Burrowing Owl Conservation and Management Plan for San Diego County

Prepared by:

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This document is a living document and will continue to be updated in the future.

Previous page: Photo of 2015 juvenile BUOW recruited to Brown Field as an adult in 2016.

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Introduction

In southern California, the western burrowing owl (*Athene cunicularia hypugaea*, BUOW) has experienced declining populations for decades (Lincer and Bloom 2007). This species was once widespread and abundant in San Diego County during the breeding season. The San Diego Bird Atlas provides a detailed account of declines in the County population since the 1920s, when the owl was common along an elevational gradient extending from coast to foothills (Unitt 2004). The number of occupied sites had declined by the 1970s, although breeding owls could still be found in coastal locations such as Mission Bay, the Palomar Airport area, and San Marcos, as well as several inland sites that are no longer occupied by BUOW. Nearly all coastal populations were extirpated by 1997 due to intensive urban development and habitat fragmentation. Extensive field surveys conducted in the years 1997-2002 for the San Diego Bird Atlas documented five locations of breeding pairs: Warner Valley, Borrego Valley, two locations in Otay Mesa, Imperial Beach Naval Outlying Landing Field, and Naval Air Station North Island (Unitt 2004). In the 15 years since those surveys, the number of breeding pairs has dropped to the point that breeding pairs are now only detected in scattered sites on Otay Mesa. On Naval Air Station North Island, successful nesting has not been observed since 2011. Imperial Beach Naval Outlying Landing Field supported nesting owls on an intermittent basis, but only wintering owls have been detected on either site in the past five years (T. Shepherd, personal communication). Borrego Valley was utilized by single pairs rather than a colony, and breeding pairs have not been detected there or at Warner Valley in recent years.

Current status

The San Diego Zoo Institute for Conservation Research (SDZ ICR) has monitored core areas of the Otay Mesa population since 2013 as a component of research and adaptive management funded by the Otay Grassland Mitigation Fund at The San Diego Foundation. As of 2016, about 15 artificial burrows were occupied by breeding owls on monitored conserved parcels (Lonestar Ridge West [Lonestar], Lonestar Ridge East [Johnson Canyon], and Lower Otay Reservoir Burrowing Owl Management Area [LORBOMA]). Up to 20 additional pairs have occupied natural burrows on adjacent managed but non-conserved lands at Brown Field Municipal Airport.

Robustness of BUOW population estimates

A lower level of effort was allocated to detections of owls elsewhere on Otay Mesa, due to access issues. Consequently, a proportion of the Otay population may have gone undetected. The magnitude of undetected breeding pairs can be estimated based on additional data from the region, including California Natural Diversity Database (CNDDB) and SanBIOS records, along with incidental sightings. CNDDB includes eight additional Otay records of one or two breeding pairs of owls each from 2002-2009 outside the core monitoring areas. SANBIOS includes approximately 50 additional non-overlapping records from biological survey reports since 2002. In SanBIOS, only 14 of 50 records provide a count of owls seen, almost exclusively of single pairs or families. There is uncertainty about whether the 50 records came from the breeding or non-breeding season, as all 50 records show an identical observation date from 2006. These are the only observations available to represent a time span of 15 years. They suggest that while owls are found scattered on Otay Mesa, the presence of a significant undetected population of owls, in unmanaged areas elsewhere on the Mesa, is unlikely in any given year. Since 2012, incidental observations have been confirmed as they were reported to SDZ ICR by a variety of sources, and no significant findings of other currently occupied areas have been made.

While BUOW pairs outside of the core areas monitored by SDZ ICR do contribute to overall population size, they are likely to respond to stressors such as drought with similar dynamics as the monitored portion of the population. Their settlement in unprotected sites additionally leaves them more vulnerable to disturbance. The potential influence of the unmonitored portion of the population is evaluated using population viability analysis and found to be minimal (Section 2.0).

Absence from apparently suitable grasslands

Breeding owls are also currently absent in a number of areas with suitable habitat where they might reasonably be expected to persist. Warner Valley still provides extensive undeveloped grassland habitat. The Ramona Grasslands area includes extensive grasslands, with significant acreage set aside as Conserved Lands or mitigation banks. This area currently supports an abundant population of California ground squirrels and offers a stable supply of burrow habitat; however, only wintering owls have been detected since 2010[1]. Sites such as Pamo Valley provide grassland habitat with squirrels and a degree of protection from development and fragmentation. Further south, the Rancho Jamul Ecological Reserve (RJER), owned and managed by the California Department of Fish and Wildlife (CDFW), offers an extensive conserved grassland area with potential connectivity to the existing population at Otay. California ground squirrels are present at RJER, but the population is relatively low and concentrated around human disturbed areas. Wintering owls have been detected almost every year between 2011-2017 but no owls have settled during the breeding season.

1.1 Purpose

In western San Diego County, the San Diego Management and Monitoring Program (SDMMP) coordinates science-based biological management and monitoring of lands in San Diego conserved through various conservation planning and mitigation efforts. The framework for the program is detailed in the 2013 Management Strategic Plan (MSP) and the updated Management and Monitoring Strategic Plan Roadmap (MSP Roadmap; 2017). The MSP Roadmap identifies goals and objectives for the management and monitoring of a list of priority species, including BUOW.

The MSP Roadmap categorizes BUOW as a species at:

"high risk of loss from Conserved Lands in the Management Strategic Plan Area (MSPA) … due [to] its limited distribution within the MSPA, small breeding occurrences, recent loss of occurrences from Conserved Lands, lack of suitable nesting habitat and high degree of threat."

Research conducted by SDZ ICR and this BUOW Conservation and Management Plan follow the BUOW objectives outlined in the 2013 MSP. The list of prioritized objectives from the 2013 MSP were: 1) Conduct an inventory of breeding owls to determine the minimum number of breeding pairs currently present;

[1] Between 2006-2010, breeding owls occupied artificial burrows at the Wildlife Research Institute, located adjacent to Ramona Grasslands Preserve.

2) Track annual metrics of survival, reproduction, and dispersal for the Otay population; 3) Address genetic questions about population homogeneity and regional connectivity; 4) Prepare an implementation plan [i.e. BUOW Conservation and Management Plan] focused on improving artificial burrow management; and 5) Implement the coordinated, science based-management strategy. Results and recommendations are incorporated into the objectives for BUOW in the 2016 MSP Roadmap for the 2017-2021 planning cycle.

The management strategy herein for BUOW is based on SDZ ICR data and findings since 2011 on optimal management for BUOW recovery in San Diego County. In addition, there is general recognition of a need to actively establish and manage additional BUOW breeding areas to lower the risk of local extinction and increase BUOW population size. These areas are sometimes referred to as "nodes," defined in this document as a colony of breeding BUOW. Given the effort and expense involved to develop and establish new node areas, it is also important to concentrate management efforts in suitable sites where the chances for success are highest.

Therefore, the overall purpose of this document is to identify and prioritize conservation and management needs for BUOW in San Diego County to support a coordinated and evidence-based species recovery strategy. This document addresses the numerous existing threats to BUOW and provides an integrated tactical plan to achieve a stable and viable population in this region. The plan focuses on establishing new areas for recovery of BUOW to lower the risk of local extinction and increase overall population size and stability.

1.2 Approach

Section 2 of this report assesses the current status of the Otay BUOW population, as the last remaining breeding population in the County, using a population viability analysis (PVA). In PVA, population trajectory over 50-100 years is simulated based on field data for demographic rates in the targeted population. PVA provides a quantitative prediction about future trends and extinction probability, while also indicating which demographic rates (e.g. mortality, reproduction) are most influential in driving population changes.

Section 3 of the report summarizes study findings on best management strategies, organized by management situations. It includes detailed treatments of the key factors for establishing new breeding sites and optimal relocation techniques for both California ground squirrels and BUOW. For example, the 2013 MSP approach for immediate interim management measures included artificial burrows and habitat enhancement on conserved lands in the vicinity of Otay Mesa/Otay River Valley to provide suitable habitat for owls that may be displaced by development. This Conservation and Management Plan supports those objectives by detailing the siting of artificial burrows, presenting improvements on existing burrow design, and identifying the level of annual maintenance required to keep artificial burrows functional and available to breeding owls.

There is also an important need to provide grassland management in addition to burrow management. Grasslands dominated by non-native annual grass species such as bromes (*Bromus diandrus*, *B. madritensis*, *B. hordeum*) and wild oats (*Avena barbata*, *A. fatua*) do not provide suitable BUOW habitat without management. These invasive plant species create a tall and dense habitat structure that impedes both squirrel and owl foraging movements and predator detection, leading to an unavoidable need for ongoing vegetation management in most existing grasslands.

The recommendations in this report emphasize habitat enhancement strategies that take advantage of established relationships between BUOW and the California ground squirrel as the ecosystem engineer providing burrows for owls in California grasslands. Habitats are dynamic and the ecological processes that influence those dynamics need to be included in management and restoration plans (George and Zack 2001). The inclusion of ecosystem engineer species that modify the environment with consequences for other species and ecosystem processes may also provide a cost-effective means of achieving conservation targets (Byers et al. 2006). The promise of this approach is twofold: reducing overall cost by focusing resources on ecosystem engineer restoration, and creating the possibility of a more self-sustaining system that is less dependent on continued human intervention.

Section 4 of this report details regional habitat suitability modeling begun in 2015, and followed up with rapid assessments conducted in 2016-2017. The rapid assessments included a suite of standardized fine-scale field surveys of prey (small mammal) availability, predator pressure, vegetation, and soil texture. These efforts were designed to identify priority sites for future species management, and ten sites have been evaluated to date. In Section 5, the suitability results from both the regional modeling and the rapid assessments are reported and discussed by site.

Each section of this report is intended to fill a previously-identified need for information, and is also intended to contribute to the ongoing consensus-based decision-making process. Over the past 5 years, this process has made significant progress toward the development of an evidence-based and biologically sound conservation strategy to stabilize the San Diego County BUOW population. Voluntary consensus efforts such as these have the potential to influence species status ahead of other likely measures, such as state or federal listing (regulatory protections). The strength of the process is that it is based on the teamwork and agreement of partners acting in accordance with different mandates, jurisdictions, and expertise. This BUOW Conservation and Management Plan, which has been written to align with the SDMMP framework for prioritized species under the MSP Roadmap, is a product of that process, and also represents the next step forward for species conservation in San Diego County.

2.0 Population Viability Analysis

A population viability analysis (PVA) of the Otay Mesa BUOW population is an important component of understanding the current status and likely future trajectories of the only remaining breeding node in San Diego County. In PVA, population trajectory over 50-100 years is simulated based on field data for demographic rates in the targeted population. For the Otay population, high-quality data representing four breeding seasons (2013-2016) are available as inputs for the PVA. Ideally, additional seasons of data would be required to fully represent annual fluctuations in demographic rates. However, long term avian demographic data on the needed time scale of 10-20 years is rarely available (Beissinger et al. 2006). The demographic data used in this BUOW PVA will be updated as additional years of field data become available.

The analysis consists of 1000 model simulations for each scenario of input values, which are then averaged together. The strengths of this approach are that it provides a quantitative prediction about future trends and extinction probability, while also indicating which demographic rates (e.g. mortality, reproduction) are most influential in driving population changes. One important caveat is that it is not possible to determine which of the many simulated outcomes most closely predicts the eventual actual population trajectory (Beissinger et al. 2006). However, in the short term, the model may be validated by comparing the first few years of the average population prediction against current datasets of population trends (Brook et al. 2000).

2.1 Population monitoring

The current demographic status of the monitored portion (Lonestar, Brown Field, Johnson Canyon, LORBOMA) of the Otay Mesa BUOW population was established using nest monitoring, camera trapping, banding, and GPS tagging during breeding seasons in 2013-2016. Nest monitoring was based on a compiled list of known natural and artificial burrow locations within the area defined by the MSPA as Management Unit 3. This area includes the eastern portion of Otay Mesa (Figure 1). All burrows were visited at the beginning of the breeding season to determine burrow status (active, inactive, need for maintenance) and establish a set of occupied nest burrows for weekly monitoring with observations through the breeding season. The number of owls seen, sex and age class of the owls, and the presence of California ground squirrels or predators were recorded for each nest burrow visit. Incidental BUOW sightings and sign (e.g. whitewash, prey remains, pellets, and feathers) at squirrel translocation plots and private lands were also recorded throughout the study period. For specific details about monitoring, see the 2013-2016 annual reports (Wisinski et al. 2013, Swaisgood et al. 2014, Hennessy et al. 2015, Wisinski et al. 2016).

Figure 1. MSP Management Unit 3. The areas included in the BUOW population monitoring and utilized in the PVA are outlined in green.

We also used remote camera systems to monitor the entrances of occupied nest burrows. Cameras were set at burrow entrances after the presence of eggs or chicks was confirmed, and cameras were added or moved when juveniles started moving to satellite burrows. All camera trap photos were organized by burrow and date and processed with quality control to identify and record daily maximum numbers of adults and juveniles, and the identities of any banded owls.

During the nestling and fledgling stages of the breeding season, we captured, banded, and collected genetic samples (blood and/or feathers) from adult and juvenile BUOW at or near their nest burrows. Standard morphometric measurements were taken for each bird. All blood, feather, and tissue samples are stored in the Frozen Zoo® at the Beckman Center, SDZ ICR. Unbanded owls received two aluminum bands: a USGS band and a green alphanumeric Acraft band.

We currently estimate the Otay Mesa breeding season population size at approximately 100 breeding individuals, including an average of 27 pairs monitored per year since 2013, plus a small uncertain number of additional birds on unmonitored sites based on incidental reports. An annual average of 53 juveniles has also been detected since 2013.

2.2 Population viability analysis methods

We conducted a PVA using a single population model representing baseline conditions at Otay Mesa. The model inputs were based on the demographic data described above. BUOW mortality was estimated from 2013-2016 band return rates modeled in Program MARK with the Cormack-Jolly-Seber model. Emigration was not estimated separately from mortality, due to the difficulty of documenting emigration events. Annual immigration was estimated from records of new unbanded individuals. Observations of breeding behavior enabled estimation of the annual percentage of the population that was reproductively active, and counts of chicks at each burrow allowed estimates of reproductive output. The demographic data represent a composite of three sub-areas on Otay Mesa: Brown Field, Lonestar, and Johnson Canyon. The PVA was run in the software package Vortex 10 (Lacy and Pollak 2015).

Model inputs

In Vortex, the BUOW reproductive system is best described as long-term monogamous, to account for multi-year pairs. Maximum lifespan was assigned a value of 8 years, and both sexes were considered reproductive from ages one to eight years. The values used for the distribution of clutch sizes (for clutches with 1-8 chicks) were drawn from the maximum count of chicks emerging from each burrow (Vortex specifies that clutch size estimates should exclude unhatched eggs). The distribution was right-skewed, in that there were a greater number of small clutches and fewer large clutches. The distribution was also platykurtic, described best by flatter- and broader-curve tails than a normal distribution would show. The percentage of breeding pairs (0.72 ± 0.11) was estimated from field data on the total number of pairs minus the pairs that did not exhibit nesting behavior and pairs with zero chicks emerging from their nest burrow. This was necessary to incorporate data about the percentage of breeding pairs with unhatched eggs and/or zero chicks. Using Program MARK, estimated mortality rate (including emigration) was 0.74 ± 0.15 for juveniles and 0.31 ± 0.10 for adults. The standard deviation estimates for mortality include both environmental variability and demographic stochasticity. Settings for inbreeding depression were turned off due to known high levels of connectivity among populations of this species, and a stable age distribution was used to calculate the number of individuals in each age class.

Immigration rates were estimated from a count of unbanded adults, breeding or not, recorded at study sites between 1 February through 31 August of each monitoring year. Survey effort varied among years from 1 February through mid-March, but survey effort through the remainder of the breeding season was standardized. Immigration occurred annually in every year of the simulation. Initial population sizes ranging from 2 to 200 individuals were simulated. Carrying capacity was specified at 500 individuals. This value was set high to avoid imposing an artificial limit on positive population growth. Therefore, the reported growth rates represent a best-case outcome.

2.3 Population viability analysis results

The average baseline model based on current data from the Otay Mesa population indicates a potential for either weak growth or decline (Figure 2). Under the scenario of one population of 100 birds (50 pairs) and no immigration, growth rates are very close to zero (r =-0.005, SE=0.002). Overall mean final population size was 133.6 (SD=165.8). For populations that did not go extinct, mean final population size was 203.6 (SD=171.0). The main question raised by this scenario is whether the extinction risk is at acceptable levels.

The probability of short-term extinction over a timeframe of 50 years (n = 1000 simulations) is 35.9% and mean time to extinction over these runs is 28.4 years (SD = 10.9).

The probability of extinction of 35.9% reported above is derived from the percentage of simulations (n=1000) where the population experienced extinction. However, the single simulation that most closely predicts the eventual actual population trajectory is impossible to foresee. The uncertainty in these simulation outcomes can be observed through a confidence interval representing 95% of the set of 1000 simulations (Figure 2). Based on the distribution of simulated outcomes, yearly population persistence in at least 95% of the simulations was only maintained for the first 17 years. After the first 17 years, individual simulated outcomes varied widely, from strong growth to extinction. This variability underscores the uncertainty in the future of this population.

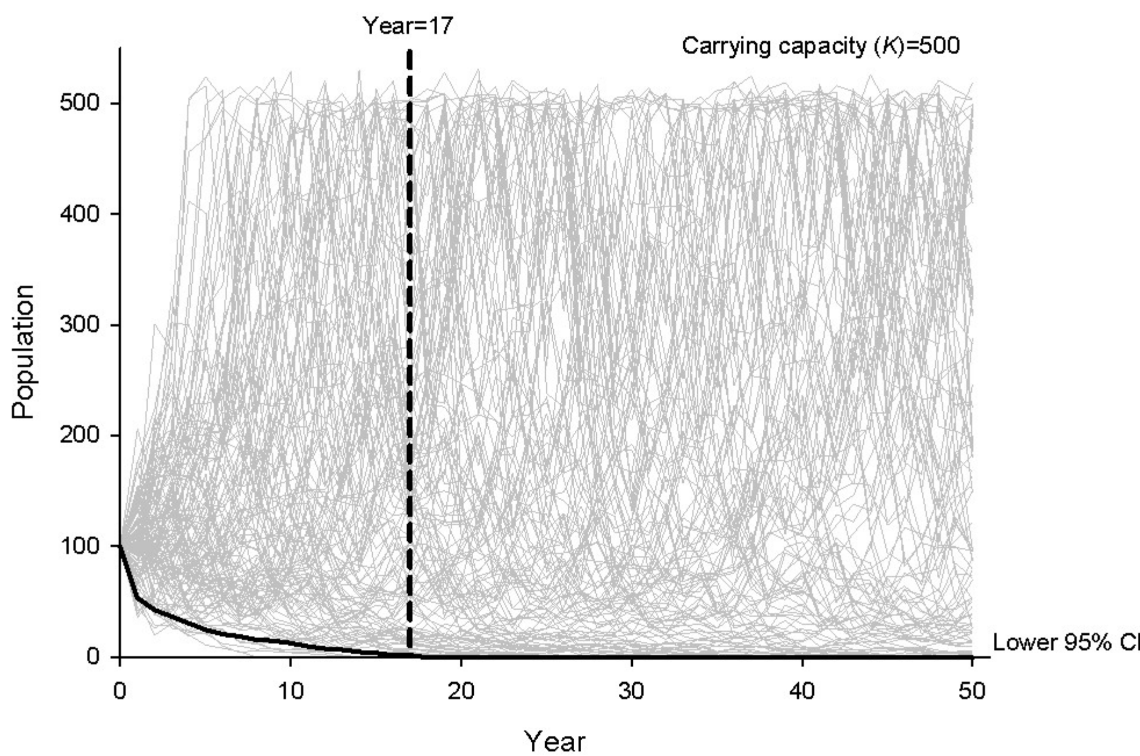

Figure 2. Estimated trajectories of Otay Mesa BUOW population after 50 years based on current demographic data 2013-2016. The lower confidence interval is shown in bold and is set at 5% of simulations (n=1000). Initial population size was 100 individuals for all runs.

Sensitivity analysis provides information about which factors influence population outcomes the most. In sensitivity analysis, a range of possible values is identified for each variable tested (Table 1). All variables are simultaneously sampled (n=1000 different combinations of all variables), according to a defined sampling increment for each variable. Each combination is then simulated (n=1000) for a time period of 50 years. The sensitivity results consist of correlation values for each input variable against both growth rate and final population size.

Table 1. Sensitivity analysis for BUOW PVA represented as correlation (*r*) of parameters with model output variables.

Parameter	Range	Sampling Increment	Correlations (*r*) growth rate (r)	Final population size
Initial population size	2-150	4	-0.002	0.05
Juvenile mortality	59-84	1	-0.94	-0.82
Adult mortality	28-35	1	-0.15	-0.13
Percent females breeding	65-87	1	0.29	0.12
Immigration	0-12	2	0.04	0.42

For growth rate, juvenile mortality is the most influential variable (*r* =-0.94), followed by percent females breeding (*r*=0.29) and adult mortality (*r*=-0.15; Table 1). Juvenile mortality has fluctuated widely from year to year, with a maximum estimated mortality of 0.84 in the 2013-2014 interval, and a minimum estimated mortality of 0.59 in the 2015-2016 interval. This variability in juvenile mortality is indicative that the variable is sensitive to environmental conditions, and thus could be influenced by management action. Juvenile mortality therefore has the potential to significantly shift population trajectory. When the range of juvenile mortality rates (0.59-0.84) is modeled, population growth rate shifts from strongly positive to negative at both small and large population sizes (Figure 3).

The primary signal from the PVA is that the owl population will closely track reproductive success. As long as average reproductive success remains near the current mean juvenile mortality rate of 0.74, risk of extinction over 50 years will remain at around 35%. If a series of bad years occurs, the population will begin to track downwards, and extinction risk will increase. At longer timeframes, the risk of extinction increases. For example, over a simulation of 100 years, the extinction rate rises to 60% at current mean juvenile mortality. In order to limit the average probability of extinction over 50 years to 5% or less (at current population levels), mean juvenile mortality must remain at or less than 69% (SD=0.15). In order to limit the risk of extinction to 5% over 100 years, an average juvenile mortality of 67% (SD=0.15) or less must be maintained.

In the event of a series of years of high juvenile mortality, immigration may be seen as an insurance factor. The best data-derived estimates of current immigration levels are of 5-10 pairs per year. Even immigration of 1 pair per year reduces the overall risk of extinction to less than 1%.

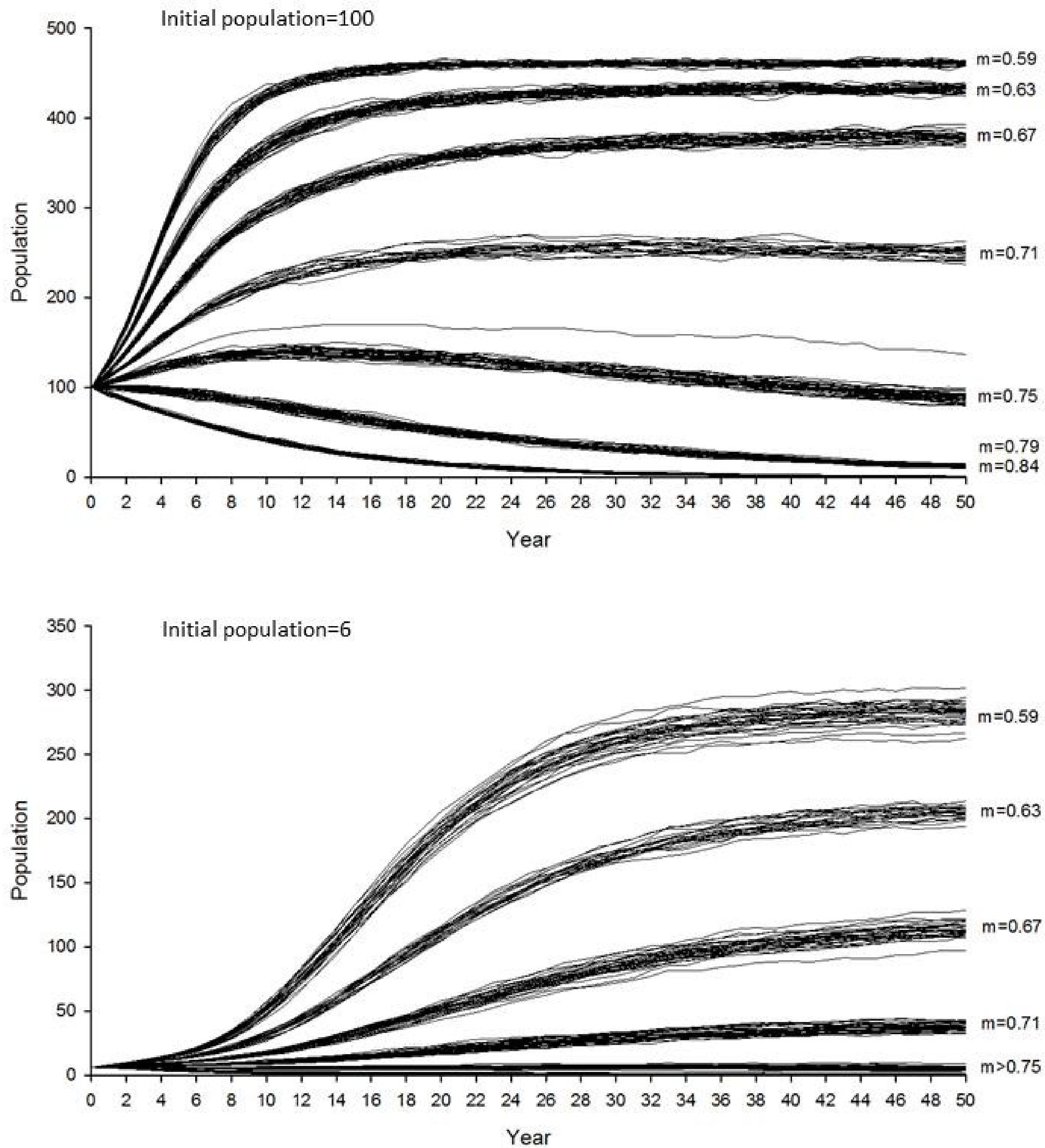

Figure 3. Top panel: variability in population trend (initial n=100) across the range of low to high values for juvenile mortality, from mortality=0.59 (growth r=0.27) to mortality=0.84 (r=-0.15). Bottom panel: For minimum translocation population of 3 pairs (n=6), potential growth rates across the range of low to high values for juvenile mortality, from mortality=0.59 (r=0.25) to mortality=0.84 (r=-0.11).

