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Energy Research and Development Division

FINAL PROJECT REPORT

Assessing California's Relocation Guidelines for Burrowing Owls Affected by Renewable Energy Development

Gavin Newsom, Governor

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The project team conducted fieldwork under the California Department of Fish and Wildlife (CDFW) Entity Scientific Collecting Permit SC-11839. The team conducted banding, bleeding, and transmittering of burrowing owls under the Federal Bird Banding Permit of Colleen Wisinski (24023) with Susanne Marczak (24023-A) as a subpermittee, and the Federal Bird Banding Permit of Noelle Ronan (23886). The team conducted translocations under SC-11839 and U.S. Fish and Wildlife Service Scientific Collecting Permit MB14619C-4. SDZG's Internal Animal Care and Use Committee (IACUC) approved this project and the project operates in accordance with all IACUC provisions under Project #17-006.

PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solutions, foster regional innovation and bring ideas from the lab to the marketplace. The CEC and the state's three largest investor-owned utilities—Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company—were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The CEC is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Assessing California's Relocation Guidelines for Burrowing Owls Impacted by Renewable Energy Development is the final report for the Assessing California's Mitigation Guidelines for Burrowing Owls Impacted by Renewable Energy project (Contract Number EPC-15-040) conducted by the San Diego Institute for Conservation Research and the U.S. Fish and Wildlife Service. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at 916-327-1551.

ABSTRACT

Once common and widespread throughout the western United States and Canada, the western burrowing owl (*Athene cunicularia hypugaea*) population has declined to the point where the species is now designated as a Species of Special Concern in California. Their presence in development areas, including renewable energy facilities, necessitates an effective strategy for protecting them. This study is the first of its kind to test both passive and active relocation techniques with burrowing owls and evaluate their relative effectiveness with and without the addition of conspecific cues (such as acoustic playback of owl calls and imitation whitewash to attract the owls).

The goal of this large-scale study on active and passive relocation was to develop management recommendations for maximizing the effectiveness of burrowing owl mitigation methods from the potential impacts of renewable energy development. A combination of satellite telemetry and field monitoring techniques was used to monitor relocated birds for longer than is generally implemented. Burrowing owl dispersal, mortality, and reproductive output were recorded in an experimental framework for both passive and active relocations and evaluated against a control group.

Results showed that short-term post-relocation owl survival is relatively high, with no apparent reproductive penalty for relocated burrowing owls. The use of conspecific cues was also effective for encouraging the owls' settlement at release sites. However, while initial survival was lower after active translocations (relative to passive), uncertainty remains without more complete long-term data. Coordinated long-term pre- and post-impact monitoring with federal, state, and local regulatory agencies is needed to achieve effective mitigation outcomes. The development of better translocation methods will benefit electricity ratepayers by improving mitigation strategies when renewable energy facilities are built in burrowing owl habitat. The results of this study will additionally enable conformance with California laws and conservation strategies while simultaneously enabling future renewable energy development.

Keywords: burrowing owl, active translocation, passive relocation, conspecific cues, mitigation, survival, reproduction, telemetry, habitat assessment, solar energy development

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EXECUTIVE SUMMARY

Introduction

Meeting the state's goals for expanding renewable resource energy development while simultaneously meeting its equally ambitious commitment to protect the vulnerable species affected by that development is one of California's biggest challenges. One of those vulnerable species is the western burrowing owl, which is considered endangered in Canada, threatened in Mexico, and either endangered, threatened, or of special concern in nine states, including California. The burrowing owl is the only owl that nests underground, often in burrows dug by small mammals such as ground squirrels. Once fairly common and widespread throughout the western United States and Canada, the western burrowing owl population is declining, and its breeding range has contracted. Agricultural lands that provide good habitat are in some cases being converted to solar energy facilities. While burrowing owls may be observed around solar panel arrays, the sterilized soils beneath the panels do not provide adequate foraging habitat for owls. For protected species impacted by a land development project, mitigation consists of actions designed to offset habitat losses or to minimize harmful impacts to individuals occupying that habitat. When permitting and building renewable energy facilities in owl habitat, the standard practice is to relocate the birds outside of the project area. This relocation can be done by blocking the burrow entrances and forcing the burrowing owls to find new nesting areas on their own (called passive relocation), or by capturing and moving the owls to a more suitable area (called active translocation). There is a lack of rigorous scientific data on which method is more successful, under what circumstances, and with what techniques. Wildlife regulators reviewing proposals for renewable energy facilities are therefore limited when choosing mitigation requirements to include in development permits to avoid or minimize impacts.

Project Purpose

This project is the only study to date that examines the consequences of both passive and active relocation methods and evaluates the relative effectiveness of relocation with and without the use of conspecific cues (natural and artificial cues such as acoustic playback of owl calls and imitation whitewash to attract the owls). Its goal is to improve wildlife mitigation strategies for burrowing owls displaced by renewable energy and other development and ultimately reduce environmental harm to this vulnerable species.

Project Approach

This research study was conducted collaboratively by the San Diego Zoo Institute for Conservation Research and the United States Fish and Wildlife Service. The goal was to develop management recommendations that maximize the effectiveness of burrowing owl relocation methods through a large-scale study of active and passive owl relocations. Incorporating a combination of satellite telemetry and field monitoring techniques, this approach allowed longer monitoring of the species than is generally either performed or required after relocation. Burrowing owl dispersal, mortality, and reproductive outputs were recorded and evaluated in both passive and active relocations, then compared with control owls in an experimental framework. The addition of conspecific cues (visual and acoustic) was also evaluated to see if they improved owl post-translocation settlement. Beginning in January

2017, 58 relocated and control burrowing owls were tracked within the study area, which included four counties in Southern California: Riverside, San Bernardino, Imperial, and San Diego. Each owl was fitted with a global positioning system transmitter to track its movements and survival. Because of the difficulty of operating sensitive electronics under field conditions, the research team worked closely with the transmitter manufacturer to create a robust unit for outdoor field use.

The 58 burrowing owls were assigned to three groups: control owls that were tracked but not relocated; passively relocated owls that were excluded from development sites and forced to find new nest sites; and actively translocated owls that were captured, transported to release sites, and held in enclosures, called acclimation aviaries, for a month to become familiar with their new sites before being released. Actively translocated owls were moved to protected lands within Riverside, Imperial, and San Diego counties. Conspecific cues were used for about half of the actively translocated owls to test whether this strategy increased settlement rates.

In addition to tracking and monitoring the burrowing owls, the research team surveyed habitat conditions at original owl burrow sites, the release sites, and sites where the owls ultimately settled. The habitat characteristics studied included terrain, climate, vegetation, and the density of burrows, which indicates burrow availability. This compiled information was used to better understand burrowing owl habitat use and its potential effect on settlement and reproduction.

A technical advisory committee was formed to advise the project team. Committee members included burrowing owl researchers, representatives of county, state, and federal regulatory agencies, and representatives of regional energy and agricultural industries. The committee met twice a year and provided guidance as issues arose. Primary issues discussed by the committee included lower-than-anticipated telemetry location rates to track owl movements and the absence of pre-project data required to distinguish between migratory and resident owls on project sites during the nonbreeding season. Committee discussions and guidance on these and other issues led to study improvements and, importantly, guided management recommendations.

Project Results

Although long-term survival was difficult to document because of frequent failures of global-positioning-system transmitters, results indicated that, after translocation, owl survival rates were relatively high in the short term. Since mortalities across many species typically happen in the first days or weeks following release in active translocations, this finding shows that this species is relatively robust and that translocation is a suitable tool to use for the species. In fact, no burrowing owls died during the first month after release. After five months post-release, survival was 61 percent for active translocations, compared with 96 percent for passive relocations and 91 percent for control residents. Active translocation is a stressor that places animals in novel conditions where they must learn quickly to survive, and mortality rates following release can be high. By comparison, 84 percent of passively relocated owls were in areas with many available burrows and were able to retain a familiar home range in the short term. These findings suggest that there may be a survival cost to active translocation but not for passive relocation performed under certain conditions. Without better long-term data on survival outcomes, uncertainty persists. Relocation effects on survival were confounded by the number of unknown fates from transmitter failure in the control and passive-relocation owl groups. The overall mean percentage of unknown fates was 22 percent after three months and 30 percent after five months. In addition, passive relocations in this study were conducted under relatively ideal conditions, with ample suitable habitat and resident burrowing owls nearby; so burrowing owls in passive relocations may not fare as well in other circumstances.

Both actively and passively relocated burrowing owls tended to settle near the release site. Passively relocated burrowing owls settled an average of 570 meters from their original burrows. Post-release dispersal for actively translocated burrowing owls depended strongly on the use of conspecific cues. Control residents dispersed, on average, only 42 meters. It therefore appears that most of the translocated owls did not suffer from long-distance post-release dispersal, which could compromise individual survival and local conservation objectives.

The distance that burrowing owls were actively translocated also influenced dispersal after release. Burrowing owls translocated farther than 17.5 kilometers (about 11 miles) were significantly more likely to settle at the release site than those relocated at shorter distances. Translocation over shorter distances was often followed by returns to the capture site (homing). Short-distance active translocation is probably not a promising strategy.

Reproduction during the first breeding season following release was strong, comparable in most cases to reproductive rates for control resident burrowing owls. Thus, there does not appear to be a reproductive penalty for translocated burrowing owls. Sample sizes for reproductive outcomes were too small for robust statistical comparisons, but active translocation was associated with slightly higher chick production and fledging rates than passive relocation.

The effects of conspecific cues were most readily evident in where burrowing owls settled. Actively translocated burrowing owls were 20 times more likely to settle within 650 meters of their release sites when cues were present. Those owls also dispersed significantly shorter distances when cues were present (average = 393 meters) than when they were absent (average = 9,521 meters). There were no significant differences in survival rates between the "cue" versus "no cue" treatments, although survival rates were somewhat higher in the no cue treatment. Sample sizes for reproductive measures were insufficient for statistical comparison though chick production and fledgling survival were higher in the cue than in the no cue treatment. No differences were found between natural cues (resident owls present) and artificial cues (such as vocal playback, whitewash that mimics droppings) for any of the measures examined. In the absence of nearby resident burrowing owls, therefore, artificial conspecific cues should be used to encourage owl settlement at or near release sites.

While generally resilient to translocation, it is possible that burrowing owls will ultimately fail to establish sustaining populations at the release sites if the habitat is less suitable than that of their original source sites. The habitats where both actively translocated and passively relocated burrowing owls settled were somewhat different than the habitats they left. Actively translocated burrowing owls ultimately settled in locations with greater vegetative growth than in their origin burrows. Passively relocated burrowing owls generally settled in burrows with lower habitat suitability, suggesting a general pattern of eviction from a preferred burrow site with sparse vegetation and flatter slope to less desirable burrow sites nearby. These results and their data-supported recommendations will help managers make informed decisions when burrowing owl relocations are required to minimize the environmental impacts of development on the species.

While this project has delivered key findings and insights into improving the effectiveness of burrowing owl translocations, it also raises additional questions that require answers before more effective translocation protocols can be developed. For example, seasonal timing of translocations was identified as a possible factor in translocation successes though data are insufficient for either analyses or conclusions. Currently, mitigation-driven relocations and translocations do not allow for control over the seasonal timing because development project schedules dictate when burrowing owls are moved offsite. Research that considers critical biological periods (such as reproductive stages) is recommended to effectively inform environmental requirements for the future development of renewable energy facilities.

Current practice does not require banding or any permanent identification of displaced burrowing owls, which means that most relocation outcomes are unknown. The findings of this project highlight the need for more research on marked burrowing owls to further improve protocols for relocation methods.

In addition, research is needed to determine the long-term consequences of passive relocation and to determine whether individual owls experience serial eviction where a bird's relocation burrow is subsequently and repeatedly developed. For active translocation, long-term monitoring is required to determine if new, self-sustaining burrowing owl colonies become established. Long-term monitoring and coordination with federal, state, and local regulatory agencies are essential to understand the survival, reproductive success, and return rates of young burrowing owls hatched at release sites.

Knowledge Transfer

For this research, knowledge transfer rather than technology transfer was the primary goal. The purpose of this knowledge transfer was to effectively communicate research results to improve conservation efforts that protect burrowing owls from any unintended consequences of developing renewable energy facilities in the owls' habitats.

This study will strengthen and more accurately focus management recommendations for burrowing owl mitigation strategies based on research results, provide a better understanding of burrowing owl movements and habitat use, provide more informed guidance for renewable energy development, and generally improve California's mitigation guidelines for burrowing owls. The target audience includes local, state, and federal natural resource regulatory agencies, energy developers and other land developers, land managers, environmental organizations, and the general public. This project also contributes to the pool of knowledge regarding the effective utilization of solar-powered global positioning system satellite telemetry units on burrowing owls.

The California Department of Fish and Wildlife, the U.S. Fish and Wildlife Service, county planners, local agencies (such as Imperial Irrigation District), scientists, and developers were all part of the Technical Advisory Committee. Key stakeholders joined the project team at semiannual meetings of the Technical Advisory Committee, project kickoff meetings, and progress updates with stakeholders, including landowners. Status reports were provided at least once a year to project partners including regulatory agencies, land managers, and developers. To reach a wider audience, a website was developed to highlight burrowing owl research and major findings (institute.sandiegozoo.org/burrowing-owl/burrowing-owl-recovery-program).

The results of this project will be publicly available and provided to local, state, and federal agencies. Research findings will also be published in peer-reviewed journals and presented at scientific conferences.

Benefits to California

Environmental mitigation to avoid or minimize impacts is an essential component of any development, including renewable energy development. California laws require new and additional sources of clean energy, but these also need to meet legal environmental requirements in the process. The development of better relocation methods benefits electricity ratepayers by expediting mitigation strategies used when renewable energy facilities are built in owl habitat. Because burrowing owls are not yet listed as threatened or endangered (at the state or federal levels), improving relocation methods will help decrease the likelihood of them becoming listed. If they do become listed, there will be much stricter regulation resulting in a longer process, potential denials of permitting, and stronger requirements for habitat protection/restoration, which may all result in higher project costs that would be passed on to the ratepayers. This study provides owl movement and habitat use data to help energy facility operators decide where best to locate new developments to avoid impacts and where best to relocate owls to minimize impacts where avoidance is not practical. This project also developed best practices to protect burrowing owls that are moved to other locations out of the way of development. These specific benefits will enable the achievement of better conformance with California laws and conservation strategies and will also allow renewable energy facility development to continue apace while minimizing environmental impacts to this species of special concern. Specific recommendations provided in this study can also serve as a roadmap for future research to further improve relocation strategies.

CHAPTER 1: Introduction

Renewable energy generation projects are an essential component of the State of California's energy policy, providing reliable power while reducing the carbon footprint of energy generation. In 2011, California mandated that utilities generate at least 33 percent of the state's electricity from renewable energy by 2020, leading to a surge in corporate investments in developing renewable energy power generation projects in Southern California (California Energy Commission, 2012) and elsewhere around the state. California is legally required to supply 100 percent of electricity from eligible renewable energy resources and zero-carbon resources by 2045 (Senate Bill 100, De León, Chapter 312, Statutes of 2018). Large-scale renewable energy projects (primarily solar photovoltaic and wind-power projects) are a rapid and increasing source of development throughout much of Southern California, including areas of known burrowing owl (BUOW) habitat. The development and operation of renewable energy projects could therefore contribute to the continuing decline of BUOW populations in the southern part of the state.

Current Species Status

Once fairly common and widespread throughout the western United States and Canada, the western burrowing owl (*Athene cunicularia hypugaea*) has experienced population declines and its breeding range has contracted (DeSante et al., 2004; DeSante et al., 2007a; DeSante et al., 2007b; Conway et al., 2010; Wilkerson and Siegel, 2010; Wilkerson and Siegel, 2011). The owl species is now listed as a Species of Conservation Concern in the United States, is federally endangered in Canada, state endangered in Minnesota and Iowa, and threatened in Mexico (Klute et al., 2003; USFWS, 2008). In California, BUOW are designated as a Species of Special Concern (Gervais et al., 2008) and may soon be re-evaluated for listing under the California Endangered Species Act (Center for Biological Diversity, 2015).

