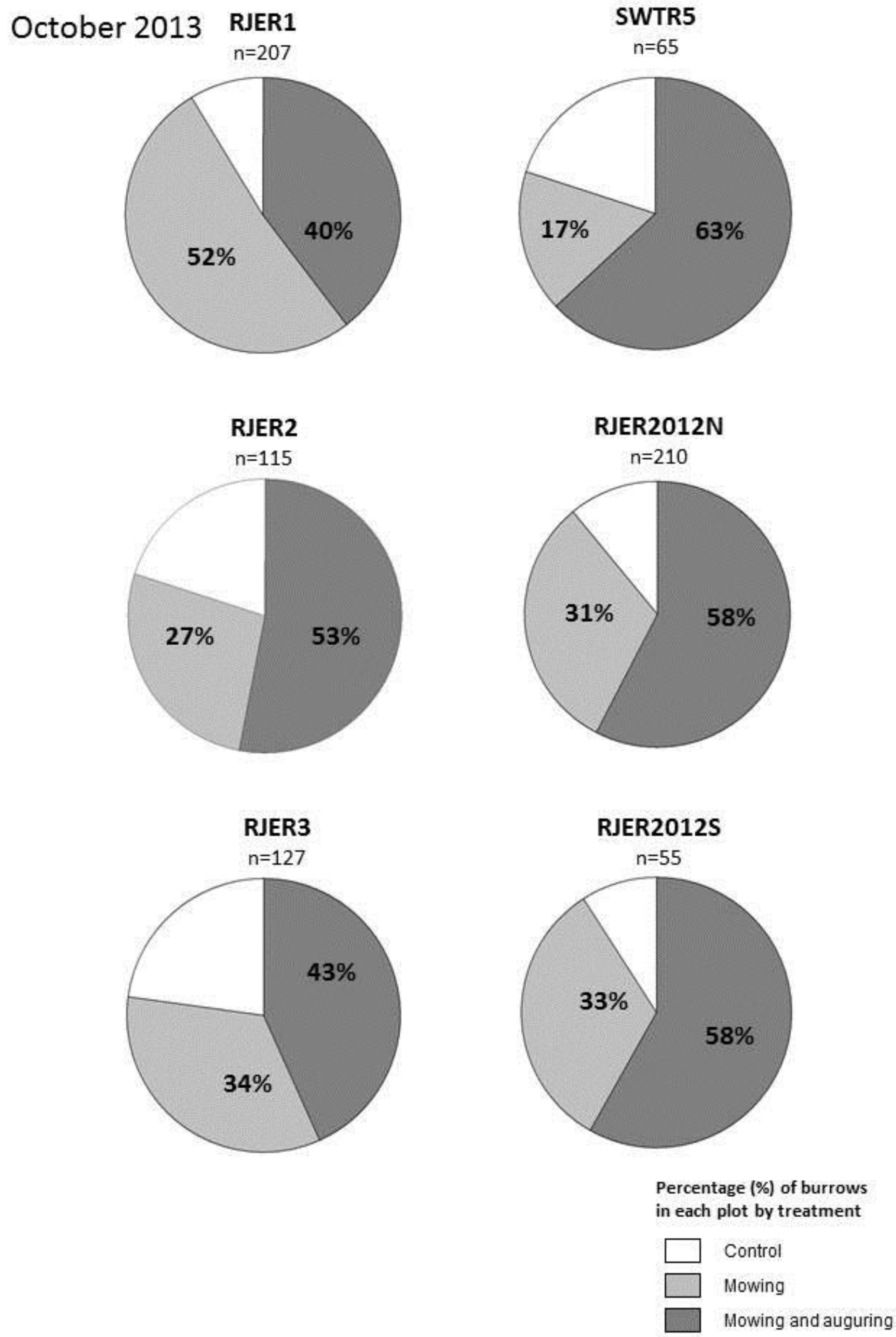

Figure 3. Percentage of burrows in each plot by treatment in October 2013. Only plots treated with squirrel translocation are included.

Table 2. GLM repeated measures results from burrowing activity sampling during 2011-2013. Only plots sampled in all three years were included in this analysis, and the data was square root transformed. These results represent the effects of two years of treatments. All interactions were modeled.

Treatment Effect		**Apron area, sqrt transformation**		
	df	ΔR^2	F	P
Between Subjects				
Squirrel	1	0.94	104.47	<0.01 *
Site	1	0.01	1.16	0.33
Error	5	0.05		
Within Subjects				
Time	4	0.36	10.75	<0.01 *
Time x Squirrel	4	0.39	11.70	<0.01 *
Time x Site	4	0.09	2.75	0.06
Error	20	0.17		
Veg	2	0.36	8.43	<0.01 *
Veg x Squirrel	2	0.36	8.47	<0.01 *
Veg x Site	2	0.06	1.34	0.31
Error	10	0.22		
Veg x Time	8	0.15	1.21	0.32
Time x Veg x Sq.	8	0.11	0.89	0.53
Time x Veg x Site	8	0.10	0.80	0.60
Error	40	0.63		

The data collected over the course of the experiment enables the use of measures of overall ground surface disturbance as a proxy for squirrel activity. Overall ground disturbance is derived from the apron areas measured at each burrow. Summing the individual apron areas within each treatment subplot gives one number per subplot that represents overall activity within each subplot. When the same repeated measures model used for analysis of the vegetation data in previous reports is applied to this response variable, the results indicate a highly significant interaction of squirrel translocation and vegetation treatment (p<0.01, Table 2). The results in Table 2 present transformed data (square root) due to the wide variation in apron areas observed across plots. The interaction indicates that both mowing and squirrel translocation are supporting squirrel activity levels.