Initial population size

The sensitivity analysis confirmed that final population size is more sensitive to changes in immigration (r =0.42) than to initial population size (r =-0.05). However, to incorporate the current uncertainty about total population size on Otay, the model was tested by increasing the baseline initial population size above the current estimate of 100 individuals. Positing a current population size of 150 individuals reduces the probability of extinction over 50 years from 35.9% to 26.3% and increases the mean time to extinction from 28.4 to 32.8 years. Increasing initial population size to 200 individuals further reduces the probability of extinction to 25% and increases the mean time to extinction to 33 years.

Reliability of estimates

This model produces a more optimistic trajectory for the Otay Mesa population than earlier models, in part due to a shift from representing mortality by year over year band return rates to the use of estimates from resight rates modeled in Program MARK. The strength of this approach is that the resight rates more effectively represent the detection of individuals after an absence of one or more years, boosting overall survival rates across the intervening years. One important consideration, however, is that new or additional data may have significant impacts on the magnitude of parameter estimates.

Another consideration is that these simulations exclude major population events such as episodic habitat loss and mortality events, although events such as these can be reasonably expected to occur at both 50- and 100-year time scales. These model forecasts also do not consider the possibility of Allee effects, with greater numbers of individuals facilitating the creation of breeding pairs and successful reproduction. In many species local extinction is accelerated when population numbers fall below some critical threshold, in part because the few individuals present are less likely to encounter and select mates (Courchamp et al. 1999). As a semi-colonial species, BUOW are predicted to be susceptible to Allee effects, and thus our model may underestimate extinction risk.

Management recommendations

The model results suggest that future management actions should focus on the factors which influence population growth and population size the most. The first tier of demographic factors that should be targeted for management consists of juvenile mortality. Sources of juvenile mortality include predation by corvids, other raptors, or coyotes, and/or starvation due to inadequate or fluctuating foraging conditions. Juvenile mortality could be reduced with a suite of predator management actions, while foraging conditions could be improved through vegetation management or supplemental feeding. Supplemental feeding as a strategy would be most effective in drought years or at times and locations where food supply is temporarily limited.

The second tier of factors influencing population outcome includes adult mortality, annual proportion of breeding females in the population, and immigration. Immigration should not be depended on to maintain the population in the long term, and increasing population sustainability should be a priority management goal. In the Otay population, both of the remaining factors may be more difficult to influence with management. The range of measured adult mortality has remained relatively stable across years through drought and habitat changes, suggesting that it may be difficult to measurably improve on the current estimated 31% mortality/dispersal rate. Conversely, the annual percentage of females that exhibited breeding behavior ranged from 81-100% across four breeding seasons. Some of the measured variability can be attributed to the difficulty of detecting the sex of single, uncaught birds seen at burrows. However, as long as there is adequate burrow availability, the population may benefit from the release of additional pairs. These additional pairs could come from a conservation breeding program, described in Section 3.5.

Active translocation planning

The PVA provides some guidance for planning active translocations. Due to the great difference between the correlation of population growth rate with juvenile mortality (r=-0.94) versus initial population size (r=-0.002), these recommendations focus more on supporting successful reproduction and reducing juvenile mortality rates rather than on the number of pairs in the translocation. However, including consideration of the semi-colonial life strategy shown by BUOW will support translocation success. We recommend maintaining a minimum translocation group of 5 pairs per translocation to improve settlement and population establishment at a site, and further recommend that only sites large enough to support at least 5 pairs, when the land manager has made a long-term commitment to maintaining appropriate habitat structure through vegetation management, should be used for translocations.

The magnitude of the correlation differences hold true for both small initial populations (as for active translocation projects), and larger established populations. For a minimum initial population of 3 pairs, the juvenile mortality rate drives population growth from negative (r=-0.13 when juvenile mortality=0.84) to positive (r=0.20 when juvenile mortality=0.59) (Figure 3). Growth rates are positive when juvenile mortality is less than 72%. It is desirable to maintain an even lower level of juvenile mortality since the probability of extinction over 50 years associated with this level of mortality is still very high (probability of extinction=88%).

Target population for San Diego County

Target population size needed to maintain species presence for 50 years in San Diego County was derived from the population level needed to maintain a 95% confidence interval above the extinction line (n<2 BUOW). At current demographic rates and levels of variability, a population of 1,500 BUOW individuals would be needed to maintain 95% confidence in population persistence for 50 years (Figure 4). For BUOW, the observed variability in demographic rates (from annual field measurements) is driving the variability in simulated outcomes. As a result, a higher number of BUOW is needed in the population to significantly reduce the chance of extinction. This could be achieved through the establishment of additional population nodes in San Diego County (e.g., 8-10 nodes with 150-200 owls per node). Alternatively, management actions that serve to mitigate those parameters making the population vulnerable to extinction, such as low and variable juvenile survival, could also reduce risk of extinction and allow for a smaller target population.

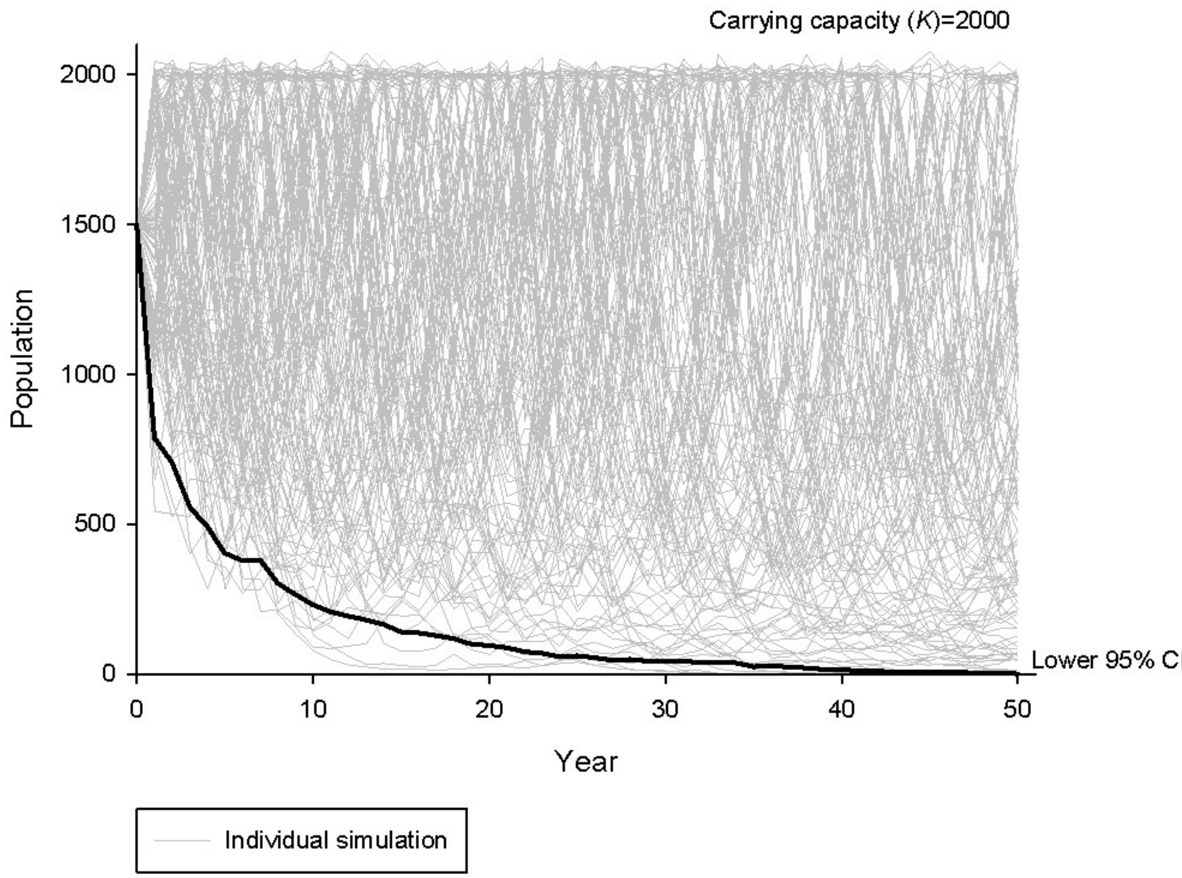

Figure 4. Target population size needed to maintain species presence for 50 years in San Diego County. Simulations are based on existing demographic data 2013-2016. At a target level of 1500 owls, 95% of all simulations (n=1000) avoided extinction for 50 years. Initial population size was 1500 individuals for all runs.

Conclusions

While the PVA does not provide specific predictions about eventual population outcome, it does indicate that at current demographic trends, population persistence is most certain over the next 15-17 years. After that, with an extinction probability over 50 years of approximately 35%, there is considerable uncertainty about population outcome. Management actions to support juvenile survival in the first year are most likely to support population persistence. The strength of the correlation between juvenile mortality and population persistence holds even for small numbers of owls, as would be the case in an active translocation. Based on this analysis, the best estimate of the overall county population size needed to prevent extinction in San Diego County over the next 50 years is approximately 1,500 BUOW.

3.0 Management Strategies

This section discusses the best management strategies for BUOW conservation, organized by management situations (e.g., vegetation density and height, the suitability of the soil for burrowing by squirrels, presence or absence of both squirrels and BUOW, and what to do with existing artificial burrows). Additionally, it identifies and discusses optimal relocation techniques for both California ground squirrels and BUOW. The collaborative research program conducted by SDZ ICR in San Diego County since 2011 forms the scientific basis for the management recommendations presented in this section.

Management strategies relying on California ground squirrels are favored over those relying on greater human intervention, such as artificial burrows. Creating owl habitats that include California ground squirrels will be more self-sustaining and less reliant on artificial burrows that require continued investment of resources. By creating a functioning ecosystem involving multiple species assemblages, the risk of creating "ecological traps" (Battin 2004) is reduced. While installation of artificial burrows in areas without squirrels are sometimes an important short term intervention, they may attract owls to habitats associated with low fitness (e.g., low egg hatchability, high predation levels, poor foraging conditions). In addition, squirrels offer numerous indirect benefits to owls, such as providing increased predator protection through vigilance and alarm-calling.

Moreover, management actions are needed to support the entire life cycle of BUOW. While the focus of local research studies has been on the creation of breeding habitat for owls, it is important to remember that the management options in this section apply to owl foraging habitat for resident, migrating, and wintering owls as well. The provision of adequate amounts of suitable foraging, wintering, and breeding habitat is critical to owl nesting success and productivity.

For some of the key strategies discussed in this section, a plan and commitment for long-term management is necessary to ensure success. If owls become established as a result of short-term non-native grass management or artificial burrow installation, as the habitat drifts into a state of lower suitability the owls may become trapped in what amounts to a population sink. Endangerment to owl survival and productivity in the long-term will negate any benefits to owls in the short-term.

3.1 Management situation: Dense non-native ground cover

The Mediterranean climate of San Diego County facilitates non-native grasses to grow quickly, competing with native grass species for soil nutrients, moisture, and space. Non-native grasses 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 (D'Antonio et al. 2007).

Tall, dense vegetation may impede BUOW and squirrel ability to forage and detect predators. Thick thatch may impede foraging and burrow digging activities. A habitat association study for California ground squirrel found the likelihood of squirrel burrows in grassland decreased with increasing vegetation cover (Wisinski et al. 2013). Specifically, the study found a negative relationship between presence of burrows and annual non-native grass cover. In many cases, habitat modification in the form of vegetation management may be necessary before squirrel reintroduction, since reintroductions are more likely to succeed in higher-quality habitat (defined as the capacity to provide resources required by the species) (Moorhouse et al. 2009). For sites with a small existing population of resident squirrels, vegetation management may help increase the size of the colony and squirrel activity levels. Due to the difficulty of re-establishing native plant communities once disruption of the native community has occurred due to agriculture or other causes, managers may choose to focus on altering the physical structure of the plant community, by reducing the height and density of non-native grasses.

A long-term commitment to management of non-native grasslands should be established before undertaking efforts to attract BUOW to a property. Experience in California has shown that breaking the cycle of non-native grass invasion, short fire return intervals, and nitrogen deposition can be very difficult (Allen et al. 2005; Gillespie and Allen 2004, 2008; Johnson et al. 2008; Seabloom et al. 2003). However, establishing a BUOW population and then allowing the return of unsuitable habitat would be counterproductive and a waste of limited resources.

Strategy: Prescribed burning and/or grazing

When possible, prescribed burning and grazing are the preferred methods for reducing the density of non-native ground cover. There is experimental evidence for the benefits of prescribed burning and grazing on burrowing mammals (Shier and Swartz 2011). Both types of disturbances decrease non-native annual grass cover and the density of thatch on the soil surface, reducing or eliminating the need for mechanical mowing. These methods may be better suited to larger sites that may already have a plan in place for rotating vegetation management on a multi-year schedule.

However, prescribed fire is not a feasible option in all locations, due to the inherent risks of fire, stringent permission processes, and intensive resources needed for controlled implementation. Where fire is utilized, using an herbicide treatment in conjunction with fire could prolong the positive effects of burning across growing seasons. Prescribed fire reduces thatch, but the subsequent recovery of the vegetation community will depend on the proportion of native and non-native species present in the seedbank. The addition of selective herbicide treatment can reduce the subsequent return of non-native grass biomass and support the competitive ability of native forbs and grasses. The focus of vegetation management for owls is on the maintenance of low, open vegetation structure rather than on supporting native species. However, in cases where co-management of multiple species is occurring, prescribed fire may provide the best opportunity for reducing undesired non-native grass impacts on other priority species in conjunction with BUOW management activities.

Grazing is most likely to be beneficial when grazing intensity is carefully managed with measures such as fence installation and regular rotation of grazers. The type of grazer also influences the impacts of grazing.

Strategy: Mowing and/or herbicide

For small sites, mowing or herbicide may be more feasible. Mechanized mowing may be conducted in many situations without significant compaction of soil layers. Mowing is a useful approach in locations where the site is flat and relatively free of obstacles. Mowing should be conducted between late February and early April as the grasses are flowering and before seed set after soil moisture has been depleted to prevent regrowth.

Mowing can replace the use of fire if prescribed burning is not possible, due to time of year or other factors. The risks of mowing equipment as potential ignition sources in flammable plant communities should be considered before initiating this management strategy. Mowing should be timed before summer heat because the risk of accidental ignition from the mower increases as the grass dries out. Maintaining fire prevention measures at the work site (e.g. shovels, fire extinguisher, a small water tank) can reduce the risk, as can posting an observer behind the mower. When mowing is utilized, thatch removal also needs to be planned, since mowing can leave a very thick layer of material on the soil surface and manual raking is not practicable. A flail mower or hay rake may be adequate for removing thatch.

Hand mowing is generally not feasible at the scales needed to provide squirrel and owl habitat. It may be utilized as an emergency measure to control vegetation growth around occupied breeding burrows. However, we encourage a focus on long-term planning and development of sustainable strategies in contiguous, protected habitat.

Treatment with a grass-specific herbicide is an option preferred by some managers. The treatment may be applied to flat/gently sloping areas with a boom sprayer on an ATV, or more targeted application can be conducted on steep or rocky areas. Coverage of moderately large areas can be accomplished at relatively low cost. If a native seedback still exists onsite, significant native plant seed germination can occur. Follow-up targeted spot spraying of herbaceous invasive species is necessary using this method.

Strategy: Native species replanting

In some circumstances, managers may consider replanting some areas with an appropriate mix of native forbs, grasses, and shrubs. The successful use of this management option may be constrained by the degree of anthropogenic change in grasslands, and by demonstrated difficulty associated with returning grasslands to historical conditions (Cox and Allen 2008; Hobbs et al. 2009). Previous efforts to restore native grasslands have met with mixed success, and native plantings are not always an effective strategy (Seabloom et al. 2003a; Cox and Allen 2008). Where sufficient resources are available or a more comprehensive restoration program is pursued as part of a larger conservation strategy, native plantings may be an option. Methods of re-establishing native vegetation are beyond the scope of this plan. However, the existing evidence suggests that BUOW or California ground squirrel populations can be established in non-native grasslands provided the physical structure is modified to create more open habitat.

In addition, grazing, mowing, and prescribed fire all have the potential to change species composition in locations where native species persist in the seedbank. Some successful projects in southern California have had dramatic effects on the composition of the plant community (CBI 2014). There is further interest in the development and use of short-term treatments to alter plant communities. The long-term efficacy of these efforts is not guaranteed, however. This document emphasizes the importance of planning for the potential need for long-term commitment to vegetation management in order to support BUOW and California ground squirrels.

3.2 Management situation: Soil suitability for burrowing

Not all soils are suitable for squirrel burrowing activities. Many grassland sites may have highly compacted soils or may contain soils with larger proportions of dense materials like clay or gravel that impede squirrel digging and burrow creation. A recent habitat association study for California ground squirrel found the presence of burrows was associated with higher sand content, less silt, and less clay. It was also associated with higher bulk density (a characteristic of sandy soils), and less gravel (Wisinski et al. 2013). Higher post-translocation establishment of squirrels is also influenced by parent material: higher establishment rates occurred at sites with lower clay content and metavolcanic parent material rather than alluvial deposits (Swaisgood et al. 2014). Grassland soils with high clay fractions also raise concerns about flooding of occupied burrows.

Strategy: On-site soil sampling

Often the first evaluation of soil type is based on the existing Soil Survey Geographic Database (SSURGO) soil map, which is helpful at larger scales but lacks fine-scale detail. It is important to verify site-specific soil texture with soil samples before making the final decision to manage a new site for California ground squirrels and BUOW. A partition analysis of data from the squirrel habitat association study indicates that a sand fraction between 60-80% is optimal (unpublished data). The clay fraction should be below 12%, and gravel should also be below 12% of the total mass (n=228).

Strategy: Creation of berms

For sites with clay or rocky soils, the creation of artificial berms can be considered. Both squirrels and owls are frequently found occupying artificial berms in constructed landscapes such as agricultural irrigation ditches and airports (Gervais et al. 2003, Wisinski et al. 2013). The attractiveness of artificial berms to squirrels could be leveraged to encourage squirrel settlement to desired areas, such as to interior habitat areas buffered from the increased mortality risks of edge habitat.

The placement of berms in interior habitat areas can be used to draw squirrels and owls into protected habitat. However, berms are often used as a visual and physical barrier between habitat areas and edge areas such as road- and fence-ways. In all cases, as the berms are intended to become BUOW nesting sites, berm placement should be designed in accordance with the State (CA DFG, renamed CDFW in 2013) recommendations for setback distances for BUOW nests. During the breeding season, the setback distances range from 200-500 m depending on disturbance intensity (CA DFG 2012).

Berms need to be constructed above the existing soil surface to alleviate flooding danger, and the degree of berm compaction needs to be high enough to enable the formation of stable burrow walls. The sustainability of this management strategy is intermediate: more sustainable than artificial burrows but less sustainable than establishing owls on sites with suitable soils and California ground squirrels. Once the berms are created, squirrels can move in and create the needed burrow habitat with no need for artificial burrows. Permitting may be required depending on the size and extent of the berm.

3.3 Management situation: Burrows absent

California ground squirrels are often found occupying the margins, rather than the interior, of grasslands with mixed native and non-native species composition. In many grassland parcels managed for the purpose of meeting BUOW conservation goals, resident squirrels may be present nearby in disturbed margins or around structures, while remaining absent in the core habitat. Although BUOW may use burrows created in these marginal areas, these sites may be associated with greater risks, such as human disturbance and traffic mortalities. In other parcels, squirrels may be completely absent due to historical patterns of pest control (Marsh 1998).

Strategy: Attract nearby resident squirrels

If an abundant population of resident squirrels is in close proximity to the selected site, natural squirrel colonization can be encouraged when vegetation management creates favorable habitat with a low, open structure. In a study of a newly cattle-grazed area adjacent to a resident squirrel population near human structures, the squirrels began to colonize the newly available areas of short, open grassland at a slow pace (Swaisgood et al. 2014). In addition, the placement of cover piles made of wood or other materials was associated with increased squirrel use in the study of colonization by resident squirrels, and with better establishment success in squirrel translocations (Swaisgood et al. 2014; Wisinski et al. 2013).

Naturally dispersing animals can use the presence of conspecifics (individuals of the same species), or cues associated with conspecifics (for BUOW, potential conspecific cues are whitewash and acoustic playback), to guide habitat selection. Individuals may copy the habitat selection decisions of others because the presence of conspecifics is a reliable cue of habitat quality that reduces the effort and cost of searching for good habitat (Stamps 1988; Valone 2007). It has been hypothesized, and in some cases demonstrated, that the presence of conspecific cues will enhance settlement for animals reintroduced into areas currently unoccupied by conspecifics (Swaisgood 2010). In experimental squirrel translocations, augered holes (0.3 m deep at a 45˚ angle) were installed to resemble squirrel burrows, and to fulfill dual purposes of providing squirrel refugia from predators and creating areas of decompacted soil. Although squirrels did not use the augered holes as burrows, squirrel activity was significantly higher around augured holes, and this increased activity was also consistently sustained over time (Deutschman and Hennessy 2015). This strategy can be used to help anchor translocated squirrels and could also be tested to determine if it attracts nearby squirrels to colonize.

Strategy: Active squirrel translocation

When squirrels are absent or present at densities too low to enable colonization at adequate rates, active translocation can be implemented using the enhanced squirrel translocation protocol developed through field experiments conducted in 2011-2015 (Shier et al. 2016). The protocol includes soft release with supplemental feeding after an initial onsite acclimation period of one week. Acclimation occurs in artificial burrows with above- and below-ground protection from predators and the site should also be prepared with debris and/or rock piles for cover. As discussed above, site selection is an important factor determining outcome, and only sites with suitable soils and open vegetation should be used for translocation. The seasonal timing of translocation affects retention and survival, and evidence suggests that translocations conducted in late summer (August) will be more successful than those conducted in early summer (May/June) (Shier et al. 2016). To support the establishment of the new population, repeated supplemental translocations should be planned and implemented. At a minimum, two translocations should occur, with at least one supplemental translocation following the initial translocation at an annual interval.

When setting target translocation densities, one factor that should be accounted for is the density of established squirrel colonies. Squirrels live in colonies of a few dozen individuals with extensive overlap of individual home ranges, and exhibit year to year site fidelity. Female California ground squirrels occupy a home range of approximately 600-900 m^2, or a radius of 14-17 m around the burrow (Boellstorff & Owings 1995). Recent translocations in San Diego County have used a target number of 30-50 squirrels translocated to 0.80-ha plots (minimum of three adult males and six adult females, plus weaned pups). Active translocations may benefit from augering starter burrows or other conspecific cues to anchor squirrels at the release site. Both settlement and survival also may be increased by maintaining familiar social groups of individuals through the transition from home site to translocation site (Shier and Swaisgood 2012). The final factor to consider is the general pattern of increased success with increasing numbers of translocated individuals (Drake and Temple 2012; Popescu and Hunter 2012). This pattern has been measured across a range of species. Despite a proportion of individuals lost to mortality, the greater numbers of individuals moved generally ensures that higher numbers of individuals will survive.

Strategy: Install artificial burrows

The installation of artificial burrows is most appropriately used as a short-term strategy and as a secondary option in locations where squirrel management has been delayed. As a precondition for burrow installation, a habitat suitability assessment for natural burrow availability, suitable prey availability, predator protection, soils, vegetation, and disturbance must be conducted. Factors such as distance to likely disturbances (in terms of the state recommendations for setback distances) should also be considered (CA DFG 2012). The setback distances provide a useful rule of thumb for siting burrows away from likely predator perches (trees, shrubs, fences) and away from electric fences. A suggested approach toward habitat suitability assessment, in the format of rapid assessments, is described in Section 4 of this document. This assessment step is critical since the average maximum foraging distance of BUOW from their nest burrow was less than 1 km, based on GPS telemetry in 2014 and 2015 (Wisinski et al. 2016; Hennessy et al. 2015). Since foraging area is tied so closely to the location of the breeding burrow, artificial burrows must be carefully sited in areas with good habitat quality and with a buffer between the burrow and potential threats such as roads/freeways. Otherwise, owls occupying artificial burrows will experience reduced reproductive success and survivorship, which may contribute to populations functioning as sinks rather than sources. Management actions that maintain population sinks in the short-term do not support long-term BUOW sustainability goals and are a poor use of resources.

Burrow design

New experimental evidence suggests that artificial burrow design can be improved by using a wooden nesting chamber and a Y-shaped double entrance. SDZ ICR productivity monitoring on Otay Mesa showed that owls occupying artificial burrows with plastic chambers experience lower reproductive success than owls breeding in artificial burrows with wooden chambers or natural burrows (Hennessy et al. 2015). While productivity differences may be due to the surrounding habitat and its foraging opportunities or predation pressure, characteristics of the burrows themselves can also influence productivity. The placement of data recorders inside burrows shows that artificial burrows experience more variable microclimates (temperature, humidity) than natural burrows, factors important for avian incubation and chick survival. Artificial burrows that allow direct passage of air through the burrow chamber may cause this reduced ability to buffer against external conditions. Natural burrows differ by having many twists and turns that impair airflow through the burrow.