Southern California supports some of the last large populations of these owls. The largest remaining contiguous populations in North America live in the Imperial Valley, which in turn comprises 50 percent of the western North American population and an estimated 70 percent of the California population (DeSante et al., 1996; Bowen, 2001; Klute et al., 2003; DeSante et al., 2004; Wilkerson et al., 2011). However, population declines have been documented across Southern California (Klute et al., 2003; Gervais et al., 2008), with BUOW population estimates from the Imperial Valley declining over the last 20 years by nearly 40 percent (DeSante et al., 2007a; DeSante et al., 2007b; Wilkerson and Siegel, 2010; Wilkerson et al., 2011).

Species Management Through Translocation and Relocation

Wildlife translocations and relocations, where people move individuals of a species from one area to a safer one, are a widely used form of conservation management (IUCN/SSC, 2013). The purpose of active translocations is to reduce animal mortality caused by development by physically relocating individuals away from project sites. The use of translocation as a species recovery tool (Seddon et al., 2007; Ewen et al., 2012) and as a wildlife mitigation strategy that is required by regulatory agencies to minimize species losses from development (Germano et al., 2015; Sullivan et al., 2015) is rising dramatically. Because active translocations can be challenging and complex, mitigation strategies have sometimes sought to avoid them altogether. In these cases, habitat is impacted, and animals are forced to relocate themselves (passive relocation). This strategy may be more effective provided that certain assumptions are met, such as that suitable habitat with available carrying capacity is available nearby.

BUOW have in fact adapted to a variety of disturbed and developed sites (Klute et al., 2003). However, their presence in development areas poses conflicts between conservation and economic activities, including development of renewable energy resources. Impact avoidance and minimization, and other conservation measures, are required when land development displaces and negatively impacts resident species. When avoidance of BUOW impacts is not deemed feasible, the California Department of Fish and Wildlife (CDFW) recommends mitigation (required in compliance with the California Environmental Quality Act) through disturbance buffers (setback distances) and burrow exclusion (passive relocation; California Department of Fish and Game[1] [CDFG], 2012).

Passive relocation and active translocation are two methods used to avoid killing or harming owls when occupied burrows are within a planned development. Passive relocation involves excluding owls from their burrows and then collapsing the burrows once owls are absent. The owls are then expected to relocate on their own without human assistance (passively). Artificial burrows may be installed nearby to encourage rapid resettlement and possibly reduce mortality risks associated with relocation to a completely new area (Trulio, 1995). In some circumstances, artificial burrows are not installed nearby, and there is no attempt to influence the birds' post-relocation choice of burrow sites. By contrast, active translocation involves capturing owls at their burrows, moving them off-site, holding owls temporarily in a large field enclosure, then releasing them (Trulio, 1995; Smith and Belthoff, 2001). Active translocation release sites are typically supplemented with artificial burrows to encourage owls to remain there. In California, passive relocation is the most common mitigation strategy for BUOW affected by renewable energy (and other) projects, though active translocations are more common elsewhere in North America (Leupin and Low, 2001; Smith and Belthoff, 2001; Bloom Biological, Inc., 2009; Mitchell et al., 2011; Wild at Heart, 2011).

However, the relative effectiveness of passive versus active relocation strategies has never been tested, so their effects on BUOW, compared with non-relocated owls, remains unknown. Although well-implemented passive relocation can be successful (Trulio, 1995), too few passive relocations have been rigorously documented to draw general conclusions about their success rate across various situations. 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; Wild at Heart, 2011). However, the behavioral and demographic consequences of relocation methods have not been comparatively evaluated. Citing a lack of scientific study, active translocation is currently not authorized by the CDFW, except within the context of scientific research or a Natural Community Conservation Plan (NCCP; CDFG, 2012).

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[1] The name of the California Department of Fish and Game was changed to California Department of Fish and Wildlife in 2013.

Both methods of BUOW relocation have advantages and disadvantages. Passive relocations are less costly in terms of expense and human labor. However, they are strongly limited by the availability of suitable habitat in close proximity to release sites, with relocations of less than 100 meters producing the best results (Trulio, 1995). While short-distance relocations may address highly localized impacts to resident BUOW, they do not address long-term risks associated with ongoing activities at development sites, such as the installation of wind turbines. Relocated owls may still be at risk from these continuing threats. An advantage of active translocation is that managers may select sites, such as Multiple Species Conservation Plans, Habitat Conservation Plans (HCPs), and other protected areas, where habitat is believed to be highly suitable and the risk of encountering threatening human activities is greatly reduced. Temporarily holding relocated animals in acclimation enclosures at the release site is expected to encourage them to remain in the vicinity after they are released. Active translocations can therefore be more strategically implemented than passive relocations.

Improvements to Efficacy

There is a large and growing number of wildlife translocations that evade academic scrutiny and common standards (Germano et al., 2015). Mitigation translocations in particular have been recently targeted for several shortcomings, including poor implementation, lack of documentation, failure to apply scientific principles, and poor outcomes (Dechant et al., 2002; Germano et al., 2015; Sullivan et al., 2015). BUOW relocations, both passive and active, are frequently conducted with unknown outcomes, in part due to the lack of or poorly executed monitoring schemes, as well as the low success rate of finding and tracking BUOW outfitted only with leg bands or no bands at all. Reliance on leg bands requires considerable effort to re-sight relocated owls, but most birds are not re-sighted and thus dispersal and mortality events cannot be untangled. Very high frequency (VHF) transmitters can yield important data on survival and movement, but only if the owls disperse a short distance and can be located with receiving equipment. These shortcomings must be addressed if mitigation actions are to be cost-effective and produce the desired outcome of reducing impacts on sensitive, threatened, or endangered species.

However, the field of translocation biology is moving steadily forward through the application of scientific principles (Seddon et al., 2007). A growing body of literature is developing biologically and ecologically based techniques that can improve translocation outcomes if considered during design and implementation of the programs (Seddon et al., 2007; Batson et al., 2015). It is critical that the increased application of scientific principles and the theoretical framework developed for translocation biology be incorporated into mitigation-driven translocations in order to increase successful outcomes and enhance the cost-effectiveness of environmental mitigation strategies (Germano et al., 2015).

Post-Translocation Dispersal

Perhaps one of the most significant obstacles facing successful animal relocations is the problem of long-distance movement away from the release site, or dispersal (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., 2012; Shier and Swaisgood, 2012). While holding animals in acclimation pens (called acclimation aviaries or hacking cage) at the release site can reduce post-release dispersal (Bright and Morris, 1994; Batson et al., 2015), this method alone does not always succeed (Shier, 2006; Shier and Swaisgood, 2012). Close attention to the species' behavioral and ecological needs can aid in the understanding of factors driving post-release movements (Shier, 2006; Stamps and Swaisgood, 2007; 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.

Conspecific Cues

A common misconception is that dispersers will find and occupy empty suitable habitat if it is present. However, the 'build-it-and-they-will-come' conservation approach does not always work. Even territorial and less social species often prefer to settle near others of their own species, or conspecifics (Stamps, 1988). The end result from a conservation perspective is that once a species no longer lives in an area, conspecifics will not re-occupy that area because there are no signs that members of their species inhabit it. Suitable habitat may therefore remain unoccupied. 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 (Kotliar and Burger, 1984); whitewash (mimicking droppings) to attract vultures (Sarrazin et al., 1996), and rhino dung to encourage settlement for translocated black rhinos (Linklater and Swaisgood, 2008). These cues can be either natural or artificial. Conspecific attraction as a conservation tool is proving particularly powerful in reintroduction and translocation programs, because, in fact, these conservation actions force a dispersal-like event upon animals whether or not dispersal is biologically appropriate. This may be one explanation for why so many reintroduction programs fail: released animals, following simple behavioral rules-of-thumb for site settlement, may ultimately vacate otherwise suitable sites because the sites lack conspecific cues.

Goals and Objectives

This study is the only one to date that tests the consequences of both passive and active relocation methods and evaluates the relative effectiveness of relocation (with and without the addition of conspecific cues) as a conservation method for BUOW. The primary goal was to improve wildlife mitigation strategies used for BUOW impacted by renewable energy development to decrease impacts on the species. By conducting a large-scale study on active and passive relocation of owls using a combination of satellite telemetry and field monitoring, the aim was to:

- Record and evaluate BUOW dispersal, mortality, and reproductive output in passive and active relocations compared with BUOW not planned for relocation (controls).
- Evaluate whether the addition of experimentally planted conspecific cues (visual and acoustic stimuli) improves owl post-translocation settlement.
- Determine the most effective mitigation method for BUOW impacted by development, and recommend best management practices and improvements.

CHAPTER 2:
Project Approach

Study Areas and Treatment Groups

Beginning in January 2017, relocated BUOW and control BUOW were included in the study across four regions of Southern California (western San Diego County, western Riverside/San Bernardino Counties, Imperial County, and Coachella Valley, Figure 1).

Figure 1: Project Locations Across the Study Region

Locations of all projects included in the study. Coachella Valley is located north of the Salton Sea in Riverside County, and Imperial Valley is located south of the Salton Sea in Imperial County.

Source: San Diego Zoo Global (SDZG)

Climate gradients of increasing temperature and decreasing precipitation stretch from the coastal western boundary of the study area to the desert eastern boundary. Urban development is concentrated in San Diego, western Riverside, and San Bernardino counties. Sites in Imperial County were influenced by a large existing matrix of subsidized agricultural habitat. Coachella Valley is divided between desert and subsidized areas of urban development, with a smaller proportion of agricultural habitat. While sample sizes were dependent on planned development projects, efforts were made to evenly distribute study owls by region and relocation type. A total of 58 BUOW were part of the study (Table 1). Additional BUOW were captured and fitted with global positioning system (GPS) transmitters but failed to provide enough data for inclusion in data analysis, typically because of transmitter malfunctions.

Table 1: Effective Sample Sizes for Each Treatment Group Representing the Number of BUOW That Provided Data

Group	Location	Project	Number BUOW	
			Project Total	Group Total
Passive Relocation	Total			**19**
	Western Riverside	Menifee Hts, Renaissance	2	
	Coachella Valley	29 Palms	3	
	Imperial Valley	Wistaria	5	
	San Diego	OtayX, Border	9	
Active Translocation w/Cues	Total			**13**
	Western Riverside	McElhinney	4	
	Imperial Valley	Sonny Bono	3	
	San Diego	MAP, JC	6	
Active Translocation, No Cues	Total			**10**
	Western Riverside	Lakeview	6	
	Coachella Valley	WRP4	4	
Resident Control	Total			**16**
	Western Riverside	El Sol, Morongo	3	
	Coachella Valley	29Palms, DHS	3	
	Imperial Valley	Sonny Bono, Wistaria	8	
	San Diego	Lonestar, MAP	2	
Study Total				**58**

Project locations are shown in Figure 1, with project names used to identify each relocation effort. Abbreviated names are used consistently throughout the report for all projects: Border Fence Replacement (Border), Caltrans Lonestar (Lonestar), Coachella Valley Water District Water Reclamation Plant 4 (WRP4), Desert Hot Springs (DHS), El Sol Conservation Area (El Sol), Johnson Canyon (JC), Lakeview/Nuevo Conservation Area (Lakeview), Lewis Management sites (Renaissance), McElhinney-Stimmel Conservation Area (McElhinney), Menifee Heights (Menifee Hts), Metropolitan Airpark Project (MAP), Otay Crossings (OtayX), Rancho Jamul Ecological Reserve (Rancho Jamul), Sonny Bono Salton Sea NWR (Sonny Bono), Spotlight 29 Casino (29Palms), Wistaria Solar (Wistaria).

Source: SDZG

Translocation Methods

For passive relocations, owls were captured, marked (banded), and fitted with GPS satellite telemetry units (Biotrack PinPoint Argos Solar, Wareham, UK) before excluding them from their burrows, with a timing target of one week prior to relocation (Figure 2). Relocation included creating artificial burrows if required by the regulatory agencies, installing one-way doors at entrances to original burrows, and plugging or collapsing the original burrows after owls had exited. Burrow excavation and collapse remained the responsibility of each development project, and was carried out in accordance with agency requirements.

Figure 2: GPS Telemetry Units on BUOW

Lotek/Biotrack PinPoint Argos Solar tags were fitted to BUOW before relocation

Source: SDZG

Active translocation included capturing and marking owls, immediately moving owls to release sites, and holding them in an aviary for an acclimation period ("soft release"). Actively translocated BUOW were moved to protected lands within Riverside, Imperial, and San Diego counties. Available release sites were limited and were identified through consultation with CDFW, USFWS, and other wildlife management agencies. Habitat suitability, predation risk, and security from disturbance were among the factors considered in selection decisions. As part of the soft release, actively translocated owls were kept in a temporary holding field enclosure (acclimation aviary) for 30 days. The acclimation aviaries were 12 x 12 x 6 feet in dimension and were removed after the holding period (Figure 3). Water and food, including rodent and invertebrate prey (crickets, mealworms) were provided approximately 2-4 times per week. In one case, supplemental food was provided throughout the breeding season. GPS telemetry units were attached 7 days before owl release and removal of the acclimation aviaries.

Figure 3: Acclimation Aviary Setup Used for Active Translocations During Study

Remote cameras were installed inside and outside the acclimation aviary to monitor BUOW welfare and activity around the acclimation aviary (wildlife and human).

Source: SDZG

Resident owls in areas adjacent to relocation sites were identified and included as controls. Control owls were captured and telemetered using the same protocols as those for relocated owls. GPS transmitters were attached using a backpack-style harness and the total weight of all attachments (GPS tag, backpack harness, bands) did not exceed 5 percent of body weight, in accordance with the federal banding permit. Efforts were made to capture owls to remove transmitters at the end of the study period, or when transmitters failed during the study period. At the end of the study period, transmitters were removed from 9 BUOW, 18 mortalities were documented, and 8 BUOW continued to be tracked past the study period. The remaining BUOW (23) provided data for the study, but despite being monitored with all available tools, could not be recaptured for transmitter removal before transmitter failure when their locations and fates became unknown.

Conspecific cue treatments consisted of: whitewash and auditory cues from existing resident owls (natural cues, Figure 4), artificial visual and auditory conspecific cues near installed artificial burrows, and no resident owls present and no artificial cues. The artificial cues were designed to indicate that other BUOW had settled in the area and found the habitat suitable. Artificial visual cues consisted of simulated whitewash (non-toxic latex paint). Acoustic cues consisted of playbacks of pre-recorded vocalizations from multiple individuals, using online sources with permission or proprietary recordings (Figure 4). The playbacks primarily consisted of territorial "coo-coo" calls. While territorial calls are not expected to attract settlement immediately adjacent to the playback speaker, they can still be attractive and encourage settlement in a variety of territorial avian species (Ahlering et al., 2010). No experimental manipulation of conspecific cues took place at resident control sites or for passively relocated owls.

Figure 4: Types of Conspecific Cues Used in the Study

Artificial acoustic cues were provided through timed recording playbacks (top left photo), and artificial visual cues to simulate whitewash were created using nontoxic white paint applied at burrows (top right photo). Resident owls already present at a translocation site provided natural cues (bottom photo).

Source: SDZG

Relocations were conducted across two calendar years (2017 and 2018). Several active and passive relocations were carried out during the nonbreeding season, September 1 through January 31. However, due to varying timetables of several development projects, four active translocations proceeded in consultation with CDFW between February 1 and April 15 (Table 2). In all, a total number of 47 BUOW were actively translocated for the study, and 23 of them were fitted with a transmitter and included for data analysis. To maintain data independence, one individual per actively translocated pair (n=15) received a GPS transmitter. Four additional telemetry units (2 control and 2 passive) failed within a month of deployment, preventing the collection of data for these owls. One actively translocated BUOW was also excluded from the analysis due to health concerns.

Table 2: Summary of Active Translocations Conducted Between February 2017 and April 2018 for the Complete Regional Study

County	Source Site	Capture Dates	Translocation Distance (km)	Release Site	Cue Type	Release Date	BUOW Translocated
Riverside	Audie Murphy/ Santa Rosa Academy	2/3/17 – 2/5/17	6.5	McElhinney-Stimmel Conservation Area	Artificial	3/7/17	4
Riverside (Coachella Valley)	Spotlight 29 Casino	9/3/17	14.3	Coachella Valley Water District Water Reclamation Plant 4	None	10/6/17	6
Imperial	Wistaria Solar	12/20/17	56.0	Sonny Bono Salton Sea NWR	Natural	1/22/18	5
San Diego	MAP (Brown Field Municipal Airport)	2/20/18–3/6/18	17.7	Rancho Jamul Ecological Reserve	Artificial	4/3/18	10
Riverside/San Bernardino	Lewis Management Renaissance	3/7/18 – 3/12/18	42.2	Lakeview/Nuevo Conservation Area	None	4/11/18	10
Riverside/San Bernardino	Lewis Management Renaissance	3/13/18–3/14/18	61.7	McElhinney-Stimmel Conservation Area	Natural	4/12/18	2
San Diego	Border Fence	7/4/18 – 7/5/18	5.6	Johnson Canyon	Natural	8/7/18	4 adults, 6 juveniles

Seven active translocation projects occurred during the study, including three projects that translocated 10 BUOW each.