The analysis also indicates a significant interaction ($p<0.01$) for time and squirrel translocation. The time variable represents the repeated annual fall and spring measurements conducted in each subplot since the initiation of the experiment. Thus the interaction found includes such patterns as the staggered initiation of plots in 2011 and 2012, and the seasonal timing of translocations across the two year treatment plan.

The significant patterns in ground surface disturbance from the repeated measures analysis can be seen graphically in Figure 4. Ground disturbance increased across time points from Fall 2011 to Fall 2013. Overall ground disturbance was highest in plots that received both squirrel translocation and mowing. The plots that did not receive squirrel translocation are not presented here, but they showed much lower levels of ground disturbance.

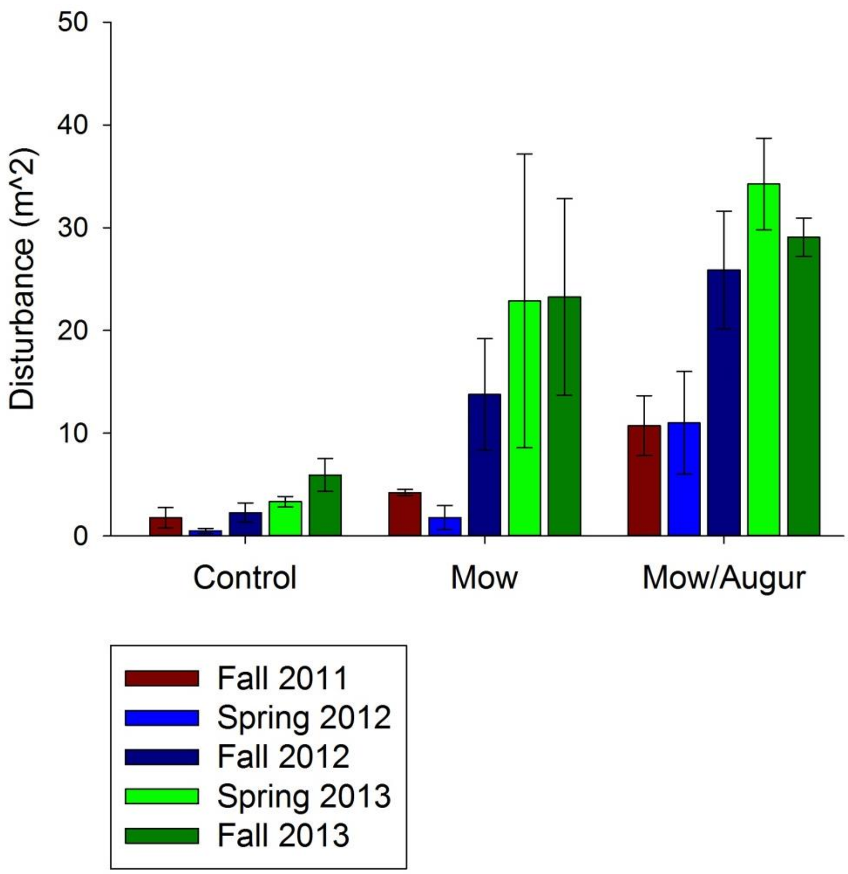

Figure 4. Percentage of burrows in each plot by treatment in September 2013. This graph includes the four plots established in 2011 and treated with squirrel translocation.

Squirrels continued to have an ecosystem engineering effect on the plots through the end of 2013, both in the plots continuing to receive treatment, and in the plots whose treatments ended in 2012. Through Fall 2013, high numbers of burrows continued to be observed, although the numbers of burrows began to drop in the plots without ongoing treatments. Greater numbers of burrows continued to be found in the subplots treated with both mowing and squirrel translocation. Both treatments appear to be required to support squirrel activity, although the 2013 data did not provide any additional support for the efficacy of auguring. The results of repeated measures modeling with surface disturbance as a proxy for activity levels provide additional evidence for the interaction of squirrel translocation and mowing.

By repeating the same data collection in spring 2014, we will measure the second year treatment effect for the two pairs of plots established in 2012. At that time, experimental replication will increase from 4 pairs of plots to 6, enabling a more powerful measure of the persistent effects of mowing and squirrel translocation on vegetation composition and structure and squirrel burrowing activity. These data will be important for addressing the wide error bars seen in some response variables to date, such as the measures of ground surface disturbance in Figure 4.