In 2016, SDZ ICR tested three different designs (standard, Y, and curvy) and found that the Y design buffered the best against outside extremes in humidity and had the most stable humidity of the different burrows. Humidity in the Y burrows was close to the levels measured in the natural burrows on Otay Mesa in 2014 and 2015. The Y design features two burrow tunnels that meet before the burrow chamber so that there is only one tunnel entrance to the chamber.

Based on these results, we recommend the “Y” burrow design with a wooden chamber and plastic tunnels (Appendix C). This design provides a more stable microclimate (particularly in regard to humidity) while preserving two entrances for predator escape. The plastic tunnels are easier to clean and scope, while the wooden chamber will likely result in a more favorable microclimate and higher fecundity. For predator-proofing, the burrow should be armored with chickenwire-type fencing placed below the nest box and above the entire length of each tunnel. The tunnel entrance should be armored with heavy rocks, which will also provide a convenient BUOW perch.

Number of artificial burrows

The number of artificial burrows is another key factor in the application of this management strategy. The question is how many burrows should be installed per breeding pair. Owls need adequate numbers of burrows to provide primary plus alternate nesting sites, to provide adequate satellite burrows for dispersing juveniles, and to provide refuge from predators. There is little consensus on the optimal number of artificial burrows required per pair. However, the range of recommendations is generally from 2 to 5 burrows (each with two entrances) per pair. More than one cluster of burrows is necessary since BUOW are colonial. Solitary pairs are more vulnerable to predation and/or reproductive failure.

3.4 Management situation: Artificial burrows present

The installation of artificial burrows has been the most widely utilized BUOW management technique to date (Johnson et al. 2010). However, artificial burrows can become unusable in as little as a single year. In San Diego County, recent management installations at several sites led to observations of other species utilizing artificial burrows and modifying them for their own purposes; specifically, woodrats (*Neotoma* sp.) filled the burrows with cholla, leaving them inaccessible. In 2015, most artificial burrows at Lonestar and Johnson Canyon were excavated and modified with improved access to the breeding chamber. During the course of that work it was found that roughly 30-50% of the burrows would have been unavailable to the owls for nesting without immediate maintenance. In early 2016 (four months later), about 50% of the burrows at Johnson Canyon were found to be refilled with cholla, suggesting that ongoing maintenance at a specific time of year is a critical part of managing artificial burrows to keep them accessible to breeding owls.

Strategy: Annual maintenance of artificial burrows

Artificial burrows need to be maintained on an annual basis to guarantee availability to BUOW for nesting and escape from predators. The first step should be the prioritization of a list of artificial burrows to keep active with an ongoing management commitment. Artificial burrows that cannot be maintained annually should not be considered a viable management strategy. Artificial burrows suspected to be functioning as population sinks in areas with poor habitat quality or close to obvious threats need to be assessed and then closed if the assessment confirms site unsuitability. Because habitat suitability for BUOW has not been fully defined, monitoring burrows to determine reproductive success can be used as a proxy for habitat suitability and to identify artificial burrows that serve as ecological traps creating a population sink. An inventory of artificial burrows should be kept and those that have not yet been evaluated should be targeted for future evaluation.

Annual maintenance should begin with an inspection. Blocked burrows should be dug out and damaged burrows (such as burrows partially dug out by coyotes or other predators) need to be excavated and repaired. To facilitate maintenance, the configuration of all artificial burrows should be designed to enable access to the burrow chamber, such as through a bucket-type access above the chamber (Johnson et al. 2010). Artificial burrows that lack this access but are chosen for active use will need to be retrofitted to enable maintenance and monitoring. Annual maintenance activities should occur during the nonbreeding winter months immediately before the onset of breeding. Maintenance activities should also occur after seasonal rains have subsided (when possible) to ensure that erosion does not compromise the artificial burrow structures. Part of annual maintenance should include an evaluation of the burrow entrance topography to lessen the chances of erosion-related deterioration of the artificial burrows. The entrance should not contain any areas where water could pool, and the apron of the burrow should slope away from the entrance so that water cannot run into the burrow.

A secondary maintenance effort can be considered during the breeding season. If burrows are temporarily blocked by annual vegetation growth, they may be cleared by mowing or weed-whacking within 25 m of the burrow. However, short-term vegetation removal such as this does not fully address the need for a comprehensive, site-wide management strategy.

3.5 Management situation: Owls absent from suitable habitat

Strategy: Encourage settlement by naturally dispersing owls

Management to enhance habitat suitability for BUOW may induce naturally dispersing owls to settle and breed. These activities will include efforts to create the more open vegetation structure favored by owls, re-establishment of California ground squirrels and natural burrows, or provision of artificial burrows. Although some of these techniques have been shown to work to attract owls from nearby populations [e.g., when used in association with passive relocation techniques (Trulio 1995)], their ability to attract owls to settle from longer distances is unknown.

The use of visual and acoustic cues from BUOW- or captive owls held in hacking cages at the site- to attract dispersing owls is in preliminary stages of testing in San Diego County. Given the low number of owls residing in the County, however, the opportunities for local owls to find and occupy newly created suitable habitat seem few. To expedite re-establishment of BUOW in other nodes in the County, a more active approach to establishing owls may be needed.

Strategy: Active translocation

If highly suitable habitat remains unoccupied, a more intensive strategy for establishing owls may be necessary. Active translocation of BUOW has been used as a mitigation method in Arizona, Idaho, California, and Canada, with some success (Leupin and Low 2001; Smith and Belthoff 2001; Bloom Biological, Inc. 2009; Mitchell et al. 2011). In California, active relocation has not been not authorized by the CDFW, except within the context of scientific research or a Natural Community Conservation Plan (NCCP; CA DFG 2012). A new policy specifying the decisionmaking process for conservation translocations was released in November 2017 (CDFW 2017). However, an advantage of active relocation is that managers may select sites, such as conserved lands or other protected areas, where habitat is believed to be highly suitable and the risk of encountering threatening human activities is greatly reduced. The reason cited by CDFW for avoiding active translocation is lack of post-release data to validate the success of the method. A collaborative research study by SDZ ICR and U.S. Fish and Wildlife Service was initiated in 2016 to evaluate the efficacy of passive vs. active translocation in a scientific framework, with the intention of better informing BUOW management and mitigation and potentially improving on existing protocols.

The current state of information for active translocations are that soft-release methods such as adding a holding period of two weeks or more can increase settlement, survival, and reproduction (Mitchell et al. 2011).). SDZ ICR currently utilizes a BUOW holding period of 30 days. The optimal release group size and composition is not known for this species. In the absence of clear data guiding this decision, it is recommended to have a target release group size of at least 10 individuals (5 pairs). This number may be revised once more information becomes available. A common method used is to relocate pairs just prior to the breeding season so that they lay eggs at the release site, and the eggs and chicks serve to anchor them at the release site. Because the species is philopatric (i.e. individuals are likely to return to their natal site), chicks raised at the release site are more likely to return to breed, establishing a sustainable breeding population. Detailed protocols guiding the release strategy need to be completed prior to initiation of the program.

One of the most significant obstacles to conducting translocations successfully is post-translocation dispersal away from the release site (Stamps and Swaisgood 2007; Batson et al. 2015). Long-distance movements following release have been shown to increase risk exposure and mortality rates of several species (Stamps and Swaisgood 2007; Le Gouar et al. 2011; Shier and Swaisgood 2012). Temporarily holding relocated animals in acclimation enclosures at the release site may encourage individuals to remain in the vicinity upon release (Bright and Morris 1994; Batson et al. 2015), but this method alone does not always yield success (Shier and Swaisgood 2012). Thus, a major consideration in animal relocation efforts is to find mechanisms to retain or “anchor” animals in suitable habitat at the release site.

Post-release movements may be further reduced by addressing the behavioral cues that conspecifics exchange (Stamps and Swaisgood 2007; Shier and Swaisgood 2012). Conspecific cues influence settlement decisions, in that individuals may avoid settlement into unoccupied suitable habitat because there are no signs that members of the same species have used the area. Even territorial and less social species often prefer to settle near conspecifics (Stamps 1988). Thus, individuals who have been translocated into unoccupied suitable habitat may fail to settle. Using this theoretical framework, conservationists have used bird song playbacks to recruit songbirds to new areas (Ahlering et al. 2010), model decoys to attract terns to new colonies (Kotilar and Burger 1984), and whitewash to attract vultures (Sarrazin et al. 1996). For BUOW, adding conspecific cues such as pellets, whitewash, and acoustic call playbacks to translocation protocols may increase the probability of settlement for actively translocated BUOW. An experimental study conducted by SDZ ICR in 2016-2019 will help address questions regarding the efficacy of conspecific cues. These methods may be utilized more widely once evidence of efficacy has been established. Another potential strategy is to place rescue birds in hacking cages on the settlement site. These birds would not be released, but would serve as a conspecific anchor to encourage settlement by actively translocated birds. For BUOW, which are a semi-colonial species, the presence of conspecific individuals may provide a more powerful attractant to induce settlement by translocated individuals than the use of cues alone. The best opportunities for this approach, which would require daily maintenance on the site, might be through partnerships with wildlife rehabilitation groups, which would offer both a supply of owls and an existing volunteer base for handling the daily maintenance.

Strategy: Release of captive-bred BUOW

To establish a viable population of BUOW in San Diego County, several newly established breeding areas (see section 5.2) will be needed. Given the low number of BUOW residing in the County, conservation breeding may be the only tool available to produce the required numbers of birds in an acceptable time window, especially given the relatively high risk of extirpation in the near future. Waiting for owls to "show up" may cause unacceptable delays in local recovery of the species, as evidenced by the PVA results. Release of captive-bred owls might also be viewed as a "probe" to test whether efforts to identify and manage suitable habitat have been sufficient. Even failed releases may provide rapid feedback that can alter management strategies (e.g., as part of an adaptive management program). Released owls that do not stay in the release site may find their way to other habitat and, ultimately, contribute to the local population.

Translocation success is more likely with greater numbers of individuals released (Drake and Temple 2012; Popescu and Hunter 2012), and this general rule is likely to apply to a greater extent in the semi-colonial BUOW. It is possible that owls will fail to establish at a release site unless there is a minimum threshold number of owls present. Looking ahead in San Diego County over the next several years, there will probably be inadequate numbers of birds (displaced through ongoing development in the County) to translocate for successful establishment of node populations. In other avian species with inadequate numbers of individuals available for reestablishment, conservation breeding methods have been successfully utilized. Previous BUOW conservation breeding programs have shown that the species breeds readily in captivity, producing many young (Leupin and Low 2001). These programs have also shown that released BUOW will settle, but that mortality from predation is high in the first month after release (Leupin and Low 2001). Survival may be increased by releasing young captive-bred chicks into wild nests to be fostered by wild adults (Poulin et al. 2006), but this approach can only be used when the selected habitat is already occupied; additionally, the long-term survival and reproductive success of fostered chicks has been undocumented. Soft-release methods such as adding a holding period of two weeks or more can increase settlement, survival, and reproduction (Mitchell et al. 2011). As noted for active translocations, there is some uncertainty with optimal release group size but the recommendation is to release several pairs, or approximately 10 individuals together.

It may also be desirable to combine conservation breeding and active translocation approaches, with a release composed of owls sourced from captive populations and from development-initiated translocations. The presence of captive-bred owls may make the release site more attractive to translocated owls and vice-versa, and there may be opportunities for social learning and cultural transmission from wild to captive-bred owls, enhancing the development of survival skills among captive-bred owls.

4.0 Data–based evaluation of potential recovery areas

As previously stated, the goal of this Conservation and Management Plan is to address the numerous threats to BUOW and provide an integrated tactical solution to achieve a stable and viable BUOW population in this region. The first step towards successful establishment of new breeding areas, or "nodes," is a science-based evaluation of the suitability of potential recovery areas. Section 4 summarizes the suitability analyses that were conducted at both landscape and local scales.

Suitability was first determined through the development and validation of a landscape-scale habitat suitability model based on remote sensing data, existing soil maps, and other GIS layers. The habitat suitability model is designed to help managers quickly identify areas important for BUOW recovery. This model provides a large-scale evaluation of site suitability for both currently available sites and areas that may not yet be available for conservation, but could potentially provide conservation opportunities in the future. The most promising sites were then subjected to further evaluation through field-based rapid assessments.

A field-based evaluation at any site considered for BUOW management is a necessary next step, due to the difference in spatial scale between the suitability map and individual owl habitat selection and use. The spatial scale of the habitat suitability model is ≥150 m, the distance between individual data points in the grid of environmental input variables. However, the minimum mapping unit of some input layers, such as the polygon-based soils data derived from SSURGO, should not be assumed to be 150 m. The scale of the input layers should be a consideration when using this suitability map. As a result, the suitability of areas of interest must be verified with a field evaluation at the smaller scales at which owls will be using habitat.

The field assessment criteria included vegetation, soil texture, prey availability, predator pressure, current land use, and presence of squirrels (or potential to support squirrels). Management factors considered include ongoing management for conserved lands, including grazing and fire, and security of boundaries. Taken together, these criteria identify the site-specific potential for establishment of a stable, long term breeding colony of BUOW.

Section 5 of this document presents a systematic evaluation of the best-suited sites in San Diego County to assist in the development of a coordinated conservation strategy.

4.1 Landscape-scale habitat suitability modeling

The landscape-scale BUOW habitat suitability model was based on a measure of similarity to habitat conditions at sites with BUOW occurrence records since 1998. A regional approach to habitat suitability was taken in order to accurately report suitability despite the current absence of BUOW in interior grassland sites in San Diego County. For example, the largest remaining interior grasslands in the County historically supported breeding populations of BUOW and would be considered suitable habitat except for the current absence of owls. As a result, the focal area of the model was expanded to capture BUOW occurrence records from interior grassland sites such as those in western Riverside County, in order to indicate the potential suitability of unoccupied areas accurately. A second reason for taking a regional approach is that most San Diego County BUOW occurrence records come from the Otay Mesa area, introducing the potential that the suitability criteria would be weighted towards habitat conditions on Otay Mesa. Unfortunately, Otay is unlike most suitable habitat locations in the County due to unique clay soils and proximity to the coast. Consideration of coastal sites for BUOW habitat is an issue since almost all of these areas are already heavily developed, and are unavailable for future BUOW management actions. Unfortunately, the current presence of BUOW on Otay Mesa is probably due more to chance than to the suitability levels of the habitat. Therefore, it was also necessary to subsample clusters of BUOW occurrences in order to evenly leverage the habitat information from a wide range of sites and produce a model with good generalizability to San Diego County. See Hennessy et al. (2015) for a complete description of the methodology.

The input data for habitat conditions are based on abiotic and biotic factors, as well as land use conditions in occupied sites across southern California, excluding desert areas. The abiotic variables include minimum temperature in April, maximum temperature in August, annual precipitation, elevation, slope, percent clay to a depth of 150 cm, and percent sand to 150 cm. The land use factors are percent cover of urban development and agriculture within 1 km of occupied sites, while the biotic factors include percent cover within 1 km of occupied sites of vegetation communities such as coastal sage scrub, chaparral, grassland, and riparian.

In general, occupied sites have warmer minimum spring temperatures, lower precipitation (winter, spring, and annual), lower elevation, and lower slope values. In terms of land use variables, occupied sites had higher median values for urban development and agriculture at 1 km. Occupied sites also had higher median values for coastal sage scrub and grassland cover. The final model is presented as a spatially-explicit map in Figure 5.

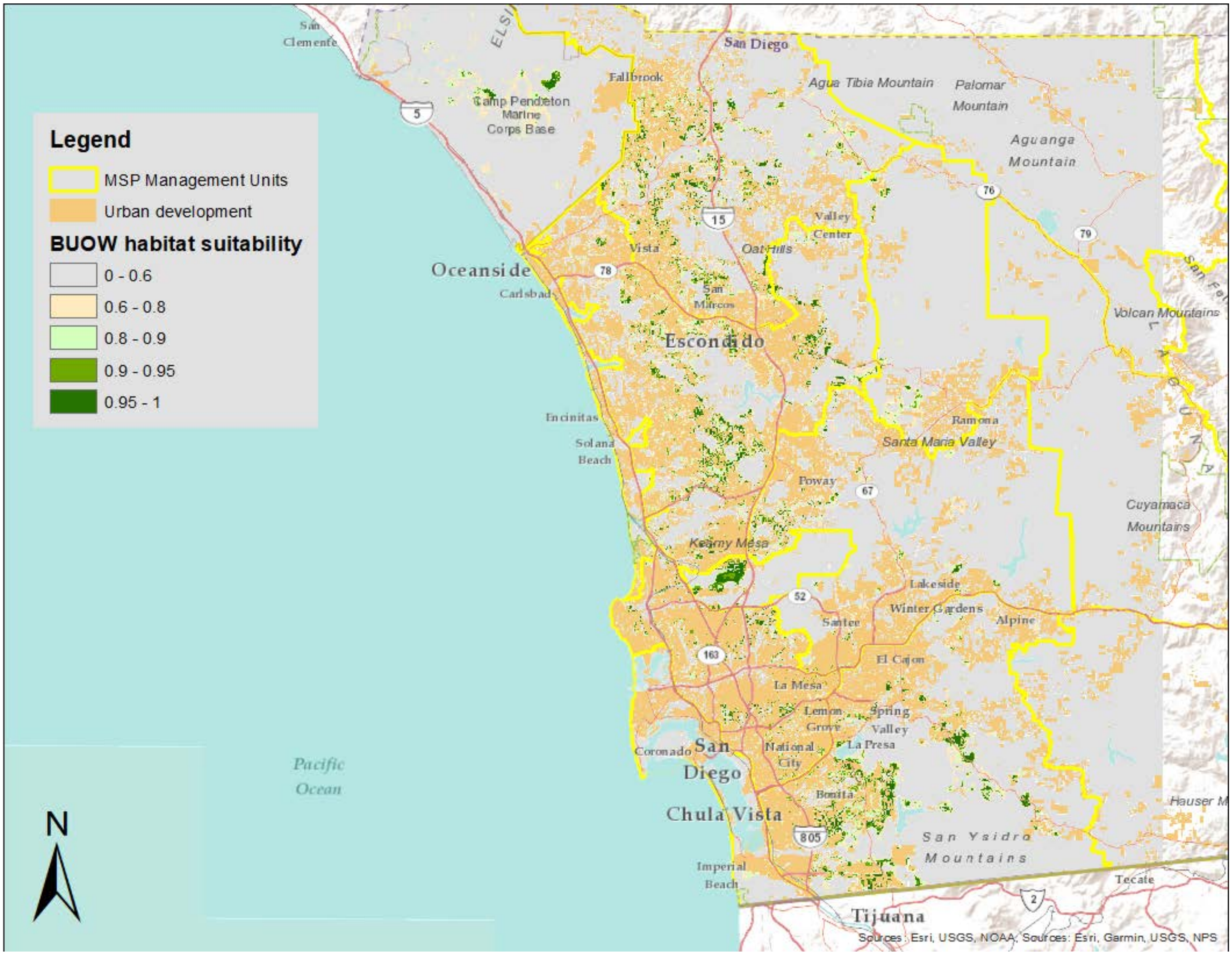

Figure 5. Habitat suitability model for BUOW in portions of San Diego County. A habitat suitability index value has been calculated for every point in the gridded extent (150 m) based on the eigenvector of the component selected from principal components analysis. On this scale, one represents habitat that perfectly matches the environmental characteristics of known occupied habitat, and zero represents poor habitat.

4.2 Rapid assessments

A rapid assessment approach was utilized to assess areas of interest at a finer spatial scale. Rapid assessments are designed to rapidly collect accurate information on several metrics of interest. As such, there is an inherent tradeoff between the number of metrics included and the intensity of data collection. The strength of the rapid assessment approach is in the ability to efficiently answer a variety of questions about a site. The data provide a snapshot of current conditions, and enable qualitative comparisons of the relative levels of multiple habitat metrics across sets of sites. Conversely, the intensity of data collection in the rapid assessments may not be sufficient for statistical analysis. In addition, measures of abundance from rapid assessments should not be interpreted as absolute measures, as would be captured by longer term or higher intensity sampling. For the purpose of quickly filling in gaps in knowledge, however, rapid assessments are useful.

This rapid assessment included metrics representing prey availability (small mammal, including rodents and squirrels), predator pressure (raptor and coyote), vegetation and soil suitability. Sampling was randomized in order to support inference. Implementation of the rapid assessment involves an initial GIS analysis to generate randomized sampling points, as described below, and data collection, which occurs in three or four site visits over a 10-day period.

The rapid assessments were focused on lands expected to be managed for conservation values in perpetuity. During 2016-2017, the sites assessed were Lonestar Ridge West, Johnson Canyon, Rancho Jamul Ecological Reserve (RJER), Hollenbeck Canyon, La Zanja Canyon O/S, Ramona Grasslands Preserve, Ramona Mitigation Bank, Barnett Ranch Preserve, Pamo Valley, and Sweetwater Authority lands (Figure 6). The assessments were conducted from late May to late September, roughly across the mid- to late-breeding season for BUOW. This methodology is available for future implementation on new sites of interest, or could be used to provide an updated report on the condition of sites that have been previously assessed.

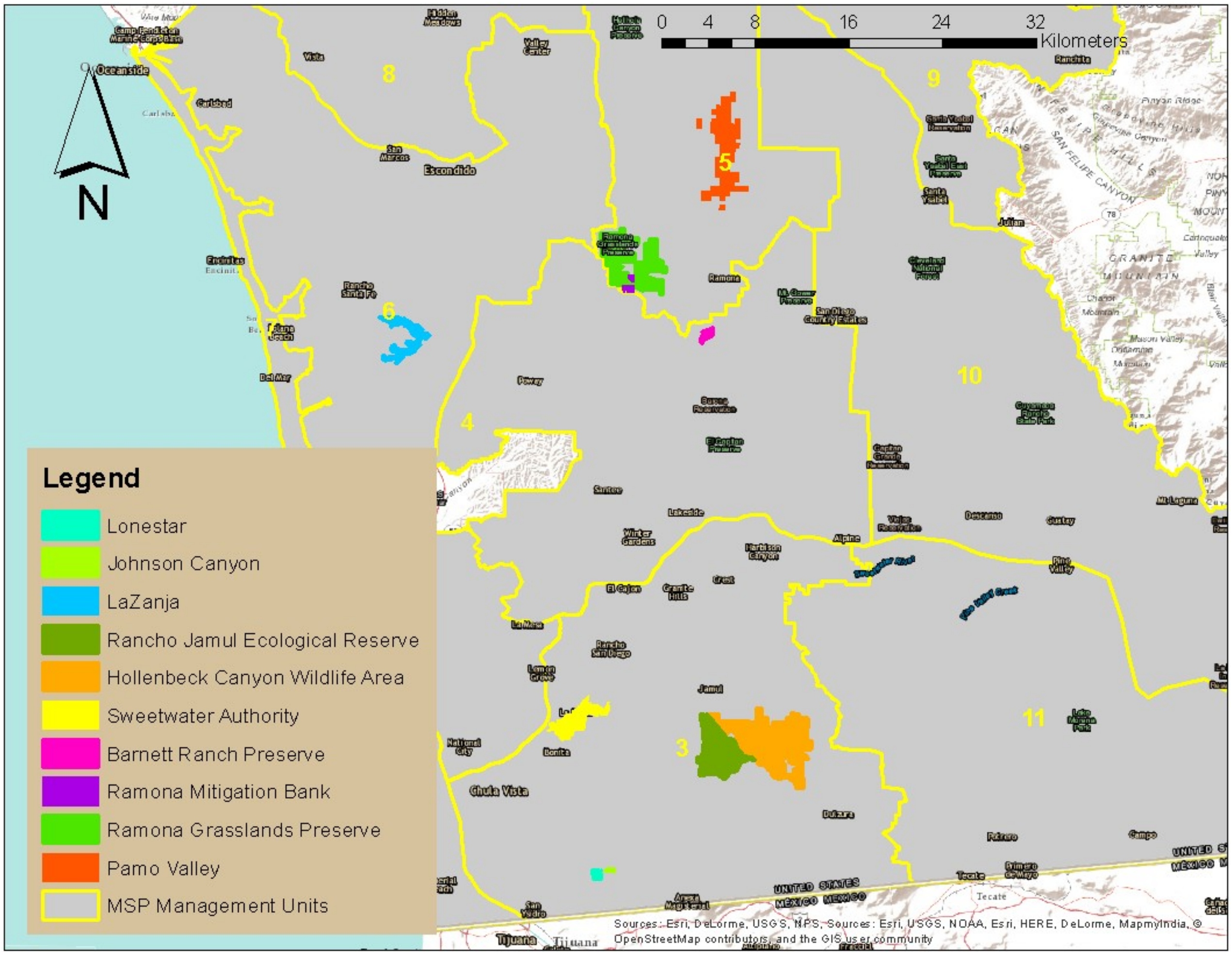

Figure 6. Sites evaluated with rapid assessment methodology in 2016.

Methods

All sampling points were randomly generated in ArcGIS 10.3 to maintain statistical independence and to support inference. For each site, the areas to be assessed were delineated in GIS according to 1) presence of grassland vegetation community and 2) slopes less than 10˚. All sampling except the coyote transects occurred at these points (i.e., small mammal, California ground squirrel, raptor/corvid surveys, soils, vegetation). Therefore, sampling was focused on the most suitable grassland areas of each site, rather than all lands within preserve boundaries. A consistent level of survey effort was maintained across sites of varying sizes by holding the sample point density constant at 1 point/12 hectares.

Prey availability

Prey availability sampling focused on small mammals rather than invertebrate prey, and was collected with camera traps and belt transects. Field data collected in 2013-2015 indicate that local prey/productivity relationships rely on small mammal prey to support higher productivity (Hennessy et al. 2015). Gophers are an important prey item in southern California, and BUOW also opportunistically prey on a variety of mice and kangaroo rat species. Conversely, the data from 2014-2015 indicated a significant negative relationship between productivity (i.e., maximum number of chicks and number fledged) and the proportion of invertebrates delivered to the breeding burrow. Both findings are consistent with an approach to prey availability sampling that focuses on small mammal species. A relative abundance measure of California ground squirrel was also included due to the obligate relationship between owls and squirrels in this region.