Source: SDZG

Owl Tracking and Monitoring

Individual owls were tracked remotely through satellite GPS points collected at least three times a day. Data were downloaded and processed remotely. Remote cameras and visual surveys were used to monitor owl survival, nesting and productivity, and burrow occupancy. Remote cameras were mounted on a 2- to 4-foot-tall stake approximately 1-3 meters from the burrow entrance. During the breeding season, cameras were not installed at burrows until after evidence of incubation to minimize chances of nest abandonment. Field observations were conducted monthly during the non-breeding season (September-February) and weekly during the breeding season (March-August).

Advances in Tracking Technology

This project represented the first field use of new tracking technology for BUOW monitoring. When the initial batch of antennas suffered high rates of breakage in the field, the supplier created a reinforced antenna design that could better withstand field conditions. Insufficient solar recharge, in part caused by owls remaining in their burrows for long periods, also contributed to lower rates of data return than anticipated. Trials with a reduced daily fix rate (three times a day) showed improved tag performance, and this fix rate was used for all subsequent monitoring. Alterations to the vertical profile of the tag were also tested; results were inconclusive and changes to tag height did not seem to affect either solar recharge or owl behavior.

Habitat Data Collection and Analysis

The research team assessed habitat surrounding target burrows at two scales: fine-scale habitat within 10 meters of the burrow and macro-scale habitat within 100 meters of the burrow. Two 50-meter transects were anchored at the burrow and oriented to both 0˚ and 180˚. For meters 0-10 along each transect, point intercept readings for substrate, bare ground, vegetative functional group, and nativity (exotic/native forb, exotic/native grass, crop, or shrub) were collected every 0.5 meter. For meters 11—50, point intercept readings were taken every 1.0 meter. Two additional 10-meter transects were anchored at the burrow in the 90˚ and 270˚ directions, with point intercepts read every 0.5 meter. The resulting four short transects characterized habitat within 10 meters, centered at the burrow (n=80). The two long transects produced a linear measurement of 100 meters representing macro-scale habitat (n=100). All functional group types intercepting the point were recorded to accurately reflect multiple layers of vegetation. Vegetation height was also recorded at each point. BUOW burrows in areas with hard habitat boundaries were identified in the data with an infrastructure cover category that included areas of transect that crossed features such as concrete canals, other concrete structures, and both dirt and paved roads. Areas of transect blocked by impassable barriers were omitted from all calculations.

Natural burrow density was measured. These burrows were counted within a 4-meter-wide belt transect centered on each of the two long and two short transects per BUOW burrow (2 meters on either side of the transect). The number of burrow entrances attributed to small mammals, defined as burrows with diameters greater than 7 centimeters, were tallied. Density was calculated as the number of burrow entrances per square meter. In Imperial County, the mammal species were smaller, so the 7-centimeter rule was adjusted to include all small mammal burrows, which provided a relative measure of burrow suitability. Presence or absence of California ground squirrels (*Otospermophilus beecheyi*) was also recorded.

For each relocated owl, the protocol was carried out at least twice. Habitat for actively translocated BUOW was assessed at the origin burrow, the release (acclimation aviary) burrow, and the settlement burrow. If the BUOW settled at the release burrow, post-translocation habitat was only assessed once. For passively relocated BUOW, habitat was assessed at origin and settlement burrows. Control BUOW were assessed at origin and any subsequent settlement burrows. Settlement was defined as a minimum of 30 days of occupation.

Data Analysis

All data collected from the period January 25, 2017 to December 31, 2018 were included in the analyses.

Unless otherwise specified, statistical analyses were conducted as analysis of variance (ANOVA) or mixed-effects models in JMP® Version 14 software (SAS Institute Inc., Cary, NC, 1989-2019), with the significance threshold set at p=0.05. Distance was transformed with a log (n+1) transformation. Migratory birds were detected when telemetry revealed long-distance migratory movements away from the study area. Migratory birds were excluded from all analyses because migrants likely use different selection criteria for wintering burrows and their chance of dispersal was 100 percent (did not constitute a rejection of the habitat). Habitat data were analyzed for first-year burrows only (excluding second-year breeding burrows if known). BUOW whose status was unknown for specific variables were also excluded from those analyses.

Settlement status (yes/no) was defined as whether settlement occurred within 650 meters, or approximately one BUOW home range. If the BUOW was translocated to a conservation area, settlement within the conservation area was verified. Dispersal distance for passively relocated BUOW was calculated as the total distance traveled by the BUOW, including rest stops between the eviction burrow and the settlement burrow, if indicated by telemetry. For actively translocated BUOW, distance was calculated between the acclimation aviary/release burrow and the settlement burrow, including rest stops. For control BUOW the home burrow was the pre-dispersal location.

Breeding ('Breeding Attempted') was categorized as breeding/not breeding, and was identified by pairing and behaviors such as territorial vocalization, copulation, and burrow decoration. Reproductive success was defined as whether at least one chick survived to fledgling stage (yes/no). Two ordinal variables were examined that focus more closely on reproductive output. Maximum number of chicks was defined as the greatest number of post-emergent chicks at a single observation point, either from field observations or camera photos. Productivity was defined as the number of chicks to reach the fledgling stage (21 days post-emergence).

Survival was modeled in RMark with the Nest Survival module (Laake, 2013). This module can be applied to telemetry data with staggered entry and unequal sampling intervals (Rotella, 2019). A daily survival rate is calculated based on the number of BUOW that sent telemetry signals by day, and an exact mortality date is not required. Instead, the input parameters are the last date the BUOW was observed alive and the final date the status of the BUOW was checked. To determine the dates of BUOW mortalities, the last known alive date was determined using all sources of information, which included remote camera photos, field visit records, and GPS telemetry. The last checked date was entered as a confirmed/suspected mortality date or the transmitter recovery date. For BUOW with unknown or alive status, the effect of time lags between the last known alive and last checked dates was examined by setting the last checked date to the last known alive date. This effectively right-censored the dataset so that BUOW were excluded from subsequent survival estimations after their disappearance dates. The quantitative effect on survival estimates was relatively small, and the censored estimates were reported because they fit the model assumption of 100 percent detection probability. The model was run for an interval of 705 days (the period from January 25, 2017 to December 31, 2018). Daily survival rates were exponentiated by the appropriate number of days to calculate monthly rates for 1,3, and 5 months; for example, the daily survival rate was raised to the 30^{th} power to obtain the 1-month survival rate, and so on. The 5-month time period was selected as the longest that could be analyzed for the entire dataset, including BUOW that were relocated in mid-2018, and the Delta method was used to estimate standard error (Powell, 2007). Explanatory relationships with translocation type and covariates (settlement within 650 meters, dispersal distance, translocation distance, conspecific cues, and available burrows) were evaluated using Akaike's Information Criteria corrected for small sample size (AICc; Burnham and Anderson, 2002) in R 3.5.3 (R Core Team, 2019).

Habitat statistics at all burrows were calculated at two scales: fine-scale habitat within 10 meters of the burrow, and macro-scale habitat within 100 meters of the burrow. Areas of transect blocked by impassable barriers were omitted from all calculations. Absolute cover values were calculated by functional group and nativity. Transect portions covered by roads or concrete (for example, irrigation canals) were reported as "infrastructure," and bare-ground cover was also reported. Burrow density was calculated from burrow counts divided by the assessed area (square meters [m^2]): the sum of all assessed transect lengths (120 meters maximum length) x 4-meter belt transect width. Areas classified as road, canal, or other concrete infrastructure were omitted from calculations of burrow density. Habitat height was evaluated as height mean, height standard deviation, and maximum height in centimeters.

Analysis of Habitat Associations

Habitat was further characterized for all burrow locations used by study BUOW from publicly available remote sensing datasets. Burrows were characterized with the following habitat variables: aspect, distance to water, elevation, slope, and normalized difference vegetation index (NDVI, Table 3). Aspect was reported as a continuous variable with a correction for the circular range of the raw variable (Neilich and McCune, 1997). Distance to water was reported as the shortest distance from the burrow to water. Elevation, slope, and NDVI were averaged over a radius of 650 meters around each data point.

Climate variables (winter precipitation, spring maximum temperature, spring minimum temperature, and summer maximum temperature) were derived from PRISM temperature and precipitation data during the three years of the study (2016–2018). Although the study began in early 2017, 2016 climate data was required to accurately represent winter precipitation for the winter of 2016–2017, which was derived from the combined months of October 2016 through March 2017. A two-sample t-test confirmed that precipitation was significantly higher across the study area during winter 2016–2017 relative to winter 2017–2018 ($n=100$, $t=19.3$, $p<0.01$). Spring minimum temperature represents the absolute minimum temperature reported in January through March of each year. Summer maximum temperature represents the absolute maximum reported in the months of June through September.

Table 3: Habitat Characteristics Calculated From Publicly Available Remote Sensing Datasets

Source	Date	Resolution	Habitat Characteristic	Units
National Hydrography Database	2015	10 m	Distance to Water	meters
USGS EarthExplorer	March 2017	250 m	Normalized Difference Vegetation Index	Index (–1 to 1)
PRISM Climate Group	2016–2018	30 arc second (approx. 1 km)	Precipitation	cm
			Temperature	°C
Digital Elevation Model	2019	10 m (within US), 30 m (within Mexico)	Elevation	meters
			Slope	degrees
			Aspect	degrees

Burrow habitat characteristics were extracted from publicly available datasets, in addition to variables measured in field surveys.

Source: SDZG

Paired t-tests were used to compare burrows grouped by individual BUOW to evaluate habitat differences experienced by passively relocated and actively translocated BUOW. Origin sites were compared with settlement sites (acclimation aviary burrows were included if the BUOW settled there after release). Pre- and post-dispersal habitat differences were not evaluated for control BUOW due to very low levels of dispersal from origin burrows (n=2). All explanatory variables were assessed. Given these multiple comparisons, the false discovery rate (FDR) was controlled using the Benjamini-Hochberg linear step-up method to adjust the p-values (Benjamini and Hochberg, 1995).

Habitat and Settlement

Settlement was analyzed to examine which habitat characteristics could be correlated to dispersal events by actively translocated BUOW. The climate variables were selected from the year the BUOW was translocated.

Site-level analysis for the response variable of settlement within 650 m was conducted with beta-binomial mixture models using the glmmTMB package, version 0.2.3 in R (Brooks et al., 2017).

Analyses were also run with individual burrows as the experimental unit. At the burrow level, linear mixed effects models were assessed for all univariate habitat characteristics. Models were run using the R package lme4 (version 1.1-21, Brooks et al., 2017). Data clusters due to multiple burrows within sites were accounted for as correlated intercept and slope random effects. Settlement within 650 m was modeled as the explanatory variable as a factor with two levels (yes/no), with no set as the base level. All p-values were adjusted using the Benjamini-Hochberg procedure.

Habitat and Reproduction

Explanatory relationships between habitat characteristics and reproductive variables were evaluated with logistic regression for reproductive success (a binomial variable), maximum number of chicks observed, and chicks fledged (ordinal variables). The analysis of habitat characteristics was limited to burrows that were occupied during the breeding season. Relocation type was examined as a fixed effect, and lack of significance between relocation types was confirmed before combining all BUOW in subsequent models.

The climate variables were selected from the first breeding year following inclusion in the study. For example, a BUOW that was actively translocated in fall 2017 was tracked for breeding during spring and summer 2018. Therefore, the response variables for reproduction would be correlated to precipitation during October–December 2017 and January–March 2018, as well as temperatures during spring and summer 2018.

Site-level analysis for reproductive success was conducted with beta-binomial mixture models using the glmmTMB package in R (Brooks et al., 2017). Ordinal logistic regression was used to assess the maximum numbers of chicks observed and fledged.

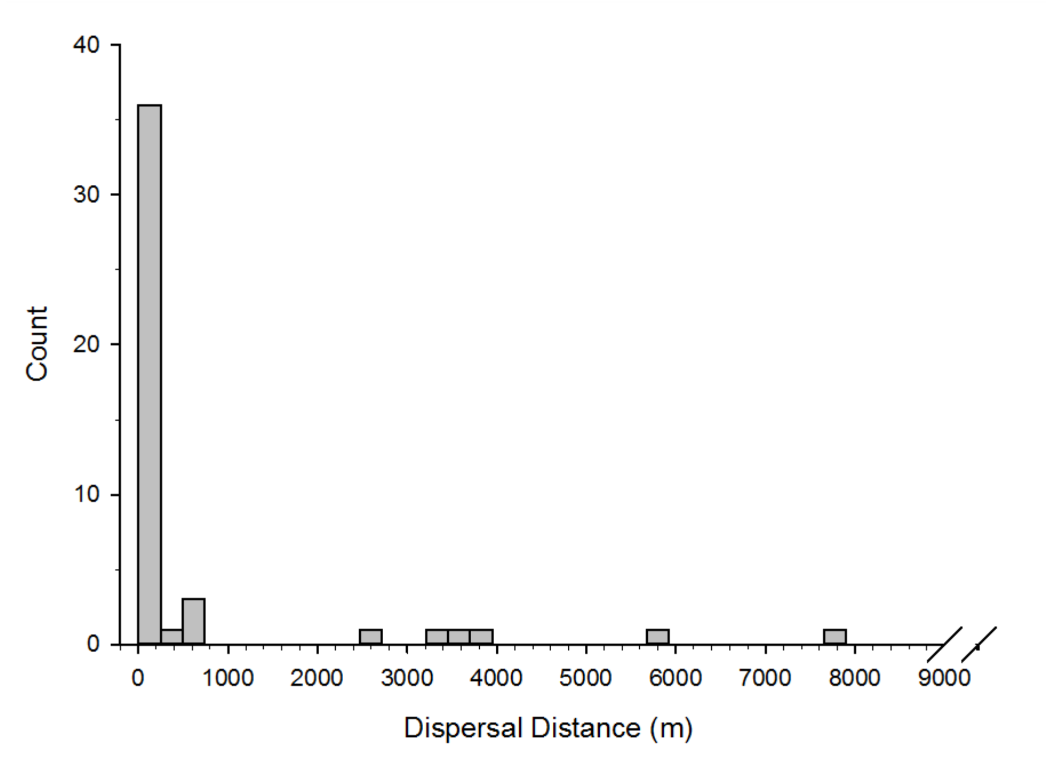
For reproductive success at the burrow level, linear mixed-effects models were assessed for all habitat characteristics. Data clusters due to multiple burrows within sites were accounted for as correlated intercept and slope random effects. Reproductive success was modeled as the explanatory variable as a factor with two levels (yes/no), and no was set as the base level. For burrow-level analyses of the maximum number of chicks observed and the number of chicks fledged, cumulative-link mixed models fitted with the Laplace approximation were assessed for all explanatory habitat characteristics, with site as a random effect and a probit link specified. All p-values were adjusted using the Benjamini-Hochberg procedure. Cumulative-link mixed models were run using the package ordinal (version 2019.4-25) in R.3.5.3 (Christensen, 2019).

CHAPTER 3:
Project Results

Settlement and Dispersal

The owls' settlement status (whether settlement occurred within 650 meters) and dispersal distances were examined. The limit of 650 meters corresponds to a break in the data between shorter and longer dispersal events (Figure 5). Most BUOW dispersal distances were less than the radius of an average BUOW home range (Gervais et al., 2003; Haug and Oliphant, 1990; Swaisgood et al., 2015). Eight BUOW undertook dispersal distances greater than 650 meters (median dispersal 4846 meters), and the maximum recorded dispersal was 40.7 km. The longest dispersal was undertaken by a BUOW that originated at the Rialto airport site, was actively translocated, and released to the Lakeview/Nuevo Conservation Area, then returned to the vicinity of the origin burrow at the Rialto airport.

Figure 5: Histogram of Dispersal Distances for All BUOW in the Study



Migratory BUOW are excluded (n=4). Two long-distance outliers are not shown at this scale (distances of 18.3 and 40.7 km).