Mouse/kangaroo rat sampling: Camera stations were established at the randomly sampled independent points. Bushnell Trophy Cams were mounted on a wooden stake about 20 cm above the ground, and sterilized millet seed was left at a bait station 2 m in front of the camera. The cameras were set on the low sensitivity trigger setting, and collected 15 sec of video at 30-sec intervals. Cameras sampled a minimum of 10 nights. The resulting video data were processed using Adobe Bridge, and occupancy estimates were calculated in the software program Presence using a simple single-season model. Occupancy estimates represent a measure of the proportion of sampling points occupied by a species. In this context, the occupancy values can be interpreted as a relative index of abundance between sites. Concerns that baited stations may skew abundance measures upwards by attracting individuals from greater distances apply when the objective is to estimate population levels. However, baited stations may be used for relative measures of abundance, as long as the stations are implemented consistently across sites.

Gopher sampling: At each camera station, three 25-m transects were set out along three of the four cardinal directions, making sure to avoid large obstructions. A line-intercept method was used to measure areas of bare or disturbed ground resulting from gopher activity, with additional notation for recent digging activity. Ground cover was measured to the nearest 5 cm (precision). Individual segments of bare ground began when the transect first intercepted bare ground, and were ended when the transect intercepted vegetation, so that measurements were limited to bare ground. The segment lengths were totaled and used to calculate a percentage of the overall transect length (75 m) that intercepted gopher-disturbed areas. The percentage of gopher-disturbed ground was averaged by site to produce mean and standard error estimates which indicate relative abundance of gophers by site.

California ground squirrel presence: Along each of the aforementioned 25-m transects, a 4-m-wide (2 m on either side of the centerline) buffer was established to determine the abundance of California ground squirrel burrows present at each sampling location. Squirrel burrows falling within the belt were tallied with a simple count to indicate presence and relative abundance of California ground squirrels.

Predator pressure

The rapid assessments of predator pressure included both aerial predators (raptor and corvids) and ground predators (coyotes). Camera traps at nest burrows in San Diego have recorded predation events, and the data show that these are the most significant predators of BUOW in this region. Great horned owls and barn owls are also known predators that should be included in the assessment if feasible.

Raptor and corvid surveys: For these surveys, corvids were defined as crows and ravens. Raptors were defined as any raptor species that could reasonably be expected to prey on BUOW, including hawks, falcons, and eagles. Turkey vultures and BUOW were excluded from the raptor counts. Surveys were conducted on two separate occasions at each camera station. The surveys were 10 min in duration and timed to fall between the morning hour when raptors began catching thermals (roughly three hours after sunrise) and noon, when activity declined due to heat. The 10 minute interval was long enough to detect the raptors in the viewshed, and short enough to limit accidental double counting as individuals moved around. Weather and the number of each species observed, including unknowns, was noted. The data were summarized by first selecting the survey date at each camera with the greater sum of raptors and corvids observed, and then averaging across all camera stations onsite to produce relative abundance site estimates.

Coyote transects: Roads and trails were walked or driven at 2-3 mph. We recorded the number of coyote scats and examined the contents of each. Fresh scat was noted (based on moisture level) and scats were classified by content (fur and bone/seeds and vegetation). The ends of transects were recorded with GPS to enable calculation of scat density per kilometer. Scats within 0.3 m of one another were counted as the same scat, unless there was a difference in age or composition. These counts provided a relative index of coyote activity levels, which would be expected to be more tightly associated with predation levels than estimates of coyote population size.

Vegetation and soils

Vegetation sampling was conducted to assess the current composition and structure of the plant communities within the delineated grassland areas of suitability described above. Grassland structure varies significantly throughout the growing season with respect to vegetative height and percent cover. Since sampling occurred late in the growing season (as grasses were senescing), ocular estimates of percent cover and height within $10m^2$ plots were taken to provide a snapshot of the vegetative condition at each sampling station. The sampling included estimated percent cover of bare ground and all dominant grass species, with a specific focus on recording the presence of wild oats (*Avena barbata*, *A. fatua*), ripgut (*Bromus diandrus*) and foxtails (*Bromus madritensis*). In San Diego County, these particular species impact BUOW more than any other non-native grassland species. The two species of wild oats grow to more than a meter tall, while both brome species grow very densely and create thick layers of thatch.

Soil sampling was conducted to assess suitability of soils for squirrel burrowing activity at each sampling station, one sample per station. Samples of approximately 100 g from the top 8 cm of soil was collected and assessed for soil texture and gravel content. Soil texture is reported as percent clay, percent sand, and percent gravel. Previous SDZ ICR studies have shown that the likelihood of squirrel presence increases with increasing percent sand (Wisinski et al. 2013).

Spider plots

The results of the rapid assessments are reported numerically in Table 2, and graphically by site in spider plots. Spider plots were utilized because they graphically display all metrics included in the rapid assessments (prey availability, predator pressure, and vegetation and soils) in one plot, with one metric per axis. The site habitat suitability value from the landscape-scale habitat suitability model is also included in the plot. Spider plots provide a user-friendly snapshot of site condition, and enable visual comparison of relative site suitability with consistent axes across all plots. The axis labels and scales utilized across all sites are presented in a model spider plot (Figure 7).

Each axis is defined by the units and scale used for one specific metric. Higher values, which represent high habitat suitability, are at the ends of each axis. Lower values are anchored at the base of each axis, the center of the “spiderweb.” Note that the scale is a qualitative high to low scale, since detailed data on suitability thresholds for each metric are not available. The plots present each site value independently (no baseline defined). Once the results of each method are plotted, a connecting line is drawn, and the site value of each axis becomes a vertex of the resulting polygon. In the resulting polygon, a large polygon size indicates generally high suitability, and a small polygon size indicates generally low suitability.

These plots are useful in the planning stage of restoration projects, as they focus attention on suitable versus unsuitable aspects of each site. Suitable characteristics of the site require no further manipulation, other than to avoid degradation. Unsuitable characteristics of the site will require further restoration and management actions. Some characteristics (e.g., soils and vegetation) may be more costly and difficult to manipulate than others. Plotting the rapid assessment results by site enables a side-by-side comparison that quickly reveals the restoration needs of each site and allows conclusions about which sites may be more easily utilized.

Spider plots are not designed to support a numerical ranking. A numerical ranking would require combining the different metrics above, with an infinite number of potential ways to combine the metrics. The weakness of the ranking approach is in its somewhat arbitrary nature. Therefore, the spider plot approach is utilized here because it is informative, relevant, and defensible.

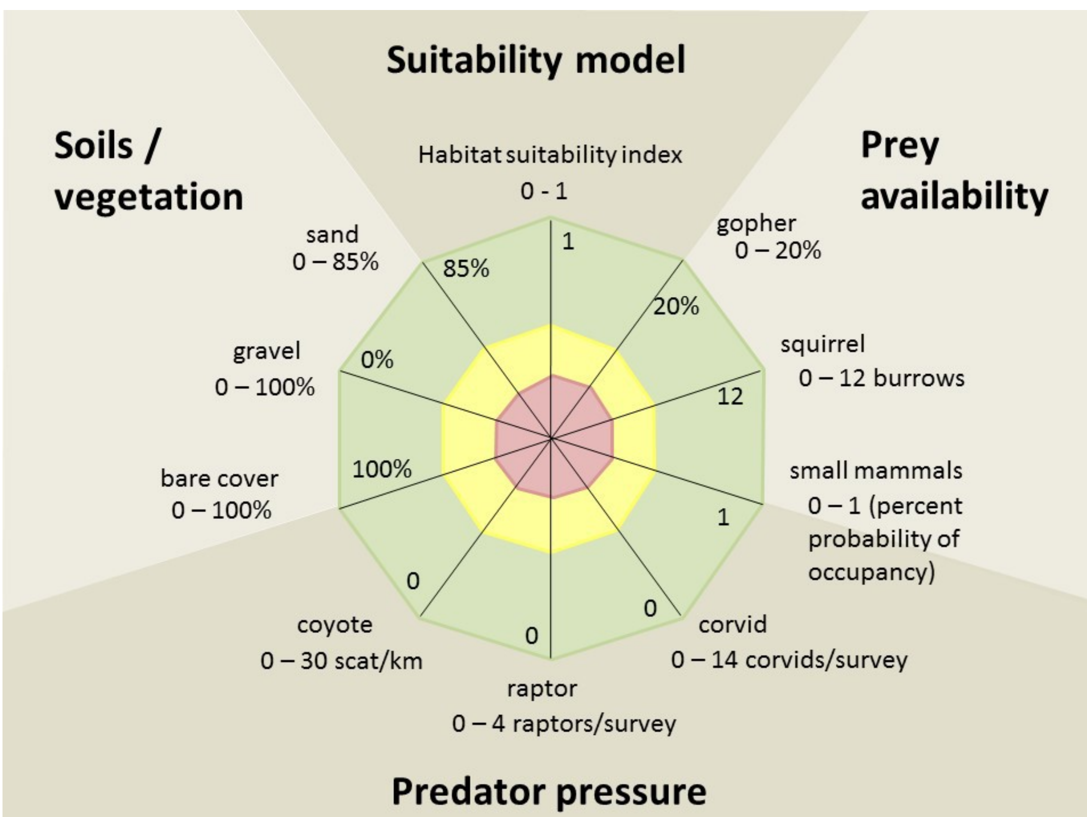

Figure 7. Format of the spider plots utilized for interpretation of the rapid assessments.

Table 2. Summary of rapid assessment results for prey availability, predator pressure, and habitat suitability index by site.

Site		Mouse/ k-rat	Gopher		Squirrels		Ground predators	Corvids		Raptors					HSI	
		Occupancy-based index of relative abundance	*% disturbance along 75 m transect*		*burrow count, 75 m transect*		*density of coyote scat/km*	*Counts averaged by sample points*		*Counts averaged by sample points*		*Avg. Counts BUOW*	*Avg. Counts Red-tailed Hawk*	*Avg. Counts Cooper's Hawk*	*Habitat suitability index[2]*	
	Range	*0-1*	*0-20%*		*0-12*		*0-30*	*0-14*		*0-4*					*0-1*	
MU 3	samples		*Mean*	*SE*	*Mean*	*SE*		*Mean*	*SE*	*Mean*	*SE*	*Mean*	*Mean*	*Mean*	*Mean*	*SD*
Lonestar	5	0[3]	0.4%	0.3	0.8	0.6	1	13.2	7.5	2.0	0.8	5.4	1.4	0	0.829	0.184
Johnson Canyon	2	0[3]	0.0%	0	0	0	28.3	5.0	3.0	2.5	1.5	0	0.5	0	0.715	0.132
RJER	14	0.319	10.6%	2.4	see text		19.8	3.4	0.6	3.6	0.4	0	2.8	0	0.700	0.137
Sweetwater Water Authority	9	0[3]	0	0	0	0	24.9	1.5	0.6	0.5	0.3	0	0.2	0	0.497	0.351
Hollenbeck	5	0.800	19.0%	6.6	0		25.6	2.8	1.2	3.4	0.4	0	3.4	0	0.835	0.231
MU 4																
Barnett Ranch	7	0.519	5.1%	1.0	11.6	4.4	7.25	11.5	5.3	1.6	0.4	0	1.1	0	0.581	0.276
MU 5																
Ramona Grasslands Preserve	12	0.585	5.6%	2.8	9.6	3.0	13.3	4.6	1.3	2.3	0.5	0	1.4	0	0.544	0.255
Ramona Mitigation Bank	5	NA[3]	3.0%	1.5	2.2	2.0	4.7	5.5	3.5	4.0	0	0	3.5	0	0.727	0.111
Pamo	10	0.533	7.9%	2.5	7.2	3.2	11.2	1.6	0.5	0.8	0.4	0	0.6	0	0.107	0.145
MU 6																
LaZanja O/S	10	0.546	0.8%	0.5	0	0	17.8	3.0	1.2	1.4	0.3	0	1.1	0.1	0.836	0.151

[2] From landscape-scale suitability modeling reported in Section 4.1.

[3] 0 is reported when zero animals were detected by the camera traps. NA denotes camera failure.

5.0 BUOW conservation strategy for San Diego County

The first priority for the next five years (2018-2023) is to manage the existing population on Otay Mesa. This will include prioritization for artificial burrow maintenance or closure, vegetation management, burrow maintenance, population monitoring, and tracking of known threats. Without management, this node would be at risk of loss as development proceeds. The current state of information about this important breeding area is summarized below.

5.1 Otay Mesa

Otay Mesa is the site of the only remaining breeding population of BUOW in San Diego County. We recommend that Otay Mesa be treated as one node, consisting of one metapopulation, as described below.

The BUOW population is concentrated in several areas on Otay Mesa, including Brown Field and Lonestar Ridge West. At Brown Field, the current status of population information is fairly complete for the airfield but lacking for surrounding private lands. This subpopulation appears to be doing well, but will undergo change once a major redevelopment project moves forward. A second area lies to the east, roughly including San Diego Habitat Conservancy land and adjacent mitigation lands such as Johnson Canyon. This area currently receives low BUOW use, and the owls present show medium productivity. A third area includes the highly managed Lonestar Ridge West restoration site, which lies between Brown Field and the SDHC/mitigation lands to the east. Complete population monitoring information is available for this site. The 2017 BUOW population at Lonestar had the highest productivity measured since restoration began in 2011. Owls move regularly between Brown Field and Lonestar Ridge West.

Rapid assessment of Lonestar and Johnson Canyon

The sites on Otay Mesa were included in the rapid assessments to measure the suitability levels of currently occupied habitat (Figure 8). However, it is important to note that both are mitigation sites with artificial burrows, man-made mima mounds, and restored plant communities. For example, the Lonestar restoration included the creation of soil berms. The natural soils consist of heavy clay that rates low on the suitability index, so the berms provide critical habitat. Both predator pressure and prey availability also were measured at low suitability levels (Table 2). However, resident owl and squirrel populations are found on adjacent Brown Field, and the site became productive once the vegetation community was established enough to support small mammals. As a result of these site-specific factors, spider plots are not presented for these two sites in order to discourage “apples to oranges” comparisons.

The restoration effort at Lonestar has just completed the fifth year of management, including ongoing weed removal and irrigation. The site is currently dominated by clustered tarweed (*Deinandra fasciculata*) along with a diverse assemblage of native grasses, forbs, and subshrubs. The surveys detected very low levels of non-native annual grasses, but the species detected included wild oats and foxtails. Current bare ground values are variable (25-45%).

In Johnson Canyon, there exists a west to east gradient of increasing cholla (*Cylindropuntia* sp.). We sampled the vegetation community on the west side, where cholla and shrubs are sparse. Clustered tarweed dominates the vegetation community, with small components of perennial ryegrass (*Festuca perenne*), needlegrass (*Stipa* sp.), and wild oats. The range in bare ground cover is greater on the Johnson Canyon parcel than the Lonestar parcel, from 25% to 60% in more open areas (Table 3).

Table 3. Percent vegetation cover values sampled in October 2016 at Lonestar and Johnson Canyon (n=7). The sites are combined because the values for each were similar.

	Common	Percent vegetation cover (%)		
Species	**Name**	**Mean**	**SD**	**Min - Max**
Bare Ground		35.7	13.4	25-60
Non-native grasses		0.4	0.5	0-1
Bromus madritensis	Foxtails	0.3	0.5	0-1
B. diandrus	Ripgut	0	0	0-0
Avena sp.	Wild oat	0.2	0.5	0-1
Distichlis spicata	Saltgrass	0	0	0-0
Erodium sp.	Storksbill	0	0	0-0

Of all the rapid assessment sites, Otay Mesa showed the highest levels of clay and lowest levels of sand. The heavy clay soils are difficult for squirrels and other small mammals to burrow into. As expected, low levels of squirrel, gopher, and other small mammal activity were consistent with the low suitability of the soils (i.e., high clay/low sand content). In terms of predator pressure, the scat density transects showed very low coyote use of the Lonestar parcel, but very high use of the Johnson Canyon parcel. In addition, the highest recorded levels of corvid presence occurred on the Lonestar parcel, along with moderate abundance levels of raptors (in addition to BUOW).

Management considerations:

Continued planning to ensure contiguous habitat is maintained for burrowing owl is important for continued persistence of the Otay Mesa node. Although it represents the most established existing management area, Lonestar Ridge West should not be considered the only management area in the Otay Mesa node. As indicated by the PVA, this node is already at risk of local extinction and efforts to support the growth of the metapopulation will help guard against this.

Soils at the Otay Mesa sites are not suitable for California ground squirrels and translocated squirrels failed to establish at this location. Compacted soils high in clay content likely prevented the squirrels from digging burrows. Thus, intervention is necessary to create suitable areas for burrowing, by disturbing and elevating the soils in a “berm.” This softens the soil enough to allow digging, and elevates the burrows to guard against flooding. Berms also provide an elevated location from which the owls can spot prey and predators. However, without proper soil compaction, burrows in recently created berms may be subject to collapse.

California ground squirrels have colonized some areas within the Lonestar site, especially where berms have been created. Squirrels are also currently found nearby in marginal areas next to buildings and along roads. Areas near development may not be safe for nesting BUOW, and actions should be implemented to attract owls and squirrels to areas afforded more protection, away from roads and buildings. The creation of additional berms across Otay Mesa BUOW sites is recommended. Long-term plans should also include efforts to replace or restore berms as they erode. At sites with low sand content, a management strategy may include the addition of sand to create more suitable soils at localized sites (i.e., sand added to berms) where management goals include establishing more California ground squirrels. In addition, the vegetation surrounding burrows should be monitored and managed to ensure it remains suitable for California ground squirrels and BUOW. Finding additional mechanisms for funding ongoing vegetation management at BUOW sites is critical for maintaining suitability at BUOW sites.

The artificial burrows at both Lonestar and Johnson Canyon should be maintained annually to ensure they remain available to nesting owls. Lonestar is the site of 50 artificial burrows and Johnson Canyon contains 21 artificial burrows. In recent years, 8-13 breeding pairs have occupied Lonestar annually, and 1-3 pairs have occupied Johnson Canyon, although no BUOW were detected there in 2017. Since the habitat at Johnson Canyon is primarily intended for cactus wren use, and is becoming less suitable for BUOW as the cholla continues to grow, this site should not be depended on in the future. At Lonestar, BUOW reliance on artificial burrows should be reduced over time as more natural burrows are created by colonizing California ground squirrels. Annual surveys to document trends in natural burrow numbers are a simple and cost-effective way of determining whether and where management actions are required to increase squirrel presence.

At these BUOW sites, management actions should target creation of natural burrows in proportion to estimated resource carrying capacity for breeding pairs. However, it is not known whether the rate of burrow occupation by BUOW is reaching carrying capacity for the surrounding habitat; this determination requires better information on the ability of foraging habitat to support BUOW. Nesting pairs utilize multiple burrows around the natal burrow. The parents move the chicks between several burrows, and fledglings disperse to burrows in the vicinity of the natal burrow before they initiate end-of-season dispersal/migration (Davies and Restani 2006). Since the target for artificial burrow installation is 2-3 burrows per translocated pair, a similar target of 3 natural burrows per pair could be utilized.

Monitoring of burrow use and nesting outcomes on Otay Mesa has shown a positive correlation between prey delivery rates and number of fledglings, suggesting that prey availability may currently limit offspring survival at Lonestar. However, this effect should decrease with time as the restored vegetation community becomes more established and supports a greater prey base, as seen in 2016 and 2017, when BUOW productivity was at the highest levels observed since restoration began. The wide range of prey delivery rates and associated chick survival in this multi-year dataset indicates that the ability of surrounding habitat to provide sufficient prey is an important variable in determining whether a particular location may be a population source or a sink.

It will be critical to continue long term monitoring of population trends on Otay Mesa as development of Brown Field and other parcels proceeds. There will be a significant amount of disturbance both as some existing burrows are lost and as new habitat is created through mitigation. As seen at Lonestar Ridge West, it may take four years before mitigation sites have a mature plant community sufficient to support BUOW productivity. Although carrying capacity at Lonestar is uncertain, most of the burrows are currently utilized, suggesting that displaced owls and fledging owls will need to disperse and find burrows in nearby habitat. At Lonestar, further increases in tarweed growth will trigger a need for further vegetation management, to keep vegetation structure and cover low enough for BUOW and squirrel needs. The need for some level of ongoing vegetation management after the initial restoration period will be the case across most if not all restoration sites. Therefore, the future of the Otay population is currently in flux, and continued management and monitoring is a critical priority.

Benefits:

- Breeding population already established
- Significant investments in habitat restoration established and ongoing

Challenges:

- ***A: Artificial burrows present:*** heavy current reliance on artificial burrows
- ***B: Burrows absent:*** limited squirrel population located primarily in marginal and anthropogenically impacted lands
- ***D: Dense non-native ground cover***
- ***F: Fragmentation:*** high degree of ongoing development and associated threats
- ***S: Soil suitability for burrowing****:* soils compacted with high clay content, subject to flooding

Summary of recommended management actions:

- Active management of the existing BUOW population:
  - Long-term monitoring of population trends and nest productivity, to determine whether the node remains a population sink or becomes self-sustaining and whether artificial burrows in some locations are ecological traps and should be closed ***(A)***
  - Implement long-term plan for routine maintenance of existing artificial burrows. Prioritized evaluation of artificial burrows condition and status, and closure if needed. Gradual phase-out of reliance on artificial burrows ***(A)***
  - Annual burrow surveys to document trends in numbers of natural burrows ***(B)***
  - Continued management of restored grasslands and forblands to ensure that criteria for open ground and vegetation structure are maintained ***(D)***
  - Creation of a tracking system for anthropogenic threats to existing population (e.g., roadkill events, predation by subsidized predators such as corvids) ***(F)***
- Plan for management of contiguous parcels of open space, including identification of nearby areas with potential suitable habitat and initiation of vegetation management as needed ***(F)***
- Creation of additional berms to create suitable locations for natural squirrel burrows ***(B,S)***

- Habitat management for prey species within 1 km of BUOW nesting areas should also be implemented once the prey-habitat relationship is better understood ***(F)***

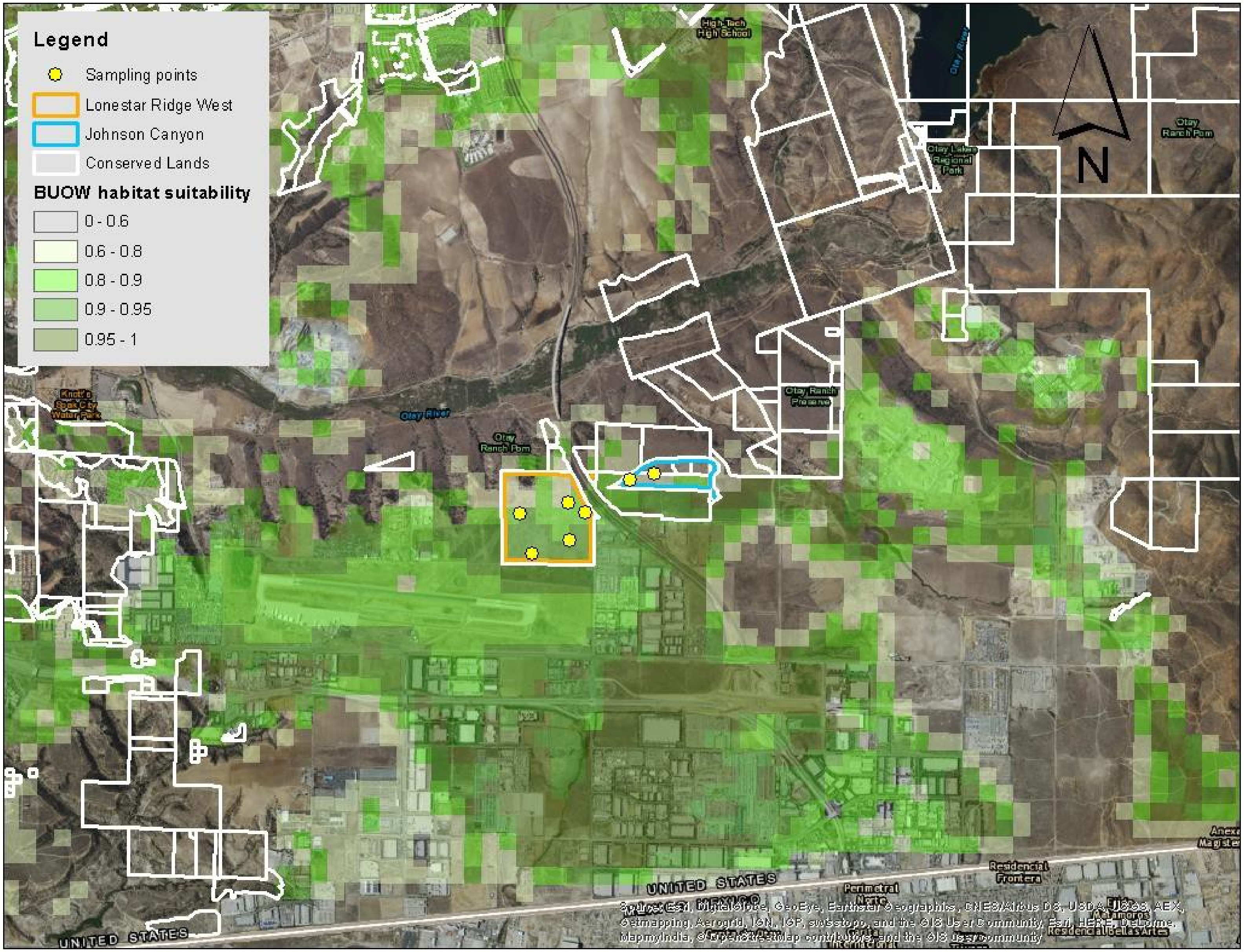

Figure 8. Habitat suitability map for BUOW in Otay Mesa. Lonestar and Johnson Canyon were assessed as BUOW-occupied mitigation sites near Brown Field.