Source: SDZG

For both actively translocated and passively relocated BUOW, the mean settlement rate within 650 meters was approximately 65 percent (Table 4). As expected, mean dispersal distance was much greater for both actively translocated and passively relocated BUOW relative to controls ($n=48$, $p<0.01$, $R^2=0.33$). Within each relocation group there were significant differences based on burrow availability (passives) or cue treatment (actives). Within the passive relocation group, dispersal distance was greater if burrows were unavailable nearby, although sample size was small and unbalanced (Table 4). When burrows were available, BUOW resettled on average 162.0 meters from their original burrow and retained their home range (n=13). By contrast, when no burrows were available nearby, BUOW left their home range and settled in new burrows an average distance of 3222.0 meters from their original burrow (n=2).

Table 4: Settlement Status and Dispersal Distance Across All Treatment Groups

Treatment	n	Settled within 650 m	Dispersal distance (m)				
			n	Mean	SD	Min	Max
Control	15	93.3%	14	35.7	133.6	0	500
Passive	19	68.4%	15	570.0	1121.1	9	3900
Burrows	16	81.3%	13	162.0	192.8	9	648
No Burrows	3	0%	2	3222.0	958.8	2544	3900
Active	20	65.0%	19	4236.0	9917.0	0	40719
Cues	11	90.9%	11	392.7	1051.7	0	3540
None	9	33.3%	8	9520.5	14006.7	0	40719
Total	54	72.2%	48	1865.0	6469.0	0	40719

BUOW that migrated (n=4) were excluded. BUOW with unknown settlement locations outside 650 meters (n=6) are included in the settlement status rate but excluded from distance calculations.

Source: SDZG

Within the active translocation group, exploratory analysis showed no significant differences between artificial and natural cues, so the cue treatments were aggregated into a single category representing the presence of cues. Actively translocated BUOW were 20 times more likely to settle within 650 meters when cues were present based on the log odds ratio (n=20, p=0.02, R^2=0.30). In addition, the farthest dispersal distances occurred when there were no cues, and the shortest dispersal distances were associated with conspecific cues (n=19, p<0.01, R^2=0.35).

For settlement within the active translocation group, both cues and translocation distance were significant predictors (n=20, p<0.01, R^2=0.57). Classification and regression tree analysis shows that the presence of cues was the primary effect (cues present were associated with increased settlement within 650 meters). There is also a secondary effect of translocation distance in addition to the presence of cues, in that BUOW that were translocated a distance greater than 17.5 km were more likely to settle.

All BUOW in the control group remained at their origin burrows through the first breeding season, except for one short-distance resettlement. While most passively relocated BUOW settled near their origin burrows, two BUOW (in western Riverside and San Bernardino counties) made longer dispersal movements. In both cases, no alternative burrows were provided, and all suitable habitat within the origin site was lost due to development. Five of the seven BUOW actively translocated to the McElhinney-Stimmel and Lakeview/Nuevo Conservation Areas settled within 650 meters, as did all BUOW translocated to Rancho Jamul Ecological Reserve and Sonny Bono National Wildlife Refuge (Table 5).

Table 5: Settlement Status and Dispersal Distance by Site

Relocation Type	Treat-ment	Site	n	Settled within 650 m	Dispersal Distance (m)				
					n	Mean	SD	Min	Max
Control Total			15	93%	14	35.71	133.6	0.0	500.0
		Sonny Bono	3	100%	3	166.7	288.7	0.0	500.0
		DHS	1	100%	1	0.0	-	0.0	0.0
		El Sol	2	100%	2	0.0	0.0	0.0	0.0
		Lonestar	1	100%	1	0.0	-	0.0	0.0
		Morongo	1	100%	1	0.0	-	0.0	0.0
		29 Palms	2	100%	2	0.0	0.0	0.0	0.0
		Wistaria	5	80%	4	0.0	0.0	0.0	0.0
	Burrows								
Passive Total			19	68%	15	570.0	1,121.1	9.0	3,900
	Present	29 Palms	3	0%	0	-	-	-	-
	Present	Border	8	100%	8	76.5	36.2	9.0	110.0
	Present	Wistaria	5	100%	5	298.8	267.0	56.0	648.0
	None	Menifee	1	0%	1	2,544.0	-	2,544.0	2,544.0
	None	OtayX	1	0%	0	-	-	-	-
	None	Renaissance	1	0%	1	3,900.0	-	3,900.0	3,900.0
	Cues								
Active Total			20	65%	19	4,236.0	9,917.0	0.0	40,719.0
	Cues	McElhinney	2	100%	2	0.0	0.0	0.0	0.0
	Cues	Rancho Jamul	4	100%	4	56.3	112.5	0.0	225.0
	Cues	JC	2	50%	2	1,770.0	2,503.2	0.0	3,540.0
	Cues	Sonny Bono	3	100%	3	185.0	191.3	0.0	382.0
	None	Lakeview	5	60%	5	11,851.8	17,965.2	0.0	40,719.0
	None	WRP4	4	0%	3	5,635.0	2,218.7	3,342.0	7,771.0
Grand Total			54	72%	48	1,865.0	6,469.0	0.0	40,719.0

BUOW that migrated (n=4) were excluded. BUOW with unknown settlement locations outside 650 meters (n=6) are included in the settlement status rate but excluded from distance calculations. Source: SDZG

Four BUOW initiated longer-distance migratory movements to the northeast. The telemetry data were consistent with use of a migration corridor through Nevada and subsequent dispersal to locations that included sites in Utah and Idaho.

Reproduction

A suite of reproductive variables was examined (Table 6). No difference in breeding attempts was detected between relocation treatment groups (n=32, p=0.36, R^2=0.13). There did not appear to be a reproductive penalty for translocated BUOW. There was a significant effect of settlement within 650 meters (n=32, p<0.01, R^2=0.55) on breeding status. The odds ratios were unstable because of unequal group sizes, but the trend could still be examined. The group of BUOW that attempted breeding (n=29) was much greater than the number that did not attempt breeding (n=3). Of the five BUOW that dispersed beyond 650 meters, a lower percentage (60 percent) bred, compared with the percentage that bred after settling within 650 meters (92 percent). This is not a surprising result, but should be cautiously interpreted due to the small sample size.

Of the subset of BUOW that did exhibit breeding behavior, there was no difference in the rates of reproductive success between relocation treatment groups (n=30, p=0.63, R^2=0.03). There were no treatment group differences for either maximum number of chicks (n=30, p=0.70, R^2<0.01) or productivity (n=30, p=0.70, R^2<0.01). All explanatory relationships between the effects of cue treatment on reproduction were also examined, but none were found to be significant. Trends in the data, however, show higher numbers of maximum chicks and fledglings after active translocation relative to either passively relocated or control BUOW. For passive relocations, burrow availability nearby also resulted in higher reproductive levels. However, these results were influenced by small sample sizes and potential site effects, such as the provision of supplemental food. This dataset does not yet have the statistical power to detect potential treatment effects on reproduction.

Table 6: Measures of Reproduction in the First Year after Relocation by Treatment Group

Relocation Type	Treatment	Release Site	Breeding Attempted		Reproductive Success		Max Chicks		Fledged		Percent Fledged	
			n	Percent	N	Percent	Mean	SD	Mean	SD	Mean	SD
Control		Total	11	100.0	11	63.6	3.0	2.9	2.1	2.4	69.0	34.8
		29 Palms	2	100.0	2	100.0	4.5	0.7	3.5	2.1	75.0	35.4
		El Sol	2	100.0	2	100.0	4.5	0.7	3.5	0.7	77.5	3.5
		Morongo	1	100.0	1	100.0	9.0	-	7.0	-	77.8	-
		Sonny Bono	3	100.0	3	0.0	0.0	0.0	0.0	0.0	-	-
		Wistaria	3	100.0	3	66.7	2.0	2.0	0.7	1.2	50.0	70.7
Passive		Total	7	85.7	6	83.3	2.8	1.9	2.3	2.1	80.0	29.8
	Burrows	Wistaria	**5**	**100.0**	**5**	**80.0**	**3.0**	**2.1**	**2.4**	**2.3**	**75.0**	**31.9**
	No Burrows		**2**	**50.0**	**1**	**100.0**	**1.0**	**-**	**1.0**	**-**	**100.0**	**-**
		Menifee	1	100.0	1	100.0	2.0	-	2.0	-	100.0	-
		Renaissance	1	0.0	-	-	-	-	-	-	-	-
Active		Total	14	92.9	13	76.9	3.5	2.0	2.7	2.2	75.0	35.6
	Artificial Cues		**5**	**100.0**	**5**	**80.0**	**4.4**	**2.6**	**4.2**	**2.5**	**95.8**	**8.3**
		McElhinney	1	100.0	1	100.0	4.0	-	4.0	-	100.0	-
		Rancho Jamul	4	100.0	4	75.0	4.5	3.0	4.3	2.9	94.4	9.6
	Natural Cues		**4**	**100.0**	**4**	**75.0**	**3.3**	**0.5**	**2.3**	**1.7**	**66.7**	**47.1**
		McElhinney	1	100.0	1	0.0	3.0	-	0.0	-	0.0	-
		Sonny Bono	3	100.0	3	100.0	3.3	0.6	3.0	1.0	88.9	19.2
	No Cues		**5**	**80.0**	**4**	**75.0**	**2.5**	**1.9**	**1.3**	**1.0**	**58.3**	**38.2**
		Lakeview	4	75.0	3	66.7	2.7	2.3	1.0	1.0	37.5	17.7
		WRP4	1	100.0	1	100.0	2.0	-	2.0	-	100.0	-
Total			32	93.8	30	73.3	3.2	2.3	2.4	2.2	74.3	32.9

BUOW that migrated (n=4) or with unknown breeding status (n=22) were excluded. Source: SDZG

Examining reproduction by region suggests a trend of lower reproductive levels in Imperial County, with a mean reproductive success of 64 percent (Table 7). In contrast, reproductive success in Western Riverside reached 78 percent. The small sample sizes for Coachella Valley and San Diego likely influenced estimates for those areas.

Table 7: Reproduction Variables Grouped by Region

Region	Breeding Attempted		Reproductive Success		Max Chicks		Fledged	
	n	Percent	n	Percent	Mean	SD	Mean	SD
Western Riverside	11	81.8	9	77.8	3.9	2.4	2.6	2.2
Coachella Valley	3	100.0	3	100.0	3.7	1.5	3.0	1.7
Imperial	14	100.0	14	64.3	2.2	1.9	1.6	1.9
San Diego	4	100.0	4	75.0	4.5	3.0	4.3	2.9
Total	32	93.8	30	73.3	3.2	2.3	2.4	2.2

The percentage of BUOW that attempted breeding are reported by region. BUOW that did not attempt to breed are excluded from calculations of reproductive success. All treatment types are included. Migratory BUOW (n=4) and unknowns (n=22) are excluded.

Source: SDZG

Survival

Examination of 95 percent confidence intervals for overlap indicated that by the end of the 5-month interval, the survival of actively translocated BUOW was lower than for passively relocated BUOW. AICc values are consistent with the presence of a treatment effect (for the treatment model, AICc=163.8 compared to AICc=173.1 for the intercept-only model). In terms of the adjusted survival rates, survival of actively translocated BUOW was 61.0 percent (SE= 9.5 percent) after 5 months, compared with 96.4 percent (SE= 3.5 percent) for passively relocated BUOW and 91.4 percent (SE= 5.8 percent) for control BUOW (Table 8). Adjusted survival estimates exclude individuals with unknown fates after their disappearance dates.

The covariate models for the effects of region, settlement within 650 meters, and dispersal distance produced AICc equal to or greater than the intercept-only model, indicating no measurable effect of these covariates on survival.

Table 8: Adjusted Survival Rates for BUOW after 1, 3, and 5 Months by Treatment Group

Relocation Type	Treatment	n	1-Month Survival (%)			3-Month Survival (%)			5-Month Survival (%)		
			Mean	SE	95% CI	Mean	SE	95% CI	Mean	SE	95% CI
Control		**15**	**98.2**	**1.2**	**93–100**	**94.7**	**3.6**	**81–99**	**91.4**	**5.8**	**70–98**
Passive		**19**	**99.3**	**0.7**	**95–100**	**97.8**	**2.2**	**86–100**	**96.4**	**3.5**	**77–100**
	Burrow	16	100	0	-	100	0	-	100	0	-
	No Burrow	3	92.5	7.2	58–99	79.1	18.6	19–97	67.6	26.5	6–95
Active		**20**	**90.6**	**2.8**	**83–95**	**74.3**	**7.0**	**58–85**	**61.0**	**9.5**	**40–77**
	Cues	11	87.4	4.4	75–94	66.8	10.2	43–83	51.1	13.0	24–73
	None	9	94.1	3.3	83–98	83.3	8.8	57–94	73.7	13.0	39–91

The estimates account for BUOW with unknown fates. Migratory BUOW (n=4) were excluded.

Source: SDZG

Within the active translocation group, the survival model was fit to test for the effects of conspecific cues. The AICc values did not indicate an effect of conspecific cues on survival (AICc=115.27 for the intercept-only model compared to AICc=115.85 for the same model with cues).

Finally, the survival model was fit to passively relocated BUOW to test for survival differences due to the presence or absence of available burrows. Model comparison using AICc did not distinguish between survival rates of BUOW evicted with and without a supply of available burrows (AICc=20.63 for the intercept-only model compared to AICc=19.90 for the model with burrows). Although the adjusted mean 5-month survival rate of BUOW relocated with burrows available nearby was much higher (100 percent, n=16) relative to BUOW with no burrows nearby (67.6 percent, n=3), the results are negatively impacted by unequal sample sizes. Greater sample sizes would be necessary to measure burrow availability effects on survival following passive relocation.

Unknown Fates

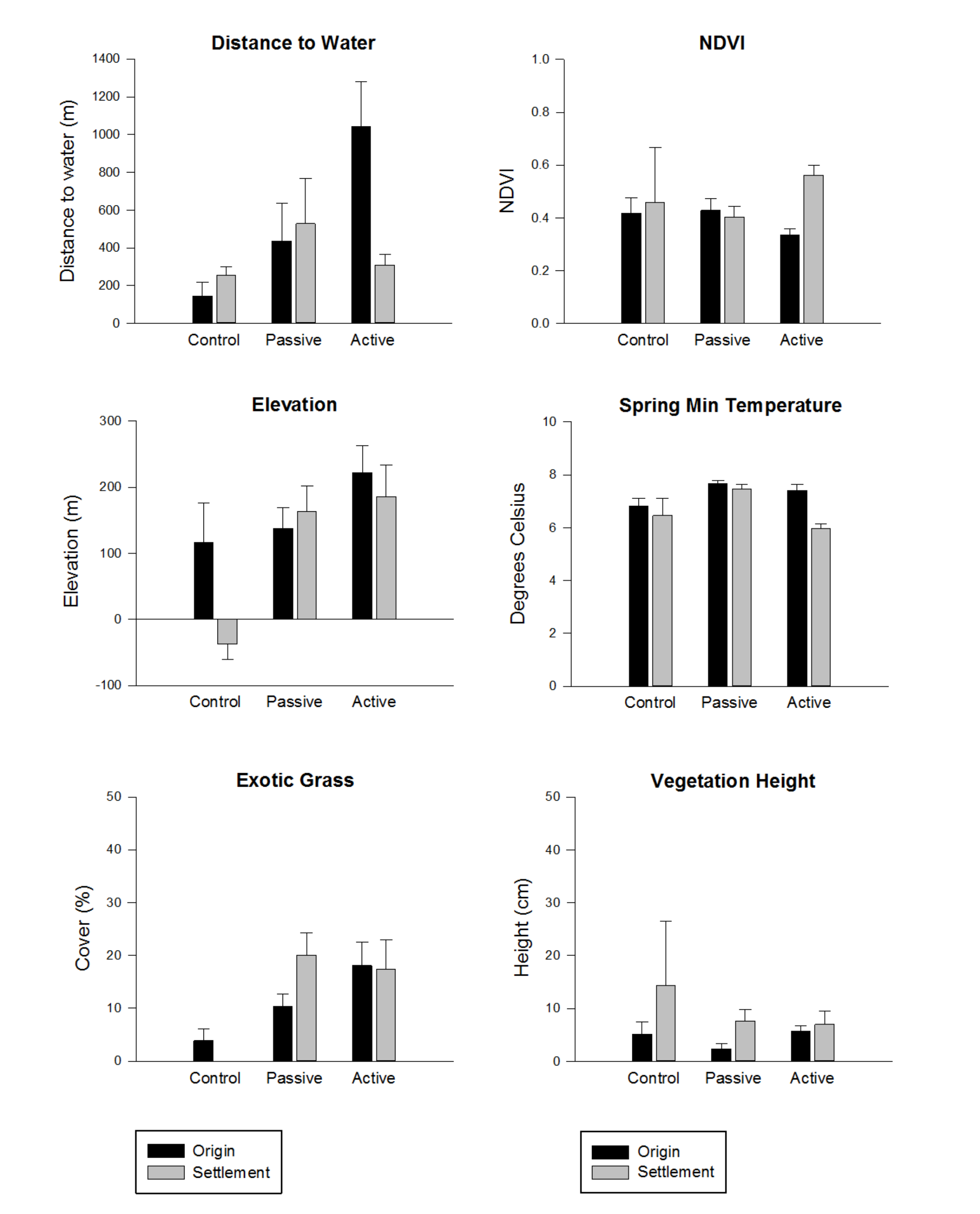
No BUOW died within the first month of inclusion in the study, but the mean percentage of unknown fates was 22 percent after 3 months and 30 percent after 5 months. By the end of the study, fate was unknown for 45 percent of the 58 BUOW in the study. The effect of this uncertainty is reflected in the increasing width of the confidence intervals up to the 5-month time point. The control group had the highest proportion of unknown fates, at 74 percent. The unknown rate of the passive group was 47 percent, and the active group was 30 percent. Even though the use of GPS telemetry produced partial data on fates, there were still a significant number of uncertain BUOW outcomes due to transmitter failure.