5.2 Potential BUOW recovery node locations

Although Otay Mesa supports the largest known BUOW population in San Diego County, it will also be important to establish nodes in other parts of the County where secure, high quality habitat exists. Long-term population persistence will depend on the establishment of more than a single node.

The following sections describe the most promising locations for establishment of additional BUOW nodes in San Diego County. These were identified through the habitat suitability model and rapid assessments described in Section 4 and are herein considered to be suitable for BUOW recovery in advance of a collaborative decision-making process that will take into account jurisdictional and other management considerations.

5.2.1 Rancho Jamul Ecological Reserve

Rancho Jamul Ecological Reserve (RJER) consists of former agricultural fields and pasture on sandy loam soils, with plant communities of non-native grasslands (dominated by wild oats and ripgut), riparian habitat, and coastal sage scrub on upland slopes. The 5,600-acre Reserve is managed by California Department of Fish and Wildlife to preserve habitat and support native wildlife, especially raptors. However, there is no historical record of a breeding BUOW colony on the site, although overwintering individuals are periodically detected. Rescued and rehabilitated birds are also periodically released on the Reserve. The Reserve has established a Burrowing Owl Habitat Management Area (BOHMA) with 25 maintained artificial burrows. Management efforts to improve the landscape in order to retain owls after release are ongoing.

Rapid assessment

The soils in the BOHMA consist of sandy loams, and the plant community is dominated by non-native grasses and forbs (Table 4). Elsewhere on the Reserve, wild oats are abundant.

Table 4. Percent vegetation cover values sampled in October 2016 at RJER (n=14).

Species	Common name	Percent vegetation cover (%) Mean	SD	Min - Max
Bare		32.1	18.5	5-60
Non-native grasses		55.3	27.0	15-93
Bromus madritensis	Foxtails	0.0	0.0	0-0
B.diandrus	Ripgut	3.2	8.7	0-30
Avena sp.	Wild oat	52.0	31.7	0-93
Distichlis spicata	Saltgrass	0.0	0.0	0-0
Erodium sp.	Storksbill	11.1	12.8	0-44

During October 2016, approximately 145-150 well-developed natural squirrel burrows were observed in the BOHMA as a part of a natural squirrel dispersal study. The measure of small mammal occupancy, which primarily reflects mouse and kangaroo rat activity, indicated a lower relative abundance of small mammals at RJER than for all other sites where these species were detected (Table 2). The gopher transects indicated moderately high levels of digging activity at RJER. Gophers are a known favorite prey item for BUOW in San Diego County, and these data provide supporting evidence for an adequate small mammal prey base at RJER. In terms of predation pressure, the data indicate that RJER has similar pressure from aerial predators as the parcels in the Ramona area, and may experience higher predator pressure from coyotes.

Management considerations

The BOHMA has 25 artificial burrows: 15 newly installed burrows and 10 existing burrows. All burrows received maintenance and were deemed accessible during summer 2016, and a routine maintenance schedule is being implemented. The number of squirrel burrows on the BOHMA is increasing as the result of a natural dispersal experiment. RJER also contains five experimental plots where squirrel translocations were conducted 2011-2014 (Hennessy et al. 2015). The data from the translocation experiment include squirrel survival and movement data as well as information on the efficacy of squirrel translocations. Established, squirrel-occupied burrow complexes persist from the experiment on three plots (as of 2016), providing a source of natural burrows for owls. Resident squirrels also live around the ranch house and on some hillsides of coastal sage scrub surrounding the floodplain and former pasture areas.

The Reserve supports a large population of resident raptors, and predator pressure could be one explanation for the absence of BUOW (Figure 9). With growing documentation of the importance of prey availability in BUOW breeding territories, prey limitation during decades of intense agricultural management may also explain this historical record. Recent habitat management changes may positively influence prey abundance and the ability of BUOW to detect and capture prey.

The current existing management strategies on the Reserve include prescribed burning and cattle grazing, both of which should benefit existing squirrel populations and future owl populations. Efforts to determine timing of cattle rotation have been made to improve the degree of control of vegetation structure. The conditions for squirrel population growth exist in some locations, as indicated by high 2015 retrapping numbers at the southernmost translocation plot (Hennessy et al. 2015).

The Reserve may be an appropriate site for seeding with a mix of native forbs and grasses and limited shrub plantings. While recognizing that native plantings are not always the most effective strategy, current grazing management at the Reserve may provide an opportunity for replanting. It should be recognized that this management action does not have the goal of replacing a novel ecosystem dominated by Mediterranean grasses with a native one, but rather to create a hybrid ecosystem containing a higher proportion of native plants for the wildlife that depends on them (Hobbs et al. 2009).

As a secure, long-term conservation site, the Reserve is suitable for both owl translocation (active translocation) and releases of conservation-bred owls. A hybrid approach to owl establishment that combines both methods may have the highest efficacy. Once the management strategies to colonize the Reserve with BUOW have occurred, monitoring to document owl survival and nest productivity will allow managers to evaluate any remaining concerns about prey availability. If BUOW population replacement rates are not being met, further study to evaluate prey base would improve our understanding of prey-habitat relations and further guide habitat management.

Benefits:

- Large contiguous areas of grassland present
- Existing conserved status
- Established BUOW habitat management area (BOHMA) with 25 maintained artificial burrows
- Grazing management of vegetation structure
- Squirrel population and natural burrows present

Challenges:

- ***A: Artificial burrows present***
- ***B: Burrows absent:*** localized squirrel population
- ***D: Dense non-native ground cover***
- ***O: Owls absent:*** overwintering owls only
- ***P: Predators:*** high levels of coyote and raptor activity and likely predation on both squirrels and BUOW. Also, high incidence of trees, snags, and other perches raptors can use to aid in prey capture

Summary of recommended management actions:

- Conduct routine maintenance of existing artificial burrows, and implement long-term maintenance plan ***(A, O)***
- Continued annual management of non-native grasslands using large-scale management methods (e.g., grazing and prescribed fire) to ensure that criteria for open ground and vegetation structure are maintained ***(D, O)***
- If needed, spot mowing at suitable BUOW breeding sites prior to the breeding season ***(D, O)***
- Identification of areas near the Burrowing Owl Habitat Management Area (BOHMA) with potential suitable habitat for nesting or foraging and initiation of vegetation management as needed ***(D)***
- Efforts to increase range and density of squirrel populations through habitat modification, translocation, or both ***(B)***
- Continued short-term experimentation to attract owls to artificial burrows during breeding and nonbreeding season, and monitoring outcomes to ensure ecological traps are not created ***(O)***
- Develop strategic (small to medium size) native plant restoration projects in order to build native plant community by supplementing native plant cover and in-situ native seedbank ***(D)***
- Habitat management for prey species within 1 km of BUOW nesting areas should also be implemented once the prey-habitat relationship is better understood ***(O)***

5.2.2 Hollenbeck Canyon Wildlife Area

As seen on the suitability map in Figure 10, Hollenbeck Canyon Wildlife Area (Hollenbeck) is located adjacent to RJER, although the two conserved areas are separated by Highway 94. The absence of squirrels from Hollenbeck limits the potential for BUOW nesting at this site, but high connectivity with RJER suggests that management could be implemented to increase the overall foraging area available to breeding or overwintering BUOW on RJER. Hollenbeck includes approximately 6,100 acres, but the habitat suitability map indicates that the areas with highest potential BUOW suitability are the grasslands directly across Highway 94 from RJER. Accordingly, the rapid assessments focused on these grasslands.

Rapid assessment

The vegetation community is dominated by non-native grasses, including a significant component of *Avena* sp. greater than 1 m tall (Table 5). The brome species grow to approximately 75 cm in this area. Vegetation structure is both tall and dense. The topography is undulating, with rocky bald areas on upper slopes and dense non-native grasses on lower slopes. This range in vegetation density can be seen in the range of bare ground cover, with bare ground above 25% recorded on upper slopes, and values below 25% recorded on lower slopes.

The small-mammal occupancy estimate at Hollenbeck was the highest measured for any site (Table 2). Gopher disturbance likewise was the highest observed, at an average of 19% disturbance along the transect, indicating a relatively abundant prey base. No squirrel burrows or other sign of squirrel activity was recorded, however.

In terms of predator pressure, the numbers of corvids and raptors recorded were similar to those recorded at RJER, as expected. Corvid pressure is moderately low and raptor pressure is moderately high relative to the other sites. Coyote pressure, however, was recorded at levels relatively higher than any other site, except Johnson Canyon. This may be a reflection of the abundant small mammal population and lower levels of disturbance at Hollenbeck.

Table 5. Percent vegetation cover values sampled in October 2016 at Hollenbeck (n=5).

Species	Common name	Percent vegetation cover (%) Mean	SD	Min - Max
Bare		25.8	18.5	4-55
Non-native grasses		51.2	32.1	20-94
Bromus madritensis	Foxtails	1.0	0.0	1-1
Bromus diandrus	Ripgut	35.5	42.6	2-94
Avena sp.	Wild oat	37.3	30.0	20-72
Distichlis spicata	Saltgrass	0.0	0.0	0-0
Erodium sp.	Storksbill	8.0	13.0	0-30

Management considerations

The two primary drawbacks at Hollenbeck are the absence of squirrels and dense non-native annual grass cover (Figure 9). The vegetation structure at Hollenbeck is not consistent with habitat suitability for either squirrels or BUOW. Without additional vegetation management through large-scale methods such as grazing, Hollenbeck will remain unsuitable for squirrels and nesting BUOW in the near future. If the unsuitable vegetation structure was successfully managed, additional measures to attract naturally dispersing squirrels or active translocation would still be needed.

However, the relatively high levels of prey availability suggest that the current value of this parcel could be as a foraging area for breeding or overwintering BUOW occupying nearby burrows at RJER. Since the two parcels are separated by a busy highway, there is a concern about vehicle strikes as BUOW move across the road. The potential for vehicle strikes would likely be difficult to mitigate, so our current recommendation is to focus on management at RJER that supports BUOW, squirrels, and the prey base, rather than Hollenbeck.

Benefits:

- Grassland areas on Hollenbeck extend the foraging area available to BUOW settled at RJER
- Existing conservation status

Challenges:

- ***D: Dense non-native ground cover***
- ***B: Burrows absent:*** squirrel abundance low or absent
- ***F: Fragmentation:*** potential vehicle strike risk from crossing Highway 94
- ***O: Owls absent:*** *overwintering owls only*
- ***P: Predators:*** High coyote activity along roads and trails. High incidence of trees, snags, and other perches for use by aerial predators

Summary of recommended management actions

- Consider annual management of non-native grasslands using grazing and fire to ensure that criteria for open ground and vegetation structure are maintained ***(D, O)***
- Once a low and open vegetation structure is achieved, consider squirrel translocation or measures to support passive squirrel dispersal ***(B)***
- Habitat management for prey species within 1 km of BUOW nesting areas ***(F, O)***

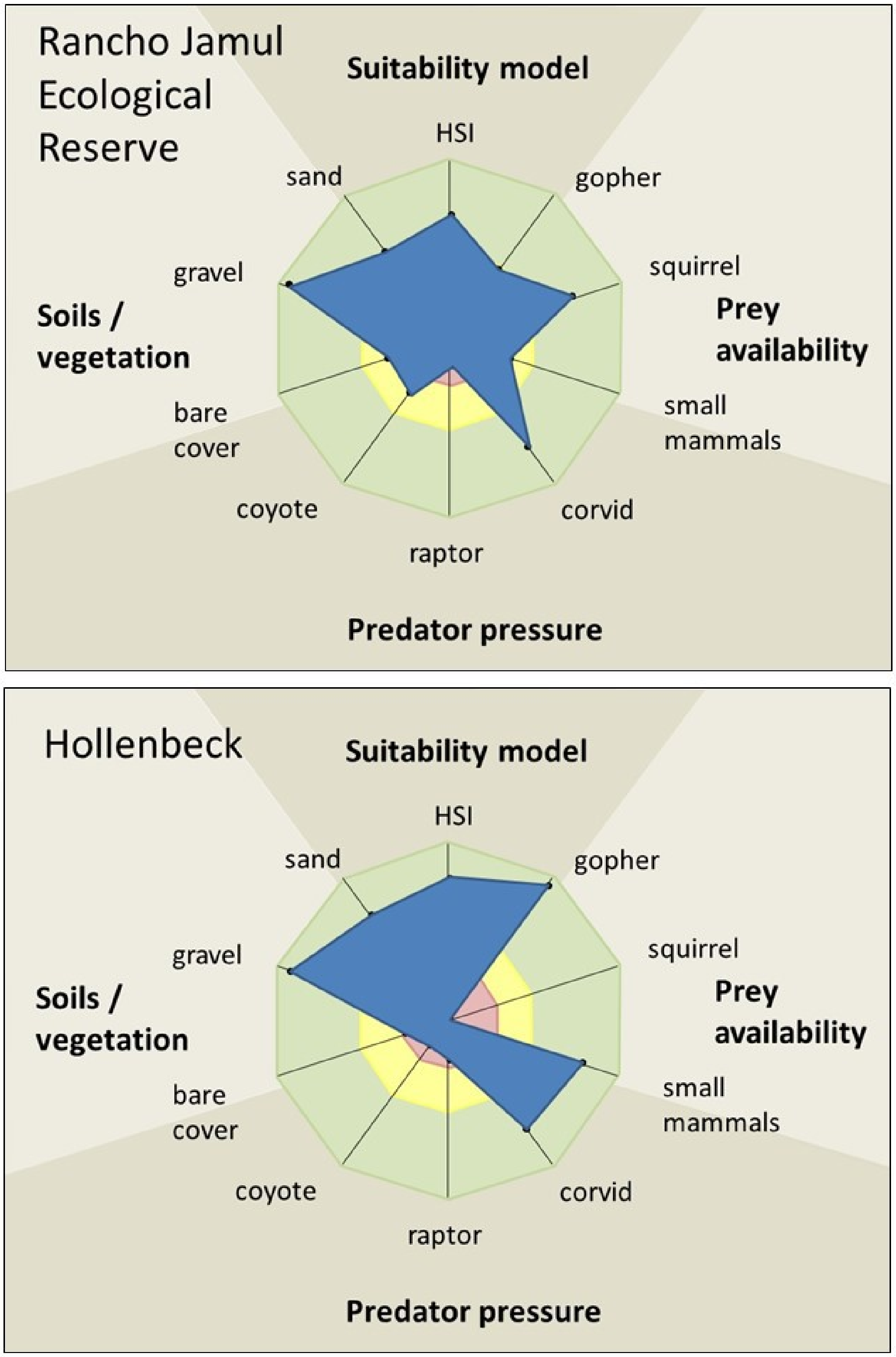

Figure 9. Spider plots for RJER and Hollenbeck Canyon

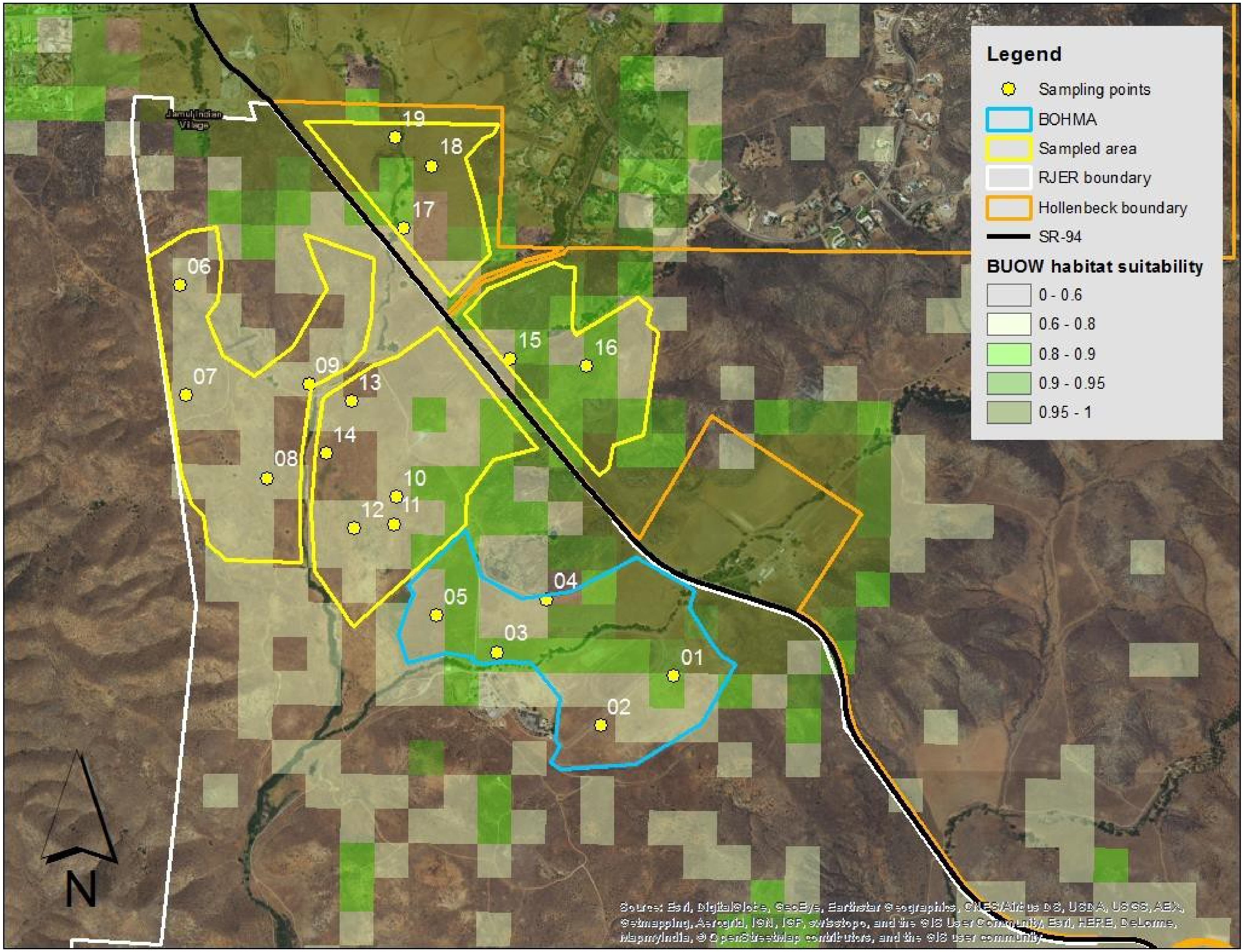

Figure 10. Habitat suitability map for BUOW in the Jamul area. The town of Jamul is represented by the developed areas at the top of the map. The white boundary line delineates Rancho Jamul Ecological Reserve, and the orange boundary line delineates Hollenbeck.

5.2.3 Ramona Grasslands Area

One of the most extensive grasslands remaining in San Diego County is located to the west and south of the unincorporated community of Ramona. The total acreage of grassland in the region has and continues to fluctuate as many parcels are privately owned and there are some existing plans for new development, currently in various stages of implementation. However, the significance of the grassland is in a number of large parcels that have conservation status and are already under management for conservation goals. We evaluated two such areas with rapid assessments in 2016. These were the 3,490-acre Ramona Grasslands Preserve owned and managed by San Diego County, and the 210-acre Ramona Grassland Mitigation Bank. These two parcels will be discussed in detail separately in the following sections.

Ramona Grasslands Preserve

Historically grasslands within the County's Ramona Grasslands Preserve supported a breeding population of BUOW, but the population declined after the mid-1970s. Currently overwintering birds are detected, but there is no breeding population at the Preserve.

Rapid assessment

Ramona Grasslands Preserve has several of the characteristics needed for BUOW population establishment. There are extensive contiguous areas of sandy loam soils with low gravel fractions and low slope. The existing vegetation is grassland with significant components of saltgrass, a native perennial species with a low height structure, and nonnative storksbill (*Erodium cicutarium* and *Erodium botrys*) (Table 6). Both species of storksbill may grow to 50 cm high, but in this region vegetation height is generally shorter. The non-native grass species with the most unsuitable structures for BUOW (e.g., foxtails, ripgut, and wild oat) are at low cover levels. Other nonnative grasses present include false barley (Hordeum murinum), velvetgrass (*Bromus hordeus*), and bermudagrass (*Cynodon dactylon*). Some areas of greater diversity of native forbs and subshrubs are present, including but not limited to: Menzies' goldenbush (*Isocoma menziesii*), Doveweed (*Croton setigerus*), Needlegrass (*Stipa* sp.), Common sandaster (*Corethrogyne filaginifolia*), and vinegarweed (*Trichotema lanceolatum*).

Table 6. Percent vegetation cover values sampled in October 2016 at Ramona Grasslands Preserve (n=12).

Species	Common name	Vegetation cover (%)		
		Mean	SD	Min - Max
Bare		25.4	19.3	6-65
Non-native grasses		1.2	1.3	0-3
Bromus madritensis	Foxtails	1.0	0.0	1-1
B. diandrus	Ripgut	1.2	0.4	1-2
Avena sp.	Wild oat	1.0	0.0	1-1
Distichlis spicata	Saltgrass	21.5	27.8	2-70
Erodium sp.	Storksbill	59.2	24.7	20-90

Ramona Grasslands Preserve also supports an abundant and widespread population of California ground squirrel. Squirrels are concentrated around clusters of boulders, but in several areas that were surveyed the burrow complexes extended at least 100 m away from boulder areas. This existing squirrel population provides an excellent source of natural burrows.

However, relatively high levels of predator pressure present one drawback. Coyote scat was found along existing cow tracks at moderate density, though density was lower than that observed at RJER, Hollenbeck, Johnson Canyon, and La Zanja O/S. Surveys also revealed moderately high raptor counts. The numbers of corvids in the area were consistent with those observed at several other sites: RJER, the Ramona Mitigation Bank, and Johnson Canyon.

The presence of many natural predators can be qualitatively interpreted to indicate that the grassland supports a good prey population. Quantitative evidence comes from the small mammal occupancy modeling, which produced the second-highest index value measured across all sampled sites (Figure 11). Gopher disturbance was relatively low in the sample areas, but a tradeoff between gopher and squirrel activity (low gopher disturbance in areas of high squirrel activity) was anecdotally observed across the rapid assessment sites.

Management considerations

A four-mile loop trail is present in the southwest portion of the Preserve that allows public access for mountain bikers, hikers, and horseback riders. The northwest and eastern portions of the Preserve are currently closed to the public with existing plans for future trail development.

Grazing occurs annually within the Preserve and is the main method of vegetation management. The rapid assessment showed that in 2016, vegetation management kept vegetation density and height relatively low in the core areas of interest for BUOW management. Some variability should be expected, as each area may not be grazed at the same time or intensity every year, and the timing of grass growth is also variable depending on the timing of winter and spring rains. The ongoing grazing regime is generally compatible with squirrel and owl management needs, although some degree of additional monitoring might be needed to maintain vegetation height and density within desired limits in core owl nesting areas.

The current vegetation management also supports management goals for the endangered Stephens' kangaroo rat (SKR), which is found in localized sites on the western and eastern portions of the Preserve. The Ramona Grasslands Preserve is being actively managed for SKR, and any changes to management activities for BUOW should not conflict with current species management efforts. There is the potential for predation on SKR by BUOW, which could affect both SKR and BUOW recovery efforts. The potential for conflict with management of SKR could be mitigated with a buffer zone set to a distance greater than a BUOW home territory. Potential BUOW nesting areas should be sited away from areas managed for SKR, and any identification of potential core BUOW nesting areas should be preceded by a survey for SKR occupancy in the vicinity of areas of interest.

The Preserve lies mostly within the boundary for the draft North County Plan area, and the areas most likely to be considered for BUOW management are also included within the draft North County Plan area. BUOW management on the Preserve would likely require additional upfront agreements about management, with mechanisms for monitoring and accountability. Components of an agreement should include targets for grass height from grazing, and management directives for protection of squirrels. The potential for control measures around core nesting areas to protect BUOW from dogs should also be discussed.

Benefits:

- Large contiguous areas of grassland present
- Existing conserved status
- Existing grazing management effectively manages vegetation structure
- Abundant squirrel population and extensive natural burrows present

Challenges:

- ***O: Owls absent from suitable habitat:*** Ample historical record of BUOW occupancy but only intermittent recent occurrence records
- ***P: Predators:*** relatively high predation pressure from ground and aerial predators
- ***Sp: Potential species conflicts:*** Avoidance of conflicting management objectives for SKR and BUOW

Summary of recommended management actions for BUOW:

- Continued annual management of non-native grasslands using grazing to ensure that criteria for open ground and vegetation structure are maintained ***(O)***
- Evaluate future BUOW management activities, including active translocation of BUOW, and incorporate into the existing Preserve Resource Management Plan ***(O)***
- A management mechanism will need to be put in place if BUOW are relocated to the Preserve ***(O)***.
- A current assessment of SKR occupancy would be needed to site potential BUOW nesting areas away from areas managed for SKR ***(Sp)***
- If needed, spot mowing at suitable BUOW breeding sites prior to the breeding season ***(O)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(O)***

Ramona Grasslands Mitigation Bank

Overwintering BUOW, though not breeding BUOW, are regularly detected on the Ramona Grasslands Mitigation Bank. The Mitigation Bank consists of two parcels (Figure 12). Field sampling (i.e., vegetation, soils, small mammals, raptors/corvids, and coyotes) was conducted on the southern parcel only, since the smaller area of suitable habitat on the northern parcel limits the potential for BUOW management. Information on the northern parcel is summarized from existing reports and a GIS analysis. The data values reported in Tables 2 and 7 only reflect the southern parcel.