Habitat Associations

Paired t-tests captured important site differences between source and receiver sites for actively translocated BUOW. BUOW were translocated on average 791 meters closer to a water source than they had been before translocation (n=18, t=2.73, p=0.01). The Renaissance BUOW that were translocated to Lakeview/Nuevo and McElhinney-Stimmel experienced the greatest difference (2.6 km closer to a mapped water source).

As a group, the actively translocated BUOW were also moved to sites with higher NDVI than their origin sites (n=18, t=–8.31, p<0.0001, Figure 6). No BUOW were translocated to a receiver site with lower NDVI. This comparison captures the difference between often degraded source sites and higher quality receiver sites (usually grasslands managed for habitat structure through grazing or mowing). Since suitable habitat for BUOW consists of short vegetation cover with some bare ground, this result emphasizes that pre-translocation site evaluations should carefully measure existing vegetation community and the anticipated level of annual management. Active translocations also appeared to move BUOW to somewhat cooler sites, with average minimum spring temperatures that were 1.6˚C (34.9˚F) cooler than the origin burrow (n=18, t=5.92, p<0.0001).

Figure 6: Site Differences Between Habitat Characteristics of Origin and Settlement Sites for Each Habitat Variable by Relocation Treatment Group



For actively translocated BUOW, settlement burrows were either the release burrow (if the BUOW settled), or a subsequent settlement site if the BUOW dispersed from the release burrow.

Source: SDZG

The displacement of passively relocated BUOW also appeared to put BUOW in sites with more vegetative growth. Once evicted from their origin burrows, passively relocated BUOW settled nearby in burrows with an average of 9.3 percent greater exotic grass cover than origin burrows (n=12, t=–0.09, p=0.02). In these settlement locations vegetation height was also on average 6.1 cm higher (n=12, t=–2.72, p=0.02). The finding that passively relocated BUOW also settled in sites with an average of 7 meters greater elevation (n=12, t=–3.33, p<0.01) suggests a general pattern of exclusion from a preferred burrow site with sparse vegetation to less preferable and less suitable nearby burrow sites. This trend was likely an indication of the quality of the remaining habitat rather than of BUOW habitat preferences.

Habitat and Settlement

Settlement at the acclimation aviary site was evaluated for actively translocated BUOW. All climate and topographic models were assessed at site level, but no significant associations were detected. A similar pattern of nonsignificance was found at burrow level for all habitat characteristics. Settlement did not appear to be based either on climate and topographic features of the site, or on habitat structure in the vicinity of burrows (Table 9). While the quality of the habitat plays a critical role in successful BUOW occupancy and persistence over time, these findings indicate that BUOW are responding to signals other than the physical appearance of the habitat.

Habitat and Reproduction

At site level, significant associations were detected with ordinal logistic models. Sites with higher minimum spring temperatures were negatively associated with the maximum number of chicks observed (n=12, p=0.01, R^2=0.50) and the number of chicks that fledged (n=12, p=0.03, R^2 = 0.39). It appears that warmer sites supported lower numbers of chicks.

At burrow level, all habitat characteristics were examined, but no significant associations were detected. Generally, abiotic features of the habitat may be less important to BUOW reproduction than biotic features such as prey availability and predation pressure.

Table 9: Habitat Variables for All Origin and Settlement Burrows

Relocation Type	Cues	Burrow Type	n	Bare % cover Mean	Bare % cover SD	Exotic Grass % cover Mean	Exotic Grass % cover SD	Exotic Forb % cover Mean	Exotic Forb % cover SD	Infrastructure % cover Mean	Infrastructure % cover SD	Height (cm) Mean	Height (cm) SD	Height (cm) Min	Height (cm) Max	Burrow Density (Burrows/m^2) Mean	Burrow Density (Burrows/m^2) SD
Active			41	31.5	23.9	18.2	22.8	17.3	23.4	6.9	14.3	6.2	9.1	0.0	55.0	0.0072	0.0154
	Cues		24	28.4	25.7	27.0	24.3	19.1	22.8	6.6	16.7	5.1	4.8	0.0	17.1	0.0069	0.0127
		Origin	12	36.5	29.2	23.8	21.1	17.4	18.7	4.2	8.7	3.9	3.7	0.5	13.0	0.0088	0.0155
		Settlement	12	20.3	19.6	30.3	27.7	20.8	27.0	9.0	22.3	6.3	5.7	0.0	17.1	0.0050	0.0093
	No Cues		17	35.8	21.1	5.6	12.8	14.8	24.8	7.4	10.5	7.7	13.0	0.8	55.0	0.0077	0.0190
		Origin	8	20.3	15.6	11.8	17.1	31.2	28.6	12.5	12.7	7.6	5.0	1.8	12.6	0.0055	0.0054
		Settlement	9	49.5	15.1	0.2	0.7	0.1	0.3	2.9	5.5	7.9	17.8	0.8	55.0	0.0096	0.0263
Control			16	46.0	36.3	3.4	7.8	6.1	13.1	17.3	28.5	6.3	9.7	0.0	26.6	0.0118	0.0217
		Origin	14	47.5	37.6	3.9	8.3	6.9	13.8	18.6	30.2	5.1	8.6	0.0	23.1	0.0133	0.0229
		Settlement	2	35.5	34.6	0.0	0.0	0.5	0.7	8.5	12.0	14.3	17.3	2.1	26.6	0.0010	0.0015
Passive			30	33.5	34.6	15.8	15.1	8.6	12.5	5.8	11.4	5.4	7.6	0.0	29.3	0.0095	0.0078
		Origin	13	33.4	33.1	10.3	8.8	9.7	15.0	3.9	4.9	2.4	3.8	0.0	14.5	0.0134	0.0088
		Settlement	17	33.5	36.7	20.0	17.6	7.8	10.6	7.2	14.5	7.6	9.0	0.0	29.3	0.0066	0.0056
Total			87	34.8	30.5	14.6	18.9	12.2	19.0	8.4	17.3	5.9	8.6	0.0	55.0	0.0089	0.0147

The origin burrow was the pre-translocation burrow. For actively translocated BUOW, settlement burrows were either the release burrow (if the BUOW settled), or a subsequent settlement site if the BUOW dispersed from the release burrow.

Source: SDZG

CHAPTER 4: Knowledge Transfer Activities

Purpose and Organization

This chapter outlines the main information generated by the research on assessing California's mitigation guidelines for western burrowing owls and identifies the tactics used to disseminate this information. The overall goal is to provide an effective means of communicating research results to help improve the effectiveness of conservation actions designed to mitigate renewable energy and other development impacts on BUOW.

As their name suggests, BUOW use burrows for shelter, protection, and nest sites. However, western BUOW typically do not dig their own burrows and are reliant upon the number of burrows available in the environment that were dug by other species.

A large, potential problem facing BUOW relocations, both passive and active, is that owls may not remain in the areas to which they are relocated. Relocated wildlife of many species make long-distance movements after release, often suffering higher mortality rates and other negative consequences. This could also be the case for relocated BUOW. Previous experience with this species has established that obtaining useful movement and demographic data is not possible solely using visual identification bands attached to BUOW and re-sightings recorded in the field. Similarly, the use of VHF telemetry equipment, which requires "line of sight" to detect BUOW wearing VHF transmitters, is limited by battery life to relatively short periods of data collection by field-based observers. Instead, solar-powered state-of-the-art GPS satellite telemetry equipment is capable of transmitting location data to office-based researchers. This technology was attached to individual owls, and was supplemented by field-based observations. Thus, owl movements of all distances could be tracked, an important consideration for a partially migratory species such as the BUOW. This technology helped fill a large gap in the understanding of the effects of BUOW relocation and movements.

A second experimental manipulation tested whether the placement of behavioral cues that signal habitat suitability at the release site would encourage owls to settle where land and wildlife managers have determined there is safe, suitable habitat, and discourage owl movements away from these protected areas. Cues, such as artificial owl whitewash and acoustic recordings of owl vocalizations, can indicate to relocated owls that other BUOW are already present. These kinds of experimental "tricks" have previously been used for other bird species, and could be especially important for the BUOW, which can often be found living in loose groups. Each of these studies was enhanced by the collection of detailed habitat (and other) data. In combination, these methods yielded unprecedented data on the efficacy of BUOW relocations, and can now help managers develop new, more effective mitigation methods.

Technology and Knowledge

Specific results from this project include a summary of the responses of BUOW following passive and active relocation, including site fidelity, movement patterns, survival, and reproductive success; evaluation of the relocation techniques; the effectiveness of incorporating conspecific cues; and a set of management recommendations based on the results. The new knowledge from this study can be applied to determine effective BUOW mitigation strategies when renewable energy facilities are built in owl habitat. Owl movement and habitat use data can assist energy developers in site selection for new facilities and where best to relocate owls. Information generated from this study may also be used to improve mitigation techniques for BUOW so that they are more effective and avoid exacerbating population losses; develop best practices for reducing risk to critical renewable energy projects; identify more cost-efficient mitigation strategies that could help lower costs for ratepayers; and achieve better conformance with California state conservation objectives.

In addition, this project contributes to the pool of knowledge regarding the effective application of solar-powered GPS satellite telemetry units on BUOW. The newest light-weight solar GPS units (Lotek/Biotrack PinPoint Argos Solar) that allow remote downloads of data via satellite were used. This cutting-edge technology enabled this project's novel research by facilitating the tracking of BUOW movements across large areas and regions, which is critical for this partially migratory species. A collaborative approach to modifications and improvements to the GPS satellite transmitter design and trials of the transmitter fit on owls was undertaken with Lotek/Biotrack. The functionality of the transmitters was tested to determine the optimal rate of GPS fixes. Valuable lessons were generated through the deployment of these units, including actual fix frequency, life span of the units, and overall transmitter performance. This information helps improve the use of this technology for future wildlife research.

Objectives of Knowledge Transfer

The main objectives of this project's knowledge transfer activities were threefold: (1) to inform key stakeholders regarding management recommendations for BUOW mitigation strategies, based on research results; (2) to provide a better understanding of BUOW movements and habitat use for more informed guidance for development projects; and (3) to update and improve California's mitigation guidelines for BUOW. The target audience includes local, state, and federal regulatory agencies, energy and other land developers, land managers, environmental organizations, and the general public. A secondary objective was to share the experience gained with the GPS transmitters, which could benefit other researchers.

Transfer Tasks

The following tactics were used to transfer knowledge generated from this project:

Incorporating Key Stakeholders Into Project Implementation

Researchers coordinated with regulatory agencies, land managers, developers, and other project partners for all major project activities. CDFW, USFWS, county planners, local agencies (such as Imperial Irrigation District), scientists, and developers were all part of the Technical Advisory Committee (TAC). The TAC met twice a year and provided information about what form the results should take to make their use most effective. TAC meetings were held on October 14, 2016; February 1, 2017; August 2, 2017; February 1, 2018; September 19, 2018; and May 30, 2019.

Researchers also conducted regular meetings (once or twice a year) with stakeholders for effective coordination. For example, at the onset of the project, presentations were given at the Imperial County Quarterly Coordination Meeting, Coachella Valley Multiple Species Habitat Conservation Plan Coordination Meeting, and Western Riverside County Regional Conservation Authority (RCA). These meetings were attended by representatives from multiple agencies including Imperial and Riverside county planners, USFWS, CDFW, Bureau of Land Management, and partners at RCA and the Coachella Valley Conservation Commission.

Meetings with many landowners were held during site visits to potential study areas in Riverside, San Diego, and Imperial counties to identify suitable sites for BUOW passive and active relocations. These included Imperial Irrigation District, Sonny Bono Salton Sea National Wildlife Refuge, Riverside County Habitat Conservation Authority, Morongo Band of Mission Indians, Twenty-Nine Palms Band of Mission Indians, Cabazon Band of Mission Indians, and Coachella Valley Water District. In particular, owl relocation efforts were coordinated with RCA and field tasks conducted jointly to provide firsthand project experience to managers and other researchers.

Status Reports and Presentations

Status reports were provided at least once per year to project partners including regulatory agencies, land managers, and developers. These reports were distributed electronically in April 2017, July 2017, and June 2018. Presentations at local meetings, such as an update at the Western Riverside Multiple Species Habitat Conservation Plan Management and Monitoring Coordination meeting on November 8, 2018, were also provided. The purpose of these status reports and meetings was to inform stakeholders of project progress and address any questions.

Public Outreach

To reach a wide audience, a website was developed to highlight BUOW research and major findings (institute.sandiegozoo.org/burrowing-owl/burrowing-owl-recovery-program). This website is hosted on the San Diego Zoo Institute for Conservation Research website (institute.sandiegozoo.org), which receives on average over 15,000 page-views per month. A page of the website is dedicated to the research results of this study to communicate findings and share information to improve the effectiveness of conservation actions to mitigate renewable energy and other development impacts on BUOW.

In addition, as part of a graduate Master of Arts program offered by Miami University and co-sponsored by San Diego Zoo Global, a for-credit internship was created to develop message content for the new BUOW website. The student-generated website-ready text tailored to the general public covers topics that include passive relocation, active translocation, conspecific cues, and habitat suitability for BUOW. This new website will also serve as a portal for fostering connections with professional individuals and groups.

Publishing and Distributing Project Results

The results of this project will be publicly available and provided to local, state, and federal agencies (such as RCA, CDFW, and USFWS). These agencies will be able to directly access and use the research results to improve California's mitigation guidelines. Research findings will also be published in peer-reviewed journals and presented at scientific conferences. For example, a presentation was delivered at the annual meeting of the Western Section of The Wildlife Society on February 7, 2019.

CHAPTER 5: Conclusions and Recommendations

Discussion

Limiting post-translocation dispersal away from release sites is critical to the success of translocations (Batson et al., 2015; Stamps and Swaisgood, 2007). Long-distance movements following translocation have been shown across species to increase risk exposure and mortality rates (Le Gouar et al., 2012; Shier and Swaisgood, 2012; Stamps and Swaisgood, 2007). In this study, dispersal did occur post-translocation, but 65 percent of actively translocated BUOW settled at release sites. In contrast, dispersal rates within the control group showed resident populations to be quite stable, with only one BUOW, or 7 percent, dispersing.

The effects of conspecific cues on settlement were significant, indicating that, going forward, cues should be a component of active translocations. Cues at release sites for actively translocated BUOW were an effective strategy for anchoring owls close to their release sites. By contrast, owls that experienced no cues dispersed on average more than 24 times the distance of owls that experienced cues. Passively relocated BUOW also dispersed much farther away than actively translocated BUOW exposed to cues. Biologically, both artificial and natural cues of conspecifics appear to be powerful attractors for BUOW.

The dataset for reproduction is smaller than for other measures because it is limited to owls that established nesting burrows accessible for monitoring. None of the experimental manipulations significantly influenced any of the measures of reproduction, though an examination of trends may be revealing in light of the low statistical power. Mean productivity, measured as the number of chicks fledged per pair, was highest (4.2) for actively translocated owls that received artificial cues. Actively translocated BUOW receiving no cues had the lowest productivity (1.3).