Rapid assessment

Southern parcel: The southern parcel encompasses 150 acres. Soils in the southern parcel are dominated by sandy loam soils, but clay soil with surface cracks is present in limited patches. The plant community on the southern parcel is post-agricultural, consisting largely of non-native grasses and forbs (Helix 2014). The community is dominated by bromes and storksbill (Table 7). Vegetation management currently relies on cattle grazing to keep vegetation height low.

Table 7. Percent vegetation cover values sampled in October 2016 on the southern parcel at Ramona Mitigation Bank (n=5).

Species	Common name	Percent vegetation cover (%) Mean	SD	Min - Max
Bare		13.4	9.0	5-25
Non-native grasses		28.2	33.0	2-80
Bromus madritensis	Foxtails	40.0	0.0	40-40
B. diandrus	Ripgut	20.2	33.7	2-80
Avena sp.	Wild oat	0.0	0.0	0-0
Distichlis spicata	Saltgrass	2.3	2.3	1-5
Erodium sp.	Storksbill	55.0	37.5	8-92

Several rock piles in the interior of the parcel provide habitat for California ground squirrel, with abundant evidence of squirrel burrows. Due to cow interference with the cameras, we were not able to estimate small mammal occupancy at this site. However, we recorded lower levels of gopher activity than at other sites. Good connectivity with the Ramona Grasslands Preserve will help ensure BUOW access to adequate prey availability, but requires the owls to cross roads. In terms of predator pressure, both the rocks and the mature eucalyptus on the southern boundary are used as perches by raptors, and high levels of raptors were observed during surveys. Coyote scat was not abundant, but it is important to note higher levels of coyote use on the nearby Ramona Grasslands Preserve (Figure 11). The last comprehensive biological surveys were conducted in 2010 and identified occurrences of sensitive species (e.g. SKR, graceful tarplant; Helix 2014).

Northern parcel: The northern parcel is smaller (about 60 acres). Approximately 62% of the surface area of the parcel is classified as the Bosanko clay soil series, which is defined by 30 in. of clay at the soil surface. By comparison, only 8% of the surface area of the southern parcel is delineated as Bosanko clay. In addition, the bank's vernal pool resources are found on this parcel, as well as occupied SKR habitat, and an extensive stand of graceful tarplant (Helix 2014). Squirrels almost exclusively utilize areas of loamier soil outside of the clay areas (B. Jones, personal communication), and the soils place some limits on the feasibility of management actions at this site. For example, California ground squirrel translocation and installation of soil berms could increase the number of squirrels and burrows, but both options require adequate space and would need to be placed to avoid sensitive resources on the parcel. The northern parcel is more frequently utilized by wintering owls in natural burrows than the southern parcel (B. Jones, personal communication), so the parcel should be considered to be a valuable resource as a site for migrating/overwintering owls.

Management considerations

The Ramona Mitigation Bank will be transferred to the San Diego Habitat Conservancy by spring 2018. It is currently managed for owl habitat, and is required to be maintained in this state. Since there are no artificial burrows currently on the southern parcel of the Mitigation Bank, any active translocation of BUOW would require the installation of at least 2-3 artificial burrows per translocated pair to guarantee a supply of alternate nesting sites, escape burrows, and satellite burrows for fledging juveniles until owls become established on the site. Artificial burrows should be sited away from occupied SKR areas. A mapping exercise would be needed to establish the maximum number of burrows that could be installed, and therefore set the number of owls that could be translocated. Since squirrels are already present, there is good potential that translocated owls could move from artificial burrows into natural burrows. The deployment of conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season should be considered. The removal of mature eucalyptus trees currently providing raptor predator habitat would also benefit BUOW. Costs and benefits of removal should be considered.

Benefits:

- Conserved land with BUOW management goals
- High connectivity to Ramona Grasslands Preserve
- Existing grazing management effectively manages vegetation structure
- Squirrels and natural burrows present

Challenges:

- ***A: Artificial burrows needed:*** no artificial burrows installed yet for potential BUOW translocation
- ***O: Owls absent from suitable habitat:*** current nonbreeding BUOW use only
- ***P: Predators:*** relatively high pressure from ground and aerial predators
- ***S: Soil suitability for burrowing:*** areas of unsuitable clay soils, particularly in northern parcel
- ***Sp: Potential species conflicts:*** Avoidance of conflicting management objectives for SKR and BUOW

Summary of recommended management actions for BUOW:

- Continued annual management of non-native grasslands using grazing to ensure that criteria for open ground and vegetation structure are maintained ***(O)***
- Potential BUOW nesting areas should be sited away from areas with SKR occupancy ***(Sp)***
- Any translocation of BUOW would require installation of artificial burrows ***(A)***
- Spot mowing as needed at suitable BUOW breeding sites prior to the breeding season ***(O)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(O)***
- Consider removal of mature eucalyptus trees to reduce predator pressure ***(P)***

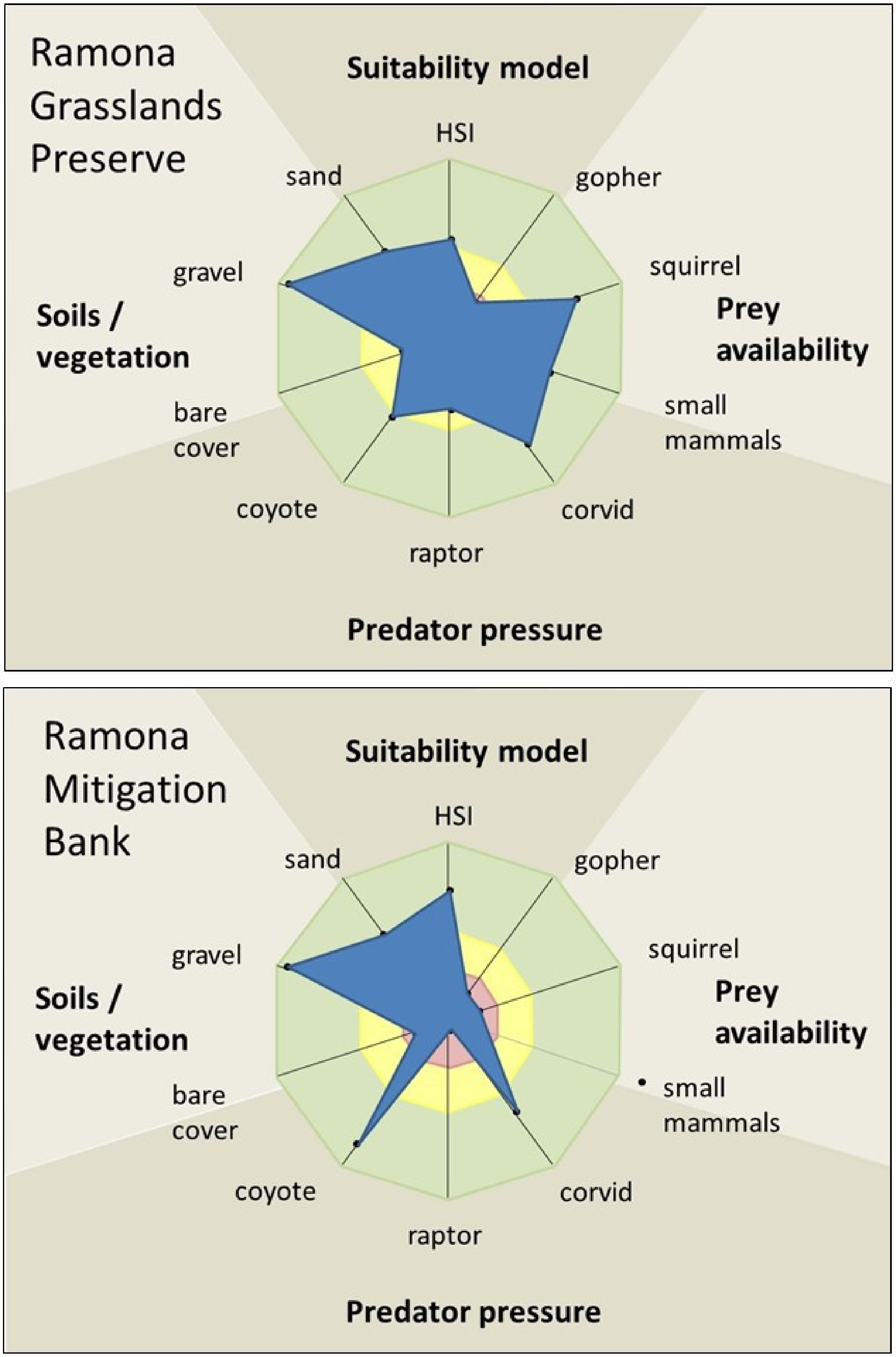

Figure 11. Spider plots for Ramona Grasslands area sites.

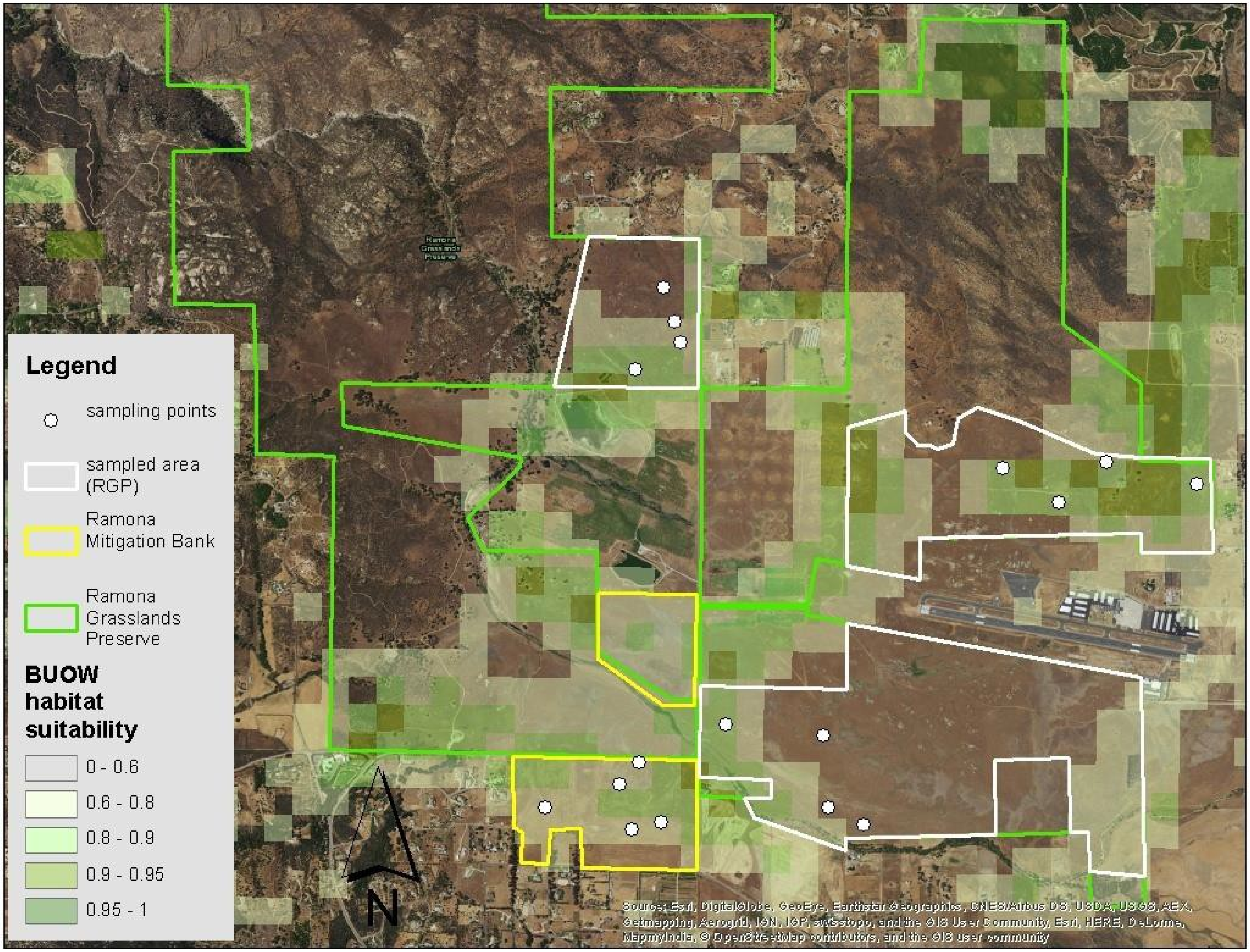

Figure 12. Habitat suitability map for BUOW in the Ramona Grasslands Area

5.2.4 Barnett Ranch Preserve

Barnett Ranch Preserve, located south of Ramona, is a 728-acre County Preserve owned and managed by the County of San Diego (Figure 14). The topography is undulating, with oaks growing on the north and south ends. Use consists of recreational trail use.

Rapid assessment

Soils on Barnett Ranch Preserve consist of sandy loams with texture characteristics similar to sites in the Ramona Grasslands area, Pamo Valley, and RJER. The core of the Preserve is a grassland community dominated by non-native brome grass (Table 8). However, wild oats is absent, which keeps the vegetation height <50 cm tall. Squirrels are abundant on the Preserve, especially in the vicinity of rock piles, and their activity is visible as well developed burrow complexes and trails between burrows. The rapid assessment sampling captured higher counts of squirrel burrows at the Preserve than at any other site assessed in 2016. The apparent coexistence of squirrels and non-native grasses in the interior of this Preserve is somewhat unique, as few local grasslands have this combination of abundant squirrels and non-native grasses. The positive engineering effects of squirrel activity may be apparent here in the wide range of vegetation density from open to dense. Open areas with abundant squirrels are found around rock piles on upper slopes of the undulating hills, with denser areas of non-native grass cover in between. Along this gradient, bare ground cover ranges from approximately 30-50% in open areas to only 10% in dense areas. Non-native grass cover ranges from 15-25% in open areas up to 75% in dense areas.

Table 8. Percent vegetation cover values sampled in October 2016 on Barnett Ranch Preserve (n=7)

Species	Common name	Percent vegetation cover (%)		
		Mean	SD	Min - Max
Bare		27.4	17.4	7-50
Non-native grasses		33.4	28.2	0-75
Bromus madritensis	Foxtails	3.5	5.4	0-11
B. diandrus	Ripgut	27.4	32.9	0-75
Avena sp.	Wild oat	0.0	0.0	0-0
Distichlis spicata	Saltgrass	0.0	0.0	0-0
Erodium sp.	Storksbill	20.7	18.7	0-43

Prey availability appears adequate, with small mammal occupancy in the same range as other grassland sites (Figure 13). Gopher activity was lower, but this was consistent with other parcels with abundant squirrels. Coyote activity on this site was relatively low. The greatest source of predator pressure on the site may be from corvids, which were abundant relative to the other assessed sites. While trees ring the grassland and provide a source of predator perches, the grassland is large enough to provide a distance buffer from these perches.

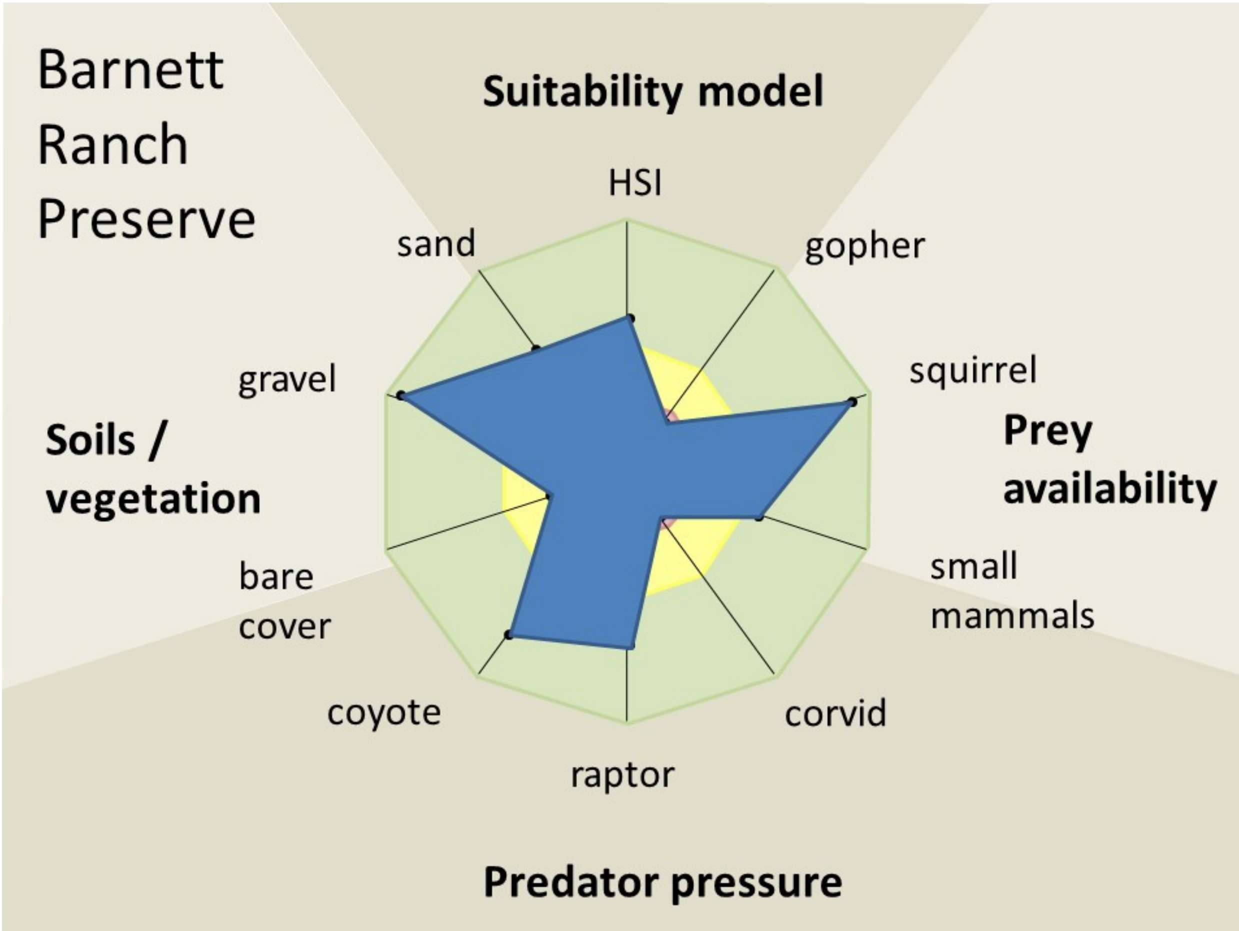

Figure 13. Spider plot for Barnett Ranch Preserve

Management considerations

In 2016, vegetation management was limited, and there was no grazing. Almost all of the Preserve is included within the boundary for the MSCP South County Subarea Plan, with a small portion of the northeastern corner of the Preserve falling within the draft North County Plan area. BUOW management on the Preserve would likely require additional upfront agreements about management, with mechanisms for monitoring and accountability. The abundant squirrel population and other factors suggest that this site could provide suitable habitat for BUOW, and that management for BUOW could include measures such as the protection of the existing squirrel population and the addition of conspecific cues such as whitewash on existing natural burrows. The site could also benefit from annual vegetation management.

Benefits:

- Existing conserved status
- Abundant squirrels and natural burrows present
- Low predator pressure from coyotes

Challenges:

- ***D: Dense non-native ground cover***
- ***O: Owls absent from suitable habitat***

Summary of recommended management actions for BUOW:

- Consider development of an annual vegetation management program, including spot mowing as needed at suitable BUOW breeding sites prior to the breeding season ***(D)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(O)***
- Protection of the existing squirrel population

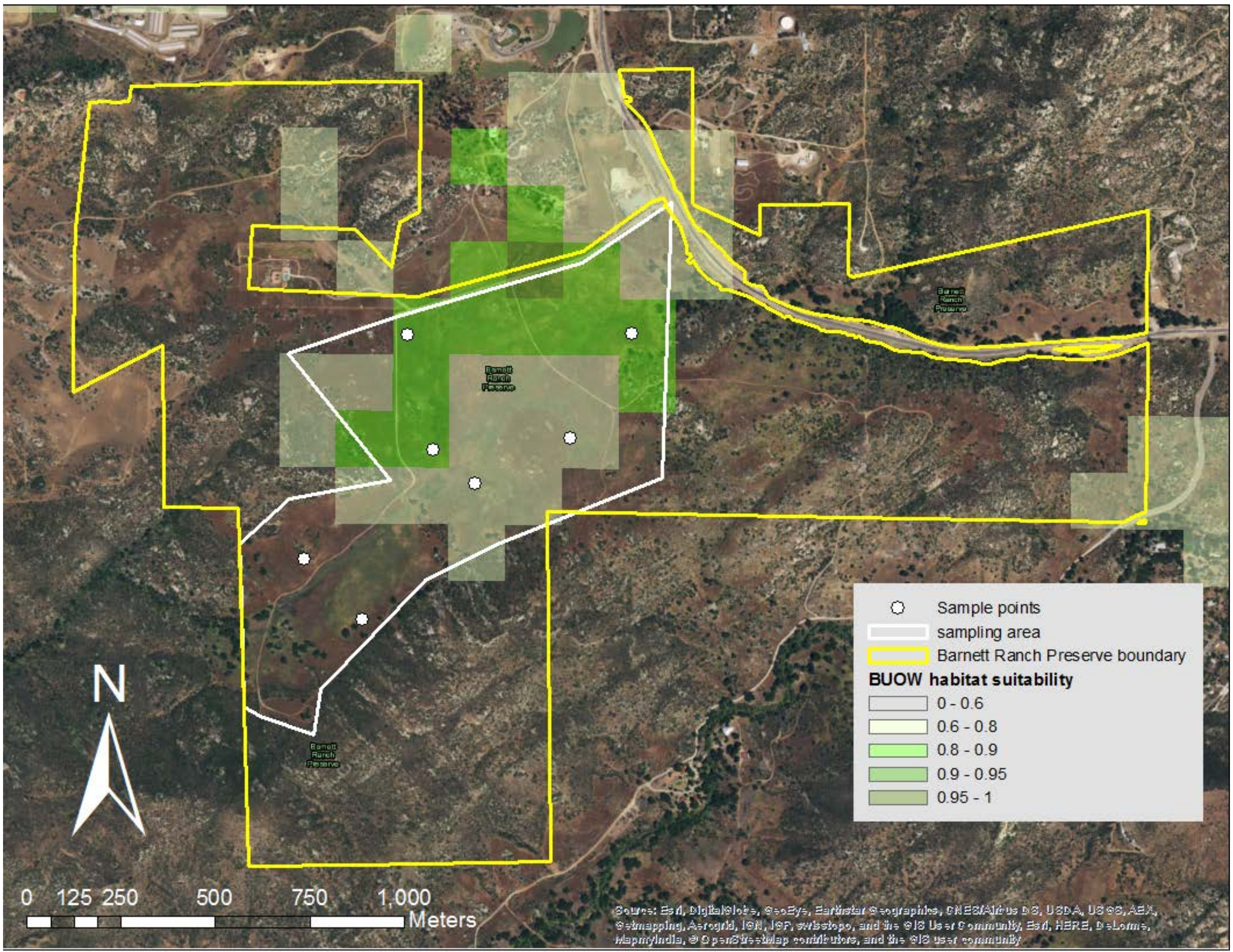

Figure 14. Habitat suitability map for BUOW at Barnett Ranch Preserve.

5.2.5 La Zanja Canyon Open Space

In this region of the County, development is proceeding within the MSCP conservation framework, which directs development and preservation areas throughout the City of San Diego. The La Zanja Canyon Open Space is one such area preserved through the framework (Figure 17). This area is noteworthy for two reasons: (1) the open space parcels include areas of high habitat suitability, as indicated by the landscape-level habitat model, and (2) BUOW were historically found in this area, and single birds or pairs are still detected incidentally. The La Zanja Canyon Open Space is owned by the City of San Diego and is managed for conservation and recreation values.

Rapid assessment

The soils at La Zanja are variable, including areas of clay and gravel (Figure 16). Soil sampling confirmed the presence of clay soils as indicated on the SSURGO soil map. The clay fraction ranged from 29-43% for six of the eight sampling points, even in soils marked on the SSURGO soil map as loamy sand soils. The remaining two samples contained clay fractions of 13% and 21%, respectively. The sand fraction was greater for these two sites as well (Figure 16), and these two areas are defined on the SSURGO map as loams. The gravel component ranged from 15-37% for all sites except for one sampling point, which included only 4% gravel.

The vegetation consists of a mix of semi-natural and non-native grassland (Table 9). The 2012 vegetation classification map for these lands has been field verified by the City recently as part of a Natural Resource Management Plan. Areas of native vegetation are found in the creek bottom in addition to the areas of semi-natural grassland. The semi-natural grasslands include native species such as *Stipa* sp., with the largest contiguous area found west of Camino del Sur. However, invasive non-native forbs such as artichoke thistle (*Cynara cardunculus*) and fennel (*Foeniculum vulgare*) are abundant in places, and *Avena* sp. is also dominant in limited areas (Figure 16).

The small mammal occupancy surveys captured the presence of mice and kangaroo rats at similar levels relative to the other sampled sites, but a very low evidence of gopher activity was observed relative to other sites (Figure 15). Small mammal activity was patchy. The highest levels of gopher activity were on the western half of the site, both south and north of Camino del Sur (Figure 16). City monitoring has detected squirrels in scattered locations, but we did not find evidence of squirrels in the sampled areas. While the raptor/corvid surveys recorded relatively low aerial predator pressure, more intensive City surveys found average to high levels of corvids in the area. City surveys also found average to high levels of coyotes, and the scat density transects recorded moderately high scat densities relative to other sampled sites.

Table 9. Vegetation cover values sampled in October 2016 at La Zanja O/S (n=8).