These effects are the mirror images of the dispersal data and suggest that the no-cues experimental treatment group suffered lower reproduction as a result of high dispersal distances, while the artificial cues treatment group benefitted from shorter dispersal distances. Passively relocated BUOW had intermediate dispersal distances and productivity. These trends make intuitive sense biologically since long-distance dispersal incurs many costs including lost foraging opportunities and delayed breeding (Swaisgood and Ruiz-Miranda, 2019).

It is also possible that BUOW translocated to protected areas are subsequently able to benefit from the resources and relative safety associated with a landscape intentionally managed for conservation. Site-specific drivers could therefore underlie productivity at some of the translocation receiver sites. For example, at Rancho Jamul, supplemental food was provided during both the acclimation period and subsequent breeding season to ensure survival of both chicks and parents through the breeding season. This site received extra management support after translocation.

In addition to the significant positive effects of conspecific cues, support was found for the hypothesis that translocation distance influences owl settlement. Longer translocation distances appear to have a secondary additive effect on settlement when combined with cues. The higher settlement associated with longer translocation distances (greater than 17.5 km) suggests that BUOW translocated farther from their origin sites are less likely to attempt returns to those origin sites. This numerical value is a data-driven result from statistical modeling; future guidelines could require a minimum distance adjusted for rounding (such as 20 km) or for units (such as miles). While the ability to control translocation distance can be limited by the availability of high-quality receiver sites, translocation success may be higher when this guideline can be observed.

Survival

The survival analysis was based on a 5-month interval to balance the longest interval of available data for all BUOW in the study against the negative impacts on overall sample size due to transmitter failures and unknown fates. BUOW survival at 1- and 3-month intervals was also examined. The assessment of BUOW fates 1-month post-treatment contributed little useful information because all BUOW tracked survived at least 1 month regardless of treatment or site differences. Likewise, using a single month of post-relocation monitoring to determine whether a particular relocation or translocation can be deemed successful or not is likely insufficient. By the end of 5 months, the survival rate for actively translocated BUOW was significantly lower than for passively relocated BUOW or controls, although treatment effect was confounded with transmitter failure. An imbalance in the number of unknown fates for passively relocated and control BUOW versus unknown fates for actively translocated BUOW obscure the true effects of translocation on survival.

A higher survival for passive relocations was expected to contrast with lower survival rates in the active translocations. Translocation is a stressor that places animals in novel conditions where they must learn quickly to survive, and previous animal translocations across many species have established that mortality is highest in the initial weeks following animal translocations (Stamps and Swaisgood, 2007). Across species, mortality rates following release can often exceed 50 percent (Harrington et al., 2013). By comparison, most of the owls in the passive treatment group were from two large relocations. Both sites coincidentally provided relatively ideal conditions for passive relocation. For the Wistaria Solar project in Imperial County, the site was developed much later than planned, so although owls were evicted from their burrows, they were able to establish nearby in readily available and plentiful burrows and did not lose foraging habitat. Likewise, eight owls were passively relocated from burrows affected by the replacement of sections of the U.S.-Mexico border fence in San Diego County. Most of the border BUOW moved less than 650 meters north of the fence. Foraging grounds were unaffected at the time, although they will eventually be lost to the development of a new border crossing. Once the fence replacement was completed, squirrels began digging along the fence again, and the passively relocated BUOW began moving into the new burrows. The passive relocations included in the current study therefore likely represent best-case scenarios. Previous research studies have reported high survival rates for short-distance passive relocations like these (Trulio, 1995). Judgement should be reserved on whether most passive relocations will have similarly high survival rates. Unfortunately, an unbalanced portion of the sample (n=3) was drawn from smaller projects, conducted under less-ideal conditions and with less incentive to work with researchers. The lower survival estimates, while not robust enough for significance testing, suggest higher mortality under these circumstances. The actual numbers of BUOW affected by passive relocation under less-ideal conditions is unknown so collecting additional data (both numbers and outcomes) is a priority.

However, the long-term value of active translocation may exceed that of passive relocation, even if initial survival is lower. The prospect of increasing future threats and habitat loss may drive the need for translocation of BUOW to protected areas. In many locations in Southern California, renewable energy and urban development are underway, with more projects planned over the next decade. Many resident BUOW face the prospect of serial passive evictions from home burrows as development unfolds. A second and related scenario develops when areas with historic BUOW populations have changed to the point where they no longer meet the habitat needs of the species, and have therefore become ecological traps (Hale and Swearer, 2016). In these locations owls are attracted to settle, but their future survival and reproduction will be restricted to low levels with little or no prospect for future population sustainability.

Burrow Availability in Passive Relocations

Examination of survival and reproductive trends also provides insights into best practices for passively relocated BUOW. Survival rates appeared lower when there was no nearby supply of available burrows. Although this dataset did not have the statistical power needed to detect differences in reproduction, trends in the data suggested that a lack of nearby available burrows was also associated with lower reproductive success. The finding that dispersal distance was greater when burrows were unavailable suggests an advantage for BUOW that quickly locate and select a new burrow. This supports the CDFW recommendation to install nearby artificial burrows (or ensure the presence of available natural burrows) for passive relocations. For passive relocation, reporting within an HCP or NCCP is not required by CDFW and may not require a mitigation plan; this could result in a significant proportion of passive relocations occurring without the provision of nearby burrows, which may incur survival and reproductive costs to affected owls.

Burrowing Owl Use of Open Habitat

The habitat data reveal additional potential consequences of relocation or translocation that depend on the habitat condition of settlement sites. In active translocations, receiver sites are usually grasslands with greater vegetative cover than the origin burrow. Suitable habitat for BUOW consists of short vegetation cover with some bare ground, and if annual vegetation management does not occur, receiver sites can quickly become unsuitable for BUOW. The data also indicate that passively relocated BUOW often subsequently settle in burrows with lower habitat quality. Since the researchers found no relationship between particular habitat characteristics and BUOW settlement, other factors such as proximity of burrows or conspecifics may play a greater role. For both active translocations and passive relocations, pre-translocation site evaluations should carefully measure existing vegetation communities and anticipated levels of annual management.

Unknown Fates

GPS transmitter issues posed a significant problem, reducing the effective sample size. While the target sample size for the study was met, the effective sample size for statistical analysis was lower due to unknown outcomes for owls with failed GPS transmitters. The cause of the failures was mainly due to antenna breakage and insufficient solar recharge of the

Lotek/Biotrack PinPoint Argos Solar tags. Feather coverage along with owl behavior (such as occupying burrows or being under cover during the day) were the leading culprits for the lack of solar recharge. Reinforced antennae replaced the more sensitive ones, and a reduced daily fix rate was adopted to reduce the draw on the battery. It was confirmed that the reduced daily fix rate provided sufficient location data for continued monitoring of BUOW locations. The back feathers were trimmed when owls were captured or recaptured to reduce feather coverage of the solar panel. These alterations provided some improvements, but the basic challenge of tracking these small owls that occupy underground burrows remains. Future BUOW studies involving GPS transmitters should take these issues into account.

Conclusions

This research provides the first data that evaluate the effectiveness of both passive relocation and active translocation when compared with control BUOW not impacted by renewable energy development. These results provide data-supported recommendations to aid managers in their decision-making when BUOW relocation must be implemented to mitigate development impacts on burrowing owls.

As recommended by CDFW (CDFG, 2012), avoidance should be given full consideration before relocation of any kind. This study showed high survivorship for BUOW that were not relocated (control treatment group). There was significant uncertainty about the owls' long-term fates, even when state-of-the-art tracking technology was used in coordination with regular field observations. Decisions regarding the suitability of passive relocation or active translocation should only be pursued when avoidance is not possible.

When avoidance and minimization measures are not possible, a determination must be made as to whether passive relocation or active translocation is the better choice. This decision should be driven by site-specific conditions and the feasibility of implementing the recommended protocol described here. Considerations will depend on each development project's location relative to urbanization, current and future rates of development infill, availability of suitable habitat and burrows, the potential for long-term BUOW security, and other conservation goals.

There is mounting evidence that mitigation-driven translocations as currently implemented may be ill-suited to the biological needs of many species (Germano et al., 2015). In California, both passive relocation and active translocation of BUOW are often mitigation-driven and suffer from some of the shortcomings outlined by Germano et al. (2015), including a lack of documentation of outcomes, a failure to contribute to conservation of the species, and inaccessibility of data from past relocation efforts. As the CDFW Staff Report (CDFG, 2012) states, it is time to move away from ad hoc approaches and toward a coordinated conservation strategy with respect to mitigations for BUOW.

In passive relocations as currently practiced, the timing of burrow eviction is often not synchronized with natural dispersal cycles. Alternate burrows are frequently not available within the home range, and there may not be adjacent suitable habitat. In some cases, adjacent suitable habitat may be temporarily available, but susceptible to subsequent development. In these situations, serial passive relocation of the same BUOW may result in cumulative impacts detrimental to survivorship. If the probability of serial evictions in a specific area is high, active translocation to a protected conservation area should be considered within a well-planned framework.

Many active translocations are also mitigation driven. Factors such as the optimal group size for translocation, translocation timing, and site preparation may not be fully considered or properly implemented. Post-release support such as sufficient artificial burrow maintenance, predator control, and supplemental feeding may not be provided. Generally, active translocation is challenging, and failure may occur even if most factors have been addressed. Seasonal variations in natural systems further interacts with all of these factors to influence the outcome of each translocation effort. However, applying scientific principles and best practices for BUOW to traditionally mitigation-driven translocations is critical for improving the success rate (Germano et al., 2015). This study provides evidence that these principles hold true for BUOW. There is an opportunity to improve existing mitigation methods for renewable energy development and to also incorporate biological principles in order to achieve more conservation-oriented outcomes for BUOW. By including additional steps and provisions to current mitigation-driven actions, BUOW translocations can move toward and enhance conservation efforts.

Recommended Translocation Protocol

Overall Considerations

Monitoring

Long-term monitoring should be implemented both before and after project impacts occur. Prior to the project impacts, BUOW should be monitored throughout a breeding season to determine the number of BUOW occupying burrows and their status (such as single owl, pair, migratory). Due to the overlap of wintering migrants and local residents in California during the non-breeding and early-breeding seasons, it is impossible to determine which BUOW are likely to depart the location on their own and which are residents likely to remain in the vicinity. Of the four study owls that made migratory movements out of the region, three were trapped in close proximity to resident BUOW. A determination of migratory status could be made through repeated field observations that include the number, breeding status, and locations of marked and unmarked BUOW. In order to track the outcomes of individual relocation projects, BUOW should be marked and a comprehensive effort made to re-sight marked owls. The best practice for an effective monitoring strategy should include early consultation with CDFW to ensure that required field information is collected.

Monitoring following passive relocation and active translocation should be done to ensure that BUOW mortality is minimized, to be informed of potential concerns to BUOW survival such as high predation requiring predator control, and to determine the success of the relocation or translocation. Post-relocation monitoring can provide information on BUOW presence and survival, local movements, reproductive success, and predation events. If relocated BUOW are marked, long-term monitoring allows for documentation of continued occupancy of the receiver site by the impacted BUOW, their use of any installed artificial burrows, and whether BUOW disappear (assumed to have left the area or died).

The results of all monitoring should be reported to CDFW. Additionally, passive relocations are generally underreported (pers. comm., CDFW Ontario office staff); this contributed to low sample sizes within the passive relocation treatment group in this study. The addition of language to the CDFW Staff Report (CDFG, 2012) requiring that monitoring reports be submitted to CDFW for all expected passive relocations prior to relocation is recommended. Reporting to CDFW needs to become an integral part of passive relocations that occur under an HCP, NCCP, or California Environmental Quality Act (CEQA).

Timing

Although it was outside the scope of this study to test the effects of the timing of relocation, this topic deserves mention. Mitigation-driven relocations and translocations do not allow for optimal timing because development project schedules dictate when BUOW are moved off-site. Aiming for biologically relevant timing should be explicitly required when planning for either relocation or translocation. Data-driven recommendations for optimal timing are not yet available, but the topic is discussed further under Future Research Needs.

Best-Practice Recommendations for Passive Relocation:

Pre-Impact

- Notify CDFW about all planned passive relocations, including those within HCP and NCCP plan areas to facilitate landscape-based planning efforts (CDFG, 2012).
- Evaluate nearby habitat suitability (for example, within BUOW home range) and long-term stability in terms of the risk of future development to determine if passive relocation will meet a conservation-driven framework. Serial eviction of the same BUOW should be avoided. If the probability of serial evictions in a specific area is likely, active translocation to a protected conservation area should be considered.
- In coordination with CDFW, monitor BUOW on the project site throughout a breeding season before relocation to determine burrow occupancy and residency status.
- Currently, passive relocation may proceed without the installation of artificial burrows. However, the results of this study suggested that the availability of burrows affects settlement and survival. If there are no suitable burrows available, install at least two artificial burrows per BUOW, ideally within 100 meters of the original burrow or within the average BUOW home range (650 meters) prior to relocation. To account for territory size, intraspecific aggression, and competition, artificial burrow complexes (minimum of two burrows) should be separated from other artificial or resident-occupied burrows by a minimum of 100 meters.
- Artificial burrow design should include two entrances per nest chamber, using a Y-design, with gently downward sloping tunnels and a gradual bend. The first 18-24 inches of the burrow entrance openings should have a 6-inch diameter narrowing down to a 4-inch diameter tunnel. A removable nest chamber top provides access for burrow maintenance and post-relocation monitoring of eggs and chicks, but security of the site should be considered before implementing this aspect of the burrow design. This study used the design depicted in Appendix A.
- To document the outcome of the relocation, marking individual BUOW prior to relocation is essential.

Exclusion/Eviction

- Install one-way doors at burrow entrances for at least 48 hours prior to burrow collapse and relocation.
- Conduct twice-daily monitoring of installed one-way doors to ensure the integrity of the exclusion device.
- Burrows should be monitored and examined using a burrow scope to ensure that no owls are inside prior to burrow excavation and collapse.
- To avoid potential re-occupancy of burrows, the original burrow and any nearby satellite burrows should be plugged or collapsed after owls have been evicted.

Post-Impact/Relocation

- Monitoring should be conducted at least through the first breeding season following relocation to document occupancy and reproductive success and to re-sight marked BUOW, as applicable. Repeated field observations should include the number, breeding status, and GPS locations of either marked or unmarked BUOW.
- Monitoring may be supplemented with remote cameras to increase the number of observations and document nest productivity and other measures.

Long-Term Commitments

- Long-term habitat management to reduce exotic grasses and forbs and promote open ground is recommended to improve settlement and retention.
- To ensure functionality and continued use by relocated owls, long-term maintenance of artificial burrows is needed at least annually to inspect for damage and repair needs, clean out dirt and debris, replace dirt fill around or on the top of the artificial burrow, and maintain any installed perches.

Best-Practice Recommendations for Active Translocation

Translocation Planning

For better long-term outcomes, an active translocation should include provisions designed to maximize settlement, survival, and reproductive success, including the following recommendations.

- Active translocation requires additional permitting. Coordinate with both CDFW and USFWS Migratory Bird Offices to acquire proper permits.
- BUOW should be translocated farther than ~20 km (at a minimum) from their origin burrow to prevent return to the site of capture ("homing") and to maximize settlement at the release site.
- Without adequate monitoring prior to translocation, resident and migratory BUOW cannot be distinguished from one another. Translocation of migratory BUOW may result in decreased settlement at receiver sites and pose survival risks to migratory BUOW.
- Receiver site selection is critical for improving the success of a translocation. Receiver sites, to the extent practical, should be conservation areas or other lands expected to be managed in perpetuity for wildlife. The conservation goals of protected lands allow

management for lower vegetation height (mowing, grazing, herbicide, controlled burns), adequate prey, natural burrows (i.e., ground squirrel populations), and an annual maintenance protocol for artificial burrows. Habitat suitability, prey availability, and predator pressure can be assessed through rapid-assessment style monitoring. An example of a protocol designed for BUOW was implemented in San Diego County in 2016-2017 (ICR, 2017).

- Receiver site selection should include an assessment of nearby trees, tree groves, power poles, and buildings that provide habitat and perches for raptors that prey on BUOW. Sites with trees, tree groves, power poles, or buildings in close proximity to BUOW nest burrows should be avoided due to the potential for increased predation pressure.
- BUOW should be translocated in groups. Translocating a minimum of five BUOW pairs together is the current best practice to produce levels of settlement and reproduction that are sufficient for establishing a new BUOW population. When only a single BUOW or small numbers of BUOW are translocated, they should be translocated to areas with existing resident BUOW.
- Translocation of known or presumed pairs is recommended to improve settlement.
- Presence of conspecifics or, in their absence, application of artificial visual and acoustic conspecific cues reduce dispersal and help anchor translocated BUOW to the release site. Acoustic cues should consist of a system to broadcast recordings of BUOW calls. The recordings should consist mainly of the coo-coo call, and alarm calls should be used sparingly or not at all. The timing and duration of recording broadcast deployment should be 1 week before and 1 week after BUOW release from acclimation aviaries. Vocalization playback frequency should be based on field recordings of wild BUOW vocalization rates (ICR, unpublished data).
- Translocation of BUOW during the early fall when recently fledged juveniles are still dependent on adults is not recommended.
- To understand the outcome of the translocation, marking individual BUOW before release is essential.
- Provision of adequate numbers of burrow clusters is an important consideration, with a long-term commitment to burrow maintenance when artificial burrows are used.
- Adequate spacing between translocated BUOW is required, with a minimum spacing of 100 meters between acclimation aviaries to reduce intraspecific aggression and competition. Since the presence of conspecifics facilitates settlement, spacing between acclimation aviaries should not normally exceed 300 meters.
- Acclimation aviaries should be at least 12 x 12 x 6 foot enclosures, with heavy gauge steel mesh side panels, and a strong nylon mesh top covering. BUOW perches should be installed inside acclimation aviaries. Perches placed at least 5 feet above the ground help reduce superficial injury to BUOW trying to avoid humans during husbandry activities.

Translocation Period/Post-Release Monitoring

- Remote cameras should be installed inside and outside acclimation aviaries to supplement regular field visits and improve monitoring of BUOW health and behavior, evidence of trespassers, and presence of predators.
- An acclimation period of 30 days in the acclimation aviary is recommended.
- Field visits to monitor and feed translocated BUOW should be conducted three times per week during the acclimation period through the breeding season and fledging, then decrease gradually to wean BUOW from supplemental food.
- Supplemental feeding should occur during both the acclimation period and through the subsequent breeding season. Breeding male BUOW are particularly stressed by the dual challenges of providing for offspring and acclimating to predator pressure at the release site. Regular provisioning can support the survival of both chicks and parents through the breeding season.
- The amount of supplemental food provisioning should be tailored to the number and life stage of BUOW at each burrow. At nest burrows, individual consumption levels of chicks increase steadily until the beginning of the fall dispersal to wintering sites.
- No provisions should be left outside the burrow or otherwise accessible to predators, especially corvids and coyotes. Unused provisions should be removed at each visit; however, natural caches should not be removed. Predator levels should be monitored routinely (potentially with the deployment of remote cameras and photo review).

Long-Term Commitments

- Predator control actions may be necessary. This study documented increased predation risk from common ravens, which necessitated hazing and control methods.
- Monitoring should be conducted at least through the first breeding season following relocation to document occupancy and reproductive success and re-sight marked BUOW. Repeated field observations should include the number, breeding status, and GPS locations of either marked or unmarked BUOW.
- Monitoring may be supplemented with remote cameras to increase observations that document nest productivity and other measures.
- Long-term habitat management to reduce exotic grasses and forbs and promote open ground is recommended to improve settlement and retention.
- Long-term maintenance of artificial burrows is needed annually (at a minimum) to inspect for damage and repair needs, clean out dirt and debris, replace dirt fill around or on the top of the artificial burrow, and maintain any installed perches.

Future Research Needs

Passive Relocation and Available Burrows

Due to the challenges encountered in this study in identifying opportunities to include passively relocated BUOW, the results relating to the availability of nearby burrows at the time of eviction or impact were limited, though tantalizing. The results suggested that there is a deep cost to BUOW without nearby burrows in terms of settlement, reproduction, and survival.

Larger sample sizes, particularly for BUOW without nearby burrows, are needed to verify the results with more statistical power.

Another important aspect regarding burrow availability during passive relocation is the proximity and number of available burrows. Trulio (1995) recommended that artificial burrows be placed within 100 meters of the impacted burrow, based on the average BUOW territory size. However, in current practice, artificial burrows may be installed well outside of the existing territory, at an entirely different site, or not installed at all. When passive relocations occur, additional data need to be collected within an experimental framework to enable a robust analysis of the effects of alternate burrow number and proximity on settlement, reproduction, and survival of displaced BUOW.

Relocation/Translocation Timing

The CDFW Staff Report states that passive relocations should only be conducted during the non-breeding season (August 31 to February 1), and only authorizes active translocation within the context of scientific research or a NCCP conservation strategy (CDFG, 2012). Active translocation studies indicate that the chance of success is best when owls are moved just prior to egg-laying (early breeding season) or while adults have young in the burrow (Trulio, 1995; Smith and Belthoff, 2001; Leupin and Low, 2001; Mitchell et al., 2011). Currently, mitigation-driven relocations and translocations do not allow for control over the seasonal timing because development project schedules dictate when BUOW are moved off-site. Timing of actions is a major area where mitigation could be tailored to better match both the biological needs of BUOW and conservation goals.

Although results from this study do not provide a sufficient sample to statistically analyze the optimal timing of passive relocation or active translocation, field observations provide a basis for hypotheses. Translocation during the non-breeding season (particularly the early non-breeding season), when owls are less site-faithful and more likely to disperse, may result in BUOW moving away from intended receiver sites. Alternatively, timing translocation to coincide with periods of natural dispersal (such as juvenile dispersal) may result in better settlement (Le Gouar et al., 2012). Translocation during the late non-breeding season, in February or early March, or in the early breeding season in March and April could also increase the likelihood that BUOW will remain to raise their young. Challenges to this approach exist. Estimating the BUOW breeding cycle can be done based on behavior; however, if BUOW inhabit natural burrows, there is no reliable access to the nest chamber to confirm breeding timing and exactly when a nest is initiated or eggs are laid. When such anchoring attempts are made, however, it is especially important to provide supplemental food or risk forcing starvation upon a parent owl committed to rearing young even if it is unable to obtain sufficient prey.

Factors such as age or sex of an individual owl that may affect relocation outcomes and how those factors interact with seasonal timing of relocation are not well understood. These are all potential variables that should be examined when relocation or translocation takes place, but may not be available without long-term monitoring in place.

Long-Term Outcomes

Even with state-of-the-art tracking technology in combination with regular field observations, the study's findings were marked by significant uncertainty regarding long-term fates for many

BUOW. Within San Diego County, where there is an on-going research program and the BUOW population is marked, it may be possible to obtain additional covariate data to help understand the longer-term outcomes of relocation. Increased support for marking BUOW exposed to relocation and translocation would benefit long-term monitoring goals.

Improved monitoring of passively relocated BUOW is necessary to quantify the extent to which individuals experience serial eviction and cumulative impacts on survival and reproduction. A wider range of approaches to passive relocation also needs to be evaluated, as this project's dataset was limited to relatively ideal circumstances and may not apply in situations where nearby suitable habitat and burrows are less available. Long-term monitoring with coordination among federal, state, and local regulatory agencies is needed to understand survival, reproductive success, and return rates or site fidelity of young BUOW produced at receiver sites, and determine the success with which new colonies can be established using active translocation approaches. These data will better clarify the extent to which active translocation can contribute to conservation by establishing new BUOW populations or maintaining and bolstering existing ones.

CHAPTER 6: Benefits to Ratepayers

Renewable energy development could potentially contribute to the continuing decline of BUOW populations because of planned facility expansions in the owls' habitat throughout Southern California. Similar impacts could also occur elsewhere in California wherever BUOW live.

Environmental impact minimization is an essential and mandated component of all development, including for renewable energy facilities. California law requires new and additional sources of clean energy while simultaneously complying with environmental laws and regulations. Californians rely on healthy ecosystems for many reasons including the services they provide, human health, recreation, and many other benefits. Ratepayers demand that environmental mitigation strategies should conserve shared natural resources as much as possible and in a cost-effective manner so that electricity rates are not raised unnecessarily.

Wildlife mitigation efforts, especially those involving the relocation of wildlife away from development areas, are often either ineffective or poorly documented. The current cost of burrowing owl mitigation is significant, approximately $20,000 per active relocation in western Riverside County (Laurie Correa, pers. comm.); and those costs will go up if this species' decline continues to the point where it becomes protected under the Endangered Species Act (ESA) of 1973 or the California Endangered Species Act (CESA) (Fish and Game Code Sections 2050-2116) (CDFW, 2015b). Stricter legal protection could halt or delay construction of renewable energy projects.

The development of better translocation methods benefits electricity ratepayers, as improved BUOW mitigation strategies will be more efficient and cost-effective. Better relocation methods support existing BUOW populations, may halt or reverse declining population trends, and minimize a future need for ESA listing. In addition, the development of proven mitigation strategies for this species decreases the chances that important new renewable energy projects could be halted. Achieving effective conservation and management of BUOW populations conforms to the California State Wildlife Action Plan (CDFW, 2015a), which identifies BUOW as a focal species for conservation strategies within six of the seven provinces defined in the plan.

Specific benefits of this project included:

- Improving BUOW mitigation strategies used when renewable energy facilities are planned in owl habitats.
- Providing owl movement and habitat use data to help energy developers decide where best to locate new developments and where best to relocate owls.
- Developing best practices to reduce risk to critical renewable energy projects.
- Achieving mandated compliance with California's environmental laws and regulations.

This research also lays fundamental groundwork for additional studies. Further research on the optimal timing of passive relocation or active translocation would be beneficial. The timing of actions is a major area where mitigation could be tailored to better match both the biological needs of these owls and broader conservation goals. Currently, mitigation-driven relocations and translocations do not allow for control over the seasonal timing because development project schedules dictate when BUOW are moved off-site. Translocation during the non-breeding season (particularly early non-breeding season) when owls are less site-faithful and more likely to disperse may result in BUOW moving away from intended receiver sites.

Increased support for marking BUOW exposed to relocation and translocation would benefit long-term monitoring goals. Improved monitoring of passively relocated BUOW is necessary to quantify the extent to which individuals experience serial eviction and how that in turn affects survival and reproduction. Long-term monitoring with coordination among federal, state, and local regulatory agencies is required to understand survival, reproductive success, and return rates or site fidelity of young BUOW produced at receiver sites. These data will further clarify the extent to which active translocation can contribute to conservation by establishing new BUOW populations or maintaining and bolstering existing ones.

GLOSSARY AND ACRONYMS

Term/Acronym	Definition
Active Translocation	The physical removal of an animal from its current location to a new location
AICc	Akaike's Information Criteria corrected for small sample size
Banding	Marking of individual birds for identification purposes using bands
BUOW	Burrowing Owl
Burrow Exclusion	Closing a burrow once an owl leaves to prohibit the owl from reentering
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
Conspecific Cues	A sign of an animal of the same species i.e., whitewash or acoustics of other BUOW
Ecological Trap	Preference of low-quality habitat typically because of rapid changes in their environment
ESA	Endangered Species Act
GPS	Global Positioning System
Acclimation aviaries	Large temporary enclosures to help acclimate owls to new burrows
HCP	Habitat Conservation Plan
NCCP	Natural Community Conservation Plan
Normalized Difference Vegetation Index	A measure of greenness from satellite imagery using near infrared and red wavelengths to calculate a vegetation index, ranging from –1 to +1, with +1 being very green.
Passive Relocation	Forcing an animal from its current location through non-physical removal, in this case, closing out burrows
RCA	Regional Conservation Authority (Western Riverside County)
Remote camera	A camera that is activated through motion typically used to take photos in remote locations
SDZG	San Diego Zoo Global
TAC	Technical Advisory Committee
Telemetry	Automatic data collection from a remote source using satellite technology
Transect	A predetermined line from which measurements are taken
Translocation	Changing location
VHF	Very high frequency radio waves used by a class of telemetry receivers

Term/Acronym	Definition
Whitewash	Chalk-like white excrement produced by BUOW and other avian species
USFWS	United States Fish and Wildlife Service

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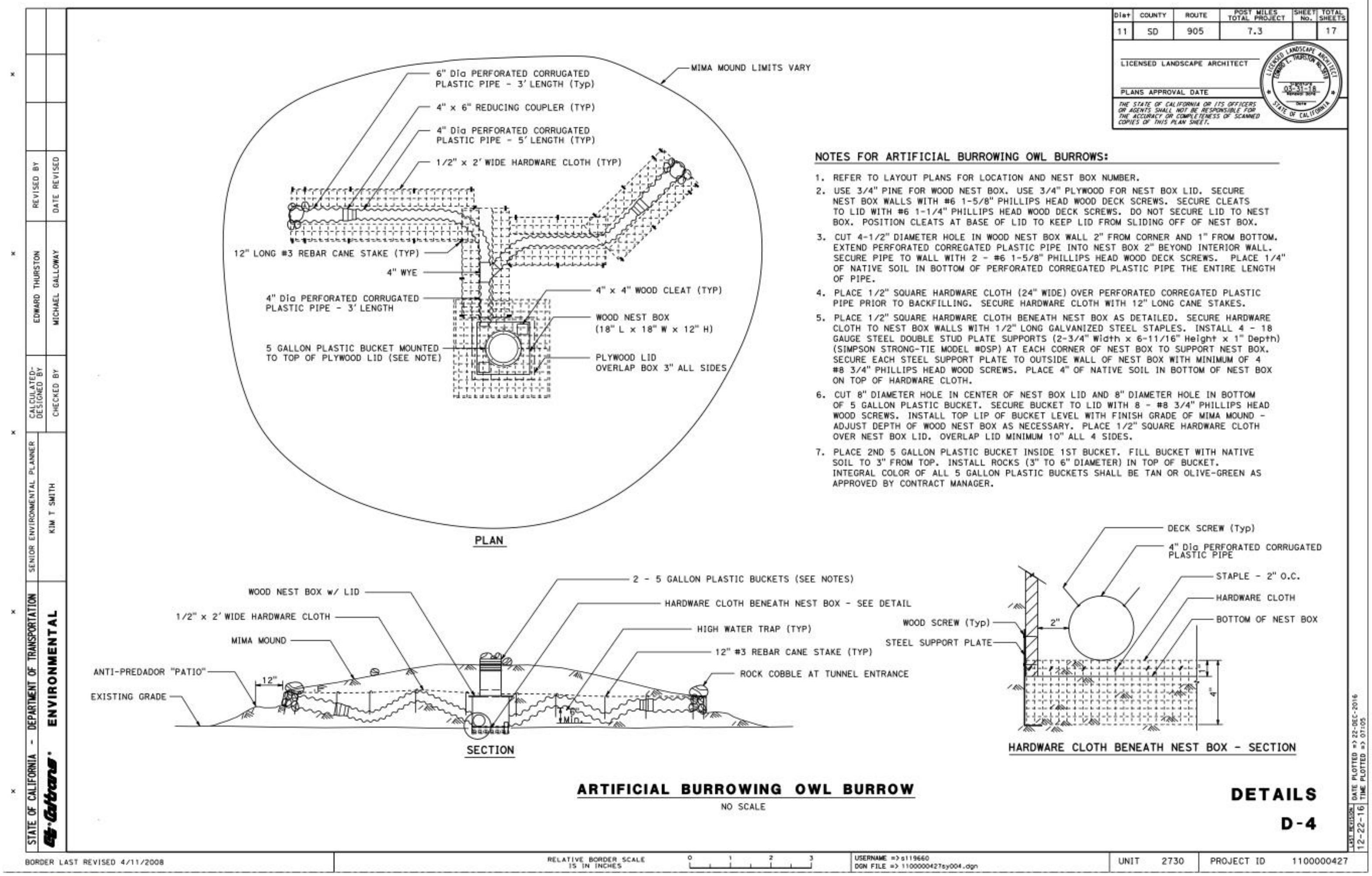
APPENDIX A:
BUOW Artificial Burrow Assembly and Installation Guide

This section contains the Burrowing Owl Artificial Burrow Assembly and Installation Guide developed by the San Diego Zoo Institute for Conservation Research. This burrow plan has been publicly shared with BUOW-managing groups since 2017. The burrow design was utilized in all active translocations for this study with one exception at a site with existing artificial burrows. The burrow design was also shared as a component of passive relocations where artificial burrow installation was included in the approved BUOW mitigation plan.