Species	Common name	Percent vegetation cover (%) Mean	SD	Min –
Bare		18.6	18.9	2-60
Non-native grasses		60.6	25.0	20-90
Bromus madritensis	Foxtails	0.8	1.8	0-5
B. diandrus	Ripgut	10.3	18.9	0-54
Avena sp.	Wild oat	46.1	29.1	5-84
Distichlis spicata	Saltgrass	0.0	0.0	0-0
Erodium sp.	Storksbill	0.3	0.5	0-1

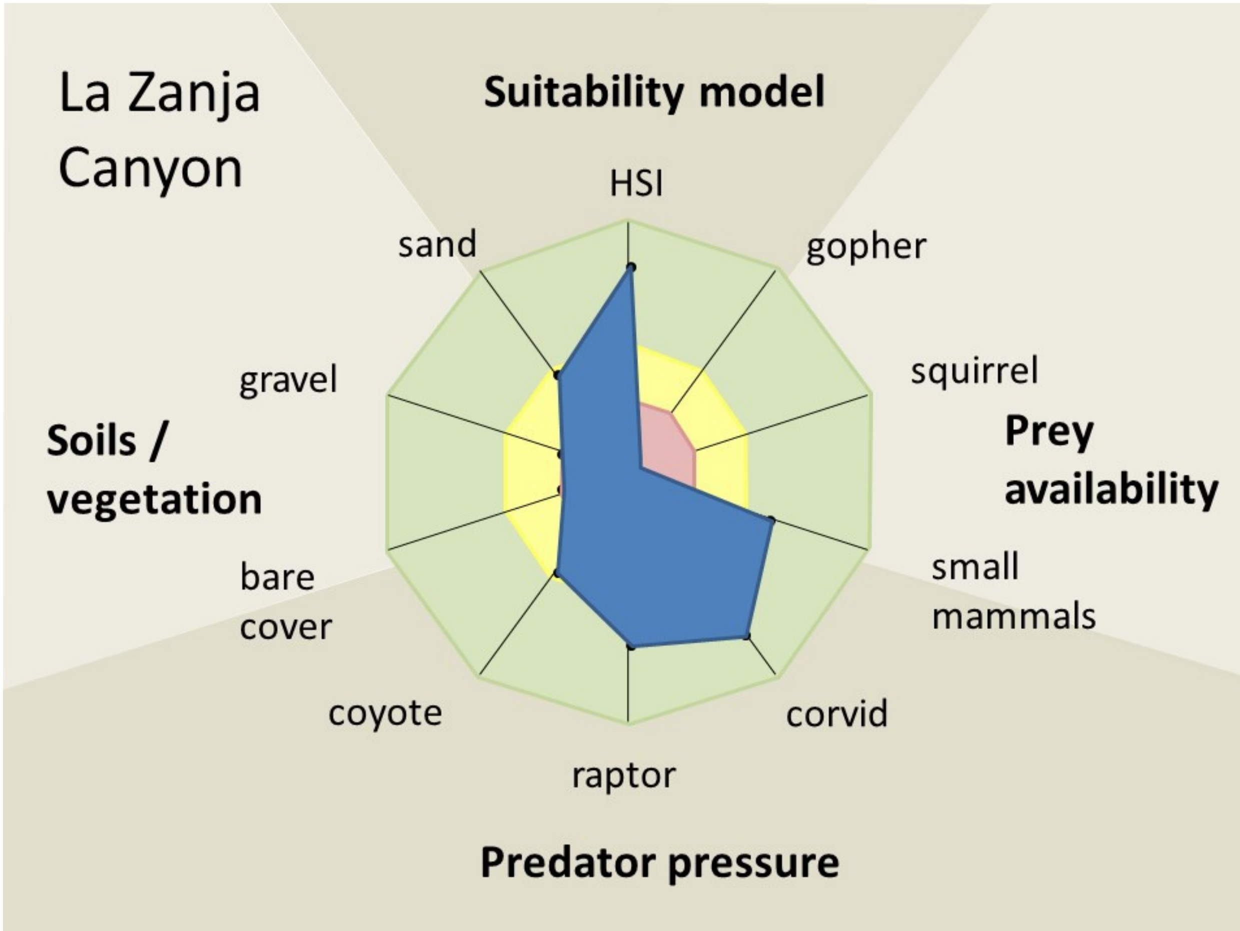

Figure 15. Spider plot for La Zanja Canyon Open Space.

Management considerations

As of 2017, the City is in the process of developing a management plan for this area, and there is an opportunity to integrate BUOW management into the plan. The potential for community buy-in and participation is also positive in this area. The City requested the identification of potential BUOW management locations, based on the suitability findings from the rapid assessment. Two priority areas of potential suitability have been identified (Figure 17). The best site is west of Camino del Sur. Soils have more sand and less gravel in this area, possibly related to past agricultural uses, and tilled ridges are visible over much of the area. This site also includes the largest area of semi-native grassland, and had one of the highest levels of small mammal activity recorded. This site is identified as the best area due to its size and the potential to establish a buffer of space between managed areas, roads, and housing developments. The area appears to receive lower levels of recreational use, and vehicle access for management is available via dirt access roads.

A second potential area is located on the east side of Camino del Sur (Figure 17). The soils at this site are suitable. There is accessibility to adjacent potential BUOW foraging areas to the northwest, where higher levels of small mammal activity were recorded. The vegetation consists of non-native grassland with artichoke thistle, and would require management for vegetation height and density, but one positive aspect of the site is that management activities such as burrow installation would not disturb high value native species. The site is located below street level, which provides a visual buffer from the road above. This area is identified as a lower priority area primarily due to its narrower geometry and proximity to the riparian corridor, where trees provide perches for predators.

The potential disadvantages of both proposed areas include high levels of road traffic on both Camino del Sur and Carmel Valley Road. The coyote population in this area also appears to be moderately high. In addition, an assessment of barn and great horned owl populations in the area would be warranted, as these may prey on BUOW but were not captured by the rapid assessment. Barn owls are known to roost in the bridge where Camino del Sur crosses over Lazanja Pass.

Since BUOW are currently absent, but overwintering owls are sometimes detected in the area, a pilot project to install a cluster of artificial burrows with conspecific cues could be a beneficial first step. BUOW management on this site would benefit from the introduction of squirrels through active translocation. Either short- or long-term fencing around artificial burrow and translocation sites would be warranted to provide protection to squirrels and owls. Since the vegetation community includes areas of woody non-native weeds, weed control will be needed. Future efforts should include securing resources for ongoing vegetation management.

Benefits:

- High suitability index on the habitat suitability model
- Opportunity to incorporate BUOW management into new management plan

Challenges:

- ***B: Burrows absent:*** squirrels not present in sampled areas
- ***D: Dense non-native ground cover:*** need for weed control management
- ***O: Owls absent***
- ***S: Soil suitability for burrowing;*** variability in soil suitability, including areas of clay and gravel

Summary of recommended management actions for BUOW:

- Implementation of weed control and targeted vegetation management ***(O)***
- Develop pilot installation of artificial burrows, with annual maintenance. Avoid areas with heavy clay soils ***(B,S)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(O)***
- Active translocation of squirrels ***(B)***
- Short- or long-term fencing around artificial burrows and translocation sites ***(B)***
- Develop community engagement program

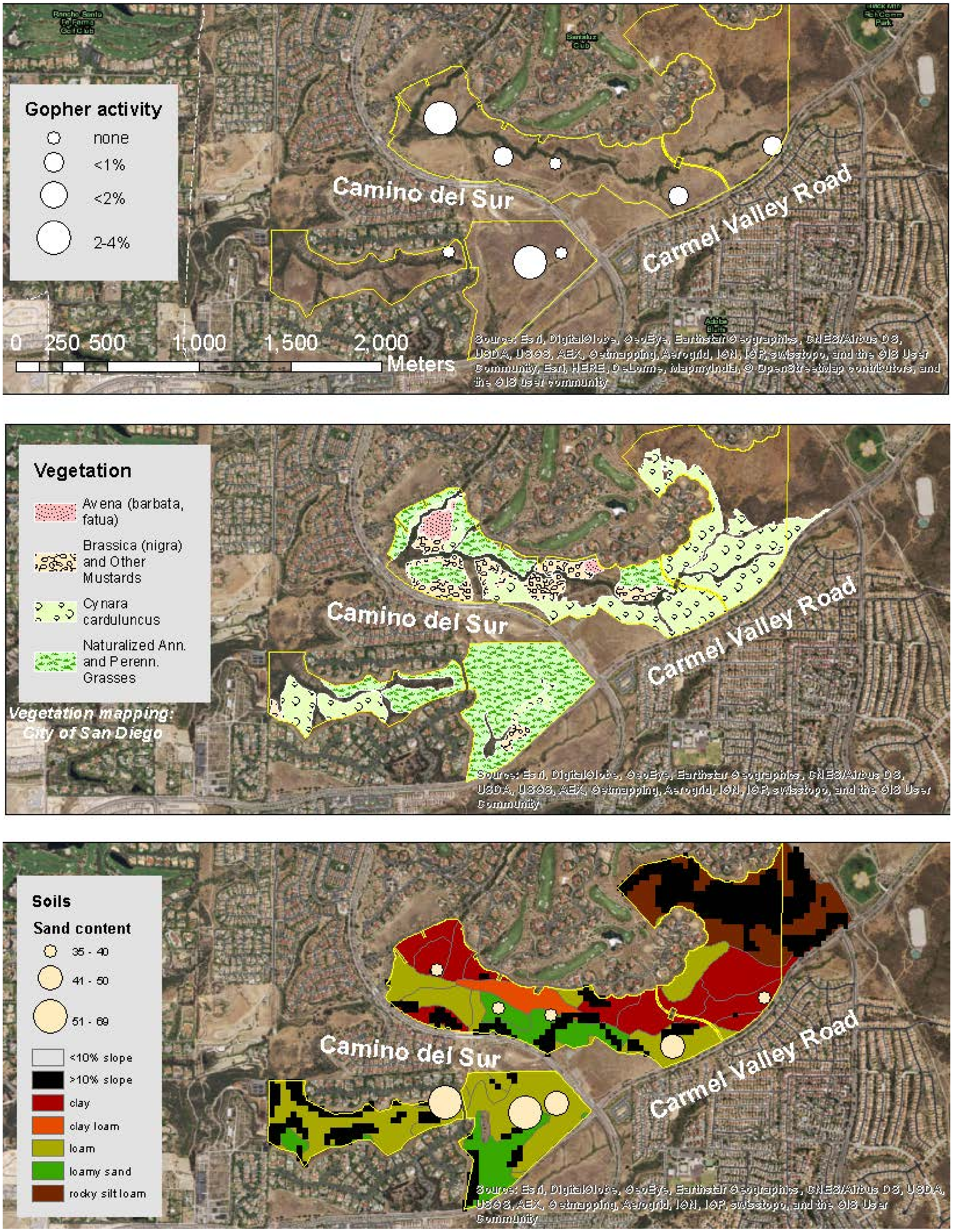

Figure 16. Gopher activity, vegetation, and soil texture of La Zanja Canyon Open Space, under City of San Diego ownership.

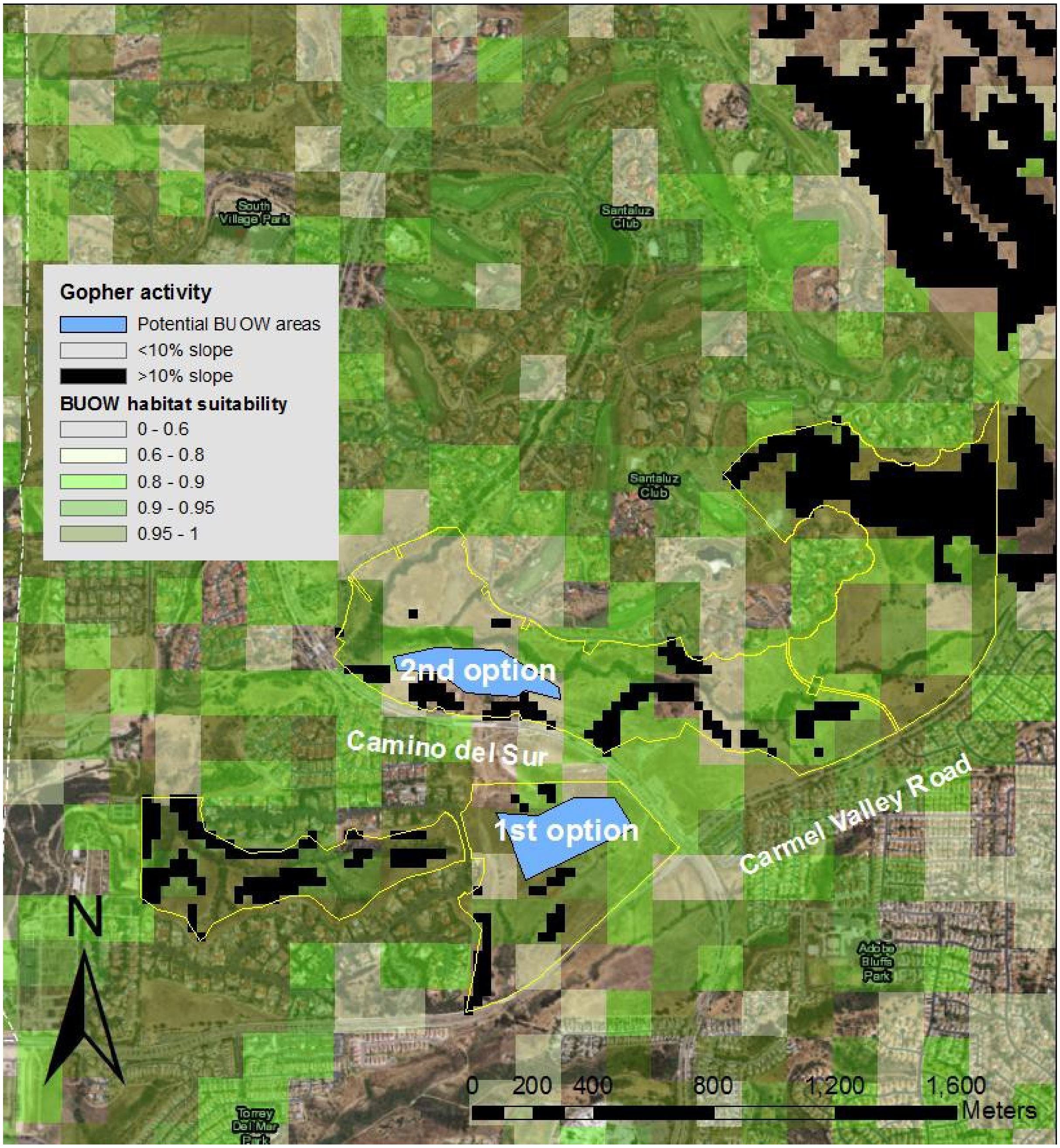

Figure 17. Potential BUOW management areas at La Zanja Canyon Open Space.

5.2.6 Pamo Valley

Pamo Valley is situated just north of the incorporated community of Ramona. The valley is approximately six miles long by three-quarters of a mile wide and is surrounded by Cleveland National Forest. Within the valley, the City of San Diego owns 3,767 acres, which are administered by the Public Utilities Department. Plans for dam construction have been suspended due to environmental concerns. Pamo Valley falls within the Multi-Habitat Planning Area, the overall area from which approximately 90% will be conserved to make up the final MSCP preserve area at the end of 50 years.

Rapid assessment

Note that mean HSI from the habitat suitability model was the lowest in the set of rapid assessment sites, but the low values are likely driven by elevation (1,220 m at the valley floor) and distance from the coast. The rapid assessment measured high suitability values for soils, predator pressure, squirrel presence, and small mammal prey availability (Figure 18). Although low numbers of raptors and corvids were detected, the trees along the creek provide abundant predator perches with accessibility to a wide swath of the narrow valley floor.

Several vegetation communities are present, with riparian woodland along Temescal Creek that includes oaks. The grasslands are dominated by storksbill, with areas of ripgut, foxtails, and wild oats. In ungrazed areas, a seasonally tall and dense vegetation structure should be expected. The native saltgrass (*Distichlis spicata*) is also present. Bare ground was estimated at 20-30% in grassland areas. Shrubby areas of coastal sage scrub and chaparral are found on the slopes both east and west of the valley floor, with greater bare ground cover. The sampling sites included ungrazed grassland, heavily-grazed pasture, and shrubby areas. Summary vegetation statistics are not presented for this site due to these fundamental differences.

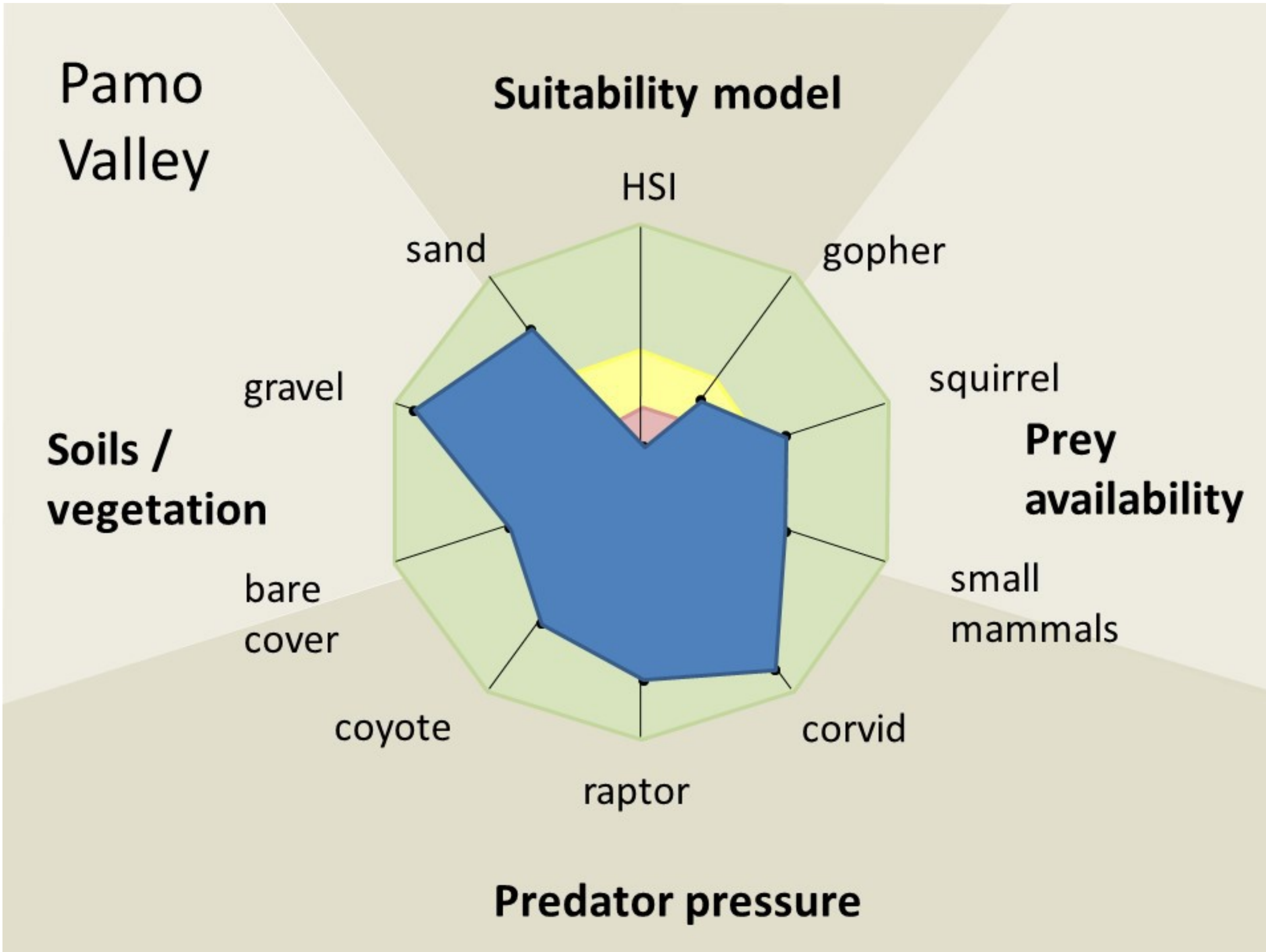

Figure 18. Spider plot for Pamo Valley

Management considerations

The parcels under City ownership extend from the valley floor to the surrounding hills (Figure 19). The valley is a working ranch, and most of the valley floor is grazed by cattle. The lands do not currently have permanent conservation status. Therefore, limited BUOW management is encouraged. The existing squirrel population should be protected. Conspecific cues could also be deployed at squirrel burrows to encourage BUOW to overwinter or breed in the area.

Benefits:

- Abundant squirrels and natural burrows present
- Existing grazing management effectively manages vegetation structure
- Isolation from disturbance and development

Challenges:

- ***N: No permanent conservation status***
- ***I: Isolation from existing and other potential BUOW management areas***
- ***O: Owls absent***

Summary of recommended management actions for BUOW:

- Protection of the existing squirrel population ***(N)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(I,O)***

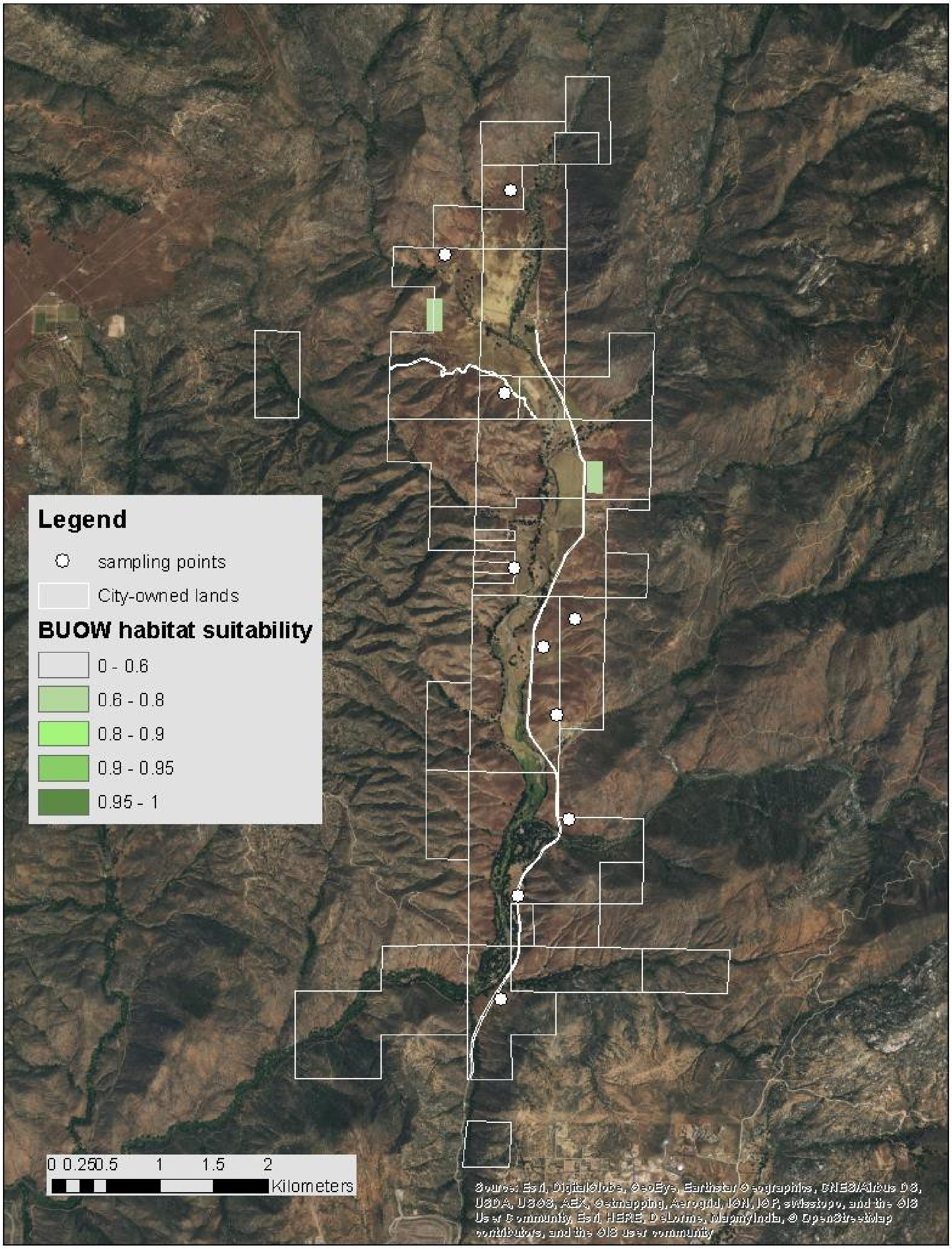

Figure 19. City-owned parcels in Pamo Valley and locations of sampling points.

5.2.7 Sweetwater Authority (SWA)

The lands surrounding the Sweetwater Reservoir were identified by the landscape habitat suitability model as likely to be suitable for BUOW (Figure 21), but BUOW were last reported on SWA lands approximately 20 years ago. Owls occupied the Shinohara vernal pool restoration area on adjacent San Diego National Wildlife Refuge lands beginning in 2008, but have not been documented onsite since 2011. The most likely grassland areas for BUOW management are found on the southwestern shore. There are areas of grassland on the north shore, but these have a relatively narrow configuration and are hemmed in between the waterline, offsite housing development, and stands of coastal sage scrub. The eastern end of the reservoir is dominated by marshy ponds and riparian habitat with dense, mature trees, and the landscape habitat suitability model identifies these areas as unsuitable for BUOW. Surrounding the reservoir, waterline fluctuates somewhat, but all sampling was conducted well above expected shoreline.

Rapid assessment

Five grassland areas were selected for assessment, with delineated polygons of suitable grassland habitat encompassing a total of 113 acres. Soils in the southern parcel are dominated by sandy loam soils, but clay soil with surface cracks is present in limited patches.

The grassland plant community is dominated by non-native grasses, primarily well-established stands of *Avena* sp. Other invasive grasses worth noting include soft brome (*Bromus hordeaceous*), ryegrass (*Festuca perennis*), and false foxtail fescue (*Festuca myuros*) (Table 10). While most of the grassland does not receive active vegetation management, herbicide treatment and removal of invasive species does occur on an annual basis where listed plant species are present. In the treated areas only, native bunchgrass species such as *Stipa* sp. may be detected. Across the untreated grassland sections, a homogeneous structure of tall, dense grass is found, with patches of bare ground almost completely absent.

Table 10. Percent vegetation cover values sampled in June 2017 on Sweetwater Authority lands (n=9).

Species	Common name	Percent vegetation cover (%) Mean	SD	Min - Max
Bare		0.0	0.0	0-0
Non-native grasses		98.5	32.9	20-137
Bromus madritensis	Foxtails	0.2	0.0	0-2
B. diandrus	Ripgut	0.0	0.0	0-0
Avena sp.	Wild oat	80	40	20-100
Distichlis spicata	Saltgrass	0.0	0.0	0-0
Erodium sp.	Storksbill	0.0	0.0	0-0

While the 2017 field surveys did not detect squirrels at the sampling points, squirrels have been observed on the southern shore in disturbed areas near the SWA boundary. Small mammals were detected, but activity was so low that small mammal occupancy model estimates were unstable (Figure 20). No gopher activity was detected at the sampling points. Good connectivity to adjacent refuge lands may help ensure BUOW access to adequate prey availability, but implementing additional annual vegetation management will be key to making this site suitable for BUOW. In terms of predator pressure, the reservoir and surrounding lands are a focus of activity by a wide range of raptors, and several mature eucalyptus on the southern shore are used as perches by raptors. Coyote scat was abundant along roadways.

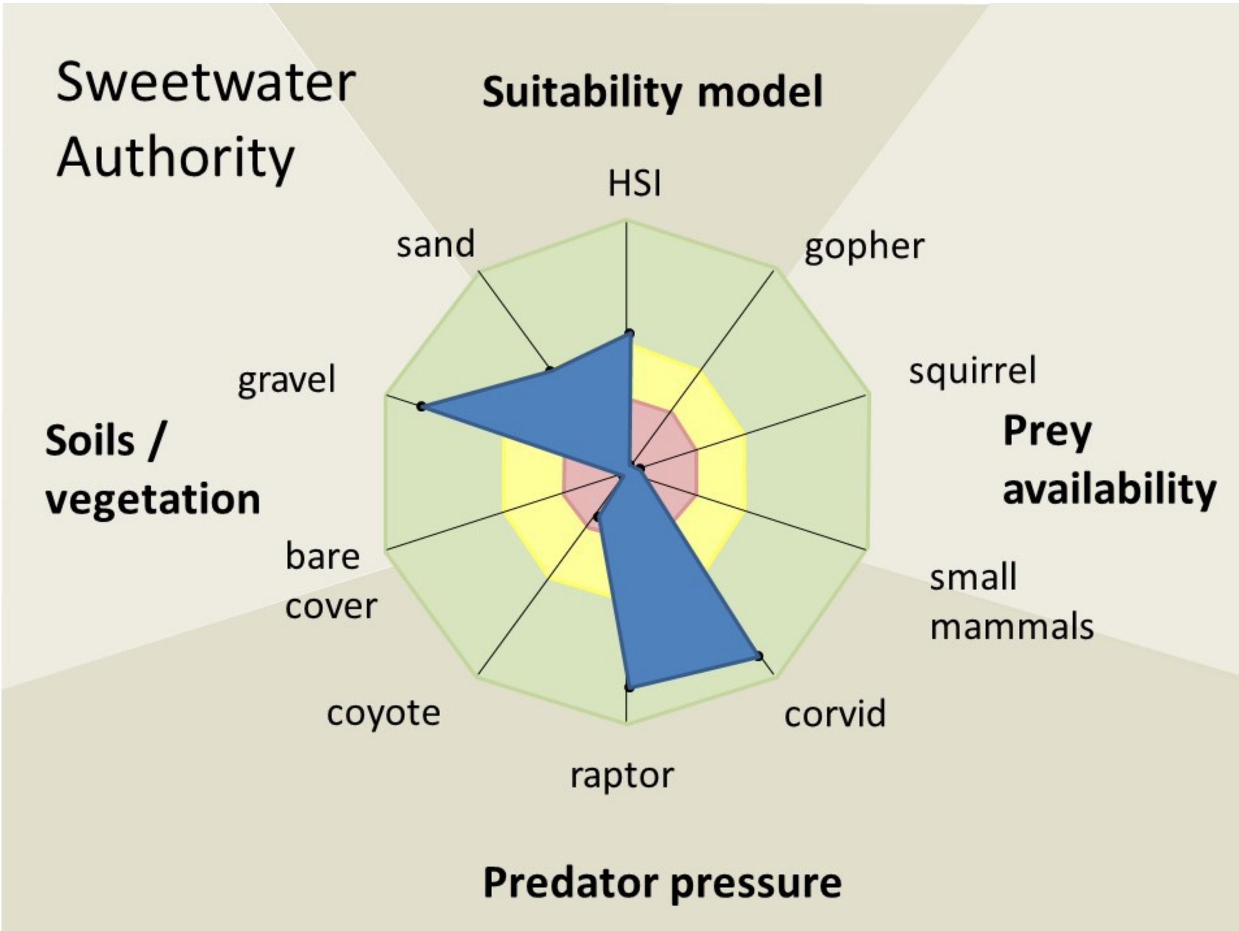

Figure 20. Spider plot for Sweetwater Authority grasslands.

Management considerations

The primary use for the reservoir is municipal drinking water storage, and the level of protection is high, with regular maintenance of all infrastructure. SWA currently implements a habitat management program for avian species such as least Bell's vireo and California gnatcatcher, as well as for vernal pools and native plant species such as Otay tarplant. Some of the available options for vegetation management are not compatible with the dedicated use of the site; neither fire nor grazing are likely to be implemented. The reservoir does provide long-term land use stability, and the existing open lands are a significant biological resource already recognized as a "hotspot" of avian species. The biological community (especially small mammals) would benefit from management efforts to lower the height and density of non-native grasses. Prey base is a concern due to the existing unsuitable habitat structure. An option would be deployment of conspecific cues at natural and artificial burrows on the Shinohara site, to attract BUOW back to the area. The removal of nearby mature eucalyptus trees currently providing predator perches would also benefit BUOW and should be discussed if future BUOW translocation is considered.

Benefits:

- Existing conserved land with ongoing habitat management program
- High connectivity to San Diego National Wildlife Refuge
- Relatively high degree of protection from human disturbance

Challenges:

- ***B: Burrows absent:*** habitat structure is currently unsuitable for squirrels
- ***D: Dense non-native ground cover:*** need for management of annual non-native grasses
- ***O: Owls absent***
- ***P: Predators:*** relatively high pressure from ground and aerial predators
- ***S: Soil suitability for burrowing:*** areas of unsuitable clay soils

Summary of recommended management actions for BUOW:

- Development of annual grassland management to maintain suitable habitat structure for BUOW, squirrels, and prey base ***(D)***
- Deployment of BUOW conspecific cues to attract BUOW or encourage overwintering BUOW to settle during breeding season ***(O)***
- Consider removal of nearby eucalyptus used as predator perches ***(P)***

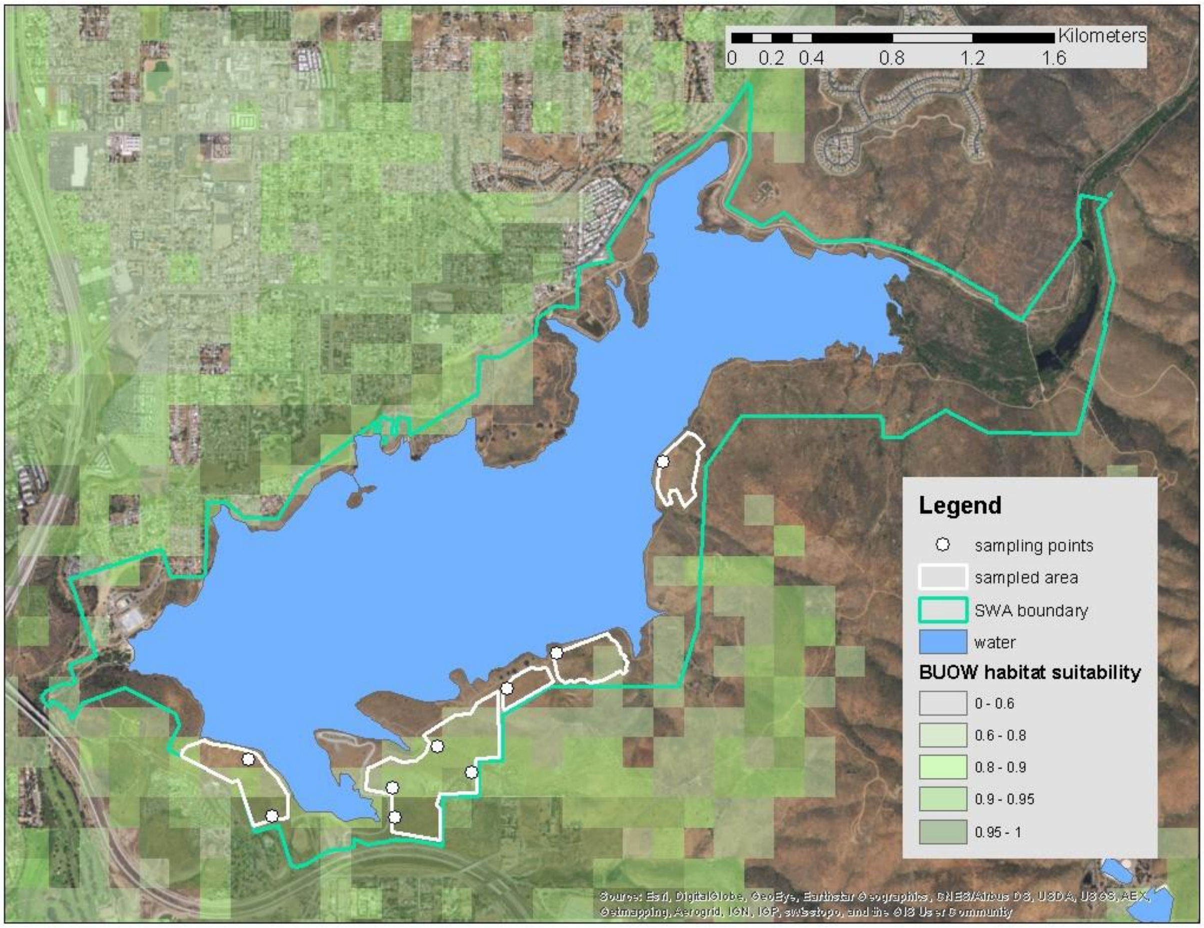

Figure 21. Habitat suitability map for BUOW in grasslands on southern shore at Sweetwater Water Authority.

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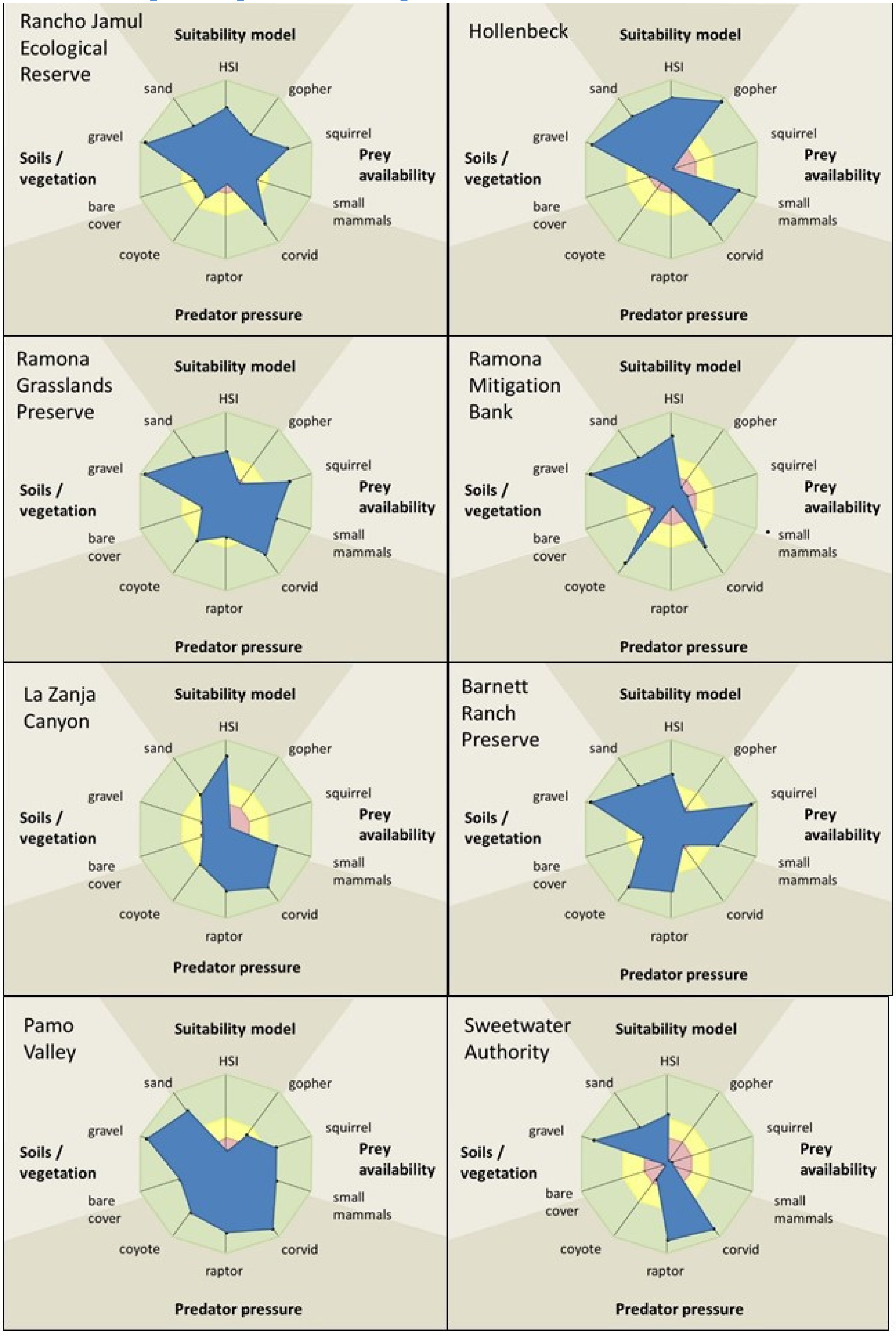
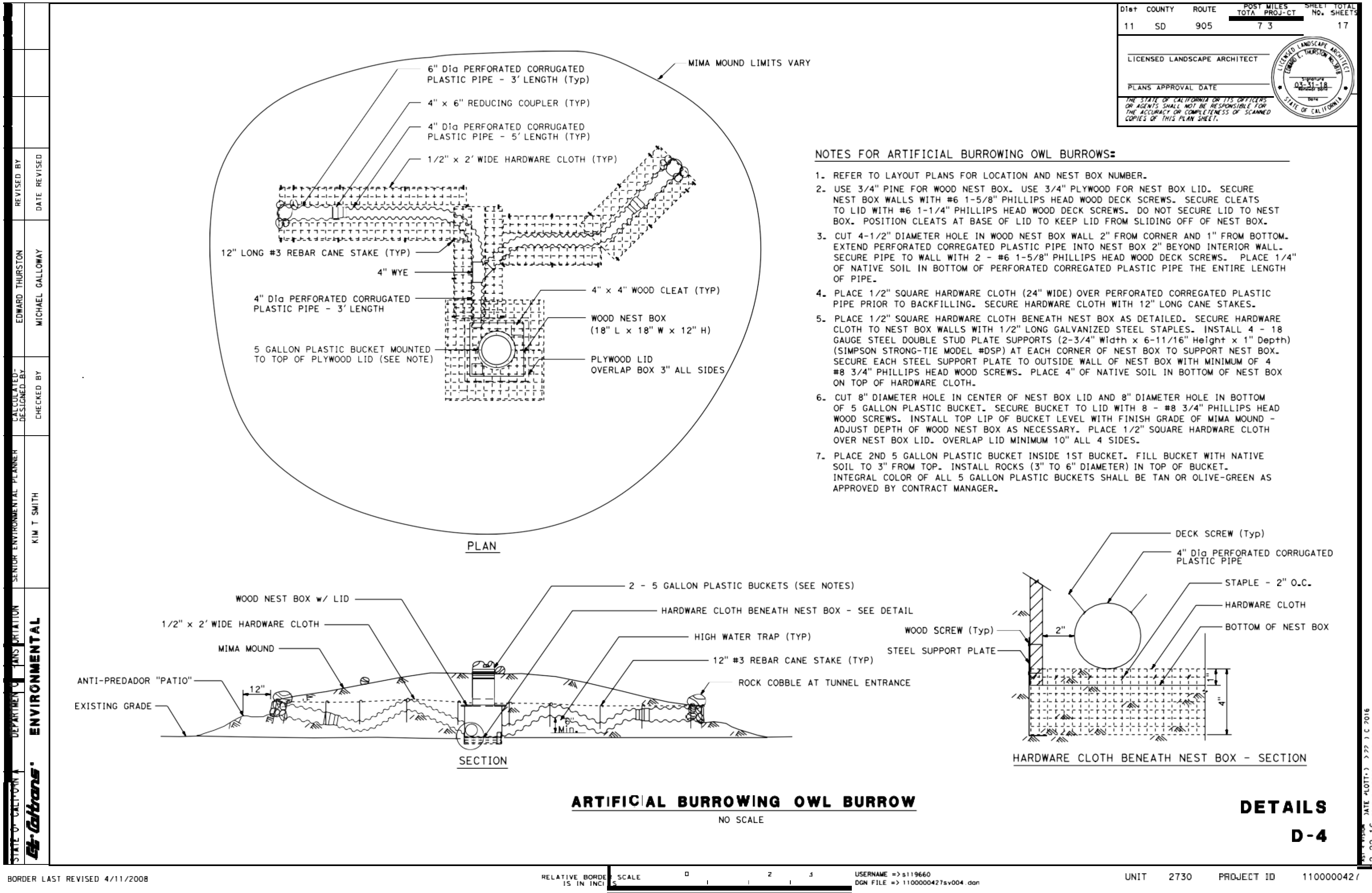
Appendix A. Spider plots for rapid assessment sites



Appendix B. Vegetation summary from all RA sites

Site		Bare Ground	Exotic grasses	Foxtails *Bromus madritensis*	Ripgut *Bromus diandrus*	Wild oat *Avena sp.*	Saltgrass *Distichlis spicata*	Storksbill *Erodium sp.*
		Percent vegetation cover (%)						
Otay	Mean	35.7	0.4	0.3	-	0.2	-	-
	SD	13.4	0.5	0.5	-	0.5	-	-
	Min - Max	25-60	0-1	0-1	-	0-1	-	-
RJER	Mean	32.1	55.3	-	3.2	52	-	11.1
	SD	18.5	27	-	8.7	31.7	-	12.8
	Min - Max	5-60	15-93	-	0-30	0-93	-	0-44
Hollenbeck	Mean	25.8	51.2	1	35.5	37.3	-	8
	SD	18.5	32.1	0	42.6	30	-	13
	Min - Max	4-55	20-94	1-1	2-94	20-72	-	0-30
Ramona Grasslands Preserve	Mean	25.4	1.2	1	1.2	1	21.5	59.2
	SD	19.3	1.3	0	0.4	0	27.8	24.7
	Min - Max	6-65	0-3	1-1	1-2	1-1	2-70	20-90
Ramona Mitigation Bank	Mean	13.4	28.2	40	20.2	-	2.3	55
	SD	9	33	0	33.7	-	2.3	37.5
	Min - Max	5-25	2-80	40-40	2-80	-	1-5	8-92
Barnett Ranch Preserve	Mean	27.4	33.4	3.5	27.4	-	-	20.7
	SD	17.4	28.2	5.4	32.9	-	-	18.7
	Min - Max	7-50	0-75	0-11	0-75	-	-	0-43
La Zanja O/S	Mean	18.6	60.6	0.8	10.3	46.1	-	0.3
	SD	18.9	25	1.8	18.9	29.1	-	0.5
	Min - Max	2-60	20-90	0-5	0-54	5-84	-	0-1
Sweetwater Authority	Mean	0	98.5	0.2	-	80	-	-
	SD	0	32.9	0	-	40	-	-
	Min - Max	0	20-137	0-2	-	20-100	-	-

Appendix C. BUOW artificial burrow plan



SAN DIEGO ZOO INSTITUTE FOR CONSERVATION RESEARCH

Plans developed by San Diego Zoo Institute for Conservation Research and California Department of Transportation with funding from the San Diego Foundation

Materials and Assembly

Tunnels:
—1-2’ of 6” corrugated plastic pipe (x2)
—4” to 6” reducing coupler (x2)
—7’ of 4” perforated corrugated plastic pipe (x2)
—4” wye connector
—3’ of 4” perforated corrugated plastic pipe
—stucco netting/poultry netting
—rubble/rocks for entrance

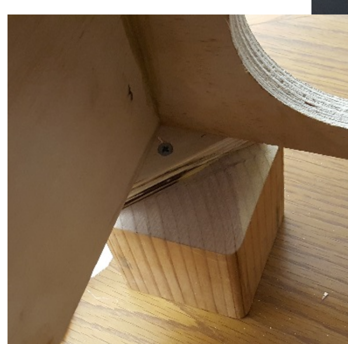
Chamber:
—18”x18”x12” plywood box (see Page 1 for assembly)
*18”x18”x16” box without feet can also be used
—1 5/8” #8 deck screws and wood glue for box assembly
—2 5-gallon buckets for access chimney
*chimney=bucket with 8” hole cut in bottom (centered) and handle removed
*plug bucket=bucket with handle, sanded and painted for camouflage
—all-purpose glue/caulking to seal chimney to chamber top
—1/2” #8 deck screws to secure chimney to chamber top
—1/2” mesh hardware cloth
—wood sealant for outside surfaces of chamber box

Total cost: ~$150 per burrow

Top: Fully assembled chamber with nested chimney and plug buckets.

Bottom: Wooden components of chamber assembled.
Opening in top = 8” dia made with jigsaw.
Opening in side made with 4.5” hole saw.

Inset: Footings made with 4”-tall 4x4 instead of stud plates. A small plywood corner brace was used as an anchor point for the footing.



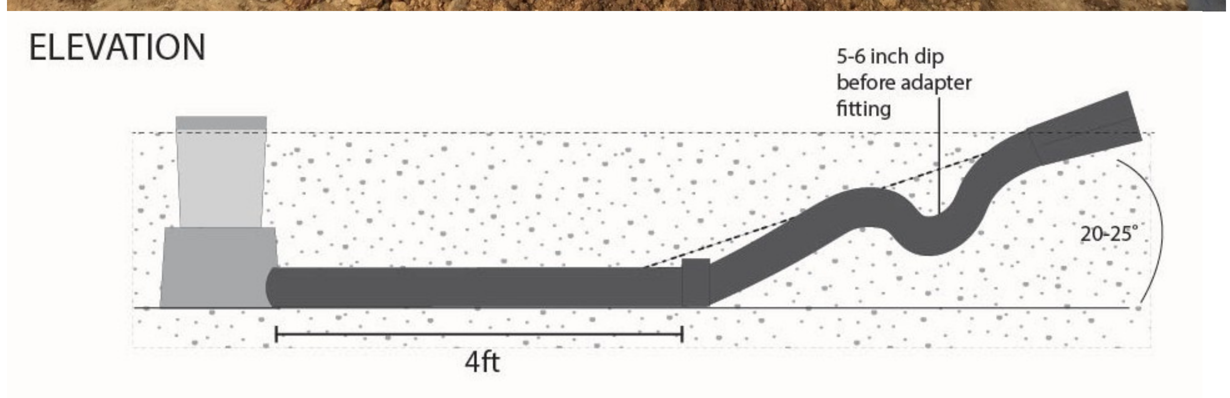
Installation

Care should be taken when siting artificial burrows to minimize potential for flooding and depredation. Burrow entrances should face any potential perches (e.g. fences, buildings, trees) so they can see predators before exiting the burrow. The entrances should always face downhill if there is any slope.

We recommend installing burrows in pairs or clusters (satellite burrows are important for dispersing juveniles). The clusters should be spaced at least 100 meters from each other.

A dip (like a drain trap, see figure to right) should be formed in the pipe approximately 2-3 ft from each burrow entrance for drainage.

Installation time will depend on soil type, the equipment used, and the temperature. In soft, friable soils, a team of 8 can hand-dig and install 6 burrows in one day. In rocky and clayey soils, 6 burrows may be dug in one day using a backhoe with an 18-24” bucket. Hand-digging in harder soils will likely double the time.



Installation Notes

A: Hole for burrow chamber should be deep enough so top lip of chimney bucket is at grade. The arms of the Y can be configured to fit the topography. The pipe that makes the base of the Y should be fitted into the chamber before placement in the ground.

B: The hole around the chamber should be filled and packed. Native soil ~4" deep inside chamber (even with bottom of pipe) and leveled. Back fill and pack around pipes making sure soil next to pipe is soft with no rocks or dirt clods that could crush the pipe.

C: Stucco/poultry netting should be placed ~4" below grade over entire length of pipe and chamber (see next page).

D: After stucco/poultry netting is covered, disturbed soil around the chamber and along pipes should be tamped down to discourage digging by coyotes and other potential predators.

Installation Notes

A: The stucco/poultry netting can be wrapped around the piping to discourage coyotes from biting and pulling on it.

B & C: To install the stucco/poultry netting over the chimney, cut a + over the bucket and fold the corners back.

D: The burrow entrances should be fortified with rocks or appropriately-sized blocks to keep predators from damaging the pipes.