This plan includes a removable nest chamber top that provides access for burrow maintenance and nest monitoring. However, site security should be assessed before implementing this aspect of the burrow design to decrease the likelihood of harassment or damage to owls, nests, or eggs. This design may be employed without the chamber access point (nested buckets). Alternatively, the chamber access point may be covered with soil or otherwise hidden and only uncovered as needed to access the nest chamber.

Burrowing Owl Artificial Burrow Assembly and Installation Guide

BUOW Artificial Burrow Plan



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

For more info contact Mike Stevens at mstevens@sandiegozoo.org

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/concrete blocks for entrances

Chamber:
—Nest box made with plywood or cedar (cedar may cut down on mold)
-Option 1: 18”x18”x12” box with 4” feet (see technical drawing [Page 1] for assembly)
-Option 2: 18”x18”x16” box without feet
—2” #8 deck screws used to attach sides of boxes together
—2 5-gallon buckets for access chimney
*chimney=bucket with 8” hole cut in bottom (centered) and handle removed
*plug bucket w/ lid=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 plywood chamber (12” tall with 4” feet) with nested chimney and plug buckets.
*Not Shown: Plug Bucket filled with substrate and sealed with lid. Both Buckets should have a minimum thickness of 90 mil.

Bottom: Wooden (cedar) components of chamber assembled (16” tall without feet). Box made with cedar fence planks and cross braces.
Opening in side made with 4.5” hole saw.

Inset: Chamber top with cleats. Opening in top = 8” dia made with jigsaw.

Assembly Notes

Tunnels:
Assemble tunnel materials on-site. Pipes can be cut to length ahead of time for ease of transport.

Chamber:
Prefabricated before installation.
Opening in side made with 4.5” hole saw.
Opening in top = 8” dia made with jigsaw.

Option 1: 18”x18”x12” box with 4” feet
-stud plates can be replaced with feet made from 4x4’s cut to 4” lengths

Option 2: 18”x18”x16” box without feet
-Box made with cedar fence planks and cross braces.
-Cross braces: 16.5" length cedar planks cut lengthwise, so braces are 16.5" long and 2.75" tall. They are used to assemble each side of the nest box. 1.25" screws were used to attach braces to the planks.
-For the opening in the side of the nest box, the 4.5" hole should be drilled after the cedar planks are assembled with the braces.
-Hole should be off-center as shown in photo.

Plug Bucket should be filled 1/3 full with soil/sand and closed with a lid. A paving stone can be placed on top to protect bucket/lid from wildlife and UV degradation. In areas where burrows will not be inspected routinely (e.g weekly) or where security may be a concern, the plug bucket should be covered with mounded soil.

Make sure any glue or sealant is only applied to outside surfaces so any off-gassing does not negatively affect the owls or other wildlife using the burrows.

Top (Option 1): Fully assembled plywood chamber (12” tall with 4” feet) with nested chimney and plug buckets.

Inset: 4"x4"x4" foot with plywood gusset.

Bottom (Option 2): Wooden (cedar) components of chamber assembled (16” tall without feet). Box made with cedar fence planks and cross braces.
Opening in side made with 4.5” hole saw.

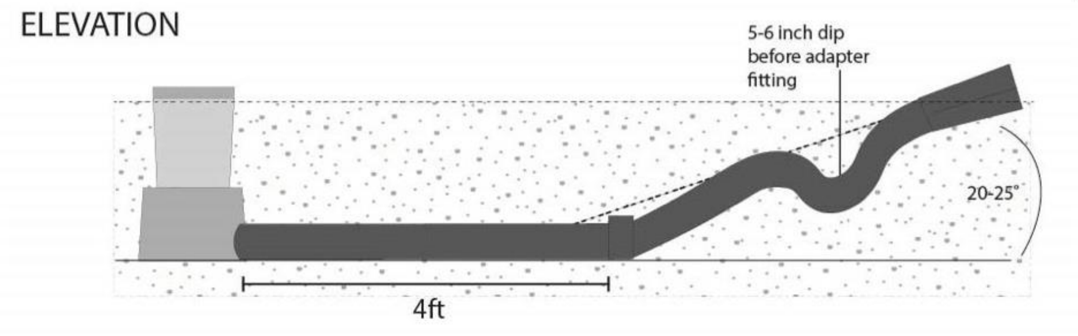
Installation

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.



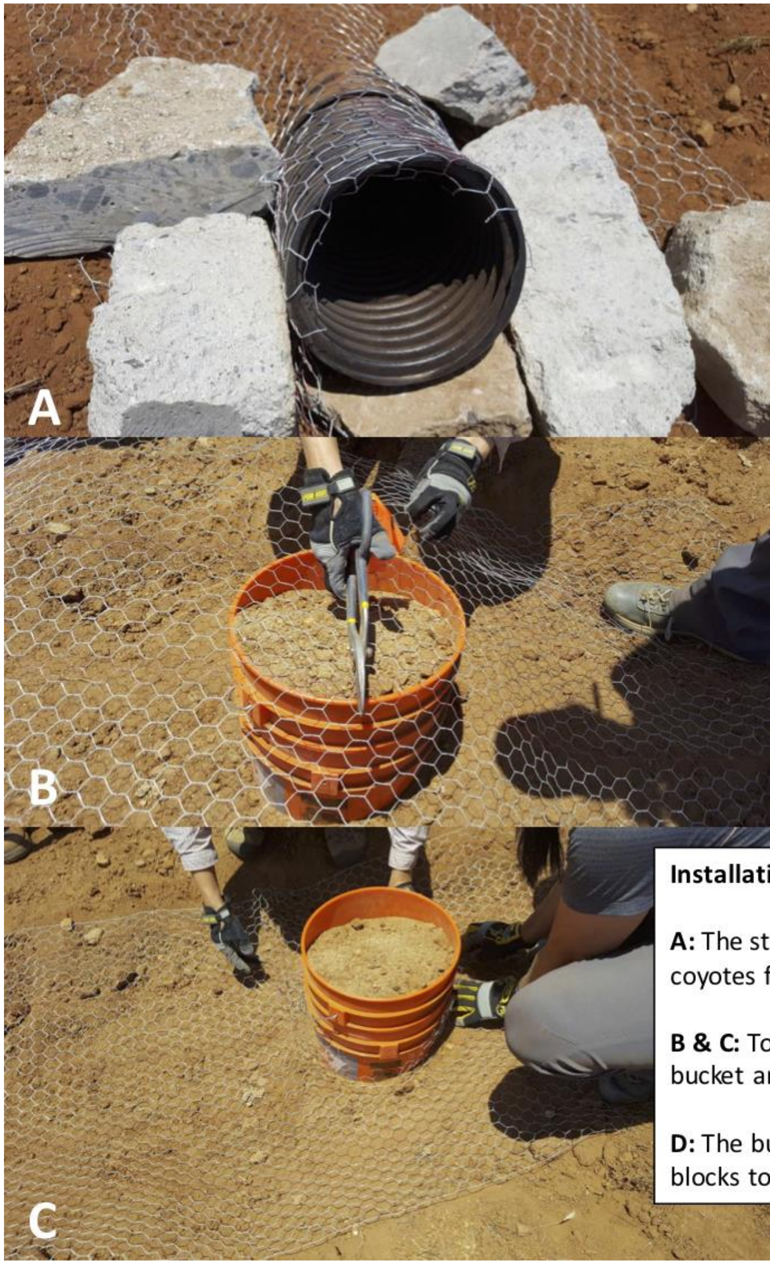
Installation Notes

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). Then should be covered back up with 4 or more inches of native soil

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.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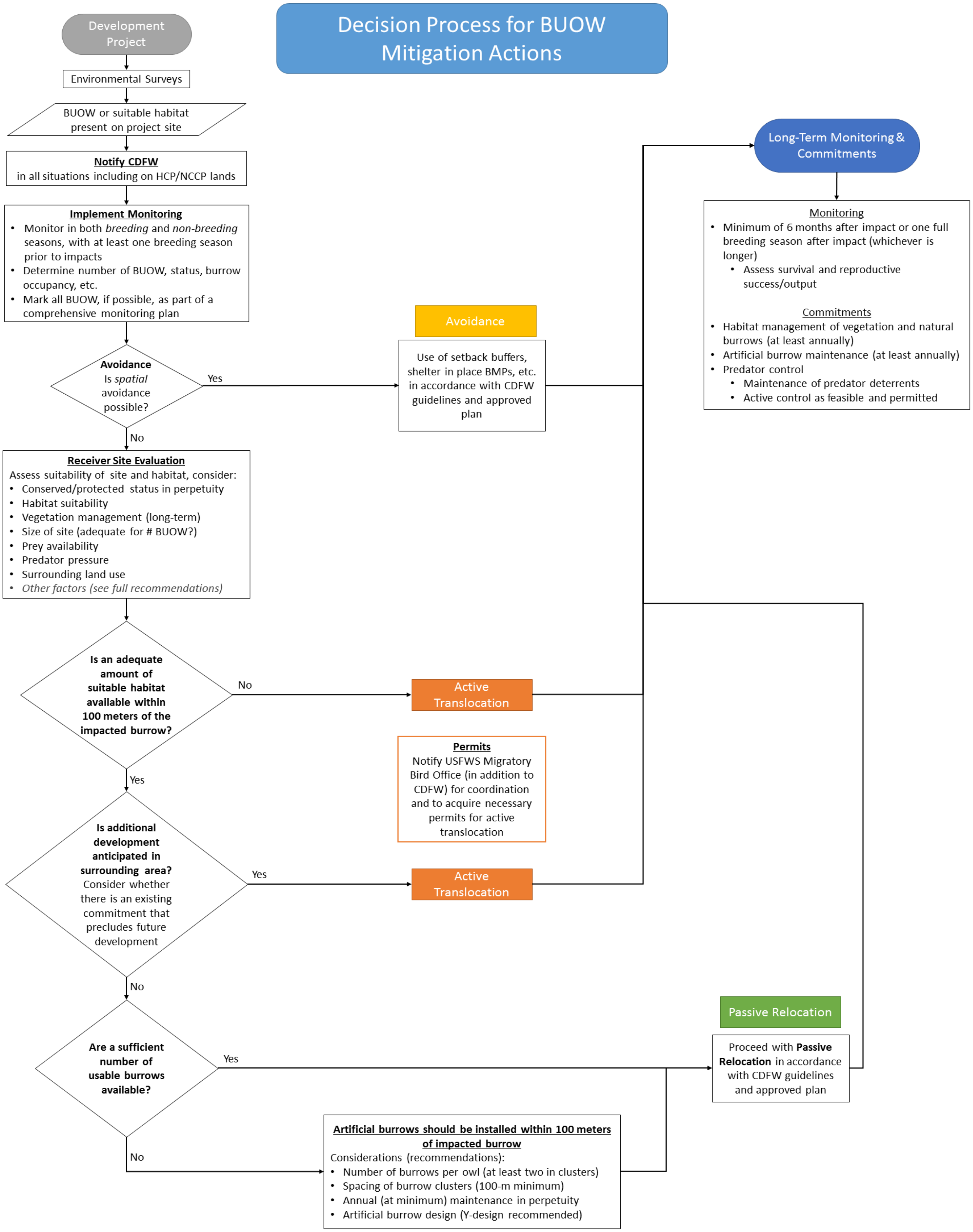
APPENDIX B: BUOW Relocation Decision Flowcharts

This section contains two flowcharts intended to assist with relocation determinations based on the results and lessons learned from this study. The first flowchart includes best-practice guidelines for making determinations of whether passive relocation or active translocation could be appropriate and/or beneficial on a case-by-case basis. Options for avoidance and minimization are included in the decision path. Decisions should be driven by site-specific conditions and the feasibility of implementing data-supported best-practice protocols. Considerations will depend on each development project's location relative to urbanization, current and future rates of development infill, availability of suitable habitat and burrows, the potential for long-term BUOW security, and conservation goals. The second flowchart provides guidelines for implementing active translocation of burrowing owls, such as selecting and preparing receiver sites and the release strategy.


Decision Process for BUOW Mitigation Actions
Development Project
Environmental Surveys
BUOW or suitable habitat present on project site
Notify CDFW
in all situations including on HCP/NCCP lands
Implement Monitoring
• Monitor in both breeding and non-breeding seasons, with at least one breeding season prior to impacts
• Determine number of BUOW, status, burrow occupancy, etc.
• Mark all BUOW, if possible, as part of a comprehensive monitoring plan
Avoidance
Is spatial avoidance possible?
Yes
No
Avoidance
Use of setback buffers, shelter in place BMPs, etc. in accordance with CDFW guidelines and approved plan
Long-Term Monitoring & Commitments
Monitoring
• Minimum of 6 months after impact or one full breeding season after impact (whichever is longer)
• Assess survival and reproductive success/output
Commitments
• Habitat management of vegetation and natural burrows (at least annually)
• Artificial burrow maintenance (at least annually)
• Predator control
• Maintenance of predator deterrents
• Active control as feasible and permitted
Receiver Site Evaluation
Assess suitability of site and habitat, consider:
• Conserved/protected status in perpetuity
• Habitat suitability
• Vegetation management (long-term)
• Size of site (adequate for # BUOW?)
• Prey availability
• Predator pressure
• Surrounding land use
• Other factors (see full recommendations)
Is an adequate amount of suitable habitat available within 100 meters of the impacted burrow?
No
Active Translocation
Permits
Notify USFWS Migratory Bird Office (in addition to CDFW) for coordination and to acquire necessary permits for active translocation
Yes
Is additional development anticipated in surrounding area? Consider whether there is an existing commitment that precludes future development
Yes
Active Translocation
No
Are a sufficient number of usable burrows available?
Yes
Passive Relocation
Proceed with Passive Relocation in accordance with CDFW guidelines and approved plan
No
Artificial burrows should be installed within 100 meters of impacted burrow
Considerations (recommendations):
• Number of burrows per owl (at least two in clusters)
• Spacing of burrow clusters (100-m minimum)
• Annual (at minimum) maintenance in perpetuity
• Artificial burrow design (Y-design recommended)

Guidelines for Active Translocation Process

Site Selection

The translocation site should provide long-term security with a commitment to maintaining suitable habitat.

Ensure:

- Conservation area protected in perpetuity
- Adequate amount of suitable habitat
- Adequate distance from origin (impacted) site

- Conduct Rapid Assessment protocols to assess habitat suitability and identify needed management actions
  - Soils, vegetation, presence of ground squirrels/burrow providers, prey availability
  - Include evaluation of predator perches, pressure, and nest sites (particularly corvids and raptors) and evaluate need for predator control

Translocation Group

The BUOW candidates for translocation should inform site selection and release strategy.

- Group size and composition (e.g. pairs vs. singles)
  - Amount of suitable habitat needed should be sufficient to support translocation group
  - Occupied site vs. novel site
    - Small group size: consider moving to an area already occupied by BUOW
    - Larger group size (≥ 5 pairs) is preferred for novel (unoccupied) receiver sites
  - Use of conspecific cues (see Release Strategy)
- Timing: for non-migrants, consider pre-breeding season to encourage nesting on site

Site Preparation

Any needed management actions identified during the site selection process should be completed and the site should be in optimal condition before BUOW are translocated.

- Vegetation management and habitat enhancement for BUOW and ground squirrels/burrow providers
- Siting and installation of artificial burrows and hacking cages

  Consider:
  - Topography or addition of mounds/berms
  - Proximity to tall structures (buildings, trees, etc.)
  - Spacing and clustering of artificial burrows
  - Artificial burrow design

Release Strategy

For better long-term outcomes, an active translocation should include provisions designed to maximize settlement, survival, and reproductive success.

Include these factors:

- Long-term commitment to site and owls
  - Vegetation management (annual)
  - Artificial burrow maintenance (annual)
  - Predator deterrence/control (on-going)
- Conspecific cues
  - Natural (occupied site) or Artificial (acoustic playback and imitation whitewash)
- Group composition
  - Larger group size is preferred for unoccupied receiver sites
  - Move pairs together, when possible
  - Ensure only resident BUOW (not migrants) are translocated
  - Hacking cage dimensions adequate for occupants
- Acclimation husbandry
  - Protocols for feeding/care, predator deterrence, etc.

Owl Translocation

Short-Term Post-Release Management

- Supplemental feeding through breeding season or six months post-release (whichever is longer)
- Predator deterrence/control
- Habitat management, as needed

Long-Term Monitoring & Commitments